

The 2026 assessment for eastern Bering Sea snow crab

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Executive Summary

This September 2026 stock assessment for eastern Bering Sea (EBS) snow crab (*Chionoecetes opilio*) was prepared for the Crab Plan Team and the Scientific and Statistical Committee and provides the basis for the 2026/27 harvest specifications.

Three kinds of year appear in this document and are written differently. A crab year runs from 1 July to 30 June and is written with both calendar years, as in 2025/26; catches, the OFL, ABC and TAC, and the overfished and overfishing determinations all belong to a crab year. The size-structured model indexes a crab year by its first calendar year, so the model's year 2025 is crab year 2025/26 and is printed that way in the tables. An assessment year is a single calendar year, as in 2026; the assessment is prepared each September, sets the specification for the crab year already under way, which began on 1 July (the 2026 assessment sets 2026/27, before the directed fishery opens in October), and determines the status of the crab year that ended on 30 June (2026 determines 2025/26). A survey year is the calendar year of the NMFS summer bottom trawl survey, as in 2026, which is the first event of crab year 2026/27.

The stock was declared overfished in October 2021 and is rebuilding under Amendment 53. The directed fishery was closed for the 2022/23 and 2023/24 seasons and has since reopened at a reduced scale. The State set a total allowable catch of 4.22 kt for 2025/26, of which 4.13 kt was retained; the total catch, counting the directed discards at their 30 percent handling mortality and the non-directed bycatch mortality, was 5.31 kt.

Stock status is reported under a Tier 4 fallback assessment rather than from the Tier 3 size-structured model. The Tier 4 fallback fits a random-effects (REMA) model to the NMFS summer survey series of morphometrically mature male biomass. This follows the October 2025 and June 2026 SSC recommendations that the Tier 4 fallback be used until the Tier 3 model's convergence problems are resolved.

Morphometrically mature male biomass (MMB; males with a large claw relative to their carapace width, the definition of maturity used for management of this stock) from the Tier 4 fallback is estimated to be 109.30 kt at the time of the 2026 survey, which is 75 percent of the B_{MSY} proxy of 146.29 kt and above the minimum stock size threshold (MSST) of 73.14 kt. Under this definition of mature male biomass, the stock is not overfished. The 95 percent confidence interval ranges from 81.9 to 145.9 kt. That interval lies above the minimum stock size threshold, and its upper bound falls short of the B_{MSY} proxy, so the stock is not rebuilt on this basis. The upper bound falls only 0.4 kt short of the proxy, and whether morphometric maturity reflects the reproductive potential of the stock is uncertain, so the authors would not consider the stock rebuilt even on the upper bound.

The Tier 3 model (Model 26.1b, the author-preferred configuration) is more optimistic. It estimates mature male biomass at mating of 135.86 kt in crab year 2025/26, the model's terminal year, and projects 183.76 kt at mating in crab year 2026/27, the year the control rule is applied to. This corresponds to a status of 1.280, above its B_{MSY} proxy of 143.53 kt.

However, the Tier 3 model does not converge to a single solution. Jittering the starting values produced several minima with similar likelihoods but substantially different management quantities. Therefore, the Tier 3 OFL is deemed unreliable and the authors recommend the Tier 4 fallback. Tier 3 results are reported in Section E.

Under the ramped crab FMP Tier 4 control rule, which gives $F_{OFL} = 0.194$ at a stock status of 0.747, and the linear catch equation $OFL = F_{OFL} \times B$ adopted by the September 2026 CPT, the OFL is 21.22 kt, and the ABC after a 50 percent buffer is 10.61 kt. The buffer, the Baranov alternative to the catch equation, and the survey-to-fishery lag are described in Sections F and G. For scale, the OFL exceeds the observed biomass of industry-preferred males (> 101 mm) in the 2026 survey, 15.9 kt.

Management performance

Table 1: Management performance over the 5 most recent crab years (1,000 t): the specifications set for each crab year and the catch and mortality taken during it. See the note below the table.

Crab year	Tier	OFL	ABC	TAC	Retained catch	Total catch (SSC)	Total catch (recalculated)
2021/22	3b	7.50	5.60	2.50	2.50	3.60	3.15
2022/23	3b	10.32	7.70	0.00	0.00	0.05	0.06
2023/24	3b	15.44	7.72	0.00	0.00	0.07	0.11
2024/25	3b	19.60	6.86	2.10	2.10	2.81	2.44
2025/26	4b	20.11	12.07	4.22	4.13	-	5.31

Table 2: Management performance over the 5 most recent crab years (million lb): the specifications set for each crab year and the catch and mortality taken during it. See the note below the table.

Crab year	Tier	OFL	ABC	TAC	Retained catch	Total catch (SSC)	Total catch (recalculated)
2021/22	3b	16.53	12.35	5.51	5.51	7.94	6.94
2022/23	3b	22.75	16.98	0.00	0.00	0.11	0.13
2023/24	3b	34.04	17.02	0.00	0.00	0.15	0.24
2024/25	3b	43.21	15.12	4.63	4.63	6.19	5.37
2025/26	4b	44.33	26.61	9.30	9.11	-	11.71

Note to the management performance tables. One row per crab year. The OFL, ABC and TAC were set in the October of that crab year, before the directed fishery opened; the retained catch and the total catch were taken during it. Tier is the tier the stock was assessed under when that crab year was specified. MSST and mature male biomass are not shown here; they are in the stock status table below, one assessment per row. Total catch (SSC) is the total the SSC adopted for that crab year; the adopted totals are not on one convention (see below), and no total has yet been adopted for 2025/26 (shown as a dash). The recalculated total catch is computed for every year from this assessment's ADF&G and NORPAC data as retained catch plus 30 percent of the directed discards plus non-directed bycatch mortality, and is the quantity compared with the OFL for the overfishing determination. No other value here is re-estimated by the current assessment.

The adopted totals are not on one convention. The 2016/17 to 2019/20 rows of the SSC's table are mortalities; from the 2020/21 row the SAFE catch table reported the raw discard instead of its mortality, and the adopted totals became retained catch plus that raw discard, with non-directed bycatch included in 2020/21 and omitted in 2021/22 and 2024/25; for the 2 closure years the adopted total is the bycatch alone, at the values of the September 2024 assessment (0.05 and 0.07 kt), which the 2025 ADF&G and NORPAC data revised to 0.06 and 0.11 kt. The 2021/22 and 2024/25 adopted totals differ from the recomputed values for both reasons: convention, and ADF&G's 2025 reprocessing of the discard series. Retained catches are those the SSC reported: this assessment's ADF&G data give a 2024/25 retained catch of 2.15 kt, against the 2.10 kt in the table. The 2025/26 total allowable catch included a 1 million lb add-on for hybrid *Chionoecetes* under the State's harvest strategy, which is why the TAC exceeds the retained catch by more than the usual margin. The 2024/25 OFL and ABC were specified in October 2024 under Tier 3 (Table 4), while the 2024/25 status determination was made in October 2025 under Tier 4; the status table below keeps each assessment's values together on one row.

The stock was determined to be overfished for 2024/25 in October 2025, on a Tier 4 mature male biomass of 60.08 kt for that crab year against the MSST of 71.40 kt, both from the September 2025 assessment (October

2025 SSC report, Table 1). The 60.08 kt is not in the stock status table below: its 2025/26 row shows the same 71.40 kt MSST beside the 105.21 kt 2025 survey estimate that assessment used to set the OFL, not the 60.08 kt it used for the determination. The stock remains in the rebuilding plan. Overfishing did not occur in any of the 5 years shown: the recalculated total catch was below the specified OFL in each.

Current status of the stock

Table 3: Stock status of eastern Bering Sea snow crab in relation to the status determination criteria (biomass and catch limits in 1,000 t; F_{OFL} per year), one assessment per row, keyed to the crab year whose specification it set. See the note below the table.

Crab year	Assessment	Tier	MSST	MMB	MMB/ B_{MSY}	F_{OFL}	OFL	ABC
2022/23	Sept 2022	3b	91.60	55.00	0.300	0.32	10.32	7.70
2023/24	Sept 2023	3b	77.95	65.77	0.422	14.96	15.44	7.72
2024/25	Sept 2024	3b	95.90	96.77	0.505	25.07	19.60	6.86
2025/26	Sept 2025	4b	71.40	105.21	0.737	0.19	20.11	12.07
2026/27	Sept 2026	4b	73.14	109.30	0.747	0.19	21.22	10.61

Note to the stock status table. Every value on a row, MSST, MMB, F_{OFL} , OFL and ABC, is from the September assessment named in the second column, as adopted by the SSC the following October; the 2026/27 row is this assessment’s recommendation, not yet before the SSC. The 2025/26 status determination is made here on the 2026/27 row, this assessment’s terminal survey estimate and MSST: mature male biomass of 109.30 kt against an MSST of 73.14 kt. MMB is the value each assessment used to set its OFL: projected to the time of mating under Tier 3, and the REMA estimate at the time of the survey, not projected, under Tier 4 (see below). F_{OFL} and the B_{MSY} proxy behind each row are explained under the basis-for-the-OFL table below. Catches, and the overfishing comparison of the recalculated total catch with the OFL, are in the management performance table above.

Is the stock subject to overfishing? No. The recalculated total catch in 2025/26, which counts retained catch, directed discard mortality and non-directed bycatch, was 5.31 kt (Table 1) compared to the OFL of 20.11 kt specified for that year.

Is the stock overfished? No. Mature male biomass of 109.30 kt is above the minimum stock size threshold of 73.14 kt (both this assessment’s values, on the 2026/27 row of Table 3), and the 95 percent confidence interval remains above the MSST (Section F). The stock was determined to be overfished for 2024/25 and remains in the rebuilding plan adopted under Amendment 53. It has not yet reached the biomass at which it would be declared rebuilt, the B_{MSY} proxy of 146.29 kt (Section H).

Is the stock approaching an overfished condition? Unknown. This requires a projection of mature male biomass. The Tier 3 models do not converge reliably and their recruitment estimates carry a large retrospective bias, and the Tier 4 fallback makes no projection, so none is available.

Under the Tier 4 fallback, biomass is taken from the REMA smooth of the NMFS summer survey, so the value is an estimate at the time of the survey. It is not mature male biomass in February after fishing, the quantity a Tier 3 model supplies from its projection. The 2 quantities are not interchangeable, and no projection to the time of mating is made here. The October 2025 SSC report notes the same substitution, footnoting that “snow crab MMB represents an estimate at the time of the survey, not at the time of mating”.

The status ratio is computed against this assessment’s B_{MSY} proxy of 146.29 kt. The May 2026 CPT report describes the stock status table as taking MSST from the most recent assessment and the B_{MSY} proxy from the previous one. On that reading the 2025/26 ratio would be this assessment’s mature male biomass of 109.30 kt over the 142.79 kt proxy specified in October 2025, 0.765 rather than 0.747. We report the ratio

on the most recent proxy for 2 reasons: it is the current estimate of the quantity status is meant to measure, and it is the proxy the control rule acts on in Section F, so the Executive Summary and the specification agree. The SSC's own Table 1 has not applied the pairing of 2 assessments to this stock: in October 2025 it listed an MSST of 71.40 kt against a proxy of 142.79 kt, and 71.40 is half of 142.79. The choice does not affect either determination, since mature male biomass is above MSST and below the rebuilt threshold on both bases, and we raise it here for the Plan Team's guidance.

Basis for the OFL

Table 4: Basis for the OFL over the 5 most recent assessments (biomass and OFL in 1,000 t; M and F_{OFL} per year), one assessment per row. See the note below the table.

Crab year	Assessment	Tier	M	B _{MSY}	B _{MSY} basis	MMB	MMB/B _{MSY}	F _{OFL}	OFL	Buffer	ABC
2022/23	Sept 2022	3b	0.29	183.10	1982-2021	55.00	0.300	0.32	10.32	25%	7.70
2023/24	Sept 2023	3b	0.29	155.91	1982-2022	65.77	0.422	14.96	15.44	50%	7.72
2024/25	Sept 2024	3b	0.28	191.81	1984-2023	96.77	0.505	25.07	19.60	65%	6.86
2025/26	Sept 2025	4b	0.27	142.79	1982-2024	105.21	0.737	0.19	20.11	40%	12.07
2026/27	Sept 2026	4b	0.27	146.29	1982-2026	109.30	0.747	0.19	21.22	50%	10.61

Note to the basis-for-the-OFL table. Each row is the September assessment that set the specification for the crab year beside it, the same row structure as the stock status table; the status of a crab year is determined by the next assessment, one row down. MMB is the value each assessment used to set the OFL: projected to the time of mating under Tier 3, and the REMA estimate at the time of the survey, not projected, under Tier 4. F_{OFL} is the directed fishing mortality rate under the Tier 3 ramp, a fraction of F_{35%}. F_{35%} itself moved from 1.50 in the September 2022 assessment (Table 13 of that document) to 49.63 in September 2024, so the column is not comparable across rows. A large value is not a large removal: at an F_{OFL} of 25.07 the OFL was still 20 percent of MMB. The Tier 4 rows scale F to M instead. The buffer is computed from the OFL and the ABC on the same row. Values for 2022/23 to 2025/26 are those used to set the specification for each crab year. The 2026/27 row is the Tier 4 fallback recommended in this document.

The stock moved from Tier 3 to Tier 4 for the 2025/26 specification because the October 2025 SSC found the Tier 3 model's convergence problems severe enough to prevent its use for advice. The 2026/27 recommendation stays with Tier 4 because those problems persist. The change of tier affects the table in 2 ways. First, the B_{MSY} proxy under the Tier 4 fallback is the mean of the smoothed survey time series rather than a spawning-biomass-per-recruit reference point, so both its value and its averaging period change between 2024/25 and 2025/26. Second, F_{OFL} under Tier 4 is set by the ramped control rule at each year's stock status, so it is below M whenever status is below 1, as for the 0.19 specified for 2025/26 and the 0.19 here.

OFL probability distribution

The OFL depends on the terminal smoothed survey biomass through the control rule and the catch equation. The REMA model estimates biomass on the log scale, so the uncertainty on the terminal value is lognormal. The terminal biomass has a point estimate of 109.30 kt and a coefficient of variation of 14.8 percent. Propagating that distribution through the ramped control rule and the linear catch equation gives the distribution in Figure 1. The median is 21.22 kt and the 95 percent confidence interval ranges from 11.29 to 39.27 kt. The distribution has a kink in its upper tail where biomass reaches the B_{MSY} proxy. Below the proxy, F_{OFL} rises along the ramp as biomass rises, so the OFL grows through both terms. Above the proxy the rule caps F_{OFL} at M and the OFL grows through biomass alone, so a given change in biomass moves the OFL less

than half as far; the density steps up at that point, at an OFL of 39.5 kt, just above the upper bound of the interval.

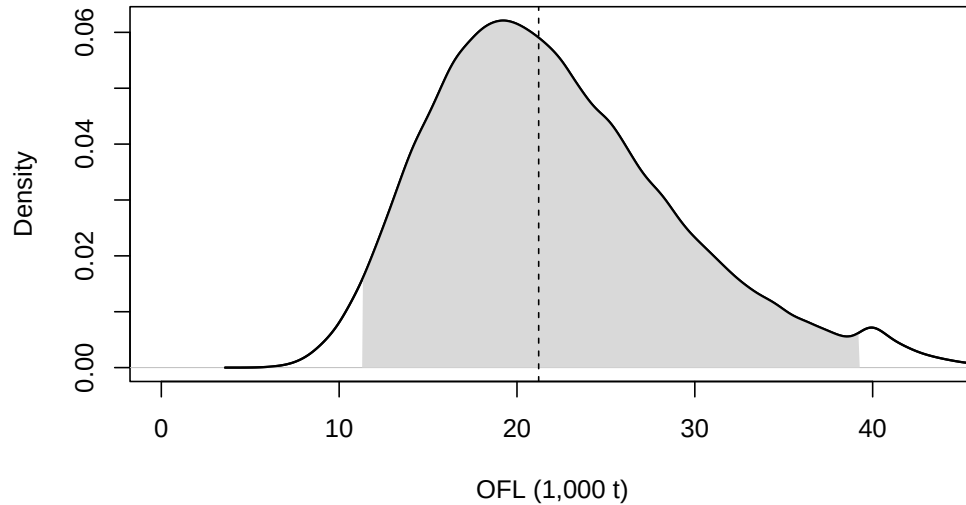


Figure 1: Probability distribution of the 2026/27 overfishing limit from the recommended Tier 4 fallback calculation (morphometrically mature male biomass, ramped control rule, linear catch equation), obtained by propagating REMA’s lognormal uncertainty on the terminal smoothed survey biomass through both. The dashed line is the recommended OFL; the shaded band is the central 95 percent confidence interval.

Models presented

This assessment evaluated 6 Tier 3 models. **Model 25.3** is the 2025 accepted model rolled forward, **Model 26.1** the model the CPT accepted in May 2026, and **Model 26.1a** is **Model 26.1** with this cycle’s 3 data corrections (the size-composition bin convention, the growth transcription error and the incidental-retention accounting); all 3 end in crab year 2024/25. **Model 26.1b** is the author-preferred Tier 3 model: **Model 26.1a** advanced to the 2025/26 fishery and the 2026 survey. Sensitivities examine the removal of the female population (**Model 26.2**) and the truncation of the data to end in crab year 2019/20 (**Model 26.1c**). Given continued convergence problems, none is proposed for the 2026/27 specification; they document progress on those problems. Jittering **Model 26.1b** found 4 well-populated minima (clusters of at least 3 runs) besides the reported fit, which had the best likelihood of any run but was reached by only 1 of the 77 converged runs (1.3 percent). The separation in likelihood is small but the management quantities differ materially. Removing the female population (**Model 26.2**) improves recovery markedly: 25.7 percent of its converged jitter runs reach its best fit, and it is the most promising direction identified this cycle. A further 4 configurations built to diagnose the convergence problems (**26.d1** stability, **26.d3** eqmdevs, **26.d4** combined, and **26.d5** male-only+eqmdevs) are reported in Appendix B; they are structural experiments, not candidate assessment models.

A. Summary of Major Changes

1. **Management:** The eastern Bering Sea snow crab population was declared overfished in October 2021 and the directed fishery was closed by the State of Alaska for the 2022/23 and 2023/24 seasons. A small fishery occurred in 2024/25, with 2.15 kt retained, and a larger one in 2025/26, with 4.13 kt retained and a recalculated total catch of 5.31 kt against an OFL of 20.11 kt. The total catch compared with the OFL is recalculated this cycle on one convention: retained catch plus 30 percent of the directed discards plus non-directed bycatch mortality, applied to all 5 crab years in the management performance table (Table 1). The 2024/25 total catch of 2.81 kt in the September 2025 assessment, adopted by the SSC in October 2025, is the retained catch plus the full directed male discard, with no handling mortality applied and no non-directed bycatch included. That document labelled the discard column as discard mortality; the 2016/17 to 2019/20 rows of that column are mortalities, but the later rows, 2024/25 included, are raw discards. The adopted values are shown beside the recomputed ones so the difference is visible. The stock remains under a rebuilding plan.
2. **Input data:** The 2026 NMFS summer trawl survey and the 2025/26 fishery data were added. The NMFS survey program applied a net-mensuration correction to the 2024 to 2026 area-swept estimates, lowering biomass and abundance in those years by about 4 percent. Earlier years are unchanged. The Tier 4 fallback, **Model 26.1b**, **Model 26.2** and the structural experiments in Appendix B use the corrected estimates. **Model 25.3**, **Model 26.1** and **Model 26.1a**, whose fishery data end in crab year 2024/25, retain the 2024 and 2025 survey estimates as used in May, so the step from **Model 26.1a** to **Model 26.1b** includes the correction; **Model 26.1c** ends before the corrected years. The maturity ogives from the Kodiak laboratory workflow were regenerated from the corrected specimen data. The authors made 6 corrections to the input data. The total-male size composition was corrected, resolving a discrepancy between the file used in September 2025 and the file produced by the script that processes the ADF&G data. The plus group was expanded to include all crab greater than 135 mm carapace width, which the previous assessments excluded. The size-composition bin convention was changed so that a crab falling exactly on a 5 mm cutoff is assigned to the upper bin. A transcription error in the growth data was corrected (a 26.3 mm crab's molt increment was recorded as 73 mm instead of 7.3 mm). The accounting for snow crab retained incidentally in other crab fisheries (mostly the Tanner crab fishery) was corrected in 2 places. The retained series is unchanged and continues to count all retained snow crab, whichever fishery landed them, as the State does against the TAC. First, the directed discard, which is derived as the directed total catch minus the retained catch, now subtracts only the directed fishery's own retention (ADF&G `dir_retained_wt`); subtracting the total retention, as in previous cycles, removed crab landed by other fisheries from the directed fishery's catch and understated its discard by exactly that amount. The correction raises the directed discard in 11 crab years, 0.376 kt in total, the largest effect being in 2025/26, where it rises by about 7 percent. Second, the non-directed bycatch pool for the other crab fisheries now excludes the crab those fisheries retained, which are already counted at 100 percent mortality in the retained series; the 30 percent handling mortality applies to their discards only. Previously the pool was 30 percent of their total catch, so the retained crab were counted a second time. This lowers non-directed bycatch mortality by 0.052 kt in 2025/26 and by no more than 0.016 kt in any earlier year. The September 2026 delivery of the ADF&G discard file confirms the directed retained column (`dir_retained_wt`) and that the directed discard is the directed total catch minus that retention, and the fishery data script now validates the directed retained and discard series against that file in every year the 2 overlap. Hybrid *Chionoecetes* catch and survey data were evaluated in the May 2026 preliminary assessment and are not included in any model presented here, following CPT and SSC advice. An immature survey index was likewise evaluated and is not brought forward. The corrected accounting is used in **Model 26.1a**, **Model 26.1b**, **Model 26.2**, **Model 26.1c** and the Appendix B experiments, all of which are fitted to the current ADF&G delivery; **Model 25.3** and **Model 26.1** keep the catch series they were fitted to in earlier cycles, because they are presented as the roll-forward and May baselines.
3. **Assessment methodology:** The Tier 4 fallback fits a random-effects (REMA) model to the survey series. The averaging period for its B_{MSY} proxy was extended to the full survey time series, 1982 to 2026 (the September 2025 assessment averaged 1982 to 2024). This changes the proxy for morphometrically

mature males to 146.29 kt and stock status to 0.747, with a minimum stock size threshold of 73.14 kt; this cycle's smoothed series averaged over the 2025 window would give 148.11 kt, 0.738 and a threshold of 74.05 kt, and the specification adopted for 2025/26 used 142.79 kt. Under the ramped control rule the proxy enters the OFL through stock status, so the wider window also changes the recommended OFL slightly (Section F). Following the June 2026 SSC recommendation, the Tier 4 fallback is the basis for the harvest specification until a simpler and more stable Tier 3 model is developed. The Tier 3 models are presented to document progress and are not proposed for specification.

The Tier 3 models presented are size-based, integrated assessments using GMACS, version 2.20.34 (Model 25.3 is reported from its 2025 fit under version 2.20.22), fit using maximum likelihood. Retrospective and jittering analyses were performed for 4 of the 6 models presented (Tables 17 and 22). Model 25.3 and Model 26.1a were not re-run for either. The probability of terminal molt at size comes, in every model except the rolled-forward 2025 model, from the maturity workflow developed by the Kodiak laboratory (Ryznar, in prep), replacing the design-based series used previously. Every fit made with the current executable was followed by additional Newton steps with the inverse Hessian, which reduce the maximum gradient to near zero without materially moving the fit.

4. **Assessment results:** Following SSC direction, the 2026/27 harvest specification is presented under the Tier 4 fallback using morphometrically mature male biomass, applying the ramped crab FMP control rule and, following the September 2026 CPT, the linear catch equation $OFL = F_{OFL} \times B$, with the Baranov result reported alongside it (Table 12). Estimated mature male biomass is 109.30 kt against a B_{MSY} proxy of 146.29 kt, a stock status of 0.747, which gives $F_{OFL} = 0.194 \text{ yr}^{-1}$ under the control rule. The OFL is 21.22 kt, and the ABC after a 50 percent buffer is 10.61 kt. On the same basis as the 2025/26 specification (ramped rule, linear equation, morphometric currency), the OFL moves from 20.11 kt to 21.22 kt, a change of 6 percent, reflecting the higher smoothed biomass and the wider averaging window for the proxy (Section F). For reference, the September 2025 assessment's own Tier 4 fallback calculation on this currency, a flat rule ($F_{OFL} = M$) with the linear equation, gave 28.41 kt; the same flat rule on this cycle's data gives 29.51 kt, and the reported OFL is lower than that because the ramped rule sets F_{OFL} below M at a stock status below 1. The specification the SSC adopted for 2025/26 was an OFL of 20.11 kt and an ABC of 12.07 kt under Tier 4b.

B. Responses to SSC and CPT comments

Comments are reproduced below in italics and grouped by the meeting at which they were made, most recent first. The 2 most recent sets of comments from each body are covered in full: the June 2026 and October 2025 SSC reports, and the May 2026 and September 2025 Crab Plan Team reports. Selected earlier comments are retained where the request is still open.

***2026(6) SSC.** The SSC recommends that the author only bring the Tier 4 model forward in October, to allow more time for development of a simpler, viable Tier 3 model.*

The recommended overfishing limit and acceptable biological catch are calculated under the Tier 4 fallback (Section F). The 6 Tier 3 models are presented to document progress on the convergence problems and are not proposed for specification. The type and purpose of each is stated in Table 17.

***2026(6) SSC.** The SSC supports bringing forward the composition correction and the expanded plus group in future models, as these appear to be clear technical improvements and corrections to the treatment of size compositions (>135 mm carapace width) that were previously ignored.*

Both corrections are included in every model presented here other than the rolled-forward 2025 model, which is reported as originally fitted. Their derivation is described in Section A. They enter the model set at **Model 26.1**, the first step from the rolled-forward 2025 model (Section E).

***2026(6) SSC.** The SSC agrees with the CPT that the immature survey index should not be treated as a convergence fix by itself. Although it may remove the visible bimodality in jitters, it also appears to shift the model toward higher natural mortality among mature males and unstable reference point behavior. Importantly, there is a clear question of whether this represents a duplicative use of the same survey data within the model.*

The immature survey index is not included in any model presented here. The underlying question of what generates the multiple minima is unresolved and is listed among the research priorities in Section I.

***2026(6) SSC.** The SSC notes that, with a new lead author, this may be an opportunity to strip the model down to a minimal parameter set that avoids convergence issues and then add back biological or process features as needed while maintaining model stability. This sequential approach to increasing model complexity by unfixing (estimating) parameters can be informed by the existing correlations among parameters in Model 25.2c.*

Model 26.2 is a first step in this direction. Removing the female population reduces the estimated parameter count from 412 to 234 and improves the numerical behavior of the model markedly (Section E). It is presented as a sensitivity, not as a candidate for specification. A staged simplification of the male-only model, removing parameters in sequence and testing convergence at each step, has not been carried out and is the obvious next step.

***2026(6) SSC.** For potential new Tier 3 models brought forward in 2027, the SSC recommends that the assessment include a focused convergence section that identifies which parameters separate the jitter clouds, including correlation diagnostics, likelihood profiles for terminal MMB, recent recruitment, M , and OFL, and targeted model simplification runs. Those simplifications should be targeted rather than broad. Examples include fixing the recruitment sex ratio at 50:50, and reducing confounding among growth, M , and selectivity.*

Partially addressed. See Model convergence and comparison in Section E. The parameters that separate the jitter minima are identified and ranked in Table 9 and Figure 23. The document presents 2 targeted simplification runs: **Model 26.2**, which removes the female population and with it the confounding among female growth, natural mortality and selectivity, and **Model 26.1c**, which tests whether the post-collapse data are the source of the problem. Jitter and retrospective analyses, in addition to convergence diagnostics, are included.

***2026(6) SSC.** The SSC continues to request a yield-per-recruit analysis that could be used to inform development of an alternative harvest control rule.*

Not completed for this cycle. See the response to the October 2025 SSC comment below, which sets out what the analysis is to contain. This will be conducted for the September 2027 assessment.

2026(6) SSC. *The SSC recommends that future snow crab SAFEs include a “Rebuilding Analysis and Update” section as appropriate, given the stock’s 2021 overfished determination.*

Section H reports the status of the rebuilding plan adopted under Amendment 53, its relationship to the 2 earlier plans, and progress toward the rebuilt threshold on the basis used for the specification.

2026(6) SSC. *The SSC agrees with the CPT that it is premature to include hybrid catch data in the snow and Tanner crab assessment models ... the SSC agrees that uncertainties associated with hybrids can be accounted for in existing buffer setting processes for Tanner and snow crab, though the SSC cautions against a predetermined direction in modifying any buffer, recognizing this uncertainty could go either way.*

No hybrid catch or survey data are included in any model presented here. Hybrid-related uncertainty is accounted for in the risk table (Table 14) and in the buffer discussion in Section G. The outstanding data problems, identification consistency between ADF&G and NMFS, the apportionment of retained catch between snow crab and hybrids, and quality control on the early hybrid estimates, are listed in Section I.

2026(5) CPT. *The base model brought forward was model 25.3 (which was mistakenly labeled as model 25 in the proposed model document and presentation), the author- and CPT-recommended model from 2025 ... Numbers for new models that were brought forward at this meeting were mistakenly labeled as corresponding to 2025 rather than 2026, and this will be corrected for the September CPT meeting.*

The models are renumbered accordingly. The 2025 accepted assessment is **Model 25.3**, and the runs introduced in May 2026 are numbered 26.x. The correspondence with the numbering used in the May 2026 preliminary assessment is given under Model scenarios in Section E, because the June 2026 SSC report refers to the accepted configuration by its May number, **Model 25.2c (Model 26.1 here)**, and the review checklist asks that model numbers be cross-validated against those the SSC endorsed.

2026(5) CPT. *The CPT noted that the authors did not present an analysis the CPT had previously requested: a model run with only data through 2019 to test the hypothesis that the model convergence problems stem from difficulties estimating recruitment following the population crash and the lack of 2020 survey data ... The CPT continues to request this analysis as the authors seek to understand the causes of the convergence problems.*

This analysis is presented as **Model 26.1c** (Section E). Truncating the data did not resolve the convergence problem. The model truncated to crab year 2019/20 converges more often and more of its runs meet the conventional gradient criterion, . It nevertheless settles into 6 well-populated minima against 4 for the full model, neither count including the reported fit, which too few runs reach to form a cluster. Its reported fit beats every jitter run, so no converged run reaches its reported fit, which beats every jitter run, against 1.3 percent of converged runs for the full model. The absence of the 2020 survey is therefore not the source of the multimodality.

2026(5) CPT. *As an additional step to investigate the convergence problems, the CPT recommended that the authors take the following approach: fix most of the model parameters that can be fixed, confirm that the model run with very few parameters converges, then add estimation of parameters sequentially and evaluate when convergence fails. The CPT also recommended that the authors look at the parameter covariance matrix, pull out the top two or three parameters that are highly correlated, and explore the effects of those parameters on model convergence.*

Neither exercise has been completed. **Model 26.2** removes 178 estimated parameters at once and demonstrates that a substantially smaller model is better behaved, but that is a single large reduction, not the sequential procedure the CPT described. The parameters separating the jitter minima were identified from the jitter runs themselves (Table 9), not from the estimated covariance matrix. This will be conducted for the January 2027 modeling workshop.

2026(5) CPT. *For September 2026, the CPT would like to see the following: Tier 4 analysis ... Model 25.2c ... Model 25.2c with only males included.*

All 3 are presented. The Tier 4 fallback is presented in Section F and is the basis for the recommended harvest specification. **Model 26.1** is included as the May baseline, and **Model 26.2** is the male-only sensitivity, requested by the CPT to test whether simplifying the model in this way might resolve the persistent convergence problems. It substantially reduces them without removing them (Section E).

2026(5) CPT. *The CPT recommended that future Tier 3 models for the snow crab stock should include all three of these error corrections [the total-male size composition, the sizes included in the plus group, and the new maturity workflow].*

All 3 are included in every Tier 3 model presented here other than the rolled-forward 2025 model. **Model 26.1a** isolates the effect of all 3 against the May baseline.

2026(5) CPT. *The CPT did not request that model runs including hybrids be brought forward for September 2026, due to their small influence on output in the sensitivity runs and the larger issues in the Tier 3 snow crab models that need to be resolved.*

No hybrid model is presented. The May 2026 hybrid candidates and their results remain available in the preliminary assessment document.

2025(10) SSC. *Snow crab was declared overfished in 2021, but the SAFE did not include a section on “Rebuilding Analysis and Update.” The SSC recommends that this section be included in future SAFEs as appropriate.*

Section H reports progress toward the rebuilt threshold on the 2026 survey, the rebuilding period set by the Amendment 53 rebuilding analysis, and the projections from that analysis. See also the response to the June 2026 comment above.

2025(10) SSC. *The SSC considered convergence problems with Model 25.3 to be severe enough to prevent its use for harvest recommendations. Due to this uncertainty, the SSC recommends the Tier 4 approach using mature male biomass as a fallback until the Tier 3 model’s convergence and identifiability are clearly improved ... The SSC intends this be a temporary approach until an acceptable Tier 3 model can be developed.*

The recommended harvest specification is calculated under the Tier 4 fallback on morphometrically mature male biomass, following this recommendation and the June 2026 SSC recommendation that only the Tier 4 fallback be brought forward. Results for the large-male (≥ 95 mm) and preferred-male (> 101 mm) definitions are reported for comparison (Table 11) but are not the basis of the recommendation. Convergence and identifiability of the Tier 3 model improved on several diagnostics this cycle, but the multiple minima persist, so the Tier 4 fallback remains the author-recommended basis for management advice.

2025(10) SSC. *The SSC recommends that the assessment author explore strategies to constrain the model complexity during this period. For example, reducing the number of years with increased natural mortality may provide the model enough constraint to allow model convergence. More generally, the snow crab assessment would likely benefit from a decrease in flexibility to ensure convergence and stable, interpretable parameter estimates and results.*

Model 26.2 addresses this by removing the female population and 178 of the 412 estimated parameters. It is the best-behaved model on the diagnostic most relevant here: 25.7 percent of converged jitter runs recover its own best fit, against 0.0 to 1.3 percent for the other 3 models jittered (Appendix B). The number of mortality-event years has not been reduced; both model years 2018 and 2019 (crab years 2018/19 and 2019/20) are retained in all models. The 2019/20 immature-female mortality deviation is the one parameter whose identifiability is in doubt: it is estimated in the accepted fit but drifts to its bound in some alternative minima, and whether to fix it is put to the Plan Team under Model convergence and comparison. Experiments that fix it are reported in Appendix B (26.d1 and 26.d4); fixing it did not resolve the multimodality. A single-mortality-event run has not been evaluated.

2025(10) SSC. *Table 13 also raises questions about what is actually being fit in the GMACS model. A significant number of parameters are either showing estimates of zero or are estimated identically to other parameters. If it is true that these parameters are active and being estimated, that would clearly cause some of the pathologies seen in the jitter analysis.*

The estimated parameters of the accepted fit of Model 26.1b are examined under Model convergence and comparison in Section E. Of the 412 estimated parameters, 24 have a standard error larger than the absolute value of the estimate. Of those, 16 are estimated within 0.1 of zero, for which a large ratio is expected and not diagnostic. The only parameters at a bound are 5 trawl-survey selectivity parameters for fully selected size classes, which sit at their upper bound of 0 on the log scale, that is at a selectivity of 1 (full selection), and the Hessian has no non-positive eigenvalues. Further analysis on parameter identifiability will be conducted in the January 2027 modeling workshop.

2025(10) SSC. *To explore development of an ABC control rule, the SSC requests that a yield per recruit analysis be developed for snow crab. This analysis should graph the yield per recruit as a function of fishing mortality, along with associated reductions in various stock metrics, including mature male biomass and male biomass >95 mm. Show the $F_{0.1}$ fishing mortality rate ... The SSC is still interested in developing a wider range of options for reference points for snow crab rather than entirely abandoning morphometric male maturity per recruit. For example, as an interim measure, adopting a more conservative F_{SPR} proxy (e.g., $F_{65\%}$) would keep the control rule tied to biology. It would also be of interest to explore a two-sex, fertilized-egg SPR analysis (“fathers matter”) so spawning output reflects male abundance/size-dependent fertilization.*

Not completed for this cycle; the SSC repeated the request in June 2026. Given the transition in authors it will be presented in 2027.

2025(10) SSC. *The SSC requests an exploration of whether the estimated large differences in male and female recruitment years could be related to the lack of fit to molt-increment data.*

Not undertaken. The growth data and the model fits to them are shown in Figure 31, and a transcription error in the growth data has been corrected this cycle (Section A), but the relationship between the fit to molt increment and the divergence between male and female recruitment years has not been examined. The male-only model removes the question instead of answering it.

2025(10) SSC. *As with a similar SSC recommendation for Tanner crab, the SSC recommends consideration of different inclusions/exclusions of hybrids into the snow crab assessment (i.e., in survey and catch data) to evaluate sensitivity to these options and ensure an internally consistent approach.*

The May 2026 preliminary assessment evaluated including hybrids in both the survey and fishery data. The effect on management advice was minor. The CPT in May 2026 and the SSC in June 2026 both concluded hybrid data should not be included at this time, and no hybrid model is brought forward. A data problem remains: retained catch already contains both hybrids and snow crab with no method to separate them, so the retained series is identical between configurations. Counting hybrid landings as snow crab removals is a source of uncertainty in the OFL and bears on the ABC buffer in Section G. The June 2026 SSC cautioned against a predetermined direction in modifying the buffer.

2025(10) SSC. *The SSC recommends that research be conducted to evaluate whether clutch fullness is a reliable indicator of female reproductive output, using histology or lab rearing experiments.*

This has been added to the list of priority laboratory studies.

2025(10) SSC. *The SSC is willing to participate in a collaborative working group during spring 2026 to facilitate additional progress on the development of an ABC control rule for snow crab.*

We appreciate the SSC’s willingness to collaborate.

2025(10) SSC. *The SSC also reiterates its general comments from December 2024 suggesting that authors use likelihood profiles to describe uncertainty in model parameters and management quantities and use jittering analyses only to ensure that the results provided come from the model with the lowest negative log likelihood (the “MLE”).*

Jittering was done for 4 of the 6 models presented (Table 17), and the accepted fit of each jittered model is the solution with the lowest negative log likelihood found, whether by the original fit or by a jitter run, which is the use of jittering the SSC describes. Likelihood profiles have not been produced. These will be produced once a stable, converged model is identified.

2025(10) SSC. *The SSC recommends that morphometric maturity status be overlaid on the size distribution plots (Figure 9) to allow visual tracking of growth and the transition to maturity by cohort.*

Figure 2 plots the abundance of immature and mature male crab at size observed in the survey by year, through the 2026 survey, with maturity assigned by the new workflow the CPT recommended for adoption in May 2026.

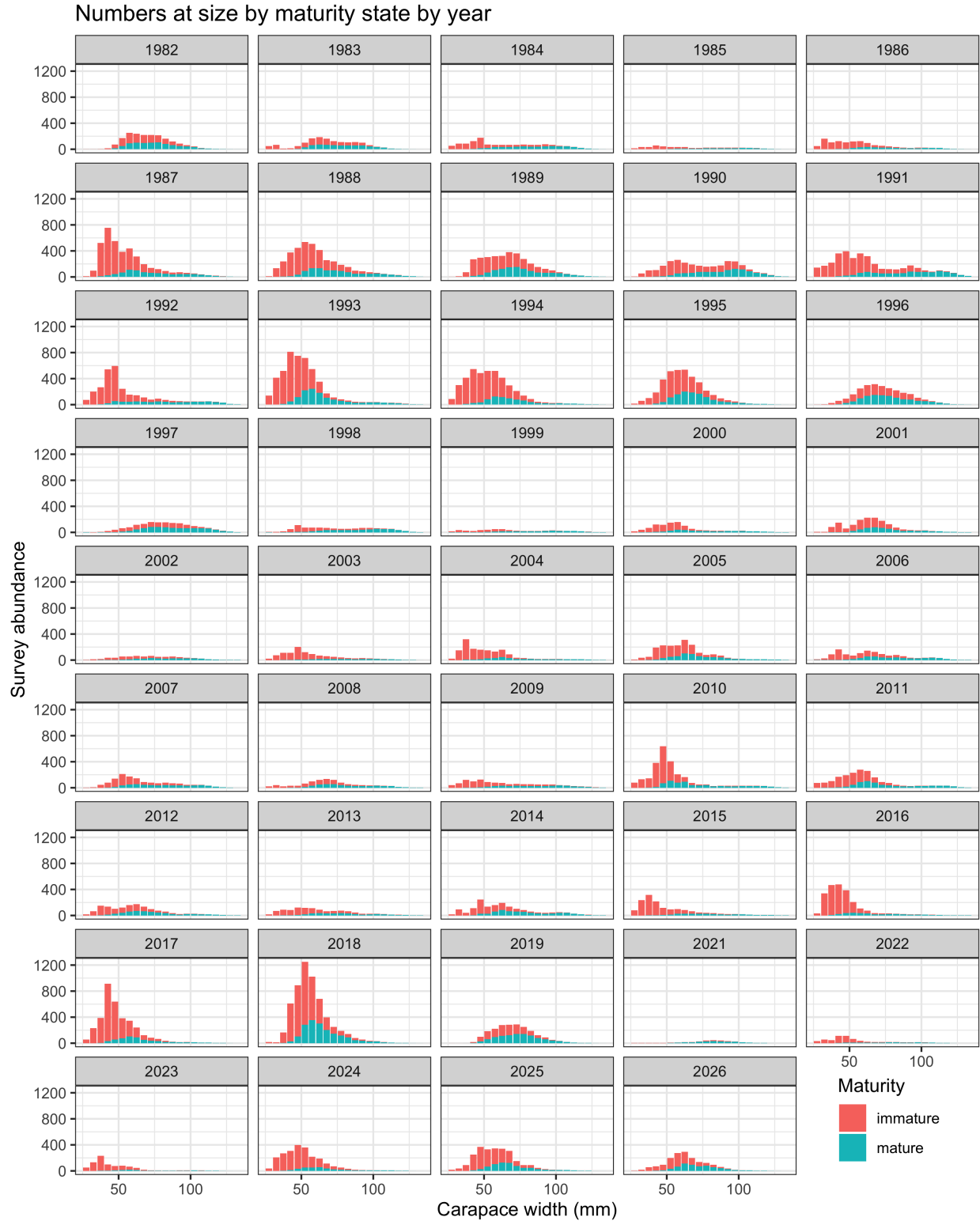


Figure 2: Survey numbers at size of immature and mature male crab by survey year, through the 2026 survey, with maturity assigned by the Kodiak workflow.

2025(9) CPT. While the model the author presented produced Hessian matrices with small gradients, a

concerning issue arose during the jittering analysis: jittering produced two clouds of model solutions at or near the MLE with OFLs that differed by 5,000 t. The author explained that the difference in OFLs resulted from differences in the terminal year estimates of MMB, driven by differences in recent recruitment estimates. In order to determine whether the absence of the 2020 survey data point is contributing to this issue, the CPT requested seeing the results of the jittering analysis from the author-preferred model but only including data through 2019.

This analysis is presented as Model 26.1c (Section E), and the absence of the 2020 survey point is not the source of the problem: truncating the data to crab year 2019/20 does not stabilize the model. It converges more often, but settles into 6 well-populated minima against 4, neither count including the reported fit, and no converged run reaches its reported fit, which beats every jitter run. The multimodality itself persists in Model 26.1b, with 4 well-populated minima besides the reported fit and a directed-fishery OFL spanning 75.4 to 84.6 kt across the converged jitter runs of the author-preferred model. See also the response to the May 2026 CPT report above.

2025(9) CPT. *For future work in which results are shown from the same model configuration using different size-at-maturity, the CPT recommended against running separate jittering analyses for each scenario. Instead, after jittering is complete for the first scenario and the putative MLE has been identified, the parameter estimates from that run should be used for all comparisons that differ only in the size-at-maturity scenario because the MLE would be the same for all such scenarios (i.e., the size-at-maturity scenario should not affect the parameter estimates).*

No model presented this cycle differs from another only in the size-at-maturity scenario, so the situation the recommendation addresses does not arise. The 3 maturity definitions are compared within the Tier 4 fallback (Table 11), which is applied to the smoothed survey series and involves no re-estimation.

2025(9) CPT. *The CPT further requested that the author investigate whether it is necessary to use the same number of size bins for males and females, noting that the BBRKC model uses different numbers of bins for the sexes.*

This was not undertaken for this cycle.

2025(9) CPT. *There is a strong consensus by the CPT that the best available scientific information supports the conclusion that the status quo definition is not appropriate in terms of conserving the reproductive potential for the stock, or in terms of supporting optimal yield of commercial-sized animals for harvest. The CPT therefore again recommended a change to the definition of maturity for this stock, from morphometric maturity to ≥ 95 mm CW.*

The CPT and SSC have not agreed on this question. The CPT recommended the ≥ 95 mm definition in 2024 and again in September 2025. On both occasions the SSC concluded that the available region-specific information was not sufficient to support the change, and directed that morphometric maturity remain the basis. The October 2025 SSC report is the most recent direction.

The authors follow the SSC's direction: morphometrically mature male biomass is the recommended definition for the Tier 4 fallback and the harvest specification. The CPT's concern remains valid. A large fraction of the population is morphometrically mature at sizes the fishery does not retain, so reference points on this definition can permit removing essentially all large males while the trend in large males is negative. The large-male and preferred-male definitions are therefore reported alongside the recommendation. For scale, the recommended OFL of 21.22 kt is 92 percent of observed large-male (≥ 95 mm) survey biomass and 134 percent of preferred-male (> 101 mm) biomass in 2026 (Table 10). This bears on the ABC buffer in Section G.

2025(6) SSC. *The maximin analysis should be completed assuming a Ricker stock-recruitment relationship, but including the same compensation ratios as the original Clark (1991) analysis.*

The Ricker curves used in Clark were implemented in the maximin analysis presented last cycle (and now published in Fisheries Research: Szuwalski and Punt (2025) "Spawning-biomass-per-recruit proxies for fisheries reference points under multiple axes of uncertainty"). Incorporating these into the analysis shifted the SPR% from ~36% to ~34%.

2025(6) SSC. *As the figures presented on the updated 1991+ catch data appear to indicate substantial differences in male discards, the SSC requests that the September document more clearly describe changes in the discard estimation and accounting process.*

An ADF&G presentation in January 2025 (available on the Council website) noted that the largest changes occurred for total catch through implementing consistent data filtering, expansion using directed pot lifts, and adjustments to biological strata. This process now allows for the production of a data file with all years of available data for each assessment cycle, instead of single years appended to an existing data file. An apparent shift upwards in discards of males from the directed fishery results primarily from a change in when discard mortality is applied (before input into the data file [before 2025] or within the assessment code itself [2025 onward]). This cycle adds a further change: the retained figure subtracted to obtain the directed discard is now the directed fishery's own retention only, which raises the discard in 11 crab years (Sections A and D).

2025(6) SSC. *Given the findings described in Mullowney and Baker (2021) from Canadian research indicating that the molt to maturity may occur at smaller sizes when lower densities of large males are present, it would be useful to determine if there is evidence for the same process occurring in EBS snow crab, and whether fishing mortality on the large males is consistently high enough to result in a strong effect. Further, it would be useful to evaluate whether clutch fullness may be related to size at maturity or the abundance of large-sized crab.*

Given that natural mortality events seem to switch among years and sexes depending on the model or input data, it would be prudent to investigate whether it is possible to estimate a direct link between natural mortality and a bottom temperature covariate of appropriate spatial and temporal scale.

A manuscript describing both of these relationships for Bering Sea snow crab was presented in May/June 2024 (Figure 3 of that manuscript; "Density dependence modulates climate change impacts on eastern Bering Sea snow crab") and was published in 2026 (Szuwalski et al., 2026). In that manuscript, warmer temperatures were associated with elevated mortality and higher densities of large males were associated with lower probabilities of terminally molting at size.

The SSC responded to this presentation with the following text: "The SSC emphasizes that projections of climate change impacts, while useful, are highly uncertain and. . . caution should be used when presenting these results."

Clutch fullness does not appear to be related to the abundance of large-size crab based on analyses in "Spatial depletion rates in the eastern Bering Sea snow crab fishery" (also presented in May 2024 and now in review for external publication). It is unclear if there is any relationship between clutch fullness and recruitment, though preliminary analyses suggest clutch fullness is not an important covariate for predicting recruitment strength.

These analyses were conducted under the legacy maturity workflow. The Kodiak laboratory has since revised that workflow, and the revision is used in every model presented here other than the rolled-forward 2025 model, so the analyses should be revisited using the new series.

2025(6) SSC. *To explore development of an ABC control rule, the SSC requests that a yield per recruit analysis be developed for snow crab.*

Not completed. The SSC restated this request with a detailed specification in October 2025 and again in June 2026. See the response to the October 2025 comment above.

2024(10) SSC. *SSC recommends standardizing the approach to the Tier 4 fallback across BBRKC, Tanner and snow crab assessments so that the same methods are used for each including all mature male biomass, a BMSY proxy based on the time-series of REMA-smoothed survey estimates and an FMSY proxy based on the best estimate of natural mortality (from the Tier 3 model). As the SSC intends the Tier 4 calculation only as a fallback if the Tier 3 analysis fails to converge, no other Tier 4 calculations need to be included in future assessments.*

In the 2025 document, a Tier 4 harvest control rule was applied to REMA-smoothed survey biomass estimates of 3 different size ranges: morphometrically mature males, large males (≥ 95 mm), and preferred males

(> 101 mm). The target biomass was set as the average of the time series from 1982 to 2024 and the target fishing mortality was set as 0.27, the median of the prior on natural mortality used in the integrated assessment. That was a flat rule, $F_{OFL} = M$ at every stock status above the closure threshold. The resulting OFLs were 28.41 kt, 8.64 kt, and 6.11 kt for morphometric, large, and preferred males, respectively.

The same 3 maturity definitions are retained, and the Tier 4 fallback is described in Section F. Following the October 2025 SSC recommendation, morphometrically mature male biomass is the basis of the recommended specification, with the other 2 definitions shown for comparison. Following the September 2026 CPT, the specification applies the standard linear catch equation, $OFL = F_{OFL} \times B$, which the other BSAI crab Tier 4 assessments use. The Baranov result is reported alongside it at the CPT's request, in Table 11 together with the flat-rule alternative, and the 4 combinations of control rule and catch equation are set out in Table 12 so the effect of each choice can be compared.

2024(10) SSC. *The SSC highlighted that more research is needed on the basic reproductive biology of snow crab, specifically addressing the question of whether small males can and do mate with large females and produce progeny that will be large males under the right environmental conditions. The SSC strongly supports the proposed collaborative research to explore in situ observations of mating crab using a camera sled.*

We agree. Camera-sled observations (Weems et al., in preparation) recorded small morphometrically mature males grasping mature females in the eastern Bering Sea ($n = 21$). Broader sampling coverage is needed before conclusions can be drawn.

2024(10) SSC. *The highest priority would be to continue to refine the Maximin analysis as requested by the SSC in June 2024, specifically using values of steepness of 0.50, 0.67, and 0.80, and considering both the Beverton-Holt and Ricker stock recruitment relationships. The yield analysis also indicated that fishing mortality rates much lower than F35% achieved a high percentage of MSY, indicating potential flexibility in specifying reference points. The SSC suggested that some type of collaborative work during the spring, perhaps including SSC members and/or others might facilitate additional progress on this topic. The SSC is interested in developing a wider range of options for reference points for snow crab for consideration in the next assessment cycle.*

The analysis was not extended beyond what was presented in Appendix A of the 2024 SAFE and would be of limited use until we know more about reproductive contribution of large male snow crab. The specific values for steepness recommended by the SSC do not match estimates or available data on the reproductive dynamics of snow crab. We suggest focusing efforts on understanding the dynamics of large males given the reliance of the fishery on large males that are at historical lows.

2024(10) SSC. *The SSC again requests an analysis of the probability of maturing/terminal molt which addresses the observation error in these data and the lack of a monotonically increasing curve. A hierarchical analysis that treats years as random effects might be a starting point. The SSC would also like to better understand the sampling design for the molt data and is concerned about the weighting of the spatial samples in the analysis. Weighting should be based on abundance if the sampling rate differs by area (which it would, unless abundance were uniform and/or the targets were in direct proportion to abundance).*

The Kodiak laboratory presented its workflow to the CPT in January 2025, with a summary to the SSC. The revised workflow fits a spatiotemporal **sdmTMB** model to the chela-based maturity classifications, borrowing information across years and locations for size bins with sparse data, and incorporates spatial weighting directly. The CPT recommended it in May 2026 and it is used in every model except the rolled-forward 2025 model, which retains the legacy series, so the 2 series can be compared directly (Figure 37). The revised series shows a markedly weaker temporal trend at intermediate sizes. Observation error is still not propagated: the ogive enters as a fixed input, not as data with a likelihood. See Ryznar (in prep).

2024(10) SSC. *Investigate whether there is information outside the assessment model (e.g., larval or post-settlement data) or in the model, supporting estimated skewed sex-ratios at recruitment and the mismatch between recent large recruitments for males and females occurring in different years. Explore whether the estimated large differences in male and female recruitment years could be related to the lack of fit to molt-increment data.*

No new information has come to light on why this might be the case. Previous discussion centered on the possibility that different spatial distributions by sex of small crab expose them to different environments, altering perceived recruitment 5 years after settlement. That is an interesting scientific question, but solving it will not address the central management problem: commercially preferred males are at historic lows. Removing the females focuses the model on that problem, and Model 26.2 does so as a sensitivity (Section E). The related request, to examine whether the male-female divergence connects to the lack of fit to the molt-increment data, has not been taken up; removing the females sets it aside instead of answering it.

2024(10) SSC. *Geostatistical (e.g. VAST) modeling of trawl survey data including both the NBS and EBS should be prioritized. This could help understand some of the inconsistent recruitment/growth trends observed in recent years as well as prepare for potential changes in stock distribution or productivity under future warming of the Bering Sea. Geostatistical modeling should evaluate alternative error distributions and other model configurations as appropriate.*

The Kodiak laboratory presented indices for mature females and large males using geostatistical modeling at the May 2025 CPT. The northern Bering Sea is not included in the geostatistical modeling because estimates would have to be extrapolated in years when that area was not surveyed.

2024(6) CPT. *Tier 4 fallback - CPT supports: The author suggested an alternative for snow crab to the basic Tier 4 calculation that is being brought forward for other stocks. Specifically, a fallback Tier 4 option would be calculated as the vulnerable biomass in this year's survey (not smoothed, and vulnerable defined by a cutoff of 95 mm CW), decremented by the proportion of natural mortality that occurs between the time of the survey and the fishery, and M applied as the proxy for FMSY to calculate the Tier 4 OFL. The motivations identified for using the annual survey design-based estimate of vulnerable biomass rather than a REMA smooth through the survey time series were: 1) that the high number of positive stations for snow crab on survey (238 stations in 2023) make the design-based estimate a robust measure of annual biomass; and 2) that the large interannual fluctuations in biomass observed in some recent years would be poorly captured by a smooth. The motivation for decrementing the biomass estimate by the proportion of natural mortality occurring between the survey and the fishery is that failing to account for this mortality could lead to unintentionally high values of F if the Tier 4 fallback was used.*

The Tier 4 fallback is presented in Section F and is the basis of the recommended harvest specification for 2026/27. It follows the standardized approach the SSC set out in October 2024 rather than the decremented, unsmoothed variant described in this comment: it uses all morphometrically mature male biomass, a B_{MSY} proxy from the REMA-smoothed survey series, and the best estimate of natural mortality as the F_{MSY} proxy, and it is not decremented for mortality between the survey and the fishery; the size of that decrement, about 15 percent over 7 months at $M = 0.27$, is reported in Section F but not applied.

2024(6) SSC. *Concerning the GMACS assessment model, the SSC continues to recommend that the assessment author explore ways to incorporate the molt to maturity data in the model in a way that reflects the observation error associated with those estimates. An analysis in a GLMM modeling framework, which treats years as random effects, would provide smoother estimates, accommodate differing sample sizes by year and length, and deal appropriately with years in which data are missing. Another possibility that was suggested in the CPT report was to include the annual observed probabilities of terminal molt as data and then fit them, as in the Tanner crab assessment.*

Observation error is still not propagated into the assessment: the maturity ogive enters the model as a fixed input rather than as data with an associated likelihood. The Kodiak laboratory presented its workflow to the CPT in January 2025 and again in May 2026, when the CPT recommended it for adoption; it is used in every model presented here except the rolled-forward 2025 model (see the response to the October 2024 comment above). The Tanner crab assessment fits to the maturity data with its observation error, and doing the same for snow crab remains an area for improvement. Given the complexity of the GMACS model, this is not a priority until convergence problems are resolved.

2024(6) SSC. *The SSC recommends that this model be brought forward in the fall but requests that an additional Tier 4 model be provided for comparison, as recommended in the Simpler Modeling Workshop report and requested in the SSC's June 2023 and October 2023 Reports. This additional model would use the random effects model (REMA) to smooth survey estimates and would not decrement with natural mortality.*

A Tier 4 fallback assessment using the REMA model to smooth the survey estimates, without a decrement for natural mortality, has been included in each assessment since 2024. It is presented in Section F, where it is the basis of the recommended specification rather than a comparison.

C. Introduction

Studies and data relevant to key population and fishery processes are discussed below to provide background for the modeling choices made in this assessment. A description of the model is available in the GMACS repository (<https://github.com/GMACS-project>), and the files needed to reproduce this assessment are archived in a separate repository. Both are linked under Supplemental information at the end of the document.

Distribution

Snow crab (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and in the western Atlantic Ocean as far south as Maine. In the Bering Sea, snow crab are distributed widely over the shelf and are common at depths less than ~200 meters (see tech memo; Zacher et al., 2026). Smaller crab tend to occupy more inshore northern regions and mature crab occupy deeper areas to the south of the juveniles (see Zacher et al., 2026; Zheng et al. 2001). The eastern Bering Sea population within U.S. waters is managed as a single stock. However, the distribution of the population may extend into Russian waters to an unknown degree.

Natural Mortality

Relatively few targeted studies exist to determine natural mortality for snow crab in the Bering Sea. Nevissi et al. (1995) used radiometric techniques to estimate shell age from last molt (Figure 3). The total sample size was 21 male crab (a combination of Tanner and snow crab) from a collection of 105 male crab from various hauls in the 1992 National Marine Fisheries Service (NMFS) Bering Sea survey. Representative samples for the 5 shell condition categories were collected from the available crab. Shell condition 5 crab (SC5 = very, very old shell) had a maximum age of 6.85 years (s.d. 0.58, 95% CI approximately 5.69 to 8.01 years; carapace width of 110 mm). The average age of 6 crab with SC4 (very old shell) and SC5, was 4.95 years (range: 2.70 to 6.85 years). Given the small sample size, this maximum age may not represent the 1.5th percentile of the population that is approximately equivalent to Hoenig's method (1983). Tag recovery evidence from eastern Canada revealed observed maximum ages in exploited populations of 17-19 years (Nevissi et al. 1995, Sainte-Marie et al. 2002). A maximum time at large of 11 years for tag returns of terminally molted mature male snow crab in the North Atlantic has been recorded since tagging started about 1993 (Fonseca et al. 2008). Fonseca et al. (2008) estimated a maximum age of 7.8 years post terminal molt using data on dactyl wear.

Shell condition	CW (mm)	Age (years)	Error (years)	Coordinates	Depth (m)	Species
0+	121	0.05	0.26	59°20'N, 171°49'W	43	<i>C. opilio</i>
0+	110	0.11	0.27	59°20'N, 171°49'W	43	<i>C. opilio</i>
0+	132	0.11	0.19	59°20'N, 171°49'W	43	<i>C. opilio</i>
1	118	0.15	0.26	59°20'N, 171°49'W	43	<i>C. opilio</i>
1	130	0.23	0.27	59°20'N, 171°49'W	43	<i>C. opilio</i>
1	116	0.25	0.24	59°20'N, 171°49'W	43	<i>C. opilio</i>
2+	93	0.33	0.28	57°00'N, 167°43'W	42	<i>C. bairdi</i>
2+	122	0.42	0.26	57°00'N, 167°43'W	42	<i>C. bairdi</i>
2+	97	0.66	0.30	59°00'N, 171°47'W	46	<i>C. opilio</i>
2+	123	0.78	0.32	59°00'N, 171°47'W	46	<i>C. opilio</i>
2+	121	0.85	0.27	57°00'N, 167°43'W	42	<i>C. opilio</i>
2+	66	1.07	0.29	59°00'N, 171°47'W	46	<i>C. opilio</i>
3	117	0.92	0.34	59°00'N, 171°47'W	46	<i>C. opilio</i>
3	69	1.04	0.28	59°00'N, 171°47'W	46	<i>C. opilio</i>
3	78	1.10	0.30	59°00'N, 171°47'W	46	<i>C. opilio</i>
4	100	4.43	0.33	57°21'N, 167°45'W	39	<i>C. opilio</i>
4	93	4.89	0.37	58°20'N, 171°38'W	52	<i>C. bairdi</i>
4	100	6.60	0.33	57°00'N, 167°43'W	42	<i>C. opilio</i>
5	111	2.70	0.44	58°60'N, 169°12'W	28	<i>C. opilio</i>
5	100	4.21	0.34	59°00'N, 171°47'W	46	<i>C. bairdi</i>
5	110	6.85	0.58	58°60'N, 169°12'W	28	<i>C. opilio</i>

Figure 3: Radiometric estimates of shell age in male snow and Tanner crab collected during the NMFS survey of 1992. Reproduced from the presentation of Nevissi et al. (1995) in Ernst et al. (2005).

In earlier assessments, the mean of the prior for natural mortality used in the eastern Bering Sea snow crab assessment was based on the assumption that longevity would be at least 20 years in an unfished population of snow crab, informed by the studies above. Under negative exponential depletion, the 99th percentile corresponding to age 20 of an unexploited population corresponds to a natural mortality rate of 0.23. Using Hoenig's (1983) method a natural mortality equal to 0.23 corresponds to a maximum age of 18 years.

In contrast to the implied natural mortalities from the methodology used above, Murphy et al. (2018) estimated time-varying natural mortality for eastern Bering Sea snow crab with a mean of 0.49 for females and 0.36 for males based on the output of state-space models fit to NMFS survey data. Further, natural mortality estimates produced from empirical analyses by Then et al. (2015) and Hamel (2015) using similar assumed maximum ages as the methodology above produced natural mortalities larger than 0.23 (Table 5). Then et al. (2015) compared several major empirical estimation methods for M (including Hoenig's method) with an updated data set and found that maximum age was the best available predictor. A maximum age of 20 years corresponded to an M of ~ 0.315 in Then et al.'s analysis. Hamel (2015) developed priors in a similar manner to Then et al., but forced the regression of observed natural mortality onto maximum age through the intercept, which resulted in an M of ~ 0.27 for an assumed maximum age of 20 years.

Table 5: Empirical estimates of natural mortality (per year) for a range of methods over a range of assumed maximum ages in years (column headers). Then et al. (2015) is their recommended maximum-age estimator ($M = 4.899$ divided by maximum age to the power 0.916); the 2 Hoenig (1983) rows are his fish-only and combined-taxa regressions of M on maximum age; Hamel (2015) is the meta-analytical prior. These are empirical estimators, not output of any assessment model.

Method	23	20	17
Then et al. (2015)	0.277	0.315	0.365
Hoenig (1983), fish	0.190	0.212	0.257
Hoenig (1983), all taxa	0.194	0.223	0.261
Hamel (2015)	0.235	0.271	0.318

In addition to the results of empirical estimates of M from updated methodologies and state-space modeling by Murphy et al. (2018), inspection of the survey data suggests that natural mortality for mature individuals is higher than assumed. A fraction of the mature population (which are assumed not to grow, given evidence for a terminal molt) are not selected in the fishery (e.g. sizes 50-80 mm; Figure 4). Consequently, all mortality observed is ‘natural’. The collapse in recruitment in the 1990s can be used as an instrument to understand natural mortality for mature individuals. The last large recruitment enters these size classes in the mid- to late-1990s and numbers of crab in these size classes return to low levels in less than 5 years.

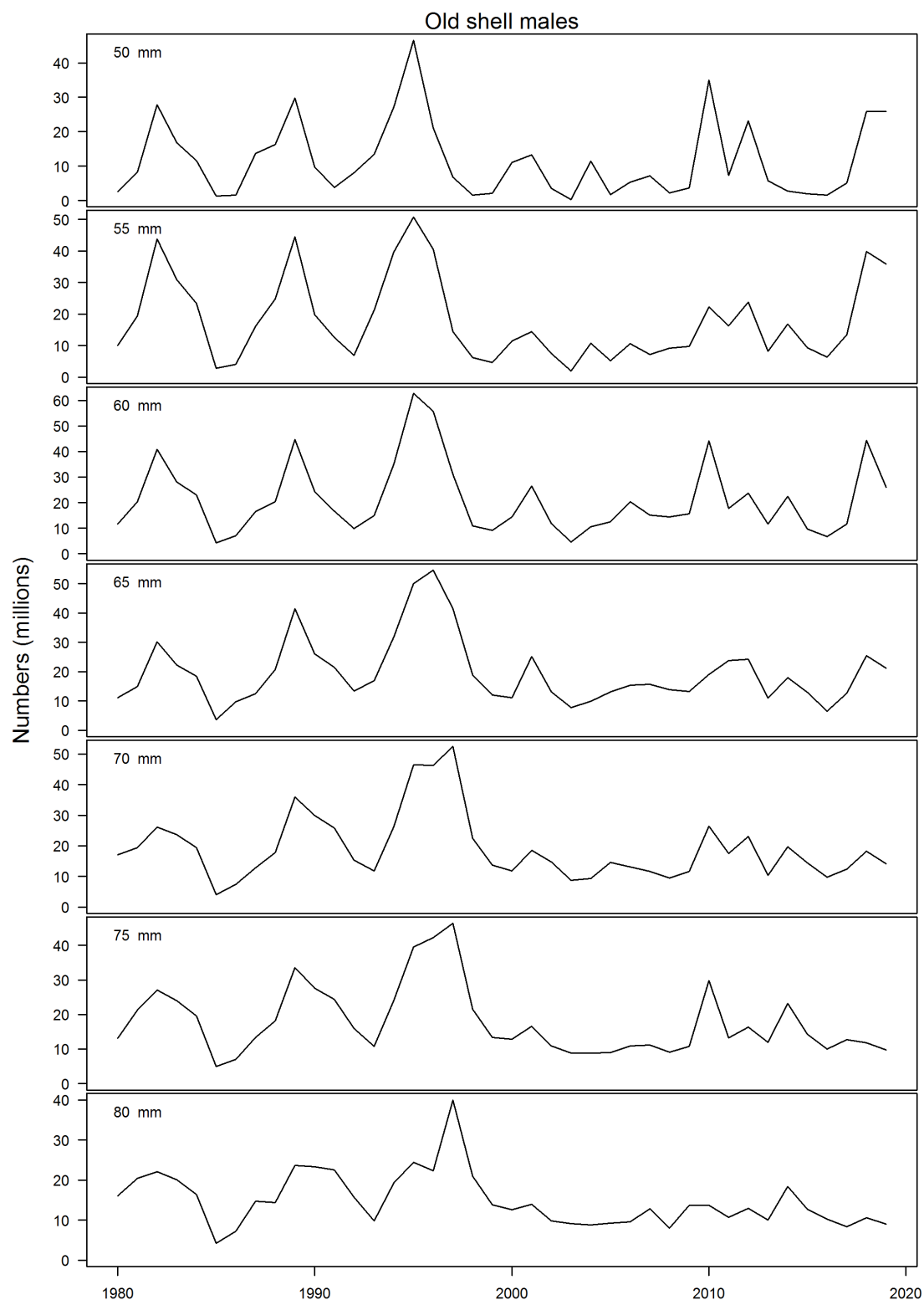


Figure 4: Observed numbers at length of old-shell mature males by size class. The size bins presented are not vulnerable to the fishery, so all mortality observed in them is natural.

The median value of the priors used in this assessment is set equal to values resulting from assuming a maximum age of 20 years and applying Hamel’s methodology (0.271). A standard error of 0.0054 was used for initial priors and was estimated using the 95% CI of ± 1.7 years on maximum age estimates from dactyl wear and tag return analysis in Fonseca et al. (2008). Mortality events in model years 2018 and 2019 (crab years 2018/19 and 2019/20) are estimated as additional mortality parameters applied by sex and maturity state to allow the model to fit recent population trends.

Maturity

Maturity of females collected during the NMFS summer survey was determined by the shape of the abdomen, by the presence of brooded eggs, or egg remnants. Maturity for males was determined by chela height measurements, which were available most years starting from the 1989 survey (Otto 1998; Figure 5 & Figure 6). Unless stated otherwise, mature male biomass means the biomass of morphometrically mature (large-clawed) males; the ≥ 95 mm and > 101 mm definitions are reported alongside it in Section F. For the models presented here, other than the rolled-forward 2025 model, the probability of terminal molt at size comes from the Kodiak laboratory’s spatiotemporal workflow (Ryznar, in prep; Section B), which fits an **sdmTMB** model to the chela-based classifications and supplies a value for every survey year, including years without chela measurements. The legacy series, a maturity curve estimated from the average fraction mature by size and applied to years without chela height data (Richar and Foy, 2022), is retained only in the rolled-forward 2025 model.

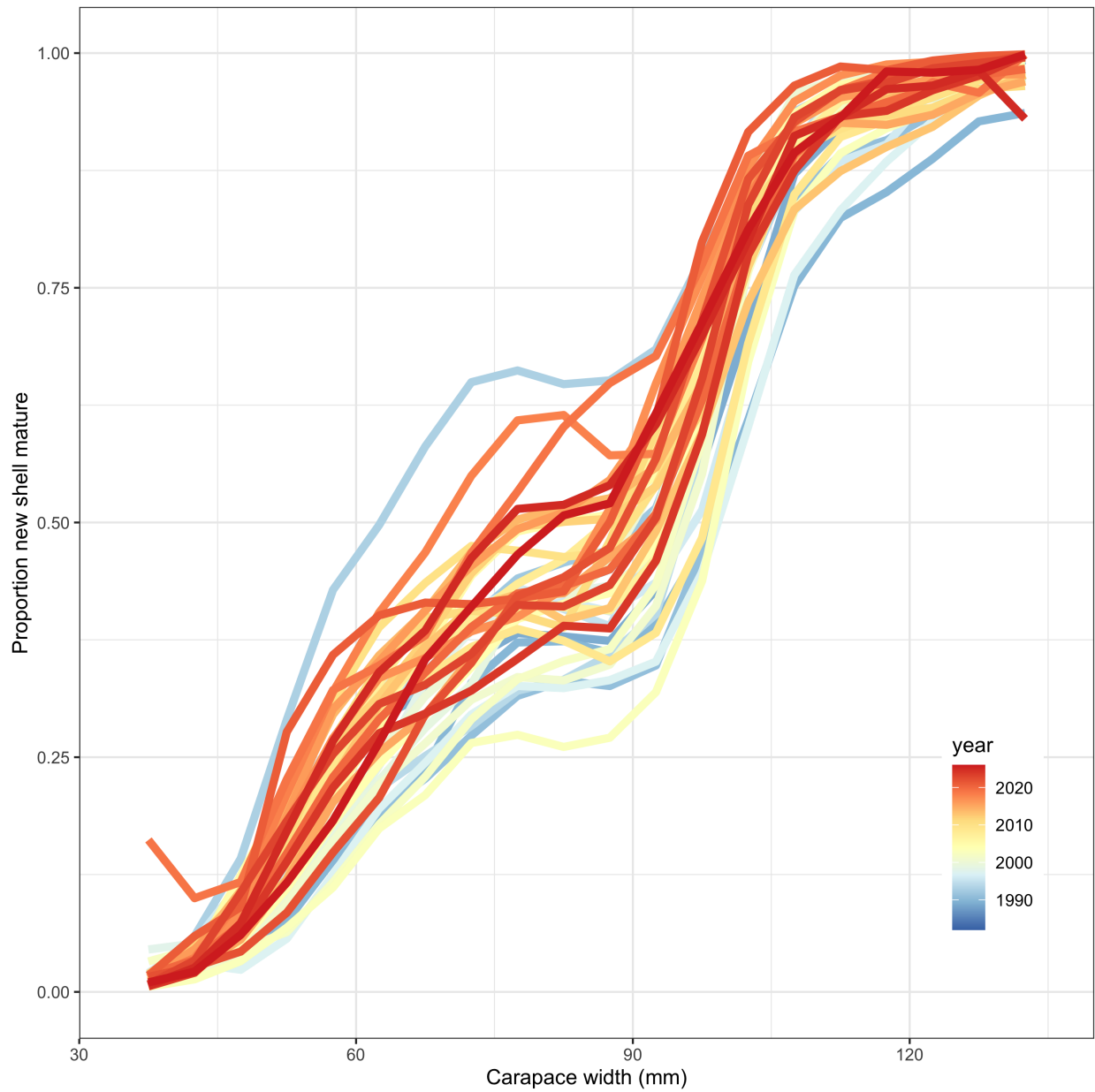


Figure 5: Observed probability of having undergone terminal molt at size for new-shell male crab, based on chela height. Blue lines are earlier in the time series; red lines are the most recent.

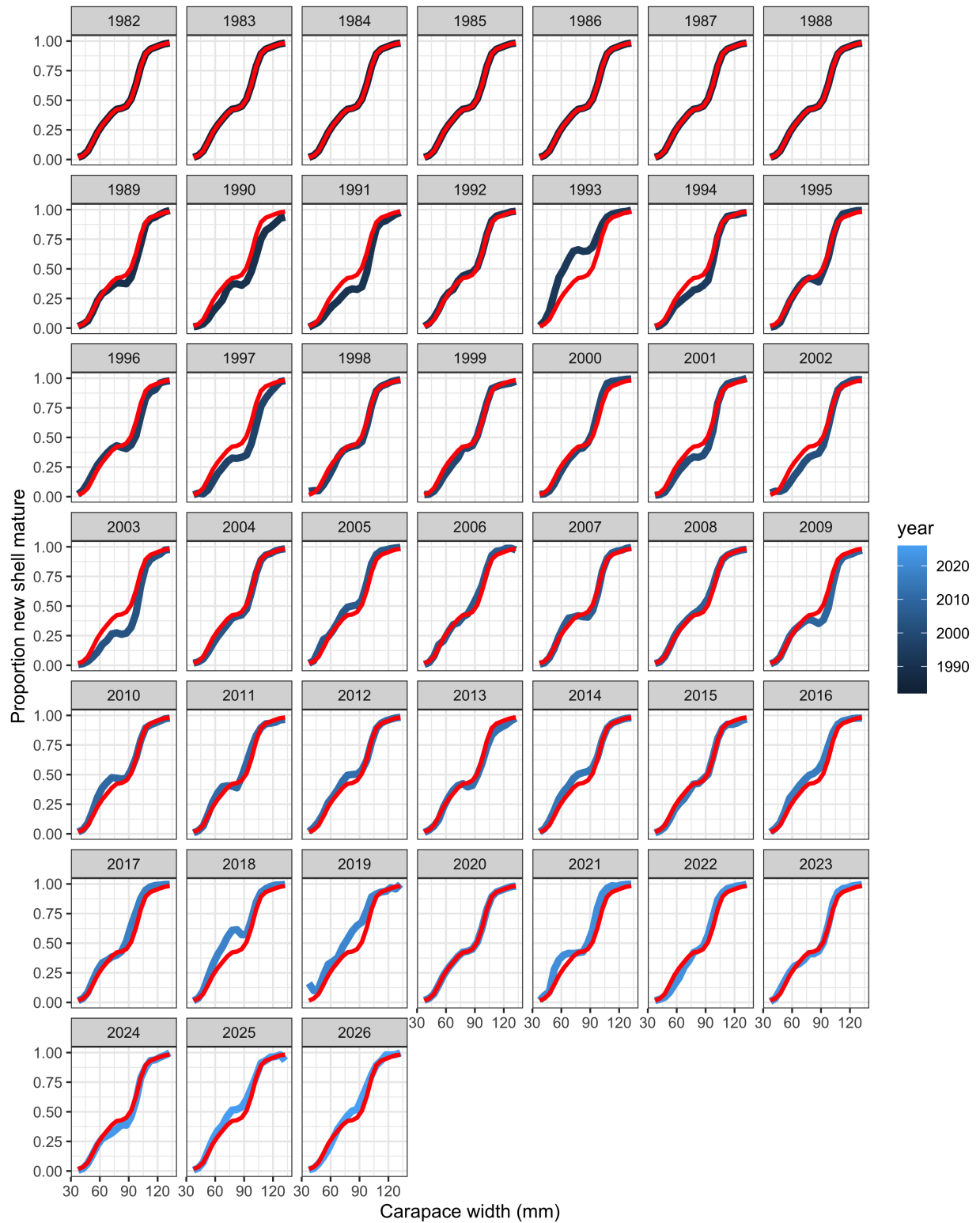


Figure 6: Observed probability of having undergone terminal molt at size for new-shell male crab, based on chela height. The red line is the median over all years; blue lines are individual years.

Bering Sea male snow crab appear to have a terminal molt to maturity based on hormone level data and

findings from molt stage analysis via setagenesis (Tamone et al. 2005). The models presented here assume a terminal molt for both males and females, which is supported by research on populations in the Bering Sea and the Atlantic Ocean (e.g. Dawe et al. 1991).

Mature male snow crab that do not molt may be important in reproduction. Paul et al. (1995) found that old shell mature male Tanner crab out-competed new shell crab of the same size in breeding in a laboratory study. Recently molted males did not breed even with no competition and may not breed until after ~100 days from molting (Paul et al. 1995). Sainte-Marie et al. (2002) stated that only old shell males take part in mating for North Atlantic snow crab.

Maturity and reproductive success

Bering Sea snow crab have historically been managed using morphometrically mature male biomass (MMB) as a proxy for reproductive potential. MMB is used for management because the fishery only retains large male crab, which are nearly 100% mature. Male snow crab are sperm conservers, using less than 4% of their sperm at each mating and females can mate with more than 1 male. The amount of stored sperm and clutch fullness varies with sex ratio (Sainte-Marie et al. 2002). If mating with only 1 male is inadequate to fertilize a full clutch, then females would need to mate with more than 1 male, necessitating a sex ratio closer to 1:1 in the mature population than if 1 male is assumed to be able to adequately fertilize multiple females. Although mature male biomass is currently the basis of management, some aspect of female reproduction is likely also an important indicator of reproductive potential of the stock.

Clutch fullness is recorded for the females measured in the survey (see ESP; Fedewa and Shotwell, 2026). However, quantifying the reproductive potential of the female population from survey data can be difficult. For example, full clutches of unfertilized eggs may be extruded and appear normal to visual examination, and may be retained for several weeks or months by snow crab. Resorption of eggs may occur if not all eggs are extruded resulting in less than a full clutch. Female snow crab at the time of the survey may have a full clutch of eggs that are unfertilized, resulting in overestimation of reproductive potential. Barren females may be a more obvious indication of low reproductive potential and increased in the early 1990s, decreased in the mid-1990s, then increased again in the late 1990s. The highest levels of barren females coincided with periods of high fishing mortality, but even then the proportion of barren females was low (see ESP; Fedewa and Shotwell, 2026). Biennial spawning is another confounding factor in determining the reproductive potential of snow crab. Laboratory analyses showed that female snow crab collected in waters colder than 1.5 degrees C from the Bering Sea spawn only every 2 years.

Further complicating the process of quantifying reproductive capacity, clutch fullness and fraction of unmated females may not account for the fraction of females that may have unfertilized eggs, since these cannot be detected by eye at the time of the survey. The fraction of barren females observed in the survey may not be an accurate measure of fertilization success because females may retain unfertilized eggs for months after extrusion. To examine this hypothesis, NMFS personnel sampled mature females from the Bering Sea in winter and held them in tanks until their eggs hatched in March of the same year (Rugolo et al. 2005). All females then extruded a new clutch of eggs in the absence of males. All eggs were retained until the crab were euthanized near the end of August. Approximately 20% of the females had full clutches of unfertilized eggs. The unfertilized eggs could not be distinguished from fertilized eggs by visual inspection at the time they were euthanized. Indices of fertilized females based on the visual inspection method of assessing clutch fullness and percent unmated females may overestimate fertilized females.

Growth

Several studies are available to estimate the growth per molt of male and female snow crab in the Bering Sea. These studies include:

1. Transit study (2003); 14 crab
2. Cooperative seasonality study; 6 crab

3. Dutch Harbor holding study; 9 crab
4. NMFS Kodiak holding study held less than 30 days; 6 crab
5. NMFS Kodiak holding study 2016; 5 crab
6. NMFS Kodiak holding study 2017; 70 crab
7. BSFRF/NMFS holding study 2018; 4 crab
8. BSFRF/NMFS holding study 2021; 177 crab

In the “Transit study”, pre- and post-molt measurements of 14 male crab that molted soon after being captured were collected. The crab were measured when shells were still soft because all died after molting, so measurements may be underestimates of post-molt width (L. Rugolo, pers. comm.). The holding studies include only data for crab held less than 30 days because growth of crab held until the next spring’s molting was much lower. Crab missing more than 2 limbs were excluded due to other studies showing lower growth. Crab from the seasonality study measured less than 3 days after molting were excluded because soft crab are difficult to measure accurately (L. Rugolo, pers. comm.). In general, growth of snow crab in the Bering Sea appears to be greater than growth of some North Atlantic snow crab stocks (Sainte-Marie et al. 1995). Crab in their first few years of life may molt more than once per year; the smallest crab included in the Tier 3 model, however, are approximately 4 years old and would be expected to molt annually.

Management history

The subsections below summarize the State of Alaska harvest strategy, the history of the B_{MSY} reference point, and the history of the fishery.

ADF&G harvest strategy

Before 2000, the Guideline Harvest Level (GHL) for retained crab only was a 58% harvest rate of the number of male crab over 101 mm CW estimated from the survey. The minimum legal size limit for snow crab is 78 mm; however, the snow crab market generally only accepts crab greater than 101 mm. In 2000, due to the decline in abundance and the declaration of the stock as overfished, the harvest rate for calculation of the GHL was reduced to 20% of male crab over 101 mm. After 2000, a rebuilding strategy was developed based on simulations by Zheng et al. (2002) using survey biomass estimates. The realized retained catch often exceeded the GHL historically.

The Alaska Department of Fish and Game (ADF&G) harvest strategy since 2000 sets harvest rate based on estimated mature biomass. The harvest rate scales with the status of the population relative to a proxy for B_{MSY} , a fixed value: the average total mature biomass at the time of the survey over 1983 to 1997, 921.6 million lb (NPFMC 1998), with MSST at one half of it, 460.8 million lb. Below 25 percent of the proxy, which is one half of MSST and 230.4 million lb, only bycatch is allowed; from there the harvest rate rises with status, from 0.0375 at 25 percent of the proxy to 0.225 at or above the proxy (Zheng et al. 2002). The September 2025 assessment described the averaging window as 1983 to present. That is not correct: a rolling window would not give the fixed 230.4 million lb threshold, and the 2022 and 2024 assessments both state the window as 1983 to 1997. The State proxy is a separate quantity from the Federal B_{MSY} proxy used for the specification, which this cycle is the mean of the REMA-smoothed survey series (Section F).

$$u = \begin{cases} \text{Bycatch} & \text{if } \frac{TMB}{TMB_{MSY}} \leq 0.25 \\ \frac{0.225(\frac{TMB}{TMB_{MSY}} - \alpha)}{1 - \alpha} & \text{if } 0.25 < \frac{TMB}{TMB_{MSY}} < 1 \\ 0.225 & \text{if } \frac{TMB}{TMB_{MSY}} \geq 1 \end{cases} \quad (1)$$

Where TMB is the total mature biomass, TMB_{MSY} is the TMB associated with maximum sustainable yield, and $\alpha = 0.10$ is the status at which the ramp would reach zero. The maximum retained catch is set as the

product of the exploitation rate, u , calculated from the above control rule and survey mature male biomass. If the retained catch in numbers would exceed 58 percent of the estimated number of new-shell males over 101 mm plus 25 percent of the old-shell males over 101 mm, the retained catch is capped at that sum.

History of BMSY

Prior to adoption of Amendment 24, B_{MSY} was defined as the average total mature biomass (males and females) estimated from the survey for the years 1983 to 1997 (921.6 million lbs; NPFMC 1998) and MSST was defined as 50% of B_{MSY} . Under Tier 3, which set the specifications through 2024/25, the biomass reference point was a spawning biomass per recruit proxy, $B_{35\%}$ (Clark, 1993). $B_{35\%}$ is the biomass at which spawning biomass per recruit is 35% of unfished levels and has been shown to provide close to maximum sustainable yield for a range of stock productivities (Clark, 1993). Consequently, it is a commonly used target when a stock recruit relationship is unknown or unreliable. The recruitment years used to calculate the Tier 3 reference points ran from 1982 (1984 in the September 2024 assessment) to the year before the assessment (Table 4). Since the 2025/26 specification the stock has been managed under Tier 4, where the B_{MSY} proxy is the mean of the REMA-smoothed survey series of mature male biomass (Section F). Any return to Tier 3 will need to revisit the SPR reference point, because recent analyses suggest SPR-based reference points do not constrain the snow crab fishery when the probability of having undergone terminal molt is specified to reflect observations in the survey. This is because a large fraction of the population matures (and ceases growing) at a size smaller than is harvested by the fishery.

Fishery history

Snow crab were harvested in the Bering Sea by the Japanese from the 1960s until 1980 when the Magnuson Act prohibited foreign fishing. After the closure to foreign fleets, retained catches increased from relatively low levels in the early 1980s (e.g. 11.85 kt during 1982/83) to historical highs in the 1990s (retained catches during 1990/91, 1991/92 and 1998/99 were 149.07, 143.02 and 88.15 kt, respectively). The stock was declared overfished in 1999, after which retained catches dropped to levels similar to the early 1980s (11.46 kt in 2000/01). Retained catches slowly increased after 1999/00 before dropping again in 2016/17. Total allowable catches were reduced with the collapse of the population in 2021, the fishery was closed for the first time in 2022/23, and the closure continued through 2023/24. A small fishery occurred in 2024/25, with 2.15 kt retained, and a larger one in 2025/26, when the State set a total allowable catch of 4.22 kt and 4.13 kt was retained.

Discards from the directed fishery are the next largest component of the catch after retained catch and approximately track the retained catch. The highest discards occurred during 1990/91 at 35.55 kt which was 23.85 percent of the retained catch during that year. Discards of males in the directed fishery were 2.69 kt in 2025/26. The directed fishery was closed in 2022/23 and 2023/24, so no directed discards were recorded in those years. Non-directed bycatch mortality was 0.37 kt in 2025/26, 88 percent of it in other crab fisheries.

Directed-fishery discards have been estimated from observer data since 1992/93, and the ADF&G total-catch file from which the discard series is derived begins in 1990/91 (Section D). Discards have ranged from 11-100% of the magnitude of retained catch by numbers. Discards reached 50-100% of the magnitude of retained catch during the 2018-2019 heatwave, before the collapse, because of the large year class entering the population. Female discarded catch has been very low compared to male discards and has not been a significant source of mortality. Discard mortality for the directed fishery is assumed to be 30%. Discard of snow crab in groundfish fisheries has been highest in the yellowfin sole trawl fishery, and decreases down through the flathead sole trawl fishery, Pacific cod bottom trawl fishery, rock sole trawl fishery, and the Pacific cod hook-and-line and pot fisheries, respectively (Figure 7). Bycatch in fisheries other than the groundfish trawl fishery has historically been relatively low. Handling mortality for the non-directed fisheries is applied before the data reach the model (see Catch data below). Size frequency data and catch per pot have been collected by observers on snow crab fishery vessels since 1992. Observer coverage has been 10% on catcher vessels larger than 125 ft (since 2001), and 100% coverage on catcher processors (since 1992).

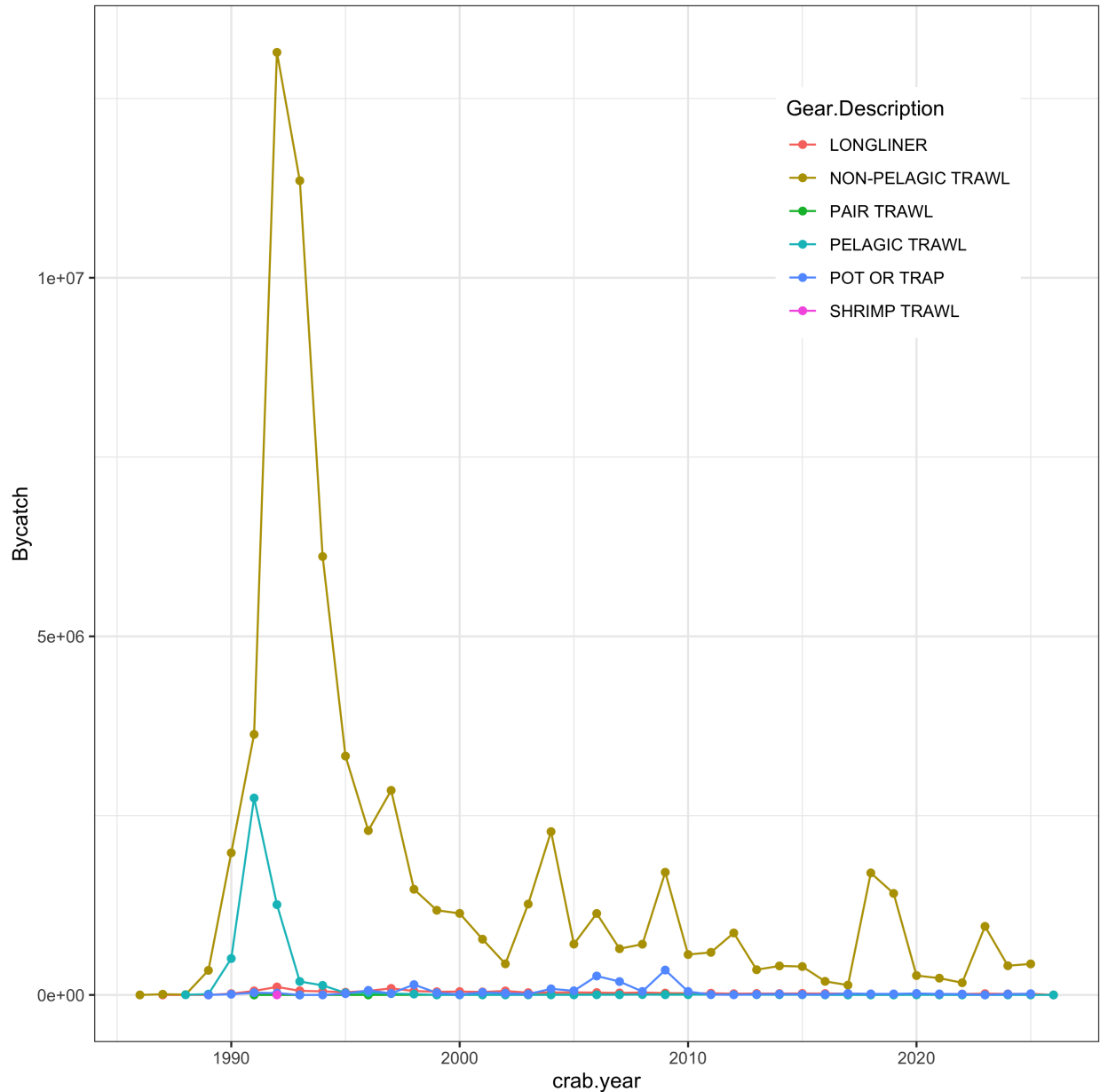


Figure 7: Time series of non-directed bycatch from the groundfish fisheries by gear, in numbers of crab.

Several modifications to pot gear have been introduced to reduce bycatch mortality. In the 1978/79 season, escape panels were required on pots used in the snow crab fishery to prevent ghost fishing. Escape panels consist of an opening with one-half the perimeter of the tunnel eye laced with untreated cotton twine. The size of the cotton laced panel was increased in 1991 to at least 18 inches in length. No escape mechanisms for undersized crab were required until the 1997 season when at least one-third of 1 vertical surface of pots had to contain not less than 5 inches stretched mesh webbing or have no less than 4 circular rings of no less than 3 3/4 inches inside diameter. In the 2001 season the escapement provisions for undersized crab were increased to at least 8 escape rings of no less than 4 inches placed within 1 mesh measurement from the bottom of the pot, with 4 escape rings on each side of the 2 sides of a 4-sided pot, or one-half of 1 side of the pot must have a side panel composed of not less than 5 1/4 inch stretched mesh webbing.

D. Data

Updated time series of survey indices and size compositions were built from the survey specimen data in the same form served by the crabpack R package (Zacher et al., 2026). The specimen data were provided directly by the Shellfish Assessment Program in September 2026 because they carry the net-mensuration correction to the 2024 to 2026 surveys (Section A), which crabpack did not yet include at the time of this assessment. Retained, total, and discarded catch and relevant size composition data were updated for crab years 1990/91 to 2025/26 from files provided by the State of Alaska. Groundfish bycatch was updated from the NORPAC database; snow crab taken in other crab pot fisheries come from the ADF&G total-catch and retained-catch files.

Catch data

Catch data and size composition of retained crab from the directed snow crab pot fishery for crab years 1982/83 to 2025/26 were used in this analysis (Table 23). Time series of discarded catch from the directed fishery are fit, but size composition data are for total catch. The discarded male catch is fit from crab year 1982/83: from 1990/91 it is derived from the ADF&G total-catch and retained-catch files, and before that it is the series used in previous assessments. Observer size composition data for the total catch are available from 1992/93. Pots had no escape mechanisms for undersized crab until 1997, so discards in the early years were probably higher relative to retained catch than in the observed period. See Table 6 for a summary of the catch data range.

The retained and discarded series for the directed fishery are not measured independently. ADF&G report the retained catch, and the discard is the directed total catch minus it. Snow crab retained incidentally in other crab fisheries, mostly the Tanner crab fishery, are handled in 3 places and counted once. First, they are included in the retained series, which is the retained catch counted against the State total allowable catch. Second, they are excluded from the retained figure subtracted to obtain the directed discard, because the directed total catch does not contain them; subtracting the total retention, as previous cycles did, understated the directed discard by exactly the incidental amount. Third, they are excluded from the other-crab-fishery bycatch pool, where the 30 percent handling mortality applies to discarded crab only. Both exclusions are corrections made this cycle (Section A), and the fishery data script checks the directed retained and discard series against the ADF&G discard file in every year the 2 overlap.

Handling mortality is applied at 2 different points, which matters whenever either series is quoted outside this document. For the **directed pot fishery** the discard series entering the model are catches, and the 30 percent handling mortality is applied by GMACS through the `discard_mortality` field of the catch data, which is set to 0.3 on the directed-fishery rows. For the **non-directed fisheries** the handling mortality is applied earlier, during data preparation in `scripts/01_prep_fishery_data.R`: 80 percent for the groundfish trawl fisheries and 30 percent for the other crab pot fisheries, the latter applied to discarded crab only, since crab those fisheries retained are in the retained series. The series that reaches the model is therefore already a mortality, and its `discard_mortality` field is set to 1 so that the rate is not applied twice. Non-directed bycatch mortality was 0.37 kt in 2025/26, of which 0.04 kt was taken in the groundfish trawl fisheries and 0.33 kt in the other crab fisheries, against 0.09 kt in 2024/25.

Table 6: Data included in the assessment, and the years each series spans, for the models fitted to the full data set; Model 25.3, Model 26.1 and Model 26.1a end in crab year 2024/25 and Model 26.1c in 2019/20. Fishery series are crab years; survey series are survey years, and a model with fishery data through crab year $N/N+1$ includes the summer survey of $N+1$. The 2020 survey was cancelled due to the pandemic.

Data component	Years
Retained male crab pot fishery size frequency by shell condition	1982/83 - 2025/26
Discarded male and female crab pot fishery size frequency	1992/93 - 2025/26

Data component	Years
Trawl fishery bycatch size frequencies by sex	1991/92 - 2025/26
Survey size frequencies by maturity, sex and shell condition	1982 - 2019, 2021 - 2026
Retained catch estimates, directed pot fishery	1982/83 - 2025/26
Discard catch estimates, directed pot fishery	1982/83 - 2025/26
Non-directed bycatch mortality (groundfish trawl and other crab pot fisheries)	1982/83 - 2025/26
Total survey abundance estimates and coefficients of variation	1982 - 2019, 2021 - 2026
Survey selectivity priors (BSFRF)	2009, 2010, 2016-2018

Survey biomass and size composition data

Estimates of the numbers of crab by sex and size from the annual eastern Bering Sea (EBS) bottom trawl survey conducted by NMFS (e.g. Figure 8 & Figure 9; see Lang et al., 2019 for materials and methods; see the most recent tech memo for detailed description) are used to calculate the primary indices of abundance used in this assessment. Additional survey stations were added in 1989, which could alter the interpretation of the catchability coefficient for the survey. Consequently, survey selectivity has been historically modeled in 2 ‘eras’ in the assessment (1982-1988, 1989-present). All survey data in this assessment used measured net widths instead of the fixed 50 ft net width based on Chilton et al.’s (2009) survey estimates. Carapace width and shell conditions were measured and reported for snow crab caught in the survey.

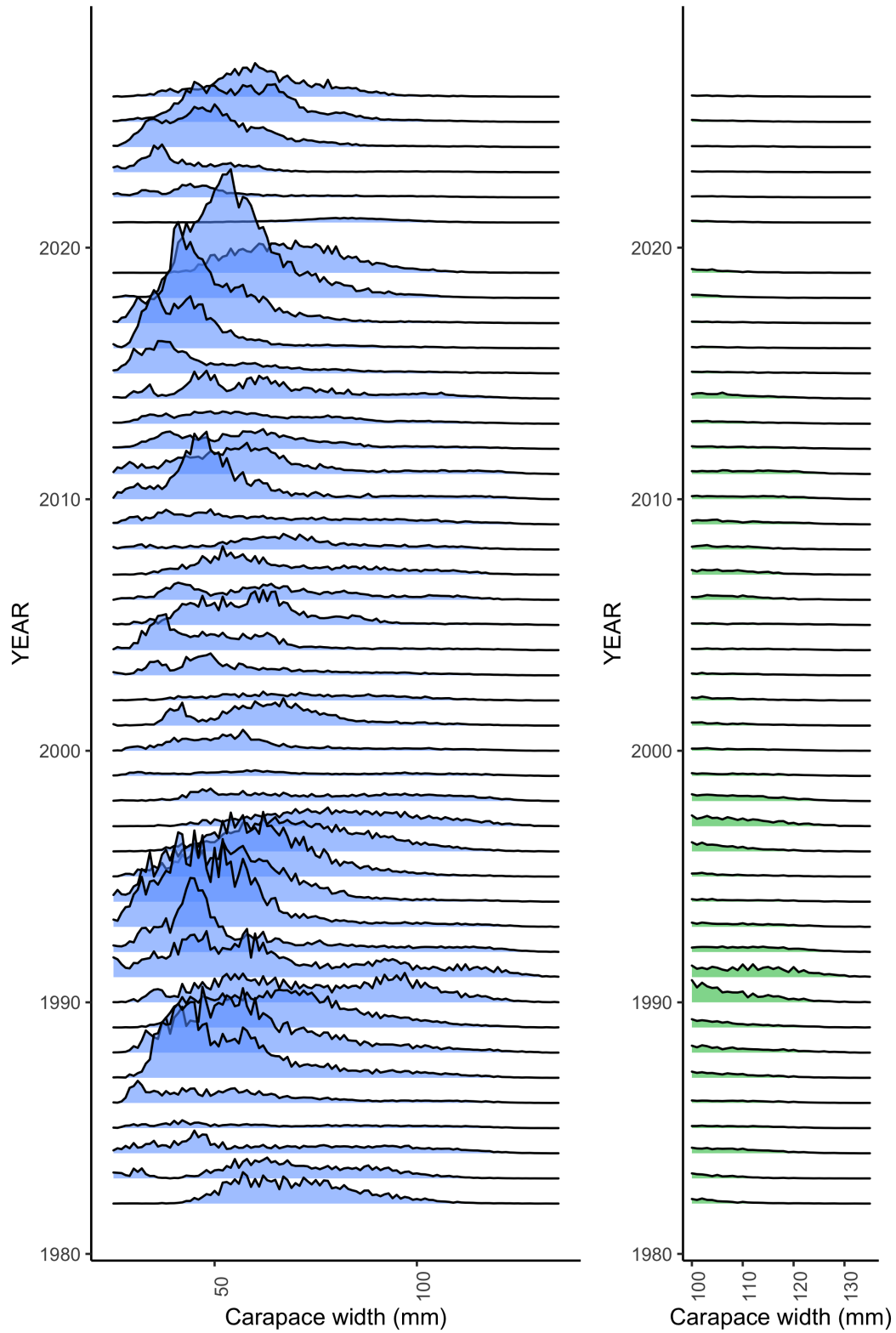


Figure 8: Raw total numbers at size of male crab observed in the survey. Blue are all numbers at size. Green are males > 101 mm carapace width, the industry-preferred size.

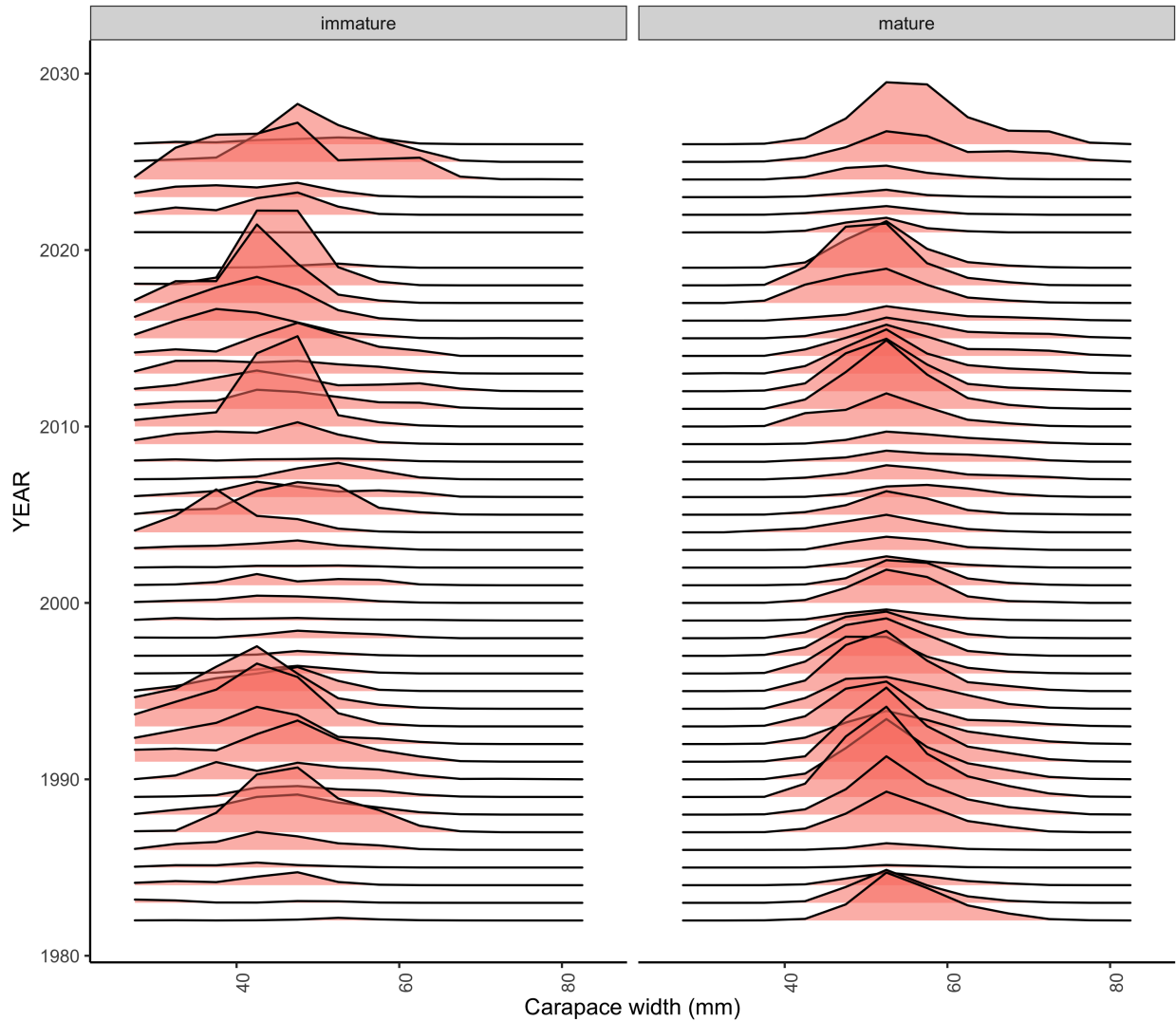


Figure 9: Raw total numbers at size of immature and mature female crab observed in the survey, binned at 5 mm intervals.

Mature male size composition data were calculated by multiplying the total numbers at length for new shell male crab by the proportion mature at length from the Kodiak maturity workflow (Section C); the rolled-forward 2025 model uses the legacy observed proportions. All old shell crab of both sexes were assumed to be mature. New shell crab were demarcated as any crab with shell condition index ≤ 2 . The biomass of new and old shell mature individuals was calculated by multiplying the vector of numbers at length by weight at length. These vectors were then summed by sex to provide the input for assessment (Table 7). The full observed survey series for all 3 maturity definitions, together with total survey abundance, is listed in Table 15. Input sample sizes are specified as 100 for both sexes and maturity states for all years of survey size composition data.

Table 7: Observed mature male and mature female biomass at the time of the NMFS summer survey (1,000 t), each followed by the coefficient of variation of that estimate in parentheses. These are the survey observations fitted by Model 26.1b and Model 26.2; the models whose data end in 2024/25 fit the 2024 and 2025 values as they stood before the net-mensuration correction (Section A). Years run down the left block and continue in the right. There is no 2020 row: the survey was cancelled that year.

Survey year	Male	Female	Survey year	Male	Female
1982	172.4 (0.14)	141.5 (0.16)	2004	71.8 (0.14)	47.7 (0.28)
1983	147.6 (0.13)	82.2 (0.20)	2005	125.1 (0.11)	62.6 (0.22)
1984	166.5 (0.12)	39.4 (0.20)	2006	138.7 (0.26)	50.6 (0.20)
1985	70.0 (0.11)	5.9 (0.22)	2007	148.9 (0.15)	54.4 (0.32)
1986	85.8 (0.11)	15.2 (0.21)	2008	126.2 (0.10)	49.4 (0.24)
1987	185.4 (0.11)	119.6 (0.19)	2009	133.4 (0.13)	50.0 (0.23)
1988	251.0 (0.15)	165.6 (0.18)	2010	157.5 (0.12)	95.0 (0.18)
1989	272.6 (0.11)	256.7 (0.32)	2011	167.7 (0.11)	169.1 (0.19)
1990	370.6 (0.14)	174.9 (0.21)	2012	124.0 (0.12)	143.3 (0.23)
1991	397.0 (0.15)	199.0 (0.24)	2013	93.1 (0.12)	125.7 (0.21)
1992	223.2 (0.09)	123.5 (0.20)	2014	164.0 (0.16)	111.4 (0.21)
1993	215.0 (0.11)	127.1 (0.17)	2015	77.0 (0.12)	81.6 (0.18)
1994	140.7 (0.08)	122.6 (0.14)	2016	62.8 (0.11)	53.1 (0.21)
1995	205.7 (0.13)	165.0 (0.14)	2017	82.8 (0.13)	105.9 (0.22)
1996	270.8 (0.12)	104.4 (0.15)	2018	233.0 (0.17)	165.4 (0.20)
1997	281.4 (0.09)	101.4 (0.20)	2019	202.9 (0.17)	109.2 (0.20)
1998	199.5 (0.09)	70.2 (0.28)	2021	58.1 (0.13)	30.5 (0.44)
1999	90.6 (0.09)	29.8 (0.24)	2022	35.3 (0.15)	21.4 (0.34)
2000	88.3 (0.14)	93.9 (0.54)	2023	24.4 (0.13)	15.3 (0.27)
2001	117.1 (0.12)	74.8 (0.30)	2024	55.3 (0.12)	40.2 (0.23)
2002	84.3 (0.23)	29.5 (0.32)	2025	113.0 (0.15)	141.5 (0.17)
2003	61.2 (0.12)	38.8 (0.41)	2026	109.9 (0.16)	268.7 (0.23)

Spatial distribution of survey abundance and catch

Snow crab are distributed widely over the eastern Bering Sea shelf, but their density and the extent of their distribution have changed over time (Zacher et al., 2026). Spatial gradients exist in the survey data by maturity and size for both sexes. For example, larger males have been more prevalent on the southwest portion of the shelf while smaller males have been more prevalent on the northern portion of the shelf. Centroids of mature female abundance early in the history of the survey were farther south, but moved north during the 1990s. Since the late 1990s and early 2000s, the centroids moved south again, but not to the extent seen in the early 1980s. This phenomenon was mirrored in centroids of abundance for large males.

The observed distribution of large males during the summer survey and the fishery catch have historically

differed, and the origin of this difference is unknown. It is possible that crab move between the fishery and the survey, but it is also possible that fishers do not target all portions of the distribution of large male crab equally. The underlying explanation of this phenomenon could hold implications for relative exploitation rates spatially and it has been suggested that high exploitation rates in the southern portion of the snow crab range may have resulted in a northward shift in snow crab distribution (Orensanz et al., 1998). Snow crab larvae likely drift north and east after hatching in spring. Snow crab appear to move south and west as they grow (Parada et al., 2010). However, little tagging data exists to fully characterize the ontogenetic or annual migration patterns of this stock (Murphy et al. 2010).

Experimental study of survey selectivity

The Bering Sea Fisheries Research Foundation (BSFRF) has conducted supplementary surveys in the Bering Sea in which snow crab were caught during 2009, 2010, 2016, 2017, and 2018. The location and extent of these surveys varied over the years as the survey goals changed. In 2009, the survey consisted of 108 tows around 27 survey stations and the goal was to improve understanding of snow crab densities and the selectivity of NMFS survey gear (Figure 10). Abundances estimated by the industry surveys were generally higher than the NMFS estimates, which suggests that the catchability of the NMFS survey gear is less than 1.

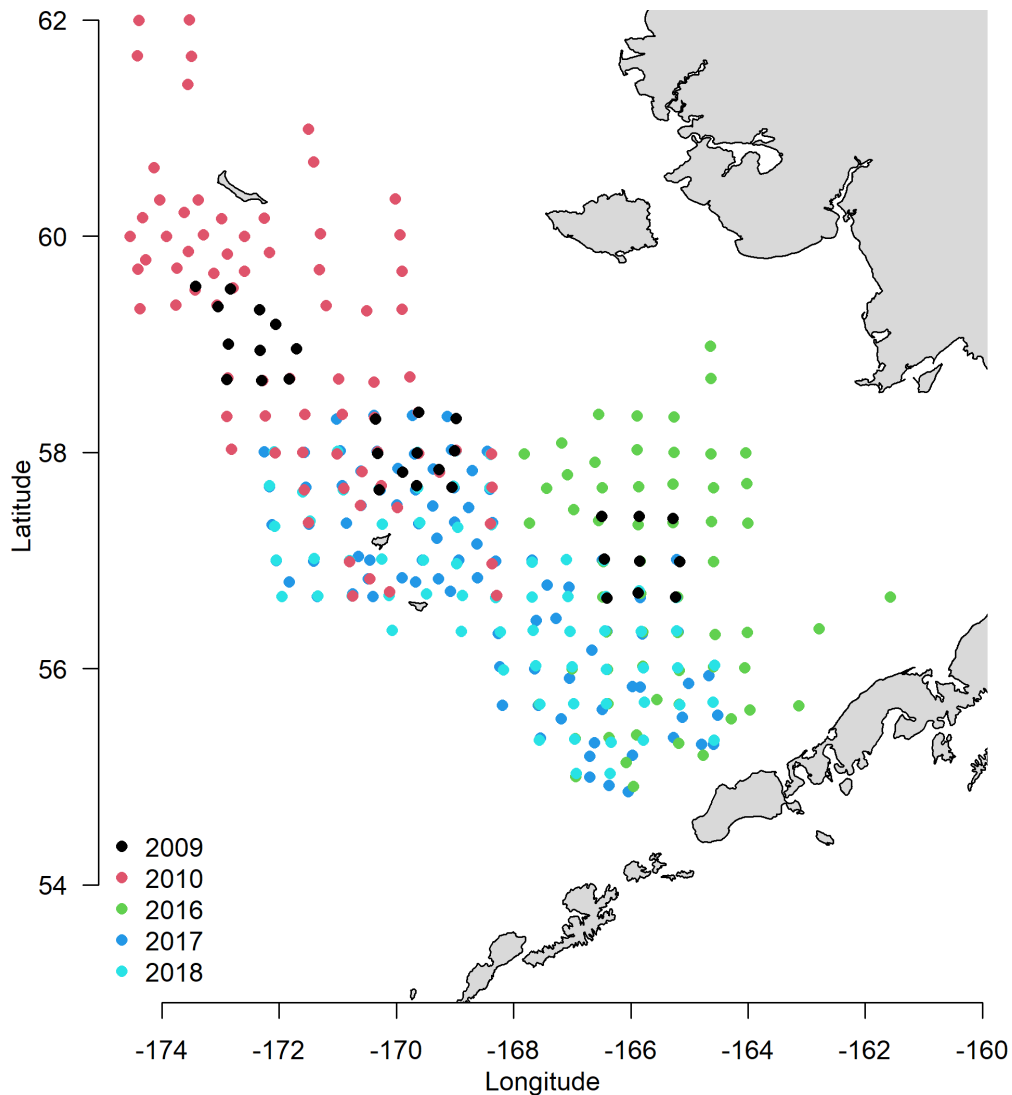


Figure 10: Location of the BSFRF survey selectivity experiments that provided data used in this assessment, over time.

In 2016, 2017, and 2018, snow crab were not the focus of the BSFRF surveys, but were still caught in the BSFRF gear. Comparing the ratio of the number of crab caught at length in the BSFRF gear (which is assumed to have a catchability/selectivity of 1 over all size classes) to the number of crab caught at length within the same area in the NMFS survey gear (which is assumed to have a catchability/selectivity ≤ 1 for at least some of the size classes) can provide an empirical estimate of catchability/selectivity (Figure 11). Empirical estimates of catchability/selectivity vary by year and size class across the different BSFRF data sets (Figure 12 & Figure 13). The number of snow crab used to develop estimates of numbers at length likely contributes to these differences among years (Figure 14), but other factors may also influence catchability/selectivity at size of the NMFS survey gear (e.g. Somerton et al. 2013 show substrate type can influence selectivity). GAMs fit to the empirical estimates of selectivity are used as priors on estimated

selectivity in the currently used assessment model. The standard errors from the GAMs are input as weighting factors for each prior of selectivity at size and sex derived from the BSFRF data.

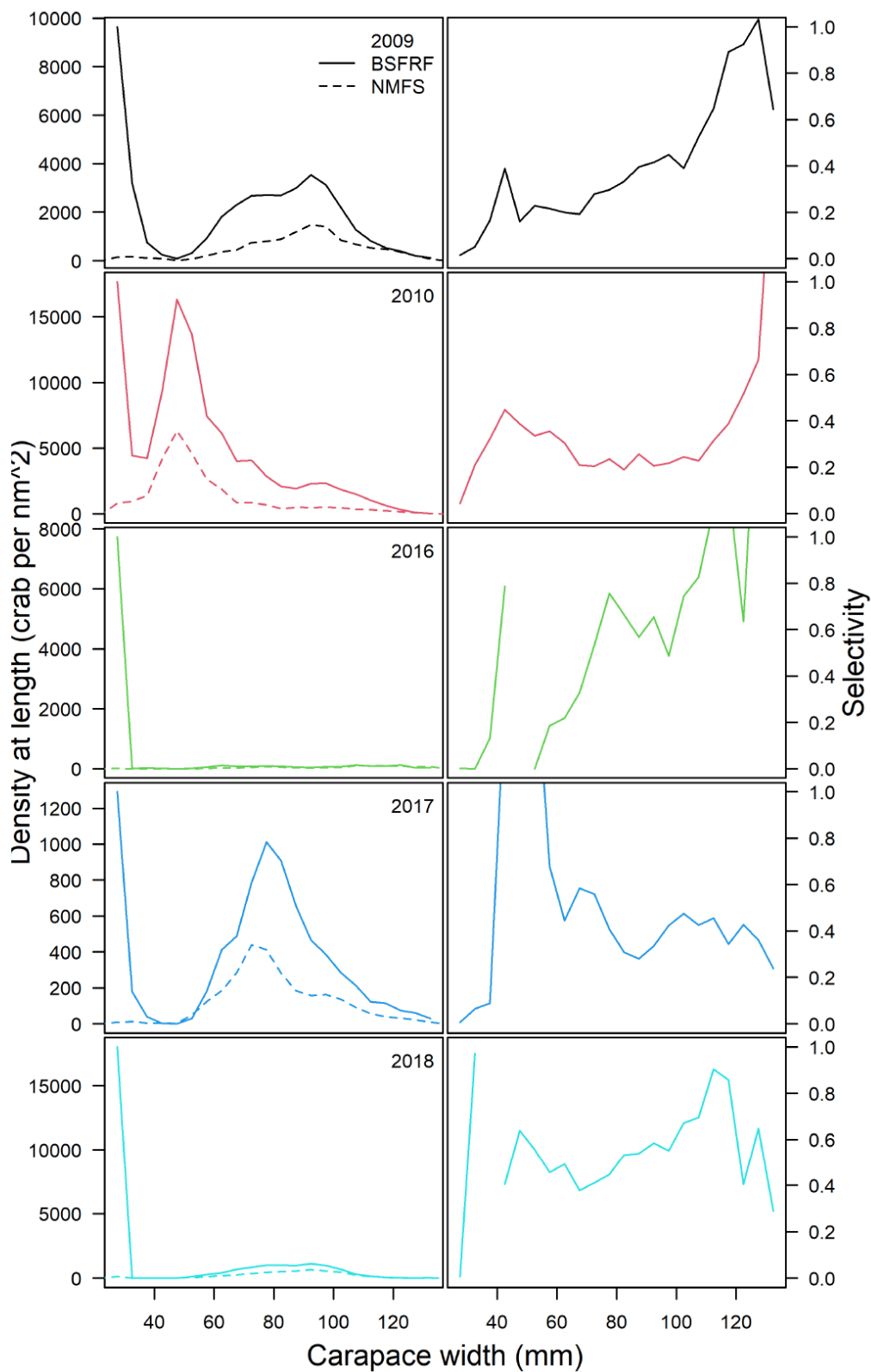


Figure 11: Observed numbers at length extrapolated from length-composition data and estimates of total numbers within the survey selectivity experimental areas, by year (left), and the inferred selectivity, the ratio of crab at length in the NMFS gear to that in the BSFRF gear (right).

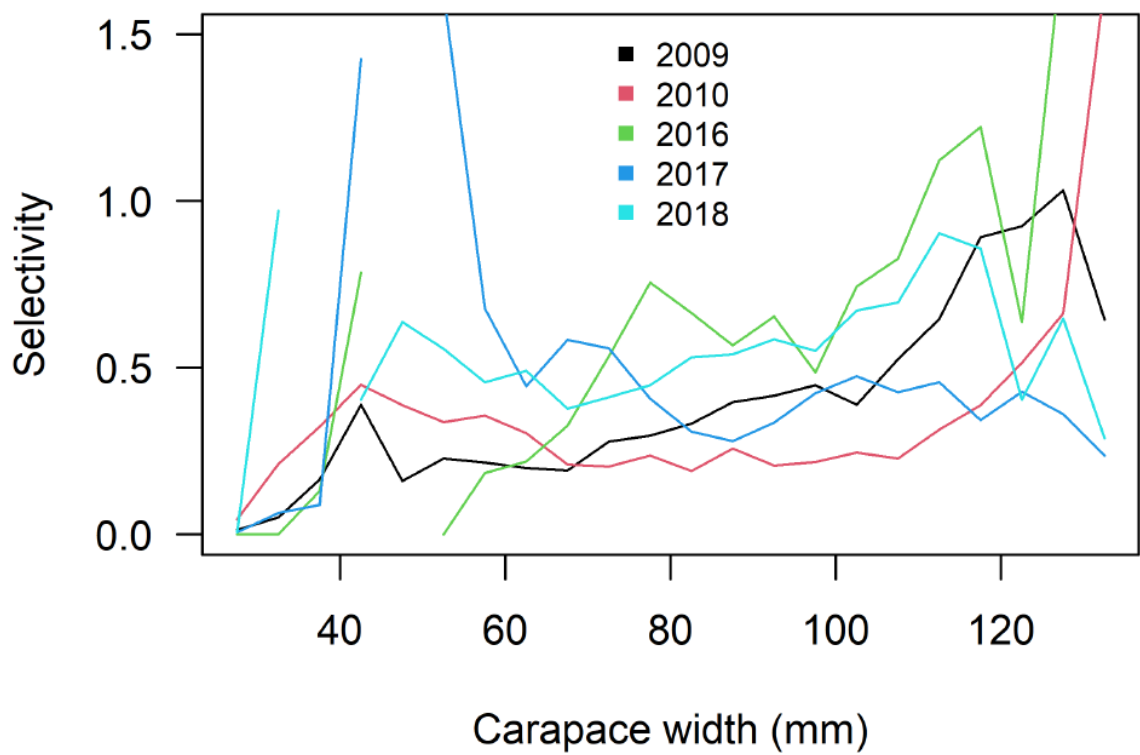


Figure 12: Inferred survey selectivity for all available years of BSFRF data.

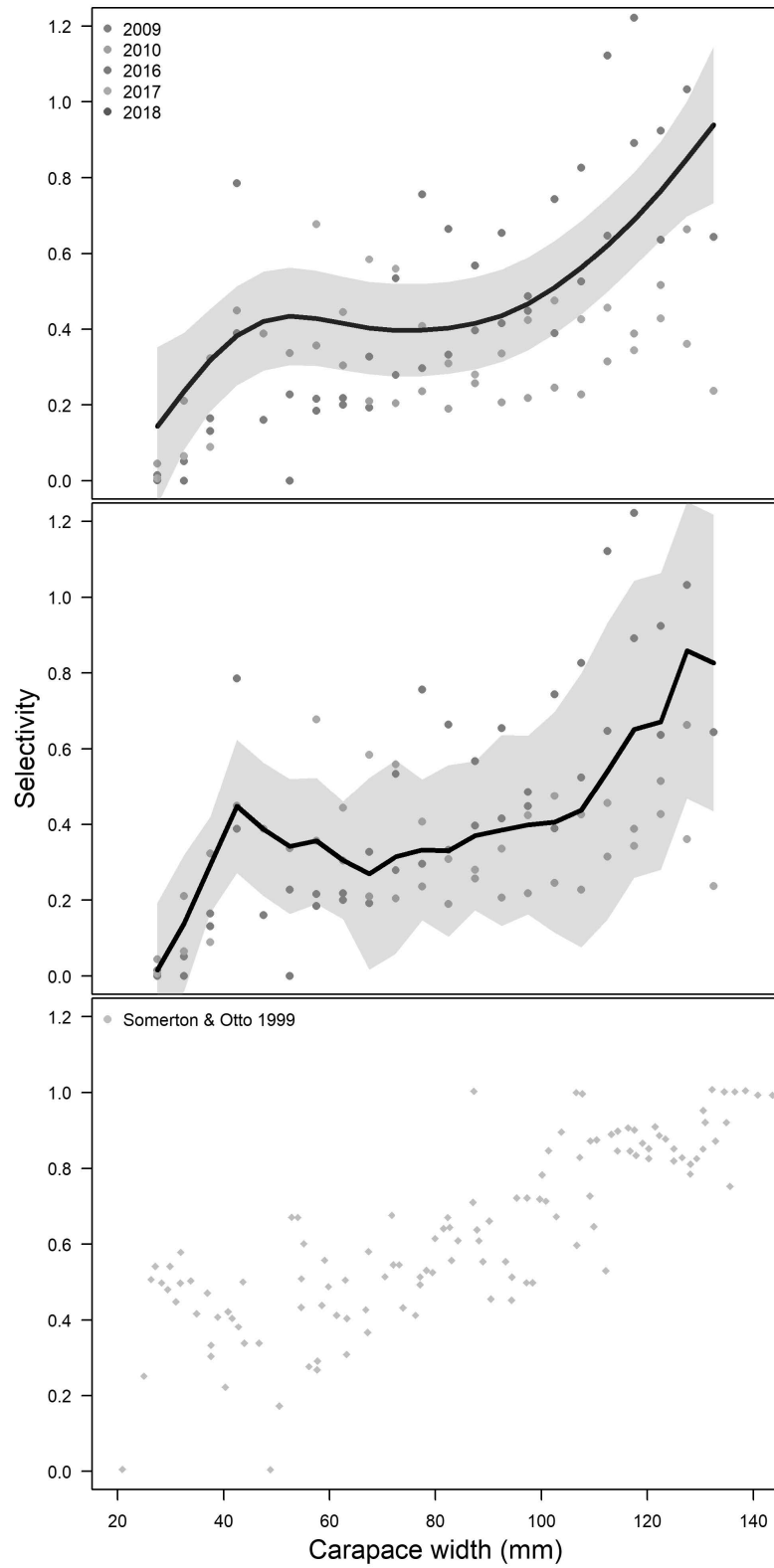


Figure 13: Inferred selectivity from the BSFRF experiments with selectivity at size class estimated by a generalized additive model (top), and by a sample-size-weighted average (bottom).

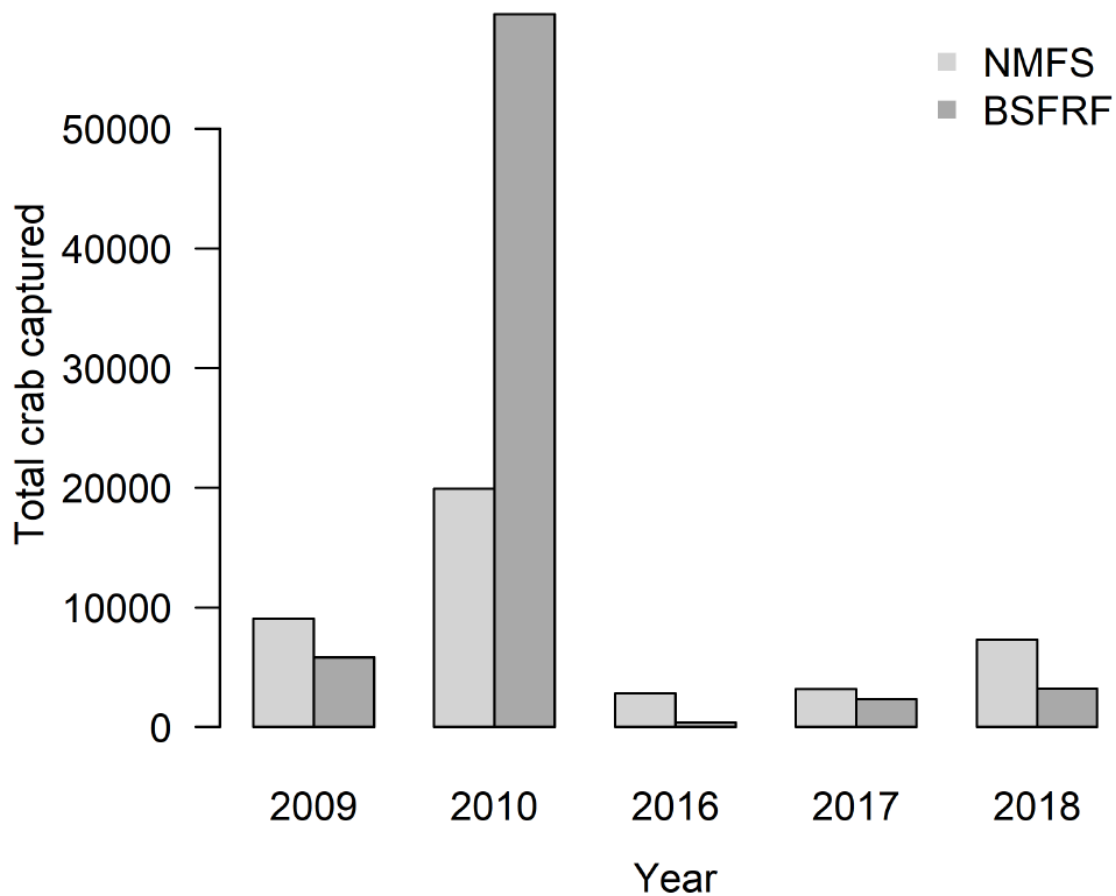


Figure 14: Number of crab collected in the BSFRF experimental areas by the NMFS survey and by the BSFRF survey.

E. Analytic approach

Model description

The Generalized Model for Assessing Crustacean Stocks (GMACS) was adopted as the assessment platform for snow crab in 2022 after a demonstration that GMACS could effectively reproduce the dynamics of the status quo model and offered structural improvements. GMACS is an integrated, size-structured model written in AD Model Builder, a C++ library that uses automatic differentiation (Griewank and Corliss, 1991) to estimate large numbers of parameters in non-linear models. GMACS version 2.20.34 was adopted for this assessment following the January 2026 CPT meeting and is used for every model fitted in this cycle; **Model 25.3** is reported as fitted in 2025 under the earlier version. Newer GMACS releases have since superseded this version. It is retained here so that all models in this cycle are fit with the version the CPT reviewed.

The snow crab population dynamics model tracks the number of crab of sex s , maturity state m , during year y at width w , $N_{s,m,y,w}$. A terminal molt was modeled in which crab move from an immature to a mature state, after which no further molting occurred. The mid-points of the size bins tracked in the model spanned from 27.5 to 132.5 mm carapace width, with 5 mm size classes. The number of estimated parameters differs among the models: 407 in **Model 25.3**, 407 in **Model 26.1**, 407 in **Model 26.1a**, 412 in **Model 26.1b**, 386 in **Model**

26.1c, and 234 in Model 26.2. Parameters estimated within the assessment included those associated with the population processes recruitment, growth, natural mortality (subject to an informative prior and 2 years of additional ‘mortality events’ estimated in crab years 2018/19 and 2019/20), fishing mortality, selectivity (fisheries and survey), and catchability. The yearly probability of undergoing terminal molt, weight at size, discard mortality, bycatch mortality, variance in growth increment, and parameters associated with proportion of recruitment allocated to size bin were estimated outside of the model or specified. The control files specifying the population dynamics are available from the GMACS repository linked in Section J.

A lognormal distribution was assumed for all catch and index time-series, while a robust multinomial was assumed for all size composition data. No likelihood weights were used in the assessment.

A ‘jittering’ approach has been historically used to explore the impact of different starting values on the assessment output (Turnock, 2016). Parameter values were jittered based on a normal distribution centered on 1 with a standard deviation of 0.10 that was then translated to the parameter space defined by the initial value and its bounds. 100 jitters were run for the author-preferred model (Table 8); each run was started from an independently perturbed parameter vector and re-fit to convergence. Each run’s random seed is stored with its results, so the analysis is reproducible. Of the 6 models presented, 4 were jittered (Table 17). Model 25.3 and Model 26.1a were not.

Model selection and evaluation

Models were evaluated based on their fit to the data, evidence of non-convergence, the credibility of the estimated population processes, and the strength of the influence of the assumptions of the model on the outcomes of the assessment. Note that for some of the model scenarios, data inputs are different and, therefore, model fits are not directly comparable.

Model summaries

The key assumptions of these models include:

- the probability of terminally molting at size varies over time and size for males and is specified as fixed inputs to the model based on observations from the survey data. The female probability does not vary over time, which should be revisited
- survey selectivity is estimated by era (1982-88; 1989-present) and sex as a non-parametric curve subject to priors based on the BSFRF survey efficiency experiment data
- growth is a linear function of pre-molt carapace width with a specified variability around post-molt size
- all immature crab molt
- natural mortality is estimated by sex and maturity state with additional mortality events estimated in crab years 2018/19 and 2019/20 and subject to a prior based on an assumed longevity of 20 years
- total and retained fishery selectivity are estimated logistic curves
- all non-directed bycatch (e.g. snow crab caught in the Tanner crab fishery or crab caught in the non-pelagic trawl fisheries) is lumped into a single ‘fishery’ for which a single selectivity is estimated. These removals are recorded for both sexes combined, so in the male-only sensitivity they are fit by the male population alone and the bycatch fishing mortality estimated for males is correspondingly inflated (the affected removals average 0.53 kt a year over 1990/91 to 2025/26 against a mean retained catch of 33.7 kt over the same crab years, and the fit to the series is almost unchanged)
- recruitment is estimated separately for females and males and is allocated in the first 3 size bins. The male-only sensitivity estimates male recruitment only

Model scenarios

Model numbering and its correspondence with the May 2026 assessment The models presented here are numbered on the 2026 cycle, following the May 2026 Crab Plan Team report, which noted that the 2025 accepted model had been mistakenly labeled **Model 25** in the preliminary assessment (its accepted number is **Model 25.3**) and that the runs introduced in May 2026 had been mistakenly numbered on the 2025 cycle. The review guidelines distinguish major changes, which take a new integer, from minor ones, which take a letter. A change to the data alone is treated here as minor. Because the June 2026 SSC report refers to the configuration accepted in May by its May number, the full correspondence is given below.

This document	May 2026 preliminary assessment	Terminal crab year	Role
Model 25.3	Model 25	2024/25	2025 accepted assessment, rolled forward
Model 26.1	Model 25.2c	2024/25	Configuration accepted by the CPT in May 2026
Model 26.1a	Model 25.2e	2024/25	26.1 with the binning, growth-data and incidental-retention corrections
Model 26.1b	Model 25.2e (new data)	2025/26	Author-preferred: 26.1a with the 2025/26 fishery and 2026 survey
Model 26.1c	Model 25.2e (2019 data)	2019/20	26.1b truncated to crab year 2019/20, convergence diagnostic
Model 26.2	Model 26.1	2025/26	26.1b with the female population removed

The configuration the June 2026 SSC report calls **Model 25.2c** is **Model 26.1** here, and the author-preferred run, **Model 26.1b**, is that same configuration with the 3 data corrections and a further year of data. Note that the May document used the label **Model 26.1** for the male-only run, which is **Model 26.2** here.

The models A total of 6 models were explored (Table 17). All models share the same structural assumptions described above and differ only in the version of GMACS and their data inputs. The only exception is **Model 26.2**, which removes the female population entirely and is therefore a structural change. The naming convention reflects an additive series of changes layered onto the September 2025 model (**Model 25.3**).

The base ('rolled forward') model:

- **Model 25.3:** the September 2025 author-preferred model, included for reference only. No data are updated and no structural changes are made. It was fitted under an earlier version of GMACS and is reported as originally fitted.

Models brought forward from the May 2026 assessment:

- **Model 26.1:** the model accepted by the CPT in May 2026. **Model 25.3** updated to GMACS 2.20.34, with the total-male size composition corrected and the plus group enlarged to include all crab greater than 135 mm carapace width, and with the molting probability controls replaced by the new maturity workflow developed by the Kodiak lab (E. Ryznar, in prep). That workflow fits an **sdmTMB** spatiotemporal model to chela-based maturity classifications to produce a smoothed probability of being mature

at size and location, integrated to a population-level annual ogive. The updated series shows a weaker temporal trend in the probability of terminal molt at intermediate sizes. As in May, the model includes fishery data through the 2024/25 season and survey data through the 2025 survey.

- **Model 26.1a:** as Model 26.1, but with the size-composition bin convention changed so that a crab falling exactly on a 5 mm cutoff is assigned to the upper bin, and with a transcription error in the growth data corrected (a 26.3 mm crab's molt increment recorded as 73 mm where the specimen master gives 7.3 mm), and with the corrected accounting for snow crab retained incidentally in other crab fisheries (Section A). Fishery data run through the 2024/25 season and survey data through the 2025 survey. Presented to isolate the effect of the 3 data corrections against the May baseline.

The September 2026 models:

- **Model 26.1b:** the author-preferred model. The Model 26.1a configuration with 1 more year of data: fishery data through the 2025/26 season and survey data through the 2026 summer survey. The data are updated. The model is not.
- **Model 26.1c:** the same configuration with fishery data ending at the 2019/20 season and survey data ending at the 2019 summer survey. Requested by the CPT in May 2026 to test whether the convergence problems originate in estimating recruitment following the 2018-19 collapse and across the 2020 survey gap. The estimated parameter count is 386.

Sensitivity to the female data and dynamics:

- **Model 26.2:** Model 26.1b with the female population removed entirely, not down-weighted. The number of sexes is set to 1, which removes the female size compositions, the female survey indices, the female discard catch, and the female growth observations from the data, and removes the female recruitment, natural mortality, growth, and selectivity parameters from the model. The estimated parameter count falls from 412 to 234. Fixing the female estimation phases alone would be insufficient: a combined-sex catch observation is predicted by summing over both sexes, and the recruitment scale and deviations are not sex-specific, so the female population would continue to influence fishing mortality and recruitment. The non-directed bycatch is recorded for both sexes combined and is therefore fit by the male population alone in this run, as noted among the assumptions above. This is the only model presented here that differs structurally from Model 26.1a, so it takes a new integer rather than a letter suffix. Requested by the CPT in May 2026 and presented as a sensitivity only. Like every other model here it is not proposed for the 2026/27 specification.

The May 2026 preliminary assessment presented a bracket of 14 candidate models exploring 3 axes of uncertainty: the treatment of *Chionoecetes* hybrids, the new maturity workflow, and a set of attempts to improve convergence by correcting the total-male composition, expanding the plus group, and adding an immature survey index. That bracket is not repeated here. The CPT and SSC concluded that hybrid catch and survey data should not be included in the assessment model at this time, and agreed that the immature survey index should not be treated as a convergence fix, so neither the hybrid nor the immature-index candidates are brought forward. The composition correction and the expanded plus group, which the SSC supported as clear technical improvements, are incorporated in every model presented above other than the rolled-forward 2025 model. The full May bracket and its results remain available in the May 2026 preliminary assessment document.

Time series of data used in the assessment are visualized in Figures 16, 17 and 18.

Results

Model convergence and comparison

All 6 models presented here inverted their Hessians; their maximum gradients are in Table 21. Additional Newton steps were applied to every fit made with the current executable, so those 5 are treated consistently.

None of the fits met the conventional threshold of a maximum absolute gradient < 0.001 before the Newton steps. Newton steps reduced the gradient without moving the fit: across the models they changed the objective function and the management quantities by less than 0.0001 percent (the largest movement was in **Model 26.1c**). **Model 25.3**, which was fitted under an earlier version of GMACS and cannot be re-run with the current executable, is reported as originally fitted and retains a maximum gradient of 0.00134. Likelihood components by category for each model are summarized in Tables 18, 19, and 20.

A zero gradient indicates that the fit is at a stationary point of the likelihood. It does not indicate that the parameters are well determined or that other stationary points do not exist.

As in past cycles, jittering was used to evaluate sensitivity to starting values. The jitter results tabulated in this section are for **Model 26.1b**; the **Model 26.1** and **Model 26.2** jitters are drawn on below, and the full results for every jittered model are in Appendix B. Of the 100 runs, 100 produced a complete set of estimates; 77 attained a maximum absolute gradient below 0.01 and 7 met the conventional threshold of 0.001 (Table 8). For comparison, the accepted fit attained 0.00371 before Newton steps and reports a maximum gradient of zero after them (Table 21); the jitter runs are reported on their gradients before Newton steps, making them comparable with one another.

The practical cost of the multiple minima is visible in **Model 26.1**. The jitter analysis located a solution 1.27 negative log-likelihood units better than the fit obtained from the model's own starting values, a difference that would ordinarily be considered small. Adopting it moved B_{MSY} by less than 1 percent, but moved the total OFL from 50.27 to 43.83 kt. The total OFL here is OFL(tot) from **Gmacsall.out**, which is retained catch plus discard mortality summed over all fleets, not the retained-only quantity **spr_cofl_ret**. The choice among solutions that the data separate only weakly therefore has more effect on the management quantities than several of the structural choices examined in this assessment.

The runs converged to 4 well-populated minima besides the reported fit (Figure 19), confirming that the multimodality reported in the 2025 preliminary and final assessments persists in the 2026 model. The best lettered cluster (mode A, the best-fitting solution reached by at least 3 runs) accounted for 13.0 percent of the runs that reached a minimum. It is not the fit adopted here. Across the runs that reached a minimum, the directed-fishery OFL (the OFL for the directed fleet alone, slightly below the total OFL of Table 24) ranged from 75.42 to 84.63 kt and mature male biomass at mating in crab year 2025/26 ranged from 120.2 to 148.2 kt, so the choice of starting values, not the data, moves the management quantities across that range. The same separation is visible in male recruitment (Figure 20) and in MMB (Figure 21).

No jitter run found a better fit, but only 1 of the 77 converged runs reached the reported solution, so the jitter gives limited assurance that it is the global minimum.

The parameters that separate the minima are summarized in Table 9 and Figure 23. Identifying which parameters differ between the minima, rather than only observing that they exist, was requested by the SSC and is intended to direct the structural work needed to resolve the multiple minima. The minima differ in many parameters at once, so no single change is likely to resolve the convergence problems. Of the 15 parameters that most separate the minima (Table 9 lists the largest), by type there are 14 recruitment scale or initial numbers at size, 1 selectivity.

Removing the female population improves the numerical behavior of the model. **Model 26.2** estimates 234 parameters compared with 412 for **Model 26.1b**. Its accepted fit attains a maximum absolute gradient of zero to reported precision after additional Newton steps, and its Hessian is markedly better conditioned than that of **Model 26.1b** (condition number 3.4×10^5 compared with 1.4×10^6 ; smallest eigenvalue 116 compared with 34), with no non-positive eigenvalues. The condition number is the ratio of the largest to the smallest eigenvalue of the Hessian. A smaller value indicates a better-determined minimum, and very large values indicate near-flat directions in the likelihood along which the parameters are poorly determined. Jittering the male-only model over 100 runs recovered its accepted fit in 25.7 percent of the runs that reached a minimum, compared with 1.3 percent for **Model 26.1b**, so dropping the females reduced, but did not remove, the multimodality that has characterized this assessment. The retrospective pattern is not smaller: Mohn's rho for mature male biomass is -0.10 (-0.09 when the terminal survey year is withheld) compared with -0.08 for **Model 26.1b**, and all 3 remain inside the Hurtado-Ferro et al. (2015) bounds. Mohn's rho for male recruitment falls from 9.8 to 0.83. The better conditioning, the higher recovery rate and the much smaller

recruitment retrospective are consistent with the female data confounding growth, natural mortality and selectivity in the two-sex model.

A caveat applies. In **Model 26.2** the base natural mortality offset for immature males is estimated at its lower bound of -1, with a standard error of 2×10^{-5} . Because M is specified as relative for that group, the bound puts immature-male M at $\exp(-1)$ times the mature-male rate, or 0.106 yr^{-1} . The same parameter in the accepted two-sex model is estimated at -0.211 with a standard error of 0.116, well inside its range, giving 0.235 yr^{-1} . Removing the females results in the model estimating immature-male mortality at about a third of the mature rate, and the estimate would go lower if allowed. Because that parameter is pinned at its bound, it no longer contributes a direction of uncertainty to the Hessian, so part of the improvement in conditioning reflects the bound rather than a better-determined likelihood. The implied immature-male mortality should also not be adopted in a specification model without further examination. The other parameters at bounds in **Model 26.2** are the 3 fully selected trawl-survey size classes, which are among the 5 at bounds in the two-sex model and are not diagnostic. Dropping the females also lowers the reference points: B_{MSY} falls from 143.53 to 130.28 kt, the total-catch OFL from 80.38 to 72.49 kt, and terminal mature male biomass from 135.86 to 111.16 kt (Table 24).

Table 8: Summary of the jitter analysis of the author-preferred model, Model 26.1b. Objective function values are negative log-likelihood and gradients are dimensionless. OFL and mature male biomass are in 1,000 t.

Quantity	Value
Jitter runs	100
Runs returning a complete fit	100
Runs with max gradient < 0.01	77
Runs meeting the conventional threshold of 0.001	7
Well-populated minima besides the reported fit	4
Runs at the best lettered mode (%)	13.0
Runs recovering the reported fit (%)	1.3
Negative log likelihood, base fit	-23545.742
Negative log likelihood, best jitter run	-23545.742
Directed OFL, range across converged runs (1,000 t)	75.42 - 84.63
MMB in 2025/26, range across converged runs (1,000 t)	120.2 - 148.2

Table 9: The 10 parameter differences that most separate pairs of jitter minima in Model 26.1b, ranked by the standardized difference in fitted value. Each row compares the 2 minima named in the Comparison column. Parameter values are in the units of the estimated parameter (log scale for most blocks). The standardized difference is dimensionless.

Parameter	What it is	Comparison	Mean in A	Mean in B	Difference	Std. difference
T_pars_est[78]	recruitment scale / initial numbers at size	A vs B	-13.8501	-13.7351	-0.1150	-3.15
T_pars_est[79]	recruitment scale / initial numbers at size	A vs B	-13.9191	-13.8448	-0.0744	-3.14

Parameter	What it is	Comparison	Mean in A	Mean in B	Difference	Std. difference
T_pars_est[77]	recruitment scale / initial numbers at size	A vs B	-13.8218	-13.6783	-0.1435	-3.11
T_pars_est[84]	recruitment scale / initial numbers at size	A vs B	-15.3805	-15.3731	-0.0074	-2.95
T_pars_est[83]	recruitment scale / initial numbers at size	A vs B	-14.3294	-14.3169	-0.0125	-2.93
S_pars_est[57]	selectivity	A vs B	-0.5345	-0.5526	0.0181	2.92
T_pars_est[90]	recruitment scale / initial numbers at size	A vs B	-18.3255	-18.3244	-0.0011	-2.89
T_pars_est[89]	recruitment scale / initial numbers at size	A vs B	-18.0923	-18.0907	-0.0016	-2.88
T_pars_est[91]	recruitment scale / initial numbers at size	A vs B	-18.5268	-18.5262	-0.0007	-2.86
T_pars_est[88]	recruitment scale / initial numbers at size	A vs B	-17.8124	-17.8104	-0.0021	-2.83

The guidelines also ask whether any parameters were inestimable or reached their bounds. In the accepted fit of **Model 26.1b** the only parameters at a bound are 5 trawl-survey selectivity parameters for fully selected size classes, which sit at their upper bound of 0 (full selection). Its Hessian is positive definite: its smallest eigenvalue is 34.0 and none is non-positive, although its condition number of 1.4×10^6 is large (see the comparison with **Model 26.2** above). Of the 412 estimated parameters, 24 have a standard error larger than the absolute value of the estimate. Of those, 16 are estimated within 0.1 of zero, where a large ratio is expected rather than diagnostic: 4 selectivity parameters, 3 fishing mortality deviations, 3 recruitment deviations, 2 female fishing mortality offsets, 2 recruitment proportion parameters, 1 growth parameter, 1 natural mortality parameter. The natural mortality parameter in that group (**M_pars_est**[10], the natural mortality deviation for mature females in event block 1, estimated at 0.015 with a standard error of 0.85) is near zero with a wide standard error, so the data neither require nor rule out a mortality effect there. The remainder are 4 recruitment proportion parameters, 2 recruitment deviations, 1 fishing mortality deviation, 1 natural mortality parameter. The natural mortality parameter among them is **M_pars_est**[2], the natural mortality deviation for mature males in event block 1, estimated at 0.221 with a standard error of 0.67.

These results describe the accepted fit of **Model 26.1b**, not every fit of that model. When the model is started from its default initial values rather than from a previously identified solution, it can settle in a minimum where the 2019/20 immature-female natural mortality deviation, **M_pars_est**[15], is not identified: the estimate drifts toward its upper bound of 10 with a standard error of order 5×10^3 , and the smallest Hessian eigenvalue falls to 1.1×10^{-6} . In the accepted fit the same parameter is estimated at 1.84 with a standard error of 0.58, consistent with the 2018/19 deviation for the same group (1.79). Whether an exponential time-varying natural mortality block on immature females is identifiable from these data is a question for the Plan Team. The alternative is to fix it, as the corresponding rows for the other sex and maturity combinations already are.

Retrospective analysis

Retrospective analyses were performed by sequentially removing the terminal year of data from the model, re-fitting, and comparing the resulting time series of estimated mature male biomass with the estimates from the model fit to the full data set. A retrospective pattern is a consistent directional change in an assessment estimate for a given year as additional years of data are added. The retrospective comprised 10 peels in each

of 2 modes, the standard sweep and one that also withholds the terminal survey year, giving terminal crab years from 2024/25 to 2015/16. Of the 20 peels that completed, 2 met the maximum-gradient criterion of 0.001 applied to the accepted fit; the maximum absolute gradient ranged from 0.00034 to 0.015. Each peel is near a local minimum and none received additional Newton steps.

Mohn's ρ is reported here as the mean across peels of the relative difference between each peel's terminal-year estimate and the estimate for that same year from the model fit to all of the data,

$$\rho = \frac{1}{P} \sum_{p=1}^P \frac{X_{T_p, p} - X_{T_p, 0}}{X_{T_p, 0}},$$

where T_p is the terminal year of peel p and $X_{\cdot, 0}$ is the unpeeled fit. A positive ρ means the peels sit above the full model, i.e. that terminal biomass is revised downward as data accumulate. Hurtado-Ferro et al. (2015) propose a rule of thumb from the 90 percent simulation intervals of their base cases: ρ outside $[-0.22, 0.30]$ for shorter-lived species (a sardine-like life history, $M = 0.4$) or outside $[-0.15, 0.20]$ for longer-lived species (flatfish-like, $M = 0.2$) indicates a retrospective pattern that should be addressed. A value inside the bounds does not confirm that the model is correctly specified. Snow crab mature-male M (0.27) lies between the 2 cases, and the shorter-lived bounds are applied here. Under the longer-lived bounds, Model 26.1 with the terminal survey dropped (-0.20) would fall outside for mature male biomass.

The document presents 2 retrospective analyses. First, the standard retrospective removes the last p years of all data streams, including the survey. Because an assessment with fishery data through crab year $N/N + 1$ includes the summer survey of calendar year $N + 1$, each standard peel still retains 1 survey year beyond its terminal fishery season. Second, the dropped-terminal-survey retrospective also withholds that final survey year, isolating the influence of the single most recent survey observation on the terminal estimate.

For mature male biomass in Model 26.1b, the standard retrospective gave Mohn's $\rho = -0.082$ and the dropped-terminal-survey retrospective gave $\rho = -0.098$ (Table 22, Figures 24 and 27). Male recruitment gave $\rho = 9.751$.

Retrospectives were also run for the other 3 jittered models, and Table 22 reports all 4. For mature male biomass, Mohn's ρ lies inside the Hurtado-Ferro et al. (2015) bounds for every model, ranging from -0.20 (Model 26.1, terminal survey dropped) to 0.07 (Model 26.1c, terminal survey dropped). For male recruitment it exceeds the bounds in every model, ranging from 0.78 (Model 26.2, terminal survey dropped) to 11.31 (Model 26.1b, terminal survey dropped), so terminal recruitment estimates are unreliable in every configuration.

Management quantities are not recomputed for each peel. GMACS calculates reference points only when the retrospective peel count is zero (`gmacsbase.TPL 2.20.34` gates both call sites on `nyrRetroNo == 0`), so every peeled run returns B_{MSY} , B/B_{MSY} and the OFL as exactly zero rather than as estimates. This is a property of GMACS, not of the runs presented here, and it applies equally to the 2025 assessment. The retrospective therefore characterizes only mature male biomass and recruitment.

The mature male biomass pattern is modest. In Model 26.1b the peels sit below the full model, so terminal biomass has tended to be revised upward as data accumulated. These retrospectives are of the Tier 3 models. The 2026/27 specification is calculated under the Tier 4 fallback from the REMA-smoothed survey series, so they have little bearing on the ABC buffer recommended here.

Historical analysis

The retrospective analysis above withholds data from a single model. A historical analysis asks how the perception of the stock has changed across successive assessments accepted for management. Figure 15 shows estimated mature male biomass, at the time of the survey and at mating, from each assessment from 2016 to 2025.

The revisions are much larger than the within-model retrospective pattern. The 2020 assessment estimated mature male biomass at survey time in 2020, a year with no survey, at 486.5 kt. The 2021 assessment, with

the 2021 survey, revised that to 40.95 kt, a 92 percent reduction. The revision then reversed: for biomass at mating in crab year 2020/21, the 2022 assessment gave 19.1 kt and the 2023 assessment 205.4 kt. Terminal-year estimates at mating across the 10 assessments range from 26.7 kt (2021 assessment) to 207.2 kt (2020 assessment). The main drivers of these revisions were changes in the treatment of terminal molt and of the BSFRF selectivity priors, changes in the definition of mature male biomass used, and the absence of a 2020 survey.

The practical consequence for management advice is that terminal-year mature male biomass in this assessment has historically been revised by considerably more than the within-model retrospective analysis implies, and in both directions. The historical series in Figure 15 are from the Tier 3 assessments accepted in each year, shown against Model 26.1b from this assessment, and all are absolute mature male biomass without normalization. Uncertainty intervals for the historical estimates are available in the archived model files and could be added to this figure in a future cycle.

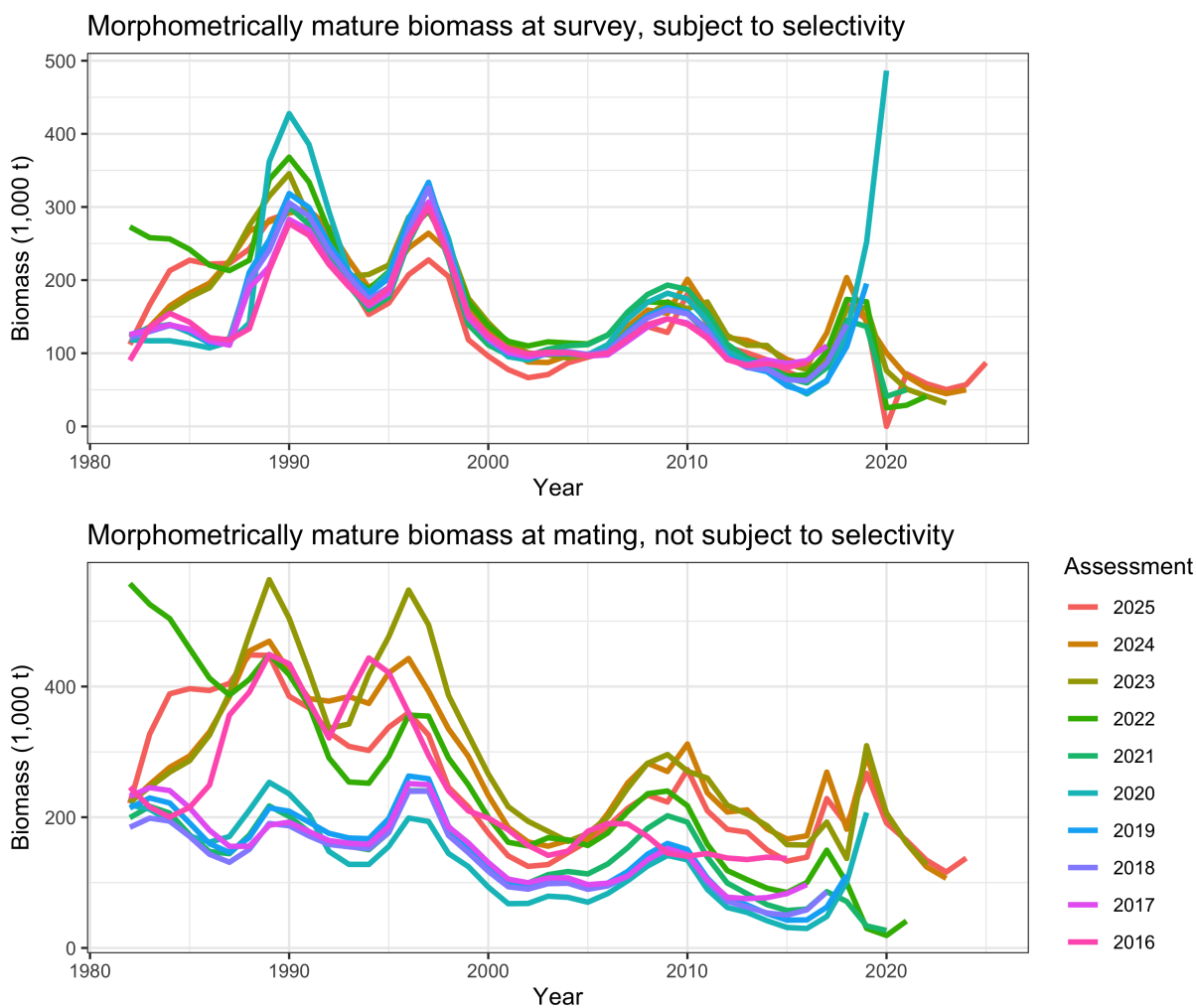


Figure 15: Estimated mature male biomass (1,000 t) as seen by each Tier 3 assessment accepted for management from 2016 to 2025, against the current assessment. The top panel is biomass at the time of the survey and the bottom panel is biomass at mating. Values are point estimates only, without uncertainty intervals.

Model fits

Fits to the survey indices of mature biomass were broadly similar across the models (Figure 29). **Model 26.1b**, the only two-sex model that includes the 2026 survey, continues to have difficulty fitting the terminal year of female biomass. **Model 26.2** estimates no female population, so the issue does not arise for it. The yearly varying probability of terminal molt from the new maturity workflow, used by every model other than **Model 25.3**, shifts the estimated population dynamics modestly but does not resolve the female terminal-year fit (Figure 29).

Fits to the non-directed fishery catches were good for all models (Figure 30). Fits to the directed-fishery retained catch were also good across the model set. Differences among models in the fits to size composition data for retained catch in the directed fishery are small (size composition figures, below). No visually discernible differences among models existed for female discards from the directed fishery. Fits to the non-directed fishery size compositions had some of the largest misfits of all data sources, particularly for males, but this is expected given a single estimated selectivity curve and changes in fishery behavior over time. Input sample sizes are assumed to be 100 for all composition data except for female discards in 2021/22, 2024/25 and 2025/26 (input sample size = 10). Actual numbers of crab measured are far larger, so the input value caps the weight given to each composition. Year-specific input sample sizes are a possible future refinement.

Fits to the survey size composition data were broadly similar across models in most years (size composition figures, below). All models had difficulty fitting the size composition data for immature females in 2009 and 2019, which could suggest some unmodeled size-based mortality or time-varying probability of terminal molt. Estimates of mean growth are shown in Figure 31.

Estimated population processes

The estimates in this section are from the Tier 3 models, which do not converge reliably (Model convergence and comparison, above; Appendix B). Inference from these estimates should therefore be treated with caution.

The estimated abundance of commercially preferred male crab (> 101 mm carapace width) varied among models (Figure 32). Annual estimates of mature biomass and preferred-male abundance from **Model 26.1b**, both at the survey and for the whole population, are listed in Table 25, and total numbers of crab in Table 26. Differences among models were largest in the early years, when the estimated survey selectivity differed. All models agreed that the abundance in recent years has been the lowest in the time series (Figure 33). The estimates of the most recent era of survey selectivity were similar across models for both sexes (Figure 34).

Estimated fisheries selectivities were similar across models (Figure 35). Estimated fully-selected fishing mortality for the directed fishery was highly variable and relatively high for most of the fishery history (Figure 36). The total fishery selectivity curve is shifted far to the right, so only the largest crab experience the fully-selected fishing mortality.

The probability of undergoing terminal molt is input as data (Figure 37). The status quo workflow produces a strong increasing trend through time at intermediate sizes (e.g., at 77 mm the probability rose from ~ 0.2 in the early 1990s to ~ 0.5 after 2010), while the new maturity workflow produces a much weaker temporal trend (~ 0.35 to 0.45 throughout the time series). The new workflow uses a spatiotemporal **sdmTMB** model fit to chela-based maturity classifications and borrows information across years and locations for size bins with sparse chela data. It does not extrapolate the predicted spatial probability surface beyond stations with measured crab.

Trends in recruitment were very similar across models for the early time series, with some variability in scale and differences in timing between the sexes (Figure 38). The male and female series are not independent. GMACS estimates a single annual total recruitment and allocates it between the sexes with an estimated annual logit-scale proportion parameter, so a difference in timing between the sexes reflects the estimated allocation, not separate recruitment processes. Differences in estimated recruitment in the most recent years were observed among models for males and contribute to differences in OFLs across the model set.

Base estimates of natural mortality for mature animals of both sexes were broadly similar across the models presented (Figure 39; Table 24 for males). All models estimated additional mortality events that removed a large fraction of crab by sex and maturity state, except for mature females, at some point during the marine heatwave of 2018-19. In some of the alternative minima found by the jitter analysis, the immature-female natural mortality deviation for the second event block is poorly determined, with a standard error far larger than the estimate. In the accepted fit of the preferred model (**Model 26.1b**) it is estimated at 1.84 with a standard error of 0.58, but in other minima the likelihood is nearly flat along it (Appendix B), so the estimate should not be read as well determined; Model convergence and comparison, above, discusses whether it should be fixed rather than estimated.

MMB and management quantities

Estimated mature male biomass time series had similar trends across models but differed in scale (Figure 40). Annual MMB, male recruitment and directed-fishery fishing mortality for Model 25.3 and Model 26.1b are listed in Table 27. Estimates of B_{MSY} , current MMB relative to B_{MSY} , F_{MSY} , F_{OFL} and the Tier 3 OFL are summarized in Table 24. Across the models presented, the B_{MSY} proxy ranged from 130.3 to 180.1 kt and terminal mature male biomass from 108.0 to 137.5 kt among the comparable models (86.9 kt in 2019/20 for the truncated run). The 3 models whose fishery data end in crab year 2024/25 place projected mature male biomass at mating in the crab year of the fishery below its B_{MSY} proxy (status 0.80, 0.88 and 0.96), while the 2 that include the 2025/26 fishery and 2026 survey place it above (1.19 and 1.28). Status here is the Tier 3 quantity of the control rule, projected MMB at mating in the crab year of the fishery over B_{MSY} , not terminal biomass over B_{MSY} . The additional year of data, rather than any structural change, accounts for that difference. **Model 26.1c**, whose fishery data end in crab year 2019/20, gives a status of 1.05, just above the proxy, but its reference points are computed from a different span of data and are not comparable with the others.

F. Calculation of the OFL

Methodology for OFL

Tier 3

Historically, the Tier 3 OFL was calculated using proxies for biomass and fishing mortality reference points and a ramped control rule. Proxies for biomass and fishing mortality reference points were calculated using spawning-biomass-per-recruit methods (e.g. Clark, 1991). After fitting the assessment model to the data and estimating population parameters, the model was projected forward 100 years using the estimated parameters under no exploitation and constant recruitment to determine ‘unfished’ mature male biomass-per-recruit. Projections were repeated in which the bisection method was used to identify a fishing mortality that reduced the mature male biomass-per-recruit to 35% of the unfished level (i.e. $F_{35\%}$ and $B_{35\%}$). Calculations of $F_{35\%}$ were made under the assumption that bycatch fishing mortality was equal to the estimated average value over the last 10 years.

Calculated values of $F_{35\%}$ and $B_{35\%}$ were used in conjunction with a Tier 3 control rule to adjust the proportion of $F_{35\%}$ that is applied to the stock based on the status of the population relative to $B_{35\%}$ (Amendment 24; NPFMC 2007). To determine the F_{OFL} , the population is projected to the time of fishing for the upcoming fishery under no fishing. If the MMB at that time exceeds 25% of $B_{35\%}$, a fishery can occur and the F_{OFL} is calculated as:

$$F_{OFL} = \begin{cases} 0 \text{ (bycatch only)} & \text{if } \frac{MMB}{B_{35}} \leq 0.25 \\ \frac{F_{35}(\frac{MMB}{B_{35}} - \alpha)}{1 - \alpha} & \text{if } 0.25 < \frac{MMB}{B_{35}} < 1 \\ F_{35} & \text{if } \frac{MMB}{B_{35}} \geq 1 \end{cases} \quad (2)$$

Where MMB is the mature male biomass at mating in the crab year of the fishery, projected after fishing at F_{OFL} , $B_{35\%}$ is the mature male biomass at the time of mating resulting from fishing at $F_{35\%}$, $F_{35\%}$ is the fishing mortality that reduces the morphometrically mature male biomass per recruit to 35% of unfished levels, and α determines the slope of the descending limb of the harvest control rule (set to 0.1 here).

Calculated total Tier 3 OFLs across the 5 comparable models ranged from 43.8 to 80.4 kt, and the truncated run gives 146.9 kt (Table 24). The 3 models with data through crab year 2024/25 give an OFL for the 2025/26 fishery; the 2 with the new data give one for 2026/27, the crab year the 2026 survey observes. For reference, the observed biomass of morphometrically mature males in the 2026 survey, the first observation of crab year 2026/27, was 109.9 kt and of preferred males (> 101 mm) 15.9 kt. The model accepted in May, **Model 26.1**, gives an OFL of 43.8 kt. Correcting the size-composition bin convention, the growth transcription error and the accounting for incidentally retained crab (**Model 26.1a**) lowered the B_{MSY} proxy from 172.7 to 162.5 kt and raised the OFL to 54.0 kt. Adding the 2025/26 fishery and 2026 survey (**Model 26.1b**) lowered the proxy further to 143.5 kt, raised projected status above 1, and raised the OFL to 80.4 kt. The male-only sensitivity gives a lower OFL than the model it is derived from (72.5 kt compared with 80.4 kt). The run truncated to crab year 2019/20 is not comparable with the others because its reference points are computed from a different span of data.

Tier 4 fallback

The Tier 4 fallback is the basis for the 2026/27 harvest specification. The SSC assigned this stock to Tier 4 when it set the 2025/26 specification (October 2025 SSC report, Table 2), and the stock remains in subtier b this cycle (status 0.747, below the B_{MSY} proxy). A random-effects model (REMA) is fitted to the observed survey biomass series, the B_{MSY} proxy is the mean of the smoothed series, and stock status is the terminal smoothed biomass relative to that proxy. $F_{OFL} = M = 0.27 \text{ yr}^{-1}$, the median of the prior on natural mortality, applies at or above the B_{MSY} proxy; below it the ramped control rule reduces F_{OFL} with stock status, as set out below.

The September 2026 CPT questioned calling this approach Tier 4 and refers to it as the fallback option. The crab FMP places in Tier 4 those stocks for which there is enough information for simulation modeling that captures the essential population dynamics of the stock and the performance of the fisheries, and a REMA smooth of the survey series captures neither. The OFL calculation used here also differs from the one the Tier 4 stocks modeled in GMACS use, St. Matthew Island blue king crab and Norton Sound red king crab, which apply the Baranov form rather than $F_{OFL} \times B$. Following the CPT, this document calls the approach the Tier 4 fallback. The stock itself remains in Tier 4, the tier the SSC assigned when it set the 2025/26 specification, and the crab FMP Tier 4 control rule sets F_{OFL} .

The averaging period for the B_{MSY} proxy is the full survey time series, 1982-2026. The proxy represents the long-term average productivity of the stock, so the most recent observation is included. The September 2025 assessment averaged 1982 to 2024 and omitted the terminal year. The average is taken over the smoothed series rather than the observations because the smoothed series supplies a value for 2020, when the survey was cancelled. The smoothed series, with its 95 percent confidence intervals, is listed by maturity definition in Table 16.

The September 2026 CPT discussed which years belong in the proxy and did not reach a change for this stock. It noted that the BSAI crab assessments are not consistent on this point: snow crab, St. Matthew Island blue king crab and Norton Sound red king crab average the whole series, while Pribilof Islands blue and red king crab use a subset. In principle the years should be ones in which the stock was fished at

F_{MSY} , but F_{MSY} is not known. The crab FMP leaves the period open, stating that the proxy is the average biomass over a specified time period and that the SSC may recommend a different value for a stock as the best available science merits. The CPT concluded that leaving out years without a directed fishery is likely the better practice, did not recommend changing the window for snow crab this cycle, and asked the SSC whether assessments should report reference points computed both ways, over all years and over fishery years only. That comparison is not made here and is a candidate for the next cycle.

The choice of averaging window affects the reference points and, through stock status, the recommended OFL. Averaging this cycle's smoothed series over the narrower 1982 to 2024 window gives a B_{MSY} proxy of 148.11 kt and a status of 0.738, compared with 146.29 kt and 0.747 on the full window. The effect of the window choice is small, 1.2 percent on the proxy and 1.4 percent on the OFL (both computed with the ramped rule and the linear equation). The flat-rule sensitivity ($F_{OFL} = M$, linear equation) does not depend on the proxy and is unchanged by the choice of window.

As in the September 2025 assessment, 3 definitions of mature male biomass are reported: morphometrically mature males, large males (≥ 95 mm carapace width), and preferred males (> 101 mm). These are alternative definitions of maturity that reflect the uncertainty in the reproductive potential of the stock. The observed survey biomass for each, in the terminal survey year and the year preceding it, is:

Table 10: Observed NMFS summer survey male biomass (1,000 t) by maturity definition, for the terminal survey year and the one preceding it. These are survey observations, not output of any assessment model. The Tier 4 fallback calculation below is applied to the REMA-smoothed series.

Maturity definition	2025	2026	Change (%)
Morphometrically mature males	113.04	109.91	-2.77
Large males (≥ 95 mm)	31.85	23.00	-27.78
Preferred males (> 101 mm)	22.36	15.88	-28.99

The preferred-male estimate is reported in full because it is the measure industry and the State track. The 2026 survey estimates 28.33 million preferred males (survey CV 13.1 percent), a biomass of 15.88 kt (CV 13.2 percent). This is a decline of 29.0 percent in biomass and a decline of 27.8 percent in abundance from the 2025 survey, and it leaves preferred-male biomass the 4th lowest in the 44-year series, at 23 percent of its long-term mean. The 2025 value was itself a 2-year recovery from the 2023 low, and that recovery has not continued. Morphometrically mature male biomass, which the control rule acts on, is nearly unchanged over the same year (Table 10), so the choice of maturity definition, rather than the survey, determines whether the stock appears stable or declining.

Applying the Tier 4 rule to each maturity definition gives:

Table 11: Tier 4 fallback management quantities by maturity definition (biomass and OFL in 1,000 t; F per year), computed from the REMA-smoothed survey series, not from a GMACS model. See the note below the table.

Maturity definition	B _{MSY}	B current	Status	M	F _{OFL}	OFL (ramped rule, F × B)	Rule changed: flat F _{OFL} = M	Equation changed: Baranov
Morphometrically mature	146.290	109.302	0.747	0.270	0.194	21.221	29.512	16.977
Large (>= 95 mm)	85.203	23.525	0.276	0.270	0.053	1.243	6.352	1.062
Preferred (> 101 mm)	64.426	16.313	0.253	0.270	0.046	0.750	4.405	0.643

Note to the Tier 4 fallback maturity-definition table. 2 independent choices set the OFL, and they are easily confused. The control rule sets F_{OFL} from stock status: the ramped crab-FMP rule scales F_{OFL} down between the closure threshold and the B_{MSY} proxy, while the flat rule holds $F_{OFL} = M$ anywhere above the closure threshold. The catch equation then turns F_{OFL} into a catch: the linear form is $OFL = F_{OFL} \times B$, and the Baranov form is $OFL = B (F_{OFL} / Z)(1 - \exp(-Z))$ with $Z = F_{OFL} + M$. F_{OFL} and the reported OFL are the basis the September 2026 CPT adopted, the ramped rule with the linear equation. The final 2 columns each change exactly one of those choices, so their difference from the reported OFL isolates that choice. The table below sets the 4 combinations out together for the recommended maturity definition.

Table 12: The 2 choices behind the OFL, set out together, on morphometrically mature male biomass (1,000 t). The rows are control rules, which set F_{OFL} from stock status. The columns are catch equations, which turn F_{OFL} into a catch. The ramped rule with the linear equation is the basis the September 2026 CPT adopted and is the OFL reported throughout this document. The other 3 cells are shown because the terms are easy to conflate: flat and ramped are not alternatives to linear and Baranov; they are a separate decision.

Control rule	Linear, $OFL = F_{OFL} \times B$	Baranov
Ramped (crab FMP)	21.22	16.98
Flat, $F_{OFL} = M$	29.51	22.80

Morphometrically mature male biomass is the definition of maturity used, as directed by the SSC (Section B), giving an OFL of 21.22 kt and, after the 50 percent buffer, an ABC of 10.61 kt. The authors caution that fishing at the resulting OFL could remove a large share of the industry-preferred males: the OFL of 21.22 kt is 134 percent of the preferred-male biomass observed in the 2026 survey (Table 10). This comparison does not account for natural mortality between the survey and the fishery, nor for the discard mortality entailed in taking that catch.

The guidelines require reporting the uncertainty in the biomass used by the control rule. The REMA model estimates terminal morphometrically mature male biomass at 109.30 kt with a 95 percent confidence interval of 81.89 to 145.89 kt (a coefficient of variation of 14.8 percent). This is the interval REMA returns for the smoothed series, reflecting the process error the REMA model estimates. It is not the sampling uncertainty of the survey itself: the survey CVs are an input to the fit, not an output. The assumed distribution was lognormal, so the log-scale standard deviation is (log of the upper bound minus log of the lower bound) divided by 2×1.96 , and the coefficient of variation follows from it.

Propagating that interval through the control rule and the catch equation gives an OFL of 21.22 kt with a 95 percent confidence interval of 11.29 to 39.27 kt. The OFL interval is wider than the biomass interval because F_{OFL} also rises with status under the ramped rule: at the lower bound F_{OFL} falls to 0.138 and at the upper bound it rises to 0.269. Stock status is 0.747 with a 95 percent confidence interval of 0.560 to 0.997. The lower bound of the biomass interval, 81.89 kt, is above the minimum stock size threshold of 73.14 kt, so the stock is not overfished at any point in the interval. The upper bound is below one, so the stock is below the B_{MSY} proxy across the whole interval (Section H).

This interval reflects the REMA process error only. It does not include uncertainty in the B_{MSY} proxy, the choice of maturity definition, or the averaging window.

The control rule is the ramped Tier 4 rule from the crab FMP, under which F_{OFL} falls linearly with stock status below the B_{MSY} proxy, $F_{OFL} = M (B/B_{MSY} - \alpha) / (1 - \alpha)$ with $\alpha = 0.10$, and is set to zero at or below the closure threshold $\beta = 0.25$ (where the ramp still gives 0.17 M, so the rule steps to zero rather than reaching it). At the current status of 0.747 this gives $F_{OFL} = 0.1941$ compared with $M = 0.27$.

The flat alternative, $F_{OFL} = M$ above the closure threshold with no ramp, is reported for comparison: it raises F_{OFL} to 0.2700 and the OFL from 21.22 to 29.51 kt (linear equation in both), a difference of 39 percent. It is not recommended. The flat form has sometimes been defended by analogy with the groundfish Tier 5 rule, under which the target rate is the natural mortality rate with no ramp, but that analogy does not apply to this stock: the crab and groundfish FMPs define separate and independent tier systems, and a crab stock assessed under crab Tier 4 takes the crab Tier 4 control rule.

The reported OFL uses the linear catch equation, $OFL = F_{OFL} \times B$, which the September 2026 CPT adopted. It is the form the other BSAI crab Tier 4 assessments apply, so it keeps the comparison across stocks. The author draft had recommended the Baranov form instead, and the CPT asked that both be reported. Table 12 sets them out beside the 2 control rules.

The 2 choices, the control rule and the catch equation, are independent (note to Table 11). Both the ramped rule and the linear equation are in force here, and neither term describes the other choice.

2 features of the reported calculation bias the OFL high, and the 50 percent buffer the CPT applied is set against them, with the remainder for scientific uncertainty.

First, the equation. F_{OFL} is an instantaneous rate and natural mortality acts on the stock over the same year, so the yield taken by fishing is the fishing component of total mortality $Z = F_{OFL} + M$ rather than F_{OFL} applied to the starting biomass. The linear form is the first-order approximation to that and always gives the larger number. The ratio is $(1 - \exp(-Z)) / Z$, which at this cycle's F_{OFL} of 0.194 and M of 0.27 is 0.800. The Baranov form gives 16.98 kt on the same rate and the same biomass, 20 percent below the reported 21.22 kt. The gap widens as F_{OFL} rises, because Z rises with it: holding $F_{OFL} = M$ so that only the equation changes, the Baranov form gives 22.80 kt against the linear 29.51 kt, 23 percent below.

Second, the timing. B is the smoothed estimate of the biomass present at the summer survey, and the directed fishery opens about 7 months later. Natural mortality removes crab over that interval, so the biomass the

rate is applied to is not the biomass present when the fishery fishes. Decrementing the survey estimate by $\exp(-M t)$ over 7 months, a factor of 0.854, would give 18.13 kt, 15 percent below the reported figure. The September 2024 assessment applied a decrement of this kind to its own Tier 4 fallback calculation. It is not applied here: the CPT adopted $F_{OFL} \times B$ on the survey biomass, and this document reports the basis that was adopted and quantifies the bias beside it rather than adjusting it away. The 2 effects overlap rather than add, because both are ways of counting the natural mortality between the survey and the catch. A fishery that takes its catch as a pulse about 7 months after the survey removes $B \exp(-M t)(1 - \exp(-F_{OFL}))$: the biomass surviving to the opening, times the fraction a pulse fishery at F_{OFL} removes. On this cycle's rate that is 22 percent below the linear figure, against 20 percent for the Baranov form alone, which spreads the same natural mortality across a year of continuous fishing instead.

The basis the SSC used to set the 2025/26 specification can be inferred from its reported values. At a stock status of 0.74 ($105.213 / 142.79 = 0.737$ before rounding) the SSC reported $F_{OFL} = 0.19$ (October 2025 SSC report, Table 2). A flat $F = M$ rule would have given 0.27, whereas the ramped rule at that status gives $M \times (0.737 - 0.10) / (1 - 0.10) = 0.191$. The specified OFL of 20.11 kt divided by the MMB of 105.213 kt implies $F_{OFL} = 0.1911$. The 2025/26 specification was therefore set with the ramped rule and the linear catch equation. This assessment applies the same ramped rule and, following the September 2026 CPT, the same linear catch equation, so neither the control rule nor the catch equation is a point of divergence from the 2025/26 specification.

Parameters estimated independently of the assessment

The Tier 4 fallback does not estimate biological parameters. The only quantity it takes as given is natural mortality (first bullet below). The remaining quantities listed are fixed inputs to the Tier 3 models:

- **Natural mortality**, $M = 0.27 \text{ yr}^{-1}$ for mature males. This is the median of the prior on natural mortality used in the integrated assessment. It is the target fishing mortality at the B_{MSY} proxy and the maximum from which the Tier 4 control rule ramps down below it.
- **The probability of terminal molt at size**, supplied as a fixed input from the Kodiak laboratory's spatiotemporal `sdmTMB` maturity workflow rather than estimated within the model.
- **The variance in the growth increment**, specified rather than estimated. Mean growth per molt is estimated within the assessment, and the model is fit to the growth data (Figure 31). Only the variability about the predicted post-molt size is fixed.
- **Weight at size**, specified from the published relationship.
- **Discard and bycatch mortality rates**, specified rather than estimated.

Status determination

Is the stock subject to overfishing? No. Overfishing is determined by comparing the catch from the most recent complete crab year with the OFL specified for that year. The catch compared is the recalculated total catch, the crab that died as a result of fishing. It was 5.31 kt in 2025/26: 4.13 kt retained, 0.82 kt of directed-fishery discard mortality (30 percent of 2.69 kt of male and 0.03 kt of female discarded catch), and 0.37 kt of non-directed bycatch mortality (components rounded), of which 0.04 kt was taken in the groundfish trawl fisheries and 0.33 kt in other crab fisheries.

The discard and bycatch series reach the model on different bases, which matters for anyone quoting either one on its own. The directed discards enter the data as catches, and the 30 percent handling mortality is applied inside the assessment model rather than to the data, which is why the discarded catch and its mortality are both given above. The non-directed bycatch already has handling mortality applied to it in the data preparation (Section D), 80 percent for the groundfish trawl fisheries and 30 percent for discards in the other crab fisheries (crab those fisheries retained are in the retained series), so the 0.37 kt is the bycatch mortality with handling rates applied. It is 4.3 times the 0.09 kt of 2024/25, almost entirely because bycatch in the other crab fisheries rose from 0.05 to 0.33 kt, while the groundfish trawl component was little

changed. The recalculated total catch is compared to the OFL of 20.11 kt that the SSC specified for 2025/26 in October 2025. It was 26 percent of the specified OFL. Counting the directed discards in full, with no handling mortality, would give 7.22 kt. The SSC has not yet adopted a total for 2025/26; its 2024/25 total of 2.81 kt (Table 1) was retained catch plus the full male discard, without bycatch, and is not a mortality.

Is the stock overfished? No. For 2025/26, mature male biomass is 109.30 kt against a minimum stock size threshold of 73.14 kt, both from this assessment, so the stock is above the threshold on the point estimate and across the whole of its 95 percent confidence interval (Section F). It remains below the B_{MSY} proxy of 146.29 kt, so it is not rebuilt. The stock was determined to be overfished for 2024/25 in October 2025, with mature male biomass of 60.08 kt against a minimum stock size threshold of 71.40 kt (October 2025 SSC report, Table 1), and it remains in the rebuilding plan adopted under Amendment 53.

Is the stock approaching an overfished condition? Unknown. This requires a projection of mature male biomass. The Tier 3 models do not converge reliably and their recruitment estimates carry a large retrospective bias, and the Tier 4 fallback makes no projection, so none is available.

F_{limit}

Under the Tier 4 control rule, the fishing mortality rate above which the stock is considered subject to overfishing is the natural mortality rate when biomass is at or above the B_{MSY} proxy. Under the FMP ramp it is reduced below that point. This document applies the FMP ramp (Section F), so at the current status of 0.747 the F_{limit} is 0.194 yr^{-1} rather than M . Under the flat alternative it would be $M = 0.27 \text{ yr}^{-1}$ across the whole range above the closure threshold. This is a different quantity from the reverse-engineered F reported for Tier 1-3 stocks, which is the rate that would have produced a catch equal to the previous year's OFL. That quantity is not computed here.

G. Calculation of the ABC

The recommended acceptable biological catch (ABC) is calculated by subtracting a buffer from the OFL. The buffer applied here is 50 percent, giving an ABC of 10.61 kt against an OFL of 21.22 kt.

The buffer covers 2 things: the known upward bias in the reported OFL, and the scientific uncertainty in it. The 95 percent confidence interval on the OFL ranges from 11.29 to 39.27 kt, and the OFLs under the alternative maturity definitions fall below it, so the choice of maturity definition moves the OFL further than the statistical uncertainty in the biomass does (Section F).

The September 2026 CPT adopted the linear catch equation and, with it, a 50 percent buffer set against the known upward bias in the reported OFL. Both components of that bias are quantified in Section F. The linear form $OFL = F_{OFL} \times B$ ignores that natural mortality removes crab over the same year the fishery operates; on this cycle's rate the Baranov result of 16.98 kt is 20 percent below it. The biomass it multiplies is the summer survey estimate, roughly 7 months before the winter fishery, and decrementing it for natural mortality over that interval would remove 15 percent on its own. The 2 effects overlap rather than add: the catch a fishery operating 7 months after the survey would take at F_{OFL} is about 22 percent below the linear OFL, or 16.48 kt. The ABC of 10.61 kt is 36 percent below that figure, and that margin is the part of the buffer that covers scientific uncertainty. The bias is offset in the buffer; the OFL itself is not adjusted for it.

The September 2026 CPT gave 5 reasons for the 50 percent buffer. Only 3.5 percent of terminally molting males molted into the industry-preferred size range in 2026. Recruitment is very low. The sex ratio is strongly skewed, at roughly 85 mature females for every mature male. The OFL is computed on morphometrically mature male biomass rather than on males ≥ 95 mm, which the CPT considers the more appropriate basis and which changes the OFL by more than an order of magnitude (Table 11). And the $F_{OFL} \times B$ calculation is biased upward, as quantified above.

A further 2 considerations bear on the buffer but did not drive it. The ESP indicates favorable thermal and feeding conditions for snow crab (Table 14), and the Tier 4 fallback OFL of 21.22 kt is considerably lower than the Tier 3 OFLs, which range from 43.8 to 80.4 kt across the comparable models and reach 146.9 kt in the truncated run (Table 24).

The June 2026 SSC supported reporting a stock-specific history of the buffers applied to the OFL and the CPT's suggestion that a historical buffer could initially be set at the average buffer from the previous 5 assessments (Table 13).

Table 13: History of the ABC buffer applied by the SSC, as a percentage of the OFL, for the 5 most recent assessments. The mean is 41 percent. Each value is read from Table 2 of the October SSC report for that assessment year, except 2021, which is as printed in the September 2025 assessment.

Assessment year	SSC buffer (% of OFL)	Source
2021	25%	2025 SAFE, Section G
2022	25%	October 2022 SSC report, Table 2
2023	50%	October 2023 SSC report, Table 2
2024	65%	October 2024 SSC report, Table 2
2025	40%	October 2025 SSC report, Table 2

The 50 percent buffer falls within the range the SSC has applied to this stock in recent years. For the 2025/26 specification the SSC applied a 40 percent buffer, setting an ABC of 12.07 kt against an OFL of 20.11 kt (October 2025 SSC report, Table 2). Against the history in Table 13 the recommended 50 percent buffer matches the buffer the SSC applied in the 2023 assessment (for 2023/24) and is above the 41 percent average of the 5 years shown. The author draft recommended 20 percent, which would have been the smallest in that history, and the increase to 50 percent follows from the CPT's choice of the linear catch equation over

the Baranov form the author draft used, described above, rather than from any change in the stock or in the control rule.

The recommended OFL of 21.22 kt is 6 percent above the 20.11 kt specified for 2025/26, while the recommended ABC of 10.61 kt is 12 percent below the 12.07 kt specified, given the change in buffer from 40 percent to 50 percent. The biomass the control rule acts on is nearly unchanged: the smoothed mature-male series rose about 4 percent, and the survey observation behind it fell about 3 percent (Figure 25). On the 2025/26 buffer the ABC would have been 12.74 kt, so the fall in the ABC is a consequence of the buffer, not of a change in the stock, the control rule or the catch equation. The contrast is sharper against the measure industry tracks: preferred-male biomass fell 29.0 percent over the same year (Table 10), to the 4th lowest value in 44 years (Table 15). In the current-year row of the risk table (Table 14), the assessment-related, ecosystem and fishery-informed categories score Level 1, Normal, and population dynamics scores Level 2, Increased concern, reflecting the low observed biomass of industry-preferred males.

Risk table

The risk table follows the 4 categories used for groundfish, in the tiered form the June 2026 SSC described: a long-term row for persistent uncertainty, which justifies a base or historical buffer, and a current-year row for year-specific risk. The SSC scopes the long-term row to the assessment and population-dynamics categories only, so the ecosystem and fishery cells in that row are not scored.

The ecosystem and fishery-informed cells below are taken from the 2026 risk table summary prepared from the ESP (Fedewa and Shotwell 2026), the AFSC Spring Preview of Ecosystem and Economic Conditions Workshop (AFSC Spring PEEC 2026), and the eastern Bering Sea Ecosystem Status Report (Siddon 2026, in press). The risk table summary scores current-year population dynamics Level 1, Normal. The authors raise that cell to Level 2, Increased concern, because the observed biomass of industry-preferred males is the 4th lowest in the 44-year survey time series. The ESP is Appendix A to this assessment.

Table 14: Risk table for eastern Bering Sea snow crab. Current-year ecosystem and fishery-informed levels are from the 2026 ESP/ESR risk table summary. The summary scored current-year population dynamics Level 1; the authors raised it to Level 2. The assessment-related levels and the long-term population dynamics level were assigned by the authors. The long-term row is scoped to the first 2 categories, following the June 2026 SSC.

Category	Long-term / persistent	Current year
Assessment-related	Level 2: Increased concern. Multimodality has persisted across assessment cycles and is the reason the stock moved from Tier 3 to Tier 4. Jittering Model 26.1b returns to the reported fit in only 1.3 percent of converged runs. A likelihood improvement of 1.27 units moved the OFL of Model 26.1 by 12.8 percent. Successive assessments have revised the same historical years by up to an order of magnitude (Section E, Historical analysis), which is far larger than the within-model retrospective pattern. Model 26.1b estimates about 400 parameters, many highly correlated, which the June 2026 SSC identified as consistent with overparameterization.	Level 1: Normal. The OFL is based on a Tier 4 fallback assessment whose terminal biomass has a CV of 14.8 percent, a 95 percent confidence interval of 81.9 to 145.9 kt, and a status interval of 0.560 to 0.997.
Population dynamics	Level 2: Increased concern. There is considerable uncertainty regarding the population dynamics estimated in the GMACS model. Estimates of M across the various models have large CVs and recruitment estimates have been shown to have high retrospective bias. There is also evidence of decreasing size-at-maturity and an increasing proportion of hybrids in the data.	Level 2: Increased concern. Observed biomass of industry-preferred males (> 101 mm) is the 4th lowest in the 44-year survey time series. A highly female-skewed sex ratio, a downward shift in male size at maturity, and the depressed abundance of large males add to the concern and should continue to be monitored.

Category	Long-term / persistent	Current year
Ecosystem	Not scored (long-term row is scoped to the first 2 categories)	Level 1: Normal. Spring 2026 offshore transport moved crab away from suitable benthic habitat. Thermal conditions over the shelf from winter 2025 to summer 2026 have been favorable for snow crab, with an extensive cold pool and high sea ice extent. Pelagic feeding conditions have remained favorable since 2023, while benthic prey indicators were mixed in 2025. Competition for space remained high and competition for prey remained low in 2025. Predation pressure from Pacific cod was reduced in 2025. Overall, ecosystem concerns are minor with uncertain impacts on the stock.
Fishery-informed	Not scored (long-term row is scoped to the first 2 categories)	Level 1: Normal. Fishery-informed indicators generally support stable stock condition. Shifts in fleet behavior appear motivated primarily by weather, sorting, fuel costs and TAC considerations rather than stock health or distribution. Many skippers noted increased hybrid abundance during the 2025/26 fishery, consistent with the dramatic increase in hybrid abundances observed on the 2025 EBS bottom trawl survey.

Author recommendations

The June 2026 SSC recommended that only the Tier 4 fallback be brought forward in October, to allow time for the development of a simpler and more stable Tier 3 model. The overfishing limit is calculated on that basis. The Tier 3 models are presented to document progress and are not proposed for specification.

The May 2026 preliminary assessment put 3 questions to the CPT and SSC that have since been settled and are not reopened here. The composition correction and the expanded plus group were endorsed as technical corrections and are included in every September model except the rolled-forward 2025 model (**Model 25.3**). The immature survey index was rejected as a convergence fix on the grounds that it shifts the model toward higher natural mortality among mature males and raises a question of duplicative use of the same survey data. Hybrid catch data were judged premature for inclusion in the snow and Tanner crab assessment models, with hybrid-related uncertainty to be handled through the existing ABC buffer-setting process.

The maturity definition used for management has a large effect on the recommendations, and the decline in size at maturity and the possibility of density-dependent maturity make that choice uncertain. The definition also changes the OFL: morphometric maturity gives 21.22 kt against 1.24 kt on ≥ 95 mm and 0.75 kt on > 101 mm (Table 11). The September 2026 CPT set the specification on morphometric maturity, and that is the definition reported here. The 2025 assessment recommended ≥ 95 mm, arguing that morphometric reference points permit the removal of essentially all large males while the trend in large males is firmly negative.

The authors' priorities for the coming cycle are to identify and construct a simplified Tier 3 model (fixing the recruitment sex ratio at 50:50, reducing confounding among growth, natural mortality and selectivity, estimating growth externally, and considering an earlier equilibrium start year) in preference to further iterations of **Model 26.1b**. The male-only model (**Model 26.2**) is a first step in that direction and is reported here. The September 2026 CPT identified it as the most promising of the Tier 3 models presented and recommended a simplified male-only model with parameters added back in sequence, testing convergence at each step, so the staged simplification described above will start from the male-only structure rather than from **Model 26.1b**. The CPT expects to see that work at its January 2027 modeling workshop. Additionally, improvements to data treatment following discussions with the CPT are a priority, particularly the construction of separate immature and mature data sets.

A yield-per-recruit analysis, requested by the SSC in June 2025 and again in June 2026 to inform development of an alternative harvest control rule, has not been completed for this cycle and is a priority for the next cycle, together with an MSE.

H. Rebuilding analysis and update

Status of the rebuilding plan

On 19 October 2021 NMFS determined, and notified the Council, that the eastern Bering Sea snow crab stock was overfished, the estimated mature male biomass having fallen below the minimum stock size threshold specified in the fishery management plan. The Council developed a rebuilding plan under section 304(e) of the Magnuson-Stevens Act, adopted as Amendment 53 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs and implemented before the start of the 2023/24 fishing season.

The rebuilding analysis in the Amendment 53 final environmental assessment (NPFMC and NMFS 2023) set the minimum time to rebuild in the absence of fishing ($T_{\min}$) at 6 years, which under the National Standard 1 guidelines sets a maximum time to rebuild ($T_{\max}$) of 10 years. The stock is considered rebuilt when mature male biomass reaches B_{MSY} . Median projections placed rebuilding in 2029 under no fishing, under bycatch only, and under the State harvest strategy, and in 2030 under fishing at the ABC. The 5th inter-simulation percentile is 2027 across all scenarios. The 95th is 2034 under no fishing and under bycatch only. Under the State harvest strategy and under fishing at the ABC the upper tail does not rebuild within the projection horizon. If mortality events of the kind observed in 2018/19 and 2019/20 recur in roughly 1 year in 7, the

projected rebuilding time under no fishing extends to 2034, and under the State harvest strategy and under fishing at the ABC the stock does not rebuild within the projection horizon. The analysis concluded that the main driver of the rate of rebuilding is recruitment and the ecosystem conditions that permit it, rather than fishing mortality.

Relationship to previous rebuilding plans

This is the third rebuilding plan for the stock. Snow crab was first declared overfished on 24 September 1999, and a rebuilding plan was adopted as Amendment 14 in 2000. The Amendment 53 environmental assessment's reference list cites Amendment 15 for that plan, but the 2000 environmental assessment itself is titled for Amendment 14 (NPFMC 2000), and Amendment 14 is cited here. In 2009 the NMFS Alaska Region notified the Council that the stock would not be rebuilt by the end of that rebuilding period, 2009/10, and that a revised plan was required. Amendment 39 followed. Amendment 53 replaces those earlier provisions, which were removed from the fishery management plan when it was adopted.

Progress toward rebuilding

The stock was determined overfished for 2024/25 in October 2025, on a mature male biomass of 60.08 kt against a minimum stock size threshold of 71.40 kt. The REMA-smoothed survey estimate of mature male biomass at the time of the 2026 survey is 109.30 kt against a B_{MSY} proxy of 146.29 kt, or 75 percent of the proxy, with a minimum stock size threshold of 73.14 kt. The stock is above its minimum stock size threshold but has not, on the point estimate, reached the biomass at which it would be considered rebuilt. The random-effects fit (Section F) puts a 95 percent confidence interval of 0.560 to 0.997 on that status of 0.747. The lower end is above the overfished threshold and the upper end below the rebuilt threshold.

Recruitment

Because the rebuilding analysis identifies recruitment as the main driver of the rebuilding rate, recruitment is reported here directly. Estimated male recruitment from the author-preferred Tier 3 model (**Model 26.1b**) collapsed to 0.06, 0.08 and 0.06 billion crab in 2017/18 to 2019/20, among the lowest in the time series, before rising to 1.54, 2.33 and 4.11 billion in 2020/21 to 2022/23, then falling to 1.45 billion in 2023/24 and settling at 0.91 and 0.99 billion in 2024/25 and 2025/26. The mean over the last 5 crab years, 1.96 billion, is above the 1982/83 to 2019/20 mean of 1.24 billion.

That comparison should be treated with caution. Terminal-year recruitment is the least well determined quantity in the assessment: the retrospective analysis gives a Mohn's rho for male recruitment of 9.75, meaning that recent recruitment estimates change substantially as data accumulate. The apparent post-collapse recruitment pulse is consistent with the survey observing small crab, but its magnitude in the terminal years should not be relied on. Terminal recruitment is not used in the reference-point calculations, and recruits are observed in the survey for roughly 5 years before entering the fishery, so the practical consequence of this uncertainty for management is limited.

I. Data gaps and research priorities

Several data and structural issues warrant follow-up:

- **Hybrid identification consistency between ADF&G and NMFS.** ADF&G classifies hybrid crab into 3 categories (opilio-type, bairdi-type, and unspecified) using a hybrid identification key based on eye color, epistome shape, and secondary morphological characteristics. ADF&G and NMFS do not currently agree on the number of secondary characteristics required for a positive hybrid identification, and the unspecified-hybrid category is present in a non-trivial portion of the time series. Resolving identification criteria across agencies and propagating the resulting categorization back through the historical observer time series would improve the hybrid-data products available to the assessment. However, the benefit to the snow crab assessment may be minimal given the low percentage of opilio-type hybrids in the data.
- **Apportionment of retained catch between snow crab and hybrids.** Hybrids are currently retained under either the snow-crab or the Tanner-crab IFQ depending on regulatory identification but are not separately tracked in the retained-catch data. ADF&G has indicated it does not yet have a method for partitioning historical retained catch into hybrid versus parent species. Developing such a partitioning would allow the hybrid sensitivity to be explored more fully (presently the retained time series is identical between the hybrid and non-hybrid configurations evaluated in May 2026 because retained catch already contains hybrids).
- **Quality control on early hybrid catch estimates.** The ADF&G hybrid total-catch estimates contain unexpectedly large values in 1997/98 (about 18 kt of legal-male hybrid catch) and 1998/99 (about 15 kt), with high-CPUE pots peppered around the fishery footprint rather than concentrated in obvious hot spots. ADF&G has flagged these years as requiring follow-up before the data should be considered reliable for regular assessment use.
- **Maturity workflow comparison.** The new spatiotemporal maturity workflow produces a much weaker temporal trend in the probability of terminal molt at size than the legacy workflow. Side-by-side documentation of the 2 workflows, an evaluation of the spatial sample sizes of chela measurements (which are sparse at many stations and many sizes) and of their uncertainty, and quantification of the degrees of freedom consumed by the spatial process would help the CPT and SSC evaluate the 2 approaches.
- **Source of the multiple minima in the snow crab assessment.** The immature survey index removed the bimodal jitter signal seen in the May 2026 candidate models, but the underlying source of the multiple minima (4 in the author-preferred model this cycle) is not understood. The jitter attribution in Section E identifies the parameters that most separate the 4 minima, but not why those combinations are alternative solutions. Extending that work to the correlation structure and to likelihood profiles would show whether the minima arise from the data or from the model structure, and would apply equally to the male-only model.
- **Reproductive biology of large male snow crab.** As noted in 2024 and 2025 SSC comments, more research is needed on whether small males can and do mate with large females and produce progeny that will be large males under favorable environmental conditions, and on what determines terminal molt. This question remains the main axis of uncertainty because the fishery cannot exist without large males and large males are at historical lows.

J. Ecosystem considerations

See the ESP for snow crab-specific indices of environmental variation that may be relevant to stock dynamics (Appendix A). See the risk table (Table 14) for factors that may influence the choice of buffer.

Supplemental information

Input and output for the models described here can be found at https://github.com/afsc-assessments/snow_crab.

The new maturity workflow can be found at <https://github.com/eryznar/Chionoecetes.maturity.workflow>.

GMACS code and documentation can be found at <https://github.com/GMACS-project>.

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Appendices

Appendix A. Ecosystem and Socioeconomic Profile, provided as a separate document: Fedewa, E. and Shotwell, K. 2026. *Ecosystem and Socioeconomic Profile of the eastern Bering Sea snow crab stock - Update*. It is the source of the ecosystem and fishery-informed indicators summarized in the risk table (Table 14) and of the indicator series referenced in Section J.

Appendix B. Convergence diagnostics. Jitter results for every model that was jittered this cycle, including 4 structural experiments built to diagnose the multimodality and not proposed as assessment models. It follows the figures.

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Tables

Table 15: Survey biomass and total abundance, from the NMFS summer bottom trawl survey. All values are design-based survey estimates; no assessment model is involved. Columns 2-4 are male biomass (1,000 t) by maturity definition, coefficient of variation in parentheses, and are the series the random-effects (REMA) model of Section F is fit to; the morphometric CV is the legal-male (≥ 78 mm) value, used as a proxy. Column 5 is total abundance (millions of crab, both sexes, all maturity stages, including crab < 25 mm), the quantity 50 CFR 679.21(e)(1)(iii) specifies for the *C. opilio* prohibited species catch limit. No survey in 2020.

Survey year	Morphometrically mature	Males ≥ 95 mm	Males > 101 mm	Total abundance
1982	172.4 (0.14)	65.9 (0.15)	38.1 (0.15)	4321.3
1983	147.6 (0.13)	68.0 (0.14)	38.9 (0.14)	3342.8
1984	166.5 (0.12)	120.0 (0.14)	89.4 (0.15)	2683.1
1985	70.0 (0.11)	55.7 (0.11)	45.0 (0.11)	866.9
1986	85.8 (0.11)	58.7 (0.13)	47.9 (0.13)	2363.2
1987	185.4 (0.11)	107.5 (0.11)	78.8 (0.11)	8970.0
1988	251.0 (0.15)	144.1 (0.19)	110.5 (0.21)	7796.2
1989	272.6 (0.11)	143.2 (0.10)	98.4 (0.10)	8594.0
1990	370.6 (0.14)	347.7 (0.15)	238.6 (0.15)	7026.9
1991	397.0 (0.15)	348.0 (0.16)	286.3 (0.17)	9766.3
1992	223.2 (0.09)	166.5 (0.11)	143.4 (0.12)	7000.4
1993	215.0 (0.11)	98.9 (0.11)	80.0 (0.11)	10293.9
1994	140.7 (0.08)	57.4 (0.11)	46.3 (0.12)	9112.2
1995	205.7 (0.13)	61.8 (0.17)	41.0 (0.15)	7894.0
1996	270.8 (0.12)	143.9 (0.18)	95.1 (0.21)	4977.8
1997	281.4 (0.09)	232.4 (0.13)	178.3 (0.14)	3795.5
1998	199.5 (0.09)	164.1 (0.10)	132.5 (0.11)	2809.2
1999	90.6 (0.09)	67.4 (0.10)	54.0 (0.12)	1286.0
2000	88.3 (0.14)	53.9 (0.15)	43.0 (0.14)	3114.4

Survey year	Morphometrically mature	Males $\geq$ 95 mm	Males $>$ 101 mm	Total abundance
2001	117.1 (0.12)	56.4 (0.10)	42.8 (0.10)	3355.3
2002	84.3 (0.23)	55.9 (0.25)	39.4 (0.25)	1334.9
2003	61.2 (0.12)	44.4 (0.12)	32.8 (0.12)	2384.4
2004	71.8 (0.14)	44.2 (0.17)	36.7 (0.19)	3878.9
2005	125.1 (0.11)	50.1 (0.10)	41.2 (0.11)	4602.6
2006	138.7 (0.26)	90.2 (0.35)	74.9 (0.36)	2860.3
2007	148.9 (0.15)	99.9 (0.19)	77.6 (0.21)	2917.6
2008	126.2 (0.10)	79.6 (0.11)	63.5 (0.12)	2306.8
2009	133.4 (0.13)	103.2 (0.15)	81.4 (0.17)	3058.2
2010	157.5 (0.12)	105.3 (0.13)	90.2 (0.14)	7450.4
2011	167.7 (0.11)	111.7 (0.12)	96.8 (0.12)	6336.3
2012	124.0 (0.12)	67.5 (0.14)	55.2 (0.15)	5329.9
2013	93.1 (0.12)	58.4 (0.13)	45.4 (0.14)	4420.0
2014	164.0 (0.16)	105.4 (0.20)	84.3 (0.22)	5138.3
2015	77.0 (0.12)	46.4 (0.15)	37.3 (0.18)	4288.0
2016	62.8 (0.11)	30.3 (0.12)	23.1 (0.13)	5367.5
2017	82.8 (0.13)	29.7 (0.13)	22.3 (0.14)	8181.4
2018	233.0 (0.17)	47.7 (0.20)	30.2 (0.19)	11744.3
2019	202.9 (0.17)	55.3 (0.18)	32.1 (0.17)	4295.9
2021	58.1 (0.13)	24.7 (0.16)	14.0 (0.18)	940.2
2022	35.3 (0.15)	20.7 (0.18)	14.7 (0.21)	1957.3
2023	24.4 (0.13)	15.7 (0.14)	12.2 (0.15)	2074.1
2024	55.3 (0.12)	22.6 (0.13)	17.4 (0.13)	6578.1
2025	113.0 (0.15)	31.9 (0.14)	22.4 (0.14)	6945.5
2026	109.9 (0.16)	23.0 (0.12)	15.9 (0.13)	6102.9

Table 16: Random-effects (REMA) smoothed survey biomass (1,000 t), 95 percent confidence interval in parentheses, by survey year and maturity definition. The terminal survey year's value is the biomass the Tier 4 control rule acts on; the mean over the series is the BMSY proxy. 2020 has a fitted value although the survey was cancelled, so the proxy is averaged over the smoothed series rather than the observations.

Survey year	Morphometrically mature	Males $\geq$ 95 mm	Males $>$ 101 mm
1982	170.1 (131.6-219.7)	66.4 (50.4-87.6)	38.5 (29.4-50.5)
1983	149.9 (119.4-188.2)	70.8 (55.4-90.6)	41.6 (32.3-53.6)
1984	156.5 (126.0-194.3)	106.8 (83.2-137.1)	77.0 (58.9-100.7)
1985	74.3 (60.9-90.6)	58.5 (47.6-71.9)	47.0 (38.1-57.9)
1986	89.0 (72.5-109.4)	61.5 (49.0-77.2)	49.8 (39.4-62.8)
1987	180.7 (148.3-220.0)	105.3 (85.6-129.7)	77.8 (63.5-95.3)
1988	245.1 (188.6-318.6)	138.2 (101.1-189.1)	102.8 (73.4-143.9)
1989	275.4 (225.8-335.9)	149.6 (123.2-181.6)	103.2 (85.1-125.1)
1990	361.1 (281.9-462.5)	315.0 (241.6-410.6)	220.2 (169.5-285.9)
1991	372.6 (287.4-483.0)	317.3 (241.7-416.3)	253.2 (188.7-339.7)
1992	227.8 (191.2-271.5)	167.8 (137.1-205.5)	143.3 (116.0-177.1)
1993	211.0 (173.8-256.3)	99.1 (80.3-122.1)	80.4 (65.4-98.9)
1994	144.8 (123.5-169.6)	60.0 (49.1-73.2)	48.0 (38.9-59.3)
1995	204.2 (162.3-256.9)	67.9 (51.0-90.3)	45.6 (34.7-59.9)
1996	265.5 (211.8-332.9)	136.9 (100.6-186.3)	91.8 (65.5-128.6)
1997	275.9 (231.0-329.6)	216.3 (172.1-271.8)	161.3 (124.5-209.0)
1998	195.9 (165.6-231.8)	159.1 (132.1-191.7)	127.4 (104.6-155.2)
1999	93.5 (79.0-110.8)	70.0 (57.7-85.1)	56.6 (45.6-70.3)
2000	90.6 (71.1-115.5)	55.7 (42.8-72.5)	44.2 (34.3-57.0)
2001	112.7 (91.0-139.6)	56.2 (46.5-68.1)	42.6 (35.5-51.2)
2002	84.4 (59.2-120.4)	53.5 (37.1-77.4)	38.7 (26.8-56.0)
2003	63.4 (51.0-78.9)	45.1 (36.1-56.3)	33.5 (26.9-41.8)

Survey year	Morphometrically mature	Males $\geq$ 95 mm	Males $>$ 101 mm
2004	74.4 (58.2-95.1)	45.1 (33.9-60.0)	36.9 (27.1-50.2)
2005	121.8 (98.9-149.9)	51.0 (42.1-61.8)	42.0 (34.4-51.3)
2006	136.3 (92.5-200.6)	77.2 (49.5-120.4)	62.4 (39.5-98.4)
2007	145.4 (112.0-188.8)	93.4 (68.4-127.8)	72.6 (51.6-102.1)
2008	127.6 (105.6-154.2)	81.6 (66.7-99.8)	65.1 (52.5-80.7)
2009	134.6 (106.8-169.6)	100.8 (77.3-131.4)	80.1 (60.2-106.6)
2010	156.2 (125.2-194.8)	105.1 (82.8-133.3)	89.4 (69.5-115.0)
2011	163.7 (132.8-201.9)	107.5 (86.7-133.3)	92.7 (74.7-115.1)
2012	124.3 (100.2-154.4)	70.0 (54.4-90.0)	57.4 (44.3-74.5)
2013	97.7 (78.7-121.4)	61.1 (48.4-77.2)	48.0 (37.6-61.5)
2014	142.0 (106.6-189.1)	84.8 (60.8-118.4)	66.0 (46.3-94.0)
2015	79.3 (64.0-98.3)	47.5 (36.3-62.2)	37.9 (28.1-51.1)
2016	64.9 (53.2-79.3)	31.4 (25.3-38.8)	24.1 (19.2-30.2)
2017	87.3 (68.9-110.5)	30.9 (24.5-38.8)	23.0 (17.9-29.6)
2018	201.0 (149.3-270.6)	44.9 (32.3-62.3)	29.0 (21.1-39.8)
2019	186.6 (137.6-253.1)	50.6 (36.9-69.2)	30.0 (22.1-40.6)
2020	104.6 (56.5-193.5)	35.7 (19.5-65.4)	21.2 (11.5-38.9)
2021	58.6 (45.9-74.9)	25.3 (19.0-33.6)	14.9 (10.8-20.6)
2022	36.1 (27.8-46.9)	20.6 (15.2-28.0)	14.4 (10.3-20.1)
2023	26.8 (21.2-33.8)	16.6 (13.0-21.3)	12.8 (9.9-16.6)
2024	55.0 (44.1-68.7)	22.5 (18.0-28.2)	17.2 (13.6-21.9)
2025	105.0 (80.9-136.3)	29.9 (23.3-38.4)	21.1 (16.4-27.3)
2026	109.3 (81.9-145.9)	23.5 (18.6-29.7)	16.3 (12.7-20.9)

Table 17: Overview of the models presented in the September 2026 assessment, with the type and purpose of each. 'Jittered' records whether a jitter analysis was run for that model this cycle. The 4 jittered models also received retrospective sweeps; their statistics are in the retrospective table below.

Model	Type	Jittered	Purpose
Model 25.3	Reference	No	The 2025 accepted model (GMACS 2.20.22), carried as the bridge from the previous assessment.
Model 26.1	Research	Yes	Carries the composition correction, expanded plus group and new maturity workflow endorsed in May and June 2026.
Model 26.1a	Research	No	As above with the data corrections applied; documents the effect of those corrections.
Model 26.1b	Research	Yes	The same configuration advanced to the 2025/26 fishery and 2026 survey; author-preferred Tier 3 model.
Model 26.1c	Diagnostic	Yes	Convergence diagnostic: data truncated to crab year 2019/20 to test whether the recent data drive the multimodality.
Model 26.2	Research	Yes	Simplification sensitivity: removes the female population, addressing the SSC's request to reduce the parameter set.

Table 18: Catch and index likelihood components (negative log-likelihood, dimensionless), 1 row per component and 1 column per model. Row labels name the fleet and, where it applies, the sex: M is male, F is female. Survey rows are labeled by era, NMFS 1982 for 1982-1988 and NMFS 1989 for 1989-present. A dash marks a component the model does not have, not a value of zero.

Component	Model 25.3	Model 26.1	Model 26.1a	Model 26.1b	Model 26.1c	Model 26.2
Catch: Pot retained M	121.0	124.9	131.2	126.5	68.3	133.4
Catch: Pot discarded M	377.2	379.0	313.6	274.6	105.6	288.7
Catch: Pot discarded F	-71.4	-71.4	-71.4	-73.1	-66.2	–
Catch: Trawl bycatch	-54.1	-54.1	-54.1	-55.5	-47.1	-55.5
Index: NMFS 1982 F mature	51.8	51.5	49.5	47.8	47.7	–
Index: NMFS 1989 F mature	7.7	7.8	6.3	14.3	-4.1	–
Index: NMFS 1982 M mature	95.1	88.2	80.9	73.0	48.2	66.8
Index: NMFS 1989 M mature	-12.5	-8.5	-4.8	5.5	-0.4	2.7

Table 19: Size-composition likelihood components (negative log-likelihood, dimensionless), 1 row per component and 1 column per model. Row labels name the fleet, the survey era where it applies (NMFS 1982 is 1982-1988 and NMFS 1989 is 1989-present), the sex (M male, F female) and the maturity state.

Component	Model 25.3	Model 26.1	Model 26.1a	Model 26.1b	Model 26.1c	Model 26.2
Pot M retained	-3,645.2	-3,679.6	-3,810.4	-3,899.8	-3,425.4	-3,891.9
Pot M total	-2,639.0	-2,669.8	-2,879.6	-2,957.3	-2,644.9	-2,941.7
Pot F discarded	-2,528.8	-2,527.5	-2,683.7	-2,757.2	-2,502.2	—
Trawl F discarded	-2,605.7	-2,606.5	-2,549.5	-2,622.9	-2,151.2	—
Trawl M discarded	-2,543.0	-2,592.9	-2,585.9	-2,665.1	-2,158.5	-2,672.3
NMFS 1982 F immature	-635.5	-635.8	-633.4	-630.3	-630.1	—
NMFS 1989 F immature	-3,167.9	-3,160.2	-3,191.7	-3,276.9	-2,761.0	—
NMFS 1982 M immature	-581.4	-585.3	-579.0	-567.8	-561.8	-560.7
NMFS 1989 M immature	-3,002.6	-2,992.1	-2,998.7	-3,068.1	-2,562.6	-3,051.3
NMFS 1982 F mature	-684.2	-684.4	-685.0	-685.4	-685.6	—
NMFS 1989 F mature	-3,401.6	-3,404.1	-3,396.9	-3,489.7	-2,918.2	—
NMFS 1982 M mature	-575.5	-584.0	-579.9	-577.6	-576.5	-577.8
NMFS 1989 M mature	-2,976.0	-2,940.9	-2,932.9	-2,986.7	-2,495.2	-2,994.6

Table 20: Remaining likelihood components (negative log-likelihood, dimensionless), 1 row per component and 1 column per model. These are the penalties, priors and data components that are not catch, index or size composition. No model includes tagging data. Model 25.3 was fitted under GMACS 2.20.22, which reports the growth-increment likelihood as a tagging likelihood; it is shown here under Growth, where 2.20.34 reports it. The step down from Model 26.1a onward is the growth transcription fix. A dash marks a component GMACS 2.20.22 does not report.

Component	Model 25.3	Model 26.1	Model 26.1a	Model 26.1b	Model 26.1c	Model 26.2
SRR	185.4	192.2	191.3	197.8	170.2	124.4
Growth	7,965.1	7,970.3	4,881.4	4,883.8	4,877.2	1,531.7
Penalties	760.3	761.0	758.9	757.8	752.1	406.9
Priors	387.0	395.1	386.6	386.7	377.3	183.2
Positive growth penalty	–	0.0	0.0	0.0	0.0	0.0
Initial size structure	0.0	0.0	0.0	0.0	0.0	0.0
Total	-19,173.8	-19,227.2	-22,837.2	-23,545.7	-19,744.5	-14,008.1

Table 21: Maximum absolute gradient (dimensionless) for each model, and the parameter with the largest gradient. See the note below the table.

Model	N parameters	Parameter	What it is	Max gradient
Model 25.3	407	theta[3]	log mean recruitment	0.00134
Model 26.1	407	T_pars_est[3]	log mean recruitment	0.00000
Model 26.1a	407	T_pars_est[3]	log mean recruitment	0.00000
Model 26.1b	412	T_pars_est[3]	log mean recruitment	0.00000
Model 26.1c	386	T_pars_est[3]	log mean recruitment	0.00000
Model 26.2	234	T_pars_est[3]	log mean recruitment	0.00000

Note to the gradient table. The Parameter column gives GMACS’s internal name and “What it is” the quantity that name refers to: the T_pars (theta) block holds the recruitment scale and the initial numbers at size, M_pars natural mortality, S_pars selectivity and G_pars growth. A gradient of zero is the result of the Newton polishing described in the text. Model 25.3 could not be polished and is reported as originally fitted.

Table 22: Retrospective statistics for the 4 models with retrospective sweeps this cycle. Mohn's rho and Ralston's sigma are dimensionless. See the note below the table.

Model	Quantity	Retrospective	Peels	Mohn's rho	Ralston's sigma	Min rel. diff.	Max rel. diff.
Model 26.1	Mature male biomass	Standard	10	-0.124	0.468	-0.653	0.232
Model 26.1	Mature male biomass	Terminal survey dropped	10	-0.197	0.547	-0.651	0.340
Model 26.1	Male recruitment	Standard	10	3.917	1.359	-0.459	35.654
Model 26.1	Male recruitment	Terminal survey dropped	10	4.547	1.570	-0.769	37.788
Model 26.1b	Mature male biomass	Standard	10	-0.082	0.313	-0.509	0.170
Model 26.1b	Mature male biomass	Terminal survey dropped	10	-0.098	0.290	-0.510	0.128
Model 26.1b	Male recruitment	Standard	10	9.751	2.288	-0.911	36.126
Model 26.1b	Male recruitment	Terminal survey dropped	10	11.307	2.211	-0.487	45.280
Model 26.1c	Mature male biomass	Standard	10	0.055	0.154	-0.194	0.286
Model 26.1c	Mature male biomass	Terminal survey dropped	10	0.068	0.245	-0.291	0.416
Model 26.1c	Male recruitment	Standard	10	4.605	1.616	-0.458	25.204
Model 26.1c	Male recruitment	Terminal survey dropped	10	3.546	1.579	-0.722	17.470
Model 26.2	Mature male biomass	Standard	10	-0.097	0.287	-0.498	0.156
Model 26.2	Mature male biomass	Terminal survey dropped	10	-0.087	0.279	-0.498	0.117

Model	Quantity	Retrospective	Peels	Mohn's rho	Ralston's sigma	Min rel. diff.	Max rel. diff.
Model 26.2	Male recruitment	Standard	10	0.830	0.998	-0.755	4.293
Model 26.2	Male recruitment	Terminal survey dropped	10	0.781	1.070	-0.796	4.293

Note to the retrospective table. Mohn's rho is the mean over peels of (peel - full model) / full model at each peel's terminal year, so a positive value means terminal estimates are revised downward as data accumulate. Ralston's sigma is the log-scale RMSE of the same pairs. Dropped-terminal-survey peels are compared with the full model. Peels for Models 26.1c and 26.1 are relative to their own terminal crab years, 2019/20 and 2024/25. Model 26.1 is fit to the survey estimates before the 2024-2026 net-mensuration correction; the other models either use the corrected estimates or end before 2024.

Table 23: Observed catch used in the assessment (1,000 t), by crab year, with the pot-fishery discards of Model 25.3 and Model 26.1b side by side. See the note below the table.

Crab year	Retained	Bycatch mortality	Male disc. 25.3	Male disc. 26.1b	Female disc. 25.3	Female disc. 26.1b
1982/83	11.85	0.37	1.27	1.27	0.02	0.02
1983/84	12.16	0.47	1.24	1.24	0.01	0.01
1984/85	29.94	0.50	2.76	2.76	0.01	0.01
1985/86	44.45	0.43	4.01	4.01	0.01	0.01
1986/87	46.22	0.00	4.25	4.25	0.02	0.02
1987/88	61.40	0.00	5.52	5.52	0.03	0.03
1988/89	67.79	0.00	5.82	5.82	0.04	0.04
1989/90	73.33	0.10	6.68	6.68	0.05	0.05
1990/91	149.07	0.33	35.55	35.55	1.52	1.52
1991/92	143.02	4.45	9.03	9.03	0.20	0.20
1992/93	104.67	2.05	21.18	21.18	0.28	0.28
1993/94	67.94	1.13	22.27	22.27	0.12	0.12
1994/95	34.16	0.70	7.78	7.78	0.08	0.08
1995/96	29.80	1.04	14.73	14.73	0.02	0.02
1996/97	54.24	1.22	23.23	23.23	0.10	0.10
1997/98	110.44	0.73	7.10	7.10	0.10	0.10
1998/99	88.15	0.58	19.50	19.91	0.01	0.01
1999/00	15.10	0.24	4.13	4.13	0.01	0.01
2000/01	11.46	0.25	3.25	3.25	0.00	0.00
2001/02	14.80	0.18	3.98	3.98	0.02	0.02
2002/03	12.84	0.10	4.50	4.50	0.00	0.00
2003/04	10.86	0.14	2.40	2.45	0.00	0.00
2004/05	11.29	0.18	3.58	3.58	0.00	0.00
2005/06	16.77	0.18	0.62	0.65	0.00	0.00
2006/07	16.49	0.35	4.17	4.23	0.00	0.00
2007/08	28.59	0.30	5.77	5.78	0.02	0.02
2008/09	26.56	0.19	5.11	5.11	0.02	0.02
2009/10	21.78	0.39	4.28	4.28	0.01	0.01
2010/11	24.61	0.14	4.47	4.47	0.01	0.01
2011/12	40.29	0.14	3.73	3.73	0.19	0.19
2012/13	30.05	0.15	5.53	5.53	0.06	0.06
2013/14	24.49	0.16	10.61	10.62	0.12	0.12
2014/15	30.82	0.62	11.62	11.62	0.30	0.30

Crab year	Retained	Bycatch mortality	Male disc. 25.3	Male disc. 26.1b	Female disc. 25.3	Female disc. 26.1b
2015/16	18.42	1.58	10.90	10.91	0.12	0.12
2016/17	9.78	0.04	4.51	4.51	0.03	0.03
2017/18	8.60	0.09	5.88	5.92	0.03	0.03
2018/19	12.51	0.39	8.63	8.66	0.02	0.02
2019/20	15.43	0.21	15.61	15.61	0.02	0.02
2020/21	20.41	0.19	6.12	6.12	0.00	0.00
2021/22	2.52	0.13	1.68	1.69	0.00	0.00
2022/23	0.00	0.06	0.00	0.00	0.00	0.00
2023/24	0.00	0.11	0.00	0.00	0.00	0.00
2024/25	2.15	0.09	0.66	0.69	0.00	0.00
2025/26	4.13	0.37	—	2.69	—	0.03

Note to the observed catch table. Retained catch is the same series in both models. The bycatch column is Model 26.1b's series; Model 25.3 uses the earlier bycatch accounting, which is higher by up to 0.02 kt in some years (Section A, item 2). Male and female pot-fishery discards are shown for both so that the effect of the current ADF&G delivery and of the corrected discard subtraction on the discard series is visible. The discard columns are catches, to which the model applies a 30 percent handling mortality; the bycatch column is already a mortality (80 percent of the groundfish trawl bycatch and 30 percent of the discards in the other crab fisheries). A zero is no catch (the directed fishery was closed in 2022/23 and 2023/24). A dash means the model's data do not extend to that crab year.

Table 24: Management quantities by model, from maximum likelihood estimates using Tier 3 reference points. Biomass and OFL in 1,000 t; natural mortality per year; average recruitment in billions. See the note below the table.

Model	BMSY	B _{curr} /BMSY	F _{msy}	F _{oFl}	OFL	M (imm males)	M (mat males)	Terminal crab year	MMB (terminal)	Avg recruitment
Model 25.3	180.06	0.88	39.52	34.37	44.29	0.29	0.28	2024/25	137.46	1.98
Model 26.1	172.67	0.96	43.35	41.23	43.83	0.30	0.29	2024/25	123.09	2.00
Model 26.1a	162.49	0.80	40.73	31.62	54.03	0.22	0.29	2024/25	108.02	1.40
Model 26.1b	143.53	1.28	57.46	57.46	80.38	0.24	0.29	2025/26	135.86	1.35
Model 26.1c	161.21	1.05	133.64	133.64	146.92	0.08	2.25	2019/20	86.91	1.43
Model 26.2	130.28	1.19	20.75	20.75	72.49	0.11	0.29	2025/26	111.16	0.67

Note to the management quantities table. M is for immature and mature males in each model's terminal crab year; Model 26.1c terminates in 2019/20, within the mortality event, so its M is an event value and not comparable. MMB is at mating in that terminal crab year. Status is $B_{\text{curr}}/B_{\text{MSY}}$, B_{curr} being the projected biomass the control rule acts on. Average recruitment is GMACS Spr_rbar for males. The F_{MSY} and F_{OFL} columns are GMACS fleet-1 values, not annual instantaneous rates.

Table 25: Maximum likelihood estimates of mature male (MMB) and female (FMB) biomass (1,000 t) and abundance of preferred males (N >101, millions) from Model 26.1b. Columns 2-6 are at the time of the survey and subject to survey selectivity. Columns 7-11 (pop) are population values not subject to selectivity. FMB and MMB (columns 2-3) are the model's predicted survey index and are blank in 2020, when the survey was not conducted.

Survey year	FMB	MMB	MMB >=95	MMB >101	N >101	FMB pop	MMB pop	MMB >=95 pop	MMB >101 pop	N >101 pop
1982	72.42	114.44	109.26	77.06	144.75	161.90	271.07	150.35	99.66	189.55
1983	55.49	148.31	126.21	93.05	165.90	125.83	346.99	170.72	117.37	212.65
1984	42.77	186.47	160.60	123.68	208.48	102.81	420.79	212.58	152.25	261.75
1985	34.30	203.56	169.58	133.02	217.16	143.03	456.02	221.94	161.61	269.52
1986	37.75	205.93	153.41	118.69	192.63	268.27	475.10	201.70	143.89	238.64
1987	73.00	221.21	148.73	111.59	182.69	388.97	525.71	198.14	135.76	227.07
1988	131.04	251.77	160.00	119.16	195.16	435.86	604.24	213.92	144.95	242.37
1989	207.85	343.68	181.55	134.39	219.46	425.87	684.99	243.22	163.27	272.25
1990	190.37	375.79	216.90	163.12	265.04	366.45	717.20	288.92	197.69	327.87
1991	157.93	318.10	180.61	135.09	216.57	303.15	609.55	240.71	162.83	266.42
1992	127.80	275.72	159.88	123.08	188.30	256.54	520.58	209.01	145.84	228.38
1993	107.03	211.34	101.22	71.00	113.83	230.97	439.14	137.93	85.66	140.35
1994	96.60	208.47	67.02	42.65	70.00	226.97	489.62	94.52	51.95	87.08
1995	95.18	189.80	57.59	35.06	59.41	220.60	450.08	82.53	43.28	74.80
1996	96.51	228.63	95.51	64.86	109.09	208.07	495.93	132.49	79.71	136.55
1997	91.37	246.03	130.28	98.42	158.97	180.53	486.91	173.46	118.88	195.66
1998	79.25	202.38	111.02	86.23	132.11	150.47	391.80	144.84	102.15	160.00
1999	63.88	119.90	47.36	31.64	49.65	127.91	261.94	65.44	37.87	60.78
2000	52.61	98.50	39.16	26.27	41.45	115.88	214.99	54.09	31.50	50.85
2001	48.08	84.30	33.04	21.52	34.90	106.74	185.15	46.20	26.09	43.27
2002	46.22	72.19	27.74	17.60	29.60	102.19	159.69	39.29	21.65	37.12
2003	43.64	70.70	31.28	21.26	35.07	179.95	150.03	43.28	25.93	43.62
2004	62.57	72.54	37.97	28.18	45.36	192.33	144.80	50.82	34.02	55.86
2005	95.50	83.09	44.49	34.83	54.22	207.41	164.25	58.01	41.50	65.99
2006	94.17	101.54	48.75	35.92	57.75	194.17	211.05	65.29	43.37	71.27
2007	82.69	121.18	59.96	43.59	72.11	163.56	248.97	81.12	53.19	89.69
2008	70.87	131.90	64.70	46.43	76.87	152.35	271.19	87.87	56.71	95.74
2009	61.78	148.90	80.33	58.94	96.15	189.41	293.02	108.05	71.55	119.10
2010	72.48	147.17	85.43	65.06	104.11	201.30	280.13	113.01	78.37	128.08
2011	92.98	145.37	84.75	66.21	103.53	207.54	276.15	110.60	79.06	126.37

Survey year	FMB	MMB	MMB >=95	MMB >101	N >101	FMB pop	MMB pop	MMB >=95 pop	MMB >101 pop	N >101 pop
2012	93.46	118.08	58.53	42.18	67.95	201.97	241.52	79.00	51.00	84.04
2013	85.73	104.01	46.18	30.23	51.18	176.52	221.32	64.71	37.30	64.45
2014	77.27	93.09	42.82	29.30	47.81	154.80	194.82	58.98	35.59	59.31
2015	65.69	74.90	30.65	20.37	32.98	154.77	162.84	42.60	24.66	40.78
2016	61.64	57.87	18.70	11.38	18.55	220.55	135.07	26.72	13.83	23.03
2017	83.54	67.76	17.96	10.83	18.05	374.87	168.28	25.78	13.28	22.59
2018	148.43	90.85	20.75	12.67	21.48	431.46	229.06	29.74	15.64	27.01
2019	124.32	141.50	43.43	26.34	46.80	234.18	332.35	62.59	33.16	59.85
2020			22.40	13.93	23.56	91.17	163.54	31.89	17.18	29.60
2021	38.36	50.44	13.24	7.54	12.63	88.41	120.74	19.32	9.26	15.83
2022	38.24	43.37	14.29	9.49	15.13	97.75	100.08	19.83	11.42	18.60
2023	42.04	36.84	12.40	8.60	13.58	170.53	85.78	16.95	10.31	16.63
2024	63.49	43.18	10.37	7.20	11.38	183.92	110.42	14.17	8.64	13.94
2025	91.58	67.12	16.74	10.55	18.34	186.62	169.15	23.81	13.16	23.28
2026	86.40	142.65	55.45	39.63	66.41	167.46	318.86	75.62	48.61	82.95

Table 26: Maximum likelihood estimates of total numbers of crab (billions) from Model 26.1b, not subject to survey selectivity, at the time of the survey. Years run down the left block and continue in the right.

Survey year	Total numbers	Survey year	Total numbers
1982	9.42	2005	9.58
1983	10.03	2006	8.26
1984	10.64	2007	6.67
1985	16.61	2008	7.29
1986	25.39	2009	11.04
1987	24.42	2010	9.06
1988	20.09	2011	7.72
1989	16.16	2012	7.00
1990	13.07	2013	5.93
1991	14.32	2014	5.39
1992	16.30	2015	10.70
1993	13.95	2016	15.64
1994	12.88	2017	21.65
1995	10.96	2018	16.42
1996	8.95	2019	8.39
1997	7.04	2020	3.45
1998	5.73	2021	4.87
1999	5.44	2022	7.15
2000	5.21	2023	14.82
2001	4.38	2024	12.27
2002	5.53	2025	10.16
2003	11.58	2026	9.24
2004	9.42		

Table 27: Comparison of mature male biomass (MMB, 1,000 t) at mating, male recruitment (billions), and fully-selected fishing mortality (F, per year) for the directed fishery, by crab year, for the 2025 rolled-forward reference model and the author-preferred model.

Model	Crab year	Mature male biomass	Male recruits (billions)	Fishing mortality
Model 25.3	1982/83	221.25	4.57	0.19
	1983/84	327.54	2.50	0.13
	1984/85	388.76	3.83	0.25
	1985/86	396.76	4.74	0.36
	1986/87	393.92	0.23	0.42
	1987/88	404.77	2.04	0.64
	1988/89	448.28	1.38	0.67
	1989/90	447.63	0.75	0.70
	1990/91	385.09	3.82	1.96
	1991/92	367.23	4.56	1.19
	1992/93	329.77	0.22	1.64
	1993/94	308.52	0.77	1.84
	1994/95	302.16	0.25	1.33
	1995/96	337.64	0.32	1.36
	1996/97	359.87	0.27	1.40
	1997/98	325.86	0.94	1.28
	1998/99	246.06	0.58	2.27
	1999/00	215.81	0.87	0.53
	2000/01	175.82	0.19	0.51
	2001/02	140.94	1.96	0.95
	2002/03	124.81	1.78	1.12
	2003/04	127.56	1.88	0.55
	2004/05	145.62	2.22	0.46
	2005/06	163.37	0.67	0.38
	2006/07	185.78	0.54	0.69
	2007/08	213.70	0.88	0.97
	2008/09	233.85	1.89	0.74
	2009/10	223.29	0.31	0.54
	2010/11	272.90	0.49	0.39
	2011/12	209.91	0.44	0.79
	2012/13	181.48	1.39	1.21
	2013/14	177.09	1.58	1.49

Model	Crab year	Mature male biomass	Male recruits (billions)	Fishing mortality
Model 26.1b	2014/15	150.02	10.11	2.30
	2015/16	132.86	7.35	2.19
	2016/17	138.88	1.38	1.32
	2017/18	228.51	0.44	1.02
	2018/19	188.50	1.38	2.39
	2019/20	267.09	0.97	1.13
	2020/21	191.09	1.37	1.96
	2021/22	164.42	2.79	0.28
	2022/23	134.37	6.22	0.00
	2023/24	116.17	2.33	0.00
	2024/25	137.46	2.14	0.26
	1982/83	213.62	2.61	0.28
	1983/84	276.74	2.50	0.22
	1984/85	320.70	4.28	0.41
	1985/86	336.09	4.55	0.57
	1986/87	352.84	0.16	0.64
	1987/88	386.26	1.53	0.88
	1988/89	447.59	0.63	0.89
	1989/90	508.98	0.76	0.86
	1990/91	456.78	4.06	2.43
	1991/92	410.64	4.50	1.61
	1992/93	324.05	0.19	2.58
	1993/94	294.58	0.43	3.14
	1994/95	374.77	0.30	1.69
	1995/96	341.86	0.21	2.33
	1996/97	355.62	0.48	2.31
	1997/98	332.16	0.40	1.79
	1998/99	236.18	0.65	4.21
	1999/00	201.47	0.34	0.95
	2000/01	166.12	0.06	0.87
	2001/02	138.51	1.70	1.58
	2002/03	119.14	1.20	1.80
	2003/04	113.86	1.26	0.99
	2004/05	107.60	1.97	0.85
	2005/06	123.94	0.34	0.63

Model	Crab year	Mature male biomass	Male recruits (billions)	Fishing mortality
	2006/07	156.11	0.41	1.07
	2007/08	177.54	0.96	1.54
	2008/09	198.93	1.51	1.19
	2009/10	220.47	0.16	0.71
	2010/11	207.40	0.45	0.71
	2011/12	193.37	0.18	1.11
	2012/13	170.83	0.65	1.66
	2013/14	157.01	0.52	2.40
	2014/15	130.55	4.81	3.67
	2015/16	112.73	1.90	3.59
	2016/17	101.85	0.25	2.33
	2017/18	129.39	0.06	2.59
	2018/19	167.77	0.08	3.80
	2019/20	177.27	0.06	3.16
	2020/21	118.63	1.54	4.53
	2021/22	97.25	2.33	0.70
	2022/23	83.27	4.11	0.00
	2023/24	71.32	1.45	0.00
	2024/25	89.35	0.91	0.58
	2025/26	135.86	0.99	0.84

Figures

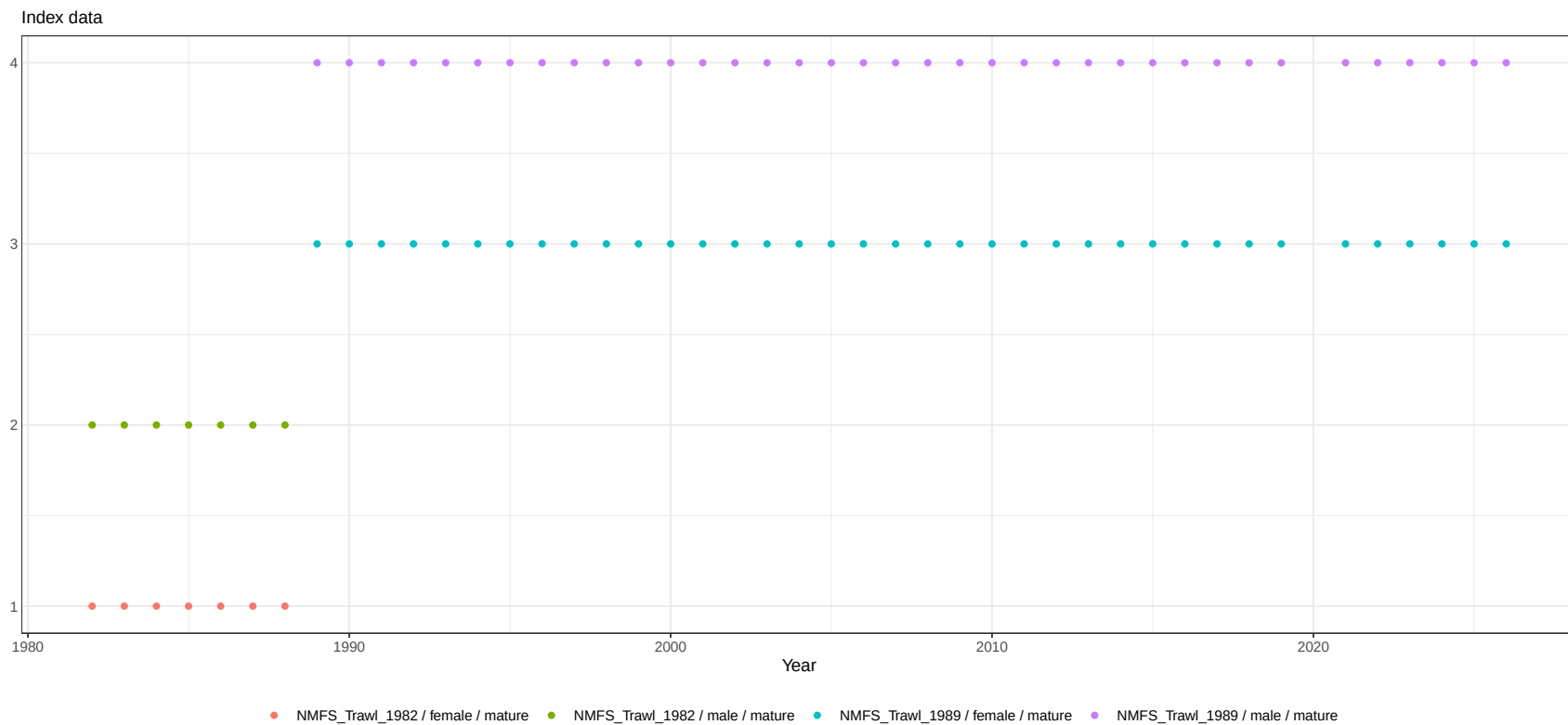


Figure 16: Survey years in which each index series is available to the author-preferred model. Each row is 1 data series.

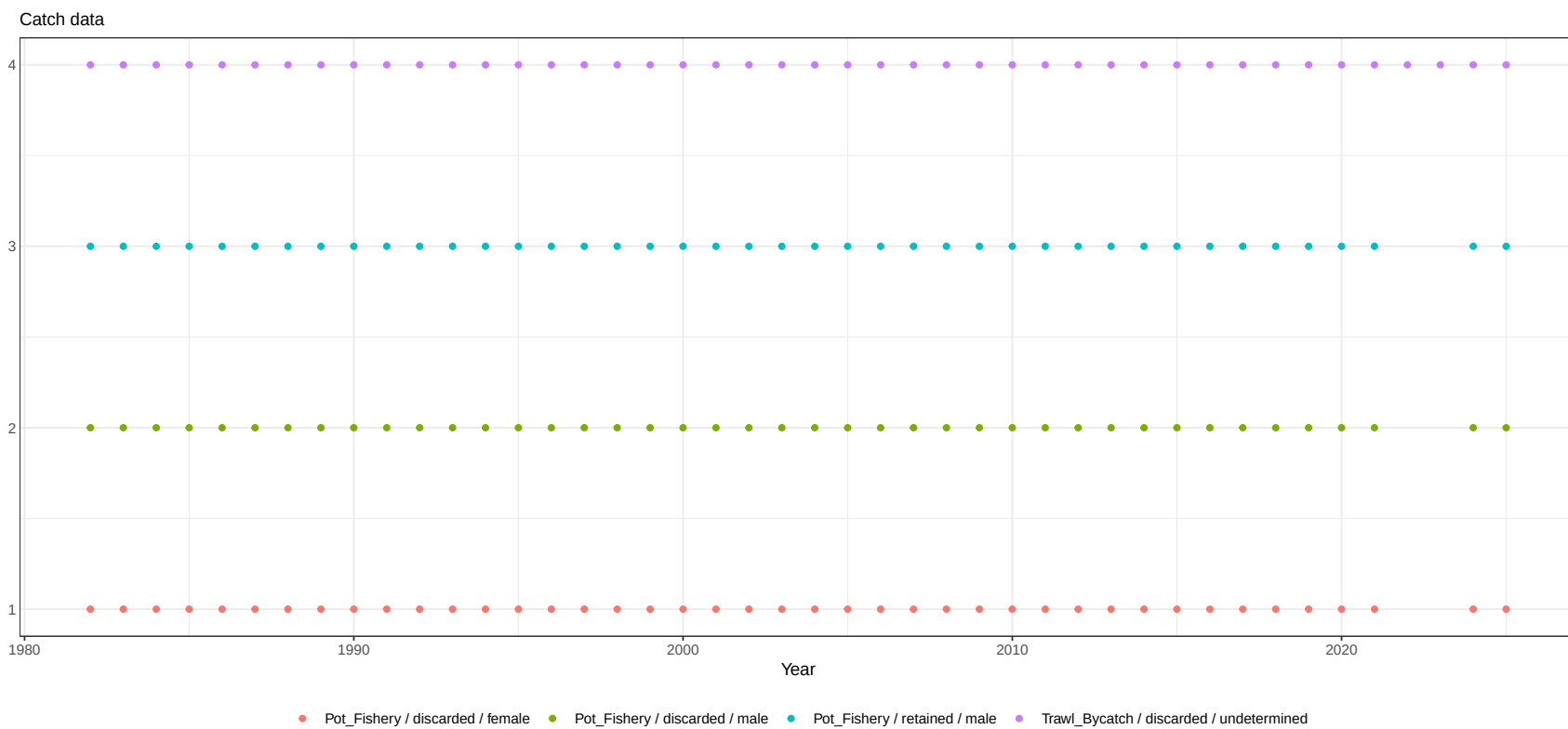


Figure 17: Crab years in which each catch series is available to the author-preferred model. Each row is 1 data series.

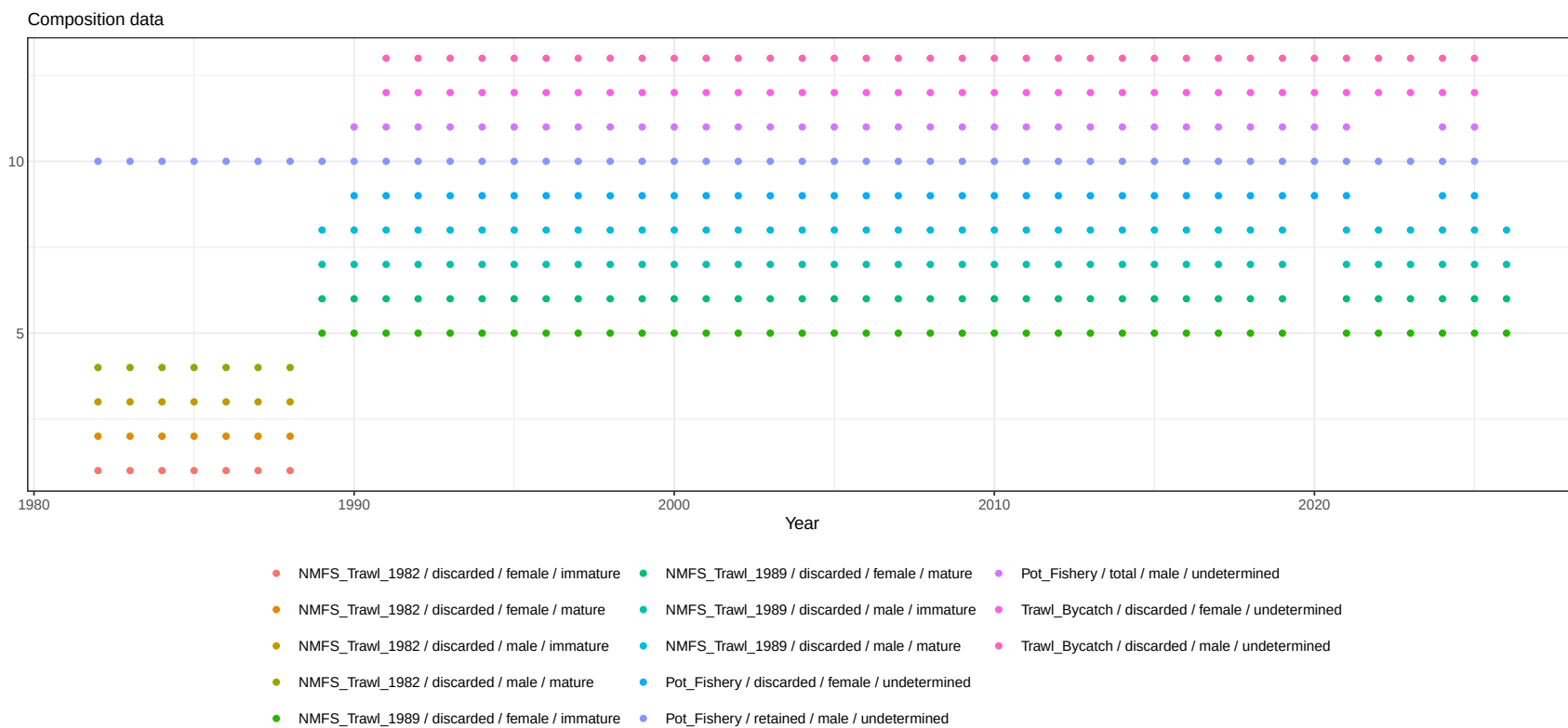


Figure 18: Years in which each size-composition series is available to the author-preferred model. Each row is 1 data series.

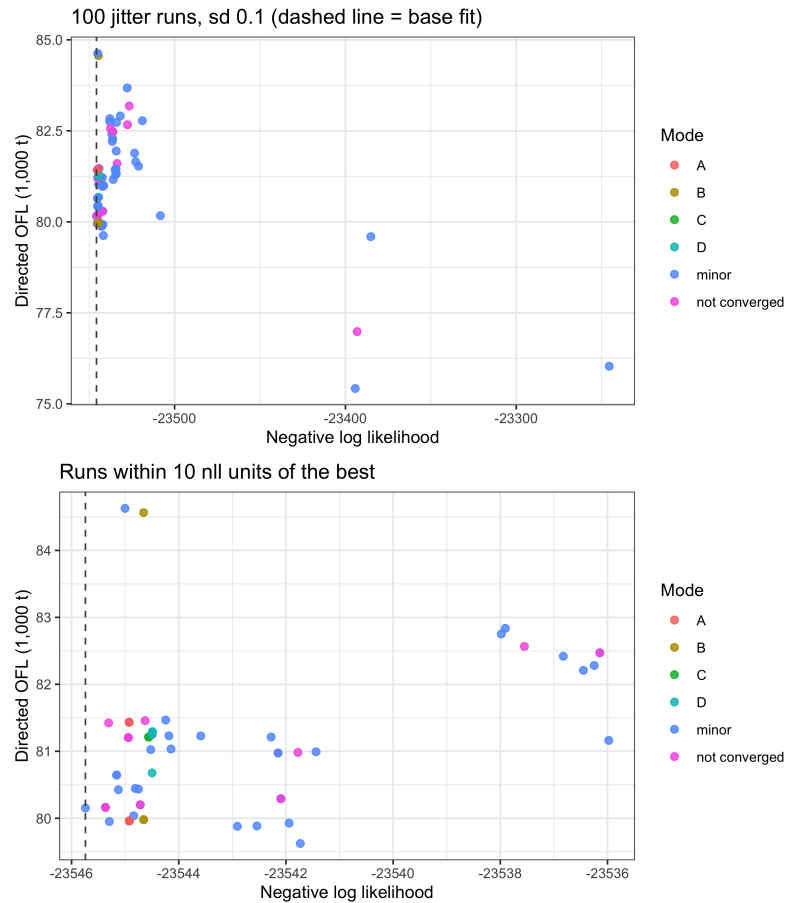


Figure 19: Directed OFL (1,000 t) resulting from 100 jitter runs of the author-preferred model, Model 26.1b. Each point is 1 run, plotted against its negative log likelihood. The upper panel shows the full spread and the lower panel the runs within 10 likelihood units of the best fit. The dashed line marks the base fit. Points separated horizontally into distinct groups are alternative local minima.

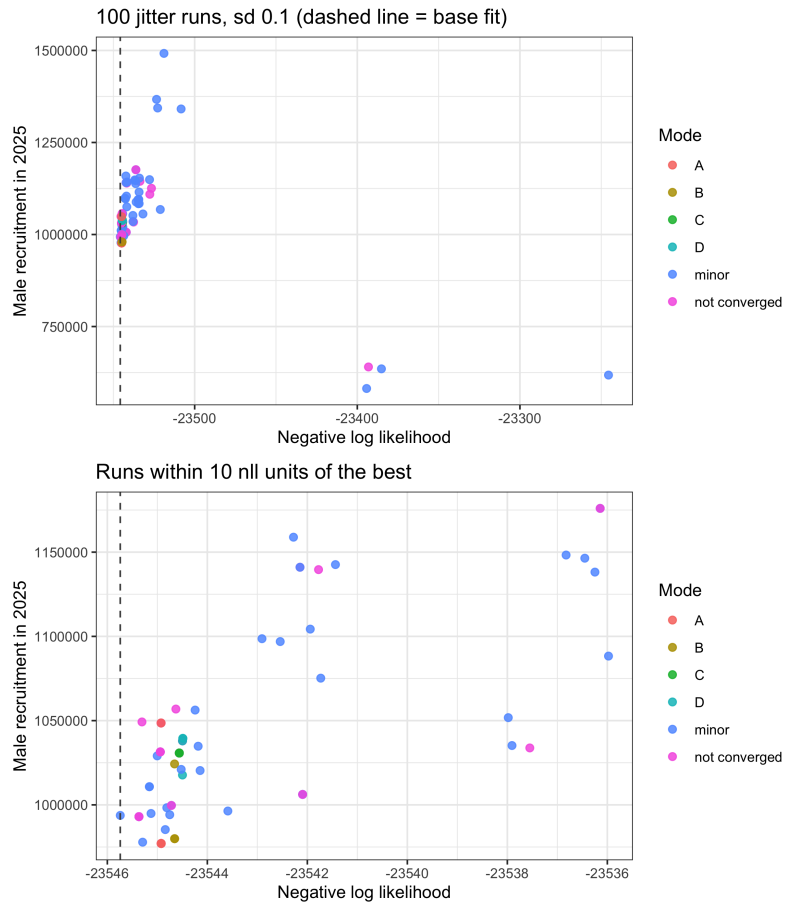


Figure 20: Estimated male recruitment in 2025/26 resulting from 100 jitter runs of the author-preferred model, plotted against the negative log likelihood of each run. The dashed line marks the base fit.

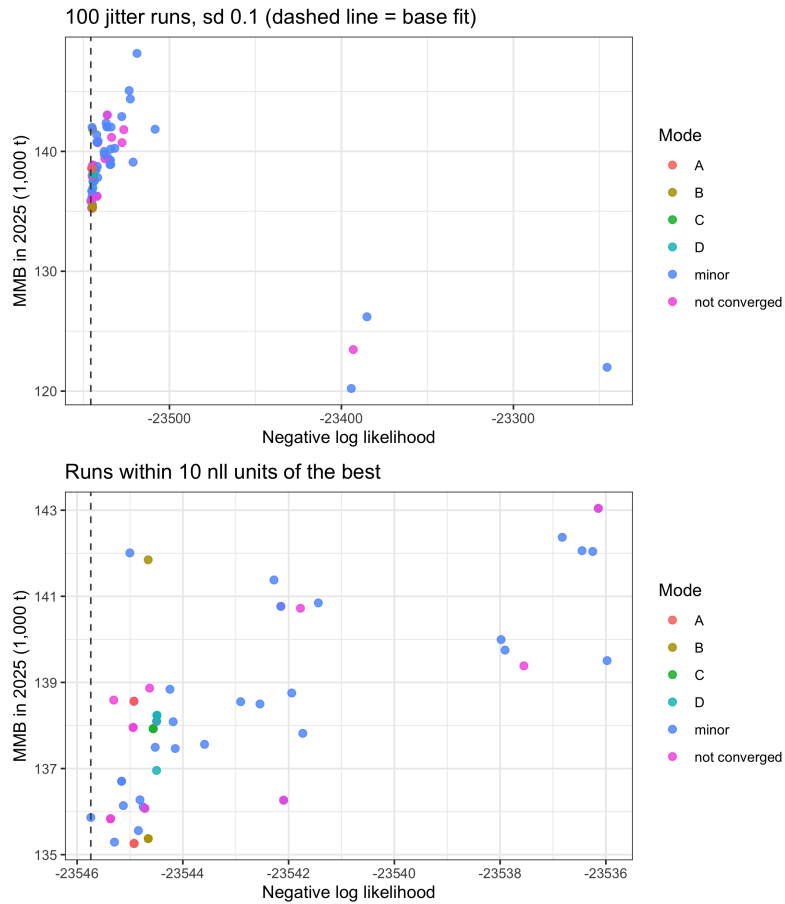


Figure 21: Estimated mature male biomass in 2025/26 resulting from 100 jitter runs of the author-preferred model, plotted against the negative log likelihood of each run. The dashed line marks the base fit.

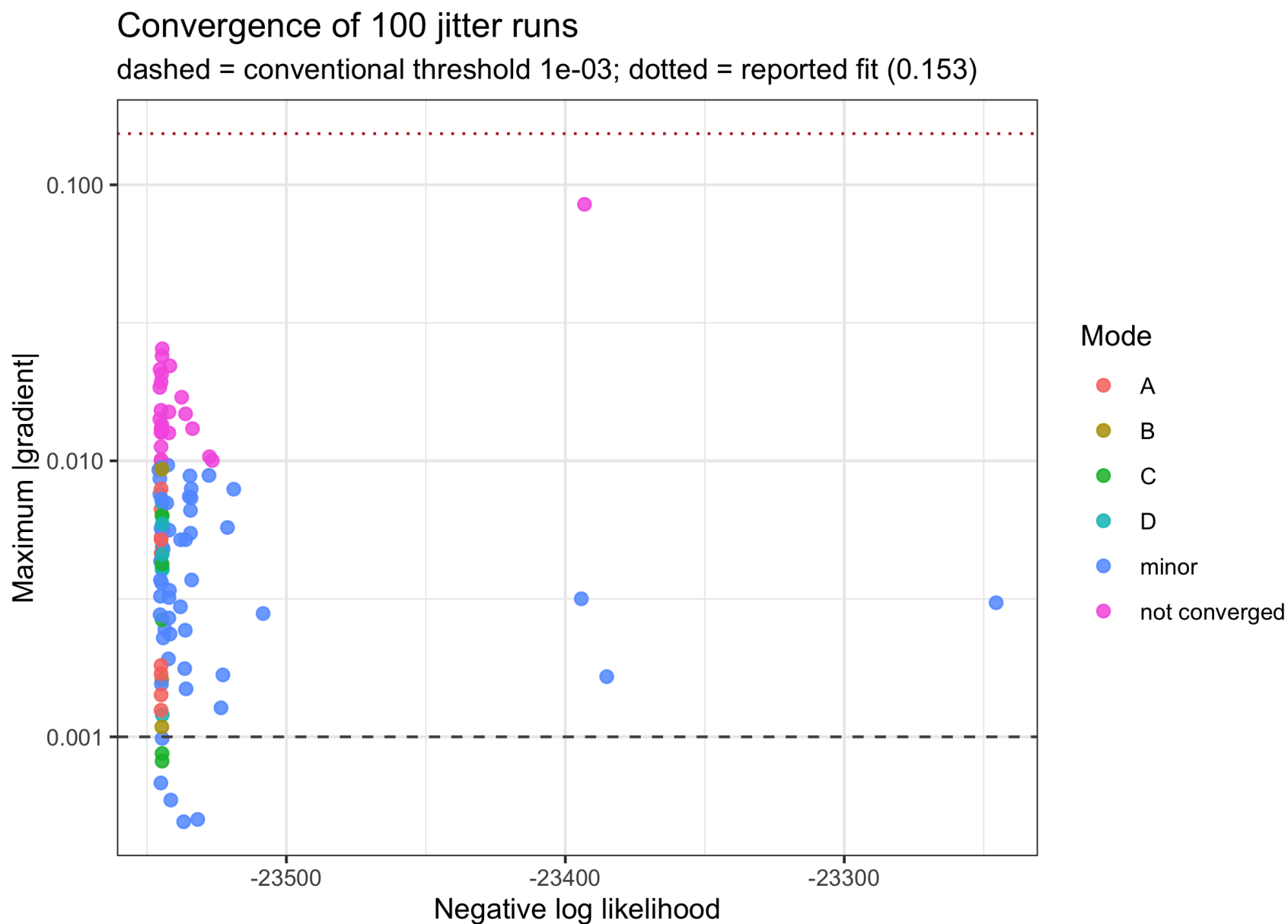


Figure 22: Maximum absolute gradient against negative log likelihood for 100 jitter runs of Model 26.1b. The dashed line is the conventional convergence threshold of 0.001. The dotted line is the base fit's maximum gradient.

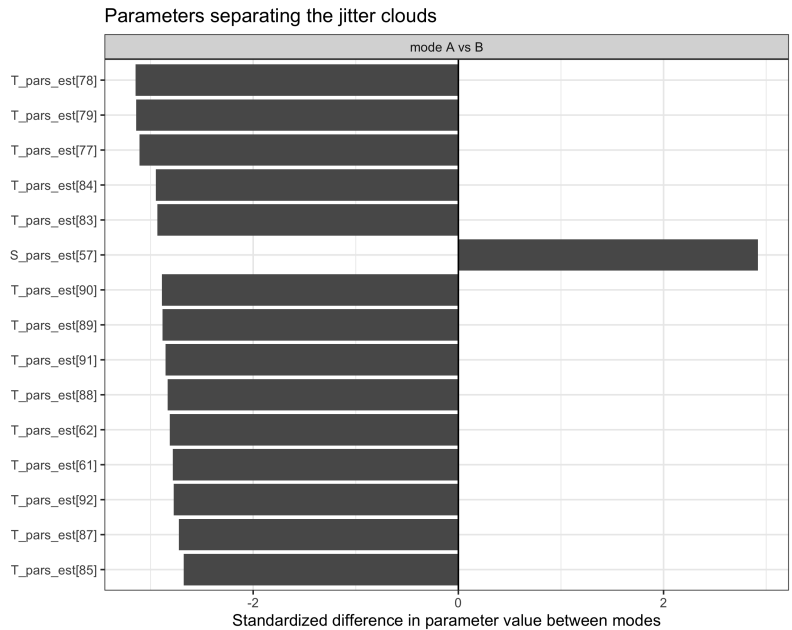


Figure 23: Parameters that most separate the jitter minima, ranked by the standardized difference in fitted value between the best-fitting mode and each alternative mode. A large value means the 2 minima disagree about that parameter.

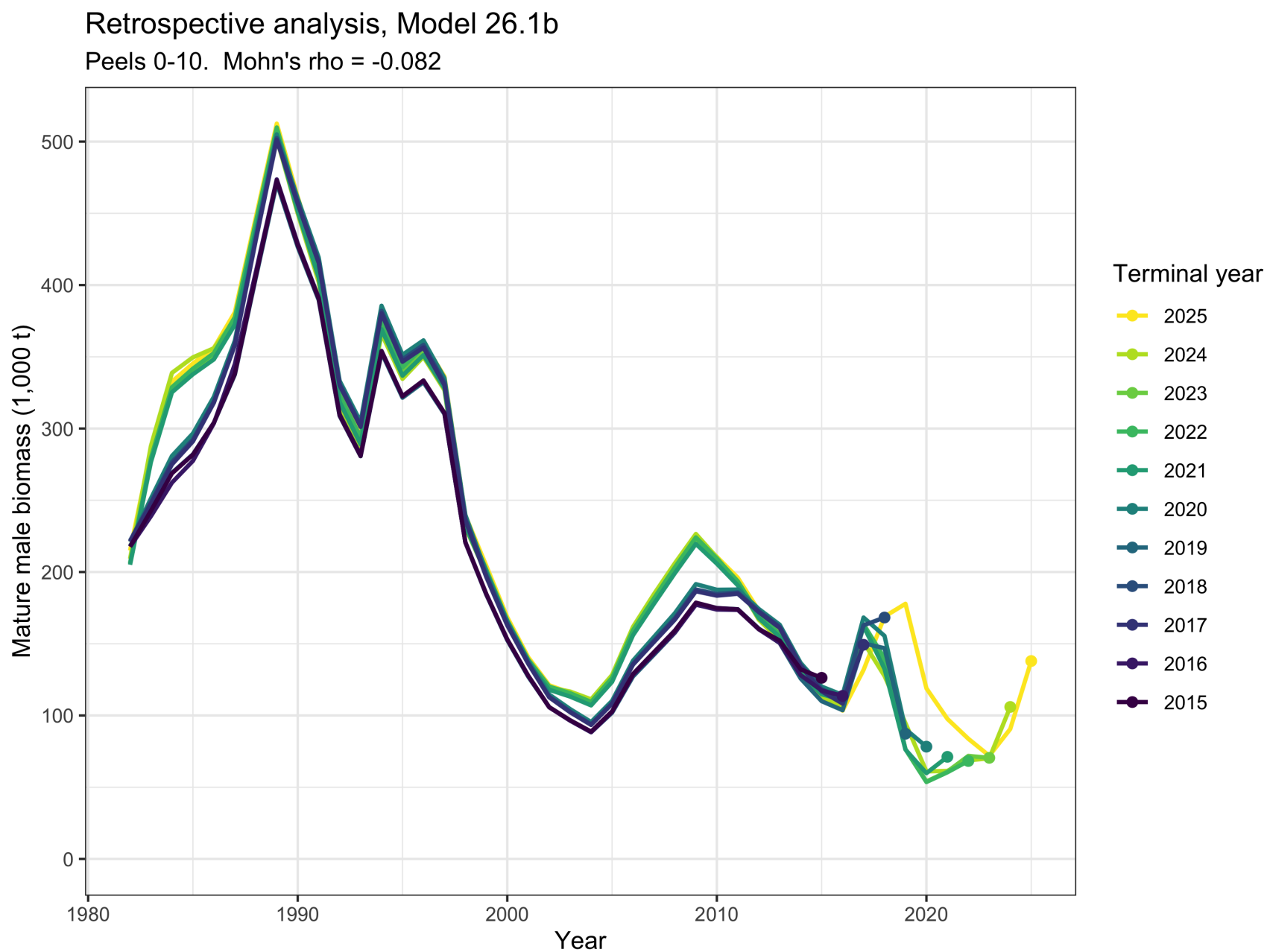


Figure 24: Standard retrospective analysis of Model 26.1b, the author-preferred model. Mature male biomass in 1,000 t. Each line is a fit with the terminal years of data sequentially removed. Color denotes the terminal year of the peel and the point marks each peel's terminal estimate.

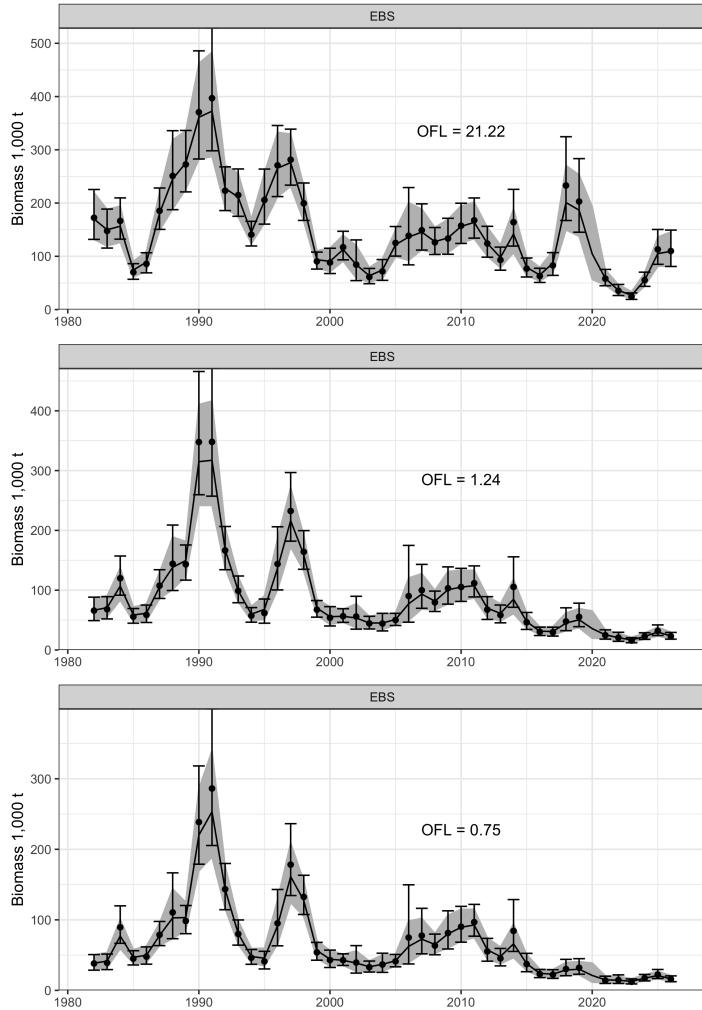


Figure 25: Random-effects (REMA) fit to the survey biomass series for the 3 maturity definitions used in the Tier 4 fallback: morphometrically mature males (top), males ≥ 95 mm (middle) and males > 101 mm (bottom). Points are the survey observations with their sampling intervals; the line and band are the smoothed series and its 95 percent confidence interval. See the note below the figure.

Note to the REMA figure. The smoothed terminal value is the biomass the control rule acts on, and the mean of the smoothed series over the full

1982 to 2026 window is the B_{MSY} proxy. There is no 2020 observation because the survey was cancelled; the random-effects model supplies a value for it, which is why the proxy is averaged over the smoothed series rather than the observations.

Tier 4 status on the raw survey series

dashed: beta = 0.25 (closure) and 0.5

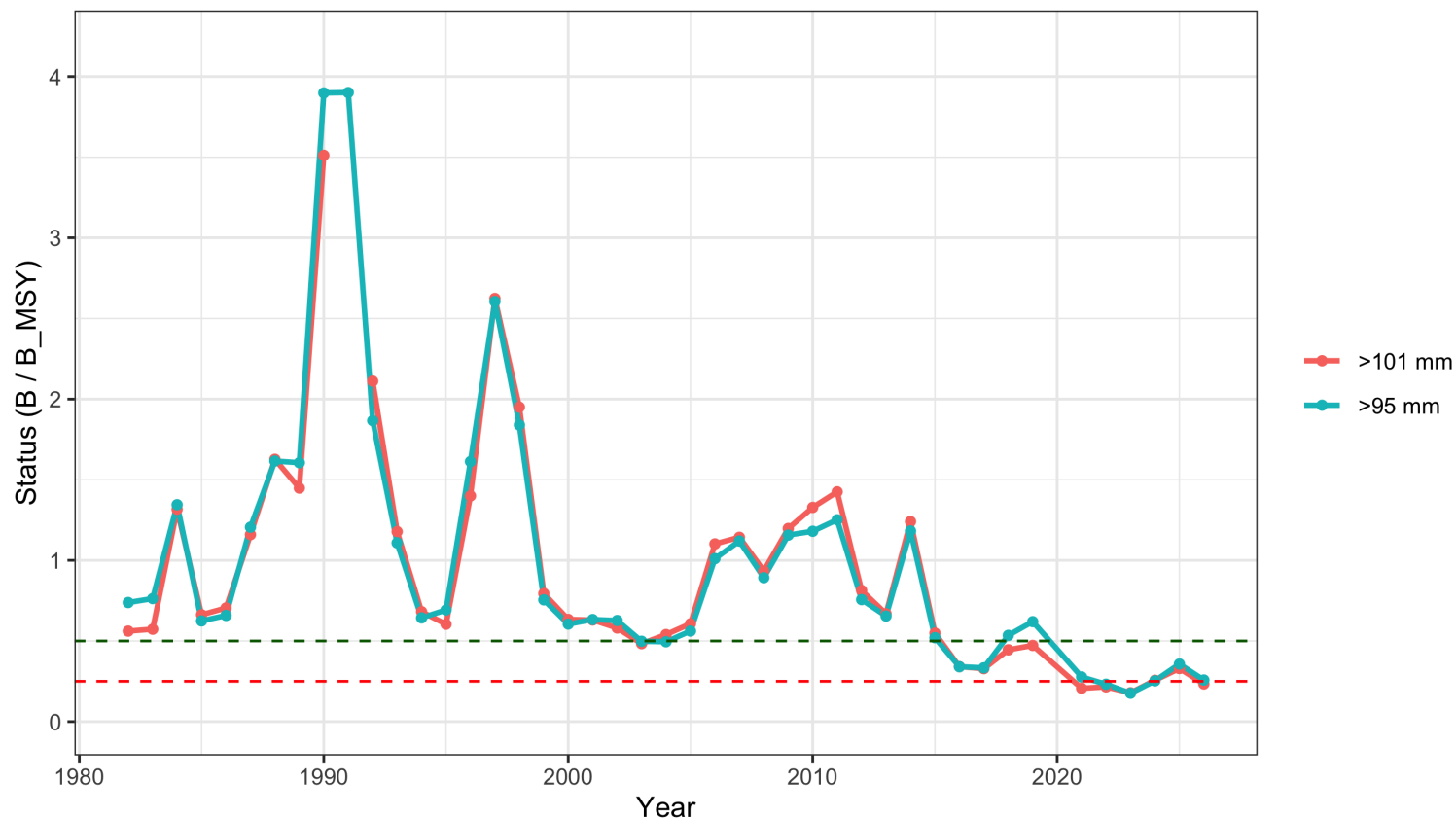


Figure 26: Tier 4 fallback stock status (biomass relative to the B MSY proxy) computed on the raw survey series for the large-male (≥ 95 mm) and preferred-male (> 101 mm) definitions. The morphometrically mature series, the basis of the specification, is in the REMA figure above. The red line is the closure threshold beta, below which the OFL is zero. The green line is half the proxy, the minimum stock size threshold. The series is shown on the raw observations rather than the smoothed fit, so it is more variable than the status reported for the specification, which is computed from the REMA fit.

Retrospective with the terminal survey year withheld, Model 26.1b

Peels 0-10, compared with the full base fit. Mohn's rho = -0.098

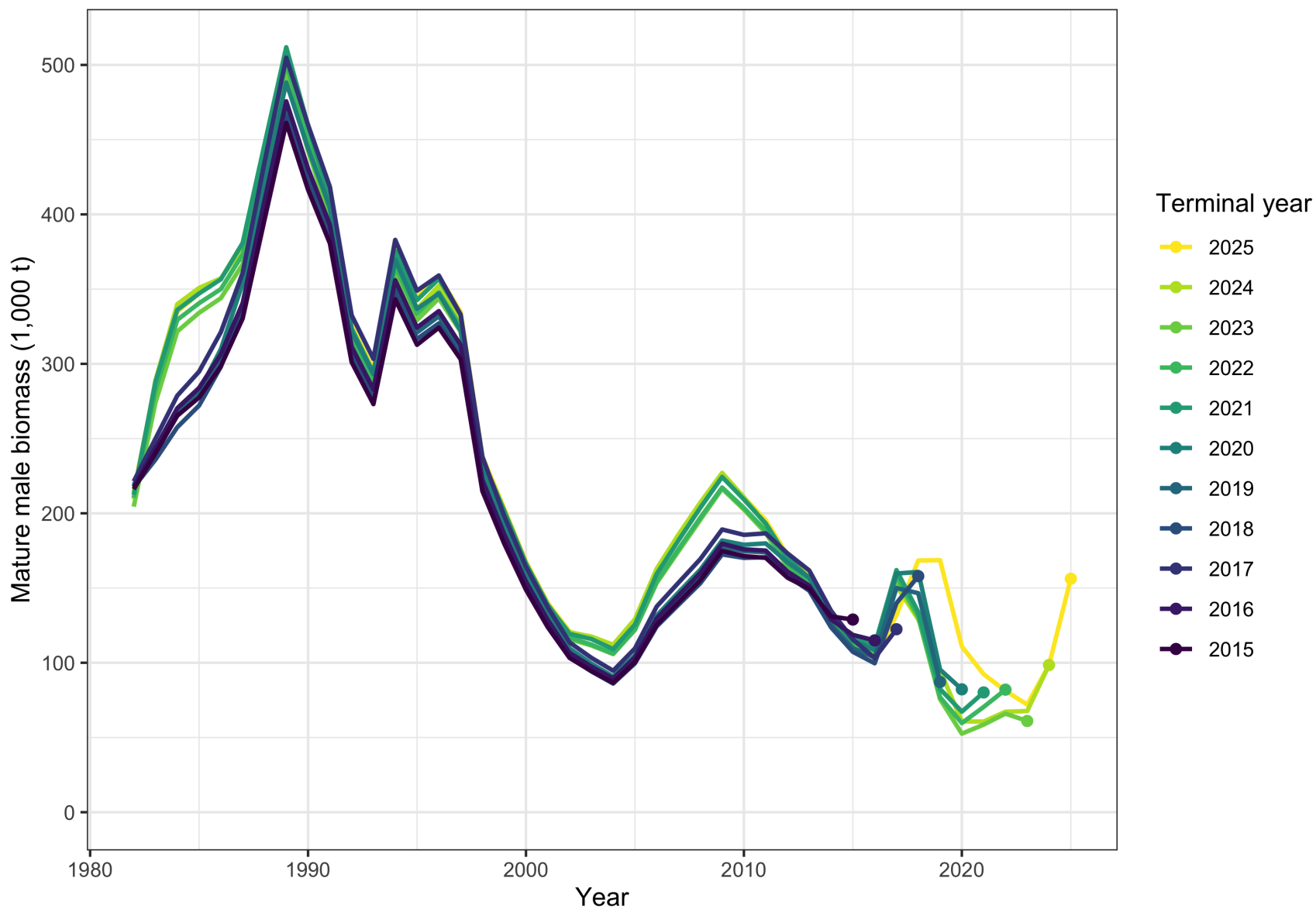


Figure 27: Retrospective analysis with the terminal survey year withheld in addition to the peeled years, isolating the leverage of the most recent survey observation on the terminal biomass estimate. Peels are compared to the model fit to all data.

Note to the dropped-terminal-survey figure. One step of the sweep removes no survey data. Each peel withholds the survey from the terminal year minus the peel count, so peel 5 ends the survey series in 2020 and peel 6 in 2019. Because the 2020 survey was cancelled, the 2 peels read identical data files and differ only in the fishery years GMACS drops internally. The step between those 2 points should not be read as the effect of removing a survey year.

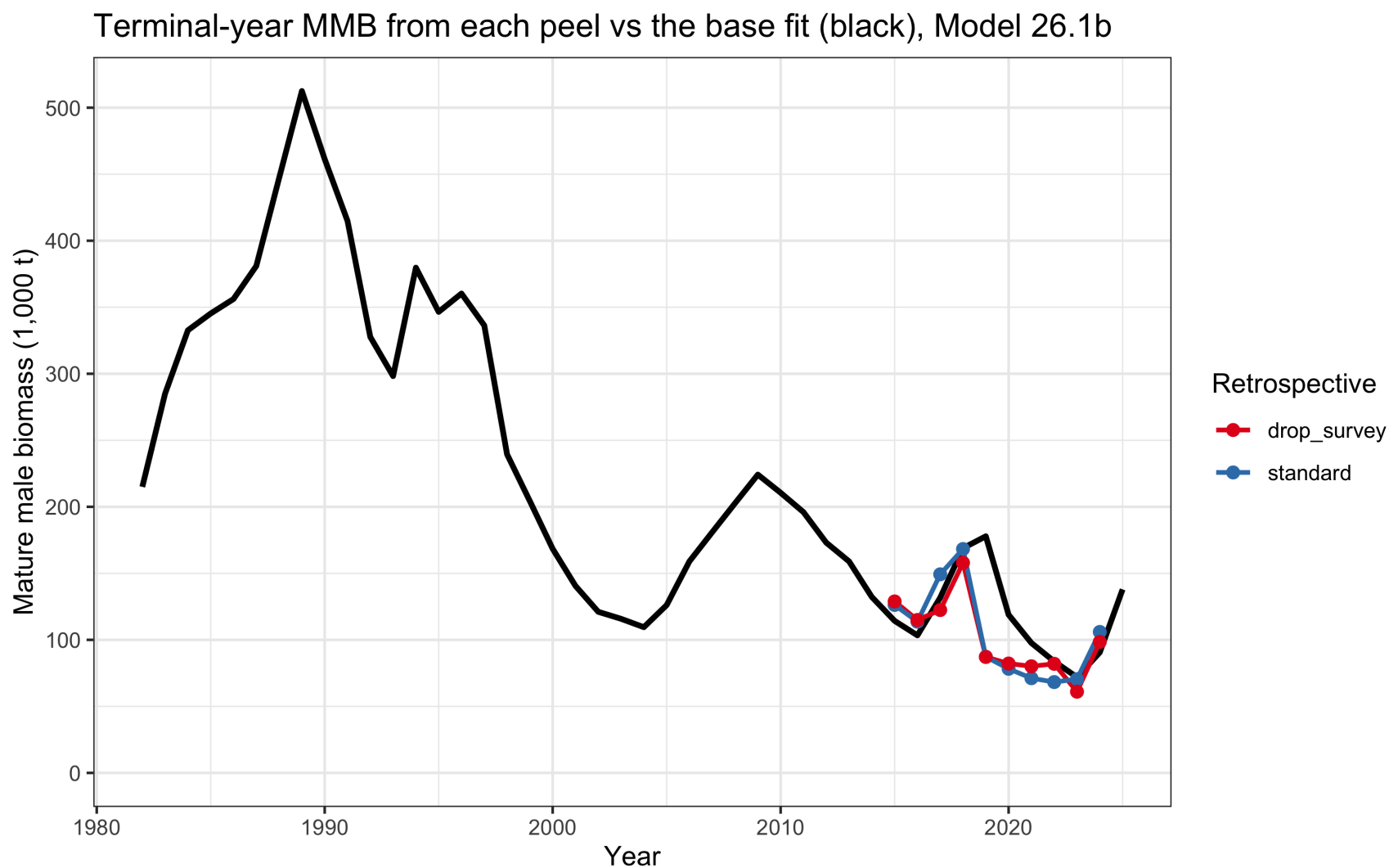


Figure 28: Terminal-year mature male biomass from each retrospective peel (colored) against the mature male biomass time series estimated by the model fit to all data (black). Systematic separation between the colored and black series is the retrospective pattern.

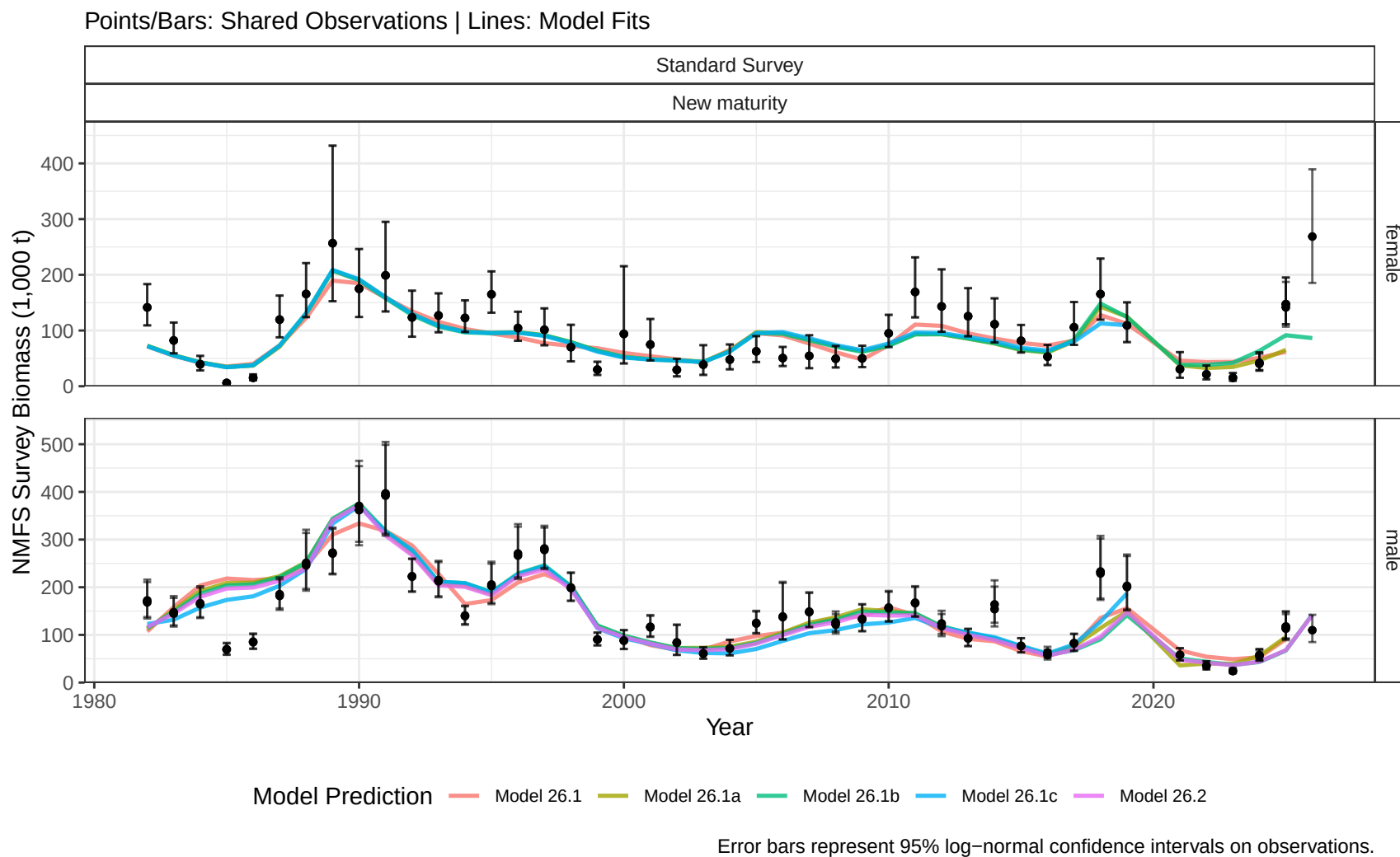


Figure 29: Model fits to the observed mature biomass at survey (1,000 t), for the 5 models fitted under GMACS 2.20.34. Model 25.3, which was fitted under GMACS 2.20.22 and is reported as originally fitted, is not plotted.

Fishery Catch and Bycatch Fits

Black points: Observations | Colored lines: Model predictions

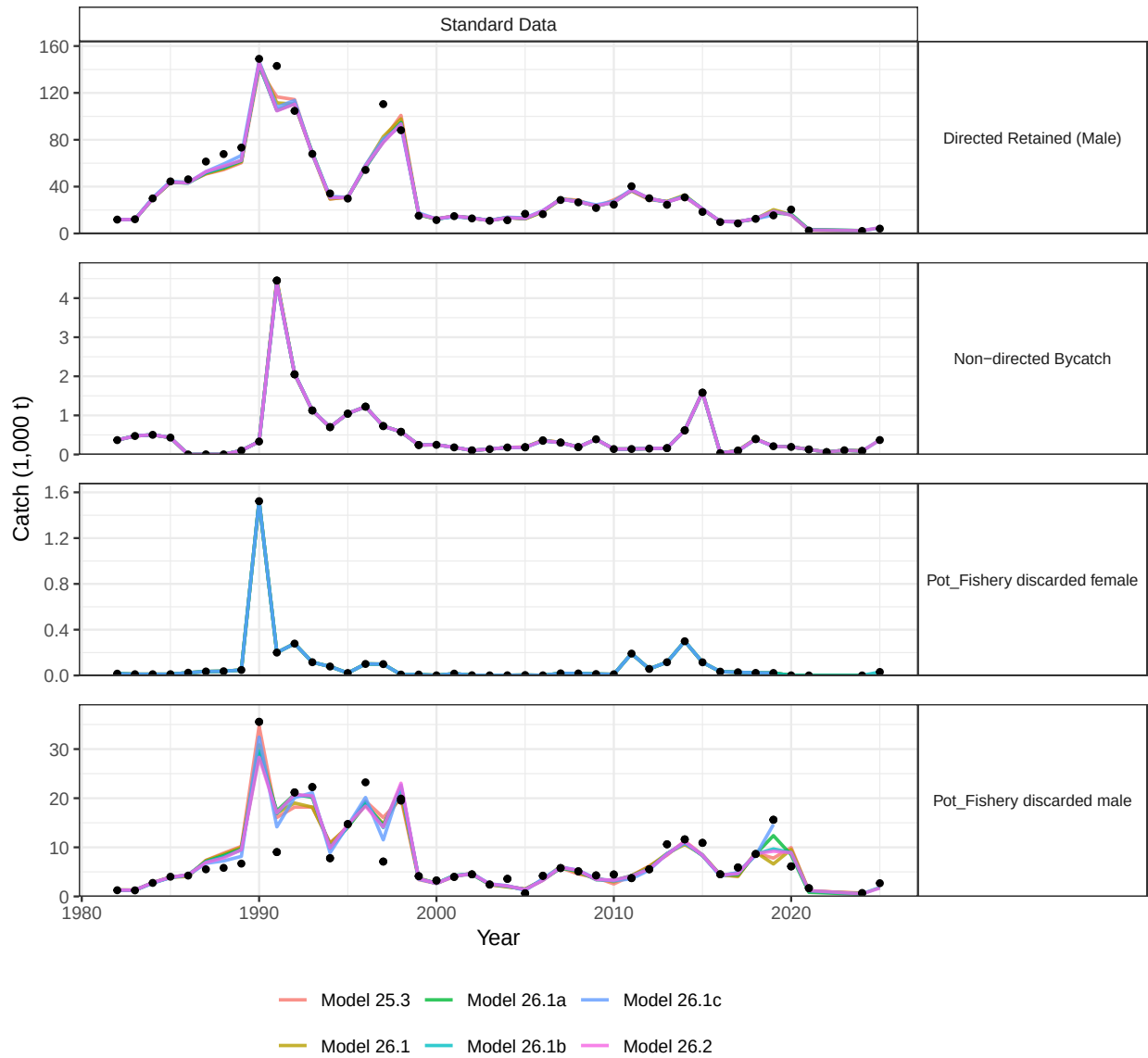


Figure 30: Model fits to catch data (1,000 t), for all models presented.

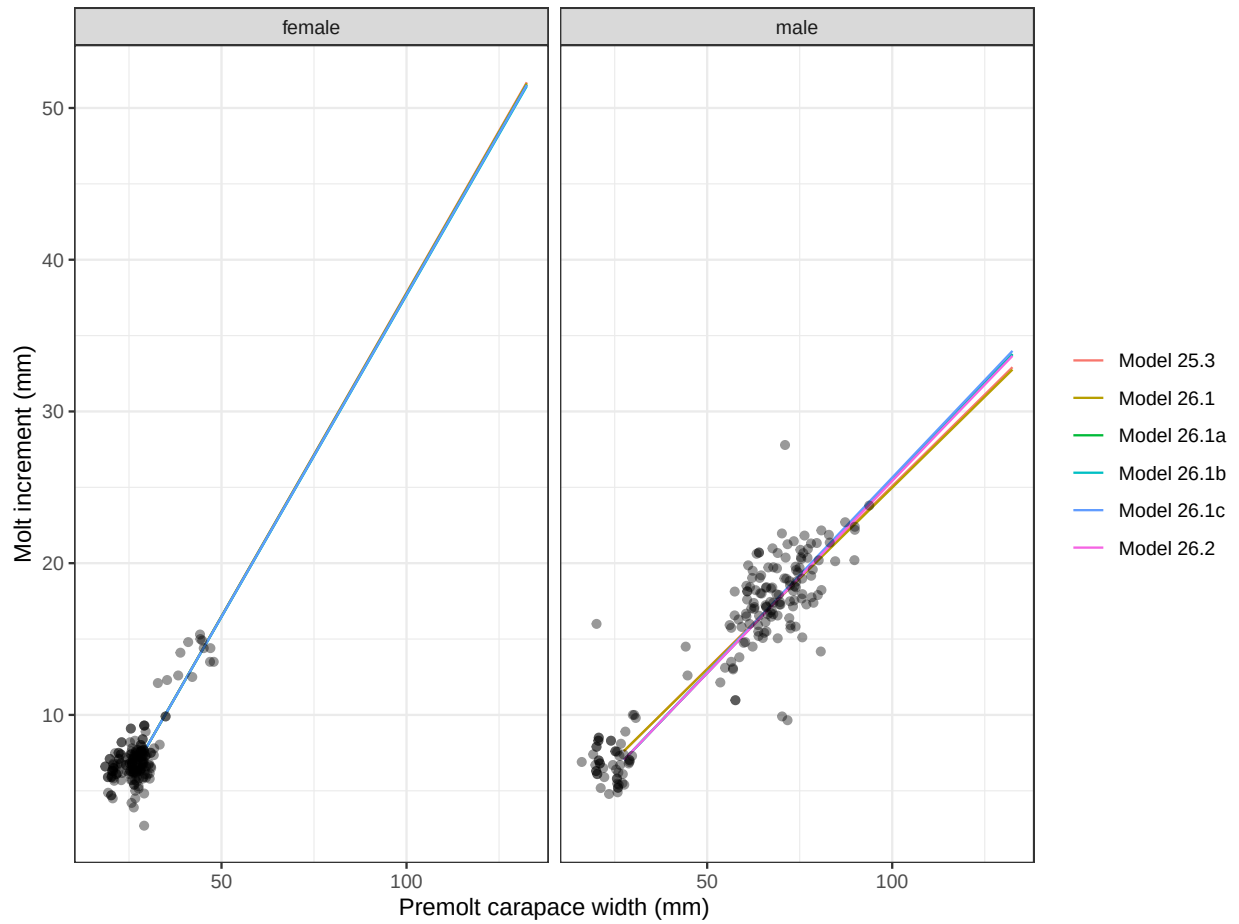


Figure 31: Estimated mean growth increment by model (colored lines) and the observed molt increments the models are fitted to (dots), by sex. All observations are drawn in the same color. The growth data combine the increment set used in previous assessments with the non-duplicate records of the specimen master, whose studies ran from 2016 to 2021.

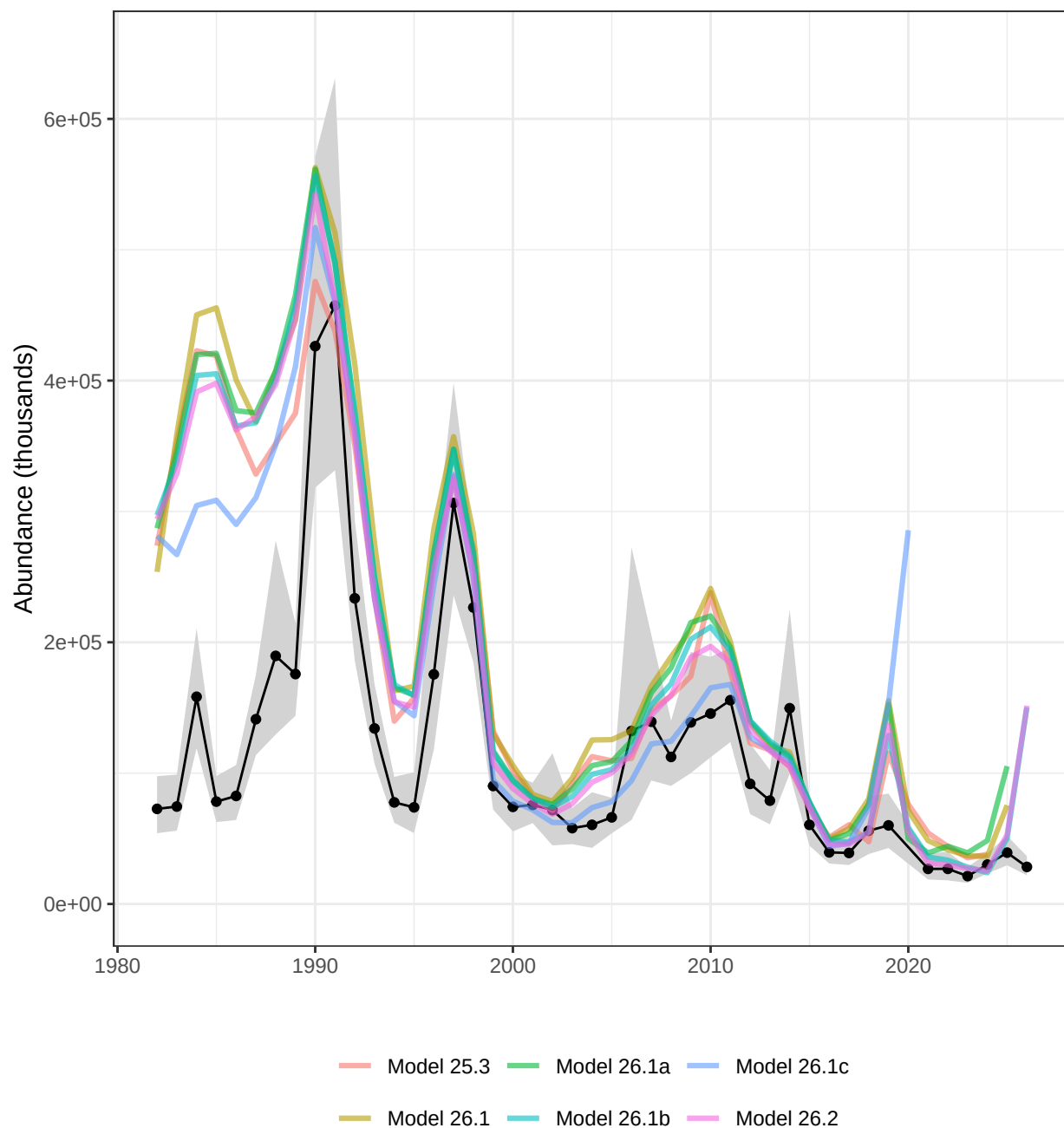


Figure 32: Estimated abundance of male crab > 101 mm carapace width from the survey (black line and dots with gray 95 percent confidence interval) and from each model in the assessment (colored lines).

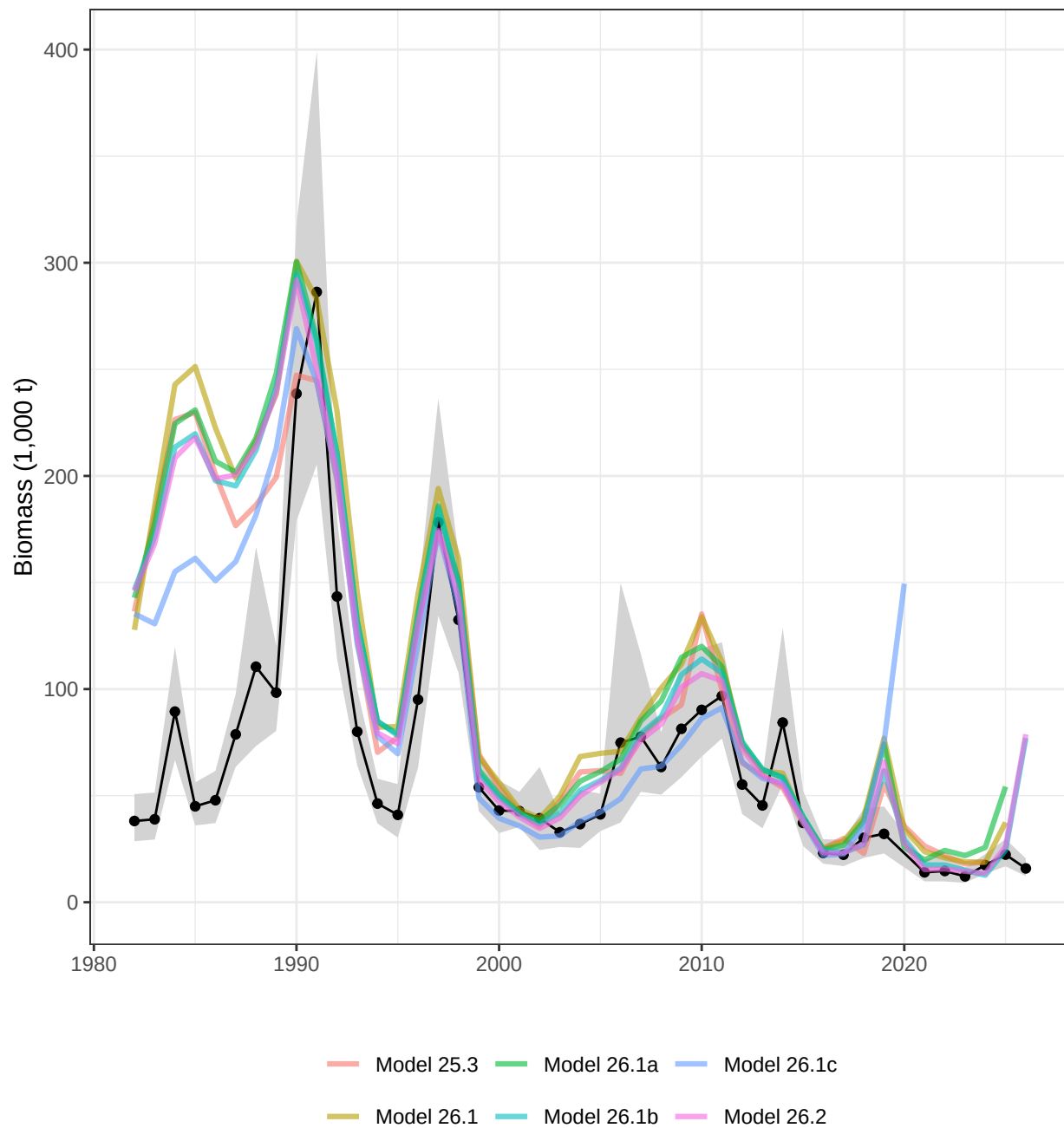


Figure 33: Estimated biomass (1,000 t) of male crab > 101 mm carapace width from the survey (black line and dots with gray 95 percent confidence interval) and from each model in the assessment (colored lines).

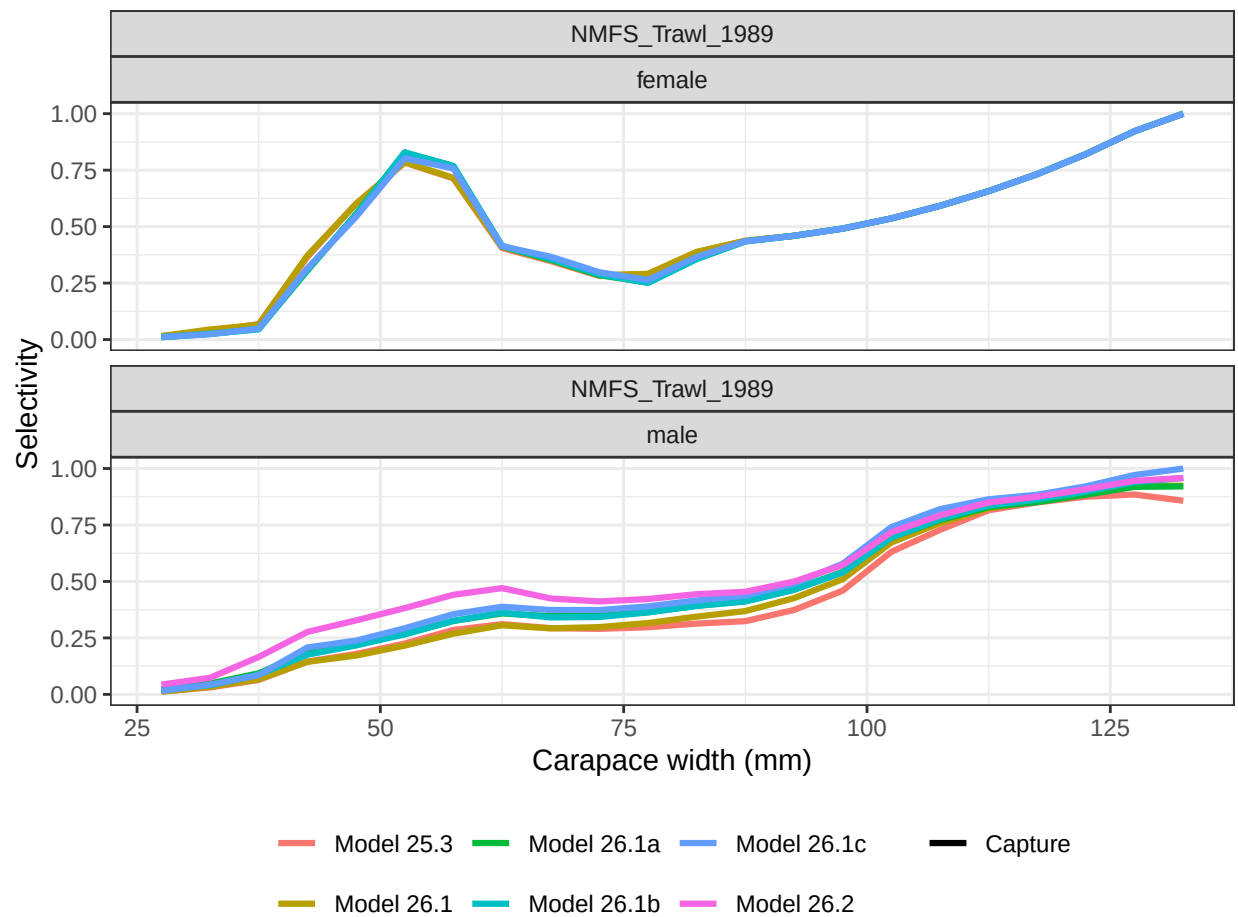


Figure 34: Estimated survey selectivity (lines) with normal priors derived from BSFRF selectivity experiment data. Points are the mean of the prior at a given size. Intervals are 95 percent intervals from the input CVs.

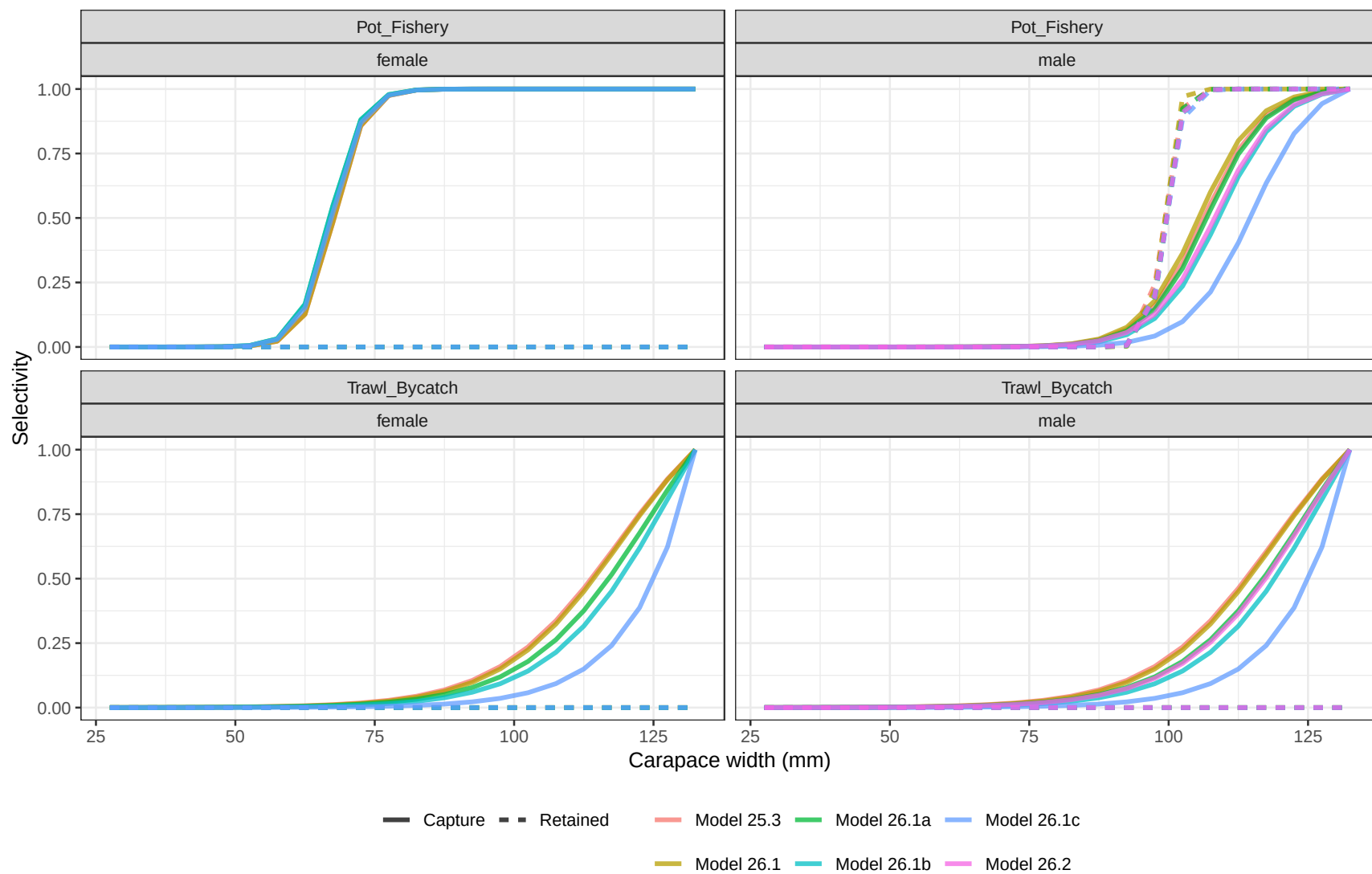


Figure 35: Estimated selectivities by fishing fleet and sex for capture and retained catches.

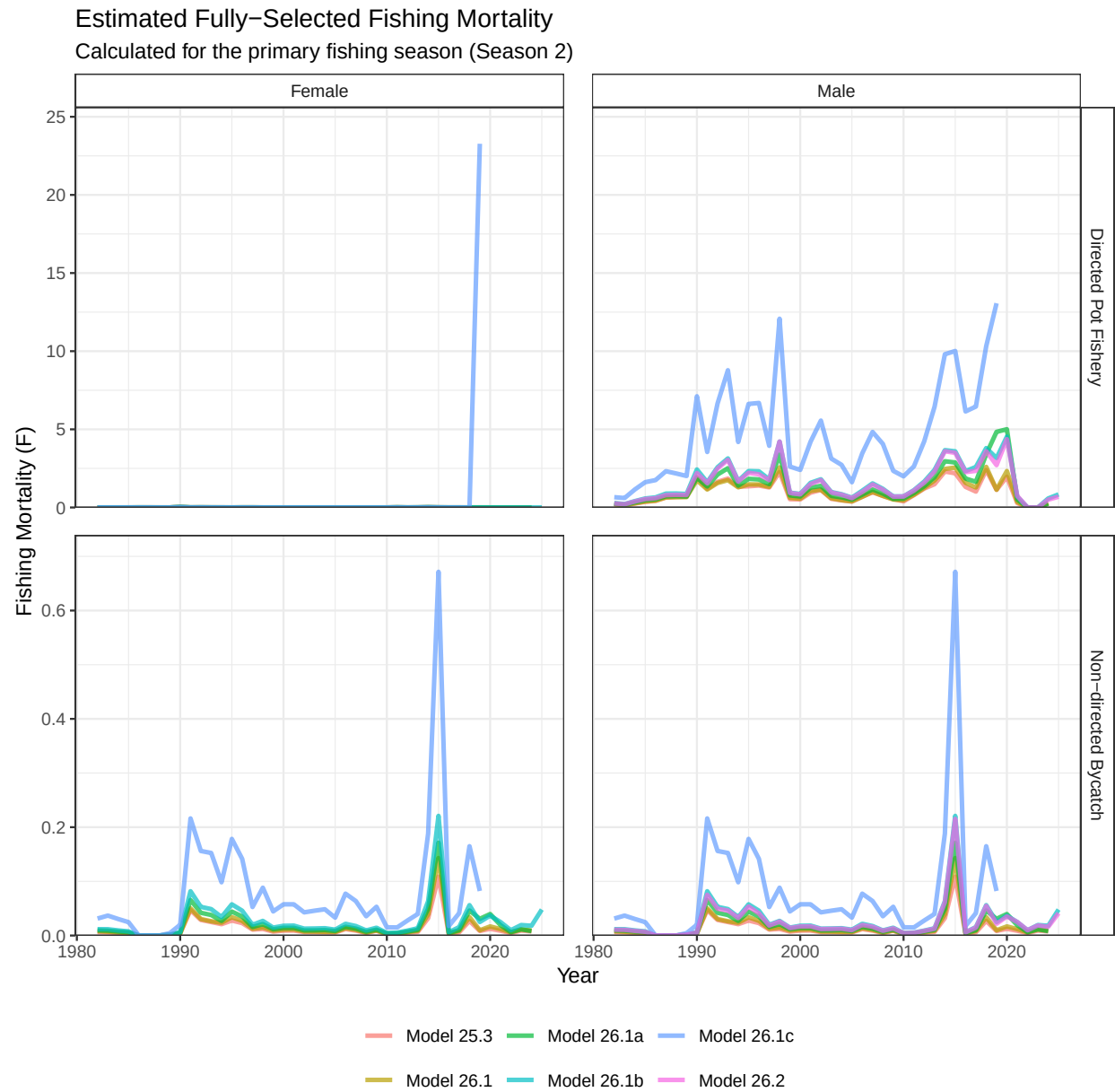


Figure 36: Estimated fishing mortalities (per year) for the directed and non-directed fisheries.

Probability of Maturing / Terminal Molt Separated by Maturity Data Specification

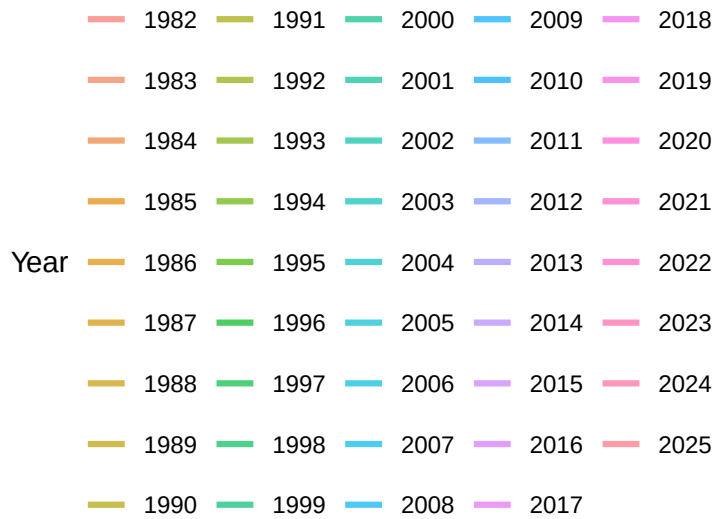
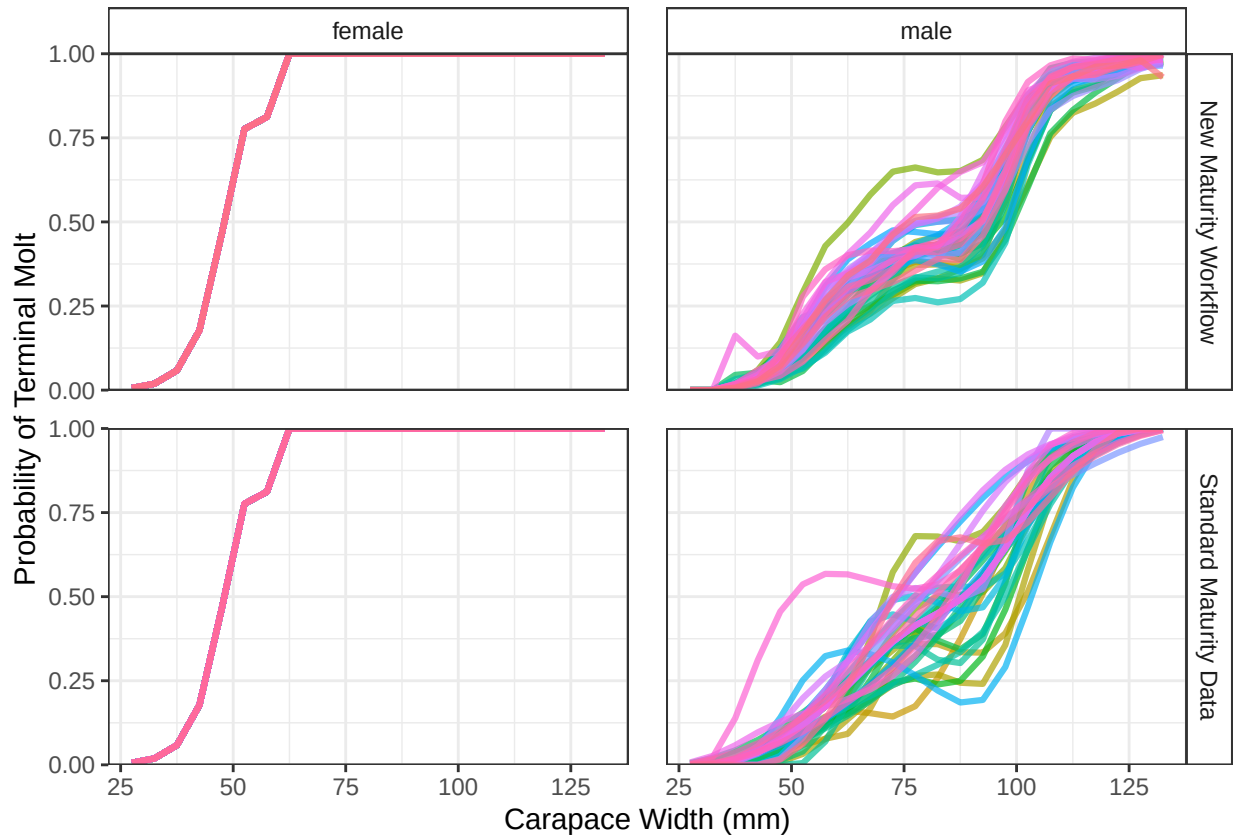


Figure 37: Probability of terminal molt at size by year, input to the models as data: the new maturity workflow (top), used by every model except Model 25.3, and the legacy series (bottom), used by Model 25.3. The female ogive does not vary over time.

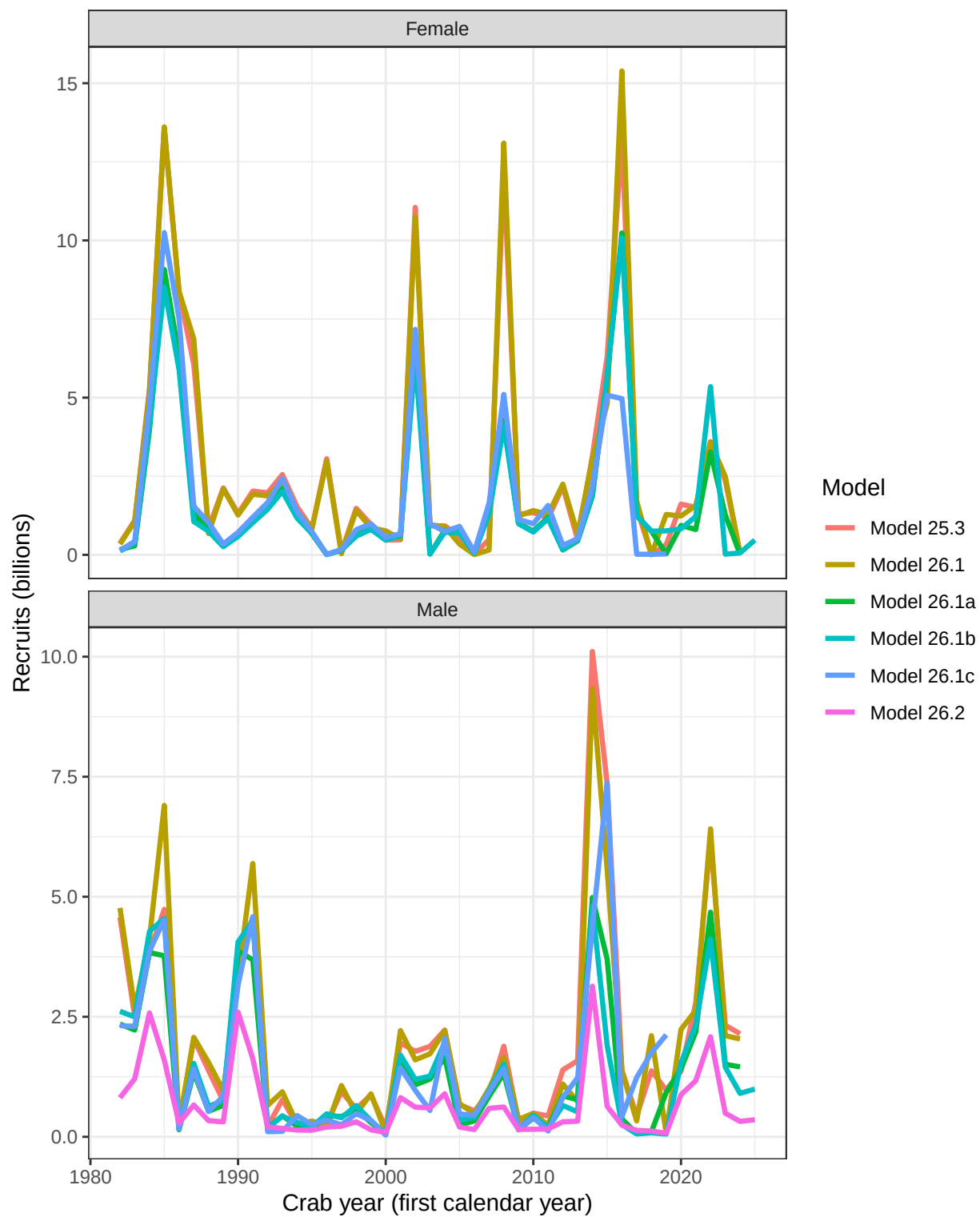


Figure 38: Estimated recruitment by sex (billions of crab), for all models presented.

Estimated Natural Mortality (M)

Mortality events in crab years 2018/19 and 2019/20

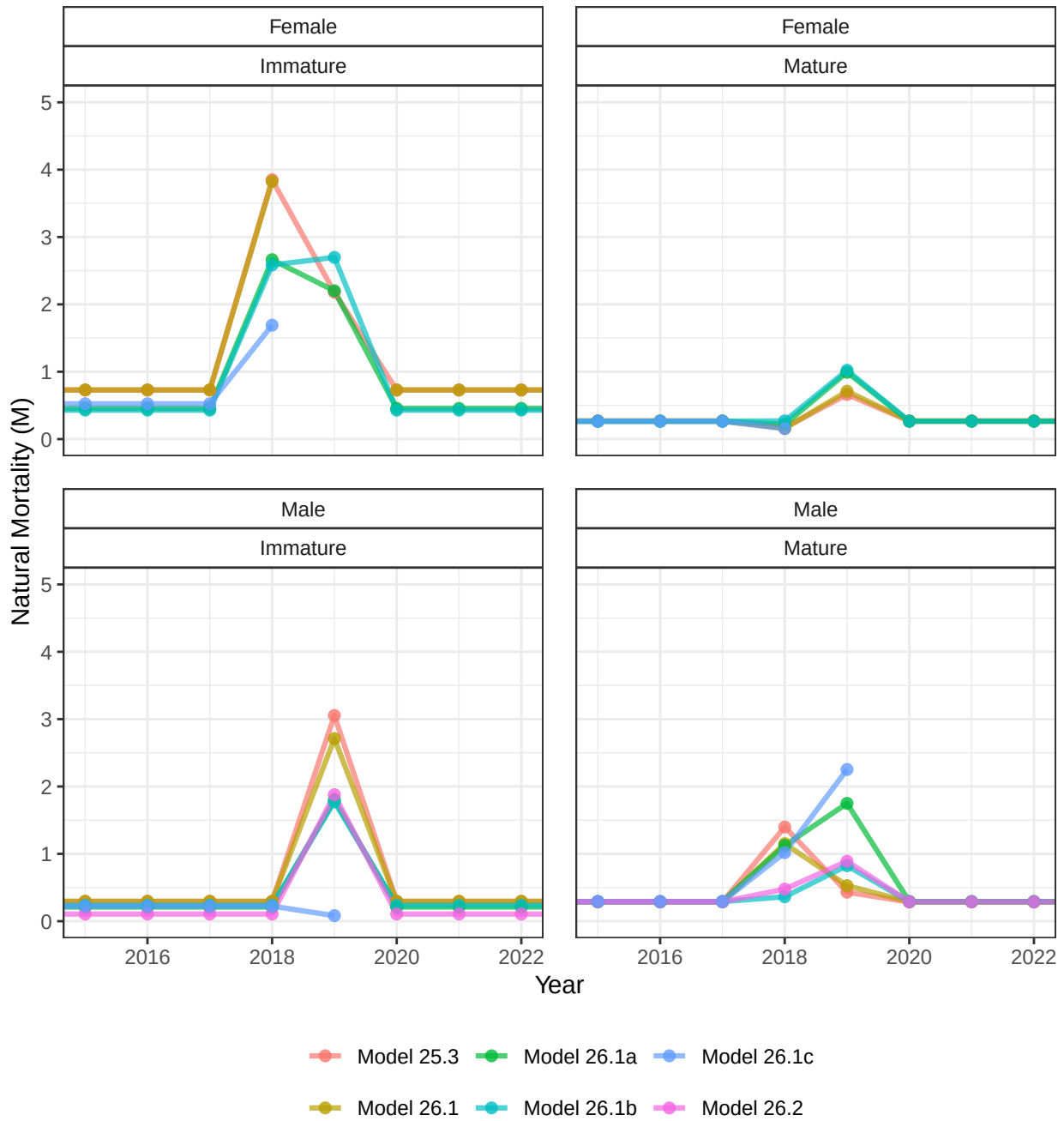


Figure 39: Estimated natural mortality (per year) by sex and maturity state. Natural mortality in all crab years before 2018/19 and after 2019/20 is equal to the estimated M in 2017/18. Note that the y-axis is capped at 5.

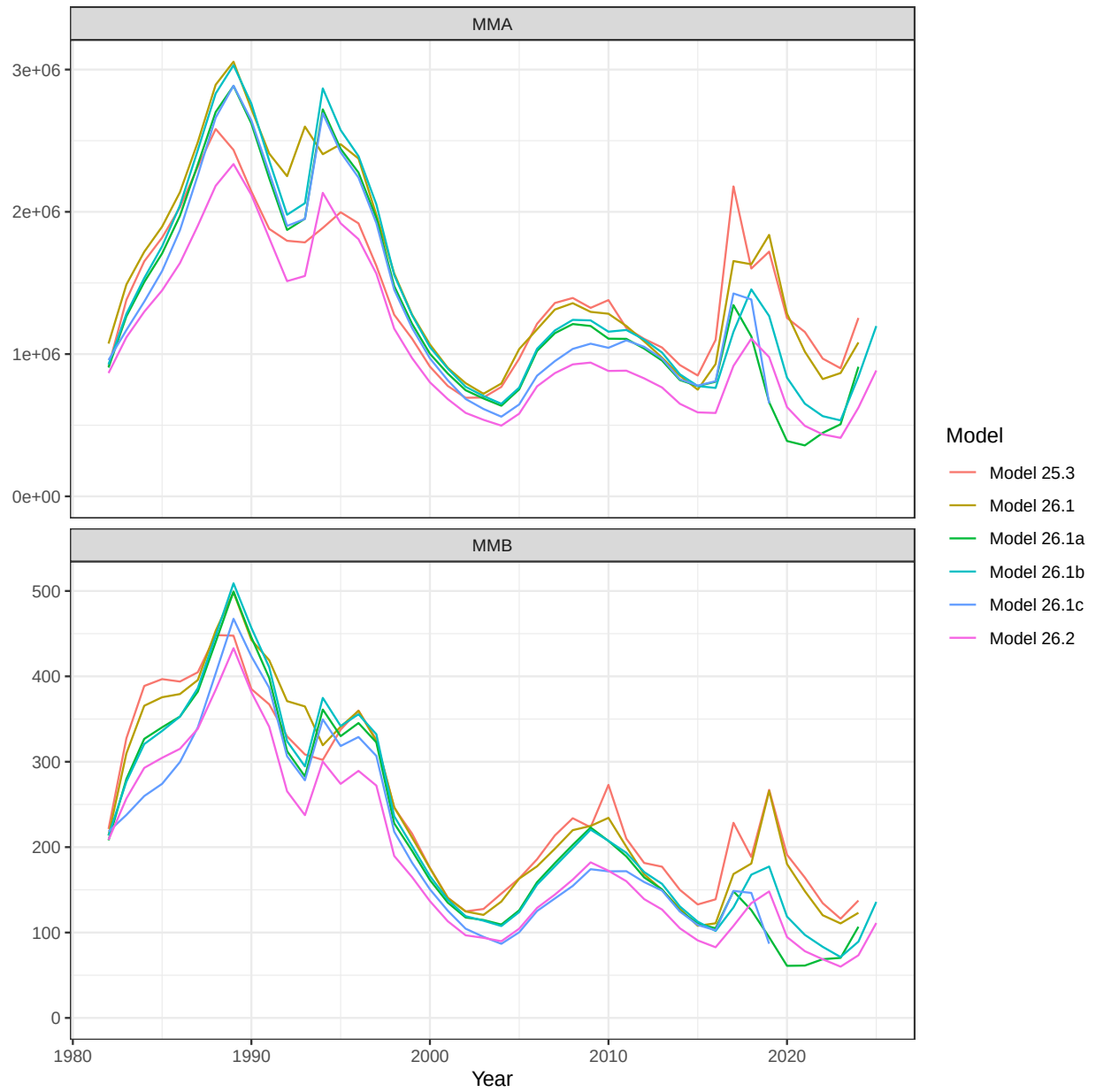


Figure 40: Model-predicted mature male abundance (MMA, thousands of crab) and mature male biomass (MMB, 1,000 t) at mating, for all models presented.

Size composition fits

Fleet: NMFS Trawl 1982

Female and Immature

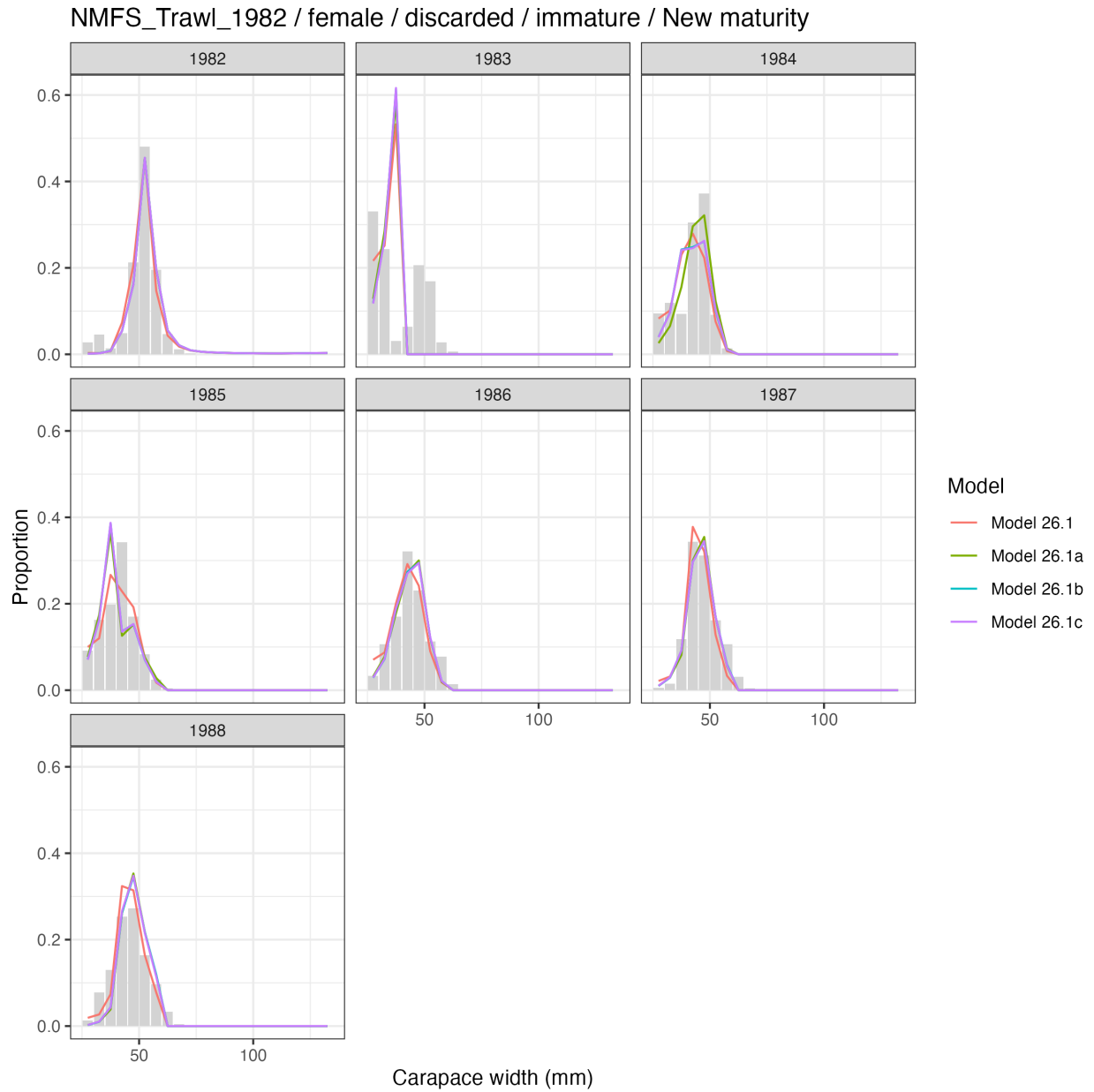


Figure 41: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1982 female discarded immature New maturity. Proportions by 5 mm carapace-width bin.

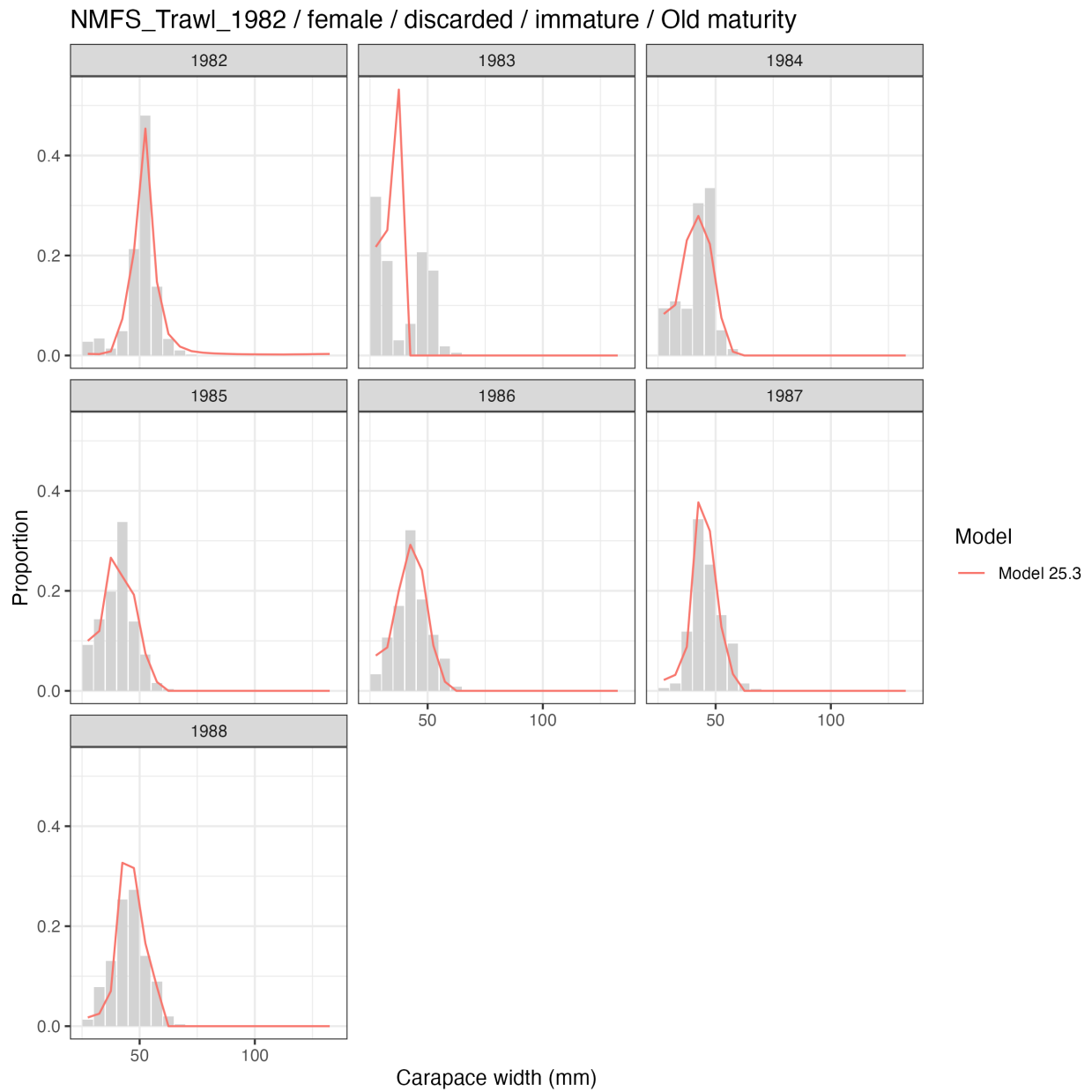


Figure 42: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1982 female discarded immature Old maturity. Proportions by 5 mm carapace-width bin.

Female and Mature

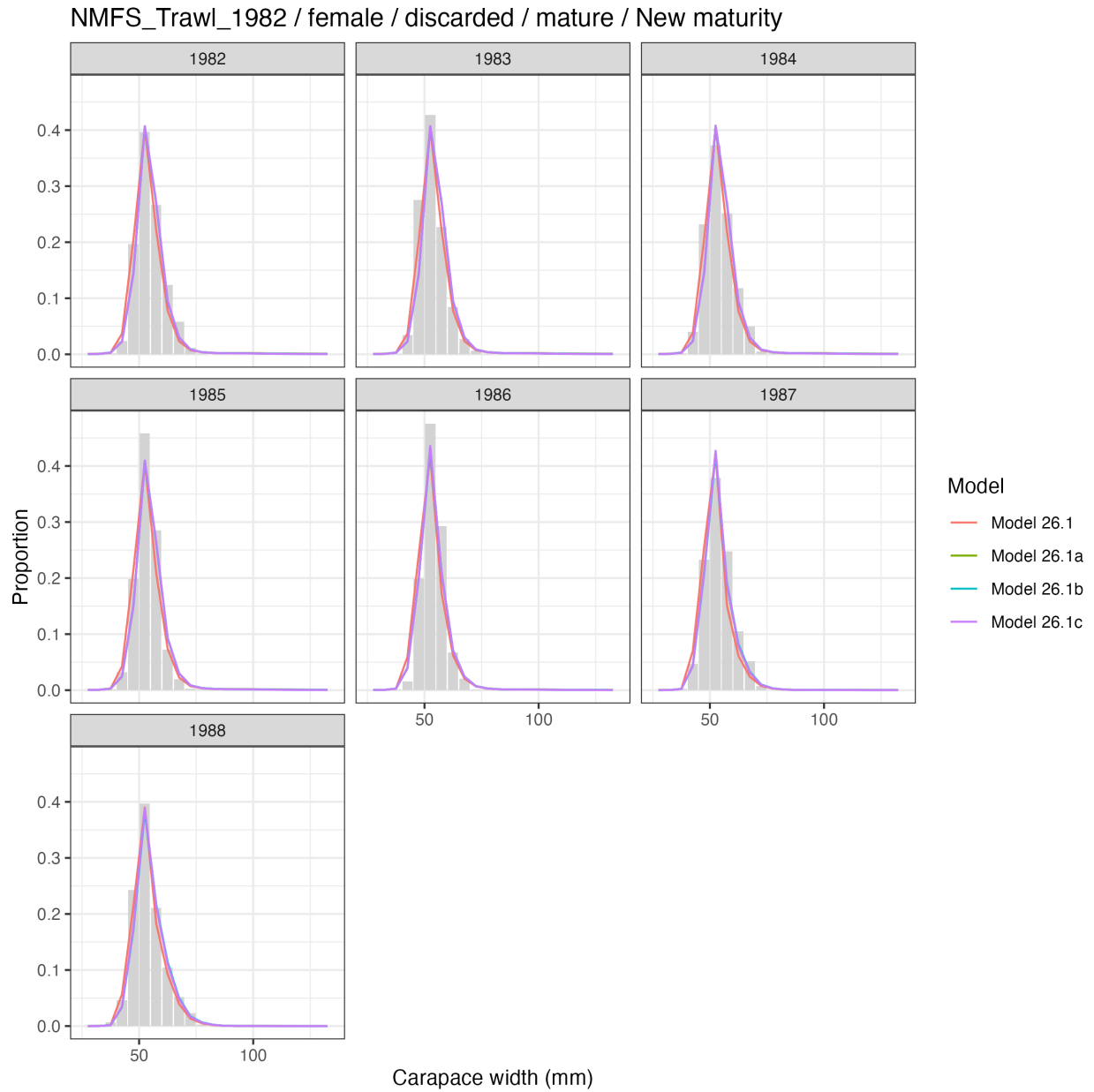


Figure 43: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1982 female discarded mature New maturity. Proportions by 5 mm carapace-width bin.

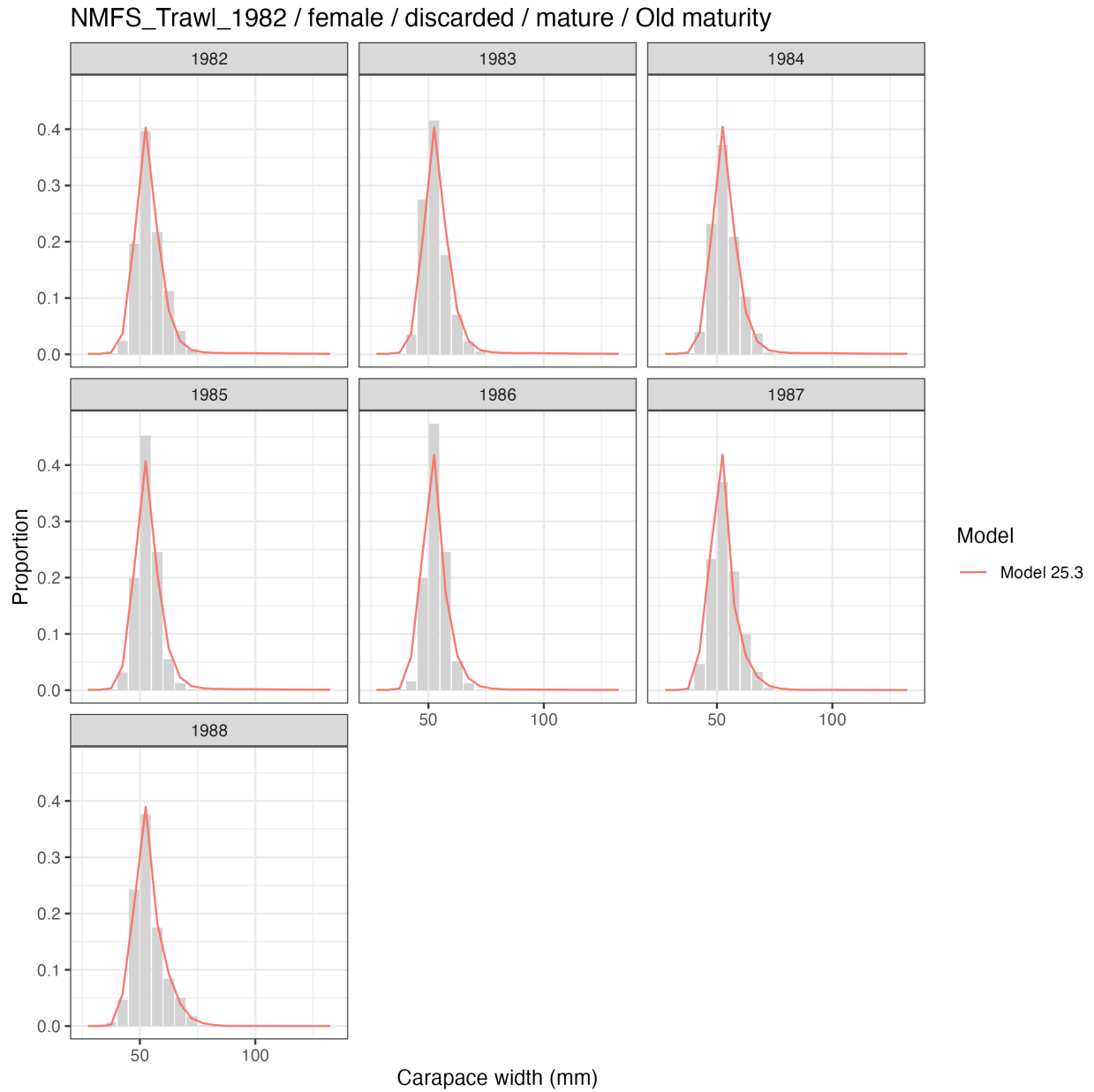


Figure 44: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1982 female discarded mature Old maturity. Proportions by 5 mm carapace-width bin.

Male and Immature

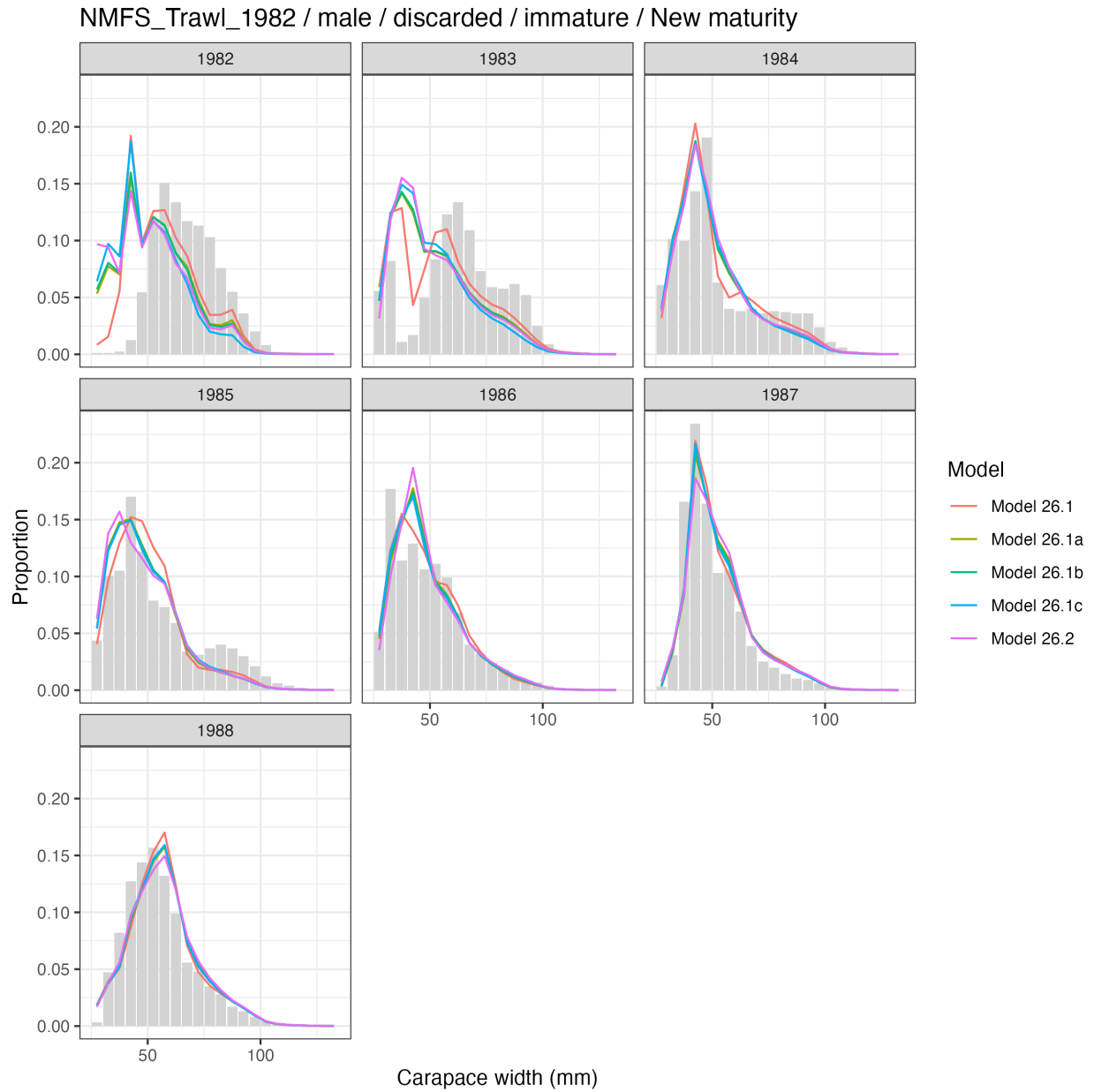


Figure 45: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1982 male discarded immature New maturity. Proportions by 5 mm carapace-width bin.

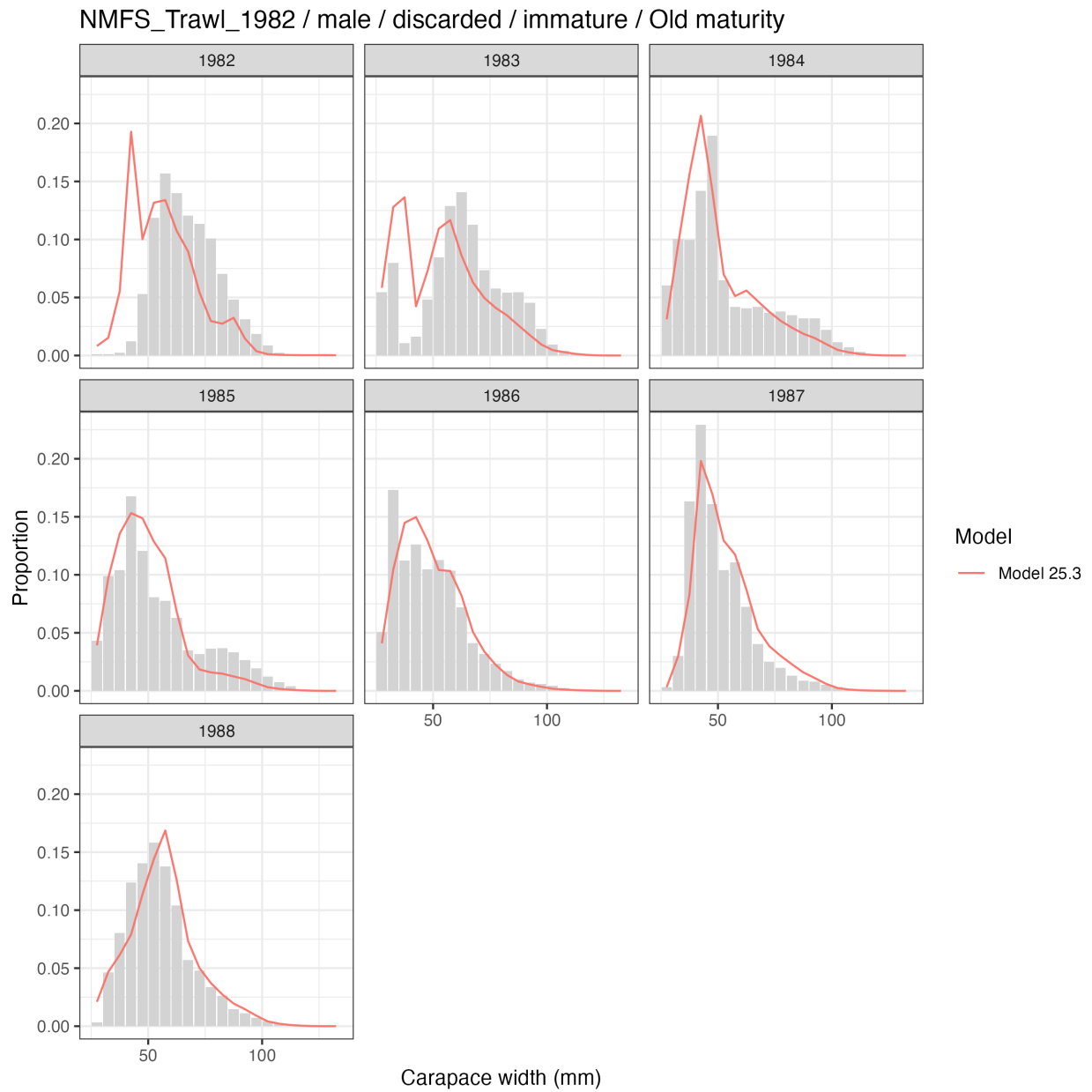


Figure 46: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1982 male discarded immature Old maturity. Proportions by 5 mm carapace-width bin.

Male and Mature

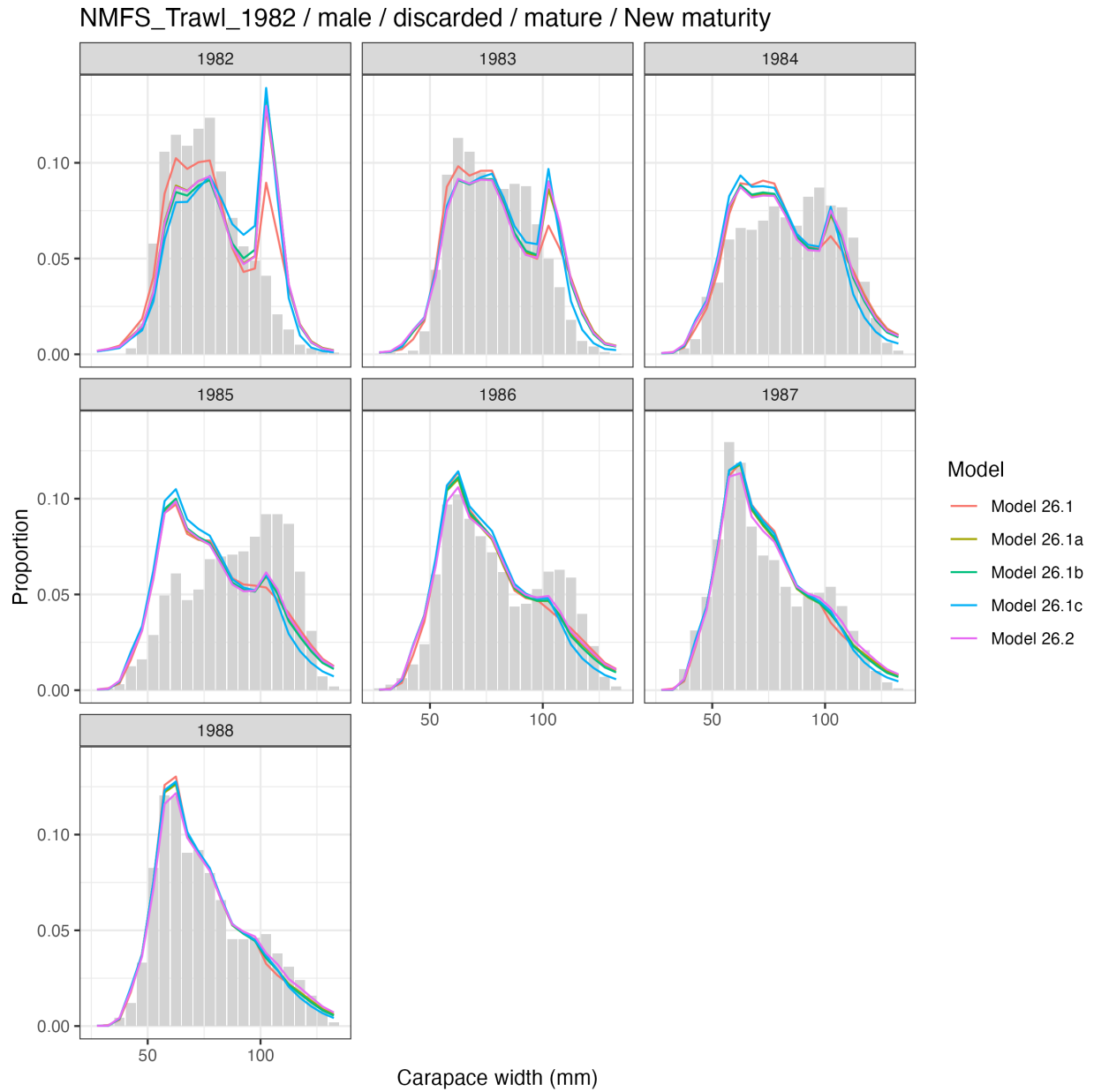


Figure 47: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1982 male discarded mature New maturity. Proportions by 5 mm carapace-width bin.

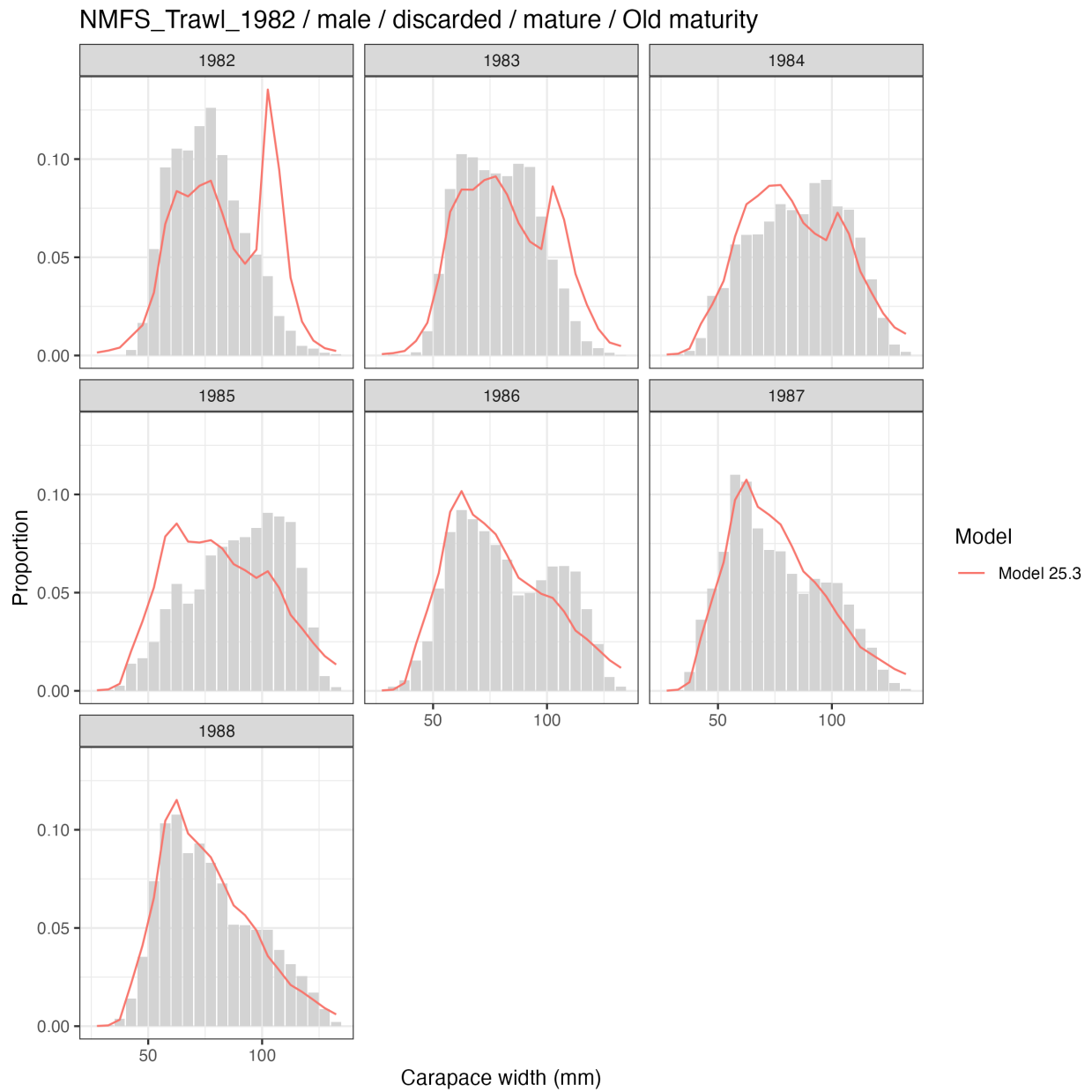


Figure 48: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1982 male discarded mature Old maturity. Proportions by 5 mm carapace-width bin.

Fleet: NMFS Trawl 1989

Female and Immature

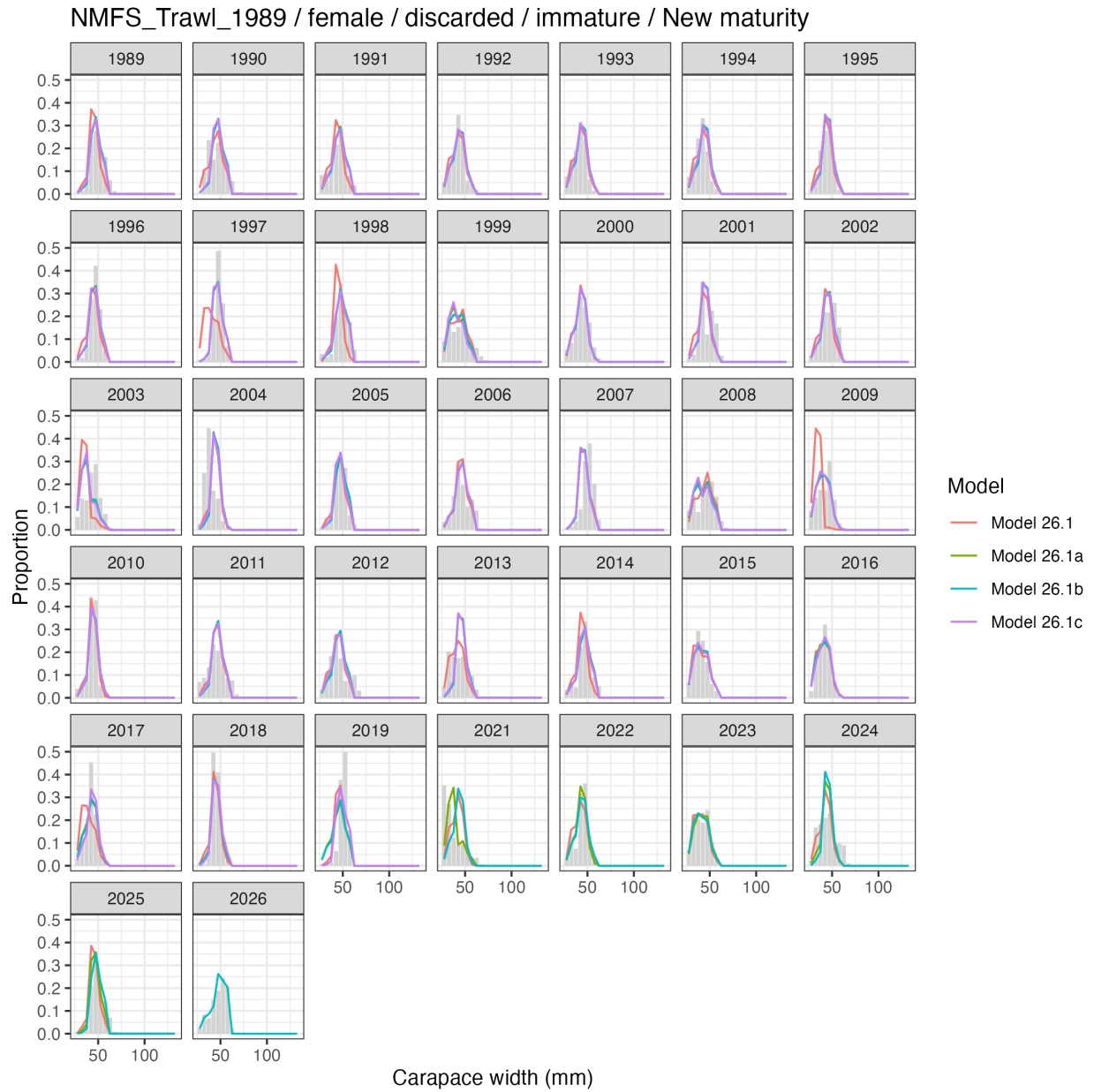


Figure 49: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1989 female discarded immature New maturity. Proportions by 5 mm carapace-width bin.

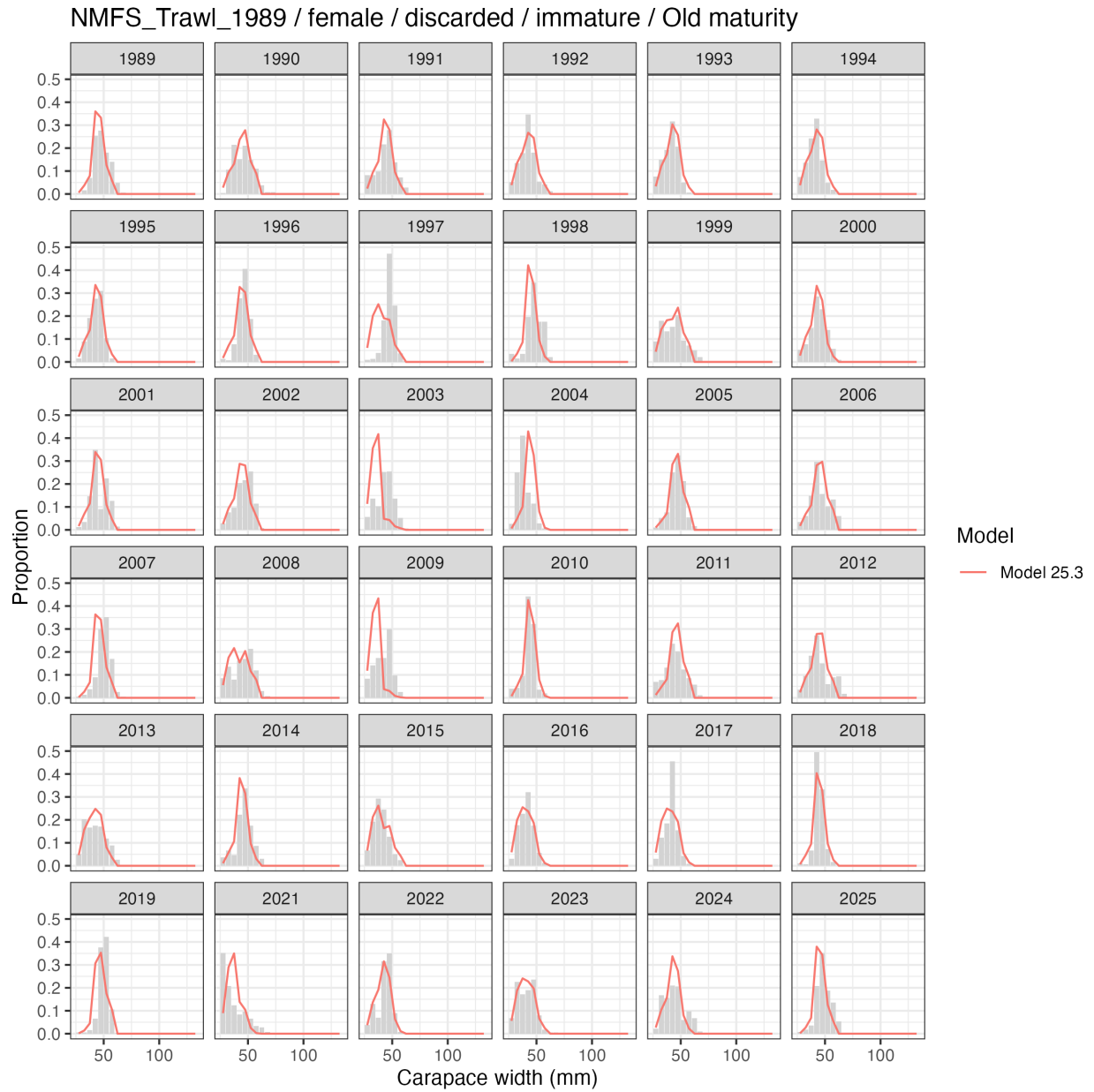


Figure 50: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1989 female discarded immature Old maturity. Proportions by 5 mm carapace-width bin.

Female and Mature

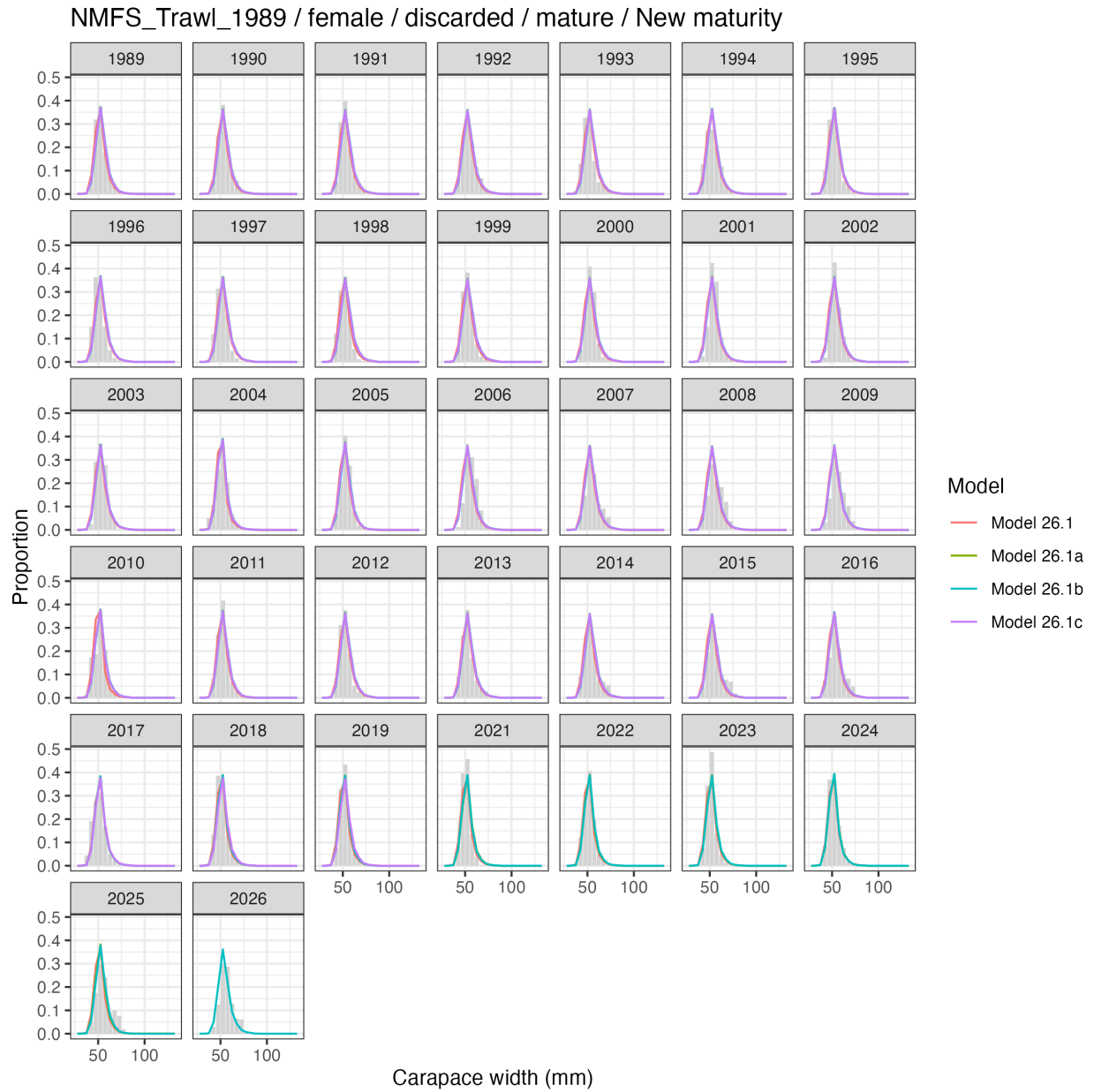


Figure 51: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1989 female discarded mature New maturity. Proportions by 5 mm carapace-width bin.

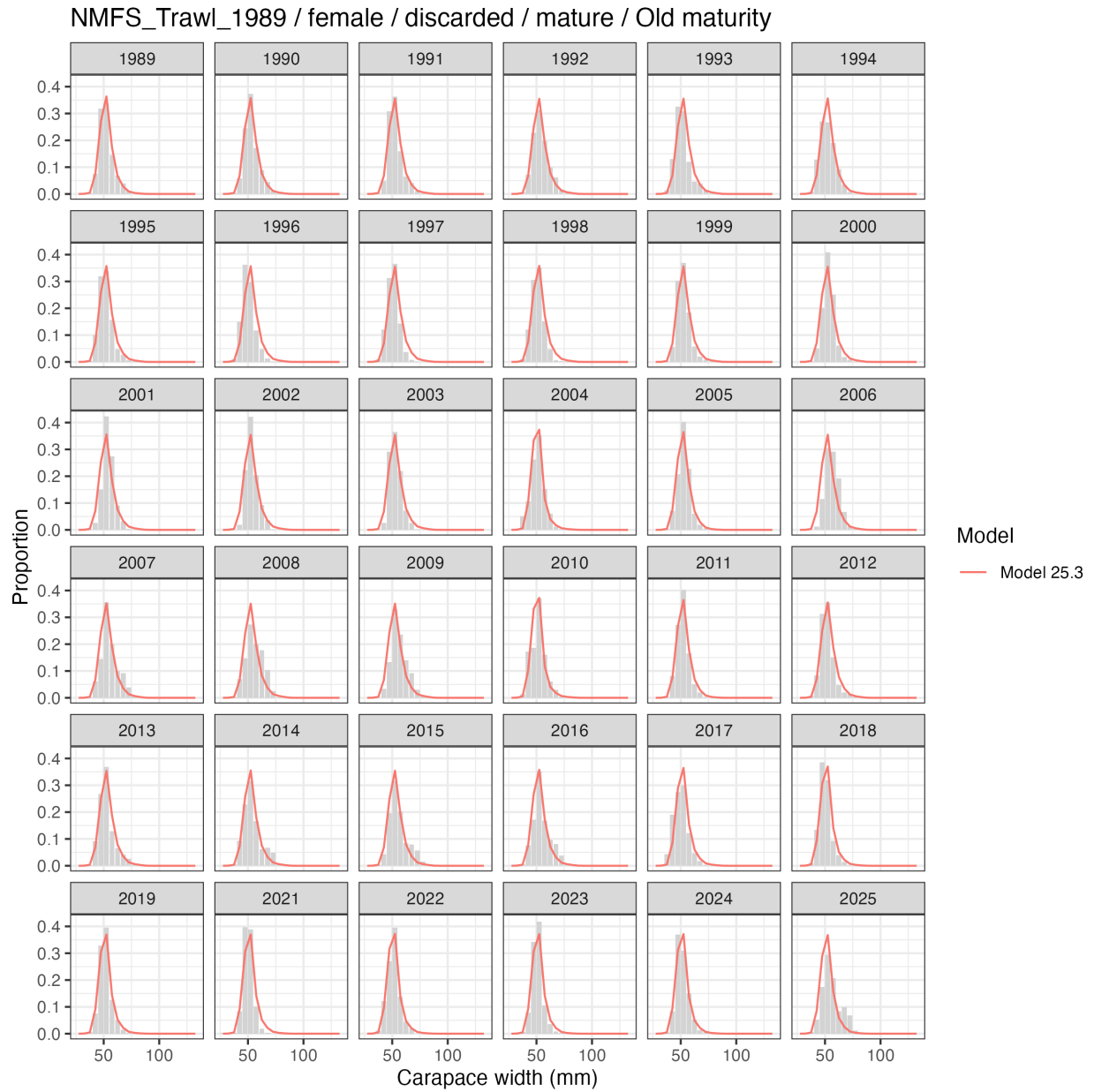


Figure 52: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1989 female discarded mature Old maturity. Proportions by 5 mm carapace-width bin.

Male and Immature

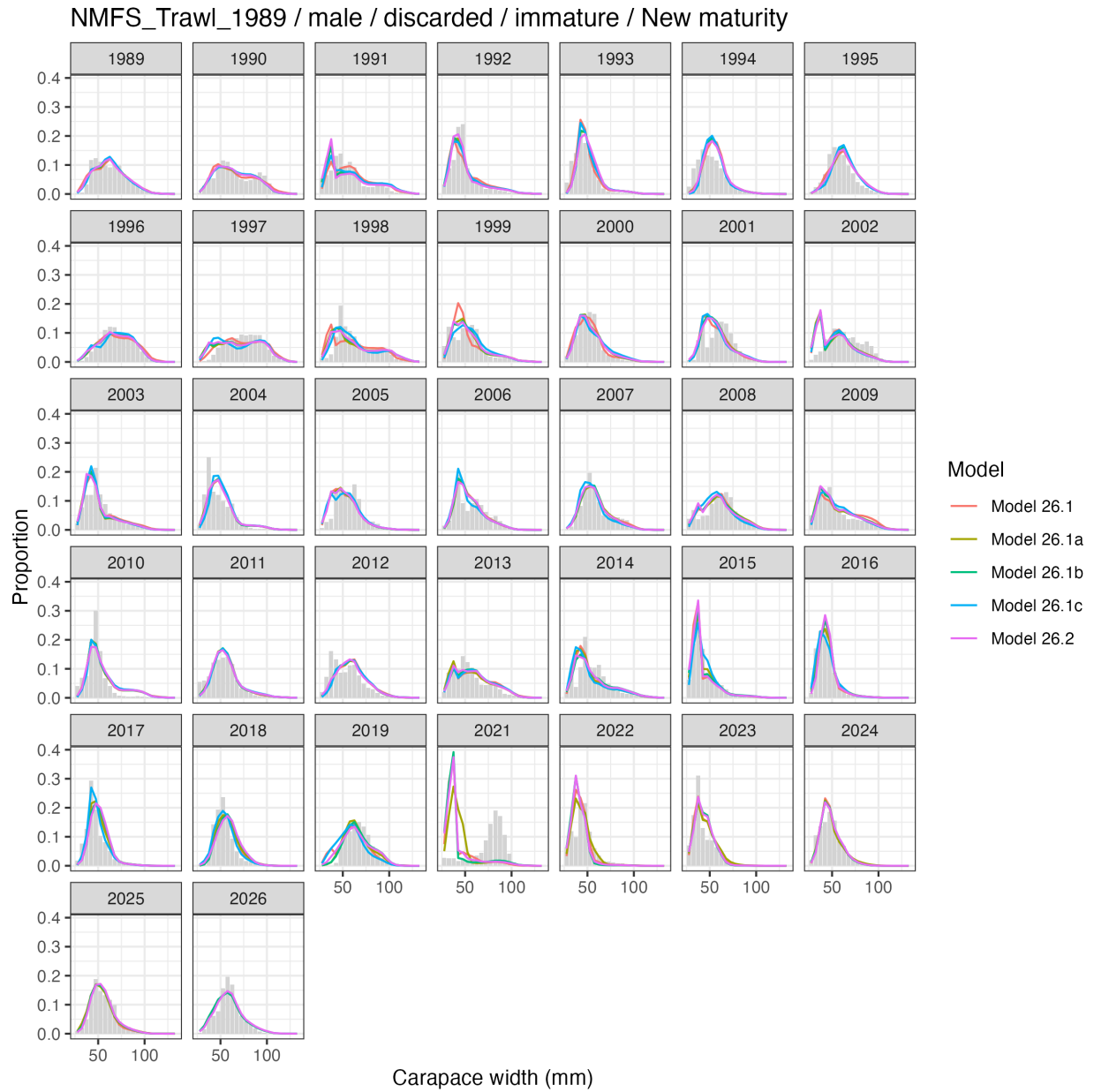


Figure 53: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1989 male discarded immature New maturity. Proportions by 5 mm carapace-width bin.

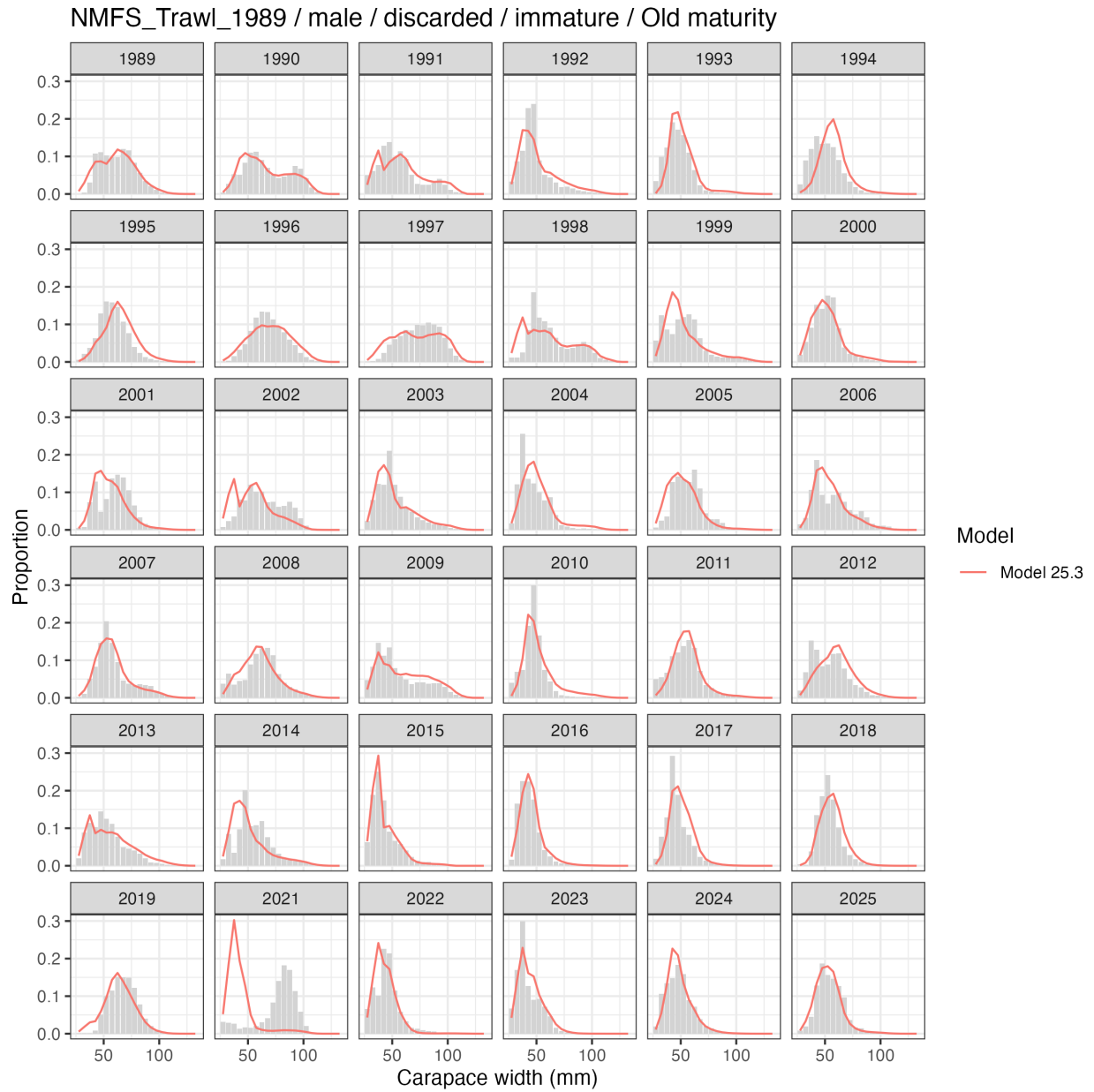


Figure 54: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1989 male discarded immature Old maturity. Proportions by 5 mm carapace-width bin.

Male and Mature

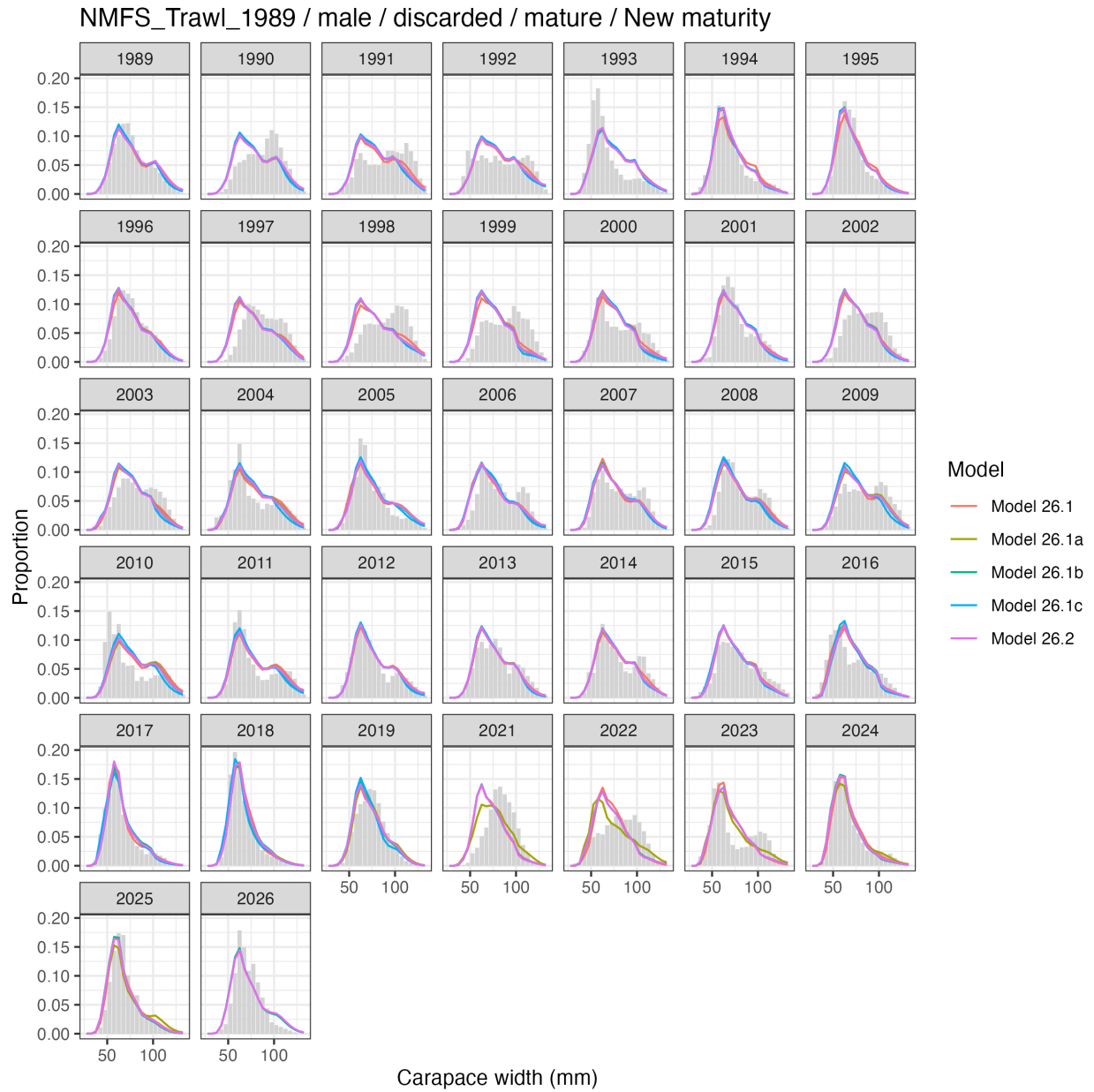


Figure 55: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: NMFS trawl survey 1989 male discarded mature New maturity. Proportions by 5 mm carapace-width bin.

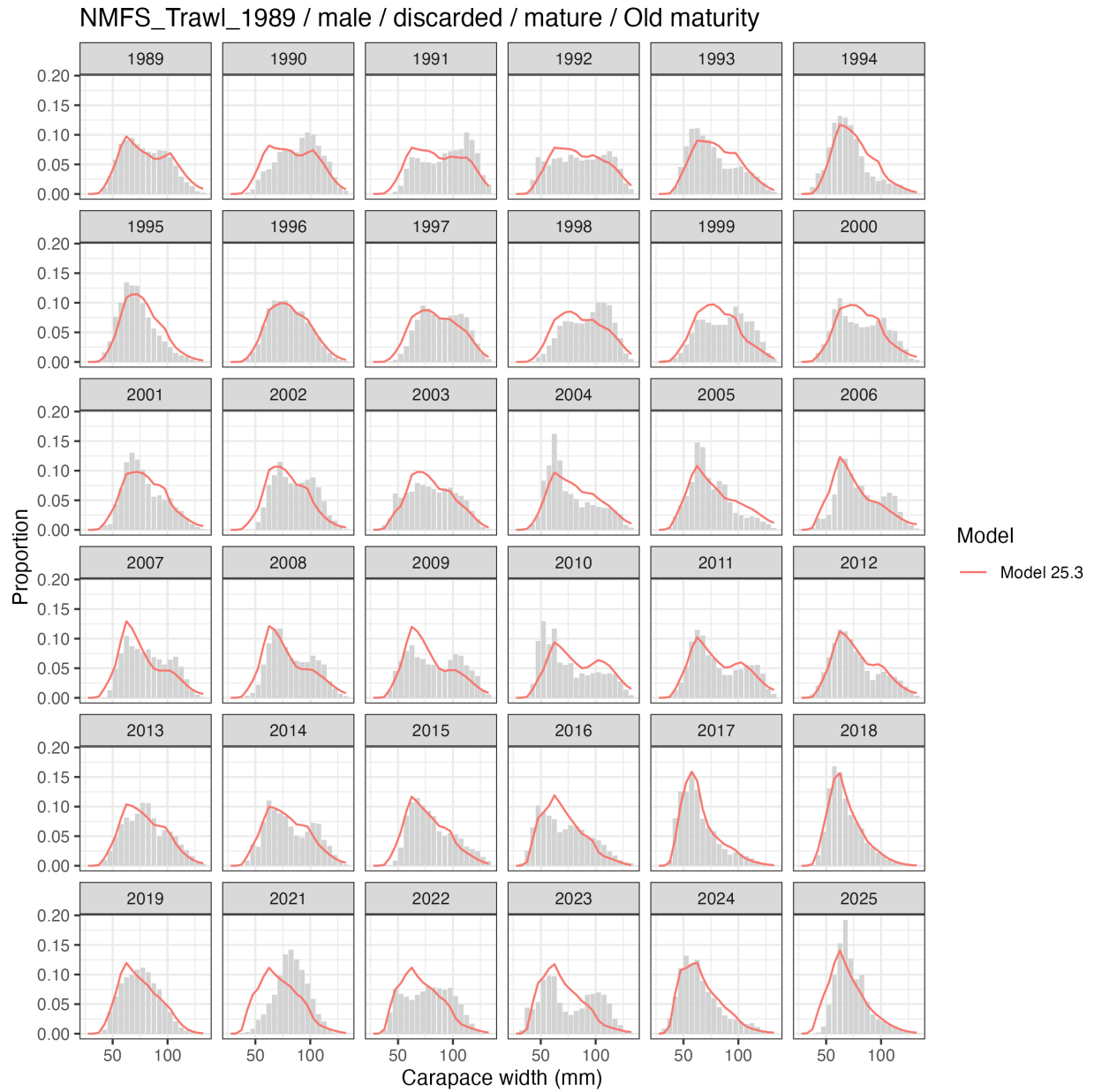


Figure 56: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: NMFS trawl survey 1989 male discarded mature Old maturity. Proportions by 5 mm carapace-width bin.

Fleet: Pot Fishery

Male and Undetermined

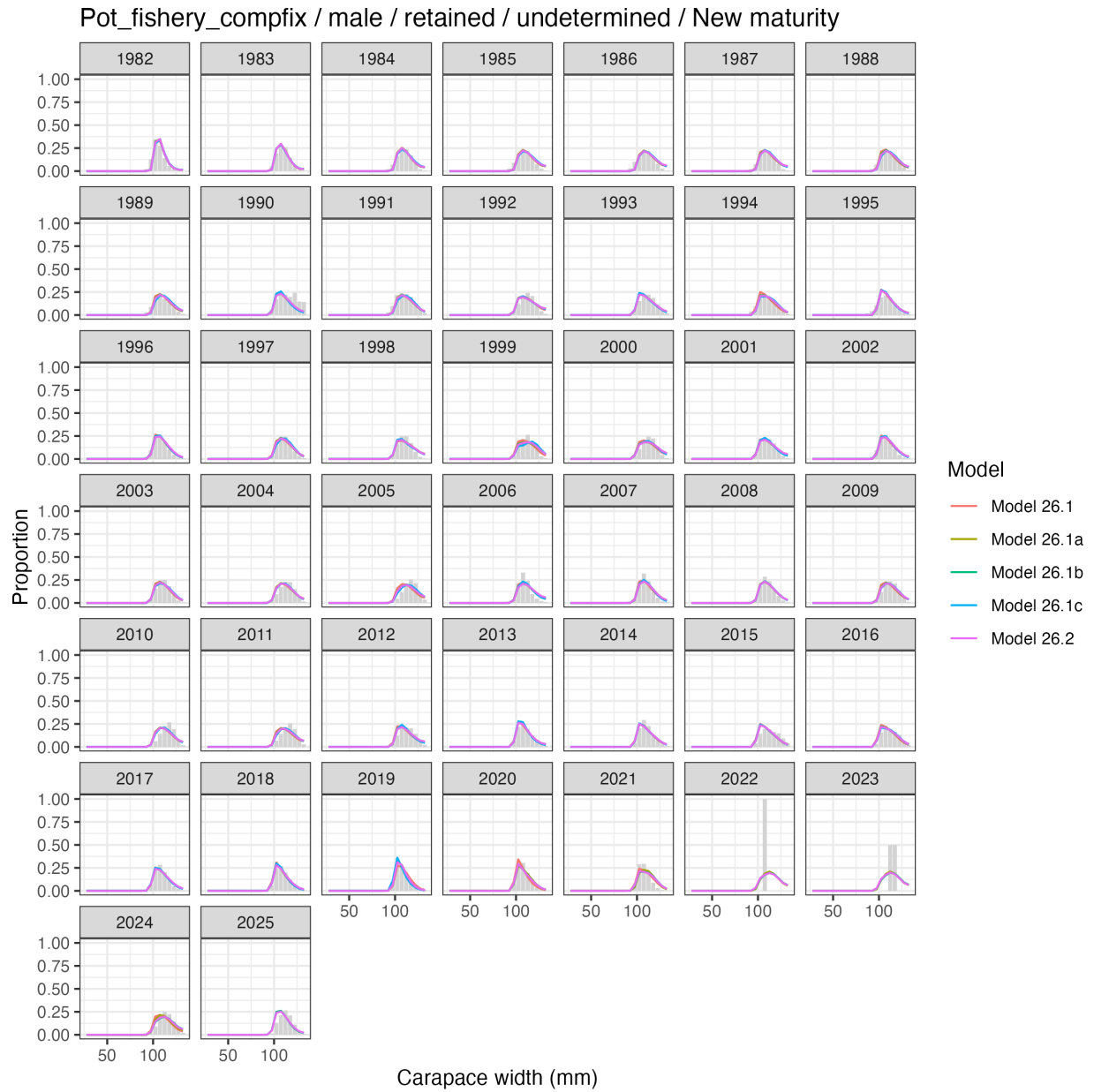


Figure 57: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: Pot Fishery (corrected composition) male retained undetermined New maturity. Proportions by 5 mm carapace-width bin.

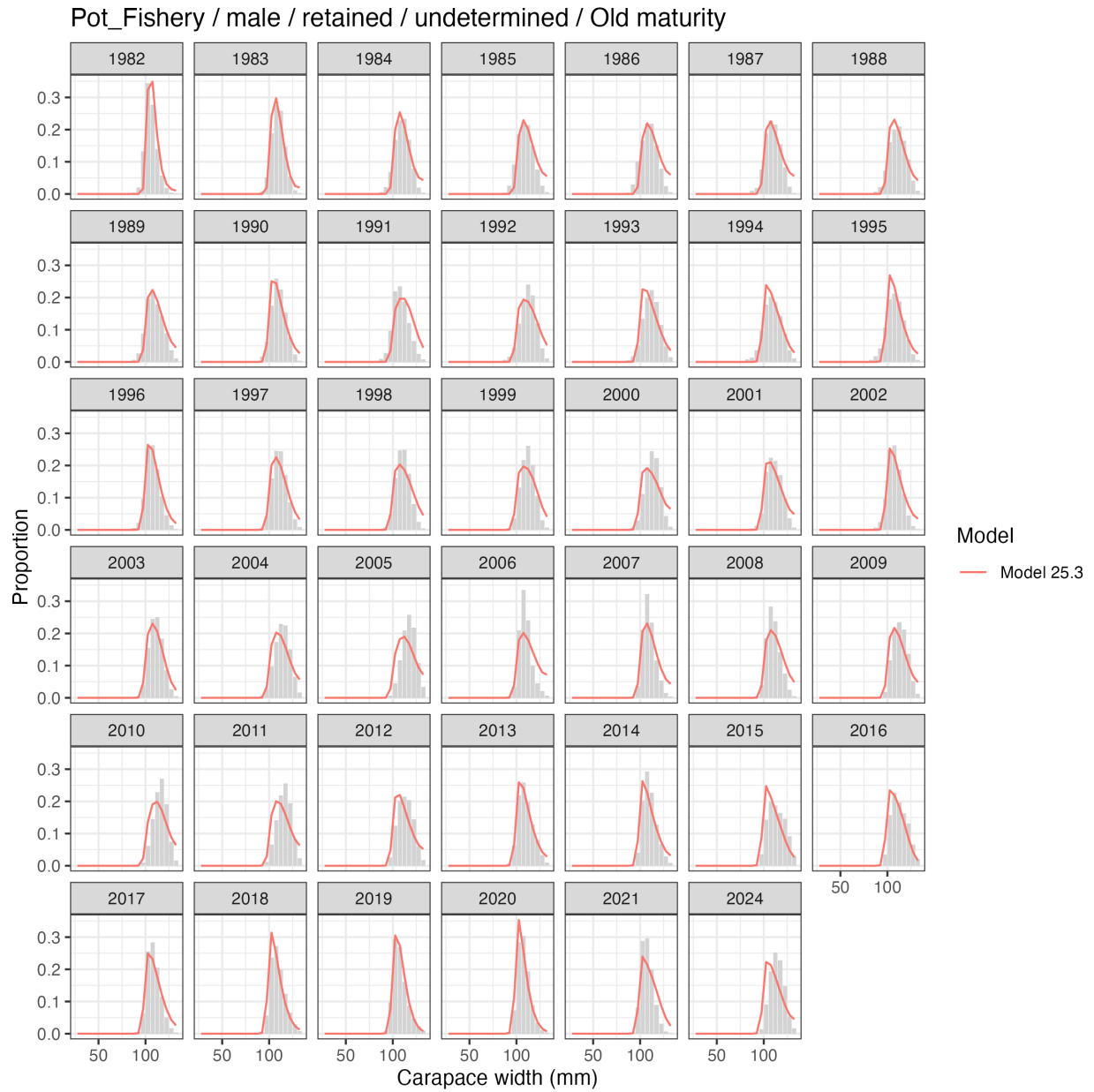


Figure 58: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: Pot Fishery male retained undetermined Old maturity. Proportions by 5 mm carapace-width bin.

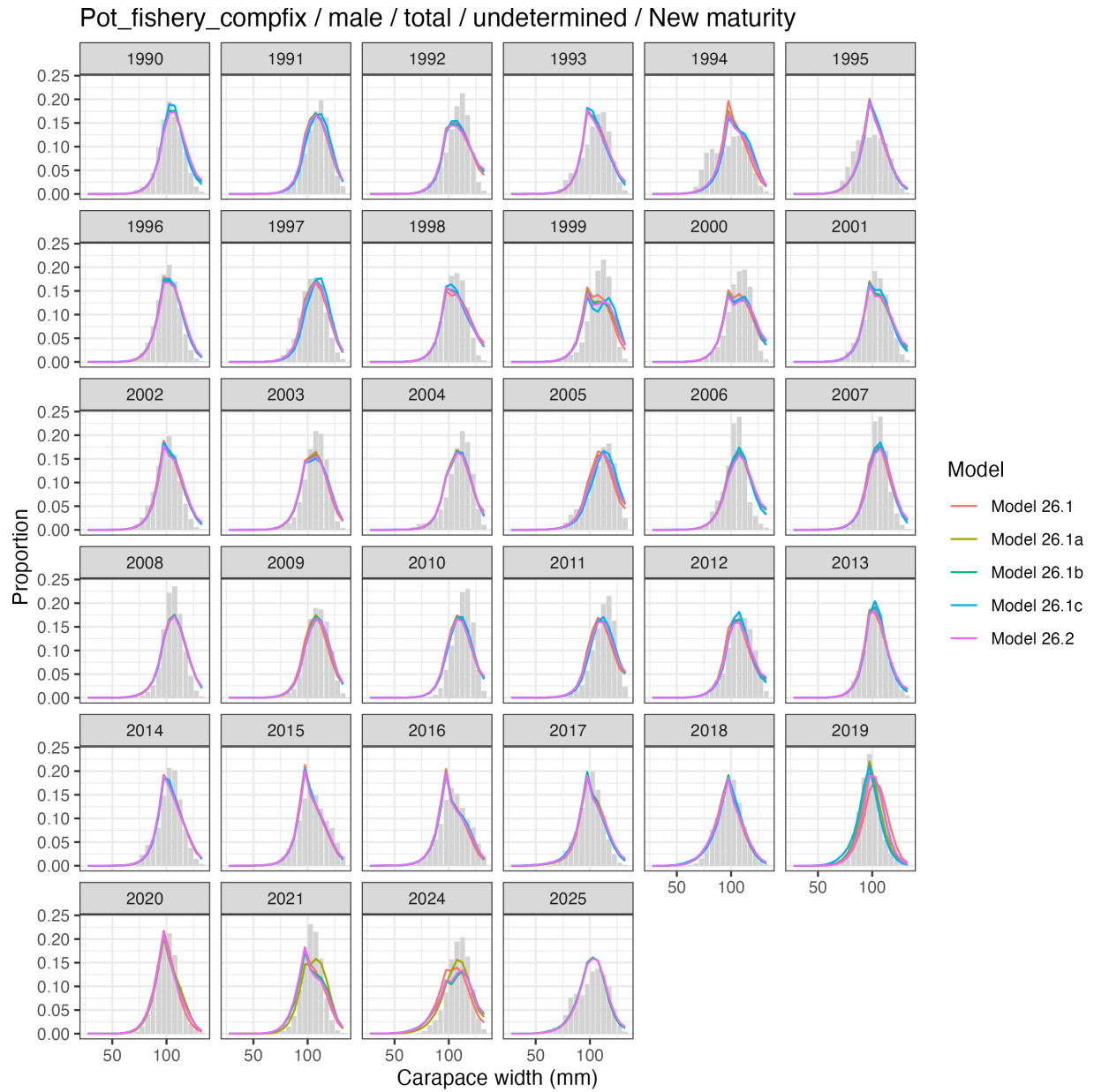


Figure 59: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: Pot Fishery (corrected composition) male total undetermined New maturity. Proportions by 5 mm carapace-width bin.

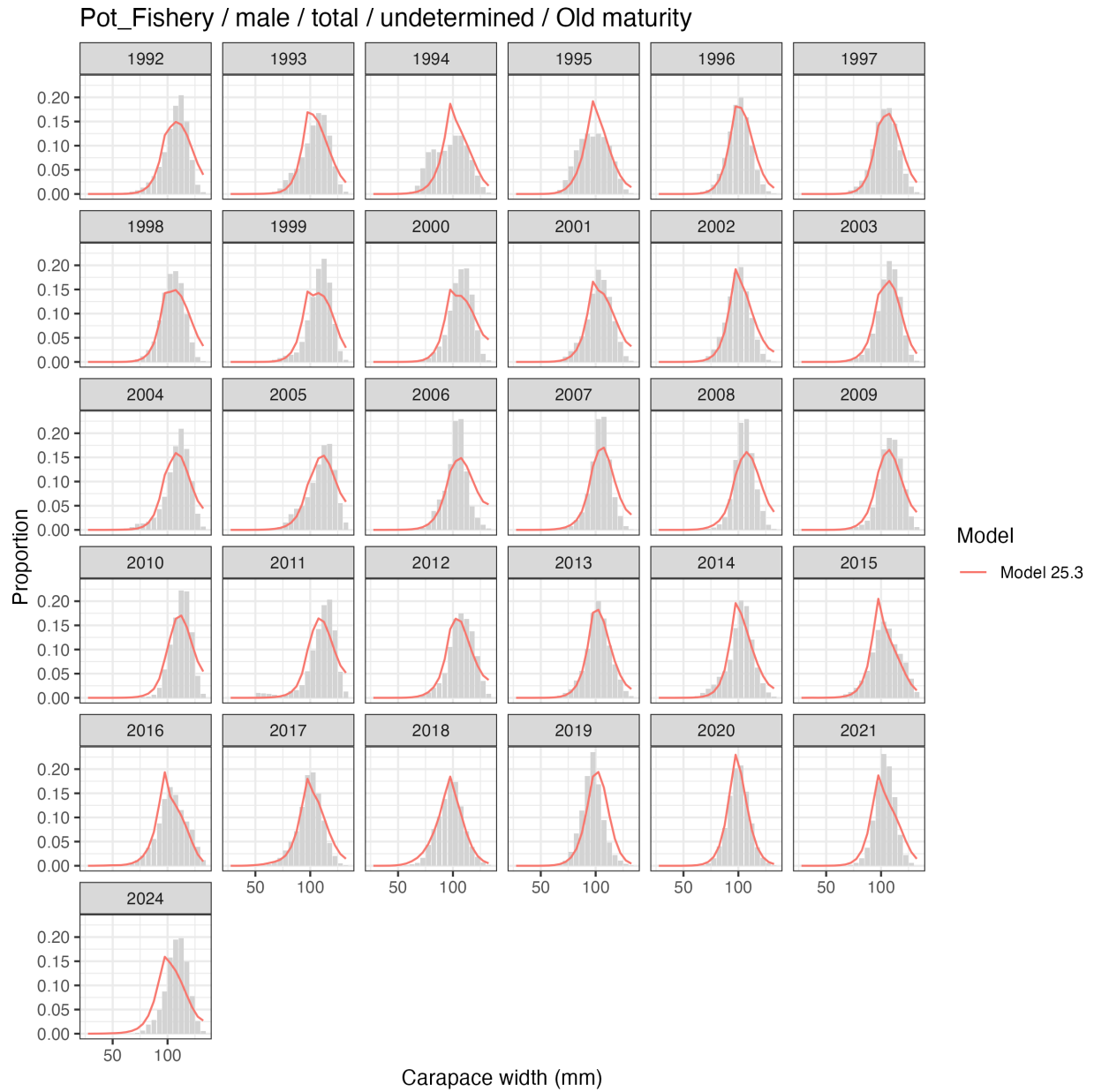


Figure 60: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: Pot Fishery male total undetermined Old maturity. Proportions by 5 mm carapace-width bin.

Female and Undetermined

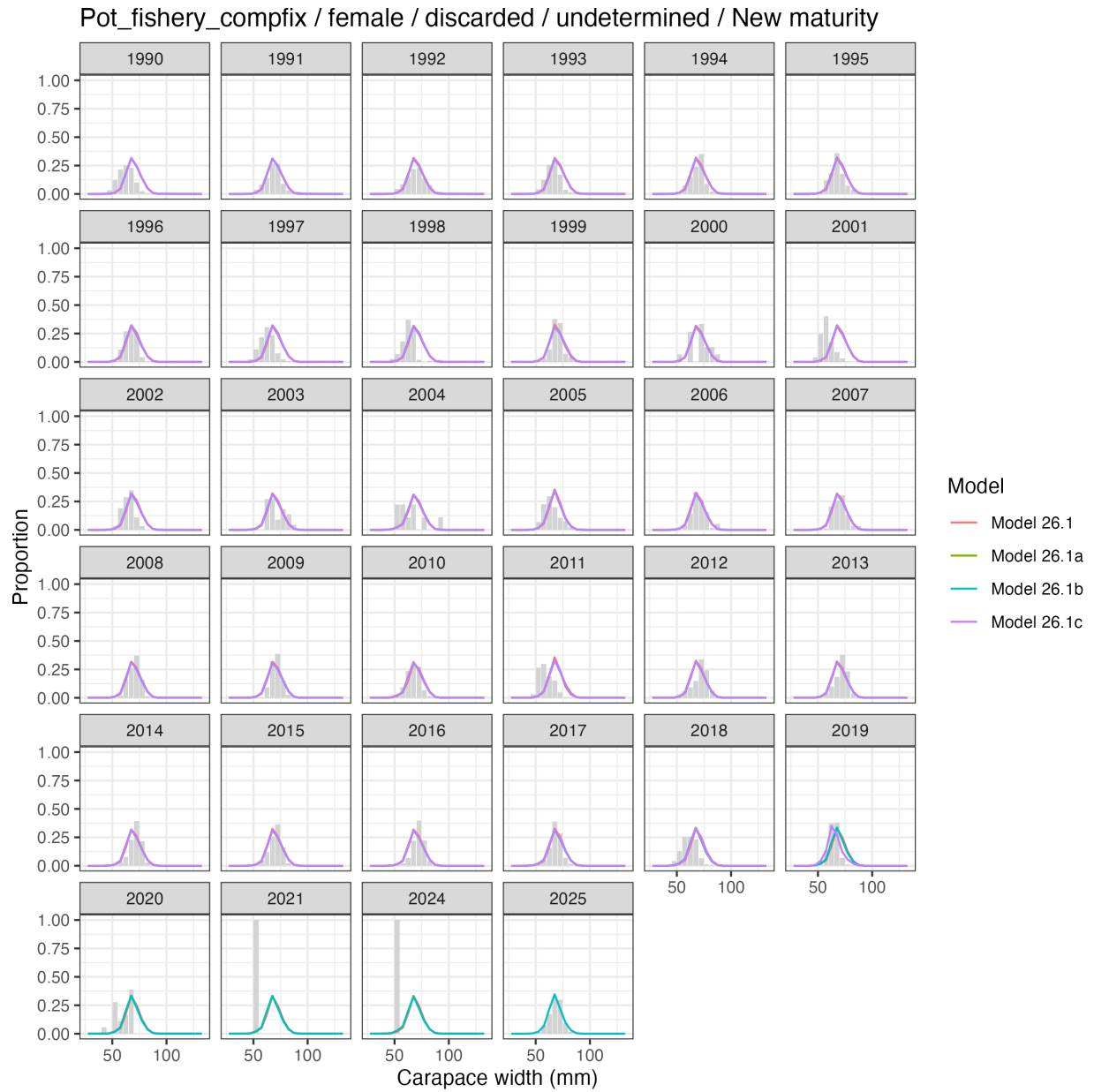


Figure 61: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: Pot Fishery (corrected composition) female discarded undetermined New maturity. Proportions by 5 mm carapace-width bin.

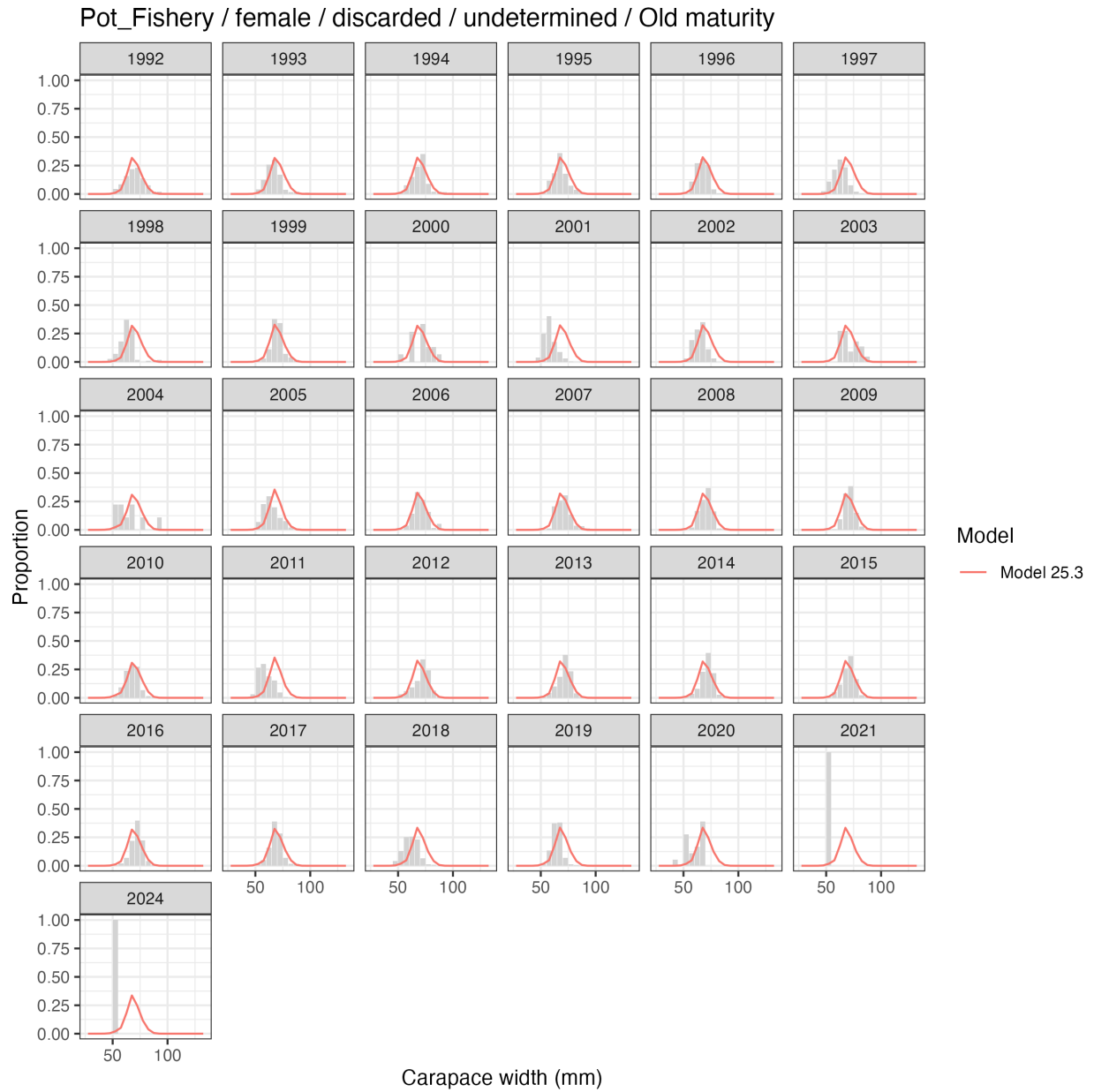


Figure 62: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: Pot Fishery female discarded undetermined Old maturity. Proportions by 5 mm carapace-width bin.

Fleet: Trawl Bycatch

Female and Undetermined

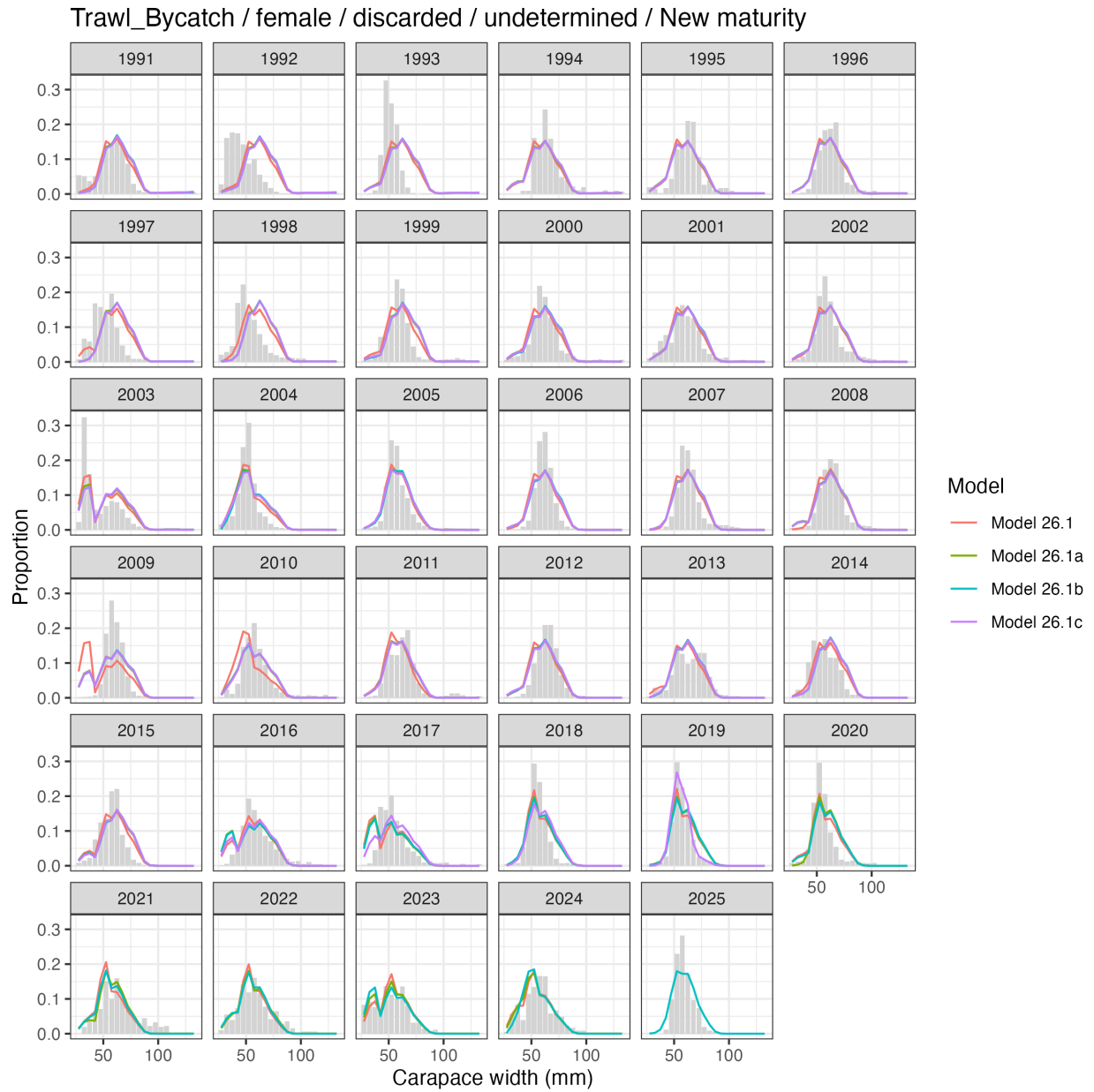


Figure 63: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: Trawl Bycatch female discarded undetermined New maturity. Proportions by 5 mm carapace-width bin.

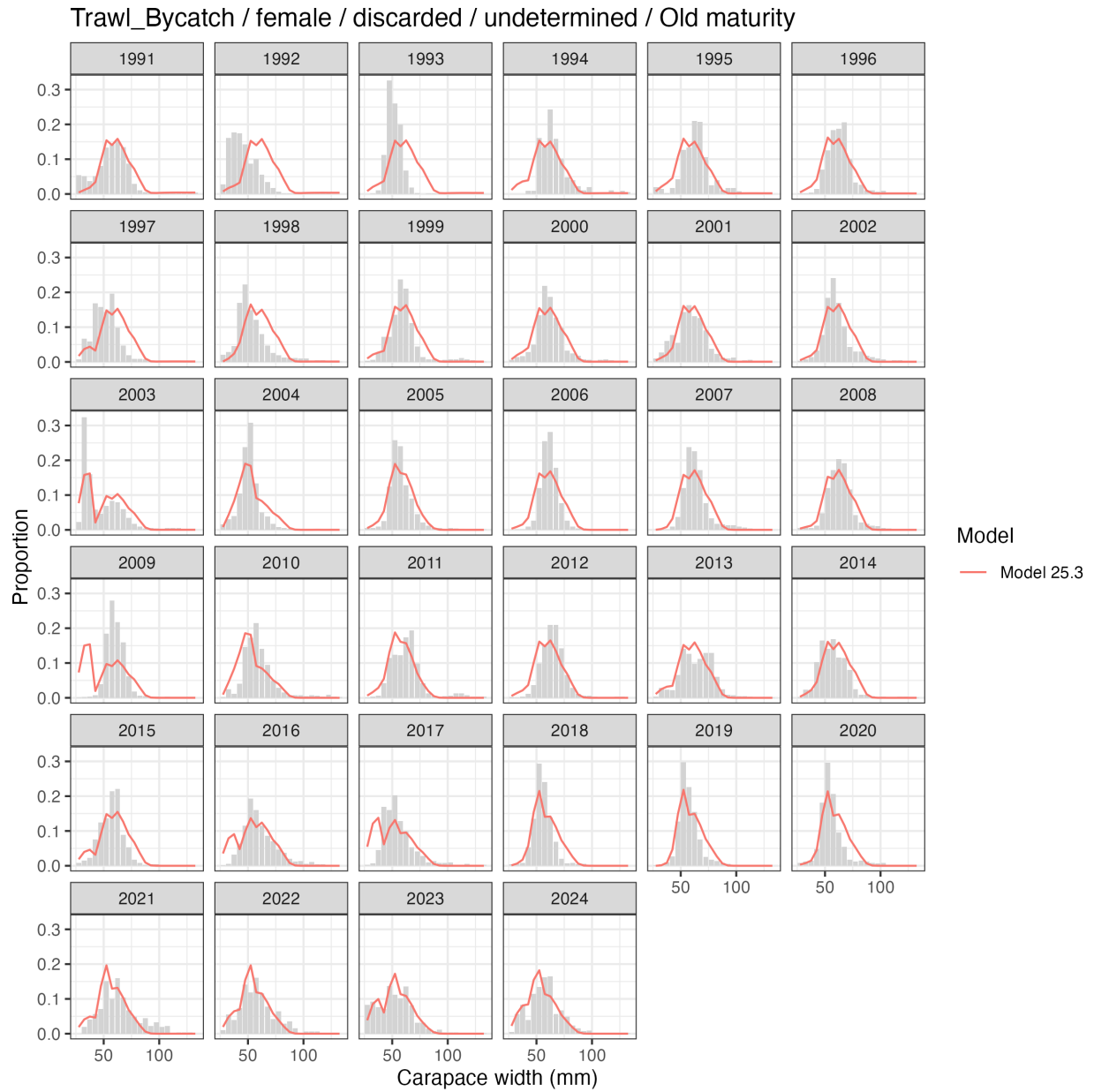


Figure 64: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: Trawl Bycatch female discarded undetermined Old maturity. Proportions by 5 mm carapace-width bin.

Male and Undetermined

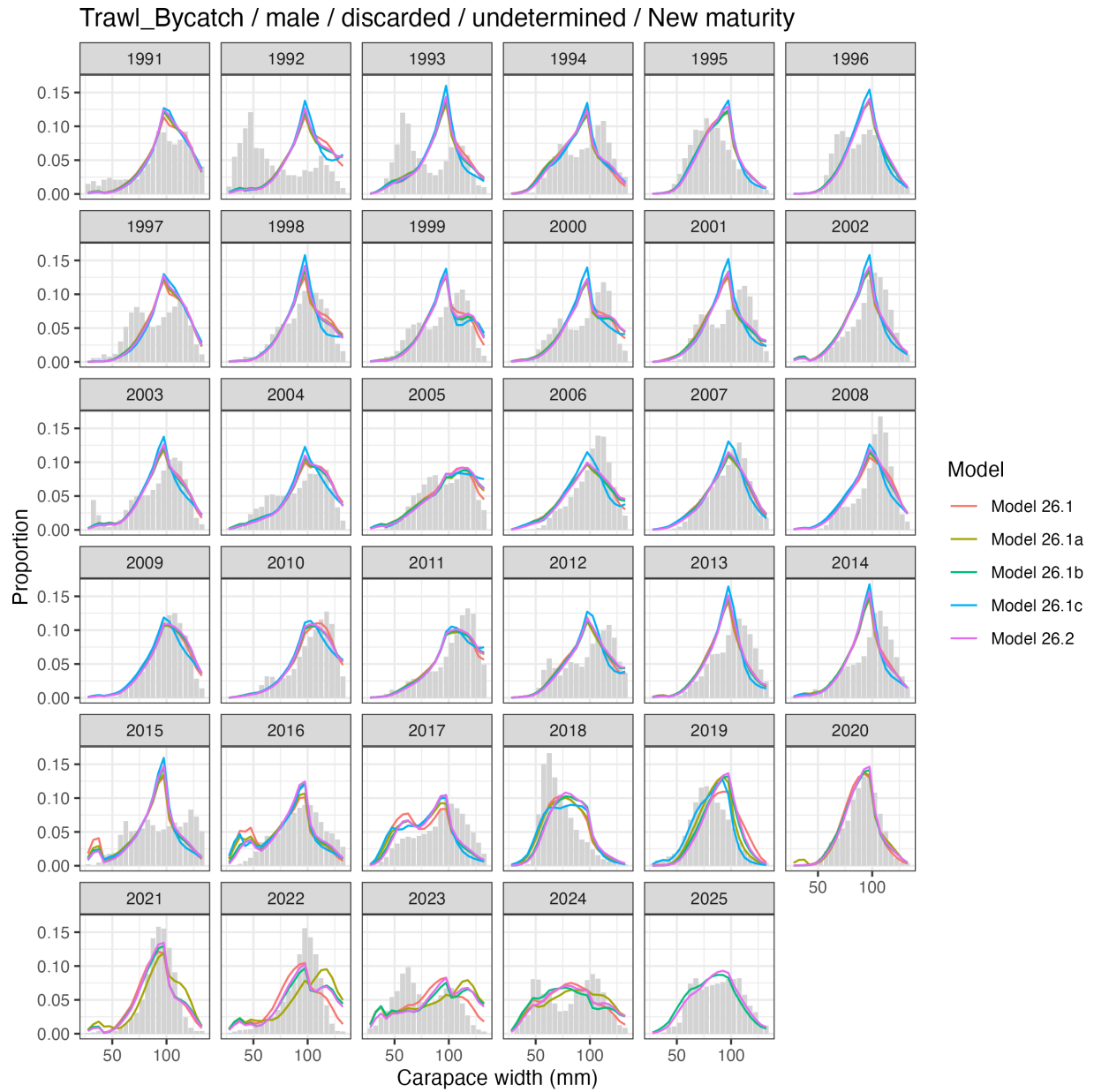


Figure 65: Model fits (lines) to size composition data (gray bars), the 5 models fitted to the new maturity series: Trawl Bycatch male discarded undetermined New maturity. Proportions by 5 mm carapace-width bin.

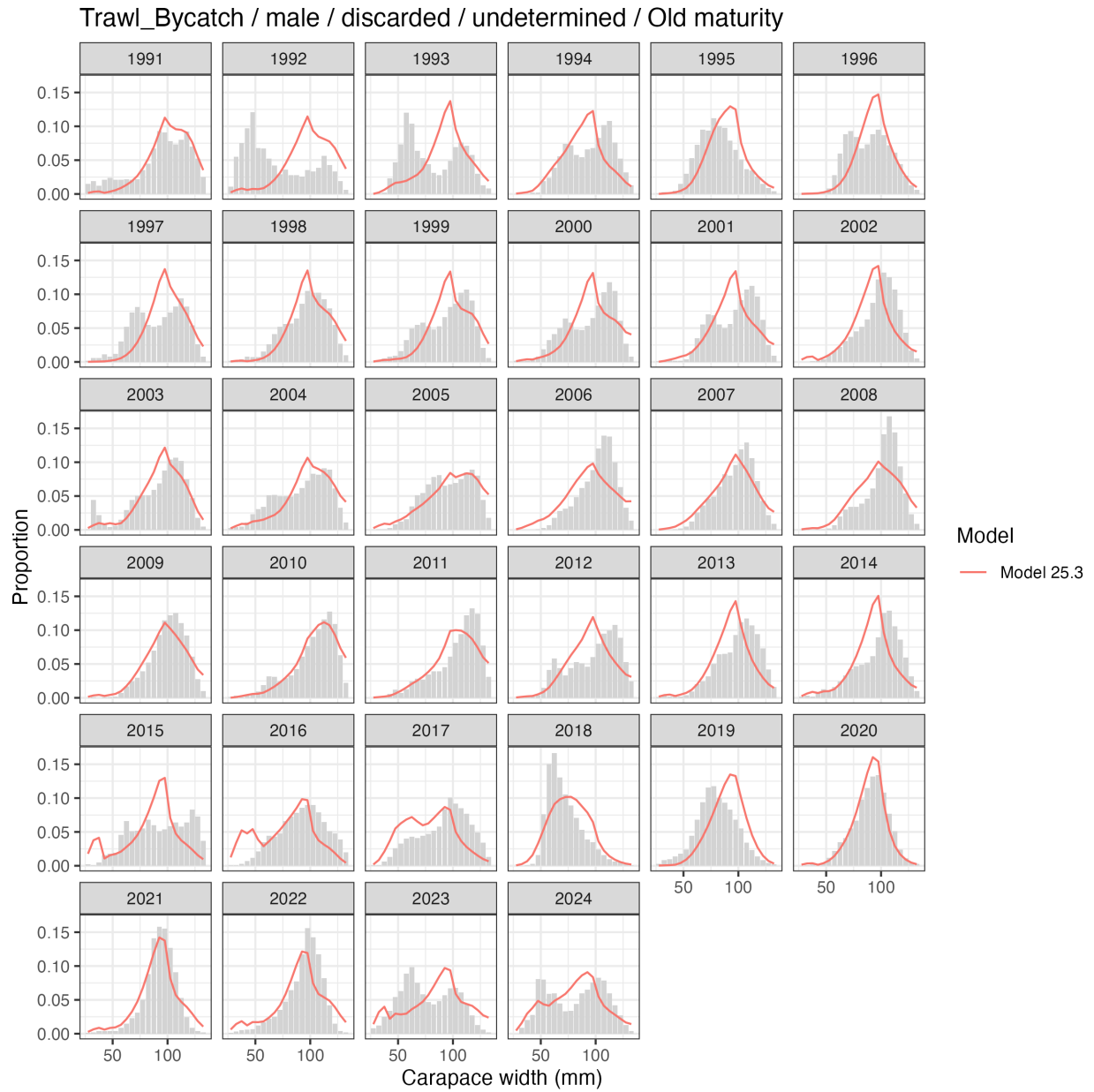


Figure 66: Model fits (lines) to size composition data (gray bars), Model 25.3, the only model fitted to the legacy maturity series: Trawl Bycatch male discarded undetermined Old maturity. Proportions by 5 mm carapace-width bin.

Appendix B. Convergence diagnostics

The June 2026 SSC asked that a focused convergence section identify which parameters separate the jitter minima. This appendix collects the jitter evidence for every model jittered this cycle, together with 4 structural experiments built specifically to diagnose the multimodality: **26.d1 stability**, **26.d3 eqmdevs**, **26.d4 combined**, and **26.d5**, the male-only model with the equilibrium-backbone initialization. A fifth, **26.d2 initscaled**, was set aside without jittering. None of the experiments is an assessment model and none is proposed for any purpose other than diagnosis. They are registered separately from the model set in `0-models.R` for that reason.

The diagnostic identified 3 independent pathologies in the author-preferred model:

1. `M_pars_est[15]`, the 2019/20 immature-female natural mortality deviation, is not identified in part of the parameter space: from default starting values it drifts to its bound while the objective function does not move, the only one of the 412 parameters to do so, although the accepted fit estimates it at 1.84 with a standard error of 0.58 (Section E).
2. The recruitment sex ratio is controlled by 44 logit parameters bounded at plus or minus 100, whose only effective restraint is a penalty standard deviation of 2.0 hardcoded in the source rather than read from the control file. Of the 44, 13 are estimated beyond 1 standard deviation of that penalty, and 1 beyond 2. They are nowhere near the plus or minus 100 bounds (the estimates span -3.7 to +4.2), so it is the penalty, not the bound, that is failing to restrain them.
3. The 1982 initial numbers at length are 83 parameters whose overall level is entirely unpenalized. The only term touching them is a first-difference smoothness penalty, and first differences are invariant to shifting a whole group.

Among the parameters that most separate the jitter minima (Table 9), the largest is `T_pars_est[78]`. The recruitment sex allocation, which led this ranking on the pre-correction data, is not among the 15 parameters the attribution ranks, of which the table lists the largest 10. The leading 10 separate the minima by standardized differences of 2.83 to 3.15, so the attribution does not isolate a single determinant; the decomposition by parameter class below is the more informative measure. This addresses the SSC's request. The ranking on its own does not explain why the 2 male-only configurations, which remove the sex allocation entirely, are the only ones in Table 28 that recover their own best fit in more than 10 percent of runs; the decomposition by parameter class below does.

Decomposing the movement between minima by parameter class quantifies this (Table 29). Across the 43 near-equivalent solutions retained, the recruitment sex allocation alone accounts for 38.7 percent of all parameter movement, and the female and sex-allocation parameters together account for 67.9 percent. The male parameters account for 20.3 percent across 101 parameters, whereas the sex allocation reaches 38.7 percent on just 44 parameters, about 4.4 times as much movement per parameter. The alternative minima are therefore largely disagreements about the female population and the split of recruitment between the sexes, rather than about the male population the assessment exists to manage. This is the clearest quantitative case for the male-only direction, and it is measured on the author-preferred model itself rather than inferred from the sensitivity.

Running the same decomposition on the structural experiments explains these results (Table 30). The equilibrium backbone in **26.d3 eqmdevs** had its intended effect: the male parameters' share of movement fell from 20.3 to 8.8 percent, because anchoring the 1982 structure removes the freedom that had been propagating through the male side. It also restrained the sex allocation, whose share of the movement fell from 38.7 to 24.3 percent. The movement did not go away, however: it shifted onto the female parameters, and the female-and-sex-allocation share rose from 67.9 to 79.3 percent. The backbone therefore moves the disagreement between minima off the male side and the sex ratio and onto the females rather than removing it, which is consistent with it not improving the recovery rate. The comparison is made on shares because the 2 models retain different numbers of runs (43 and 29), and a range grows with the number of runs that enter it.

Model 26.2 removes the sex allocation altogether, and total movement falls from 50.1 to 1.81, with the remainder dominated by the shared recruitment deviations. The parameter classes **Model 26.2** removes carry 68 percent of the movement between minima in the author-preferred model, so its advantage comes

from removing those classes, not from the lower parameter count. 2 qualifications apply. The absolute movement totals are ranges taken across different numbers of retained runs (43, 29, 62, 29 across the models shown), and a range depends on how many runs enter it, so the totals should be read as indicative while the shares, which are unaffected, are the basis for the comparison. **26.d1 stability** cannot appear in this table: only 6 of its runs land within 2 likelihood units of its best fit, too dispersed to form a cluster the decomposition can use, which is consistent with its likelihood span being the widest in Table 28 (306.6 against the author-preferred model's 300.2). **Model 26.1**, **Model 26.1c** and **26.d4 combined** were not decomposed.

Each experiment addressed a different subset of the pathologies. **26.d1 stability** fixed the first 2 and left the third. **26.d3 eqmdevs** replaced the third with an equilibrium backbone times penalized deviations and left the first 2. **26.d2 initscaled** rescaled the initial-condition parameterization and was set aside without jittering when its fit to the data proved 665 likelihood units worse. A configuration with all 3 fixed at once, **26.d4**, was then built and jittered, and it did not resolve the multimodality either. The one change that raised recovery was applying the equilibrium-backbone initialization to the male-only model rather than to the two-sex one, although 100 runs do not establish the improvement (below).

Table 28: Jitter convergence statistics, 100 runs per model. See the note below the table.

Model	Converged	Meets 0.001	Minima	Best fit found	Best lettered mode	OFL spread, near-optimal	nll span
Model 26.1b (author-preferred)	77/100	7/100	4	1 (1.3%)	13.0%	5.8% (n=43)	300.2
Model 26.2 (male-only)	74/100	13/100	6	19 (25.7%)	25.7%	4.5% (n=29)	121.7
Model 26.1c (2019/20 data)	83/100	19/100	6	0 (0.0%)	3.6%	6.3% (n=24)	206.8
Model 26.1 (May 2026)	82/100	7/100	6	0 (0.0%)	6.1%	16.9% (n=20)	176.3
26.d1 stability	81/100	2/100	7	1 (1.2%)	3.7%	2.9% (n=6)	306.6
26.d3 eqmdevs	77/100	1/100	9	0 (0.0%)	3.9%	0.0% (n=21)	45.2
26.d4 combined	76/100	1/100	9	1 (1.3%)	3.9%	- (n=1)	105.1
26.d5 male-only+eqmdevs	81/100	10/100	6	31 (38.3%)	38.3%	4.3% (n=62)	6.4

Note to the jitter convergence table. ‘Best fit found’ counts runs recovering that model’s own lowest objective function, the reported fit included. ‘Minima’ counts lettered clusters of at least 3 runs. Modes are lettered by likelihood but need 3 runs, so a best fit reached once or twice is bucketed as minor and the lettered figure then describes a worse minimum. For Model 26.1 the reported fit is the promoted jitter run 078, which stopped at a gradient above the 0.01 screen before it was polished, so it is not among the converged runs and no run counts as reaching it. The OFL spread is on the total OFL (retained plus discard mortality over all fleets). No likelihood is tabulated: the models are fit to different data and 4 of the configurations run on modified source. Spans are within-model. The OFL spread covers only runs within 2 likelihood units of each model’s best fit. 26.d4 combined has fewer than 2 such runs, so no spread is computed.

Table 29: Where the author-preferred model’s alternative minima differ, by parameter class: the range of each parameter across the 43 retained runs, summed within class and shown as a share of the total. See the note below the table.

Parameter class	Parameters	Total movement	Share (%)
sex allocation	44	19.39	38.74
female	91	12.88	25.72
male	101	10.18	20.33
shared (recruitment devs)	44	3.62	7.24
shared (fishing mortality)	88	2.19	4.38
female (F offsets)	43	1.72	3.43
shared (other)	1	0.08	0.15

Note to the movement table. The range is used rather than the variance because these are alternative solutions, not draws from a distribution. Retained runs converged and lie within 2 likelihood units of the best fit, so the table describes solutions the data barely separate, not failed runs. ‘Sex allocation’ is listed apart from male and female because it is the split between them.

Table 30: Movement between minima across 4 configurations, from the decomposition of the movement table above. See the note below the table.

Model	Runs retained	Total movement	Sex allocation (%)	Female + sex allocation (%)	Male (%)	Male movement
Model 26.1b (author-preferred)	43	50.06	38.74	67.89	20.33	10.18
26.d3 eqmdevs	29	23.76	24.27	79.31	8.79	2.09
26.d5 male-only+eqmdevs	62	3.73	0.00	0.00	60.25	2.24
Model 26.2 (male-only)	29	1.81	0.00	0.00	30.84	0.56

Note to the cross-model movement table. Shares are comparable across rows. ‘Runs retained’ is the number of jitter runs within 2 likelihood units of that model’s best fit, not the count of well-populated minima in the jitter convergence table. The absolute totals are ranges taken over different numbers of retained runs and are indicative only. 26.d1 stability is absent because too few of its runs cluster near its best fit to decompose.

The pattern across the table is that the two-sex reconfigurations did not work and the male-only one did. The author-preferred model recovers its own best fit in 1.3 percent of converged runs and **26.d3 eqmdevs** in 0.0 percent. Those differences, and **26.d1 stability**'s 1.2 percent, are too small to be resolved by 100 runs. The 95 percent confidence interval on the author-preferred model's 1-in-77 rate runs from zero to about 7 percent, and the intervals for **eqmdevs** (to 5 percent) and **stability** (to 7 percent) sit almost entirely inside it. Separating rates of this size would take several hundred runs. None of these experiments improved recovery detectably. The fit reported for **26.d3** is 1.09 likelihood units better than any of its jitter runs reached, so none of them recovered it. That reported fit itself stopped at a maximum gradient of 0.021, above the 0.01 screen applied to the runs, so it is a better but less precisely located solution. **26.d4 combined**, which applies all 3 fixes at once, is no better: 1.3 percent, well inside the range the author-preferred model's own rate could take. Its printed "best mode" share of 3.9 percent must not be quoted as a recovery rate. That mode lies 2.9 likelihood units above its own best fit, which only 1 of 76 converged runs reached. Fixing all 3 pathologies in the two-sex model therefore does not resolve the multimodality.

The 2 configurations that perform better than the rest both remove the female population. **Model 26.2** recovers its best fit in 25.7 percent of converged runs (19 of 74). The author-preferred model recovers its own in 1 of 77. That gap is far larger than 100 runs could produce by chance. **26.d5**, which adds the equilibrium-backbone initialization to the male-only model, reaches 38.3 percent (31 of 81 runs), the only structural experiment that improved on the model it was derived from. Its likelihood span across usable runs is 6.4 units, the narrowest of any configuration; **Model 26.2** spans 121.7 units and the two-sex configurations 45.2 or more. 2 qualifications apply. The 95 percent confidence intervals on the 2 recovery rates overlap (28 to 50 percent against 16 to 37), so 100 runs do not establish the improvement, and it rests on a single set of 100 runs. It met the gradient criterion in 10 runs of 100 against **Model 26.2**'s 13, so the 2 convergence measures disagree; the recovery measure concerns which minimum a run finds, the gradient measure how precisely it stops.

Removing the female population, including the sex allocation, removes 68 percent of the movement between minima in the author-preferred model. Adding the equilibrium initialization to the male-only model raises the total movement from 1.81 to 3.73, with the male parameters' share going from 30.8 to 60.3 percent, although the total is taken over 62 retained runs against 29 and a range grows with the number of runs, so the totals are indicative only. Its recovery rate is 38.3 percent against 25.7. The same initialization applied to the two-sex model, **26.d3**, did not raise the recovery rate. It did reduce the likelihood span across runs from 300.2 to 45.2 units, an improvement in conditioning, but that did not translate into finding a single minimum reliably. The male-only simplification is the configuration that materially improves recovery, at 25.7 percent, and the best fit and the best lettered mode are the same solution in only 2 rows of the table (**Model 26.2** (male-only); **26.d5 male-only+eqmdevs**). In the author-preferred model they are different solutions 0.82 likelihood units apart, and in **26.d3 eqmdevs** they also differ. In those configurations a single run from default starting values is more likely to reach a reproducible but inferior minimum than the best one. For this reason the male-only configuration is in the model set as **Model 26.2** and the structural experiments are not.

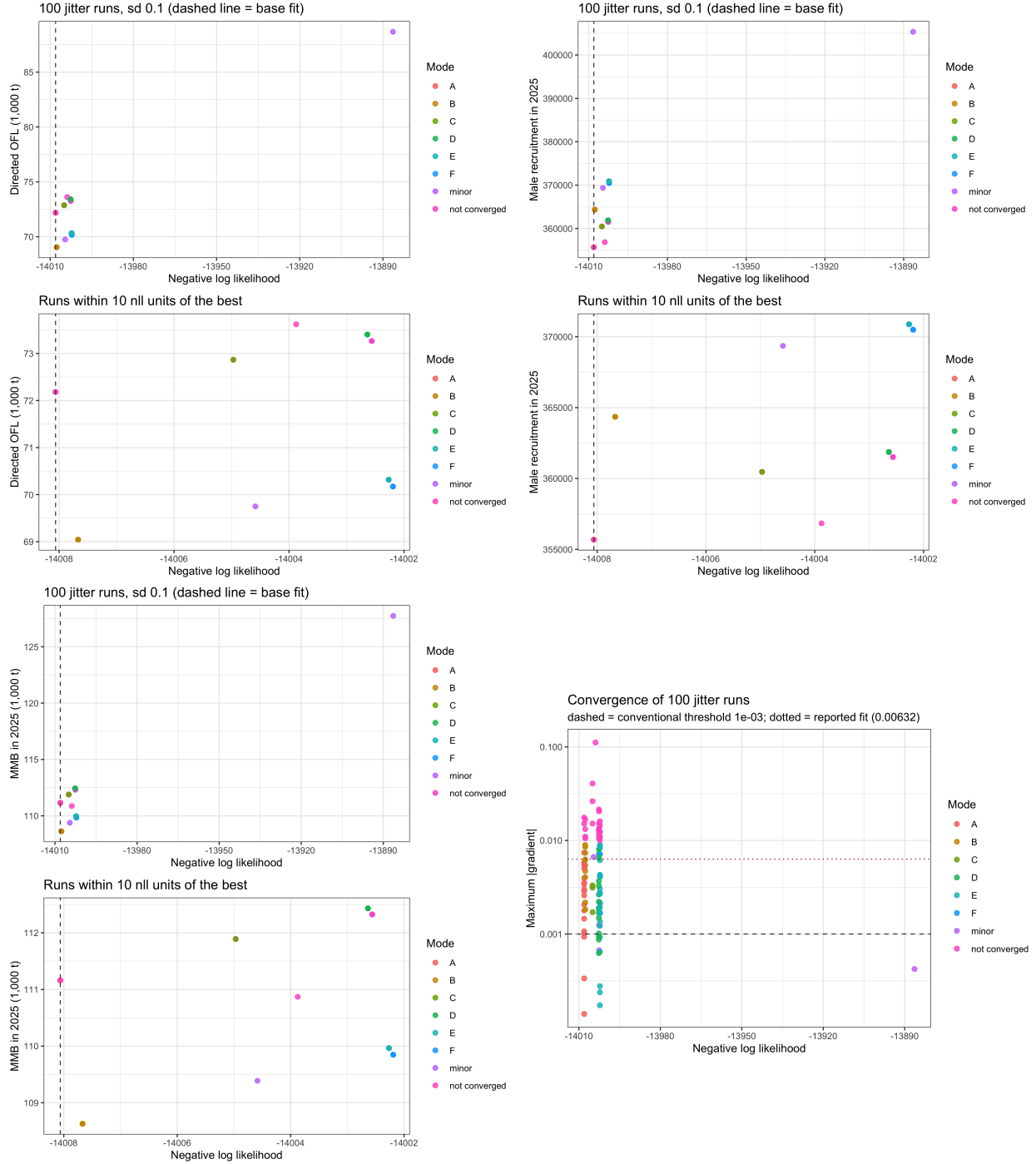


Figure 67: Jitter diagnostics for the male-only sensitivity, Model 26.2. Left to right, top to bottom: directed OFL against negative log likelihood, terminal male recruitment, terminal mature male biomass, and maximum gradient against likelihood, the same 4 diagnostics shown for the author-preferred model in Section E. Each point is 1 of 100 runs. The minima are better separated in likelihood and the best fit is recovered far more often than in the author-preferred model.

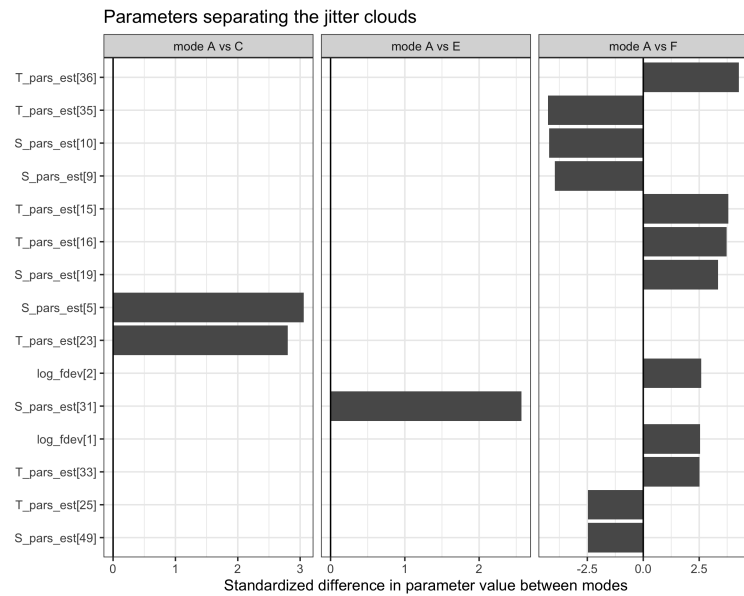


Figure 68: Parameter attribution for the male-only sensitivity, Model 26.2: the parameters that most separate its jitter minima, ranked by the standardized difference in fitted value between modes, as requested by the June 2026 SSC. The same figure for the author-preferred model is in Section E.

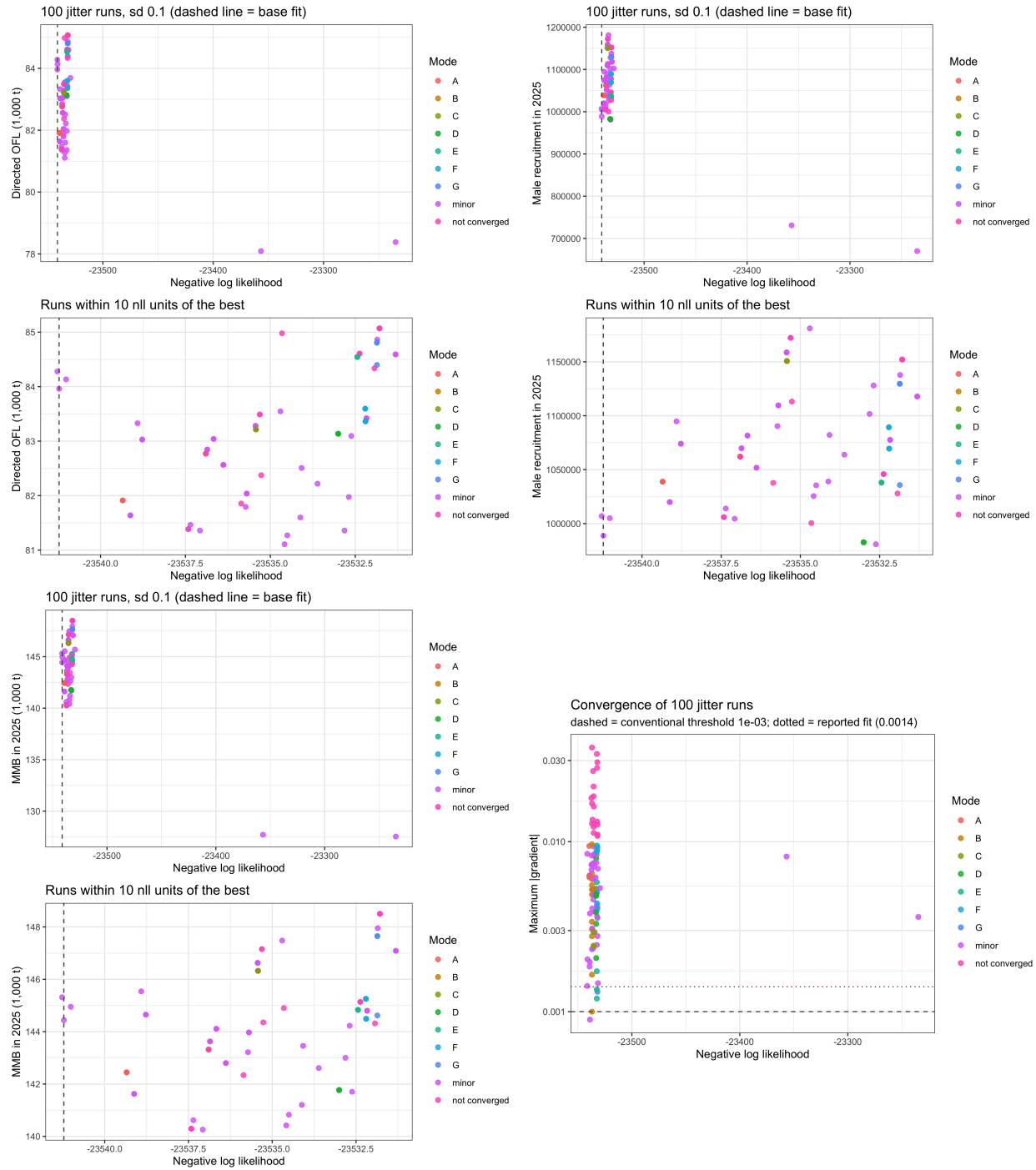


Figure 69: Jitter diagnostics for the structural experiment 26.d1 (stability), which fixes the non-identified 2019/20 immature-female mortality deviation and tightens the recruitment sex-ratio penalty. Panel order as above. It did not improve recovery of the best fit and met the gradient criterion less often than the model it was built from.

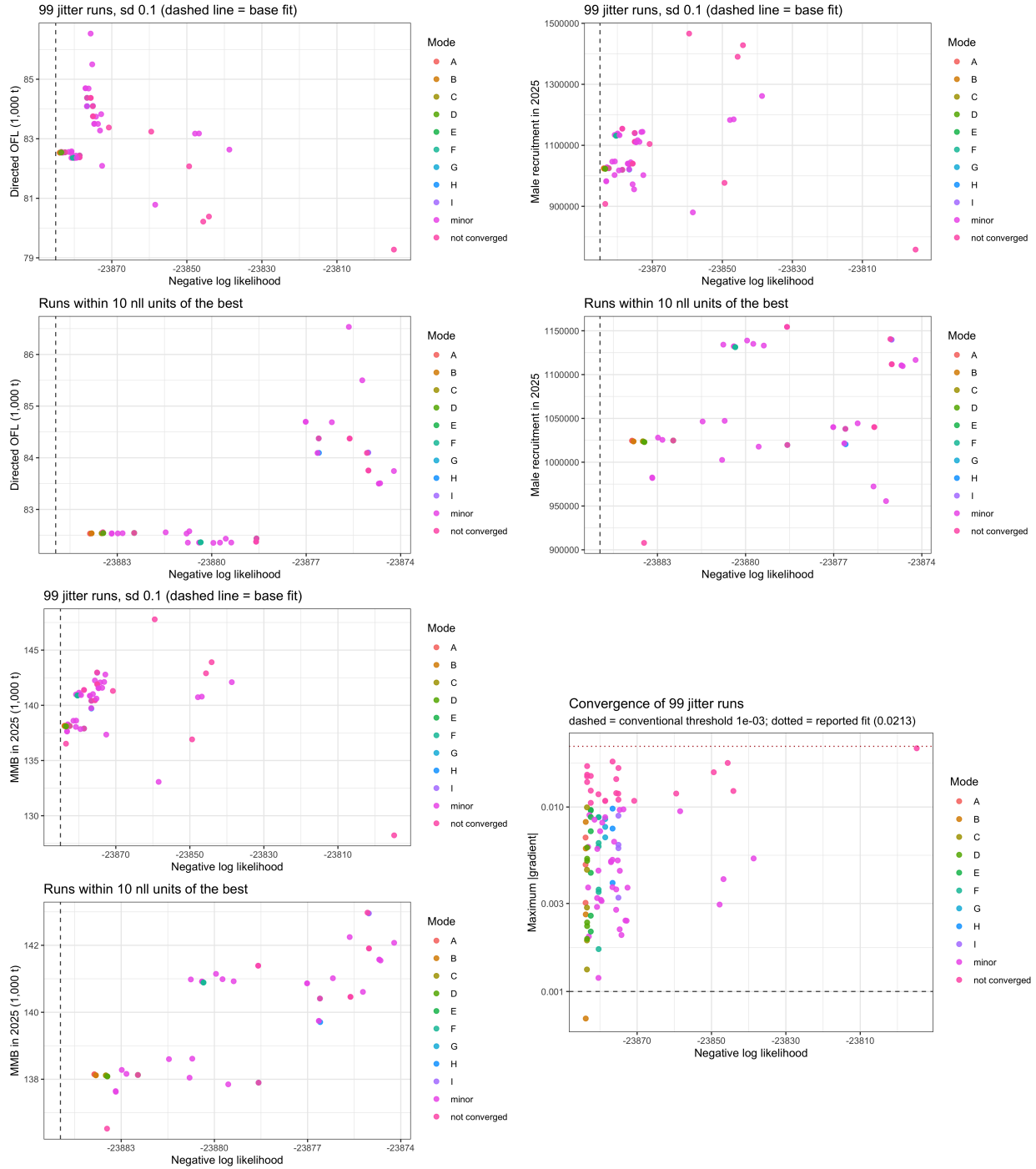


Figure 70: Jitter diagnostics for the structural experiment 26.d3 (eqmdevs), which replaces the unpenalized 1982 initial numbers with an unfished equilibrium scaled by penalized deviations. Panel order as above. The spread in likelihood is visibly tighter than the author-preferred model's, but no run recovered the reported best fit.

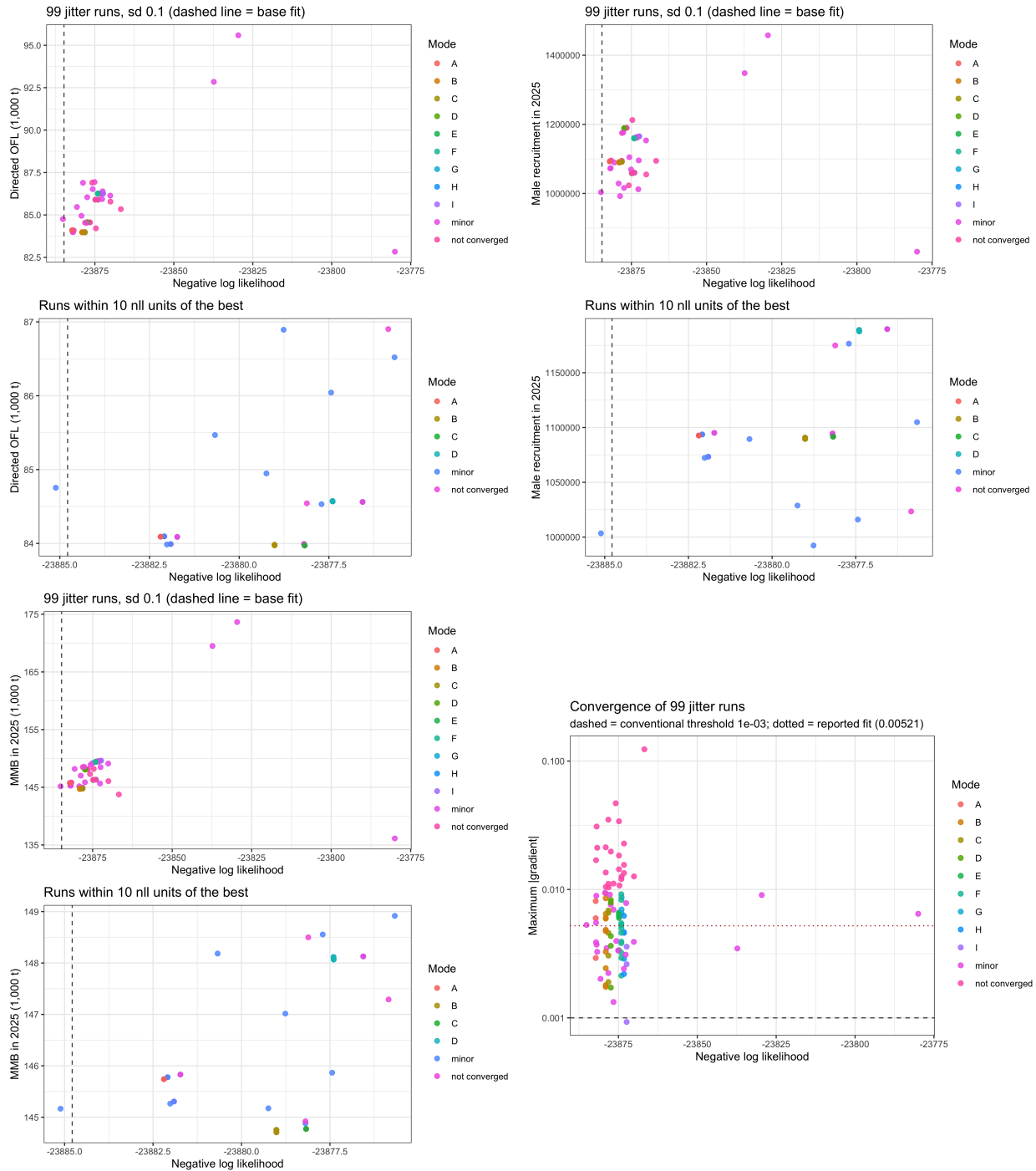


Figure 71: Jitter diagnostics for 26.d4 (combined), which applies all 3 fixes to the two-sex model at once. Panel order as above. Runs meeting the gradient criterion: 1 of 100. The best lettered cluster holds 3.9 percent of usable runs and lies 2.9 likelihood units above the best fit, which it does not include.

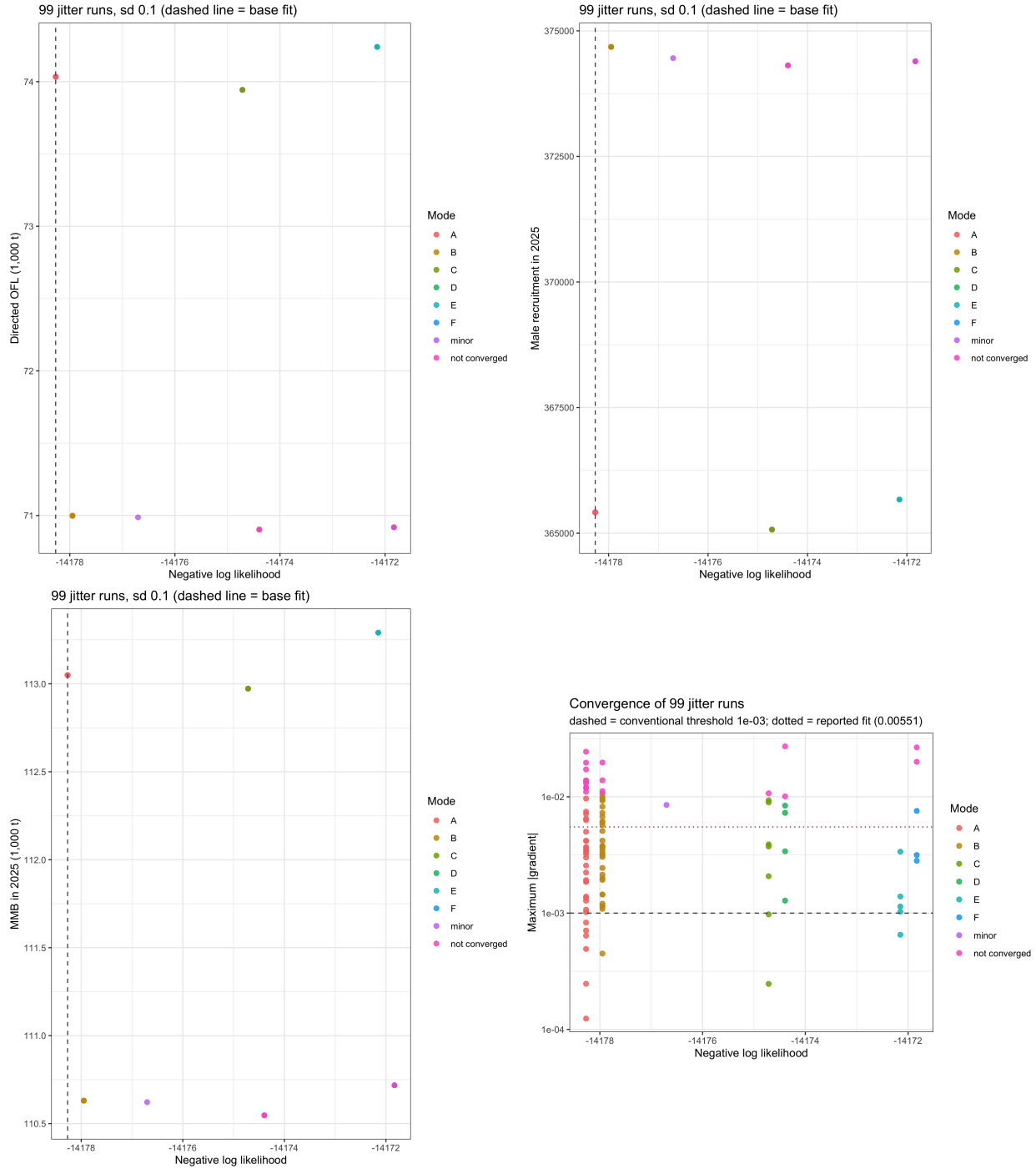


Figure 72: Jitter diagnostics for 26.d5, the male-only model with the equilibrium-backbone initialization. Panel order as above. It has the highest recovery rate of the configurations tested. Usable runs span 6.4 likelihood units, the narrowest of the configurations tested; Model 26.2 spans 121.7 and the two-sex configurations 45 or more.

Caveats

3 qualifications apply to the experiments above.

The equilibrium backbone is unfished. 26.d3 eqmdevs anchors the 1982 population on an unfished equilibrium, following the formulation it was ported from, but the eastern Bering Sea snow crab stock had been fished since the late 1970s. The effect is visible in the result: mature male biomass in 1982/83 moves from 213.6 to 302.1 kt. Switching the backbone to a fished equilibrium is a small change to the same code, and it has not been made, so this experiment should not be judged finally on the results reported here.

All 4 jittered experiments require modified source code. 26.d1 stability, 26.d3 eqmdevs, 26.d4 combined and 26.d5 were run with forked GMACS source trees rather than the stock 2.20.34 binary used for every model in the assessment except Model 25.3, which is reported as fitted in 2025 under 2.20.22. This matters most for 26.d5, the configuration these results favor: it cannot be reproduced, or brought forward as a candidate, until the initialization mode is merged into the released version. 26.d1 stability changes a penalty standard deviation that is hardcoded in the source rather than read from the control file. 26.d3 eqmdevs adds an initialization mode and a deviation penalty occupying a control-file slot that is dead code in the released version. The results in this appendix are therefore not reproducible with the stock binary, and the forks are recorded with the models. The shared source tree the assessment itself is built from is unmodified and is checked against its hash at every build.

The mortality fix is a structural assumption, not a neutral correction. Fixing the 2019/20 immature-female mortality deviation removes that mortality event for immature females entirely, while the other sex and maturity classes retain theirs. This is defensible, because the parameter is not identified from default starting values and its estimate at the accepted fit is not distinguishable from the 2018/19 deviation, but it is an assumption about what happened in 2019/20 and any configuration using it should be described that way. It is not, however, the main reason the experiments' fits differ from the author-preferred model's: 26.d3 eqmdevs, which uses the equilibrium initialization without the mortality fix, moves 1982/83 mature male biomass from 213.6 to 302.1 kt on its own, more than the mortality and sex-ratio fixes together. Differences among the experiments should be attributed to the initialization first.