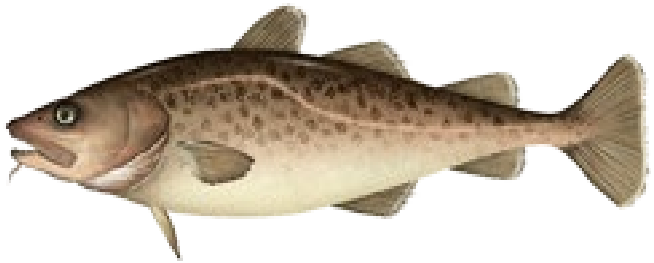
# Bering Sea Pacific Cod September 2026



Authors: Steve Barbeaux, Pete Hulson, and Ingrid Spies

# September explorations

- Plus-group sensitivity
  - 20+ (2024 model), 18+, 16+, 14+, 12+, and 10+
- Split sex model
  - Model 26.2 – same as Model 26.1 (24.1 w/ 14+), but with design-based age composition
  - Model 26.3 – same as Model 26.2 but with split-sex age and length composition data, split-sex growth, and split-sex fishery selectivity

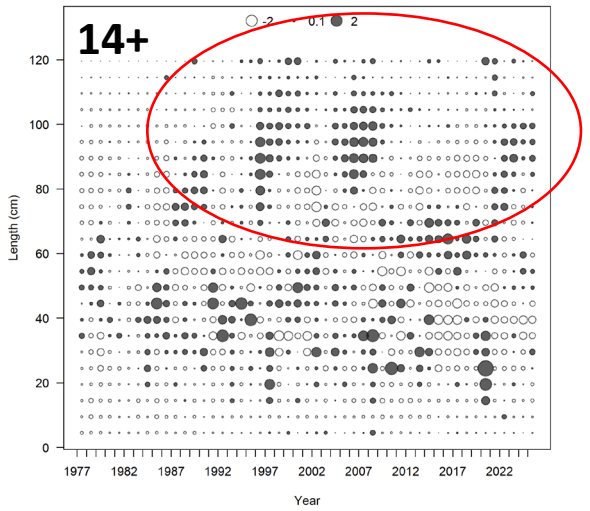
# September exploration results

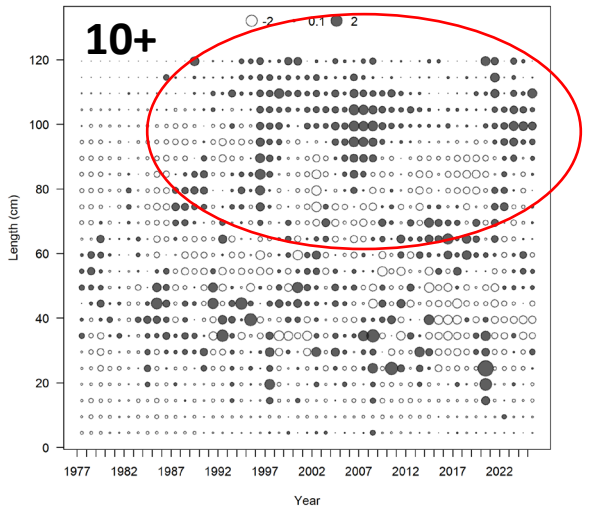
- Plus-group analysis
  - Slight improvements to fit to 14+
  - Degradation to fit in plus-groups less than 14
  - Little to no difference in results down to 14+
  - Substantial change in model results at 10+
- Split-sex analysis
  - Similar fits across all data type, but overall degradation in parsimony with increased number of parameters
  - Little to no difference in model performance and results
  - Split-sex allows for evaluation of fishing impacts and differences by sex in natural mortality on sex ratios by age and length
  - Split-sex increases the work load on GAP to produce split-sex model-based estimates.

# Plus-group Analysis

| Model | Number of estimated parameters | Total NLL | Δ NLL vs. 20+ | Length comp. NLL | Age comp. NLL | Survey NLL |
|---|---|---|---|---|---|---|
| 20+ | 180 | 366.6 | — | 335.1 | 58.5 | −58.2 |
| 18+ | 178 | 366.6 | 0 | 335.1 | 58.5 | −58.2 |
| 16+ | 176 | 366.5 | −0.1 | 335 | 58.5 | −58.2 |
| 14+ | 174 | 366.3 | −0.3 | 334.8 | 58.5 | −58.2 |
| 12+ | 172 | 367.6 | 1 | 336.7 | 58 | −58.6 |
| 10+ | 170 | 382.7 | 16.2 | 354.2 | 55.8 | −59.7 |

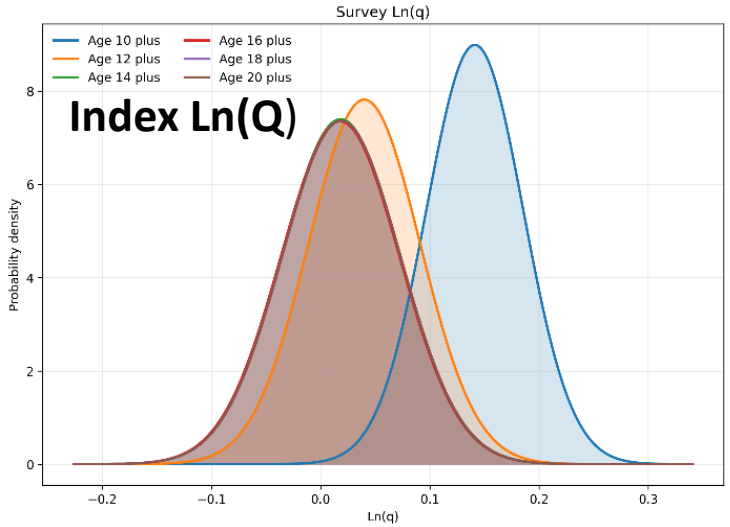
- Largest differences in fit in the length composition fits, higher residuals in the larger size bins >80cm.

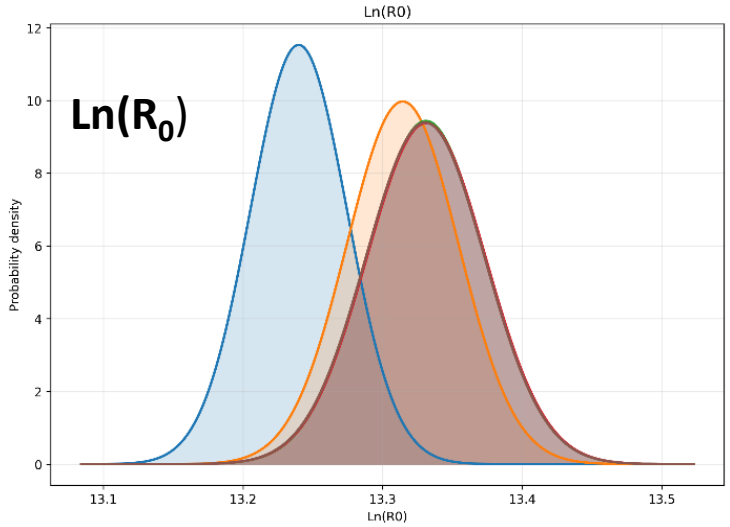


# Plus-group Analysis

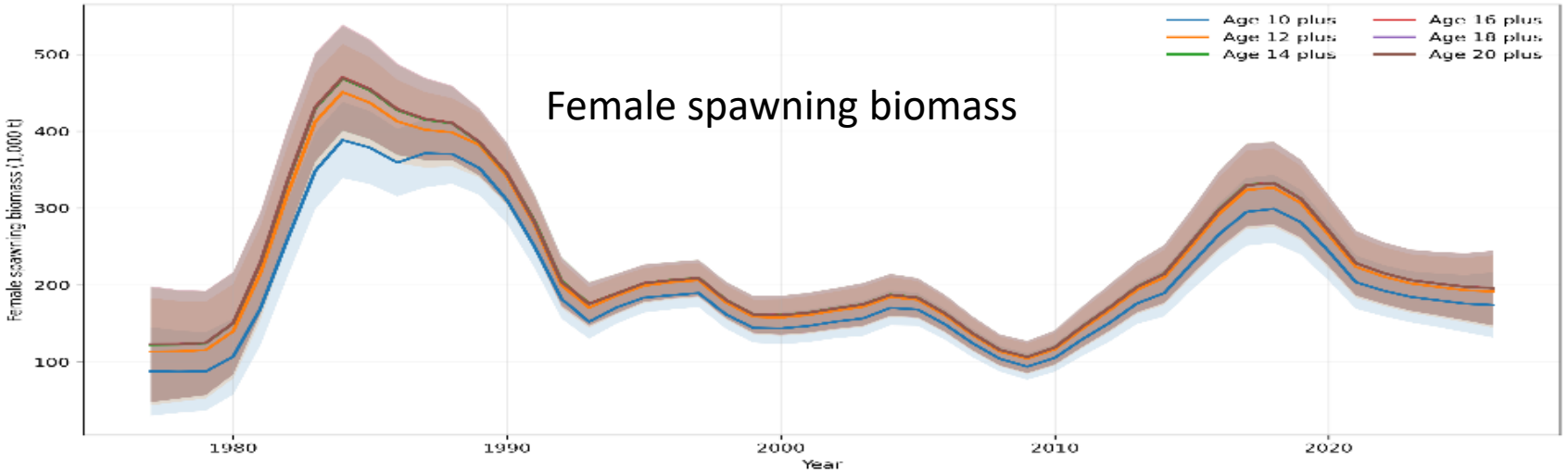
| Plus group | $L_{max}$ (cm) | von Bert. K | Richards | Ln($R_0$) | $R_0$ Δ vs 20+ | Survey Ln(q) | q Δ vs 20+ | Initial F | 1977 fishery peak (cm) |
|---|---|---|---|---|---|---|---|---|---|
| 20+ | 111.04 | 0.118 | 1.462 | 13.331 | — | 0.019 | — | 0.1122 | 76.02 |
| 18+ | 111.01 | 0.118 | 1.462 | 13.331 | 0.01% | 0.0189 | −0.01% | 0.1122 | 76.021 |
| 16+ | 110.97 | 0.118 | 1.462 | 13.331 | 0.08% | 0.0179 | −0.11% | 0.1121 | 76.025 |
| 14+ | 110.83 | 0.119 | 1.461 | 13.331 | 0.05% | 0.0183 | −0.06% | 0.1126 | 76.273 |
| 12+ | 110.92 | 0.12 | 1.451 | 13.314 | −1.60% | 0.04 | 2.13% | 0.121 | 77.445 |
| 10+ | 110.55 | 0.13 | 1.382 | 13.24 | −8.66% | 0.1412 | 13.00% | 0.1513 | 79.801 |



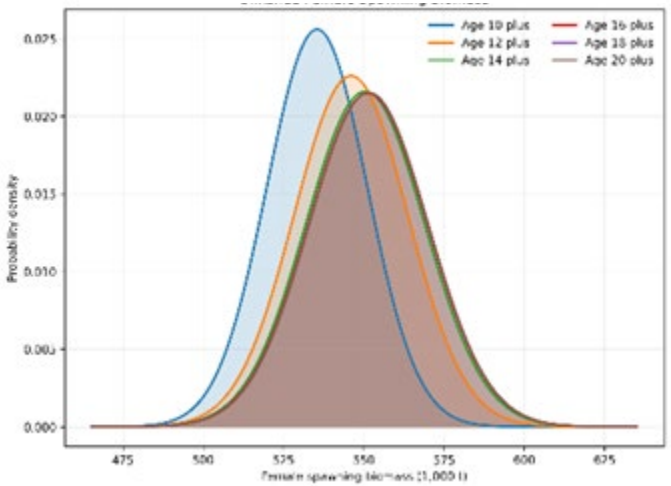
# Plus-group Analysis

Female spawning biomass

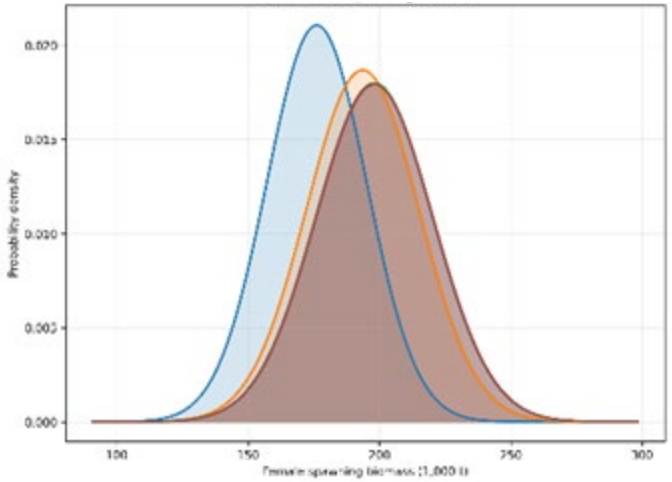



Age-0 Recruitment


Unfished spawning biomass



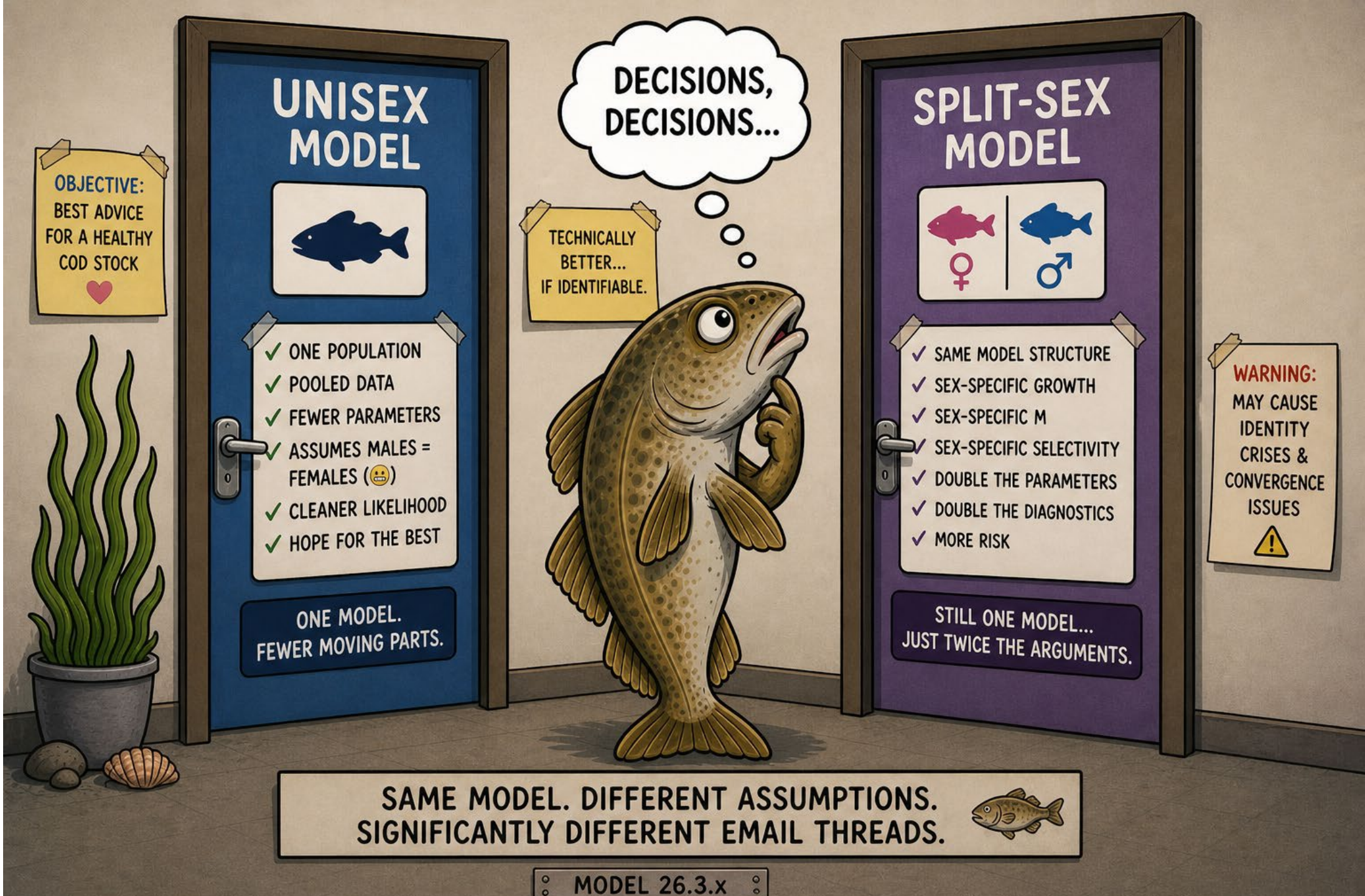

2025 Female spawning biomass



# Plus-group Analysis

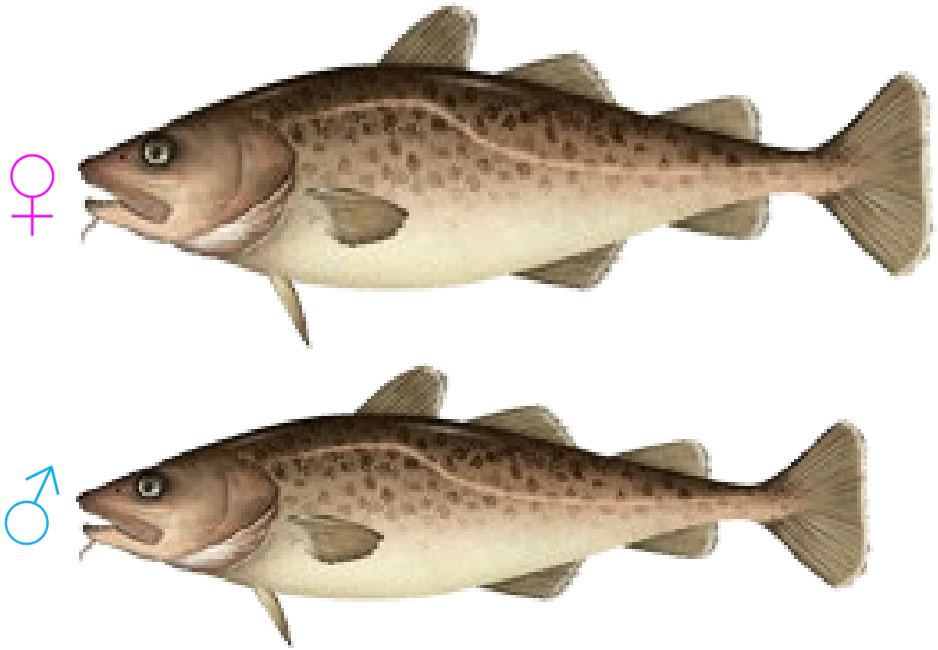
- **Conclusions**
  - Reducing plus-group to 14+ results in fewer parameters with small improvements to model fit with little change to model results and management advice from the current 20+ model.
  - Reducing plus-group to less than age 14 starts impacting model results and management advice.
  - For 2026 we recommend that the population plus-group in the assessment model be reduced to 14+ to create Model 26.1.

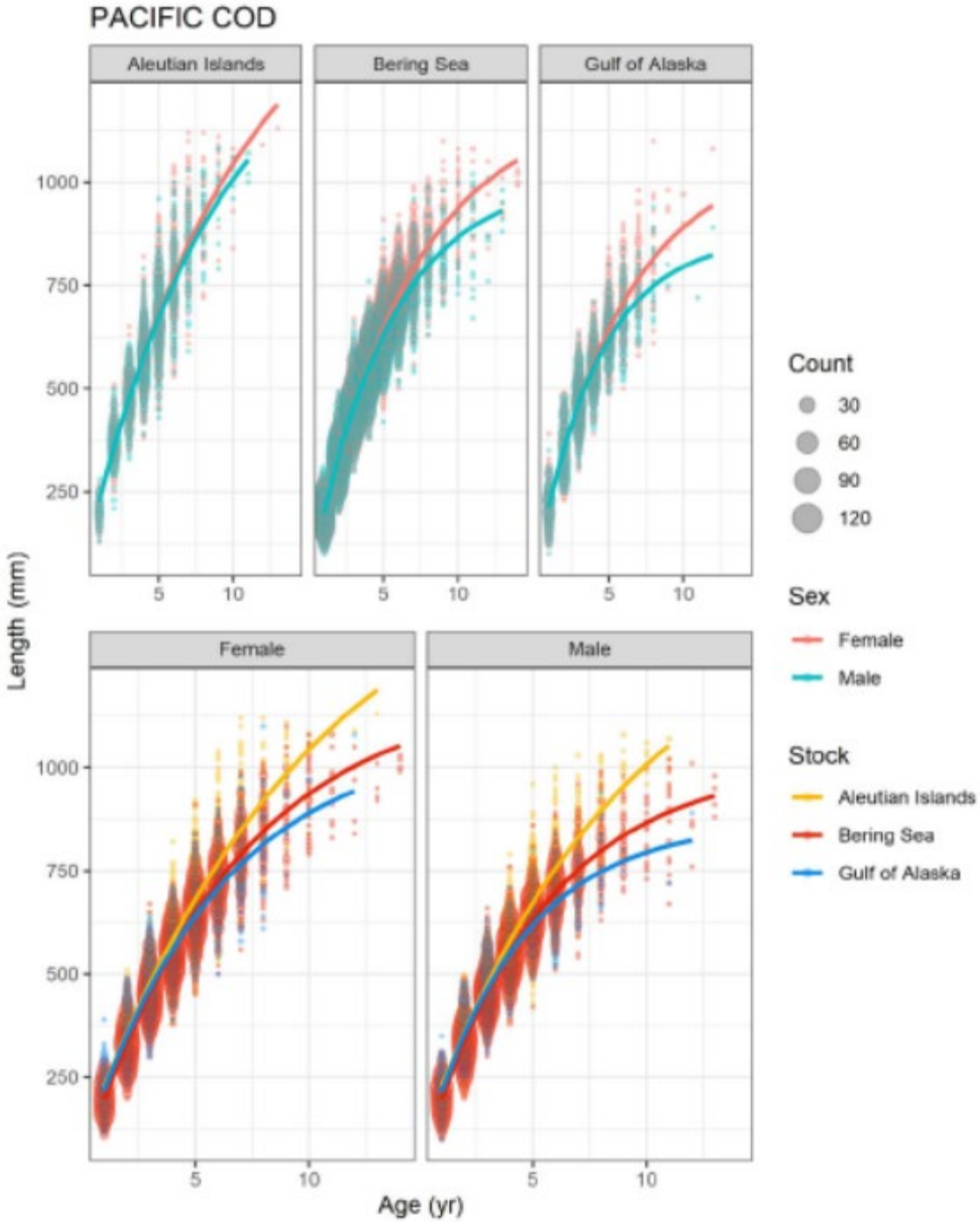
# 2026 Split-sex Model Exploration



# Split-sex Analysis

- Bering Sea cod differ in size-at-age by sex (Matte *et al.* 2026)






Matta, M. E., Short, J. A., Brogan, J. D., and Chamberlin. D. W. 2026. Characteristics and reliability of groundfish age data produced by the Alaska Fisheries Science Center's Age and Growth Program: reflecting on 50 years of age determination. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-520, 222

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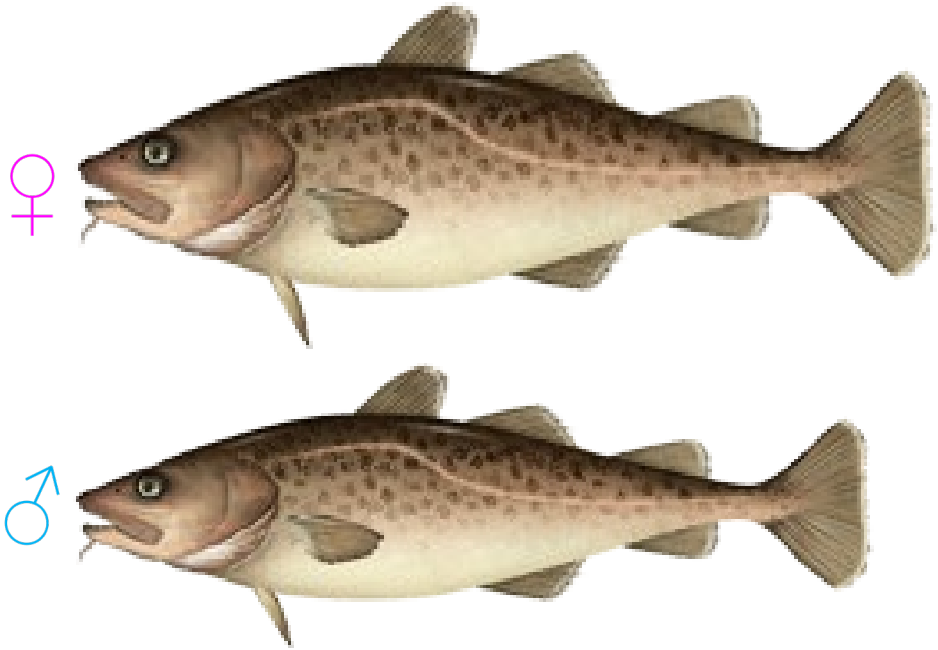

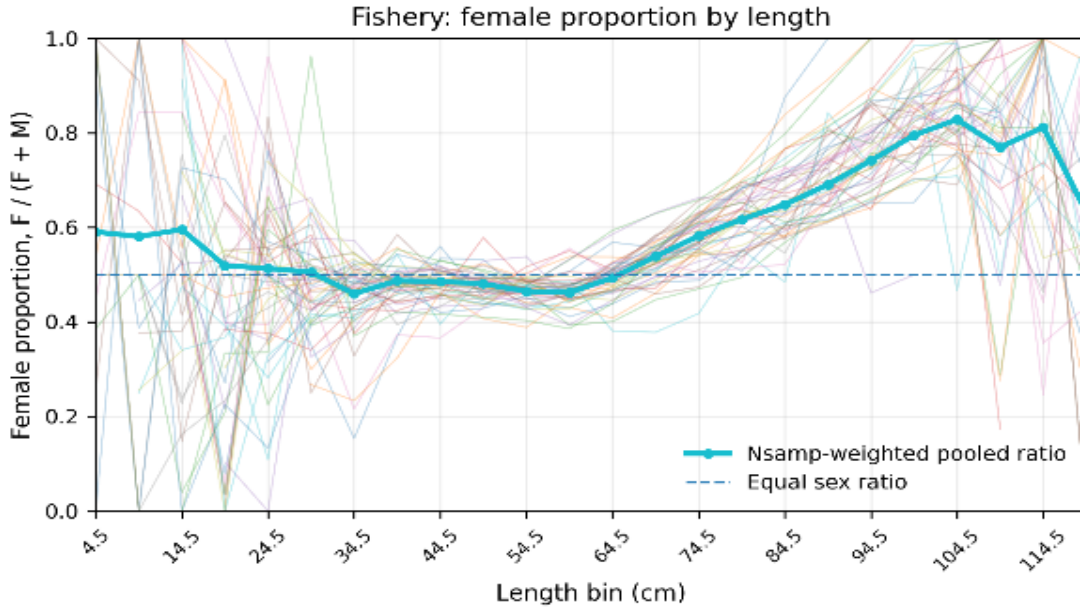


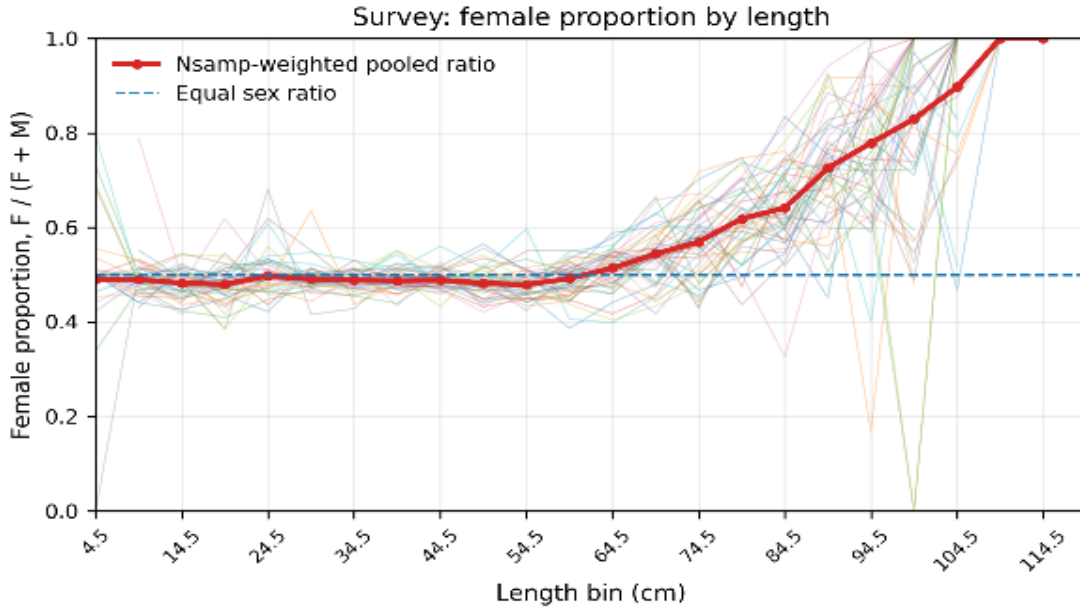


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# Split-sex Analysis

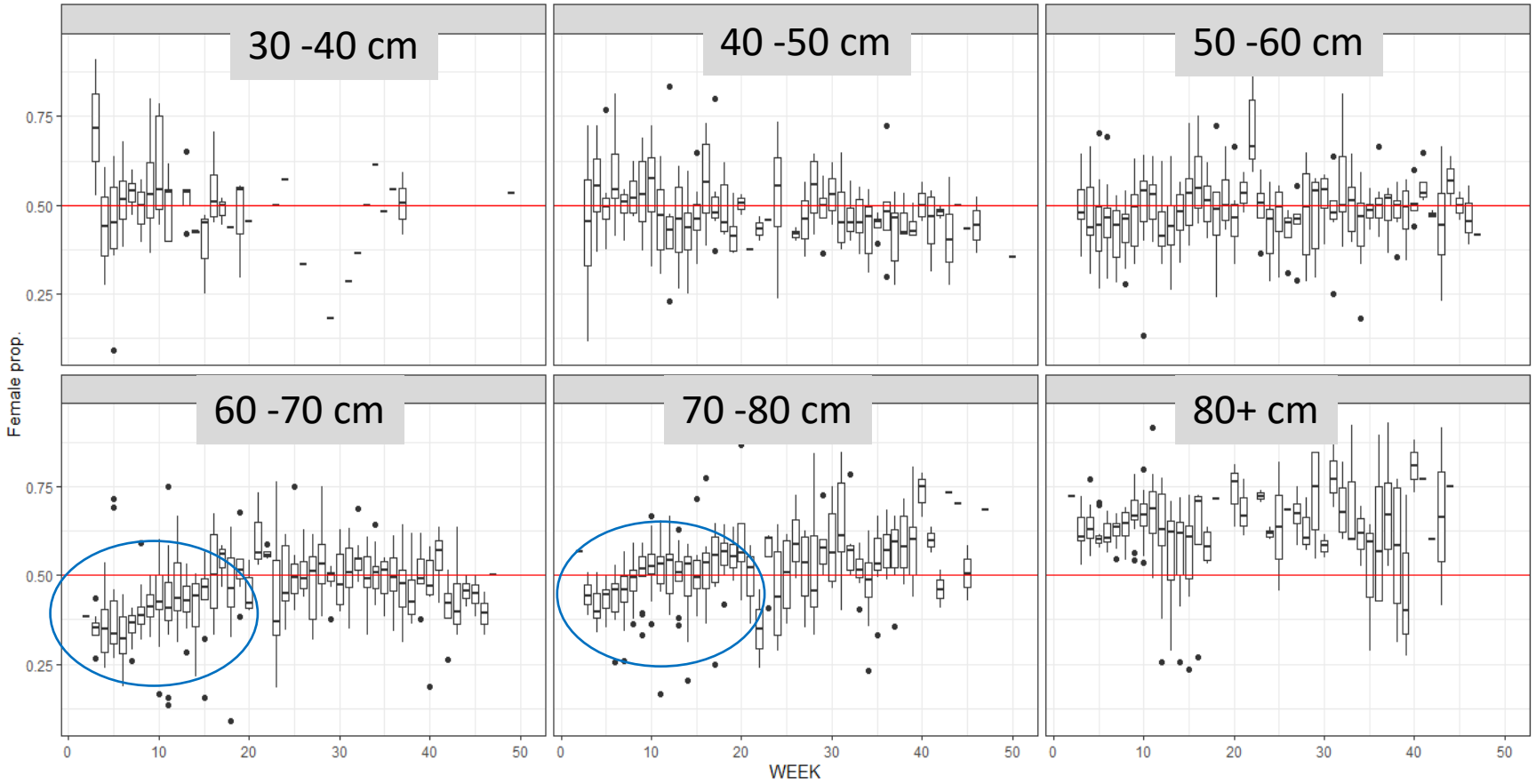
- Fishery selectivity likely differs by sex

  - Trawl fishery shows strong trends in sex ratio by week for some size classes

  - In Atlantic cod it is suggested that males arrive at the spawning locations prior to females.

  - This behavior could result in males being more vulnerable to the trawl fishery.

**Sex ratio in the trawl fishery by week of the year and size bin**



# Split-sex Analysis

**Problem:** Tiny-VAST split-sex survey age composition data are not available due to staffing and time constraints.

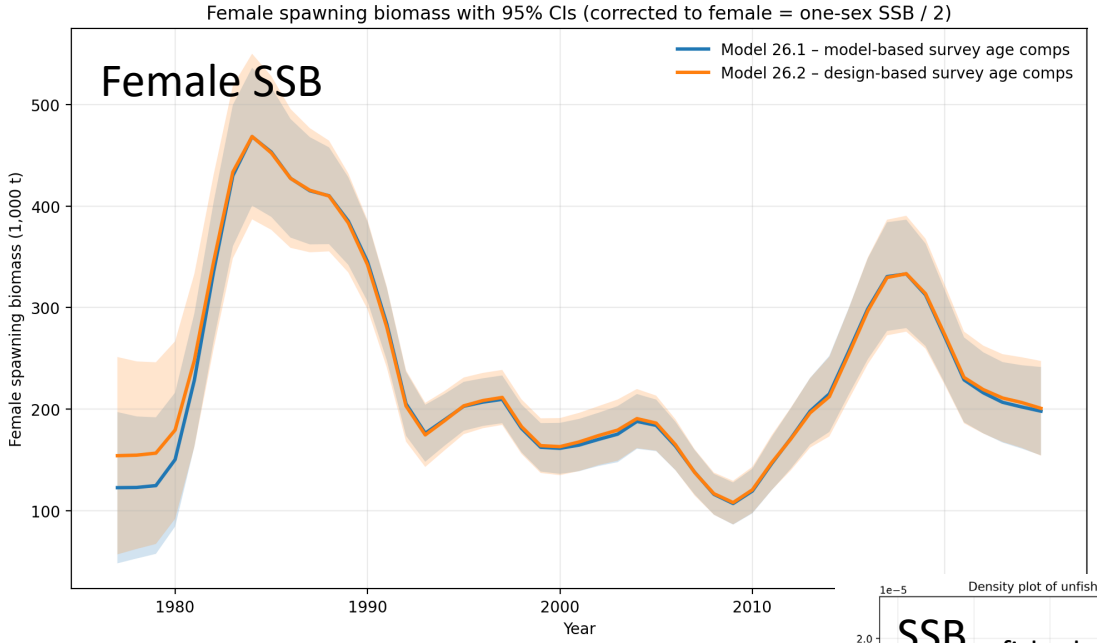
**Solution:** Used design-based age composition for both single and split-sex model to compare and explore model development.

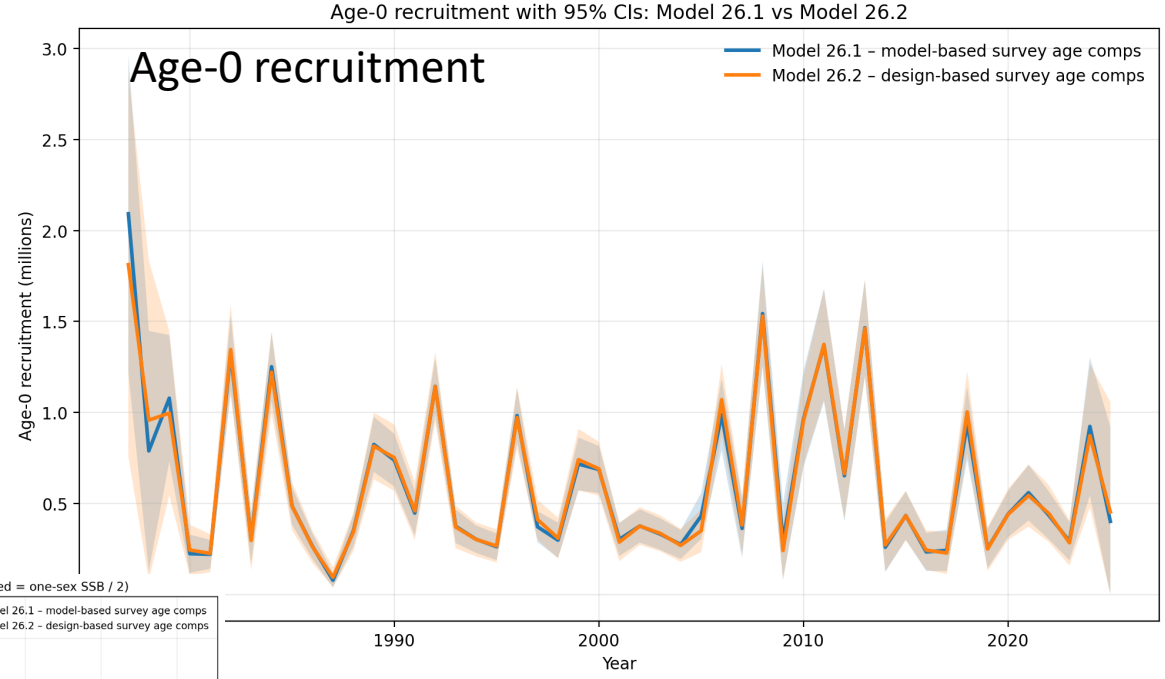
**Two models explored:**

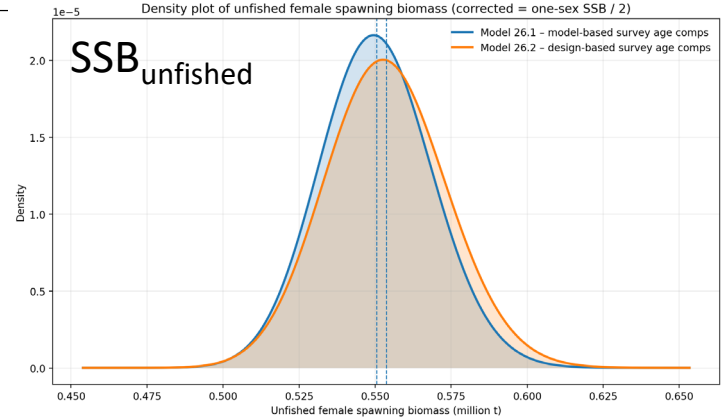
- Model 26.2 is a single sex model, but differs from Model 26.1 (plus-group 14+) in that the age composition data are design-based, not model based.
- Model 26.3 is the same as Model 26.2 except with split-sex composition data, growth, and fishery selectivity.

# Split-sex Analysis

## Model 26.1 (model-based age comps) vs Model 26.2 (design-based age comps)



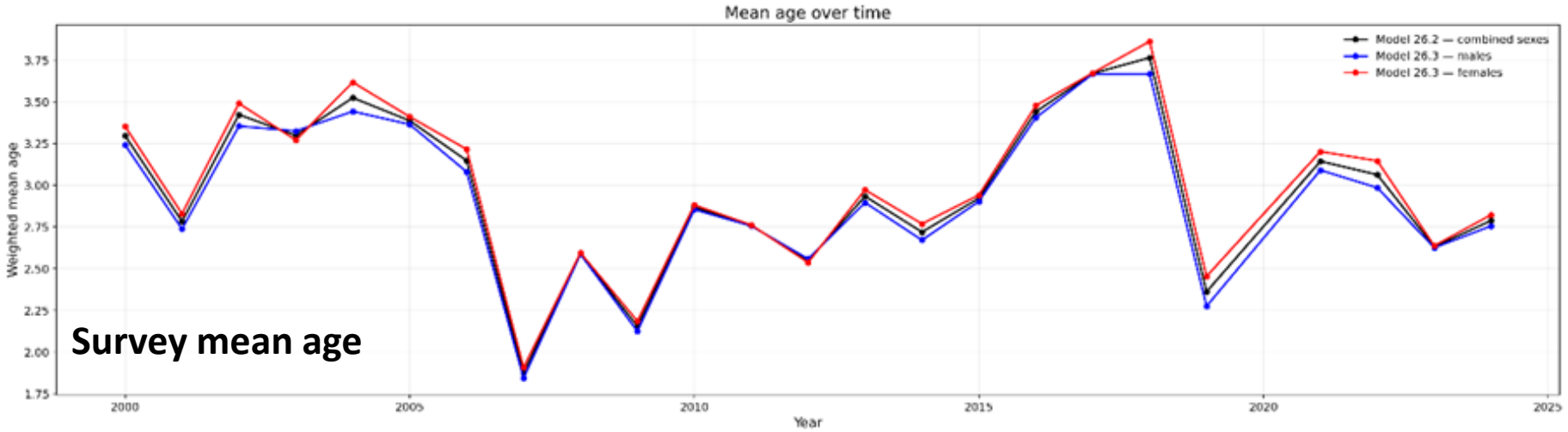



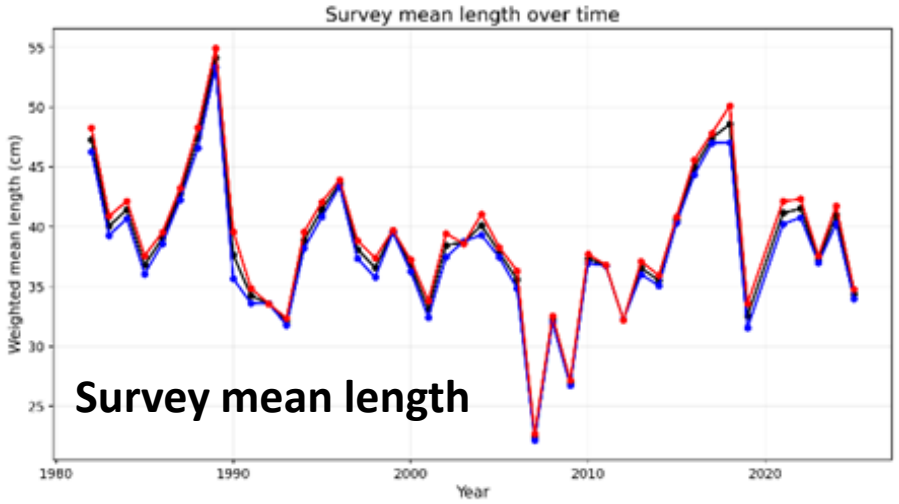



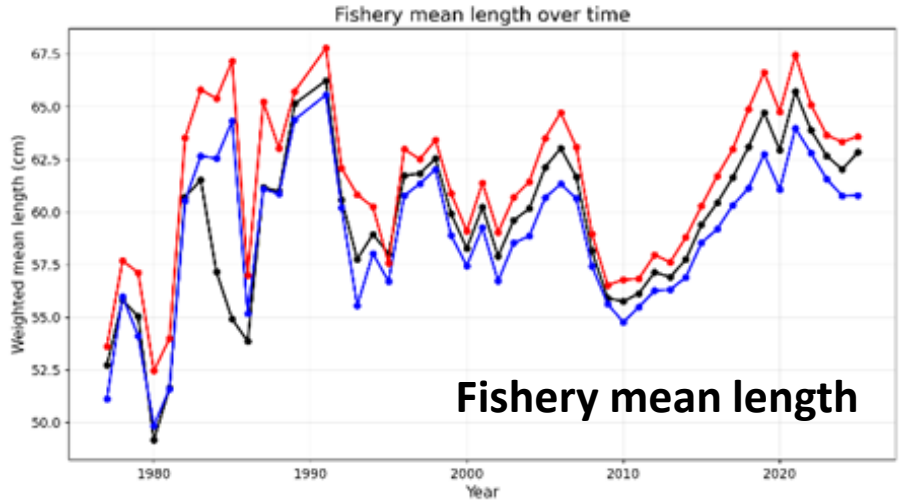

<1% difference in $SSB_{unfished}$

# Split-sex Analysis

- **Data differences**



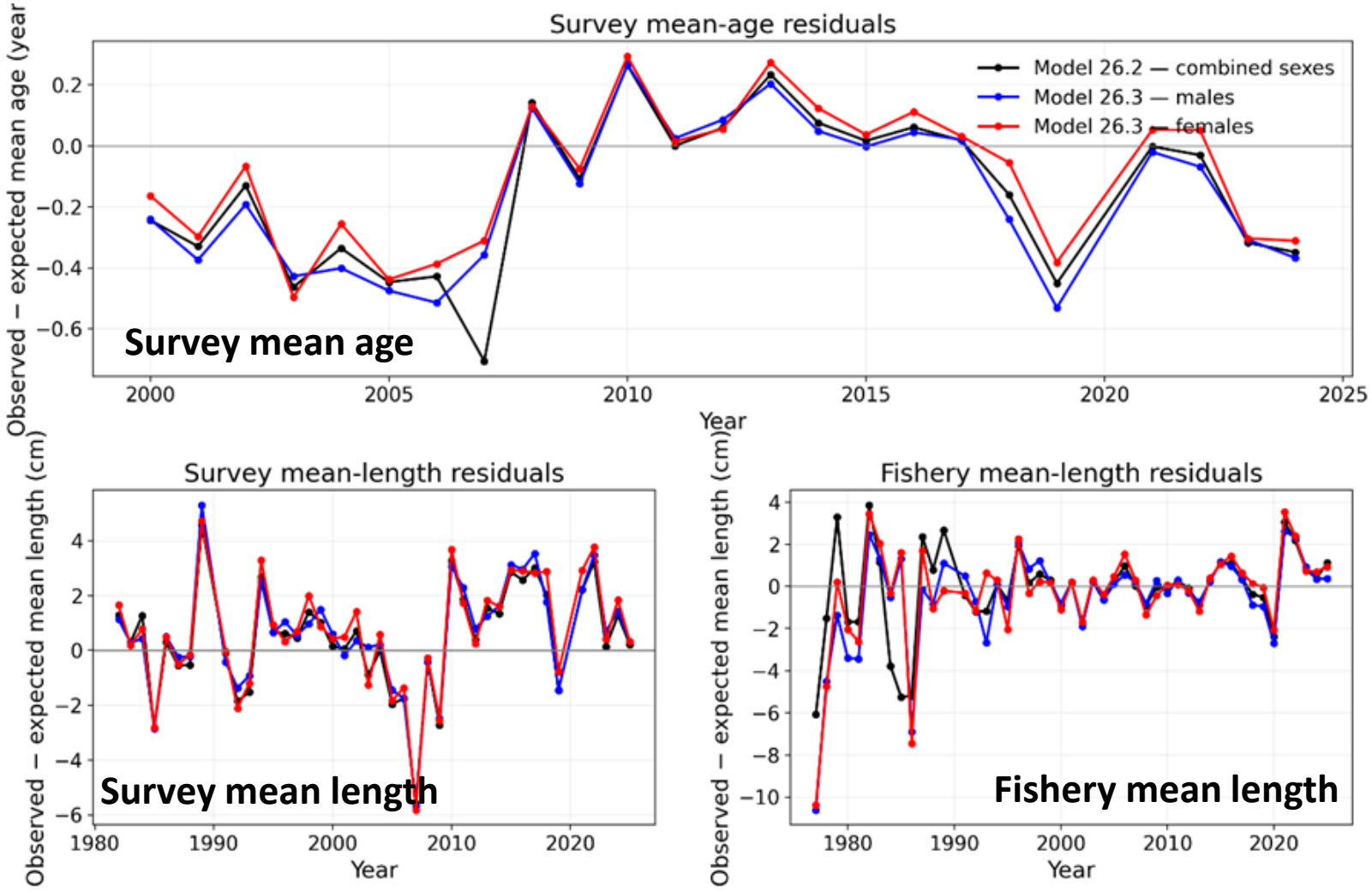



# Split-sex Analysis

- **Fit differences**

| Data component | Diagnostic | Model 26.2 | Model 26.3 |
|---|---|---|---|
| **Fishery length** | Mean residual | −0.08 cm | −0.38 cm |
| | Mean absolute residual | 1.43 cm | 1.38 cm |
| | RMSE | 2.05 | 2.33 |
| **Survey length** | Mean residual | +0.38 cm | +0.48 cm |
| | Mean absolute residual | 1.18 cm | 1.18 cm |
| | RMSE | 1.62 | 1.69 |
| **Survey age** | Mean residual | −0.151 years | −0.129 years |
| | Mean absolute residual | 0.224 years | 0.209 years |
| | RMSE | 0.290 | 0.262 |
| **Survey biomass index** | Log-scale RMSE | 0.1518 | 0.1486 |
| | SDNR | 1.0044 | 1.0037 |

**Mixed results** – minor improvements to the survey index and survey age comps, but minor degradation in fit to survey and fishery length comps.

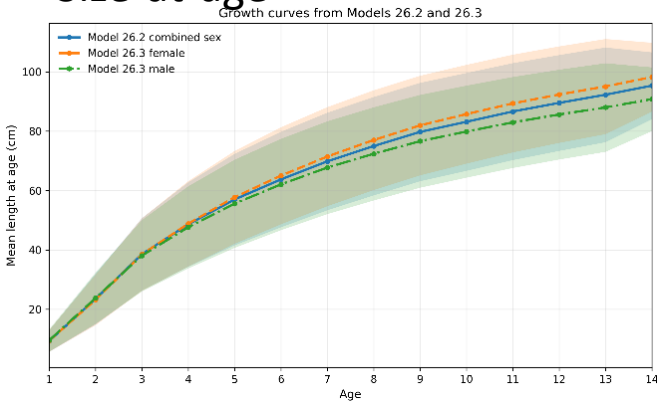


# Split-sex Analysis

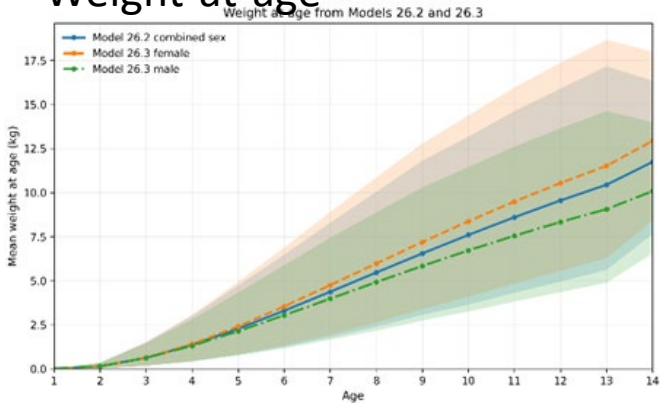
- **Results**

| Quantity | Model 26.2 | Model 26.3 |
|---|---|---|
| Survey catchability, Q | 1.0084 (0.0585) | 1.0067 (0.0569) |
| Unfished recruitment, $R_0$ | 618,282 (28,344) | 607,192 (26,965) |
| Fishery peak-selectivity parameter | 74.49 cm (0.92) | ♂74.08 cm (1.26)<br>♀75.80 cm (1.34) |
| Survey peak-selectivity parameter | 23.10 cm (1.32) | 23.65 cm (1.19) |
| Unfished female spawning biomass | 553.67 kt (19.95) | 603.63 kt (21.78) |
| 2025 female spawning biomass | 200.76 kt (23.80) | 216.66 kt (26.03) |
| $F_{40\%}$ | 0.3653 (0.0183) | 0.4116 (0.0380) |

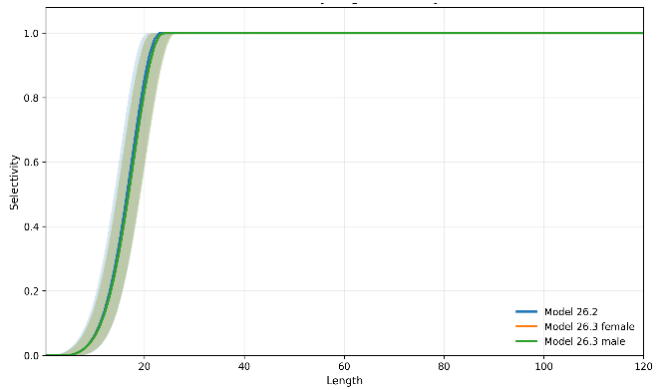
Size-at-age



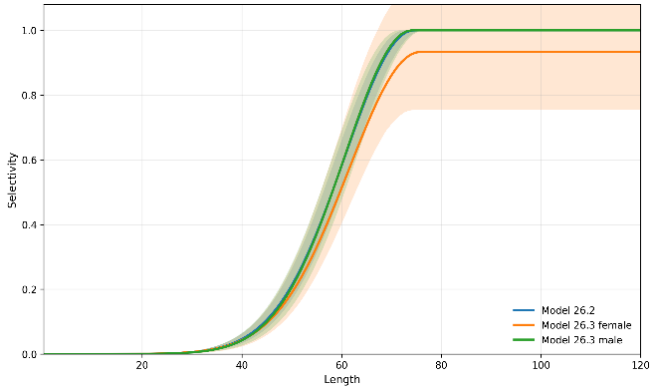

Weight-at-age




Survey selectivity

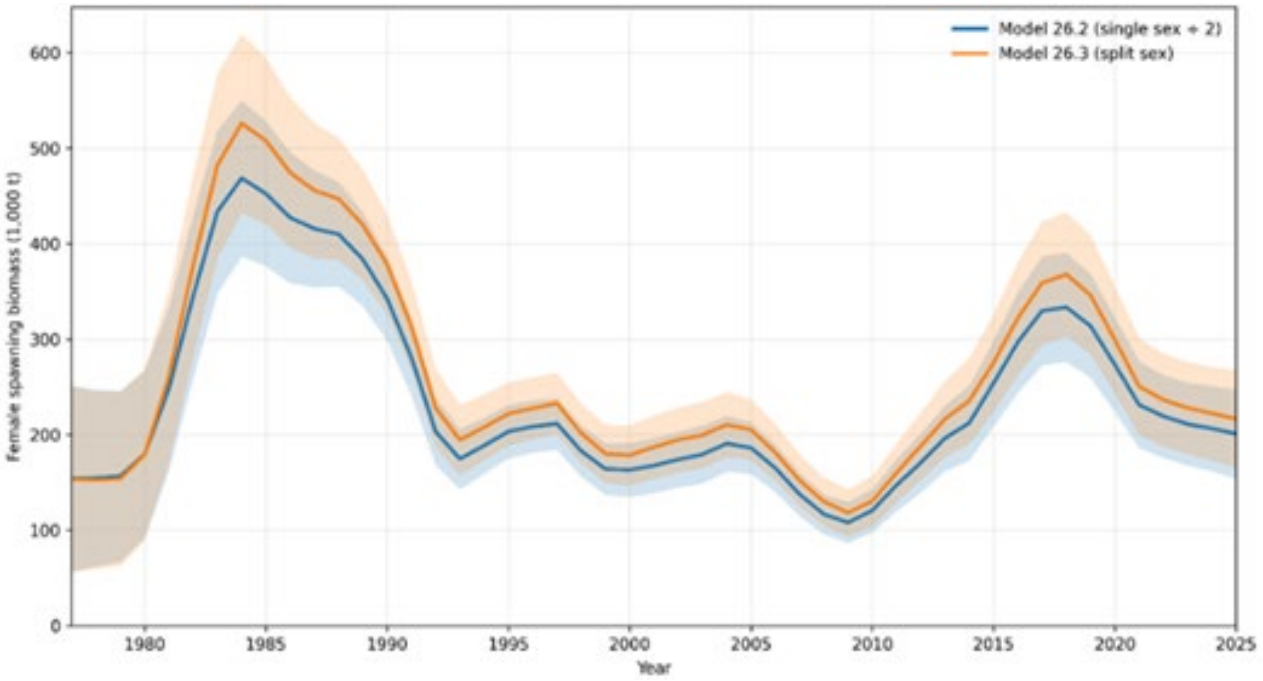


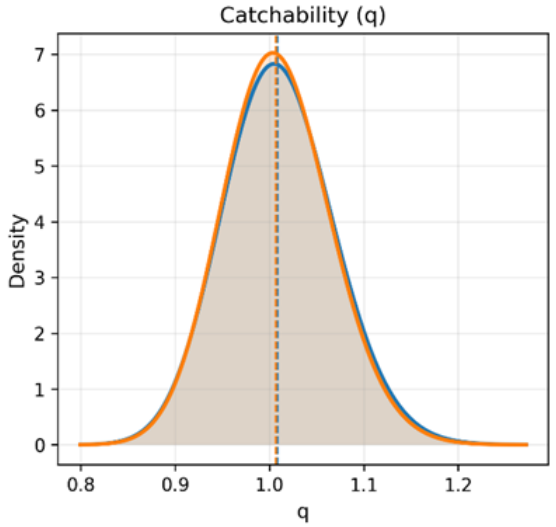

Fishery selectivity

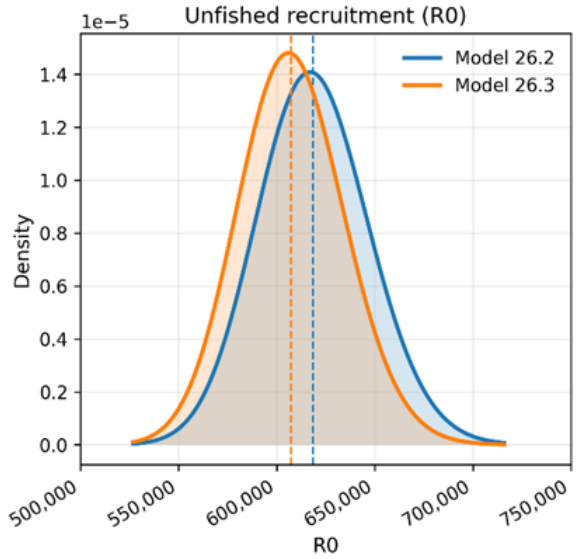


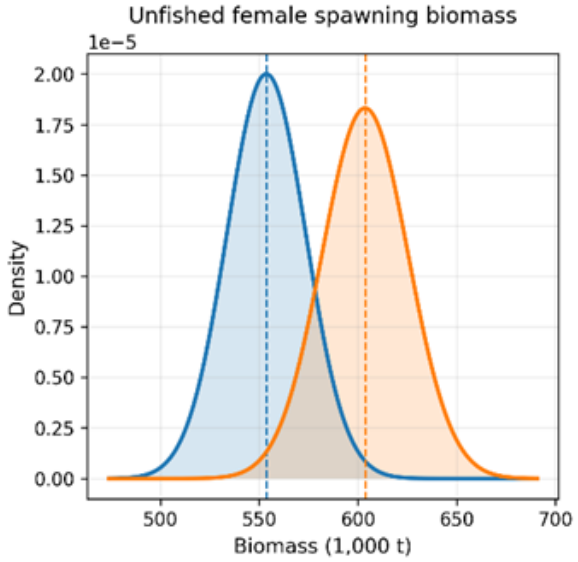
# Split-sex Analysis

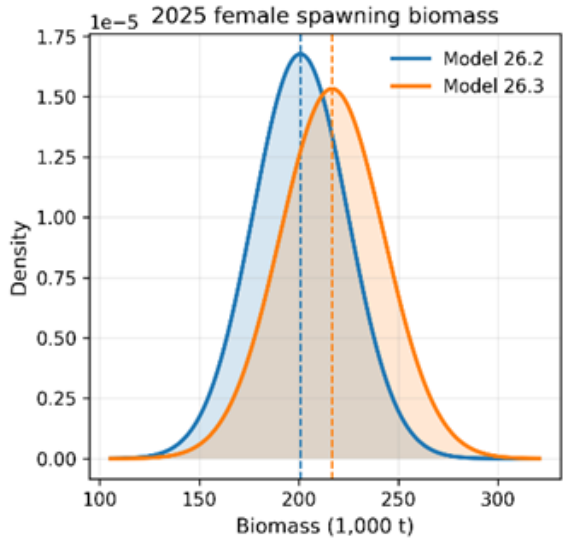
- **Results**



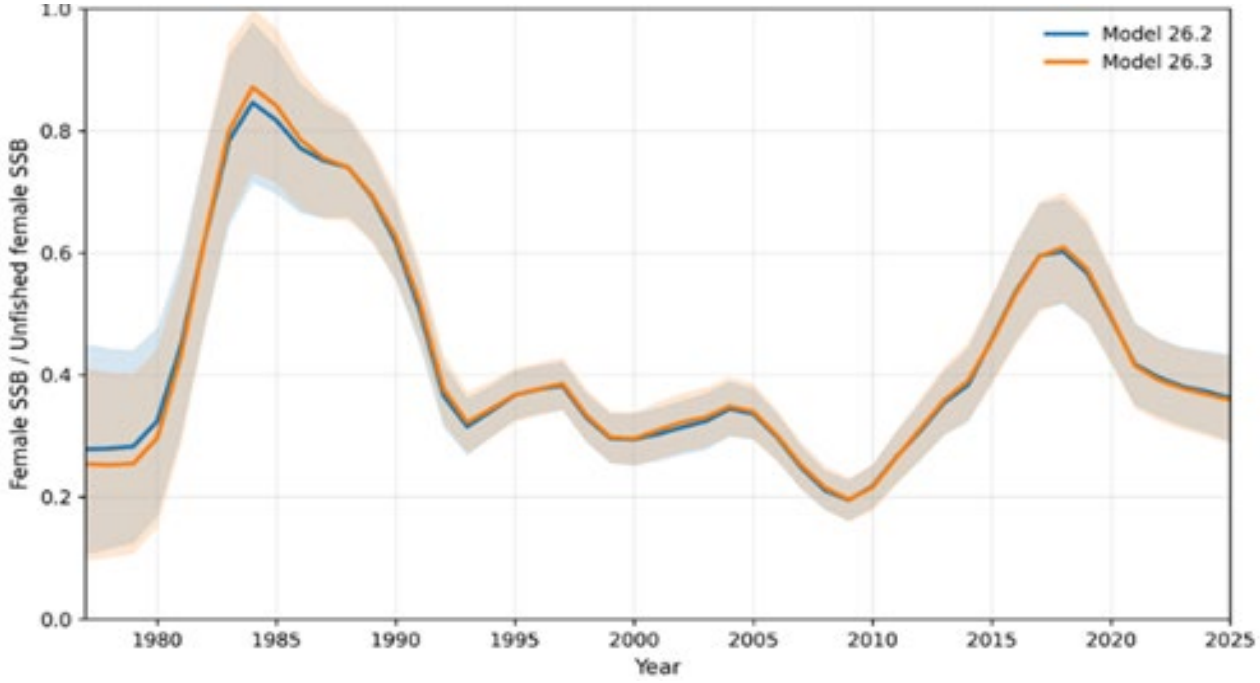



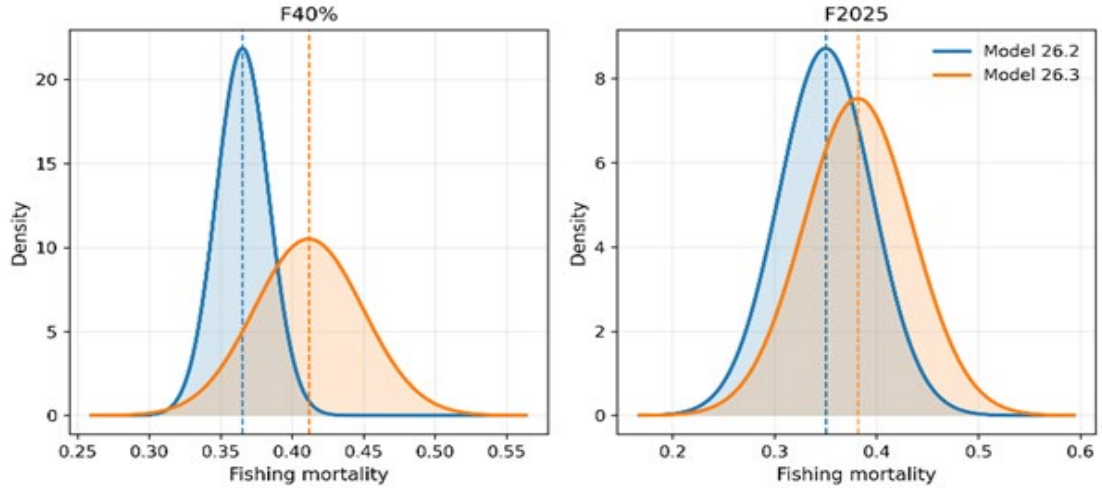




Model 26.3 has higher female spawning biomass overall

# Split-sex Analysis

- **Results**

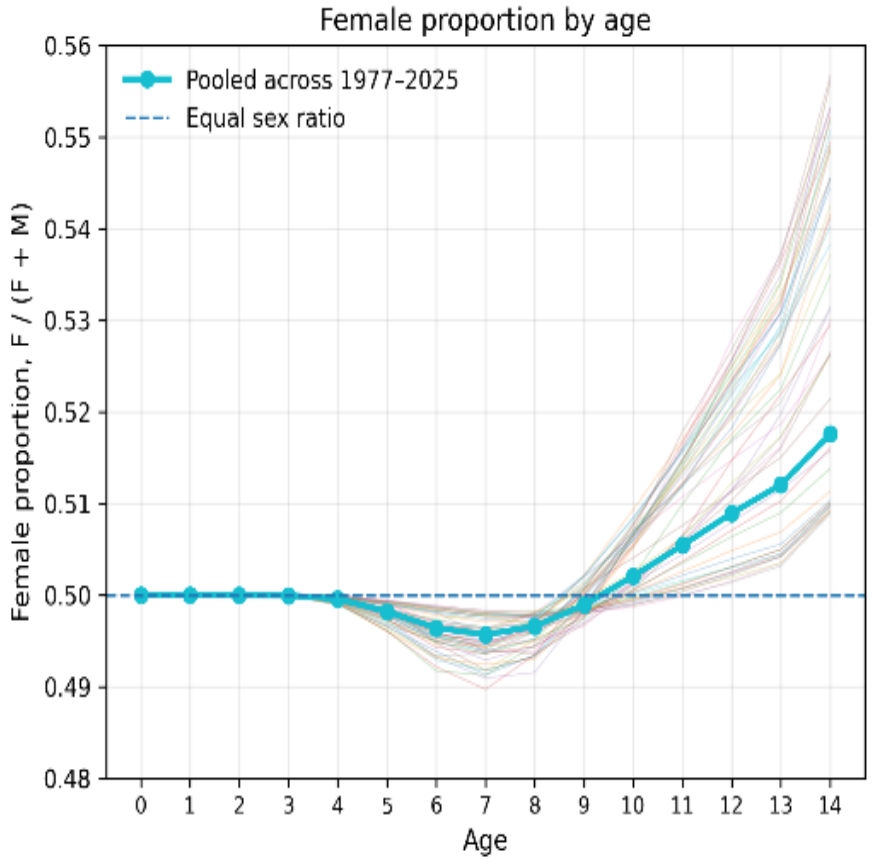


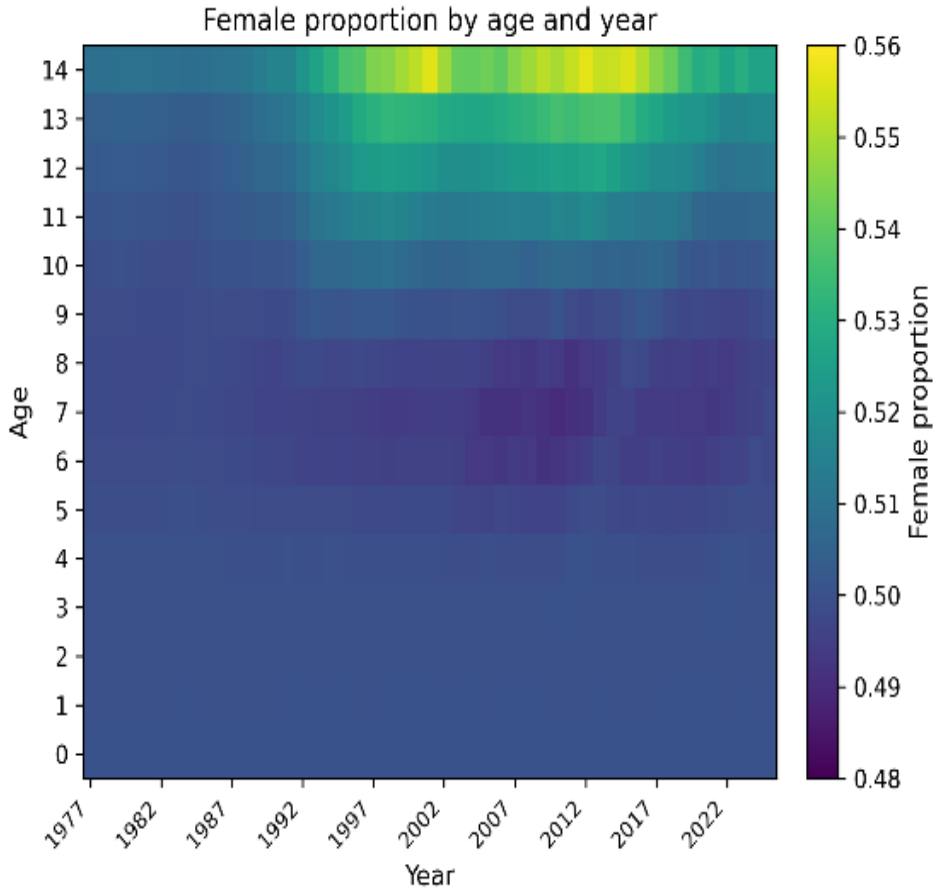




However, Model 26.2 and 26.3 recent status overlap (~1% difference) and the resulting 2026 maximum ABC differs by ~2.5%.

# Split-sex Analysis

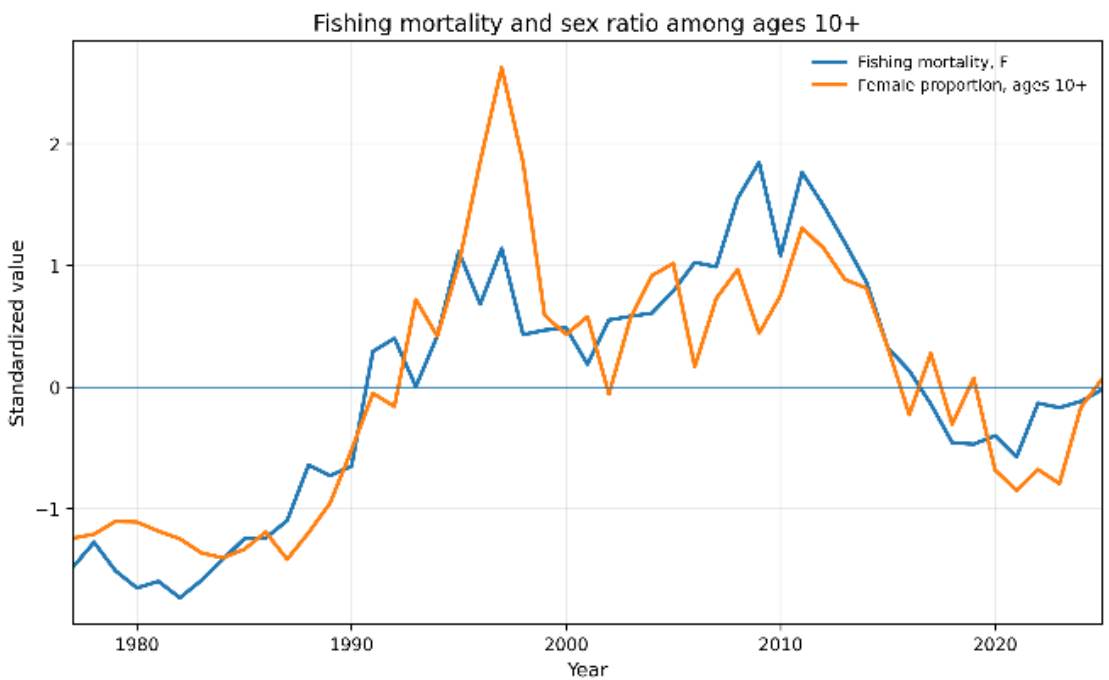
- **Results**
  - Model 26.3 shows higher female ratio at ages 10+

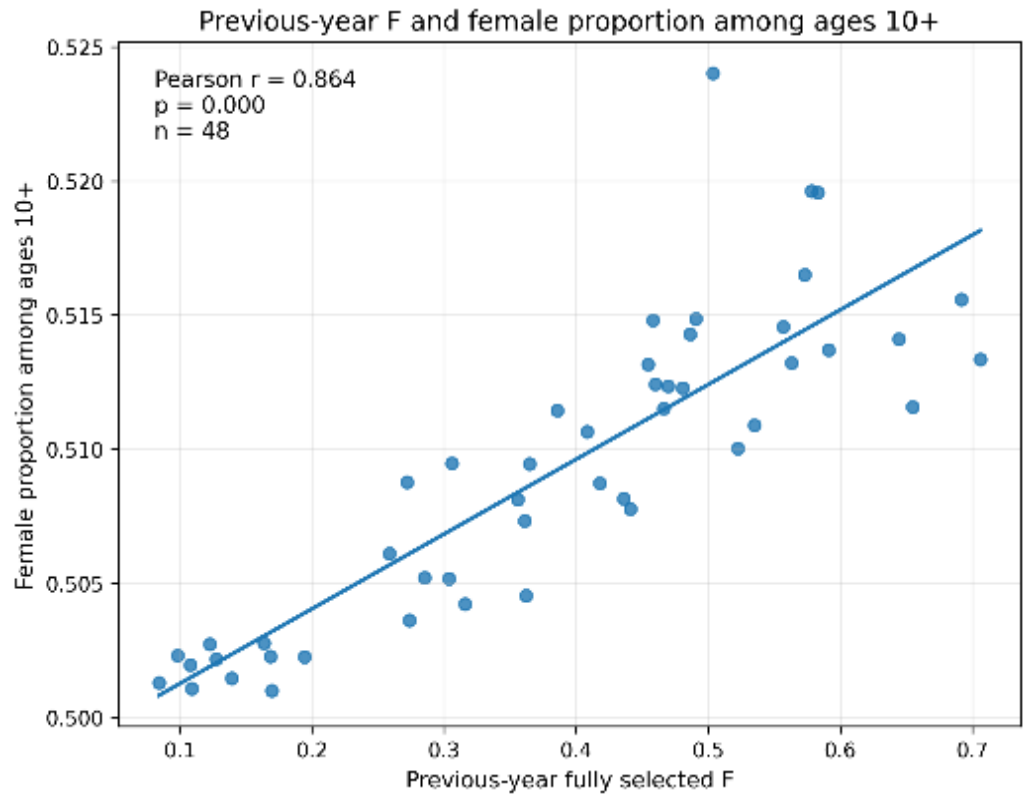


# Split-sex Analysis

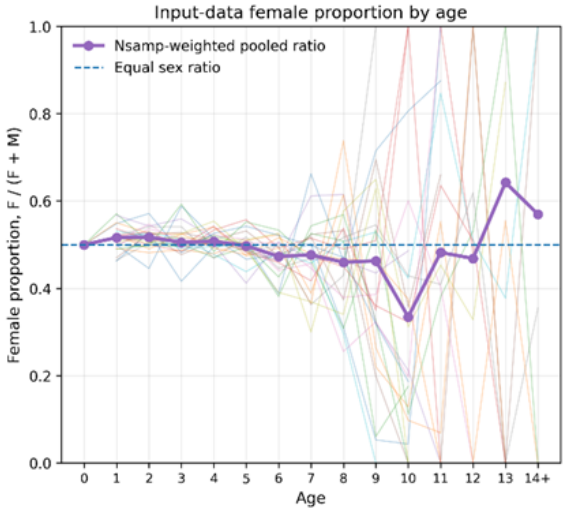
- **Results**
  - Model 26.3 show high correlation between sex ratio at 10+ and previous year's fishing mortality

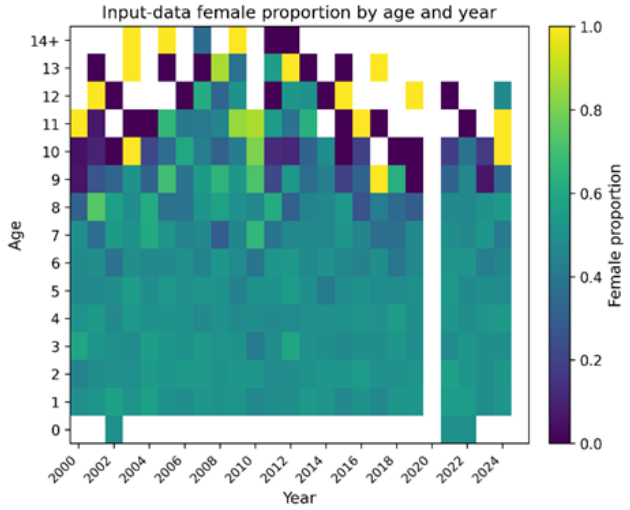


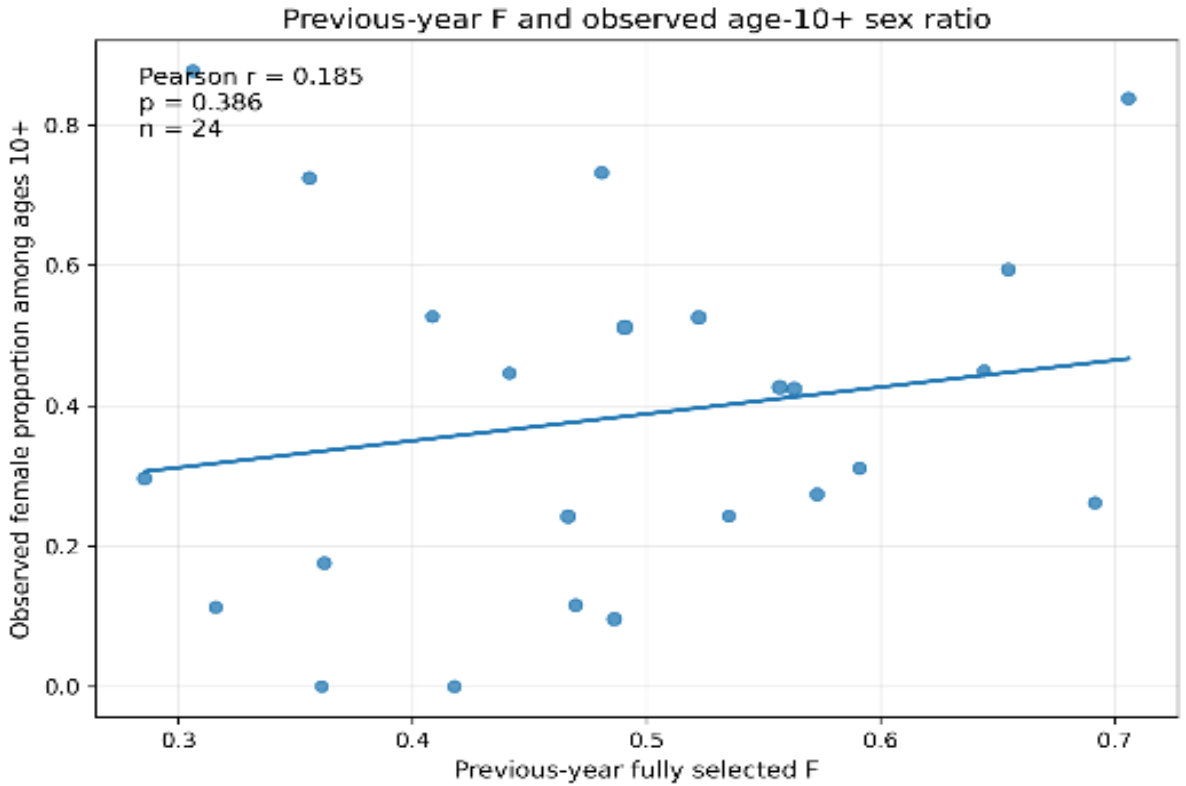



# Split-sex Analysis

- **Results**
  - However, this correlation may be an artifact of the model as this strong relationship is not observed in the survey data.



# Split-sex Analysis

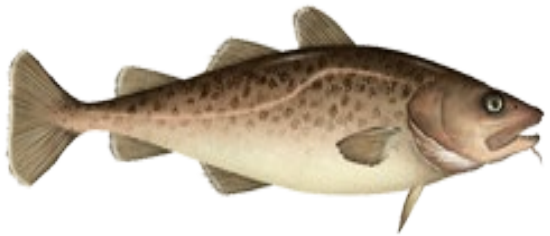
- **Conclusions**
  - The single-sex model provides an adequate fit to the available data, is more parsimonious than the split-sex model, and produces similar estimates of relative stock status and management quantities.
  - Although the split-sex model provides a more explicit representation of sex-specific growth and fishery vulnerability, the additional complexity does not substantially change the resulting catch advice and increases uncertainty in some management reference points, particularly $F_{40\%}$.
  - Some split-sex results concerning sex-ratio may be modeling artifacts and not data driven, requiring additional model exploration.
  - For 2026 we recommend retaining the single-sex model and continuing to use the survey age-composition estimates produced using tinyVAST.

# Recommendations for November

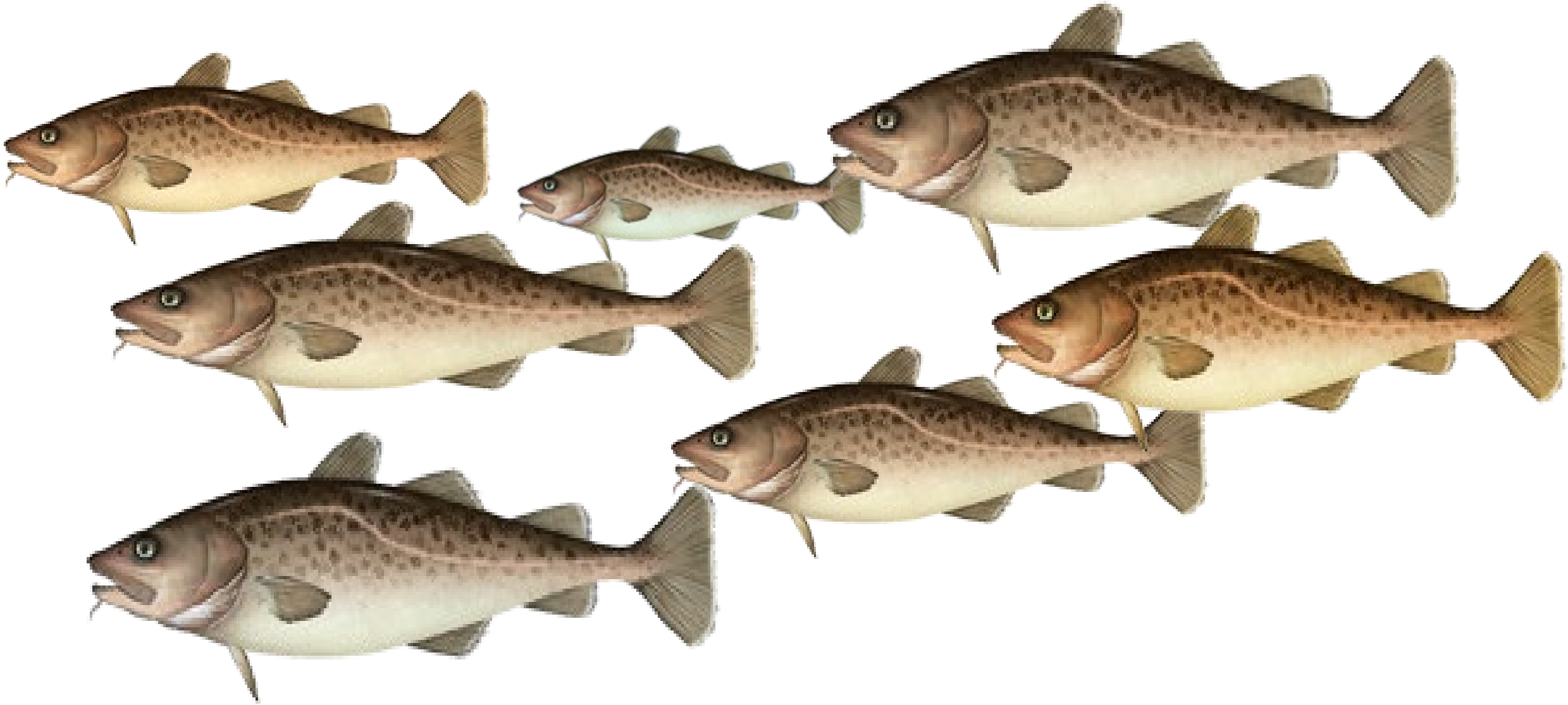
- Proposed one model for review in November
  - Model 26.1– updated data and plus-group 14+

# Data updates for November

- VAST Abundance Index
- VAST Age composition
- Survey and Fishery length composition
- Catch for 2024, 2025, and 2026
- Updated aging error/bias matrix

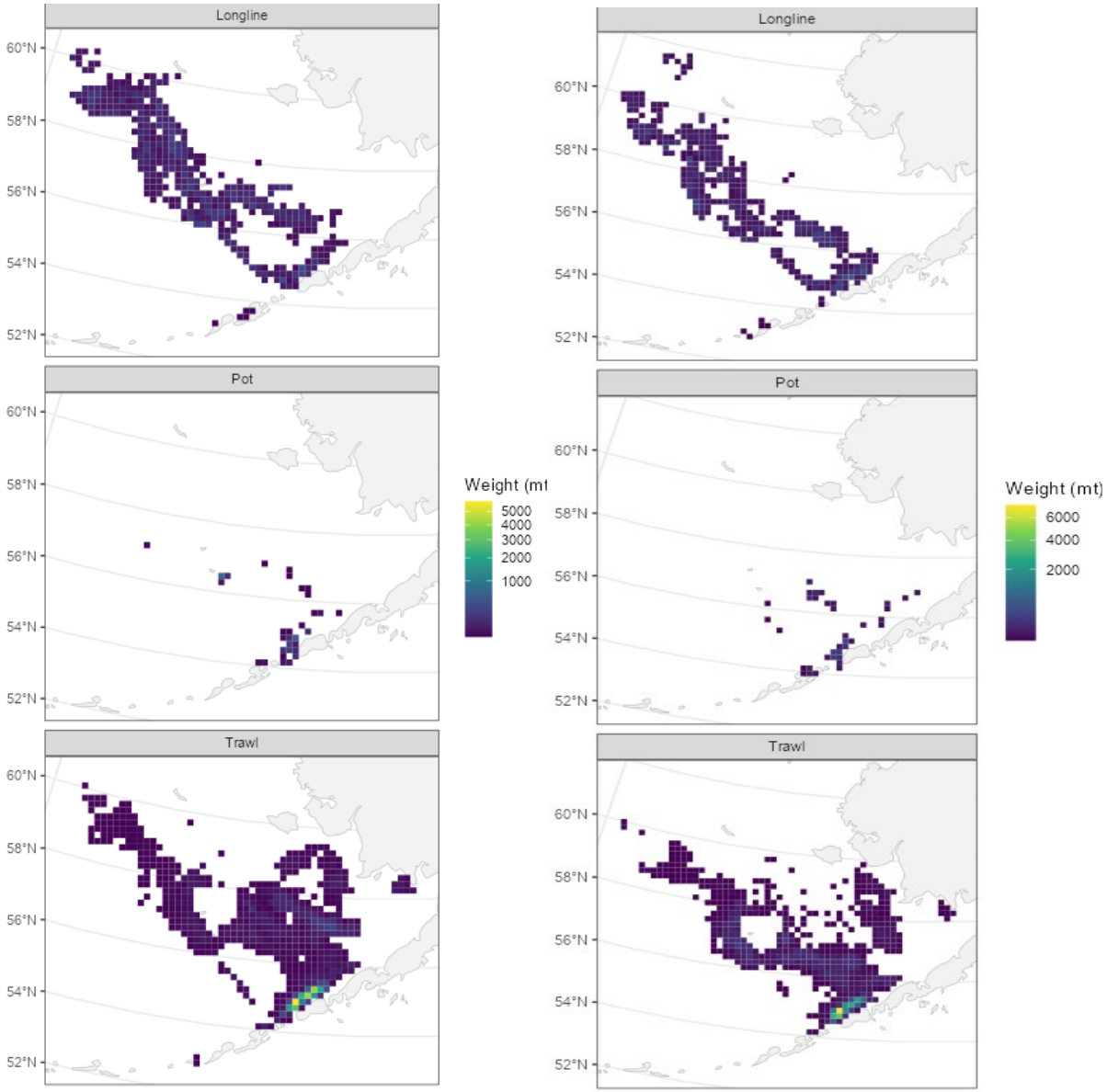


# Extra slides showing 2026 fishery



A Season (Jan-Jun)

2025

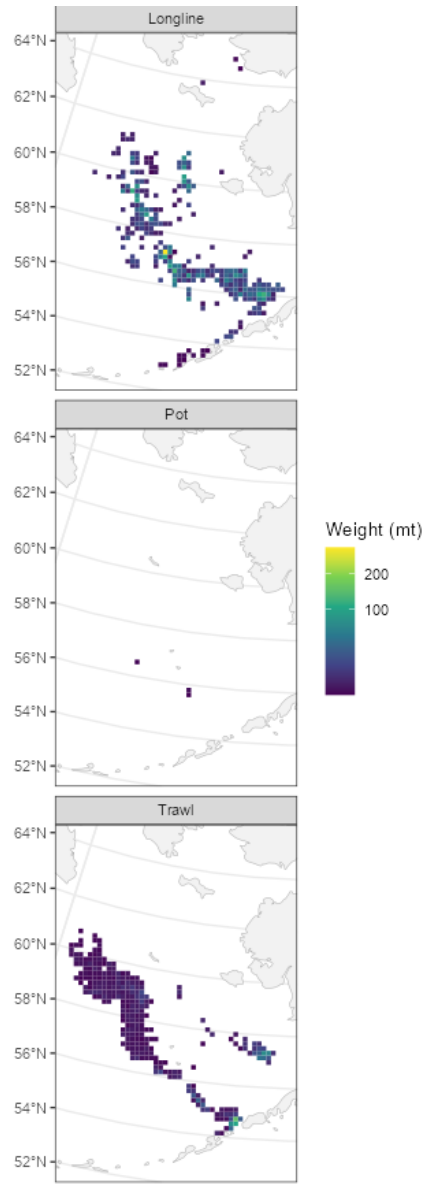



2026

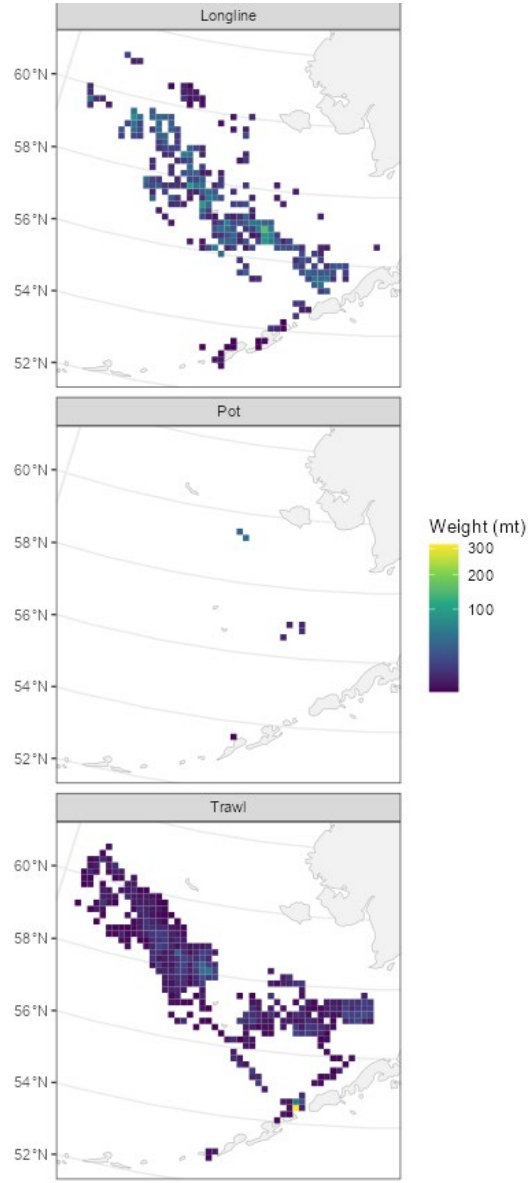



B Season (Jul-Sept 1)

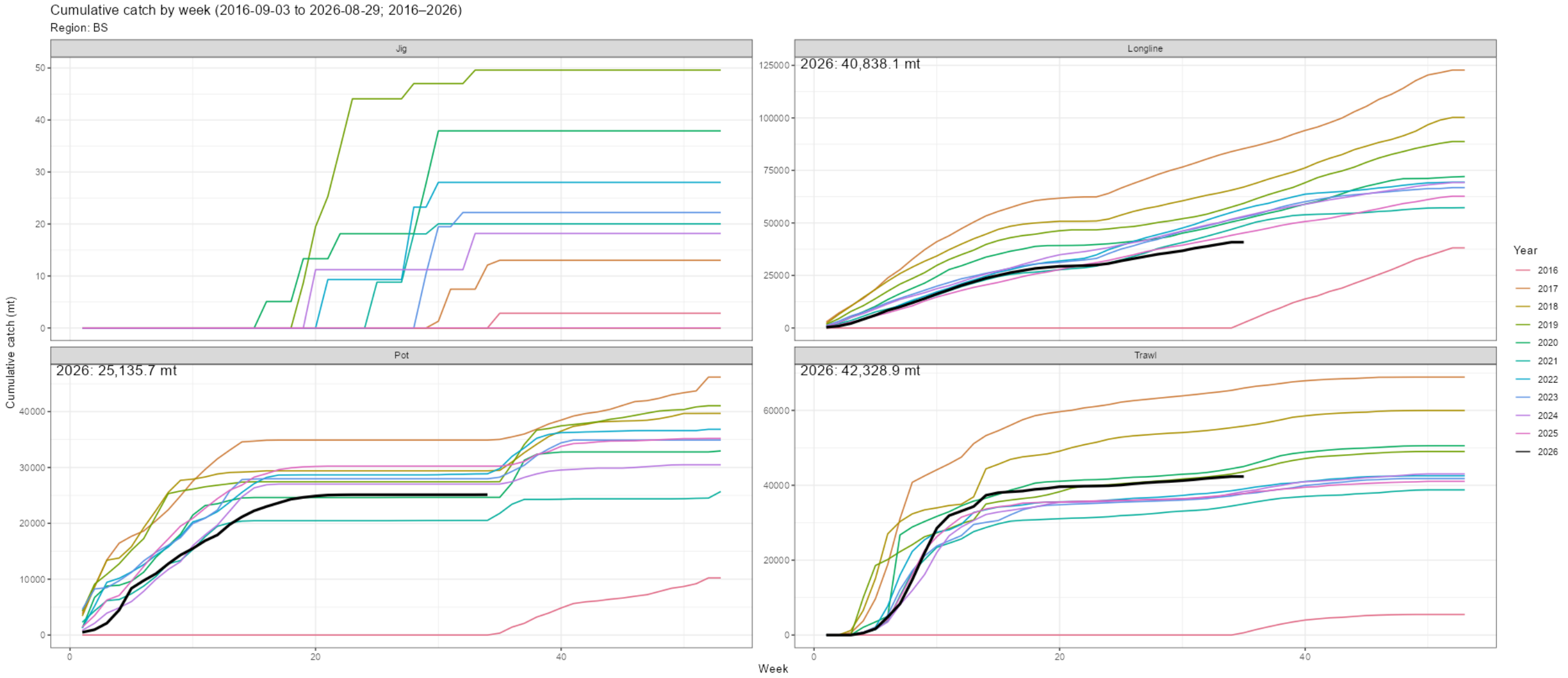
2025




2026



# Cumulative catch through August 28, 2026



# Raw CPUE (data through August 28, 2026)