# Sablefish Bridging Exercise from ADMB to RTMB

## Introduction

The Alaskan sablefish assessment is a separable age- and sex-structured assessment model implemented in the Automatic Differentiation Model Builder [ADMB; Fournier *et al.* (2012)] platform to estimate parameters and provide management advice. However, ADMB is no longer being actively developed. Template Model Builder [TMB; Kristensen *et al.* (2016)] is widely considered the successor to ADMB, offering improved capabilities for estimating random effects through the Laplace approximation. Additionally, TMB models can be written in the R language (RTMB), eliminating the need to develop models using C++ and providing an accessible framework for developing contemporary assessment models. To date, several assessments at the Alaska Fisheries Science Center have successfully transitioned to the TMB or RTMB platforms (Monnahan *et al.*, 2023; Williams *et al.*, 2024).

Several differences between the ADMB and TMB platforms exist, which could lead to variations in parameter estimation. Mainly, unlike ADMB, TMB lacks:

1. Native parameter phasing capabilities, generally requiring all parameters to be estimated simultaneously;
2. Parameter bounds cannot be readily defined;
3. The ability to define a **dev_vector** parameter class, which penalizes a vector to sum to zero;
4. The inclusion of **max** functions, which are commonly used to scale selectivity values in ADMB (though these are likely inappropriate given the non-differentiable nature of the max function).

Note that many of these ADMB capabilities, if used in an assessment, may not be considered 'good' practice.

Here, we present a bridging exercise of the 2024 accepted ADMB model [model 23.5; Goethel and Cheng (2024)] to RTMB. We utilize a generalized stock assessment package, initially developed to account for the inherent complexities associated with sablefish (e.g., sex, fleet, and spatial structure). The Stochastic Population over Regional Components model is completely generalized and capable of accommodating any number of spatial dimensions, ages, sexes, fishery fleets, and survey fleets (https://github.com/chengmatt/SPoRC). Full documentation of the model dynamics and equations are available from https://chengmatt.github.io/SPoRC/articles/c_model_equations.html.

The sablefish model bridging exercise took a step-wise approach and evaluated each individual impact of explicit identified differences between the ADMB and RTMB estimation platforms. We first developed three variants of the ADMB model to sequentially remove ADMB-specific functionality not included in RTMB:

1. Model 23.5: 2024 SAFE model;
2. Model 23.5a: remove the use of the dev_vector type;
3. Model 23.5b: remove the use of the dev_vector type and max function calls.

Model 23.5b, which addresses all of the major difference between estimation platforms, is then compared with a sablefish implementation of SPoRC (RTMB), model 24.1. As noted, SPoRC was initially developed with sablefish in mind, so it was readily able to address existing sex and fleet structure along with parameter sharing, priors, and data fitting assumptions (e.g., sex-aggregated age compositions and sex-disaggregated length compositions). While porting the sablefish ADMB model to SPoRC, a handful of coding bugs and inconsistent modeling decisions were encountered. To ensure an accurate representation of the operational assessment (as adapted for TMB functionality, model 23.5b), the SPoRC source code was updated to be able to retain all aspects of the sablefish model. However, subsequent model updates (see Section 2) aim to address these to provide a more robust sablefish assessment.

Initial comparisons involved first initializing the RTMB model 24.1 using the direct parameter estimates from the ADMB model without performing model optimization. As a kind of self-test, using the same parameter values likely demonstrates whether the two models had identical structural population dynamics. Initial comparisons indicated that differences in model outputs were < 1e-5% (results not shown for brevity), indicating that the underlying population dynamics between the models were equivalent.

In the following, we present comparisons between models 23.5b and 24.1 post-optimization using the same data inputs. The post-optimization comparisons help assess convergence towards similar parameter solutions across estimation platforms. Comparisons focus on differences in likelihood components, time-series quantities of age-2 recruitment (millions) and spawning stock biomass (SSB; kt) along with their estimated standard errors (SE), total fishing mortality (fully selected instantaneous mortality), total female and male abundance (millions of fish), fleet-specific selectivity curves, and key estimates (reference points ($B_{40\%}$ and $F_{40\%}$), fishery and survey catchability, natural mortality, and mean recruitment). All model outputs for each model are available from the 2025 sablefish SAFE Github repository (https://github.com/dgoethel-noaa/2025_Sablefish_SAFE).

**Results and Discussion**

In general, the three ADMB models demonstrate negligible differences in time-series estimates, with results generally remaining on the same scale (Fig. 1). Similarly, comparisons of model 23.5b with the RTMB model 24.1 show negligible differences. In particular, relative differences are all within < 0.001% for likelihood values, time-series estimates, selectivity, and key estimates (including reference points) (Table 1, Figs. 2 – 5). Thus, we conclude that model 23.5b and model 24.1 are essentially identical, providing effectively the same stock status and management advice (Fig. 2 and 5).

Although there are some minor differences between estimation platforms, RTMB's lack of a **dev_vector** class and inability to use **max** functions should not preclude a transition to the platform, given its improved capacity to estimate random effects and ease of implementation. Moreover, recruitment deviates are already constrained to a mean of zero through penalties, and enforcing a sum-to-zero constraint has the potential to introduce irregular behavior in optimization processes. Likewise, **max** functions are theoretically non-differentiable, making their use problematic in automatic differentiation frameworks. Given the close alignment between model 23.5b with the RTMB model 24.1, we propose that the RTMB model 24.1, which provides greater flexibility in exploring alternative model structures (spatial structure, fishery fleets, and survey fleets) and improved capacity for estimating random effects, should be the starting basis for the 2025 sablefish SAFE model development process.

## References


Fournier, D. A., Skaug, H. J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M. N., Nielsen, A., *et al.* 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software, 27: 233–249.

Goethel, D. R., and Cheng, M. L. 2024. 3. Assessment of the Sablefish Stock in Alaska: 119. Accessed from: https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2024/Sablefish.pdf

Kristensen, K., Nielsen, A., Berg, C. W., Skaug, H., and Bell, B. 2016. TMB: Automatic Differentiation and Laplace Approximation. Journal of Statistical Software, 70.

Monnahan, C. C., Adams, G. D., Ferriss, B. E., Shotwell, S. K., McKelvey, D. R., and McGowan, D. W. 2023. 1. Assessment of the Walleye Pollock Stock in the Gulf of Alaska: 128. Accessed from: https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2023/GOApollock.pdf

Williams, B. C., Hulson, P.-J. F., and Ferris, B. E. 2024. 10. Assessment of the Northern Rockfish Stock in the Gulf of Alaska. Accessed from: https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2024/GOAnork.pdf

## Tables

**Table 1.** Likelihood values for model 23.5b and the RTMB model 24.1 (post-optimization). Difference is calculated as ADMB – RTMB, while relative difference is calculated as (ADMB – RTMB) / ADMB.

| Likelihood Component | ADMB (model 23.5) | RTMB (model 24.1) | Difference | Relative Difference (%) |
|---|---|---|---|---|
| jnLL | 768.83 | 768.83 | 0.00 | 0.00 |
| Fixed Gear Fishery Age | 46.63 | 46.63 | 0.00 | 0.00 |
| Fixed Gear Fishery Length (F) | 85.55 | 85.55 | 0.00 | 0.00 |
| Fixed Gear Fishery Length (M) | 91.07 | 91.07 | 0.00 | 0.00 |
| Trawl Gear Fishery Length (F) | 25.46 | 25.46 | 0.00 | 0.00 |
| Trawl Gear Fishery Length (M) | 17.90 | 17.90 | 0.00 | 0.00 |
| Domestic Survey LL Age | 173.99 | 173.99 | 0.00 | 0.00 |
| Domestic Survey LL Length (F) | 48.07 | 48.07 | 0.00 | 0.00 |
| Domestic Survey LL Length (M) | 34.74 | 34.74 | 0.00 | 0.00 |
| Domestic Trawl Survey Length (F) | 23.12 | 23.12 | 0.00 | 0.00 |
| Domestic Trawl Survey Length (M) | 17.64 | 17.64 | 0.00 | 0.00 |
| Japanese LL Survey Length (F) | 27.92 | 27.92 | 0.00 | 0.00 |
| Japanese LL Survey Length (M) | 17.54 | 17.54 | 0.00 | 0.00 |
| Catch | 3.67 | 3.67 | 0.00 | 0.00 |
| Domestic LL Survey Index | 33.76 | 33.76 | 0.00 | 0.00 |
| Japanese LL Survey Index | 10.16 | 10.16 | 0.00 | 0.00 |
| Trawl Survey Index | 20.56 | 20.56 | 0.00 | 0.00 |
| Domestic LL Fishery Index | 13.49 | 13.49 | 0.00 | 0.00 |
| Japanese LL Fishery Index | 24.23 | 24.23 | 0.00 | 0.00 |
| FMort Penalty | 6.09 | 6.09 | 0.00 | 0.00 |
| M Prior | 0.79 | 0.79 | 0.00 | 0.00 |
| Rec Penalty | 23.27 | 23.27 | 0.00 | 0.00 |

## Figures

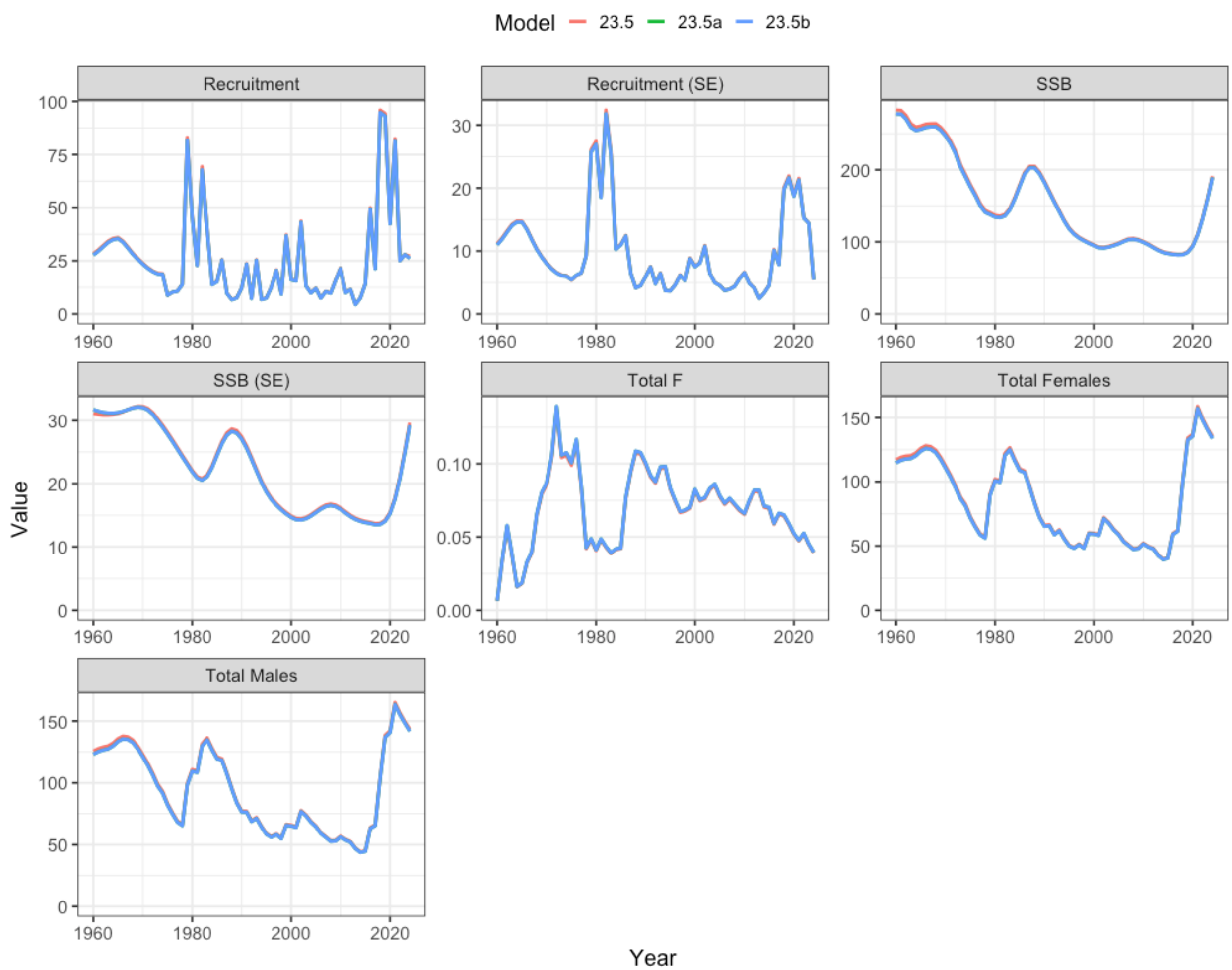


**Figure 1**. Comparisons of time-series estimates among the ADMB model variants. Model 23.5 (red) is the 2024 operational assessment, model 23.5a is the operational assessment without the dev_vector class, and model 23.5b is the operational assessment without the dev_vector class and max function calls.

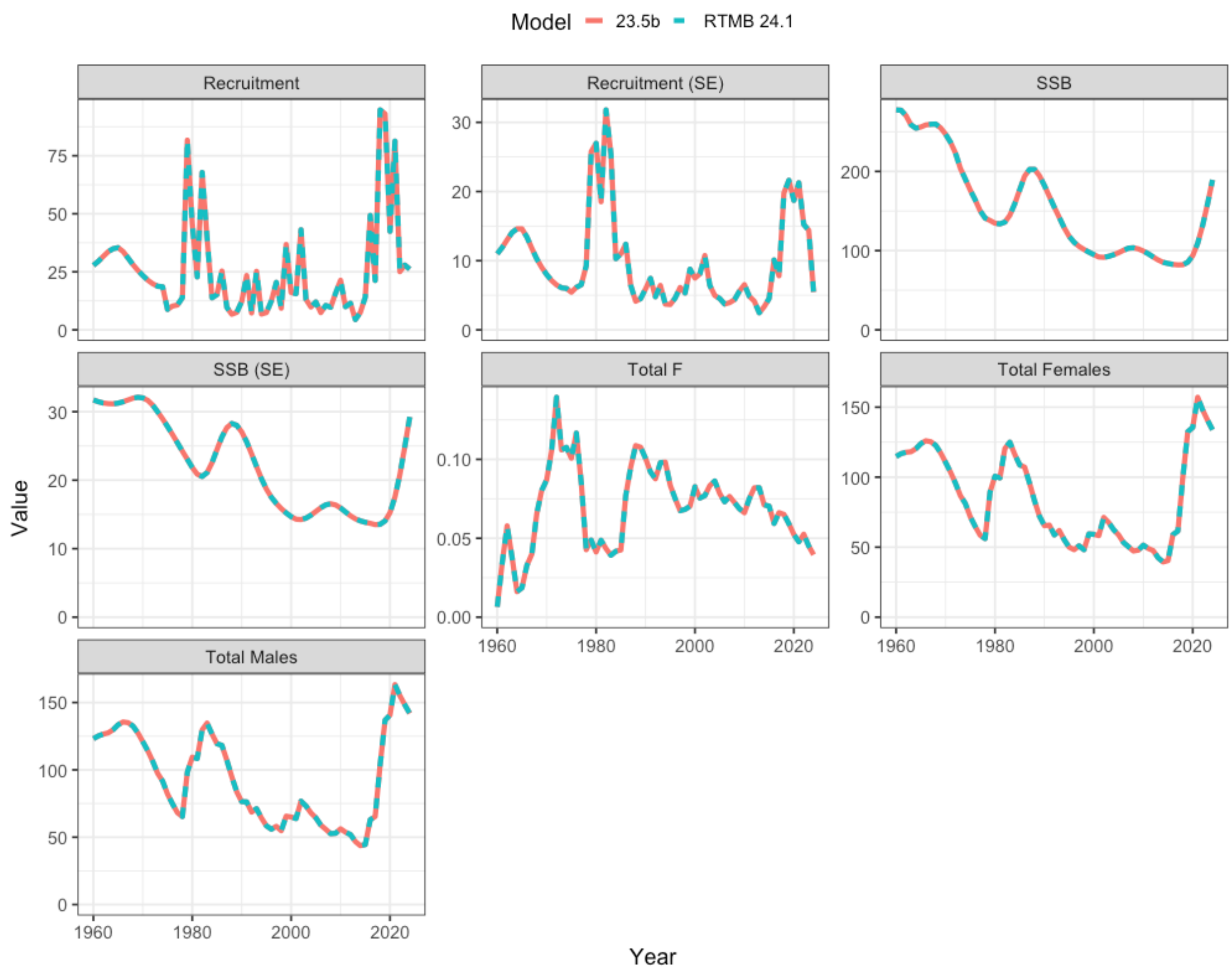


**Figure 2.** Comparison of time-series quantities (post-optimization) between model 23.5b and the RTMB model 24.1. Dashed blue lines indicate the RTMB model 24.1, while the red line denotes model 23.5b. Note that time-series estimates from the two models are overlaid essentially atop of each other.

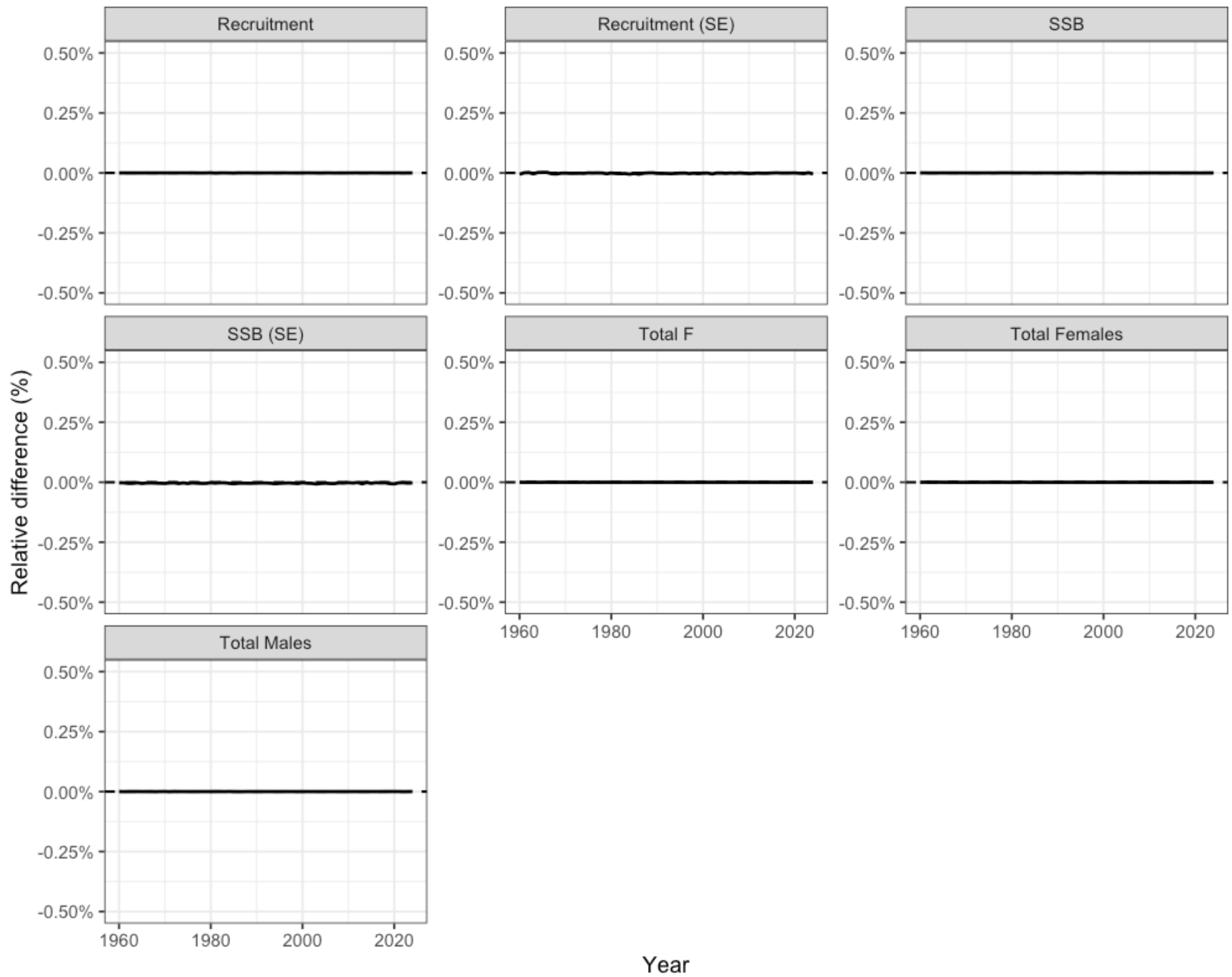


**Figure 3**. Relative percent difference ((ADMB - RTMB) / ADMB) in time-series quantities between model 23.5b and the RTMB model 24.1. The black dashed horizontal line indicates 0% difference between models.

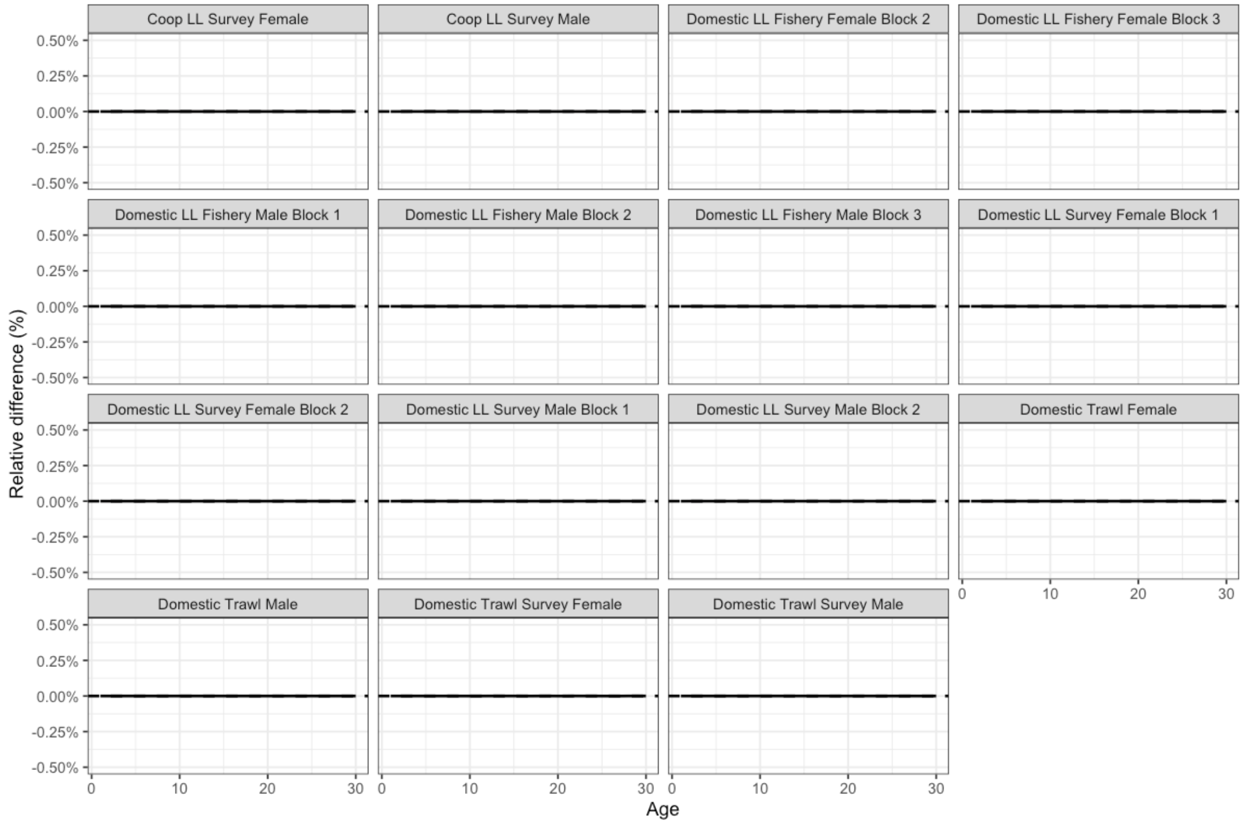


**Figure 4.** Relative percent difference ((ADMB - RTMB) / ADMB) in selectivity values between model 23.5b and the RTMB model 24.1. The black dashed horizontal line indicates 0% difference between models.

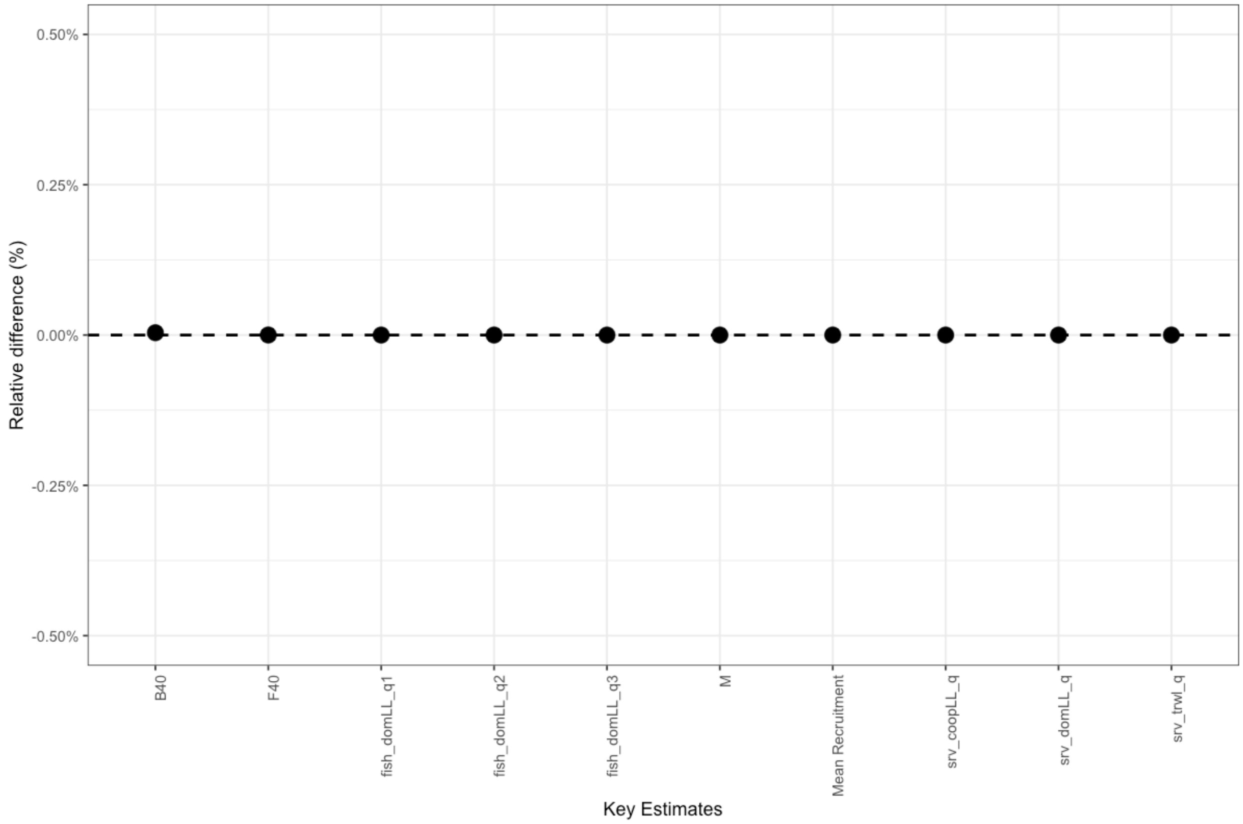


**Figure 5.** Relative percent difference ((ADMB - RTMB) / ADMB) in key parameter estimates between model 23.5b and the RTMB model 24.1. The black horizontal line indicates 0% difference between models.