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Identification and performance of stock-recruitment functions in state space assessment models

Working Paper 1

Greg Britten, Liz Brooks, Tim Miller

2024-02-07

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Background

Introduction

- State Space Research Track Working Group (SSRTWG) is investigating performance of the Woods Hole Assessment Model (WHAM)
 - Simulation studies with data generated from operating models (OMs), then fit with a series of estimation models (EMs)
 - This framework allows us to evaluate how the EM fits compare to the known OM “true values”, evaluate model selection, bias, precision, etc.

Terms of Reference (TORs) Addressed

- TOR 2: Investigate the efficacy of estimating stock-recruit functions within state-space models and their utility in generating scientific advice.
- TOR 3: Develop guidelines for including ecosystem and environmental effects in assessment models and how to treat them for generating biological reference points and scientific advice.

Outline

- 'Stock' parameters, fishery and index parameters
- OM factors and simulated data examples
- EM models
- Beta standardization
- Analysis & Results
- Conclusions
- Future Work

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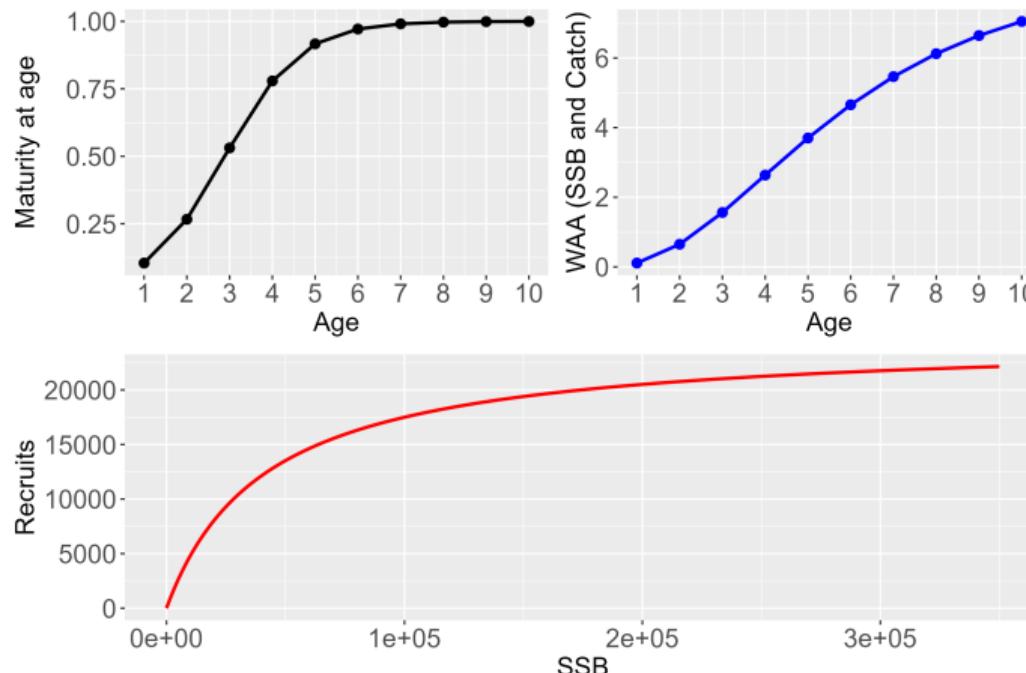
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Stock parameters for generic gadid



- Natural mortality = 0.2 at all ages
- Maturity, weight, natural mortality are time-invariant

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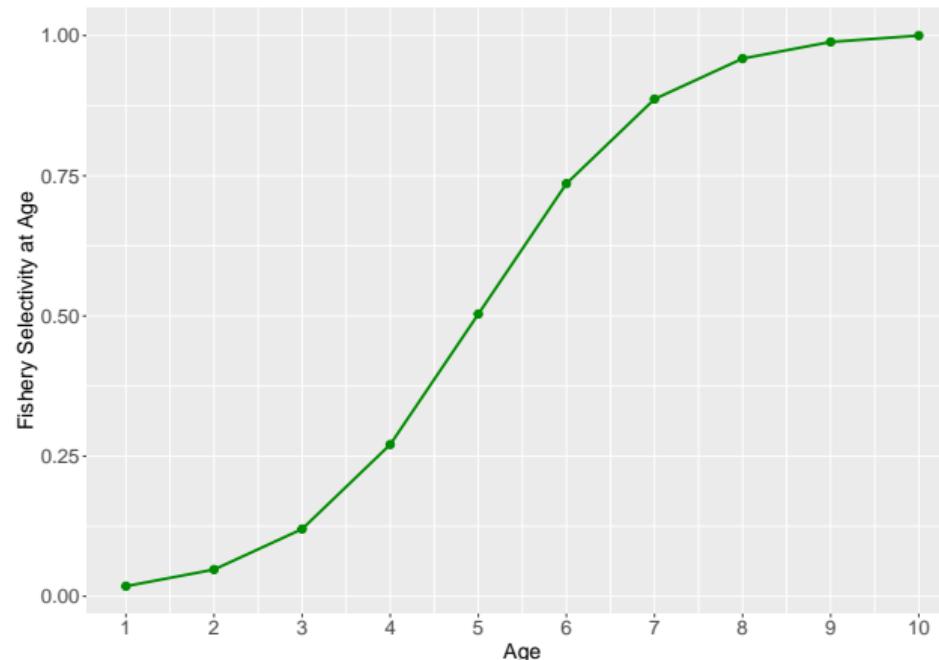
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Fishery and index parameters



- two fishery independent indices were also generated, taking place at 0.25, 0.75 yr
- catchability for both indices was 0.3; selectivity was same as fishery

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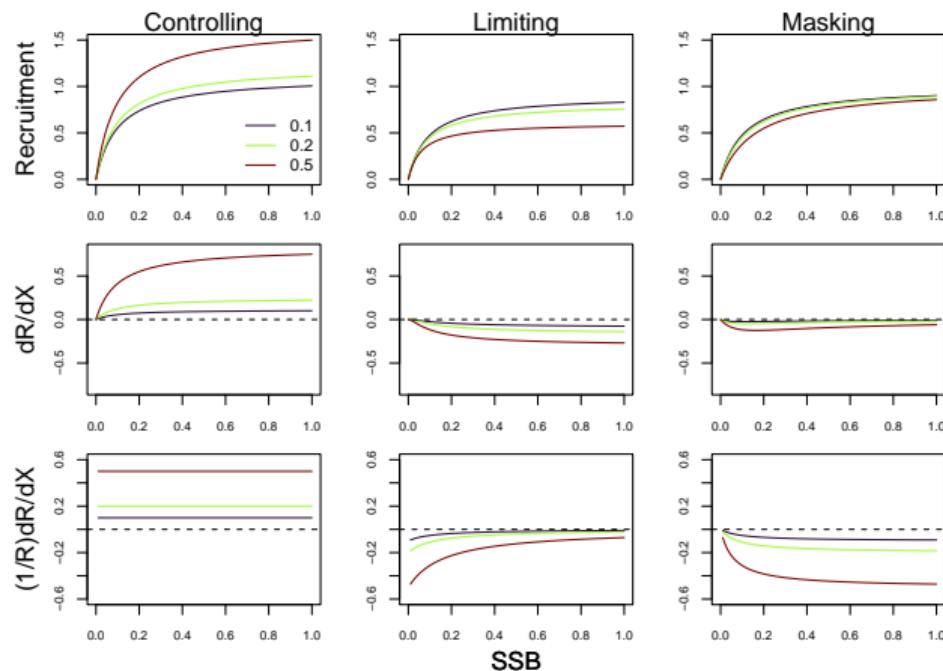
OM factors and simulated data examples

Fhistory	R_sigma	R_cor	Ecov_effect	Ecov_cor	Obs_error
H-MSY	0.1	0.2	0.1	0.2	L
MSY	1	0.8	1	0.8	H

- These levels were combined factorially with 4 stock recruit models (all Beverton-Holt) for 256 different OM
- Factors that did not vary were the observation and process error of the Ecov (both fixed at 0.1)

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OM factor: Beverton-Holt functional (1 with no Ecov effect, 3 with effect)



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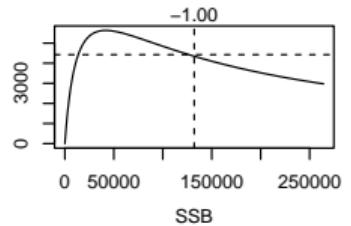
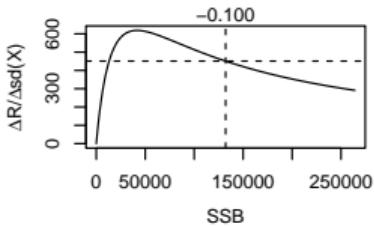
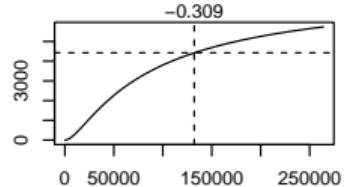
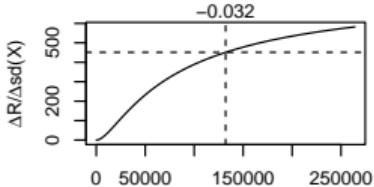
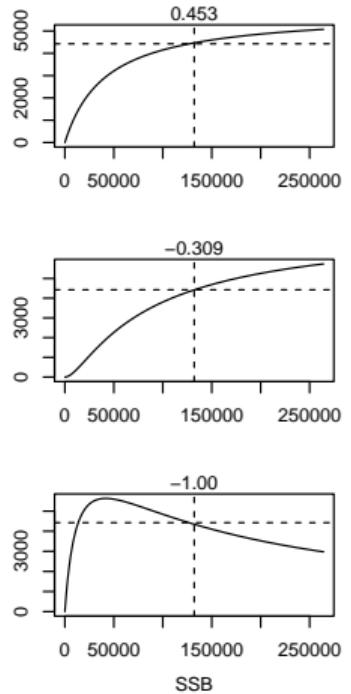
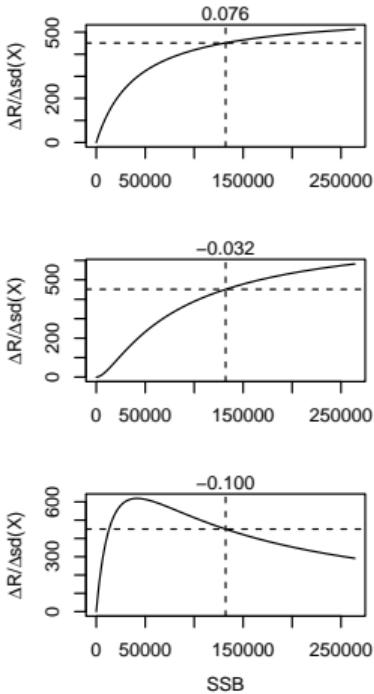
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OM factor: Beta standardization



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Some Example OM Simulated Data (100 data sets for each OM)

- still need to make this

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EM

EM models

- All OMs used Beverton-Holt stock recruit relationship (SRR)
- For the EMs, we also fit a mean SRR with random effects
- There were 6 total EMs fit to each simulated data set (100) for all 256 OMs
- 153,600 fitted models X 2 for β unstandardized and β standardized cases

EM	SRR	Ecov.How	Ecov	EM_mod
1	Mean		0 None	Mean_0
2	Mean		1 Controlling	Mean_1
3	BH		0 None	BH_0
4	BH		1 Controlling	BH_1
5	BH		2 Limiting	BH_2
6	BH		4 Masking	BH_4

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Analysis & Results

Analyses

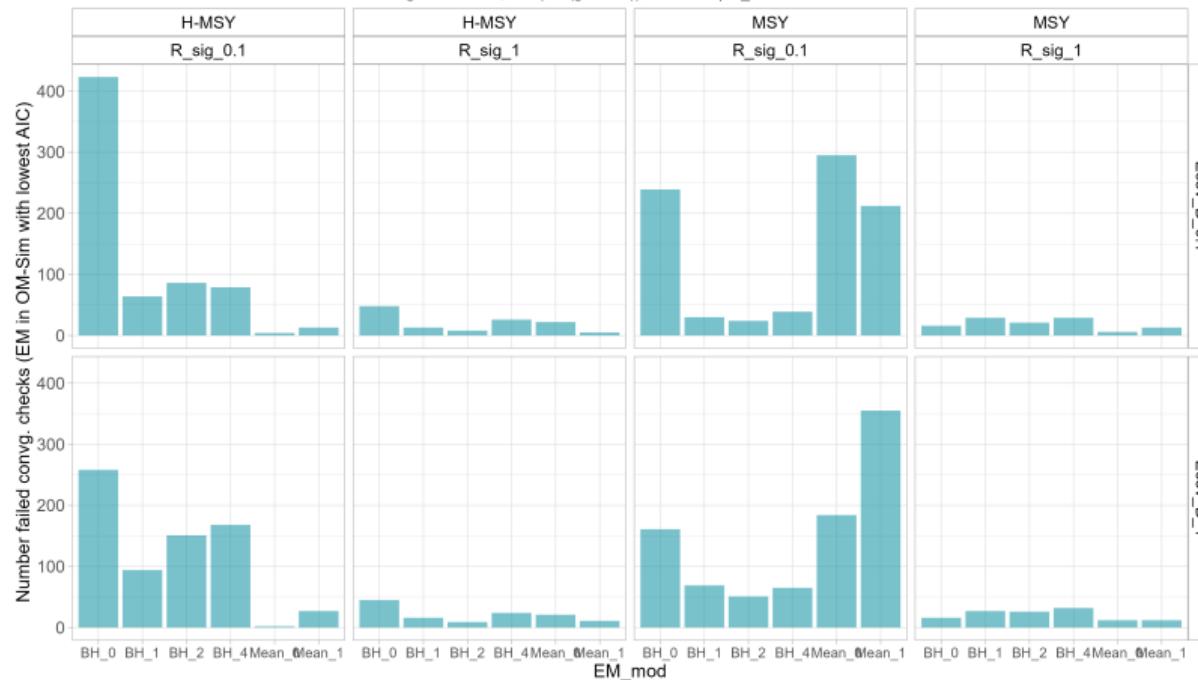
1. Convergence of the estimating models
2. Model identifiability of an underlying stock recruitment model and/or an underlying relationship between environmental covariate
3. ΔAIC and model probability
4. Assessment error (recruitment, spawning stock biomass, and Fbar)
5. Bias of estimated parameters
6. Mohn's ρ
7. Projection performance relative to assumptions about the environmental covariate
 - Results will be shown for β unstandardized case, because β standardization had no appreciable effect
 - Most results summarized by relative error (RE): $(\text{Est}-\text{True})/\text{True}$

Convergence Criteria

1. the optimization routine (`stats::nlminb`) completed without error
 2. the `stats::nlminb` convergence flag = 0 indicated successful convergence
 3. the maximum absolute value of the gradient of the log-likelihood is $< 1e-6$
 4. `TMB::sdreport` provided non-NA values for all fixed effects standard errors
 5. `TMB::sdreport` provided all standard errors < 100
- Models not satisfying all of these conditions were dropped from Results summaries

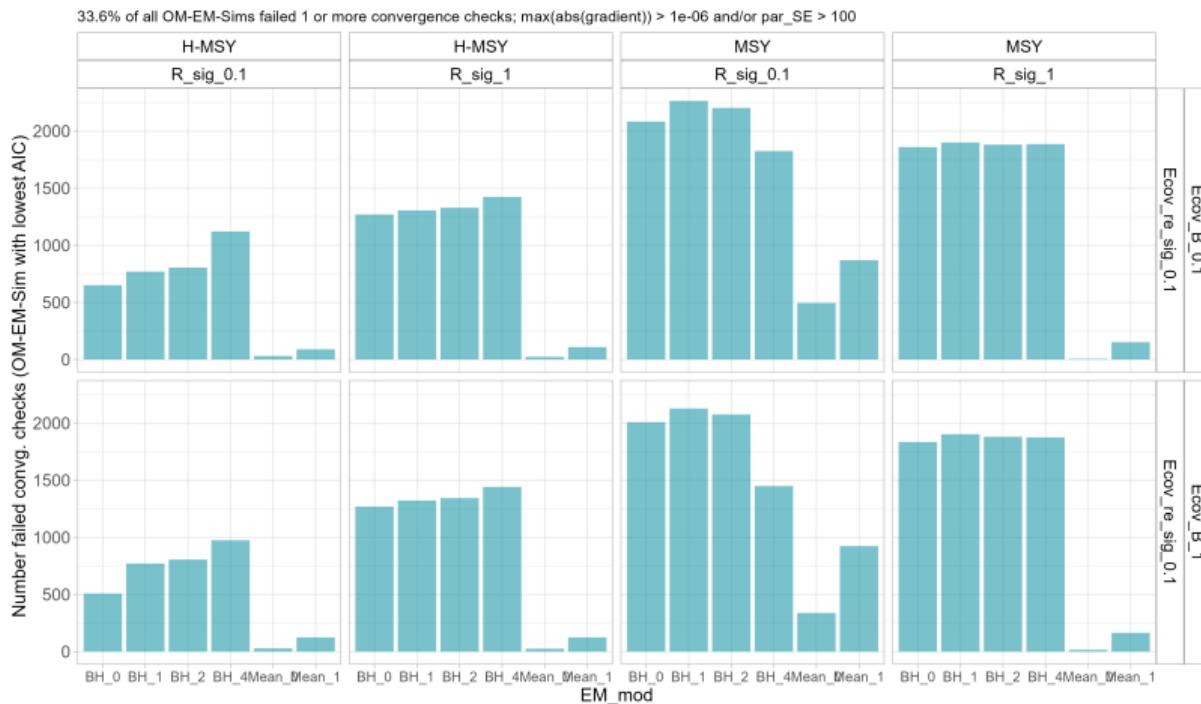
Unconverged Models (from EM having 'best' EM per OM-Simulation)

14% of lowest AIC model failed 1 or more convergence checks; $\max(\text{abs}(\text{gradient})) > 6$ and/or $\text{par_SE} > 100$



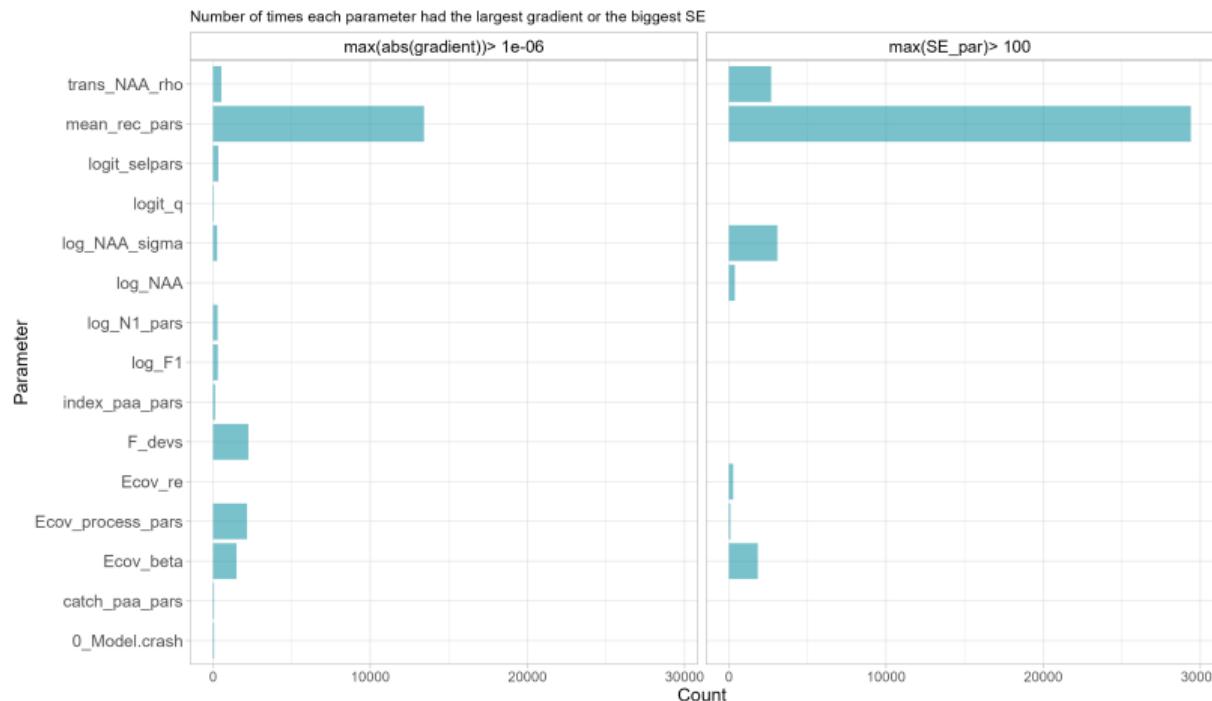
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Unconverged Models (considering all EMs per OM-Simulation)



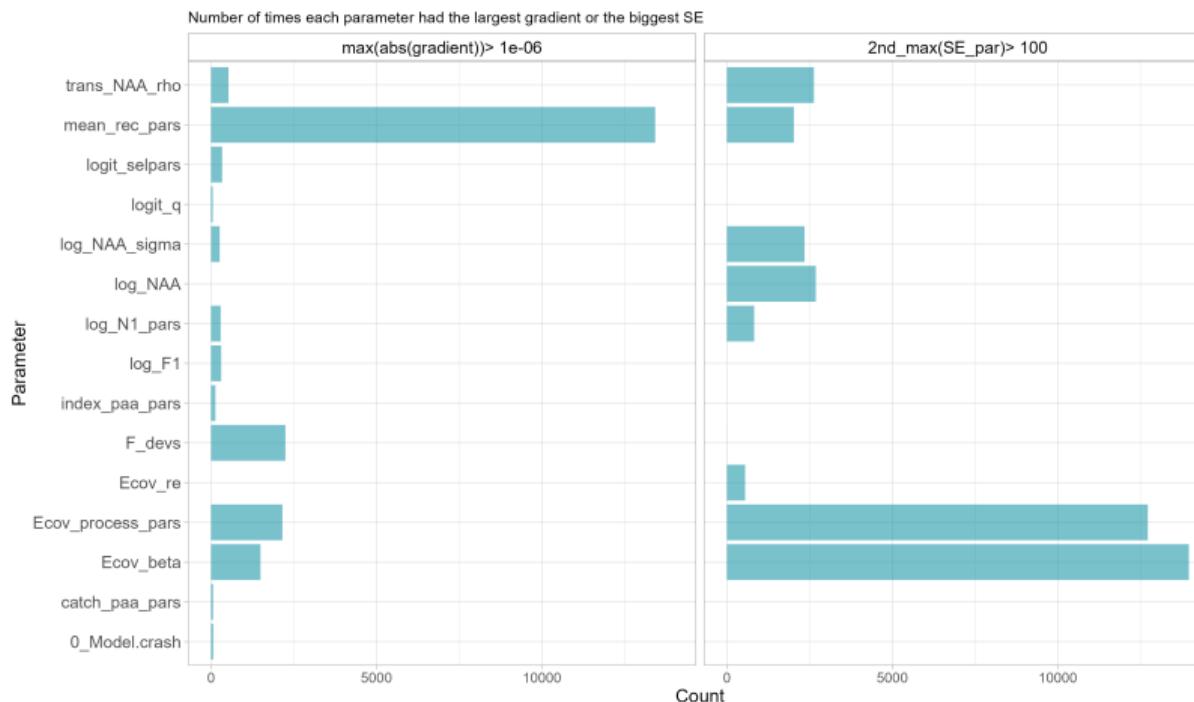
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Unconverged Model - The Offending Parameters



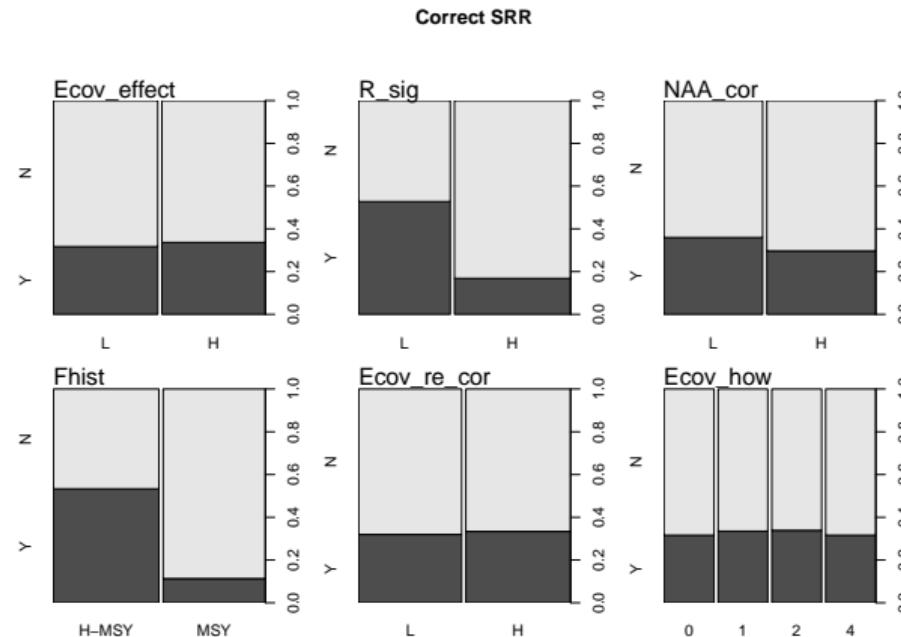
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Unconverged Model - Even More Offending Parameters



Model Identifiability - Marginal barplots for SRR

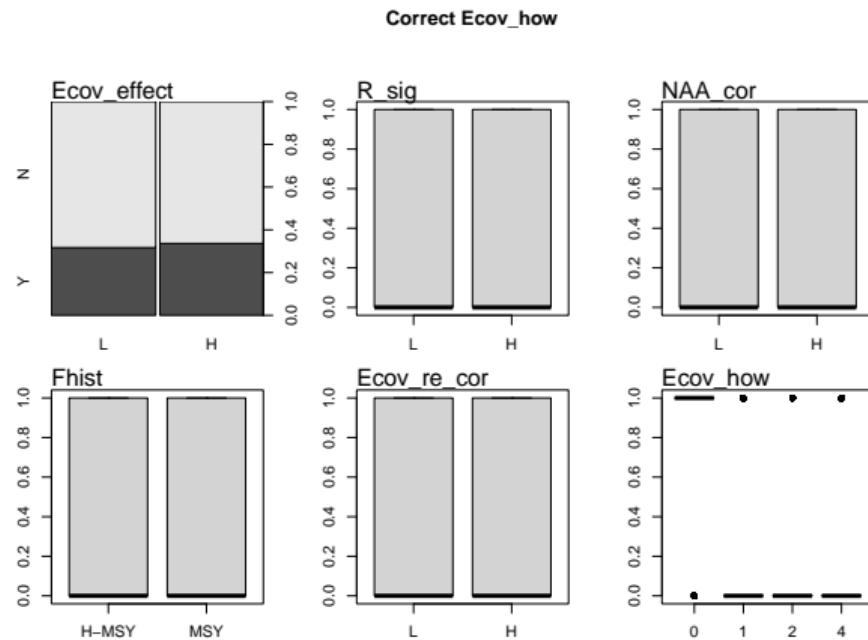
- Marginal univariate model selection results for whether an SRR relationship was correctly identified (indicated by dark shaded regions)



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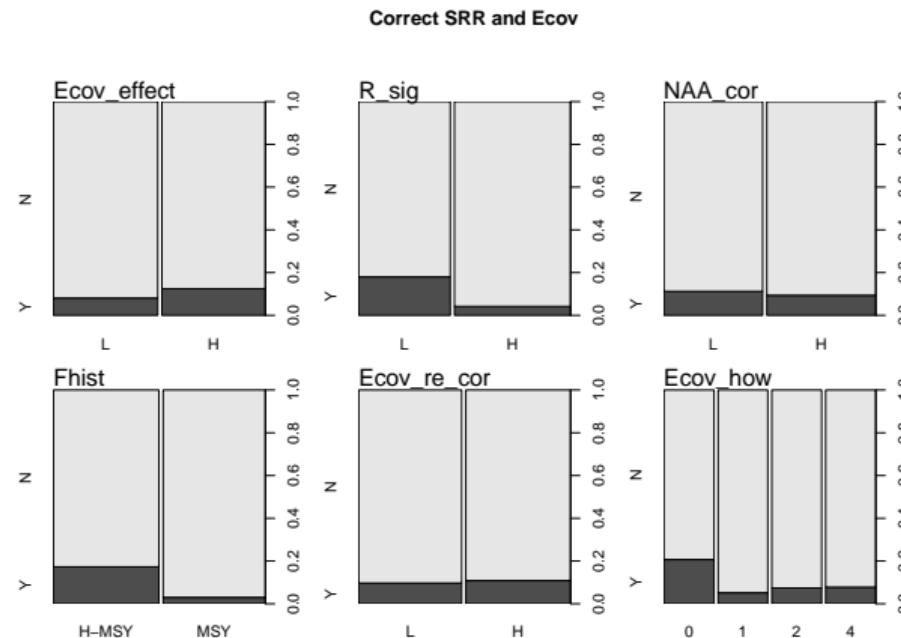
Model Identifiability - Marginal barplots for Ecov.How

- Marginal univariate model selection results for whether an Ecov was correctly identified (indicated by dark shaded regions)



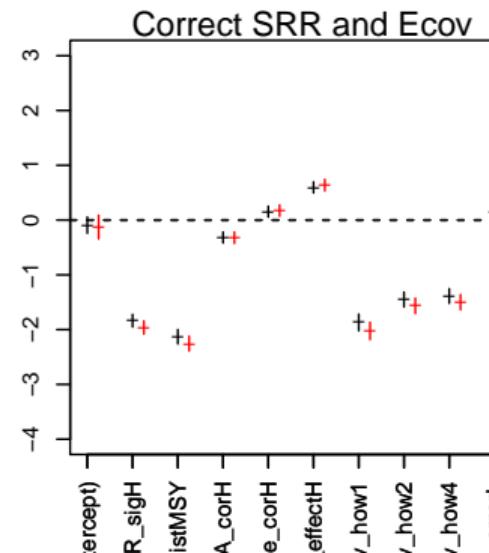
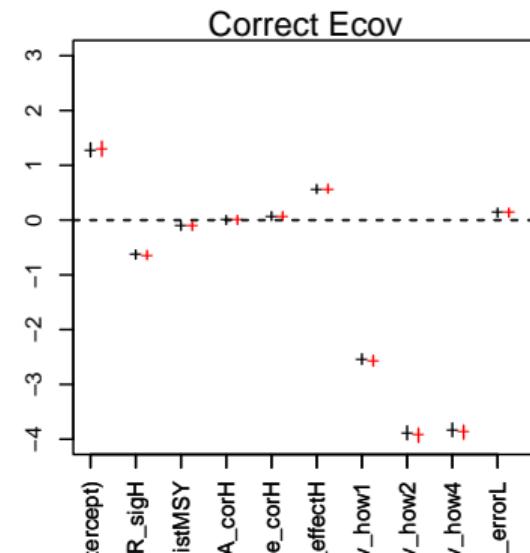
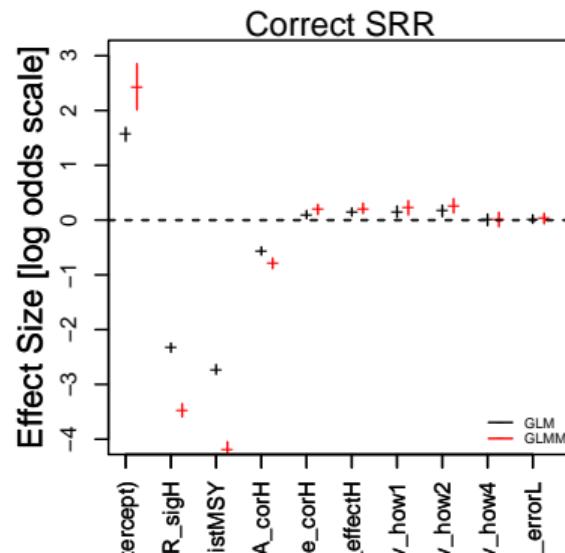
Model Identifiability - Marginal barplots for both SRR & Ecov.How

- Marginal univariate model selection results for whether the SRR AND Ecov were both correctly identified (indicated by dark shaded regions)



Model Identifiability - Effect size

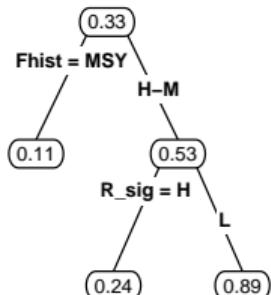
- Effect sizes for proportion correctly identified using a binomial generalized linear model and a binomial generalized linear mixed model with simulation random number seed as a random intercept



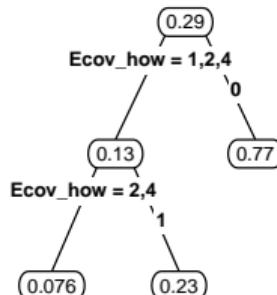
Model Identifiability - Classification tree for identifying EM = OM

- Classification tree analysis of model selection results, with default settings in R package 'rpart'. The complexity parameter is set at $cp = 0.01$, which represents the minimum classification improvement required for any split.

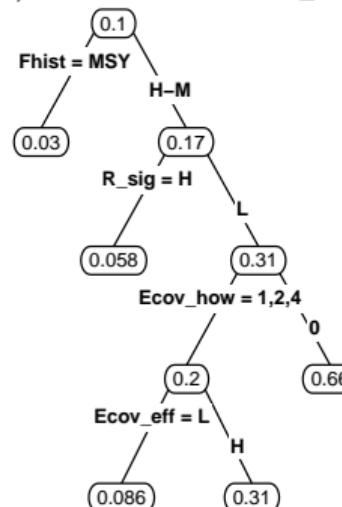
a) correct SRR



b) correct Ecov.How



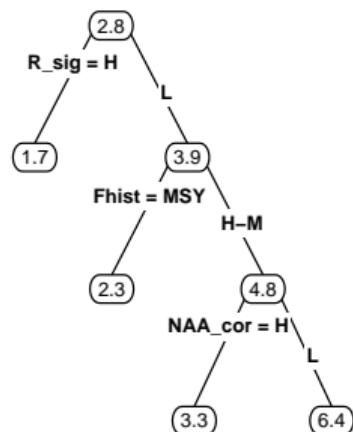
c) correct SRR and Ecov.How



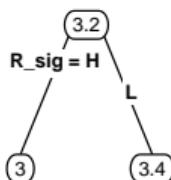
ΔAIC and model probability - Classification tree

- Classification tree analysis of for the difference in AIC among EMs, the rank of EMs, and the model probability of EMs (calculated from Akaike weights).

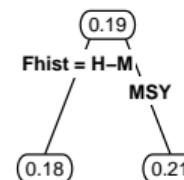
a) dAIC



b) AIC rank

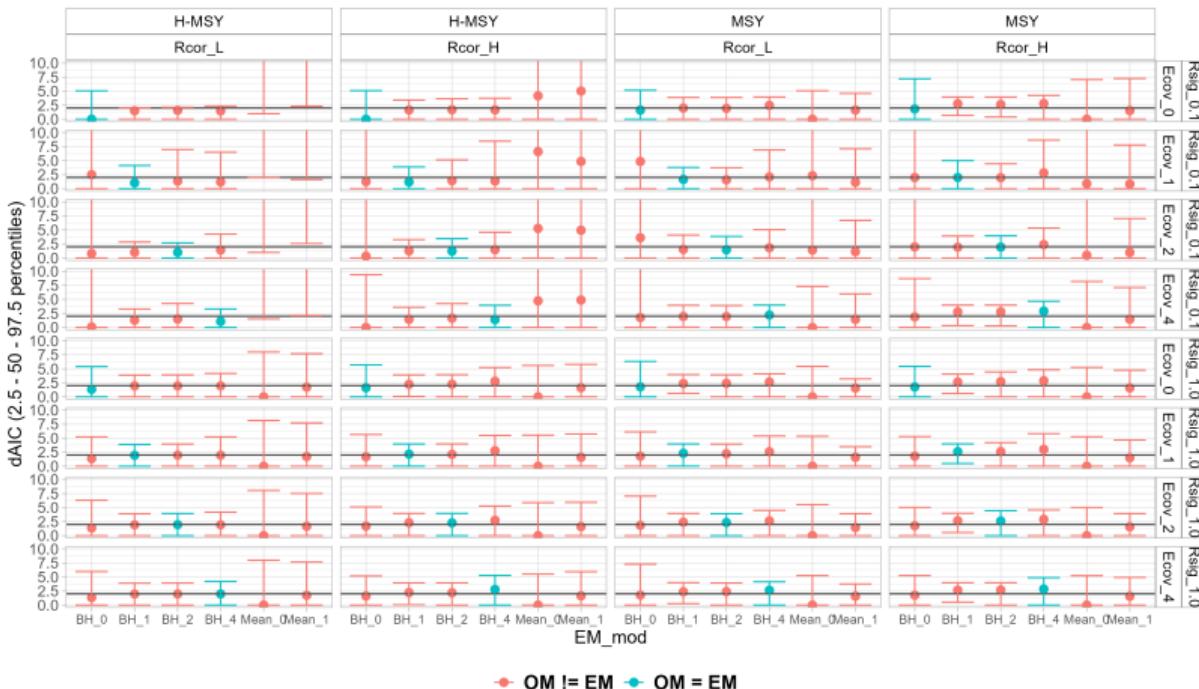


c) Model probability



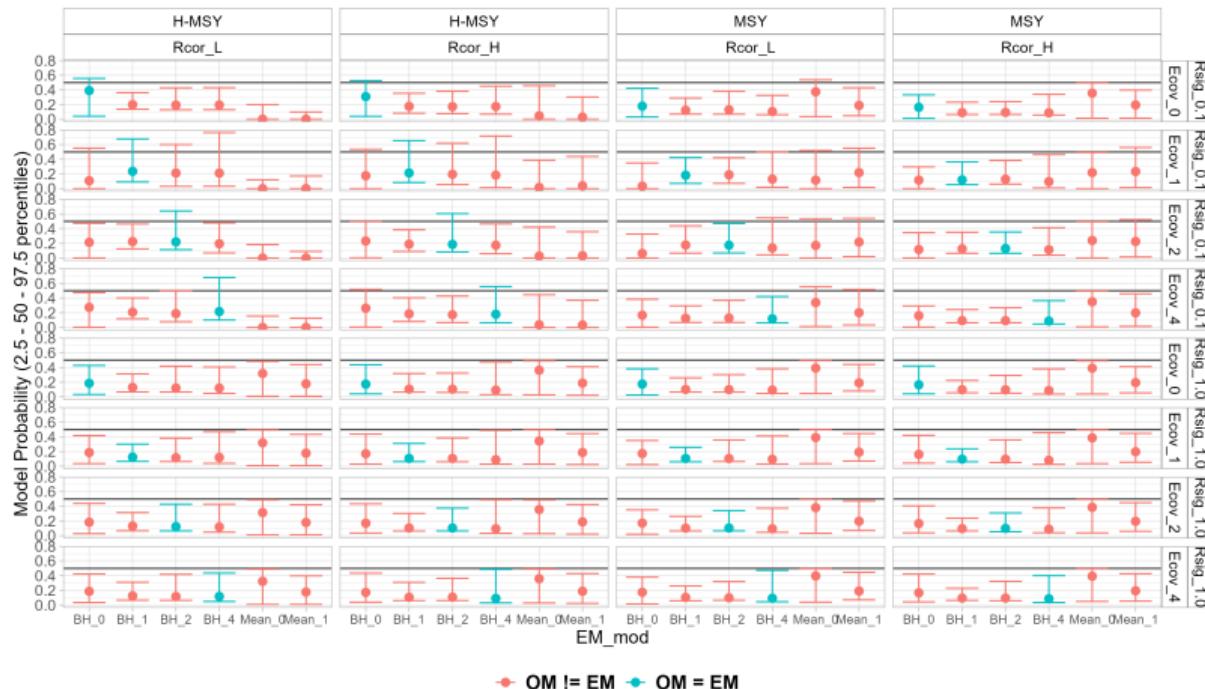
ΔAIC - Median and 95% probability interval

- Median difference in AIC (filled circle) with 2.5th and 97.5th percentiles; horizontal line at 2 for reference



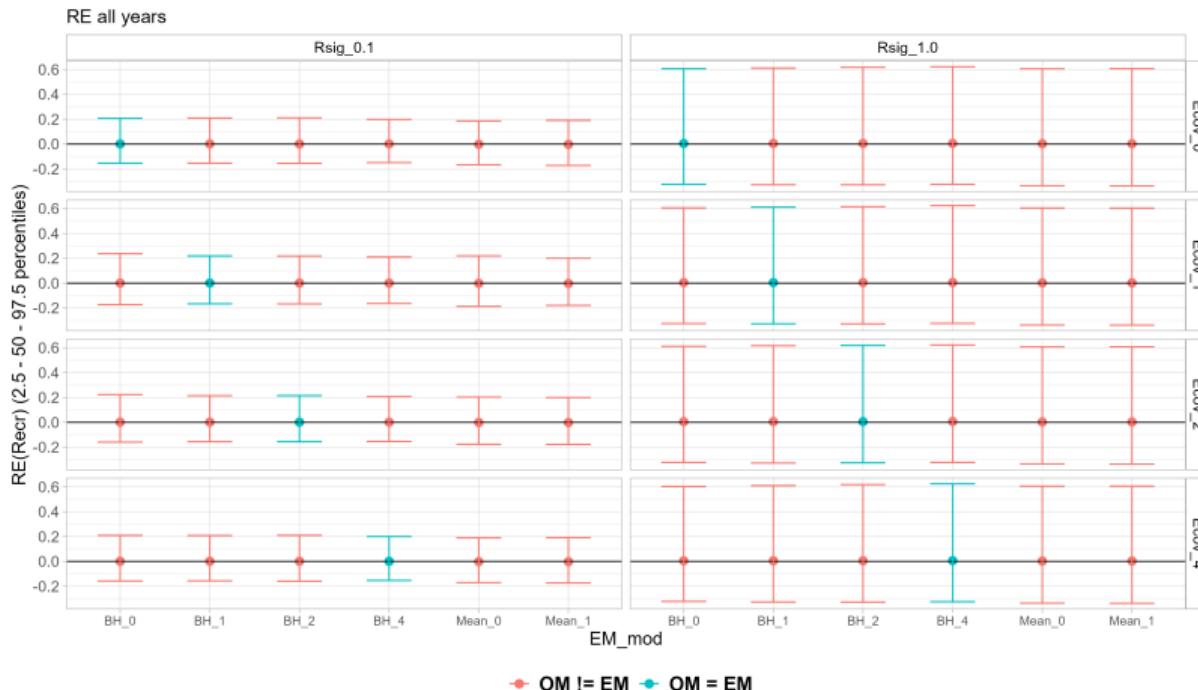
Model probability - Median and 95% probability interval

- Median model probability (filled circle) with 2.5th and 97.5th percentiles; horizontal line at 0.5 for reference



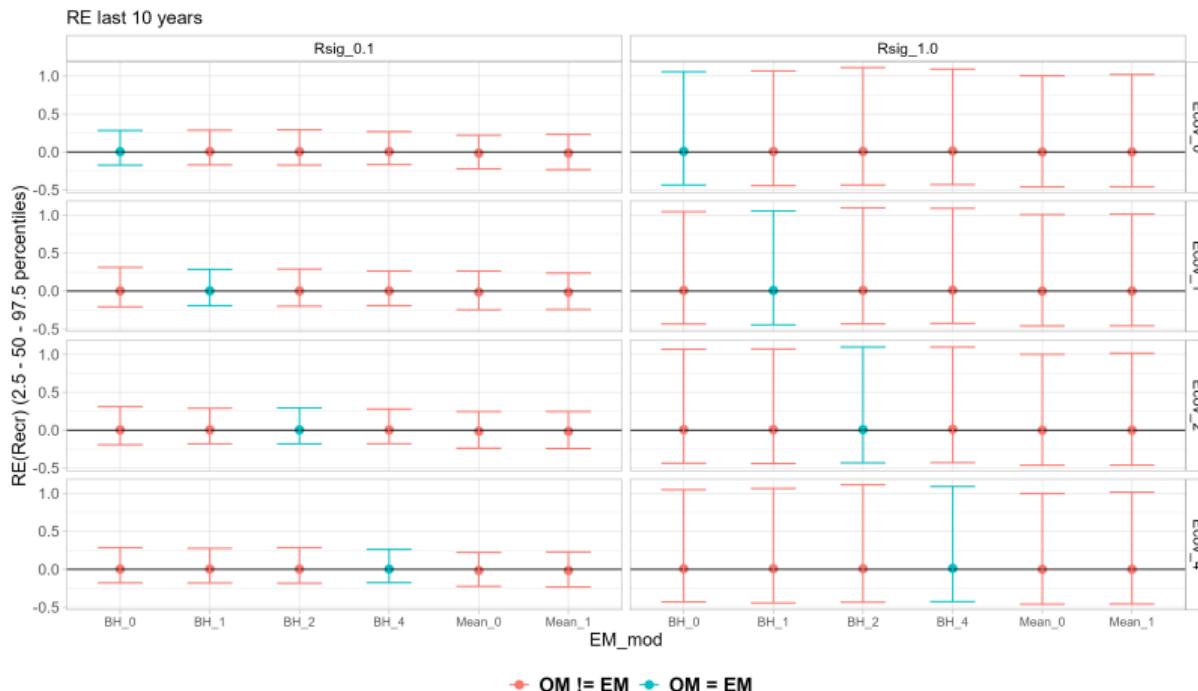
Assessment error - Recruitment (all years)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



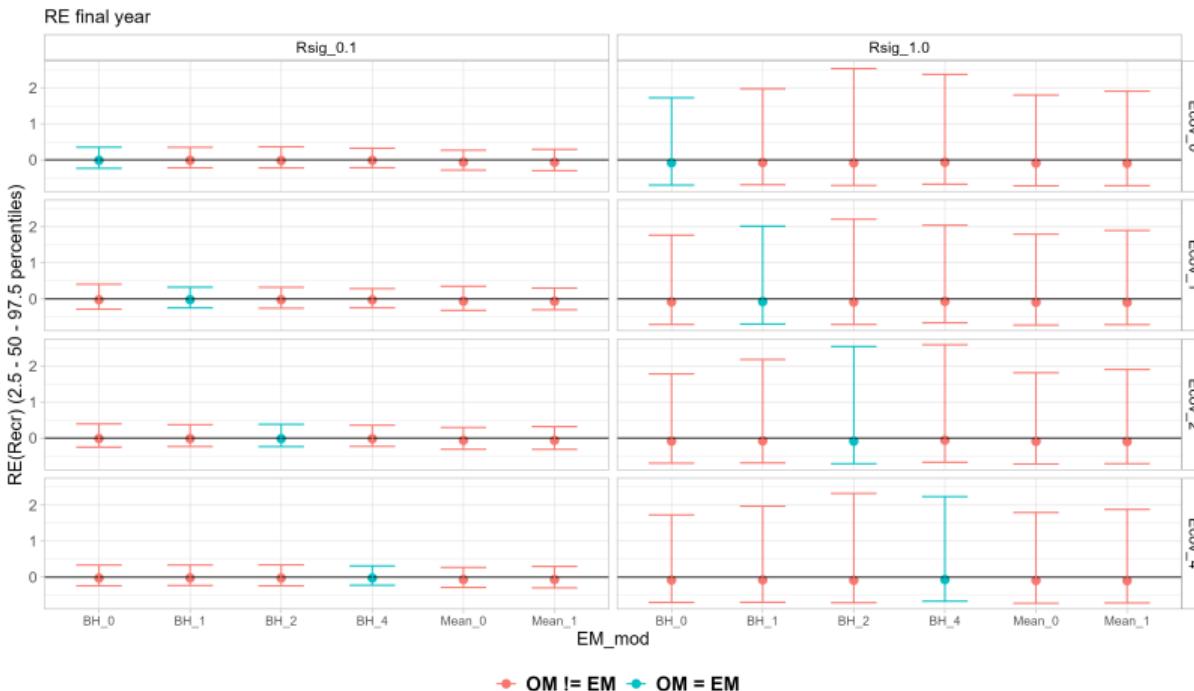
Assessment error - Recruitment (last 10 years)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



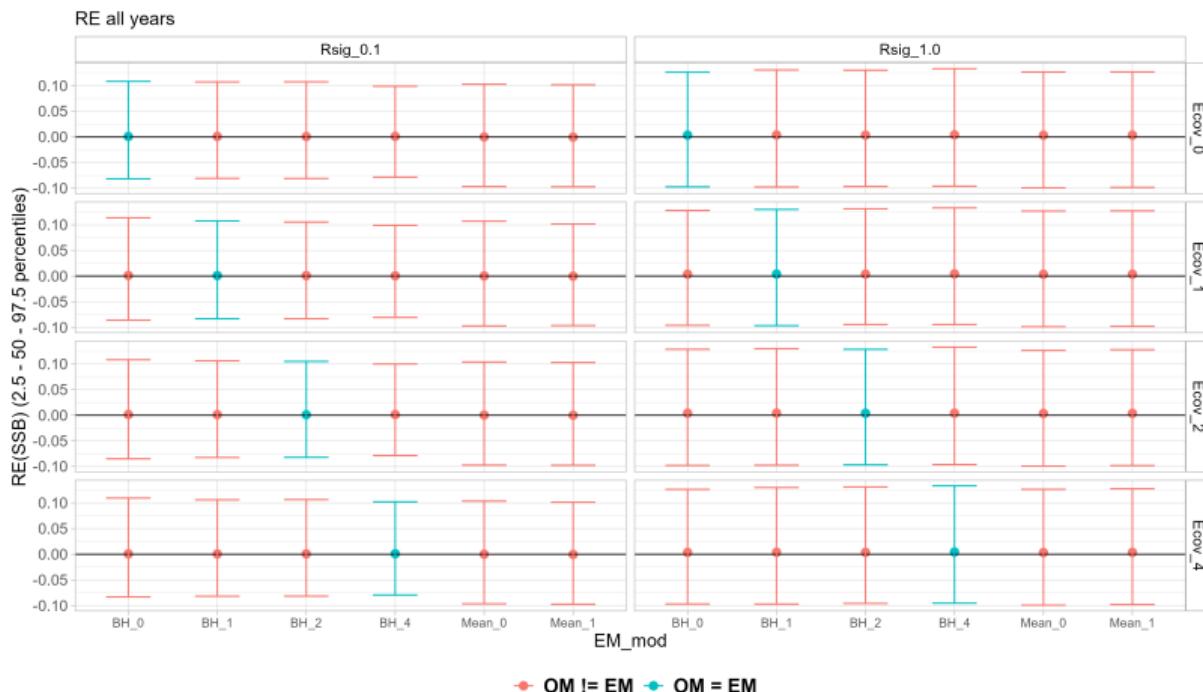
Assessment error - Recruitment (terminal year)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



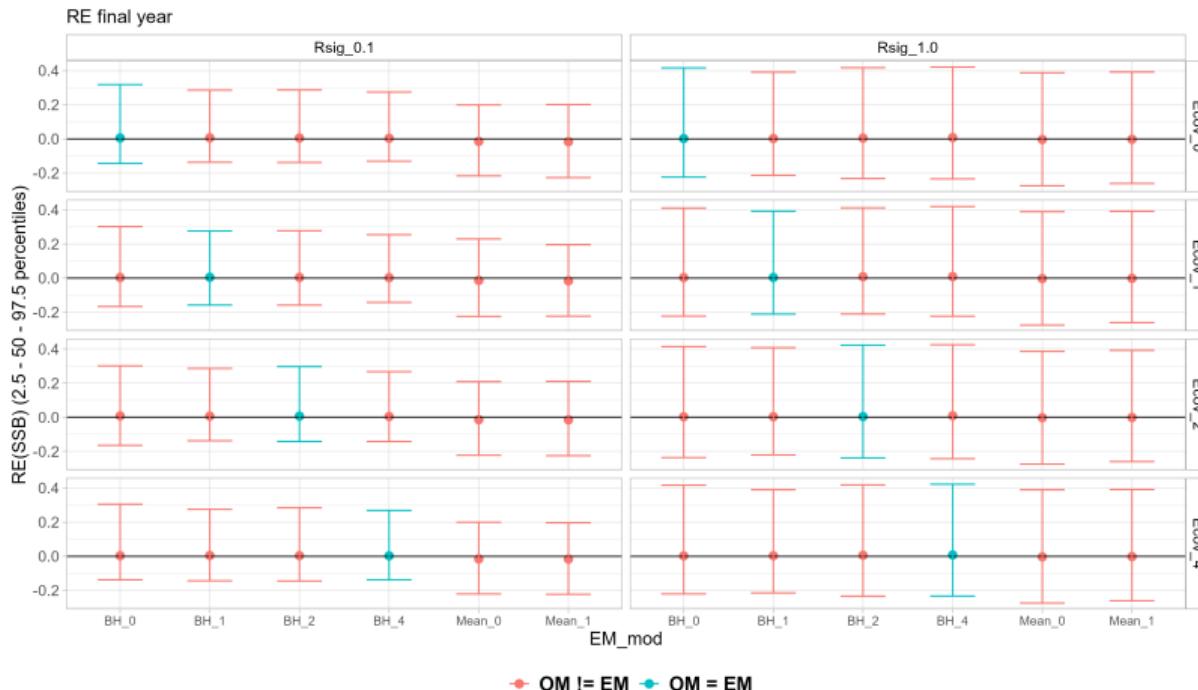
Assessment error - Spawning Stock Biomass (all years)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



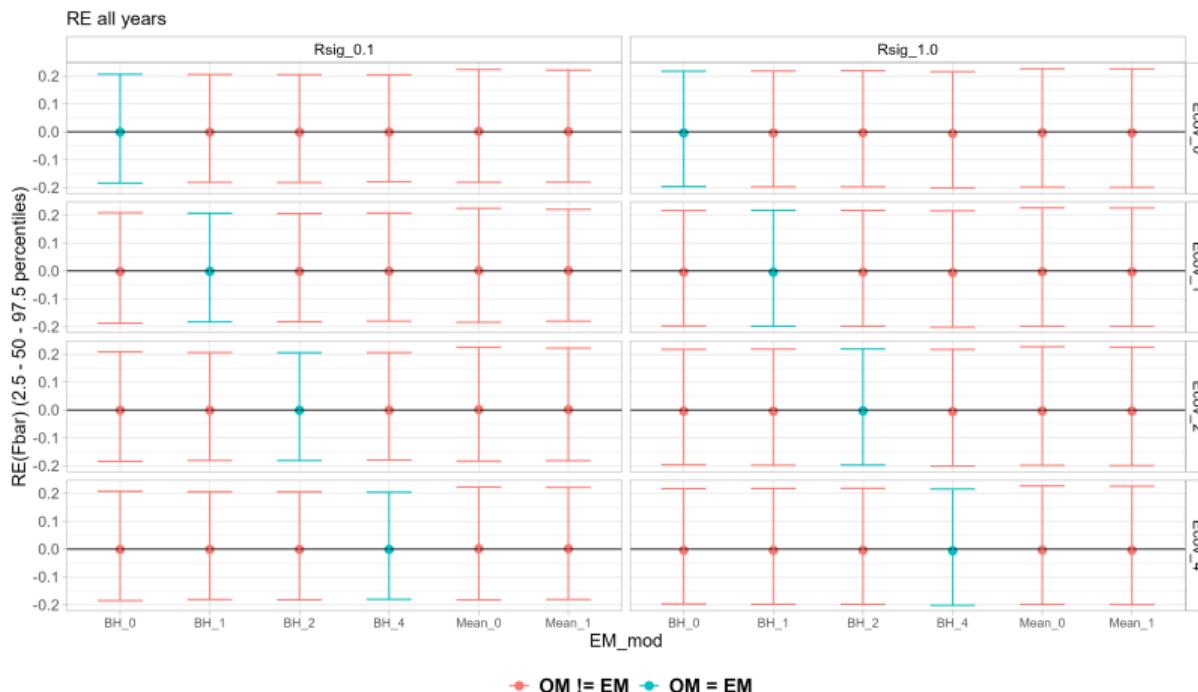
Assessment error - Spawning Stock Biomass (terminal year)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



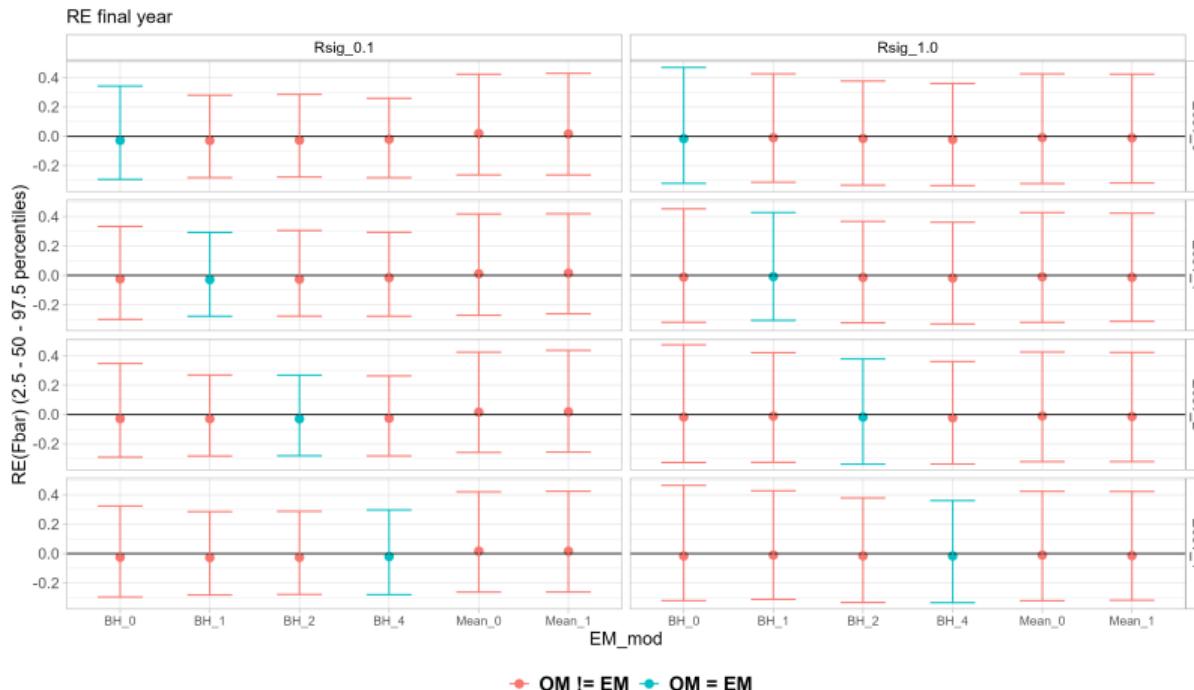
Assessment error - Fbar (all years)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



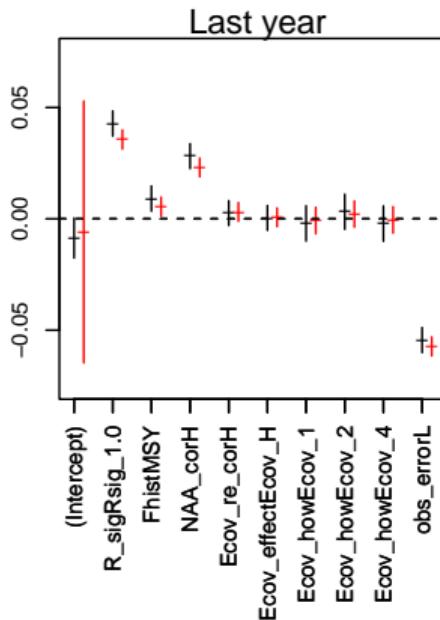
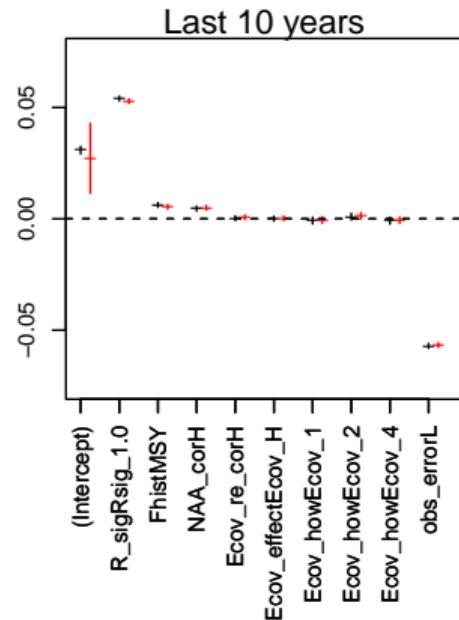
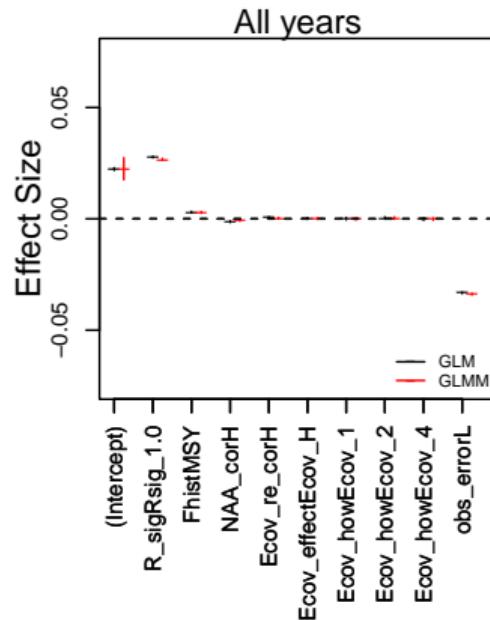
Assessment error - Fbar (terminal year)

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



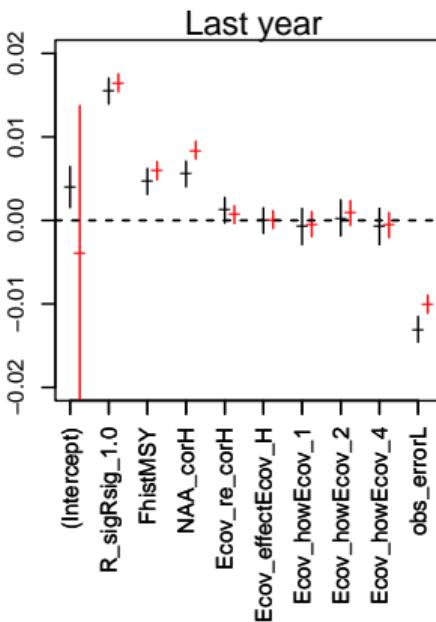
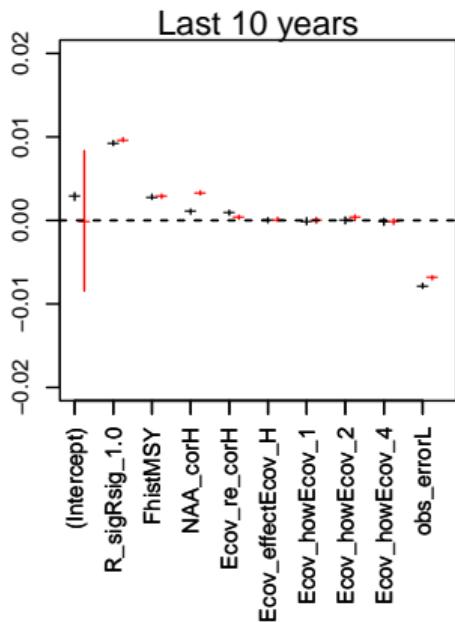
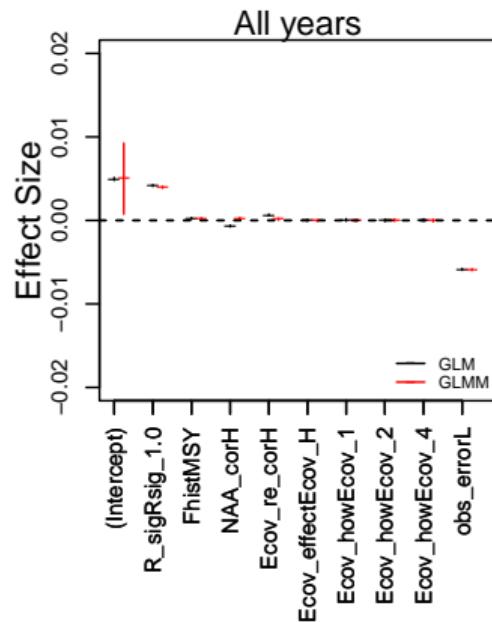
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Effect size for Relative error in Recruitment



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Effect size for Relative error in SSB



Effect size for Relative error in Fbar

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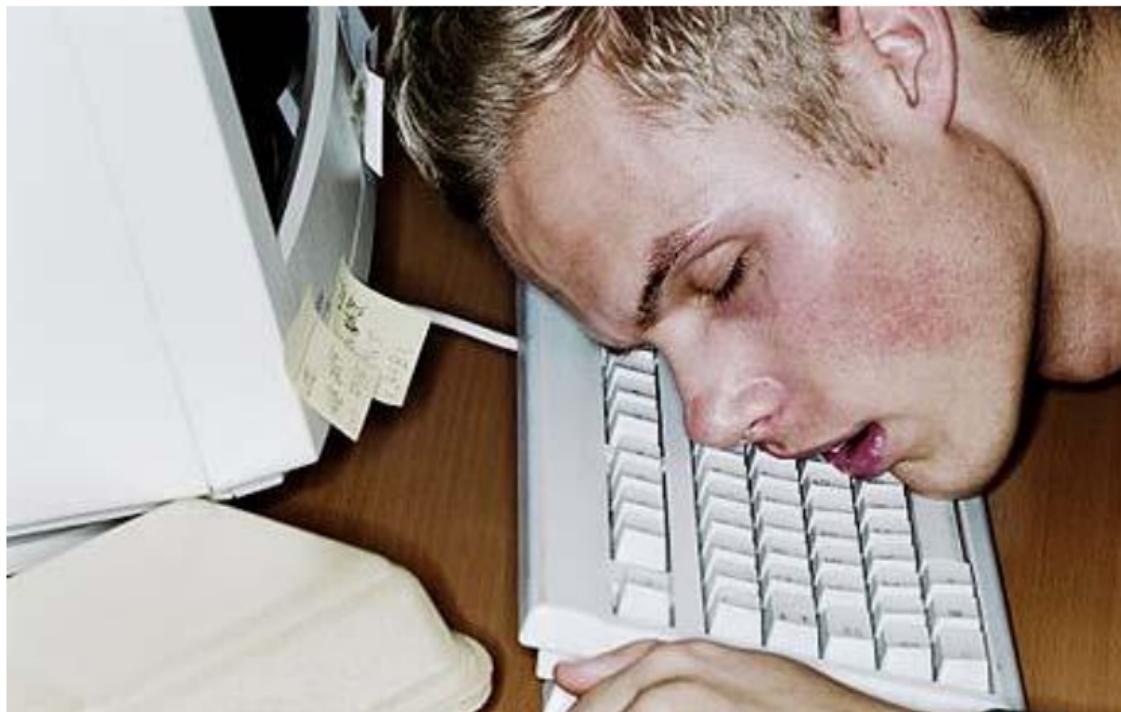
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Is everybody still awake?



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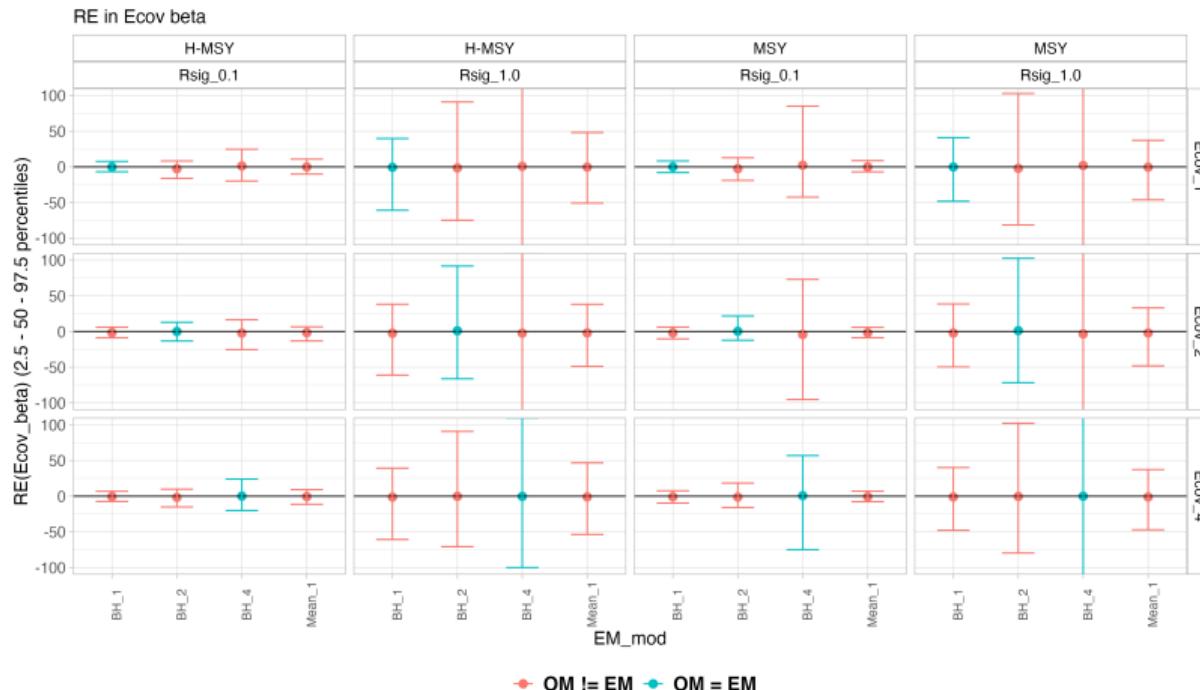
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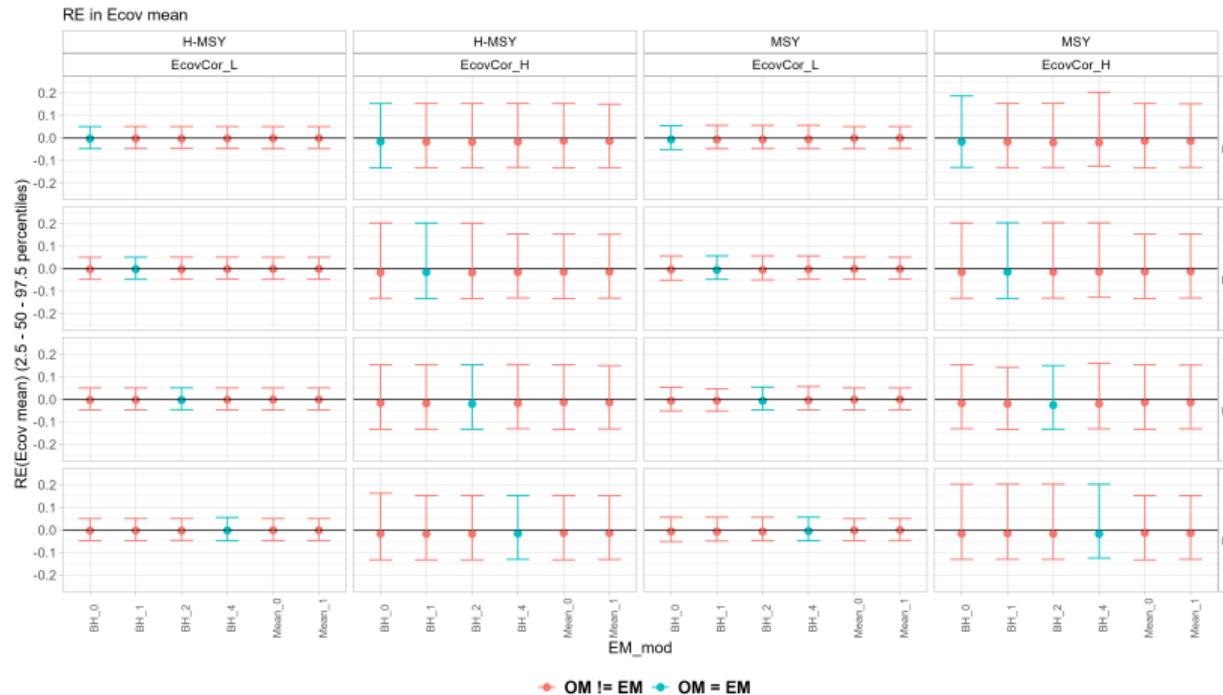
Bias of estimated parameters - Ecov β

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



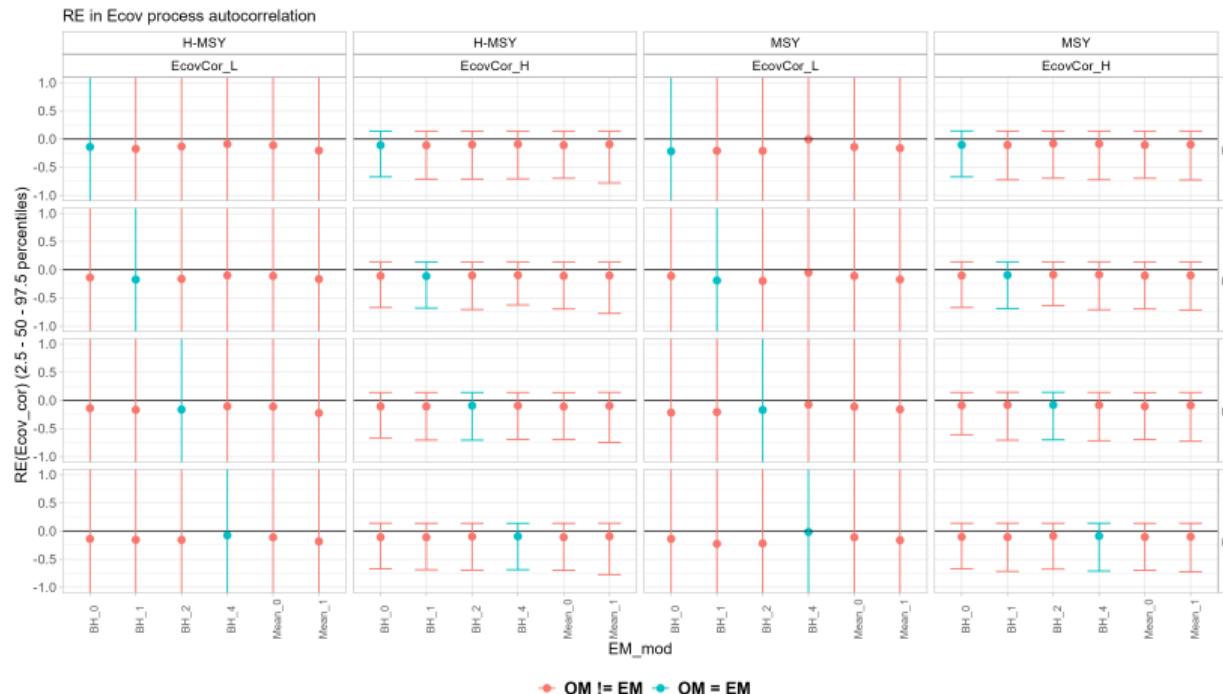
Bias of estimated parameters - Ecov mean

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



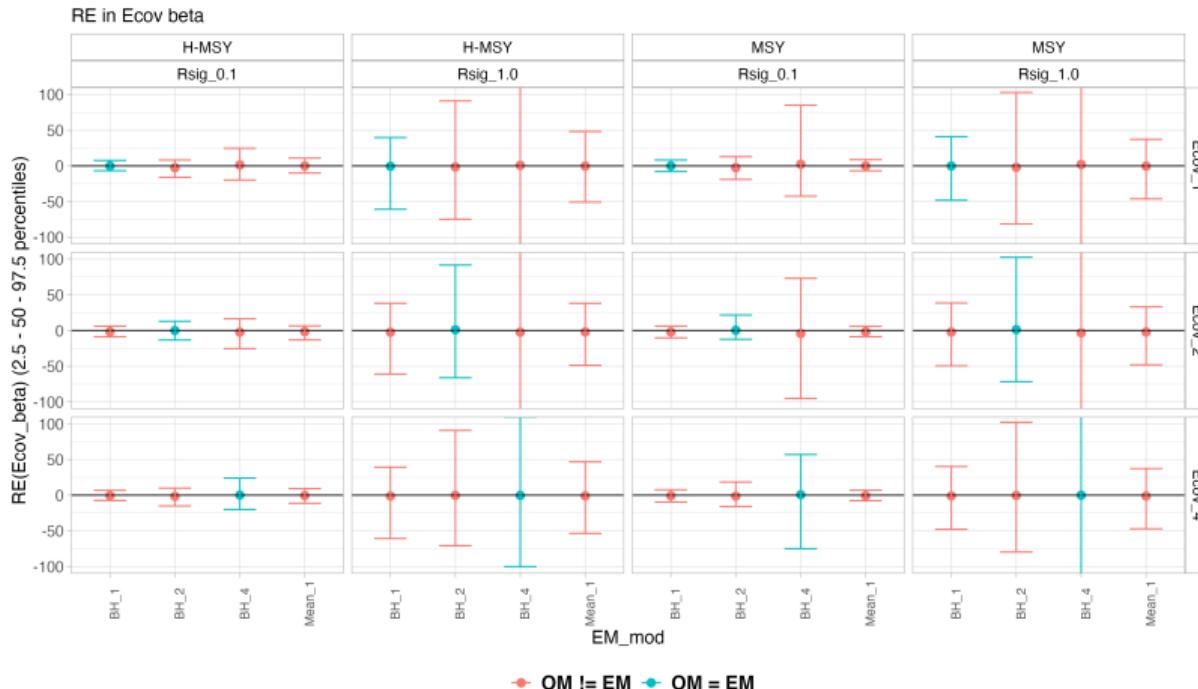
Bias of estimated parameters - $\rho_{E\text{cov}}$

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



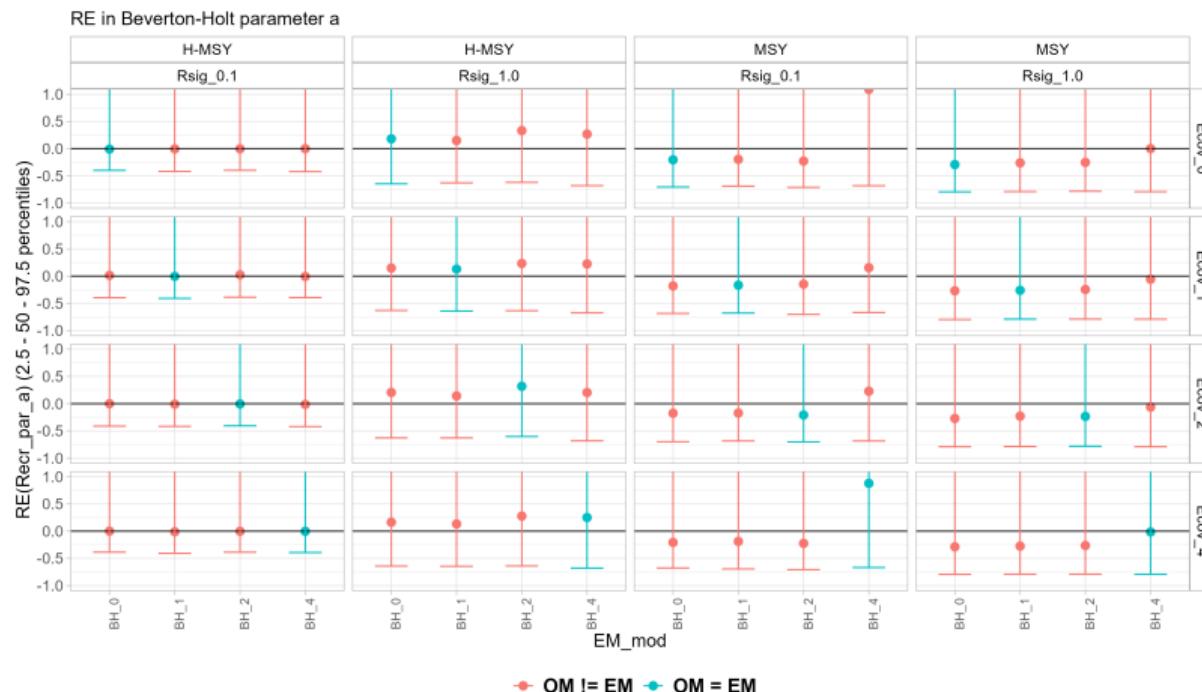
Bias of estimated parameters - $\sigma_{E\text{cov}}$

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



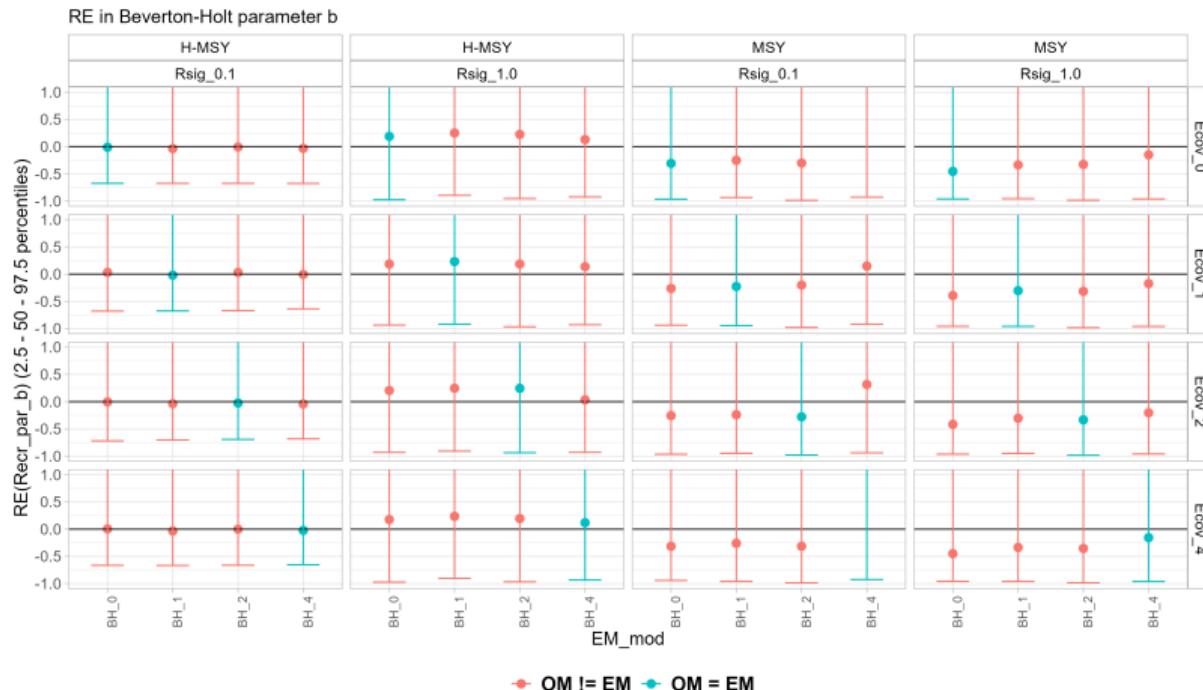
Bias of estimated parameters - SRR a

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



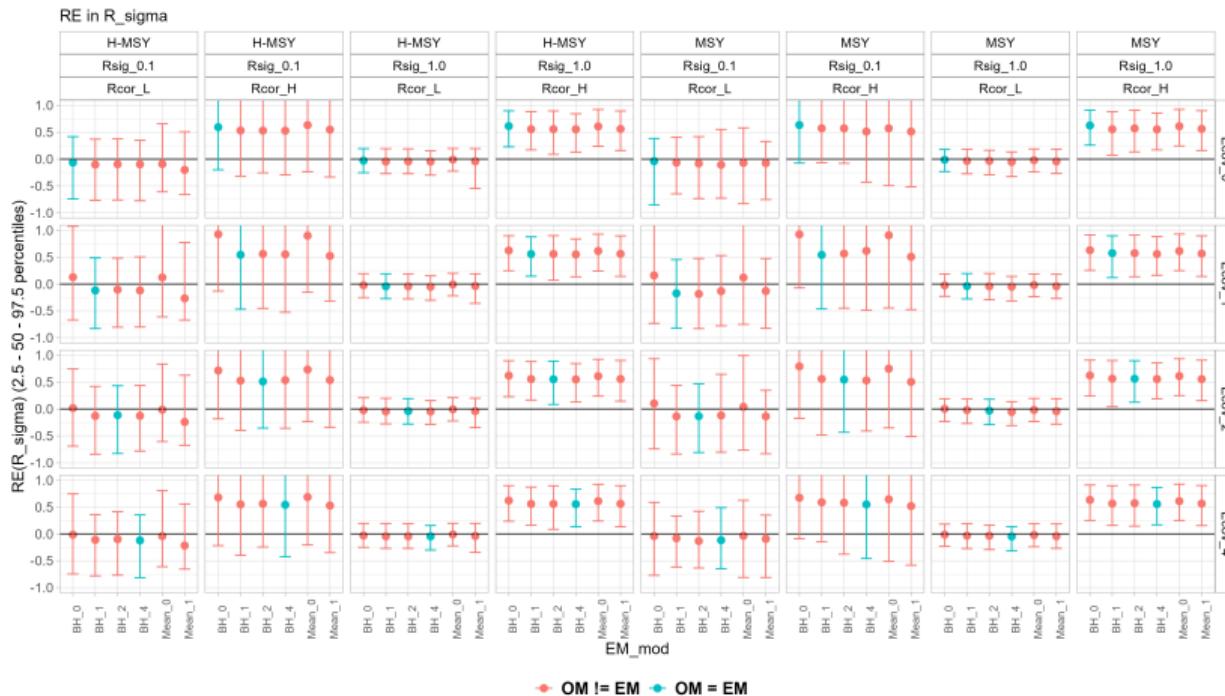
Bias of estimated parameters - SRR b

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



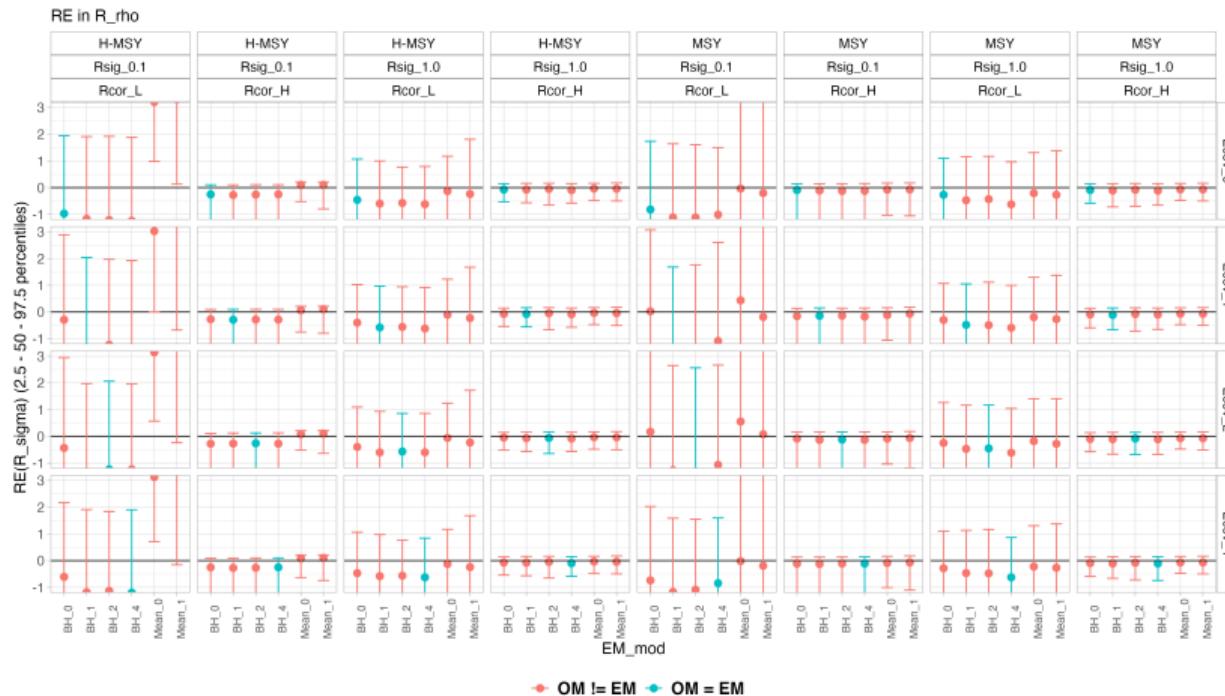
Bias of estimated parameters - σ_R

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



Bias of estimated parameters - ρ_R

- Median relative error (filled circle) with 2.5th and 97.5th percentiles



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Projections: Specifications and Ecov assumptions

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Projection performance relative to assumptions about the Ecov

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Conclusions

Take-aways

- Stock-recruitment model identification was poor, requiring unrealistic OM scenarios
- EMs with only recruitment random effects generally performed similarly well as OM=EM, including for cases with an SR relationship and/or an ecov effect
- In conclusion, we recommend recruitment random effects from a mean SRR as the default EM in WHAM

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Recommendations for further analyses

- This is what we suggest for follow-up
- Note that WP1-Appendix looked at $\sigma_R=0.5$ and found no difference from results in WP1

Acknowledgements

- This work could not have been completed without support from the Microsoft Cooperative Research and Development Agreement (CRADA) and NOAA's National Cloud Program Office (OCIO), as well as MIT (... greg to fill in)
- We thank other members of the SSRTWG for thoughtful comments during earlier discussions and presentations of this work

