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Meta-Model Evaluation of Spatial Resampling Bootstrap

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Introduction

The objective of this research project was to use Atlantis, an ecosystem model, as an operating model (OM) to test the spatial resampling bootstrap method of Elvarsson et al. (2014). This method provides uncertainty estimates for stock assessments and consists of resampling data from spatial units n times and fitting a stock assessment to each nth data set. Here we sample data from Atlantis with known error and compare output from the bootstrap models to output from models with error added.

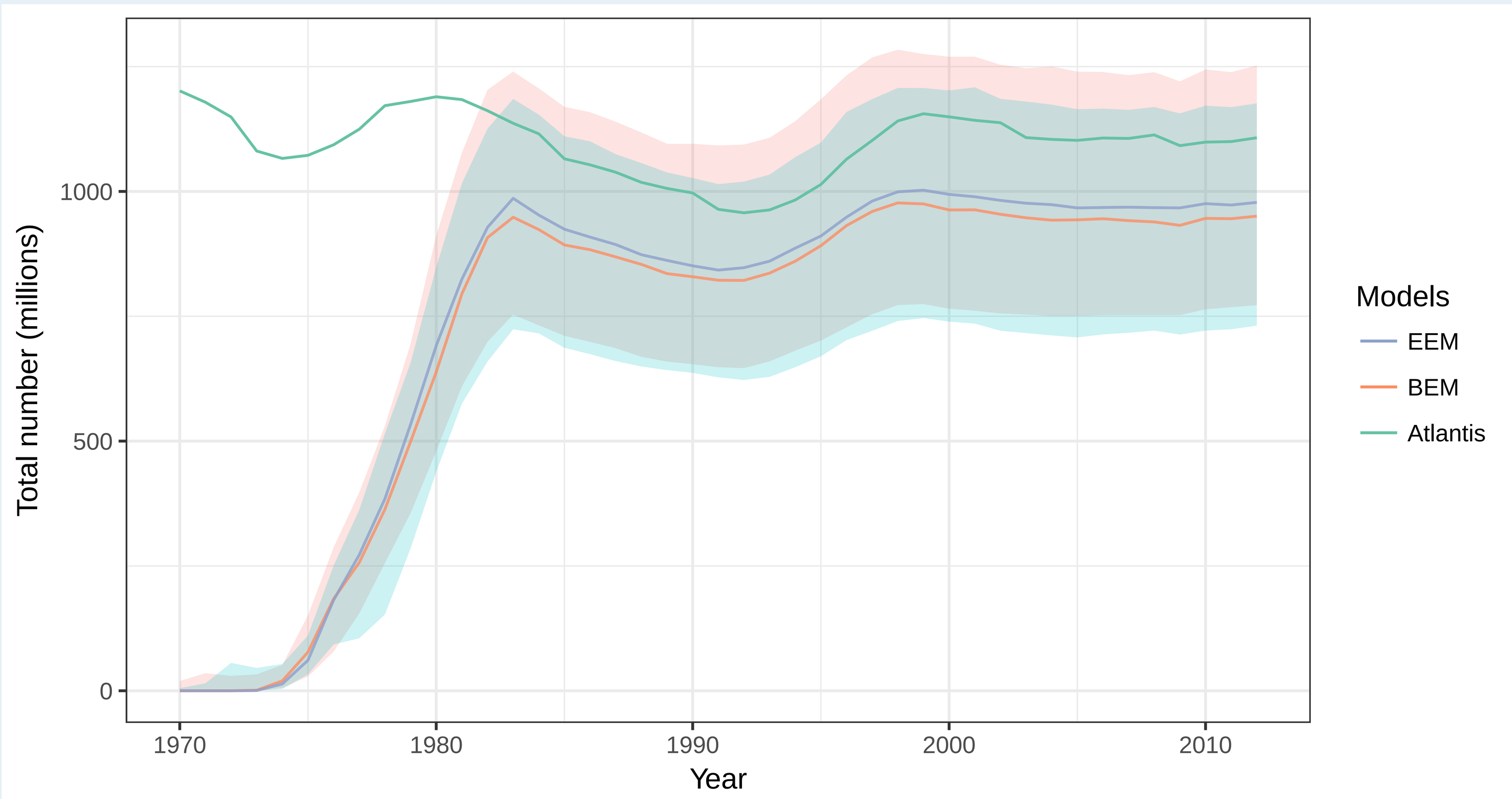

Fig. 1: Comparison of numbers across time between the EEM and BEM. Median and 95% confidence intervals of estimation models are shown. The green line is the true Atlantis value. 1970-1982 was a burn-in period without data.

Methods

We used a length-selection curve to mimic sampling of cod from Atlantis output, for which we retrieved number, age, and length data twice annually for the duration of the OM. We also sampled a subset of age-length data from the harvested fish in the OM. These samples were then used as data to fit Gadget models to estimate the cod stock in Atlantis. We added multiplicative error to the data with the formula: $I_t = S(l) \cdot N_t \cdot \exp(\epsilon_t)$, where I_t is the survey index at each survey timepoint, N_t is the total number of cod, $S(l)$ is selection at length l, and $\epsilon_t \sim \mathrm{N}(0, \sigma^2)$. We produced 50 different datasets by using a different value of σ^2, for each set, which were evenly spaced from 0 to 0.3^2.

Results and Discussion

Output for both estimation model types reveals that the spatial resampling bootstrap method that was tested performs relatively well at revealing the error associated with the data used in the stock assessment model (Figs. 1, 2, 3). The estimation of numbers tended to be biased slightly low for both EEM and BEM (Fig. 1), and SSB tended to be slightly overestimated (Fig. 2). However, the distribution of numbers for EEM and BEM within each year tended to overlap each other fairly well (Fig. 3). This study reveals that the spatial resampling bootstrap method evaluated in this study is able to accurately reflect the error that is associated with data used in the Gadget stock assessment model. Although values for total number of fish in both models was underestimated and SSB overestimated, the median values and 95% confidence intervals for both the EEM and BEM were very close indicating that any bias in estimation model results is likely due to model mis-specification rather than a bias of the bootstrap method.

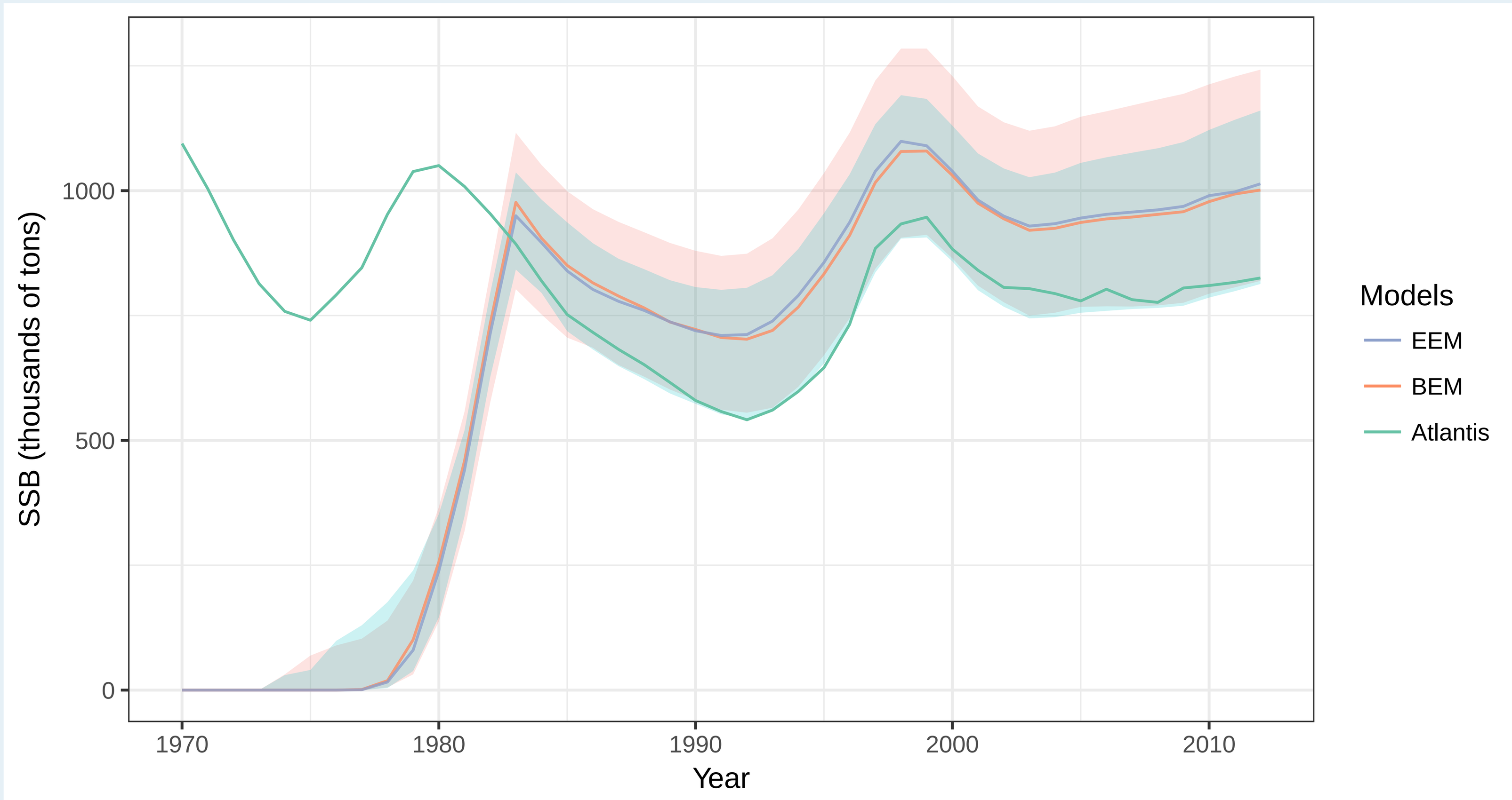

Fig. 2: Comparison of spawning stock biomass median and 95% confidence intervals for EEM and BEM. The green line is the true Atlantis SSB across time. 1970-1982 was a burn-in period without data.

Operating Model

We used an Atlantis ecosystem model of Icelandic waters as the OM for this study. The model consisted of 53 functional groups and ran from 1948-2012; however, for this study we only used data for cod (*Gadus morhua*) from 1983-2012. We created mock samples similiar to those actually performed in Iceland and sampled numbers at age and length to use as data in estimation models. Using these mock samples we produced 50 data sets each with a different level of error placed on the samples (see Methods). Data were then imported to the MareFrame Database using the R package `mfdb`.

Estimation Models

To compare the output of bootstrap models with that of models with error-added data we used two different estimation models: bootstrap estimation models (BEM), and error estimation models (EEM). EEMs were individual iteratively re-weighted Gadget models each fit to one of the 50 datasets with a different level of error added. BEMs were models fit using the bootstrap method of Elvarsson et al. (2014) with 100 bootstrap replicates. For BEMs we used the dataset with the maximum σ^2 used in the EEMs (0.3^2).

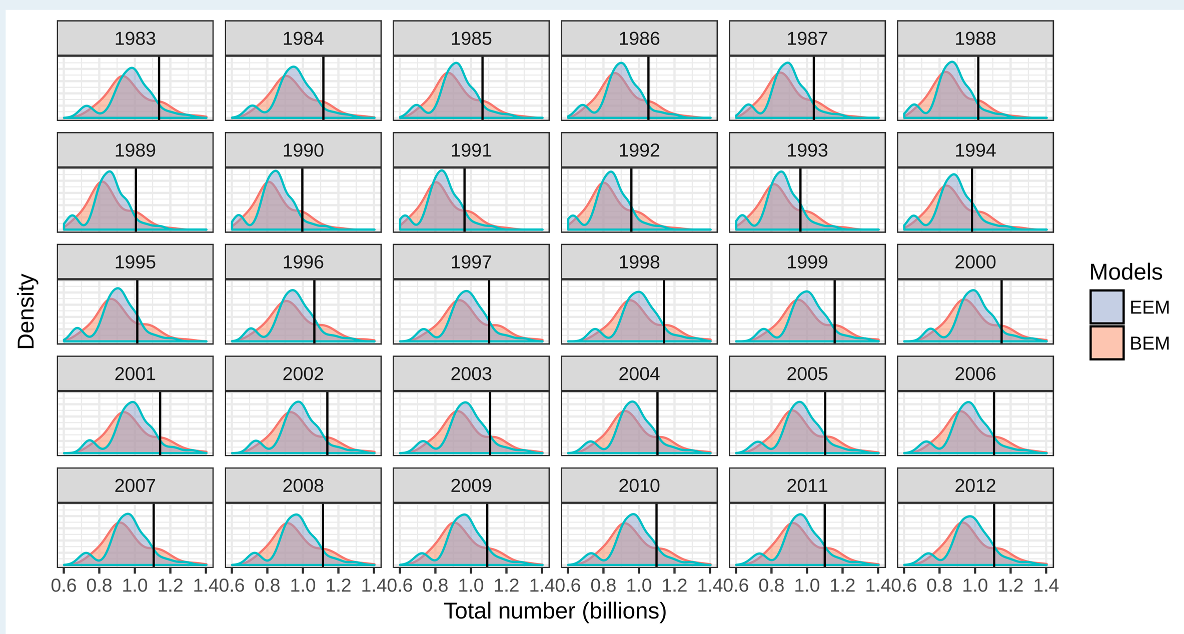

Fig. 3: Density plots of total numbers for both EEM and BEM for each year that the estimation models included data. These represent the distribution of each estimation model in terms of numbers of fish. The true Atlantis value for each year is the vertical black line.

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