Session: Modeling and Analysis

# Multispecies and Ecosystem Modeling

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Accounting for species interactions in both stock assessment modeling and fisheries management is of increasing interest in the Northeast US. As a result, there are a number of different modeling initiatives currently underway at the Northeast Fisheries Science Center (NEFSC). Fisheries models in general can span the spectrum from single species to aggregate species to full ecosystem models. The focus of this report is on the multispecies and ecosystem models that are either extant or in development at NEFSC. Having multiple models addresses different questions and allows for a variety of underlying assumptions.

Starting at the multispecies end of the spectrum, NEFSC has developed several versions of multispecies production and delay-difference models. These include Kraken, a multispecies production model using a genetic algorithm for parameter estimation, and two models (one production, one delay-difference) implemented in SAS using full information maximum likelihood for parameter estimation. Kraken can estimate survey catchability and observation error while the SAS models are process error only models that do not estimate survey catchability.

Kraken is implemented in C++ and takes aggregate survey biomass and catch time series as inputs (currently assumes that catch is known without error) and estimates intrinsic growth rate and Type I interaction parameters. In this simple formulation, all interactions between species are parameterized as predation with no feedback from prey on their predators. The same interaction parameter was also estimated within species as a density-dependent parameter. Kraken uses a genetic algorithm for parameter estimation with the modeling efficiency metric (MEF) as a fitness criterion.

NEFSC has also developed several age- and length-structured multispecies models including a statistical catch-at-age (SCAA) model and Hydra. The age-structured multispecies SCAA is implemented in ADMB and includes 9 fish species from Georges Bank and 27 predator-prey interactions. The SCAA model inputs included age structured commercial catch, survey catch, and predator food habits data. For each modeled species, SCAA estimates first year abundance, annual recruitments, annual F, fishery selectivity, survey selectivity and catchability, and food selection parameters, including species preferences. Size preference proved difficult to estimate within the model so these parameters were estimated outside the model with predator-prey length data instead.

Hydra is also implemented in ADMB and simulates ten species with length-structured population dynamics, predation, and fishery selectivity with fishing mortality coming from three effort-driven multispecies fleets. Multiple forms for growth and recruitment are implemented in the operating model so that each species may have different combinations within the model structure (*e.g*. von Bertalanffy growth with Ricker recruitment, exponential growth with Beverton Holt recruitment) and environmental covariates for each function can also be included. There is no feedback between prey consumption and predator growth in Hydra. Hydra is being used as an operating model to test the performance of the Kraken and SAS models.

Moving toward the full ecosystem approach, NEFSC and the Alaska Fisheries Science Center (AFSC) have been working to develop an R package named “Rpath” that implements Ecopath with Ecosim,. This tool will complement and expand on the open source possibilities of EwE, taking advantage of the existing statistical and graphical capabilities of R. Other advantages to developing the code in R are to encourage more community development, create a cross-platform software that works on operating systems other than Windows, and increase reproducibility of EwE models.

In addition to developing the Rpath tool, development of four ecopath models representing the four ecological production units (EPUs) is underway. These models will build on previous mass balance modelling that occurred in the region under the Energy Modeling and Analysis Exercise (EMAX). Future work will involve linking the four models together *via* emigration terms.

Finally, NEFSC has developed an end-to-end model in the form of an Atlantis model. As an end-to-end ecosystem model, Atlantis incorporates physical processes (*e.g.* sunlight, geochemistry, water flows, temperature, salinity, nutrients), biological processes for phytoplankton through whales (*e.g.* age structure, multiple recruitment functions, predation, natural mortality), and human dimensions (*e.g.* fishing effort, vulnerabilities of fish to a fishery, discard, bycatch, ports). Atlantis is primarily used as a platform for Management Strategy Evaluations (MSE), which can explore different scenarios and the tradeoffs among biological groups and fisheries in the system.

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