MAR 580: Models for Ecosystem-Based Management

Fall 2022

Homework Assignment 3

Multispecies modeling - estimating species interactions

Due: 10/13/2022

Please provide Gavin with a brief report containing your solutions, and also include your R script (or markdown file) and any additional files needed to run your assignment.

Multispcies Autoregressive Regression State Space (MARSS) models

Population dynamics of wolf and moose, Isle Royale, Michigan.

section 14.2, MARSS user guidepdf)

1. Work through the wolf/moose example using MARSS. Plot the time series of estimated dynamics of wolf and moose from the two-species state-space model.
2. Print the estimated species interaction matrices, and comment on the estimated species interactions and their implications. How do the estimates for the interaction coefficients change when the effect of environmental covariates on moose are included in the model? How does the estimated uncertainty affect our inference?
3. **BONUS** explore alternative specifications for the observation and process error matrices. How do these impact the inferences?
4. **BONUS-BONUS** implement the MARSS model in TMB. Do you obtain the same results? (*hint* this is the same model (but with two species) we implemented for lingcod).

Multispecies length structured modeling, prey proportions in survey diet

Diet composition of Georges Bank piscivores.

Multispecies statistical catch at age/length models (e.g. Gaichas et al. 2017, Trijoulet et al. 2020, Hall et al. 2006) typically incorporate predation mortality by modeling survival rates as:

$$S_{i,j,t} = e^{-(M1_{i,j} + M2_{i,j,t} + s_{i,j,q}F_{i,j,q,t})}$$

The rate of natural mortality is partitioned into two components: sources of natural mortality due to all unmodeled factors ($M1$) and predation mortality from species included in the model ($M2$).

The predation process is decomposed into size selectivity and species vulnerability in each area. The ρ, of prey species m size n for a given predator species i size j is:

$$\rho_{i,j,m,n} = \vartheta_{n,j}\lambda_{m,i}$$

where $\vartheta_{n,j}$ is the preference for a prey item of size n by predator size j, and $\lambda_{m,i}$ is the vulnerability of prey species m to predator species i. The parameter λ is set to either 0 or 1 depending on whether predator i is known to prey on species m.

The predation mortality rate on a particular prey species depends on the total consumption by predators, the suitability of that prey to each predator, and the total suitable prey biomass available to each of its predators. If the predation functional feeding response is assumed to be a Holling Type II, the $M2$ component on prey species m size n is then (Hall et al., 2006; Magnússon, 1995):

$$M2_{m,n,t} = \sum_i \sum_j I_{i,j,t} N_{i,j,t} \frac{\rho_{i,j,m,n}}{\sum_a \sum_b \rho_{i,j,a,b} W_{a,b} N_{a,b} + \Omega}$$

where a and b represent all prey species and sizes for predator i, W is the mean weight of prey a in size class b, Ω is 'other' food not explicitly included in the model, and all other terms are as above.

The proportions of prey items by weight in stomachs of predator i of size j of prey m are then:

$$\hat{\phi}_{g,t,i,j,m} = \phi^*_{g,t,i,j,m} / \left(\phi^*_{g,t,i,j,other} + \sum_m \phi^*_{g,t,i,j,m} \right)$$

$$\phi^*_{g,t,i,j,m} = \sum_n \rho_{i,j,m,n} N_{m,n,t} W_{m,n,t}$$

In the model fitting process, the observed proportions by prey species (in weight) may be compared to these predictions by assuming an appropriate observation model (e.g. multinomial, Dirichlet).

Trijoulet et al. (2020) estimated the vulnerability and size preferences directly, but an alternative (e.g. Hall et al. 2006) is to use an assumption for the distribution of size preference based on the log-ratio of body size. (big fish eat small fish). Our task is to use the Hall et al. (2006) type II functional response and biomasses for piscivores on Georges Bank to compare predicted diet composition proportions to observed data proportions.

The file 'species_params.csv' contains the relevant species information and parameters, summarized as a mean for each of ten stocks/species. `GB-dietcomps.rds` contains the recent proportions of prey items (including other food) in stomachs of these species from the NMFS Bottom Trawl Survey, averaged over season, size class of predator, and year.

5. Use the parameters in Hall et al. (e.g. Fig 2a) to estimate the diet composition for cod and dogfish. (hint: tweak 'other food'). Use LM50 (length at 50% maturity) to work out the body size ratios.
6. Compare your predictions to the diet data – do the theoretical relationships make sense? What would you suggest as a next step for modeling these data? What assumptions are being made that are likely unrealistic?