MAR 580: Models for Ecosystem-Based Management

Fall 2022

Homework Assignment 1

Extended stock assessments, dynamic reference points

Due: 09/22/2022, 1:00 pm

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

Northeast US Atlantic herring have experienced biomass decline and apparent variability in productivity, with the most recent (2022) management track stock assessment assessing the stock to be overfished. We are interested in estimating the stock-recruit relationship for herring and assessing whether there is evidence for changes over time in the apparent productivity relationship, and what the implications might be for (MSY-based) fisheries reference points for this stock.

A common model of stock-recruit dynamics is the Beverton-Holt relationship:

$$R_t = \frac{\alpha_t S_{t-1}}{1 + \beta S_{t-1}}$$

where R_t and S_t are the recruitment and spawning biomass in year t, α_t represents recruits per unit of spawning biomass as biomass approaches zero, and β represents the strength of density dependence per unit spawning biomass.

Recruitment is commonly assumed to have stochastic variability that follows a log-normal distribution, and hence working in log space is computationally easier:

$$L_t = \ln(\alpha_t) - \ln(1 + \beta S_{t-1})$$

where L_t is the expected log-recruits in year {t} per unit of spawning biomass in year $t-1$.

Bell et al. (2014) fit a state-space model for the Ricker model for winter flounder assuming that the log recruits-per-spawner observations are the observation model and that the production potential varies over time according to a random walk process. Applying this approach to the Beverton-Holt gives us the model:

$$L_t = \ln(\alpha_t) - \ln(1 + \beta S_t) + \eta_t$$

$$ln(\alpha_t) = ln(\alpha_{t-1}) + \nu_t$$

$$\nu_t \sim N(0, \tau^2)$$

$$eta_t \sim N(0, \sigma^2)$$

where τ^2 and σ^2 are the process error and observation error variances, respectively.

Tasks

1. Plot the Recruitment & Spawning Stock Biomass (SSB) time series, as well as the time series of the recruits per spawner (L).

2. Rearrange the Beverton-Holt stock recruity relationship to predict recruitment as a function of the spawning biomass per recruit, alpha, and beta. With this and the functions in `spr_functionss.R` show how the value for F_{MSY} (fishing rate at maximum sustainable yield) changes as a function of the production potential of the stock, *alpha*.
   [Note: No TMB programming is required for this part of the assignment, you can do this all in R (or Excel)]
   hint: You will want to write a function that allows you to optimize Yield given input values for F - this function will make use of the functions to calculate YPR and SBPR provided.

3. Write a TMB program to estimate the parameters of the state-space version of the Beverton-Holt stock-recruit model for Atlantic herring.

4. Fit versions of the model that estimate a constant alpha over time, as well as one that estimates time-varying production potential (hint, use the map to fix the process error variance at a value close to 0). **hint** Fort the time-varying model, set the starting value for alpha to the estimate from the constant-alpha model.

5. Plot the estimated time series of ln(S/R) and compare it to the data. Also plot the estiamted time series of alpha. Compare the models using AIC (hint, use the TMBAIC() function in TMBhelper package).

6. Compute reference point estimates (MSY, BMSY, and FMSY) as for part 2 but using the fitted values of alpha and beta from (a) the constant alpha model, and (b) using the last year's estimate for alpha, and (c) the average of the last most recent 5 years estimate for alpha. What are the implications of dynamic production potential for fisheries management advice?

7. Comment on the assumptions of your approach and potential challenges associated with applying the time-varying version of the SRR.

8. *BONUS* Management advice for Atlantic herring is based on projections that use the most recent 10 years of recruitment and a target fishing mortality rate of that which reduces unfished spawning biomass per recruit to 40% of that with no fishing. Compare your results of fitting the dynamic stock-recruit model to advice that would be generated under these assumptions.

9. *BONUS* Integrate parameter uncertainty into your evaluations of reference point performance in (6).