Operating Models Conditioned using Life History Relationships

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Revisions

- Natural mortality is always a tricky one. M is likely to be related to body length but other factors must also play a role. I personally like the idea that age at first maturity should be a good indicator as this makes intuitive sense but Then et al (2015 I think) concluded that the oldest observed age was the best predictor. Even so, the uncertainty around the predictions by Then is huge. Anyway, I suppose Gislason is as good as any but we should test the sensitivity
- I don't understand equations 4,5,6 in the document; the parameters are not explained
- How do you estimate selectivity from life-history parameters?
- Is S in eq 7 spawner or ssb?
- Is S in eq 8 SSB? Then why is fecundity in there and not weight-at-age?
- How do you use the life-history parameters to estimate the SR?

Operating models for the species (e.g. Brill)

- It is not clear to me how you go from the (multiple) lh parameters from fishbase to a single set of lh parameters. I think it happens here: mf2FLPar(lh[, -c(1,7)]). Or are you keeping them all and is that reflected in the 'uncertainty' in figure 2?
- Also, it is not clear to me which parameters are observed and which are inferred from correlations.
- Is the whole OM based on lh parameters or are you making additional assumptions on the SR (steepness?) and selectivity? It would be nice to see all the assumptions more clearly in the markdown documents.

LIfe history relationships were used to create operating models for data poor stocks based on life history relationships.

Introduction

An objective of Management Strategy Evaluation is to develop stock assessment methods, reference points and harvest control rules that are robust to uncertainty. Many Operating Models have been developed using a stock assessment parigdim, however, there are many processes for which there is little infomation about in stock assessment datasets, e.g. natural mortality, the steepness of the stock recruitment relationship, the form of population regulation and density dependence. The **FLife** package therefore allows operating models to be developed based on life history relationships and ecological processes. Doing this is particularly valuable in data poor situtations where knowledge and data are limited, but also in data rich situtaions as simulation testing an assessment procedure using a model conditioned on the same assumptions is not necessarily a true test of robustness.

Material and Methods

Life history parameters for growth, natural mortality and maturity were used to develop an age-based Operating Model. The life history parameters were first used to generate vectors at age for life history processes to derive mass (W), proportion mature (Q), natural mortality (M) and fishing mortality (F) at age. These were then used to to combine a stock recruitment relationship with a spawner-per-recruit (S/R) and yield-per-recruit (Y/R) analyses Sissenwine and Shepherd (1987). These relationships are then used to create a forward projection.

Life history processes

Growth in length is modelled by the Von Bertalanffy growth equation Von Bertalanffy (1957)

$$L = L_\infty(1 - exp(-k(t - t_0)) \tag{1}$$

where k is the rate at which the rate of growth in length declines as length approaches the asymptotic length L_∞ and t_0 is the hypothetical time at which an individual is of zero length.

Length is converted to mass using the length-weight relationship

$$W = aL_t^b \tag{2}$$

where a is the condition factor and b is the allometric growth coefficient.

Gislason et al. (2010) showed that M is significantly related to body length, asymptotic length and k. Temperature is non-significant when k is included, since k itself is correlated with temperature. We therefore model M as

$$M = 0.55L^{1.61}L_\infty^{1.44}k \tag{3}$$

Selection pattern of the fishery was represented by a double normal with three parameters that describe the age at maximum selection ($a1$), the rate at which the left-hand limb increases (sl) and the right-hand limb decreases (sr) which allows flat topped or domed shaped selection patterns to be chosen.

$$f(x) = \begin{cases} 0 & \text{if } (a_{50} - x)/a_{95} > 5 \\ a_\infty & \text{if } (a_{50} - x)/a_{95} < -5 \\ \frac{m_\infty}{1.0+19.0^{(a_{50}-x)/_{95})}} & \text{otherwise} \end{cases} \tag{4}$$

Per Recruit Analysis

$$S/R = \sum_{i=0}^{p-1} e^{\sum_{j=0}^{i-1} -F_j - M_j} W_i Q_i + e^{\sum_{i=0}^{p-1} -F_i - M_i} \frac{W_p Q_p}{1 - e^{-F_p - M_p}} \tag{5}$$

$$Y/R = \sum_{a=r}^{n-1} e^{\sum_{i=r}^{a-1} -F_i - M_i} W_a \frac{F_a}{F_a + M_a} \left(1 - e^{-F_i - M_i}\right) + e^{\sum_{i=r}^{n-1} -F_n - M_n} W_n \frac{F_n}{F_n + M_n} \tag{6}$$

The second term is the plus-group, i.e. the summation of all ages from the last age to infinity.

Stock Recruitment Relationship

The relationship between stock and recruitment was modelled by a Beverton and Holt stock-recruitment relationship Beverton and Holt (1993) reformulated in terms of steepness (h), virgin biomass (v) and $S/R_{F=0}$

$$R = \frac{0.8 R_0 h}{0.2 S/R_{F=0} R_0 (1-h) + (h-0.2)S} \tag{7}$$

where steepness is the ratio of recruitment at 20% of virgin biomass to virgin recruitment (R_0) and $S/R_{F=0}$ is the spawner per recruit at virgin biomass, i.e. when fishing mortality is zero. Steepness is difficult to estimate from stock assessment data sets as there is often insufficient contrast in biomass levels required for its estimation Pepin and Marshall (2015).

S is spawning stock biomass, the sum of the products of the numbers of females, N, proportion mature-at-age, Q and their mean fecundity-at-age, F, i.e.

$$S = \sum_{i=0}^{p} N_i Q_i F_i \tag{8}$$

where fecundity-at-age is assumed proportional to biomass and the sex ratio to be 1:1. Proportion mature is 50% at the age that attains a length of $l50$, 0% below this age and 100% above.

Combined analysis

Reordering the stock recruitment relationship as a function of S/R

The stock recruitment relationship can then be reparameterised so that recruitment R is a function of S/R

e.g. for a Beverton and Holt (1956)

$$S/R = (b+S)/a \tag{9}$$

S can then be derived from F by combining equation 3 or 4 with equation 1.

allows S to be defined as a function of F by combining the stock recruit and per recruit analyses.

Projection

The stock recruitment relationship and the vectors of weigth, natural mortality, maturity and selectivity-at-age allow a forward projection model to be created, which forms the basis of the Operating model.

References

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