A model for evolving fish stocks in a stochastic environment: the example of the North-east Arctic cod

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Background

After the introduction of heavy exploitation, a number of fish stocks have shown large changes in age and size at maturity (Law and Grey 1989, Jrgensen 1990). For the North-east Arctic cod there has been observed a decrease in age at maturation (Jrgensen, 1990). A decrease in age at maturation and the possible decrease in size at maturation can reduce the total biomass of the population and thereby reduce the long term yield of the population (Law and Grey, 1989). Knowledge about the population structure is also crucial in the quantitative assessment of a population such as the North-east Arctic cod. Heino (1998) showed that harvesting can select for life history changes in an exploited population with an age-structured population model. This model was extended by Salthaug (in prep.) by incorporating size and genotype structure in addition to age structure. If evolutionary changes in a population are caused by the harvesting regime and/or trends and fluctuations in the environment, these should indeed be taken into account by quantitative models.

Problem

Extend the existing model by incorporating environmental variations and trends in order to explain the observed changes in the North-east Arctic cod stock in a more realistic way.
Task:

It is known that the structure of a population might be influenced by the environment (Jrgensen, 1990), and thus, in order to construct a more realistic model environmental variations should be accounted for in the model. The general goal of this extension is twofold:

1. Reduce uncertainties in predictions of cod population structure and adaptation by accounting for known variability in environmental conditions and fishing pressures.

2. Analyse whether evolutionary changes in central life history traits should be taken into account in the management of renewable resources by predicting their expected rates under realistic conditions.

Approach

There exists some knowledge about which environmental factors can affect the structure in populations. Environment will, in this approach, include changes in the ocean climate, variation in the biological environment and changes in exploitation. For the North-east Arctic cod the temperature seems to affect larval and juvenile growth (Ottersen and Sundby, 1995). There is a relationship between prey abundance (e.g. capelin) and growth of cod (Bogstad et al., 1995). There has been a change in fishing effort because of more efficient vessels and fishing gears (Nakken, 1994). Fishing gears are selective, that is, fish with certain phenotypic properties such as size are more likely to be caught than others. When introducing variations and trends in the

environment we will use the observed (known) changes in environmental conditions and fishing pressures;

1. Variations in temperature (and, maybe, other climatic variables such as the North-Atlantic oscillation index)

2. Variations in fishing effort

3. Variations in fishing selectivity

4. Variations in prey abundance

Existing and documented relationships will be used. In addition, such relationships might be investigated using the theory of generalised linear models or multivariate time series. I will try to match the described variation statistics by analysing variances, auto-correlations and cross-correlations. More specifically this means that we have to formulate and fit plausible functions of the model parameters, i.e. the growth rate, as a function of the environmental variables described above.

Further, in order to investigate the described problem, we will try to find a model which:

1. Mimics observed time series for variations in stock abundance and composition as closely as possible

2. Mimics observed time series for age and size at maturation as closely as possible

In particular, I intend to follow the following progression of steps:

1. Decide which environmental variables to use. Then construct a matrix where the rows consists of the time series of observed or estimated values for each chosen variable. Of course we want as long time series as possible, but the longest possible time series for cod is from 1932 until now.

2. Determine the best possible functional forms of the model parameters as functions of the environmental variables, or use known relationships if possible.

3. Simulate the extended model by the same procedure as described by Salthaug (in prep.), but now introduce the observed variations in environmental conditions as explained. More specifically this means: i) simulate the model with no fishing pressure, ii) introduce fishing pressure and simulate the model over the time span where the changes in the population structure have been observed.

4. Based on defined test statistics, investigate how the model recovers the observed data (that is the data described by God, 2000). This will indicate where we have to focus our attention in the search for a model which describes the observed changes in the population structure for cod. When this is done, we have to consider further adjustments or extensions of the model that will help to improve the accuracy of predictions with respect to observed data.

References

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