A Bayesian two-stage biomass model applied to the English Channel stock of cuttlefish (*Sepia officinalis*)

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Summary

Among the English Channel fishery, the importance of cuttlefish stock has increased, following the cephalopods global landings and market trend. An adapted stock assessment model is needed in order to give good management advice with accurate uncertainties. Age based methods in this species are hampered by time consuming age determination with statoliths. A model requiring few data and adapted to the species life-history is therefore proposed. An assessment of this stock was conducted in June 2015 by fitting a two-stage biomass model on a 22 years' time-series (1992-2014). The use of a Bayesian framework is particularly adapted for decision making, allowing the propagation of uncertainty in the model. It also permits the use of different sources of information, and is particularly well suited to face the lack of data. In this exercise we implement the two-stage biomass model into a Bayesian framework. We also improve the Bayesian model by using length frequency data and a mortality model to better estimate the biomass growth parameter *g*. We compare results of two models: one with fixed *g* and one with time-varying *g*. The last one is more realistic and model fit is better.

Introduction

Cephalopod populations are fast growing short-lived ecological opportunists. Age based methods in these species are hampered by time consuming age determination with statoliths. There is no routine stock assessment in most of cephalopod fisheries. The English Channel cuttlefish stock is one of the most important resource for the Channel fisheries and is exploited by French and English fishermen. Inshore exploitation is managed by local rules, but no EU regulations apply to the whole stock. It experiences a short life-span and performs seasonal migrations. The two-stage biomass model (Roel and Butterworth 2000) assumes that the exploited population can be observed at two different stages: recruitment and full exploitation. It is not too much data demanding and has been adapted to the English Channel cuttlefish stock (Gras *et al*. 2014), based on a simplification of cuttlefish life-cycle and with bootstrap estimated uncertainties. A fixed biomass growth parameter *g* combining individual growth and cohort natural mortality is also needed. Bayesian methods are particularly well suited to estimate model uncertainties and to face the lack of data. This study presents the results of two Bayesian implementations of a two-stage biomass model, one with fixed *g* and one with time-varying *g*.

Materials and Methods

The two-stage biomass model assumes that the exploited population can be observed at two different stages: recruitment and full exploitation. Recruited biomass (B_1) is estimated with abundance indices from the Channel Ground Fish Survey (CGFS). Spawning stock biomass (B_2) is estimated with Landings Per Unit Effort (LPUE) from French bottom trawl fisheries. Two models are built, one with a biomass growth parameter *g* fixed externally and one with a time-varying *g*. Parameter *g* is composed by the growth rate (Gr), derived from Obsmer length data, minus the natural mortality rate (M), calculated with Caddy (1996) gnomonic time division method. To calculate LPUE, commercial data were used to know the percentage in weight of one year-old cuttlefish (animals above 300g) each year, and a Delta-GLM was applied with ICES statistical rectangle, vessel power, year and month as factors. Percentages were also applied to total catch data (from both French and UK vessels) to select individuals older than one year-old (1+). The package mixdist was used on CGFS length frequency data to calculate mean length and percentage in number of individuals older than one year-old ($\%N_{1+}$). Mean length was converted into mean weight using Dunn (1999) length-weight relationship. Percentage in weight of 1+ individuals was calculated as follows:

$$\%w_{1+} = \frac{\%N_{1+} * \overline{w}_{1+}}{\overline{w}_{1+} * \%N_{1+} + \overline{w}_{0+} * (1 - \%N_{1+})}$$

where $\overline{w}_{0+}$ and $\overline{w}_{1+}$ are the mean weight of 0+ and 1+ individuals. $\%w_{1+}$ was then applied to CGFS catch data to calculate abundance indices for 1+ individuals. Total catch of one year old cuttlefish ($C_{1+,y}$) is assumed to happen as a pulse in the middle of the fishing season (on 1st January Y). Spawning stock biomass $B_{2,y}$ of year y is therefore expressed as:

$$B_{2,y} = \left[B_{1,y} e^{\frac{g}{2}} - C_{1+,y}\right] e^{\frac{g}{2}}$$

Biomass $B_{1,y}$ at the beginning of the fishing season can be estimated with CGFS survey index:

$$S_y = q_{\text{cgfs}} B_{1,y} e^{\frac{g}{4}} e^{\varepsilon_y}$$

where S_y is the CGFS survey index, q_{cgfs} the CGFS survey catchability, and ε_y is the observation error. French standardized LPUE (U_y^{fr}) are modelled based on the mean biomass in the fishing season:

$$U_y^{fr} = \frac{1}{2} q_{fr} \left[B_{1,y} + \left(B_{1,y} e^{\frac{g}{2}} - C_{1+,y}\right) e^{\frac{g}{2}}\right]$$

where q_{fr} is the catchability of French trawlers. The model is finally fitted by minimizing the sum of squares residuals. Markov Chain Monte Carlo (MCMC) simulation was applied with OpenBUGS to numerically generate a sequence of samples from the posterior distribution.

Results and Discussion

The model with time-varying g parameter has larger confidence intervals and shows a better fit than the model with fixed g (Fig. 1). As a short-lived species, cuttlefish is expected to experience time-varying growth and natural mortality rates. A time-varying g is therefore closer to reality than a fixed g.

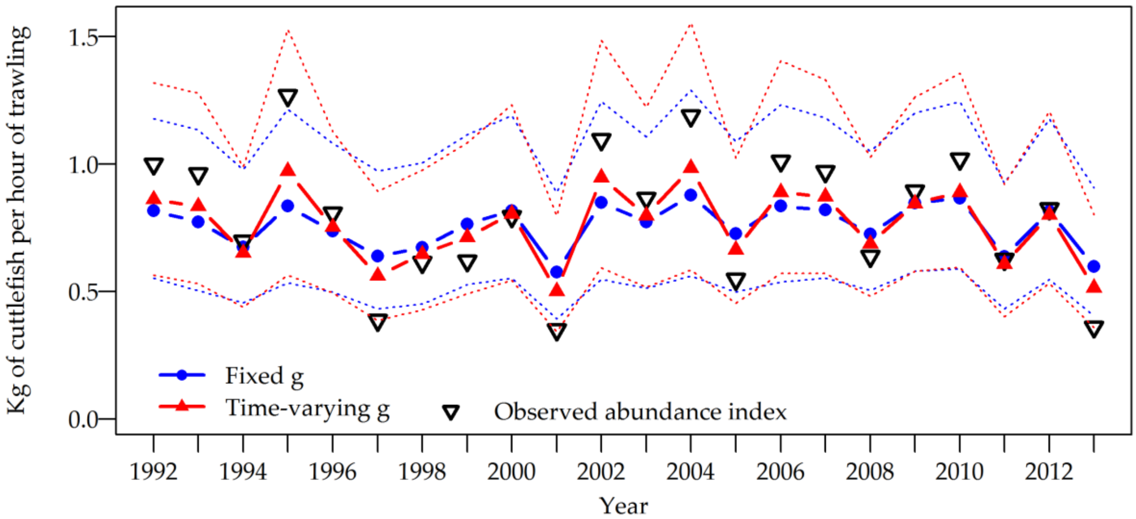

Figure 1: Plot of observed LPUE and estimated LPUE from two Bayesian models, one with fixed g (in blue) and one with time-varying g (in red), with 95% confidence intervals (dashed lines).

References

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