Stock assessment models for short-lived species in data-limited situations

Case study of the English Channel stock of cuttlefish

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Introduction

Stock assessment for short-lived species is a delicate matter because of the difficulty of swift data collection as well as the challenge of modelling fast and flexible population dynamics. Cephalopod populations are fast growing short-lived ecological opportunists. Age based methods in these species are hampered by time consuming age determination with statoliths. In spite of trials with a wide range of models (Pierce & Guerra, 1994) there is no routine stock assessment in most of cephalopods fisheries, although a precautionary approach is often advocated (Rodhouse *et al*., 2014).

- ➔ English Channel cuttlefish stock: one of the most important resource for the Channel fisheries (Engelhard *et al*., 2012).
- ➔ Exploited by French and English fishermen.
- ➔ Inshore exploitation managed by local rules, but no EU regulation for the whole stock.
- ➔ Short life-span (considered of 2 years in the English Channel) and seasonal migrations (Figure 1).
- ➔ Concentrates in the central western Channel during winter and in coastal areas during spring and summer (Boucaud-Camou & Boismery, 1991).

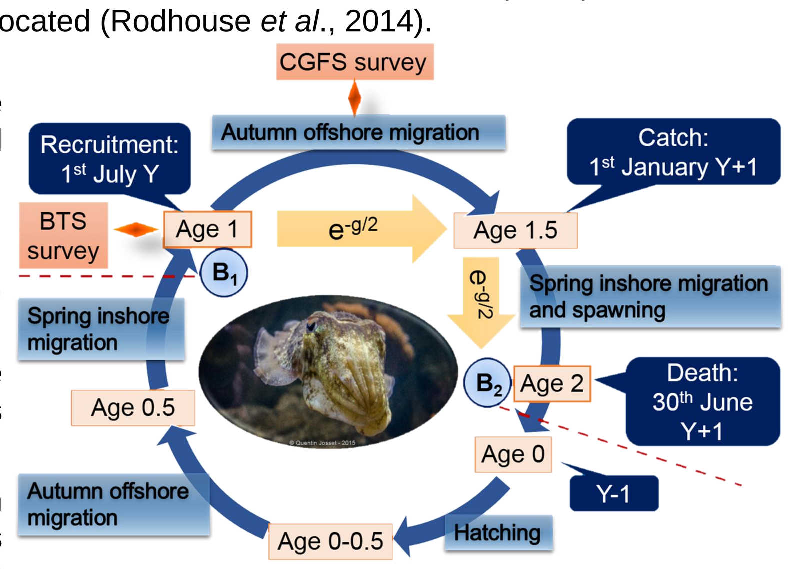

Figure 1: Life cycle of English Channel cuttlefish and simplification used for the two-stage biomass model

- ➔ Analytical methods have been used to occasionally assess the stock (Royer *et al*., 2006), but it remains difficult to correctly describe catch structure. Less data-demanding models were sought (Gras *et al*., 2014), for routine use (Duhem *et al*. in WGCEPH, 2014). Two-stage biomass model (Roel & Butterworth, 2000): not too much data-demanding, well suited for data-limited stocks.
- ➔ Advantage of using Bayesian methods for estimating uncertainties in these models (Ibaibarriaga *et al*., 2008). Use of informative prior distributions to face the lack of information in the data.
- ➔ Our aim was to improve the two-stage biomass model and compare it with another model designed for data limited stocks: a multi-annual generalized depletion model (Roa-Ureta, 2014).

Methods

Two-stage biomass model

A package with the version of a two-stage biomass model adapted to the English Channel cuttlefish stock was coded in R (Gras & Robin, 2014). The model (Gras *et al.*, 2014) is based on a simplification of cuttlefish life-cycle (Figure 1).

- ➔ Exploited population can be observed at two different stages: recruitment and full exploitation.
- ➔ Recruited biomass (B_1) estimated with abundance indices from BTS and CGFS surveys.
- ➔ Spawning stock biomass (B_2) estimated with landings per unit effort of French and UK trawlers.
- ➔ Biomass growth parameter *g* fixed externally.

We implemented the same model into a Bayesian framework and coded it with Openbugs. The Bayesian model required informative prior distributions for B_1 and catchability rates. We conducted a sensitivity analysis on B_1 prior distribution and *g* value.

Multi annual generalized depletion model

- ➔ Use of package Catdyn (Roa-Ureta, 2014).
- ➔ Catch data: catch and effort from French Otter Bottom Trawl
- ➔ Individual weights by month: biological sampling from Caen University.
- ➔ 22 perturbations, in September of each year.

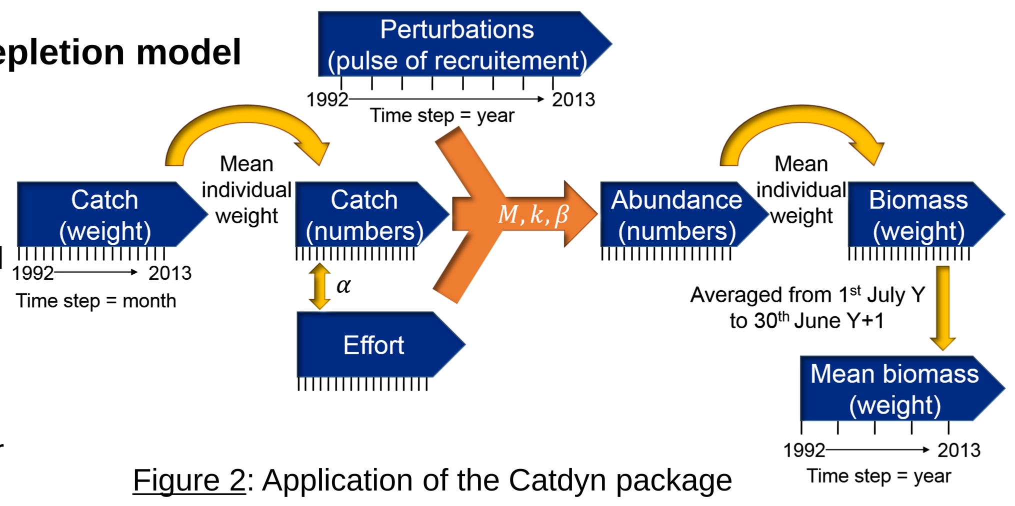

Figure 2: Application of the Catdyn package

- ➔ In a preliminary stage a one fleet normal model was fitted, using the spectral projected gradient (spg) numerical optimizer and selected with the AIC criterion.

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Results

Two-stage biomass model

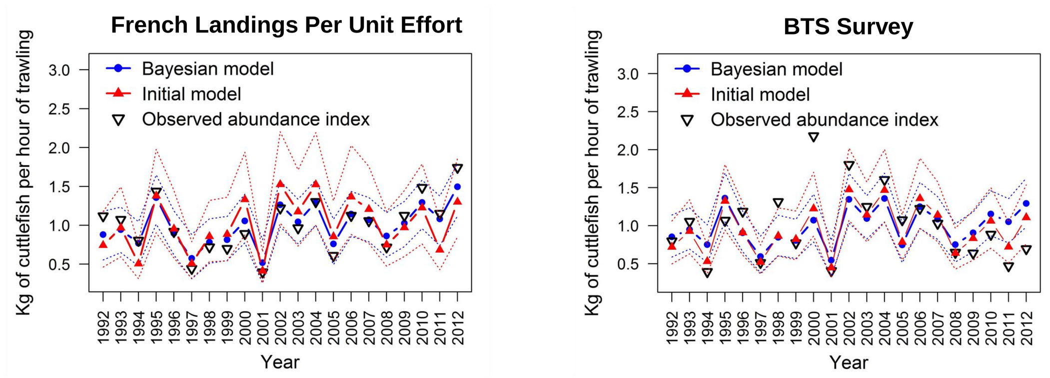

Figure 3: Comparison of initial and Bayesian model fit

- ➔ Better fit of the Bayesian model for French and UK LPUE, but better fit of the initial model for BTS and CGFS surveys (Figure 3).
- ➔ Similar catchability estimates whatever the fitting method: differences from +3.3% to +12.6%.

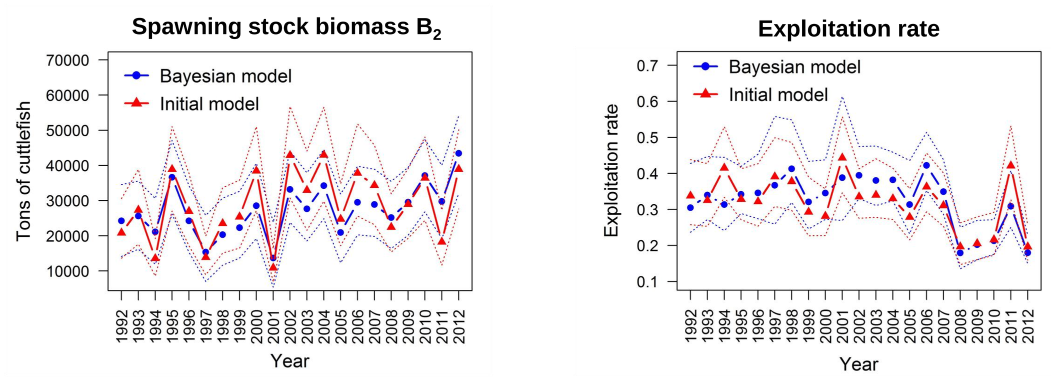

Figure 4: Comparison of spawning stock biomass B_2 and exploitation rates obtained with initial and Bayesian two-stage biomass model

- ➔ No stock-recruitment relationship for Bayesian model, nor for initial model.
- ➔ Blim can be set as the smallest estimated value of B_2 (13 690 tons for Bayesian model and 10 884 tons for initial model)
- ➔ Similar trends of B_2 and exploitation rate for both models (Figure 4).
- ➔ Bayesian outputs show a smaller range of variation than the initial fit.
- ➔ Important decrease in exploitation rate between 2006 and 2008.

Sensitivity analysis of the Bayesian two-stage model

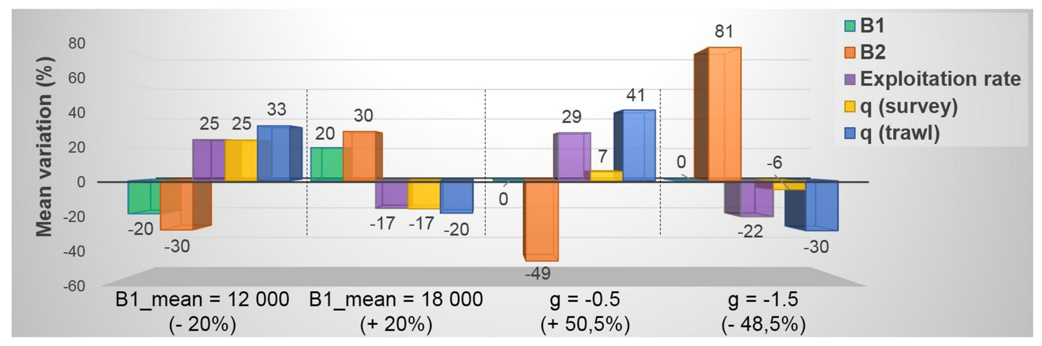

Figure 5: Variation of B_1, B_2, exploitation rate and catchabilities estimates with different values of g and B_1 prior distribution

- ➔ B_2 estimates are very sensitive to variation of *g* (Figure 5).
- ➔ A change of 20% in the mean value of B_1 prior distribution leads to 30% variation of B_2 estimates.
- ➔ Estimates of exploitation rates are most sensitive to underestimation of B_1 prior distribution and overestimation of *g*.
- ➔ Survey catchability estimates (in yellow) are most sensitive to variation of B_1 prior distribution, whereas UK and French fleet catchability estimates (in blue) are most sensitive to variation of *g*.

Multi annual generalized depletion model (MAGD)

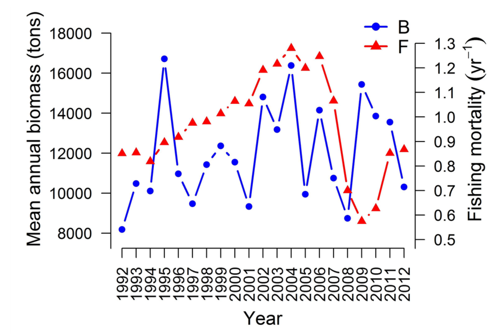

Figure 6: Evolution of biomass and fishing mortality with MAGD model

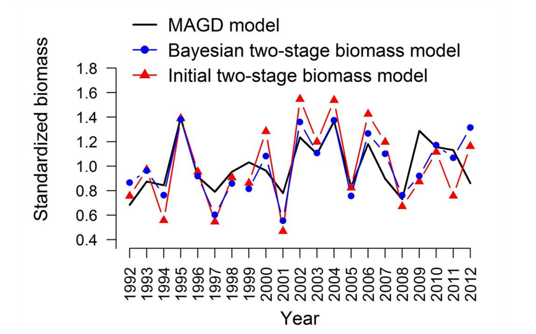

Figure 7: Comparison of the evolution of the standardized biomass

- ➔ Fishing mortality decreases from 2006 to 2009 (Figure 6), following exploitation rate trends of the two-stage biomass model.
- ➔ Plot of biomass standardized by the mean of the series (Figure 7) shows a similar evolution for all models.
- ➔ MAGD outputs show a smaller range of variation than two-stage biomass model, following the Bayesian fit closer than the initial fit.

Conclusions and discussion

- ➔ Estimates obtained from the initial two-stage biomass model (Duhem *et al.* in WGCEPH, 2014) and the Bayesian fit show similar trends.
- ➔ Although absolute values of biomass estimates are different between MAGD model and two-stage biomass model, standardized estimates show similar trend.
- ➔ The 2006 peak and the following decrease in fishing mortality (MAGD) is consistent with the exploitation rate trend (two-stage biomass model).
- ➔ MAGD biomass estimates are likely sensitive to population structure and interannual changes in individual weight.
- ➔ The need of individual weight data is the limiting factor of the MAGD model. But this model allows integration of two fleets.
- ➔ It could be interesting to integrate fishing pot fishery, but we would need to collect additional data of individual weight by month for this kind of fleet.
- ➔ In our study we included only French fleet, but we could integrate UK data if data of individual weight by month were available.
- ➔ Results of the sensitivity analysis toward *g* are similar for the Bayesian two-stage model and for the initial model. The high sensitivity of B_2 estimate to *g* stresses the need to better estimate *g*, a key parameter for this model.
- ➔ One possibility is to build an informative prior for *g*, using meta-analysis on other stocks.
- ➔ Prior distribution of Bayesian model requires prior knowledge, which can be obtained for example with experts.

Future directions

- ➔ Next step: apply a hierarchical statistical framework to combine MAGD models and biomass dynamic models, as developed by Roa-Ureta *et al.* (2015) with a random effects state-space model.
- ➔ Apply a Bayesian model combination. Use posteriors from both two-stage biomass model and state-space model, and take into account uncertainties involved in model selection.
- ➔ Integrate migration in the model. The integrated hierarchical Bayesian life cycle modelling framework from Massiot-Granier *et al.* (2014) could be a starting point to build such a model.
- ➔ Blim value could in a first step be used for management purpose, but as recruitment is highly dependant on environmental conditions, other methods should be sought.
- ➔ Integrating environmental factors in the model could help better model stock dynamics. Integrating migration could also be useful to set spatialized management rules.

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