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 modeling 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 methods (Foucher & 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 & Boisnuty, 1991).

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 (Grais et al., 2014), for routine use (Duhem et al. in WGCEPH, 2014). Two-stage biomass model (Pool & Butterworth, 2000): not too much data-demanding, well suited for data-limited stocks.

Advantage of using Bayesian methods for estimating uncertainties in these models (Baibaroglu et al., 2006). 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 (Grais 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 (B0) estimated with abundance indices from BTS and CGFS surveys.
- Spawning stock biomass (B1) estimated with landings per unit effort of French and UK trawlers.

Biomass growth parameter K fixed externally.

We implemented the same model into a Bayesian framework and coded it with OpenBUGS. The Bayesian model required informative prior distributions for B0 and catchability rates. We conducted a sensitivity analysis on B0 prior distribution and g value.

Multi annual generalized depletion model
Use of package Caddy (Roa-Ureta, 2014).
- Catch data: catch and effort from French Otter Bottom Trawls.
- Individual weights by month: biological sampling from Caen University.
- 22 perturbations, in September of each year

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.

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 posterior from both hierarchical biomass model and state-space model, and take into account uncertainties involved in model selection.

- Integrative 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 purposes, but as recruitment is highly dependent 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.

Conclusions and discussion
- Estimates obtained from the initial two-stage biomass model (Duham 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
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 B0 (13 690 tons for Bayesian model and 10 884 tons for initial model).
- Similar trends of B0 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
- B0 estimates are very sensitive to variation of g (Figure 5).
- A change of 20% in the mean value of B0 prior distribution leads to 30% variation of B0 estimates.
- Estimates of exploitation rates are most sensitive to underestimation of B0 prior distribution and overestimation of g.
- Survey catchability estimates (in yellow) are most sensitive to variation of B0 prior distribution, whereas UK and French fleet catchability estimates (in blue) are most sensitive to variation of g.

Multi annual generalized depletion model (MAGD)

- 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.