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Development of a predictive tool for English Channel squids abundance (*Loligo forbesii* and *Loligo vulgaris*) applicable early in the fishing season: linear approach using climatic data.

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Summary
In the English Channel, the long finned squid stock is one of the most abundant resource in weight and the highest in value for bottom trawlers. This resource consists of two short-life species (not distinguished by fishers): *Loligo forbesii* and *Loligo vulgaris* which are characterized by an interval in the timing of their life-cycle. Population models applied to the English Channel stocks were based on depletion methods or VPA adapted on a monthly basis. These exercises were historical analyses and because of data availability could not be converted into a fully-functional routine. However, they underlined recruitment variability and the need to estimate cohort strength. Abundance indices of the English Channel squid are computed according to the Delta-GLM method from French commercial otter bottom trawl data. The index computed is split into two time-series according to the species proportions sampled at the Port-en-Bessin fish market. Predictors of the abundance are sought among variables easily available. Significant relationships between cephalopod recruitment and environmental variations have already been described. In the present study, climatic data such as SST, speed wind, SLP and NAO are the main descriptors retained in a linear model. Predictions are computed with GLM tools using frequentist approaches for the confidence interval.

Introduction

At the English Channel scale, the long finned squid stock is one of the most abundant resource in weight and the highest in value for bottom trawlers (CHARM III, 2012). French fishers carries out around 80% of the annuals squid landings whereas UK fishers catch 20% of the resource. The English Channel long finned squid stock consists of two short-life species (not distinguished by fishers): *Loligo forbesii* and *Loligo vulgaris* (Robin and Boucaud-Camou, 1995). The two species are characterized by an interval in the timing of their life-cycle. (Robin and Boucaud-Camou, 1995). Population models were applied to the English Channel stocks for the recruitment assessment. They were based on depletion methods or VPA adapted on a monthly basis. These exercises were historical analyses and because of data availability could not be converted into a fully-functional routine. The present study has for aim to develop a predictive tool for the English Channel long finned squid stock destined to routine application earlier in the fishing season. Predictors of the abundance are sought among variables easily available. Climatic variations such as SST, speed wind and others were knows to impact cephalopod abundance (Robin and Denis, 1999; Challier et al., 2005; Pierce et al., 2008), spatial distribution and life cycle (Pierce et al., 2008; Sims et al., 2001; Vila et al., 2010). Climatic variables are now easily shared using free database which are quickly updating. For this reason, climatic variables were used as predictor in this study.

Material and Methods

In the English Channel, long finned squid are mainly catch by the French fishing fleet using bottom trawl gear. A Fishing season was determined from June of the year *y* to May of the year *y+1*. French commercial data from 1999 to 2013 was extracted from Ifremer databases into "landing" table and "effort" table. Commercial squid landings was collected by all gears whereas all effort data are related only to bottom trawlers. This data are considered enough strength to compute Landing Per Unit Effort (LPUE) using hours of trawling as effort. The whole LPUE time series was standardized using Delta-GLM method and split into two time-series according to the species proportions sampled at the Port-en-Bessin fish market. At least, three time series were analyzed according to each species and both species mixed.

Several climatic variables on a monthly scale were downloaded from NOAA databases covering the whole LPUE series from 1999 to 2013. After analyses, four of them were selected according to their correlation with LPUE series: SST, SLP (ICOADS re-analysis from ESRL NOAA), U-Wind and NAO (CPC – NOAA/National Weather Service). The predictions were carries out using linear approach (guassian GLM) according to relations described below:

(a) $LPUE_{two\ species} \sim SST_{June\ to\ October} + NAO_{June\ and\ July}$
(b) $LPUE_{L.forbesii} \sim SST_{May\ to\ July} + U\text{-}wind_{May\ and\ June} + NAO_{June\ and\ July}$
(c) $LPUE_{L.vulgaris} \sim SST_{August\ To\ October} + SLP_{May\ to\ July}$

Results and discussion

The three linear models using climatic variables as descriptors (Figure 1) show significant fit with abundance indices and residuals do not show any particular structure. According to adjusted R squared, model (a) which the two species are mix, seems show a better prediction ($R^2=0.72$) than the two others ($R^2=0.70$ for *L.forbesii*, $R^2=0.68$ for *L.vulgaris*). We can also observe a similar trend between abundance indices of *L.vulgaris* (c) and the general one (a). In the same way, the last value of the first model (a) seems highly impacted by the abundance rise in *L.forbesii* (b). Model validation methods were explored (not showed) and underline the first linear relation (a) as strongest than the two others (around 40% of precision). This preliminary results show a good correlation between squid abundance and environmental variables used here as general descriptors of climatic variations. According to the time scale used for each climatic variables and LPUE time series abundance variations seem affected mainly by climatic variation a few months before recruitment.

Climatic variables revealed to be good candidates for predicting squid recruitment strength: they can be available early enough for routine predictions and they provide the opportunity to integrate squid population climate change scenarios.

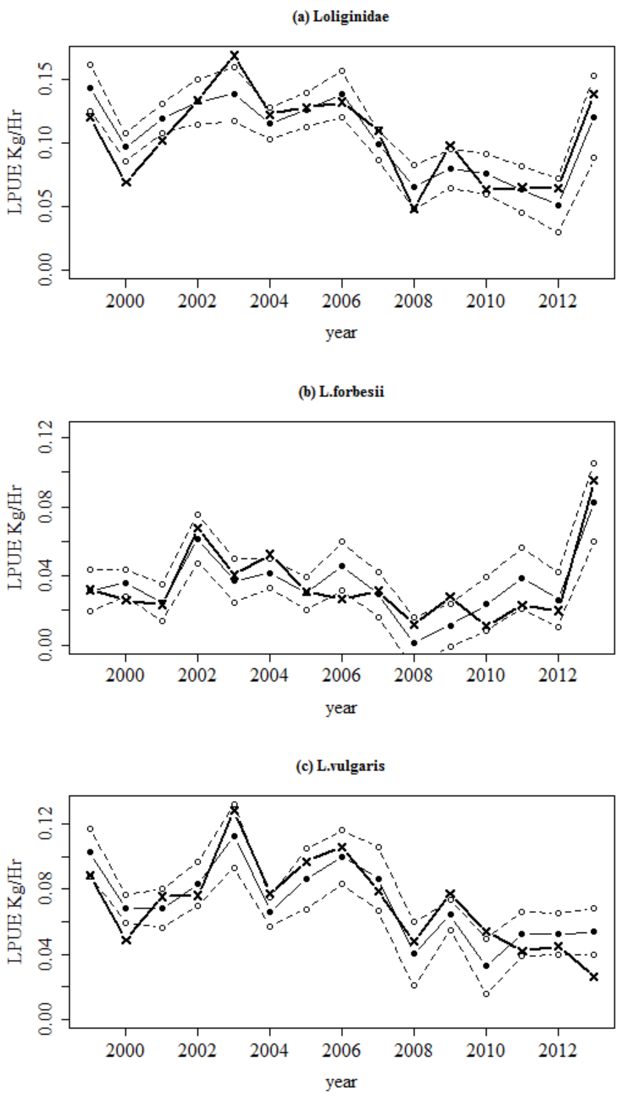

Figure 1. Time series of the observed (-X-) and predicted (-O-) abundance indices with 95% confidence interval from 1999 to 2013.

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