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# The impact of environmental variability on Atlantic mackerel *Scomber scombrus* larval abundance to the west of the British Isles

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ABSTRACT

The value of the Continuous Plankton Recorder (CPR) fish larvae dataset, with its extensive spatio-temporal coverage, has been recently demonstrated with studies on long-term changes over decadal scales in the abundance and distribution of fish larvae in relation to physical and biological factors in the North Sea. We used a similar approach in the west and southwest area of the UK shelf and applied a principal component analysis (PCA) using 7 biotic and abiotic parameters, combined with Hierarchical Cluster Analysis (HCA), to investigate the impact of environmental changes in the west and southwest area of the UK shelf on mackerel larvae during the period 1960–2004. The analysis revealed 3 main periods of time (1960–1968; 1969–1994; 1995–2004) reflecting 3 different ecosystem states. The results suggest a transition from an ecosystem characterized by low temperature, high salinity, high abundances of zooplankton and the larger phytoplankton groups, to a system characterized by higher temperature, lower salinities, lower abundances of zooplankton and larger phytoplankton and higher abundances of the small phytoplankton species. Analysis revealed a very weak positive correlation between the Second principal component and mackerel larvae yearly abundance, attributed to the North Atlantic Oscillation (NAO). The results presented here are in broad accord with recent investigations that link climatic variability and dynamics of mackerel reproduction. However, the growing body of literature that documents statistical correlations between environment and mackerel needs to be supplemented by local process studies, to gain more insight and to be able to predict mackerel response to climate change scenarios. Utilising the strength of the CPR dataset, namely its unique temporal coverage, in an analysis where other data (such as egg surveys) are drawn in to compensate for the spatial issues could prove to be the way forward.



## 1. Introduction

Atlantic mackerel *Scomber scombrus* is one of the most abundant migratory fish species in the North East Atlantic. It is pelagic in all life stages and its distribution encompasses the entire ICES area (ICES, 2012). The most important spawning areas in recent decades are located to the south and west of Ireland. Outside the spawning season, the centre of distribution shifts northwards as the mackerel migrate to the feeding grounds between Greenland, Norway and in the North European shelf Seas. Over the years, great variability in abundance and distribution of mackerel population has been observed (ICES, 2012; Jansen, 2014). Substantial quantities of mackerel are now being landed from Icelandic and Greenland EEZs where mackerel was not caught in great quantities before (ICES, 2014). The changing spatial dynamics of the mackerel population is a challenge for the international management. This is clear from the fact that, despite protracted negotiations over Total Allowable Catches (TACs), no international agreement that includes all fishing nations has been achieved since 2007. A deeper understanding of the abundance and distribution dynamics of this commercially important species may facilitate international agreements and in turn, a more optimal utilisation of the resource.

The Continuous Plankton Recorder (CPR) Survey's marine monitoring programme was established in 1931, and has been collecting data from the North Atlantic and the North Sea on the ecology and biogeography of plankton, consistently since 1946. The spatio-temporal coverage of the CPR is therefore one of the longest and largest offered by any biological monitoring programmes worldwide. The utility of this dataset has been established with the many, and increasingly complex, studies published, aiming to relate spatio-temporal changes in plankton distribution to underlying ecosystem changes. It has also provided valuable

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information concerning the scale and nature of processes affecting fish stocks (Brander et al., 2003). As well as zooplankton and phytoplankton (the main focus of the CPR), fish larvae have been analysed up until-through 2005 (Edwards et al., 2011). The value of the CPR fish larvae dataset, with its extensive spatio-temporal coverage, has been recently demonstrated with studies on long-term changes over decadal scales in the abundance and distribution of fish larvae in relation to physical and biological factors (Pitois et al., 2012), on blue-whiting populations in the North Atlantic (Pointin and Payne, 2014), and on the use of a larval index to inform stock assessments for sandeels (Lynam et al., 2013) and mackerel (Jansen et al., 2012b) in the North Sea. Analyses in the North Sea (Pitois et al., 2012) suggest that the larvae of clupeids, sandeels, dab and gadoids seem to be affected mainly by changes in the plankton ecosystem via bottom-up effects, while the larvae of migratory species such as mackerel respond more to hydrographic influences. Here we use a similar approach to this previous work and focus on the larvae of mackerel collected by the CPR in the west and southwest of the British Isles. Firstly we attempt to identify regimes with defined environmental conditions and second, to identify potential linkages between the environment and fish larvae. We then compare our results with those obtained from the North Sea by Pitois et al. (2012).

## 2. Materials and methods

### 2.1. The CPR survey

The CPR device is towed by ships of opportunity at speeds of 15 to 20 knots, at an approximate depth of 10 m. Water enters the recorder through an aperture of 1.27 cm$^2$, and is filtered through a continuously moving band of silk with an average mesh size of 270 µm. Each sample represents ~3 m$^3$ of filtered seawater. Methods of counting and data processing have been described by Colebrook (1975) and Batten et al. (2003). All plankton data were extracted from the CPR dataset.

### 2.2. Area of study

Results from the CPR survey show two separate spawning areas for mackerel in the central North Sea and to the west and southwest of the British Isles (Fig. 1a). Mackerel larvae caught by the CPR have declined substantially over the period 1948–2005 reflecting a decline of first the North Sea stock and subsequently the western population (Edwards et al., 2011). This was however followed by a period of stock extension, not included here (ICES, 2014). The area of study for this analysis was selected according to the distribution of mackerel larvae from CPR samples within the west and southwest area of the UK Shelf (Fig. 1b). We extracted a total of 43,882 data points within the area delimited by latitude 47°N to 60°N and longitudes 14°W and 2°W, over the period 1960–2004, this ensured consistency across all datasets used. It is important to bear in mind that the study area does not cover the total spawning grounds of NE Atlantic mackerel; an important spawning grounds also exists in the Bay of Biscay (ICES, 2013). The CPR also collects samples from the Bay of Biscay but this only includes one route from Bilbao (Spain) to Land's End (England). Based on limited coverage and resolution of the data and the low number of larvae caught from the Bay of Biscay (Fig. 1b), we decided to limit our work to the area which the highest number of larvae caught in CPR samples.

### 2.3. Plankton data

Zoo- and phytoplankton data were extracted from the CPR dataset along with the mackerel larvae data. As a proxy for zooplankton, we extracted the total abundance of copepods and of cladocerans. These 2 groups were selected because they are important prey of many fish larvae, including mackerel, in their early stages of life (Last, 1980). The CPR underestimates zooplankton abundance compared with other datasets (Clark et al., 2001; John et al., 2001). As we thought it important to take into account the relative contribution of each potential prey species to the total zooplankton abundance, undersampling was corrected using species-specific WP-2/CPR ratios (Pitois and Fox, 2006). We gathered together all these species-specific corrected abundances to create an index of total zooplankton abundance.

A lot of recent work has shown notable prey selectivity in mackerel larvae that does not support the view that all copepods are the same (Paradis et al., 2012; Peterson and Ausubel, 1984; Robert et al., 2014). Because, prey selectivity seems to vary from area to area depending on the particular prey available; we could not extract some selectivity index that could be applied on the CPR data as a whole.

Fish larvae caught by the CPR are very small. Johnson (1977) reported that the larvae of Atlantic mackerel caught by the CPR were <7 mm long, on average 5 mm; and Jansen et al. (2012b) estimated that these had a length of 4.8 mm using a backwards-advection model based upon an estimate of time-since-spawning. Such larvae are very young and likely to be 5–12 days old (Robert et al., 2014; Jansen et al., 2012b) depending on temperature and food conditions mainly. These small larvae tend to feed on the smallest prey available, such as phytoplankton and copepod eggs

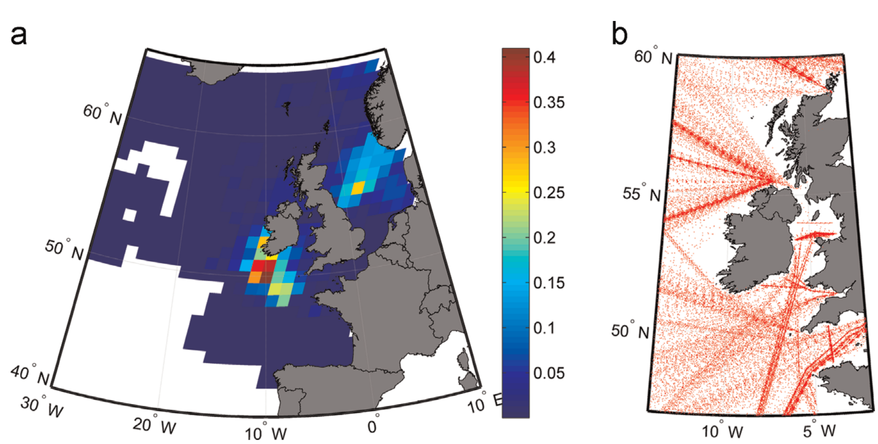


**Fig. 1.** (a) Mackerel larvae distribution from Continuous Plankton Recorder (CPR) samples collected between 1948 and 2005. (b) Area of study (47°N to 60°N, 14°W to 2°W) and ichthyoplankton sampling locations over the period 1960–2004 (43,882 data-points).