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Impact of climate variability on ichthyoplankton communities: An example of a small temperate estuary

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ABSTRACT

Recent variations in the precipitation regime across southern Europe have led to changes in river fluxes and salinity gradients affecting biological communities in most rivers and estuaries. A sampling programme was developed in the Mondego estuary, Portugal, from January 2003 to December 2008 at five distinct sampling stations to evaluate spatial, seasonal and inter-annual distributions of fish larvae. Gobiidae was the most abundant family representing 80% of total catch and *Pomatoschistus* spp. was the most important taxon. The fish larval community presented a clear seasonality with higher abundances and diversities during spring and summer seasons. Multivariate analysis reinforced differences among seasons but not between years or sampling stations. The taxa *Atherina presbyter*, *Solea solea*, *Syngnathus abaster*, *Crystallogobius linearis* and *Platichthys flesus* were more abundant during spring/summer period while *Ammodytes tobianus*, *Callionymus* sp., *Echiichthys vipera* and *Liza ramada* were more abundant in autumn/winter. Temperature, chlorophyll *a* and river flow were the main variation drivers observed although extreme drought events (year 2005) seemed not to affect ichthyoplankton community structure. Main changes were related to a spatial displacement of salinity gradient along the estuarine system which produced changes in marine species distribution.

1. Introduction

Nearshore estuarine and marine ecosystems serve many important functions in coastal waters. Often referred to as nurseries, estuaries play an important role in many species lifecycles, including fish (Beck et al., 2001; Elliott and McLusky, 2002; Martinho et al., 2007a) providing food abundance and shelter to marine fish larvae and juveniles and therefore maximizing their survival (Whitfield, 1999; Elliott and McLusky, 2002). Larval fish dynamics contribute significantly to understanding the ecology of fish populations (Doyle et al., 2002) as they can indicate the spawning-stock biomass and recruitment in adult fish stocks (Hsieh et al., 2005). Initial development stages of fishes are particularly vulnerable and are influenced by physical and biological processes. Indeed, several factors have already been related to survival and distribution of ichthyoplankton (e.g. hydrological conditions, transport processes, seasonal variability, spawning patterns of adults, food availability) (Franco-Gordo et al., 2002; Alemany et al., 2006; Sabatés et al., 2007; Isari et al., 2008). The effects of climate on fish populations can also be shown by long-term trends in ichthyoplankton populations. Lower trophic level organisms should be more sensitive in reflecting environmental perturbations more quickly than higher trophic levels but early life stages may be environmentally sensitive prior to buffering through density-dependent mechanisms and community effects (Boeing and Duffy-Anderson, 2008). Thus knowledge of the ichthyoplankton community dynamics is important in understanding changes in fish communities.

Recent studies indicate that the Mondego estuary (40°08′N, 8°50′W), Portugal, is an important nursery ground for several commercial fish species (e.g. *Dicentrarchus labrax*, *Platichthys flesus* and *Solea solea*) (Leitão et al., 2007; Martinho et al., 2007a). Studies on ichthyoplankton started with Ribeiro (1991) but recently only Marques et al. (2006) referred to these communities. Previous works focused on community assemblages but information of the way environmental factors force community structure is still limited. In addition, Portugal recently has been under varying precipitation regimes with values of 45–60% below average in the hydrological year 2004/2005 producing the biggest drought in a century (Portuguese Weather Institute: http://www.meteo.pt/en/index.html) and thus providing a unique opportunity to investigate ichthyoplankton responses to extreme events. Hence this study

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aimed to characterize ichthyoplankton assemblages, to evaluate environmental influence in its structure and establish the consequences of extreme events, such as droughts, on estuarine fish larvae communities. The hypothesis tested was that reduced river flow resulted from the decrease of precipitation mean levels lead to changes on community structure and longitudinal displacement of species according to salinity gradients.

2. Materials and methods

2.1. Study area

The Mondego estuary, located on the Atlantic coast of Portugal (40°08′N, 8°50′W), consists of two channels (northern and southern) with different hydrological characteristics separated by the Murraceira Island (Fig. 1). The north channel is deeper (4–8 m depth at high tide) has lower residence times (<1 day) and constitutes the main navigation channel, while the south channel is shallower (2–4 m deep, at high tide), has higher residence times (2–8 days) and is almost silted up in the upper areas. Most of the freshwater discharge is throughout the northern channel since it is directly connected with the Mondego River. In the southern channel, water circulation is mostly due to tides and the freshwater input from a small tributary, the Pranto River which is small and artificially regulated by a sluice. Previous studies demonstrated that distinct environmental factors provide a large variety of aquatic habitats for populations of marine, brackish and freshwater zooplankton species, mainly due to salinity and water temperature gradients (Azeiteiro et al., 1999; Marques et al., 2006; Primo et al., 2009).

2.2. Sample collection

Sampling was carried out monthly during daylight at high tide, from January 2003 to December 2008 at five stations distributed throughout both arms (Fig. 1). Samples were collected by horizontal subsurface tows (Bongo net: mesh size 335 μm, mouth diameter: 0.5 m, tow speed: 2 knots), equipped with a Hydro-Bios flowmeter (the volume filtered averaged 45 m^3) and preserved in a 4% buffered formaldehyde seawater solution. Additionally, at each site, salinity, water temperature (°C), dissolved oxygen ($mg\,l^{-1}$), pH and turbidity (Secchi disc depth, m) were also recorded. Subsurface water samples were also collected for subsequent determination in the laboratory for chlorophyll *a* ($mg\,m^{-3}$) and total suspended solids ($mg\,l^{-1}$). In the laboratory, the ichthyoplankton was sorted, counted (number of individuals per 100 m^3) and identified to the highest possible taxonomic separation (Petersen, 1919; Fives, 1970; Nichols, 1976; Demir, 1976; Russell, 1976; Ré, 1999; Ré and Meneses, 2009). Copepod densities ($ind\,m^{-3}$) were also recorded. Monthly precipitation values were acquired from INAG – Instituto da Água (http://snirh.pt/) measured at the Soure 13 F/01G station and the freshwater discharge from the Mondego River was obtained from INAG station Açude Ponte Coimbra 12G/01AE.

2.3. Data analysis

Sampling months were combined into four conventional seasons: winter (W) included December, January and February; spring (S), March, April and May; summer (SM), June, July and August and autumn (A), September, October and November. Species were characterized in three main ecological guilds (adapted from Elliott et al., 2007): marine stragglers (MS – species that spawn at sea and typically enter estuaries in low numbers occurring frequently in the lower reaches), marine migrants (MM – species that spawn at sea and often enter estuaries in large numbers) and estuarine species (ES – including estuarine species capable of completing their entire life cycle within the estuarine environment and those with stages of their life cycle completed outside the estuary).

Salinity anomalies were calculated by subtracting the mean seasonal value from the mean value of the given time period. The differences between seasons and years in each sampling station were tested by Analysis of Variance (ANOVA) for environmental factors. log $(x + 1)$ transformation was performed and for pairwise multiple comparisons the Holm–Sidak method was applied. Temporal and spatial ichthyoplankton distribution maps were obtained by Sigmaplot software as well as diversity, expressed by Shannon–Wiener index (log_2).

PERMANOVA+ for PRIMER software (PRIMER v6 & PERMANOVA+ v1, PRIMER-E Ltd.) was used to perform a non-parametric permutational multivariate analysis of variance (PERMANOVA) to test for differences in the assemblage structure between years, seasons and sampling stations. The analysis was based on Bray–Curtis similarities

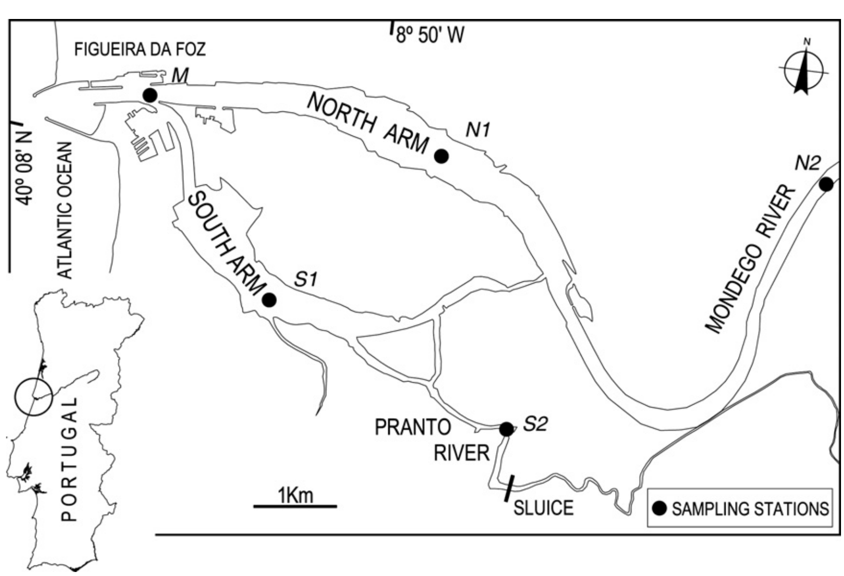

Fig. 1. Map of the Mondego estuary, located on the western coast of Portugal. Sampling stations surveyed in this study are indicated (M, mouth station; S1 and S2, southern arm stations; N1 and N2, northern arm stations).