Environmental forcing and ichthyoplankton composition and distribution off the NW and N Iberian Peninsula coast, in spring

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Introduction

Environmental physical processes are of major importance for the horizontal distribution of icthyoplankton abundance and for the horizontal structure of larval fish assemblages. The location and spawning strategy of adult fishes, the vertical distribution of fish larvae and their migratory behaviour are also involved in the horizontal distribution of fish larvae. Nevertheless, in plankton communities, biological-physical interactions are more important in determining patterns of horizontal distribution than purely biological forcing mechanisms (Mackas et al. 1985).

The oceanography off the Portuguese and Spanish coasts is highly influenced by seasonal factors. During winter, the shelf slope circulation is dominated by the Iberian Poleward Current (IPC). In spring-summer, dominant northerly winds produce coastal upwelling and equatorward flow. The IPC generates convergence zones over the shelf-break and mesocale eddies (Fernandez et al. 1993; Relvas et al. 2007). All these structures are important for the horizontal distribution of fish larvae, working as retention and/or poleward/equatorward transport mechanisms.

The aim of this study is to examine the relationship between selected environmental variables and ichthyoplankton off the NW and N Iberian Peninsula coasts, in spring.

Methods

Sampling procedures

The study area, sampled during the cruise Pelacus 0405, included the shelves and upper slope (coast-500 m isobath) of two geographic regions: the Atlantic region, from river Duero to Estaca de Bares cape, and the Cantabrian region (Fig. 1).

Hydrographic conditions were measured at every sampling station with a CTD SeaBird 25. Spiciness was analysed following the method proposed by (Gonzalez-Nuevo and Nogueira 2005).

Mesozooplankton and ichthyoplankton were sampled at three stations in every transect (Fig. 1) with a triple WP2 net.

Data analysis

The hydrographic data revealed the presence of two hydrographic regions (see "Results"), which coincided with the Atlantic and Cantabrian geographic regions. Within each region, the horizontal structure of its assemblage was analysed using hierarchical agglomerative clustering and the non-metric multidimensional scaling (MDS).

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The relationship between the larval fish assemblage and environmental variables was analysed with Canonical Correspondence Analysis (CCA), using CANOCO 4.5. Only species caught in more than three samples were inclued in the analysis. The explanatory variables were sea surface temperature (SST), sea surface salinity (SSS), Chlorophyll *a* concentration, mesozooplankton biomass and station depths.

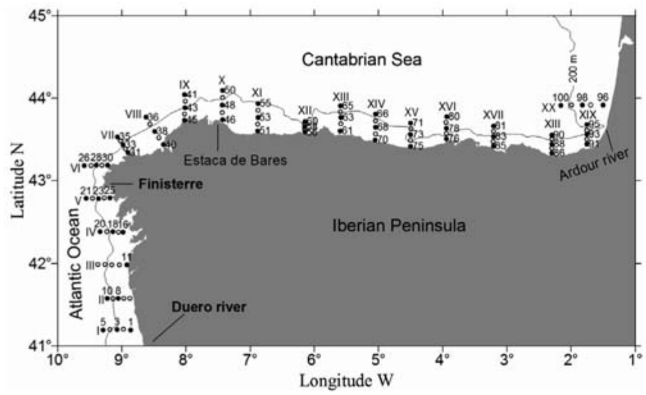

Figure 1. Study area and station map. (○) stations sampled for hydrography, (•) stations sampled for zooplankton and ichthyoplankton

Results

Hydrography

The spiciness analysis revealed the presence of an apparent frontal structure, located around Estaca de Bares cape (7.2 ºW), which separated two hydrographic regions. The Atlantic region showed significantly warmer (>13.0) and saltier (>36.66) surface waters than the Cantabrian region (t-test, df = 55, $p < 0.0001$, in both cases). In the Cantabrian region, SST significantly decreased and salinity, on the contrary, significantly increased offshore (Kruskalll Wallis test, $W < 0.02$). The spiciness analysis and cross-shelf vertical profiles of salinity revealed the presence of a salinity front located around the shelf break, which increased its intensity from west to east. This front was not found in the Atlantic region.

Ichthyoplankton composition, abundance and distribution

In all, 51 species of fish larvae, belonging to 26 families, were identified. *Sardina pilchardus* (58.7% of the total catches) dominated the larval fish assemblage.

Fish egg abundance was significantly lower (t-test, df = 55, $p < 0.02$) in the Atlantic than in the Cantabrian region. In both regions, abundance decreased offshore. Larval abundance was also lower in the Atlantic than in the Cantabrian region, decreasing offshore in both regions, but significantly (KW, p <

0.001) in the Cantabrian region only.

Results of the the Spearman's rank correlation indicated that fish egg and larval abundance were negatively correlated with SSS and depth and positively correlated with mesozooplankton biomass. Also, larval abundance was positively correlated with SST.

Larval fish assemblages

Larval diversity was significantly higher in the Atlantic than in the Cantabrian region (t-test, df = 55, $p < 0.01$). This indicated differences in the larval fish assemblage structure between both regions (Legendre and Legendre 1998).

In the Atlantic region, the classification (cluster) and the ordination (MDS) analysis grouped together, apart from three outliers, all the sampling stations. In the Cantabrian region, the classification and the ordination techniques produced two larval assemblages: a neritic and an outer assemblage.

The Monte Carlo permutation test showed that only three environmental variables (depth, SST and mesozooplankton biomass) were significant ($p < 0.05$) in explaining species distribution. Depth was highly and positively correlated with axis 1 while temperature was the environmental variable that showed the highest correlation with axis 2. Larvae of oceanic mesopelagic species were clustered on the right side of the ordination biplot while all the other species (neritic fish larvae) were clustered on the left side of the biplot.

Discussion

Hydrography

The Pelacus 2005 cruise was carried out at the beginning of the transition from typical winter downwelling conditions to summer upwelling ones (Fraga 1981), a period characterised by strong hydrographic variability (Torres and Barton 2007). The IPC would have been the main responsible for the presence of the shelf slope front found in the eastern Cantabrian region (Fernandez et al. 1993). The absence of the shelf break front along the Atlantic and westernmost Cantabrian regions could have been related with the offshore displacement of the IPC under upwelling favourable conditions (Torres and Barton 2007) recorded a few days after the beginning of the cruise.

S. pilchardus widely dominated the ichthyoplankton population. This is not surprising because this is the most abundant fish species along the west and north shelves of the Iberian Peninsula, and the cruise was carried out at the time of the spawning peak of this species in the region.

Whether fish spawning patterns may be interpreted as an adaptive strategies to certain environmental factors to optimise larval survival (Roy et al. 1989), the more intense spawning recorded in the Cantabrian Sea suggests that environmental conditions in this region were more suitable for eggs and larval survival than in the Atlantic region. Results of the correlation analysis indicated that spawning was more intense in shallow, coastal waters with lower salinities, because of river runoff, and with higher mesozooplankton biomass. Rivers runoff are much more important in the Catabrian Sea. They transport nutrients into the sea and produce a strong haline stratification that, in the absence of thermal stratification, gives stability to the water column, favours biological production (Borja et al., 1996), increases food concentration and makes it available to fish larvae (Lasker, 1984). Moreover, the shelf break front may contribute to larval survival, working as a retention mechanism for neritic spawners (Fernandez et al. 1993; Gonzalez-Quiros et al. 2004)

Larval assemblages

The Atlantic region, as revealed by multivariate analysis, was inhabited by a homogenous larval fish assemblage. The upwelling event, which occurred at the beginning of the cruise, could have been responsible for this homogeneity.

In the Cantabrian region, the shelf slope front, located in the central and eastern zones, seems to have been the responsible for the structuring of the larval fish community into two assemblages.

The CCA analysis revealed that depth, a cross-shelf gradient, was the main environmental gradient in explaining larval fish distribution. Larval fish species, associated with depth waters, were clustered on the right side of the plot, while larval species associated with shallow waters, were clustered on the left side of the plot.

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