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Spatial distribution and vertical migrations of fish larvae communities off Northwestern Iberia sampled with LHPR and Bongo nets

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ABSTRACT

The spatial distribution and diel vertical migration of fish larvae were studied in relation to the environmental conditions off NW Iberia during May 2002. Larvae from 23 families were identified, the most abundant were the Clupeidae, Gobiidae, Callionymidae, Blenniidae, Sparidae and Labridae. *Sardina pilchardus* was the most abundant species, mean concentrations 1 order of magnitude higher than the other fish larvae species. Larval horizontal distribution was mainly related to upwelling-driven circulation, resulting in an offshore increase of larval abundance while the vertical distribution was closely associated to the Western Iberia Buoyant Plume. Despite this general trend, taxon-specific relationships between the distribution of larvae and environmental variables were observed, and temperature was an important regressor explaining the distribution of most taxa. A comparison between ichthyoplankton samples collected alternatively with the LHPR and Bongo nets resulted in captures of larvae $\approx$1 order of magnitude higher for the LHPR, probably related to its higher towing speed. The spatial distribution and relative composition of larvae were also different for both nets, although the most frequent/abundant groups were the same. A fixed station sampled for 69-h showed diel vertical migrations performed by the larvae, with the highest larval concentrations occurring at surface layers during the night and most larvae being found in the neuston layer only during that period.

1. Introduction

Dispersal and transport of fish larvae are key factors affecting the recruitment of fish populations because the physical and biological processes that promote the aggregation of larvae in appropriate conditions possibly determine their survival (e.g., Hinckley et al., 1996). The heterogeneity of the survival of the early life stages of fish for different taxa, year-classes and areas may therefore be the result of the suitability of the environment for larvae development. However, larvae are not inert particles at the mercy of the physical processes, and can increase the probability of staying in appropriate environments by means of active vertical migrations. Vertical migrations of fish larvae are taxon-specific, can change with ontogeny and can reflect local adaptations, which has complicated the simple determination of the signals that trigger those migrations and their advantages for larvae survival. As reviewed in Neilson and Perry (1990), the most commonly accepted candidates as signals for fish larvae vertical migrations are light, prey concentration, thermocline, tides and changes in the buoyancy of larvae. The advantages of the vertical migration are generally proposed to be light-related predator avoidance, choice of optimal prey concentrations, selection of appropriate water temperature to adjust the metabolic rate to the available food in the water, rhythms of swim bladder inflation, and a strategy to guarantee their retention in shallow waters, this latter of crucial importance in upwelling regions. For upwelling areas, the diel vertical position of fish larvae determines if they are retained in shallow and productive waters or advected offshore, and larvae with near-surface distributions are more susceptible to offshore transport associated with coastal upwelling than deeper distributions that render larvae to shoreward transport (Rodriguez, 1990).

The Northwest Iberian coast is characterized by seasonal coastal upwelling during spring and summer (e.g., Wooster et al., 1976) and influenced by significant river runoff. Coastal upwelling is induced by the prevalence and steadiness of northerly winds between April and September, strengthened during summer by a thermal low pressure centre located typically over the Iberian Peninsula at this

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time of the year. The presence of filaments reappearing each year at the same locations is a conspicuous characteristic of the Western Iberia upwelling system (e.g., Haynes et al., 1993), promoting an important shelf–ocean exchange of water properties that can have an important impact in the dispersion and survival of fish larvae (e.g., Barton et al., 2001; Rodriguez et al., 2004). The Aveiro filament (e.g., Peliz et al., 2002) is one of these mesoscale features that occur in the region under study.

Besides upwelling events, two important oceanographic features have implications in the transport of fish larvae in the northwestern coast of Portugal: the Western Iberia Buoyant Plume (WIBP) and the Iberian Poleward Current (IPC) having a differential impact on larval fish depending on their vertical distribution (Santos et al., 2004, 2006). The WIBP is a recurrent low-salinity lens extending along the coast with origin in the discharge of many rivers present all year round in the region, despite the seasonal variability of riverine discharges. It is characterized by salinity values <35.7–35.8, a thickness of about 25 m from the surface (Peliz et al., 2002) and a rapid response to changes in wind conditions (Ribeiro et al., 2005; Otero et al., 2008). During upwelling favourable conditions, the WIBP spread offshore over the shelf and slope, being a favourable environment for larval fish survival (Chicharo et al., 2003; Santos et al., 2004, 2006; Ribeiro et al., 2005). On the contrary, during the influence of southerlies the plume is confined to the shelf and near-shore (Ribeiro et al., 2005). The IPC is a warm and salty surface slope current flowing poleward with mean velocities of about 0.2–0.3 m s^{-1} and a volume transport of about 1–2 Sv (Frouin et al., 1990; Haynes and Barton, 1990) and it is a clear feature of the autumn–winter season but probably occurs year round (e.g., Peliz et al., 2005). The implication of the IPC for larval fish transport is its blocking effect that prevents the seaward extension of the WIBP and leads to the formation of a convergence zone in the shelf break, thereby creating a mechanism for larval retention over the shelf (Santos et al., 2004). On the contrary, the Aveiro filament can promote the offshore extension of the WIBP in its zone of influence (Ribeiro et al., 2005).

The study of the relationship between oceanographic features and plankton distribution can be influenced by the type of sampling method that is used, given that different methods may have differential efficiency and selectivity while capturing plankton organisms. The Longhurst–Hardy Plankton Recorder (LHPR) and the Bongo nets are frequently used to capture fish larvae. A detailed comparison of the characteristics of these two nets is given in Stehle et al. (2007), where data collected from the same cruise as the present work has shown that the LHPR net captured 5 times more mesozooplankton biomass than the Bongo net, while the diversity of zooplankton species was similar between both nets. It is crucial to know the differences between the sampling strategies in the estimated abundances and composition of fish larvae communities, to be able to recognize which sampling device is more appropriate for the objective under study, e.g., estimate the diversity of species or directed towards specific larvae taxa or specific depth ranges.

The objectives of this study are 1) to examine the spatial distribution and diel vertical migrations of fish larvae communities off NW Iberia during the spring season, when upwelling events occur in this area and 2) to compare the abundance and composition of fish larvae caught by two different nets, the LHPR and Bongo nets. Results of this cruise referring specifically to the vertical distribution of the sardine (*Sardina pilchardus*) captured by the LHPR net were published elsewhere (Santos et al., 2006). As far as we are aware of this is the first time a study is carried out with sufficient temporal and vertical resolution to enable an investigation of the diel vertical migration for a broad number of marine fish larval taxa.

2. Materials and methods

The vertical distribution, concentration and community structure of fish larvae were studied off the NW Iberian coast during an oceanographic survey carried out in May 2002 on board of the RV "Noruega". From 15 to 17 May 2002 plankton samples were collected along four transects perpendicular to the coast, over a grid of 38 stations (Fig. 1). LHPR and Bongo stations were performed alternatively along the 4 transects. The LHPR net (Williams et al., 1983) had a 42 cm diameter aperture and a 280 μm mesh. This net collected vertical-stratified samples at each station, operating at 3–4 knots on oblique tows from the surface to 5–10 m above the ocean floor. The Bongo net had a 60 cm diameter aperture and a 335 μm mesh, was operated at ≈2 knots and collected double-oblique hauls from the surface until 5–10 m above the bottom. Temperature, salinity and chlorophyll-*a* concentration profiles were taken in all stations with a SBE 9plus CTD (Conductivity–Temperature–Depth) fitted with a Seapoint fluorometer.

A fixed station positioned at about 20 km away from the coast over a bottom depth of 60 m was sampled continuously for 69 h, from 18 to 21 May 2002 (Fig. 1). At this station, samples were taken every 2 h with LHPR and neuston nets and CTD data were collected hourly. The neuston net had a rectangular opening of 0.20 m^2 and a 335 μm mesh size and was towed at ≈1.5 knots for 3 min in the first 20 cm of the surface layer.

Plankton samples were preserved for posterior analysis in seawater with 4% borax buffered formaldehyde. In the laboratory, samples were sorted for fish larvae and the displacement volume (ml 10 m^{-3}) was used as a proxy of mesoplankton biomass as described in Stehle et al. (2007). Fish larvae were then identified and quantified using a stereomicroscope.

To estimate the depth at which the fish larvae were found in higher concentrations for the grid of stations, the Weighted mean depth was estimated for each larval group, using the formula of Worthington (1931) to analyse the vertical distribution of larvae:

$$W = \sum_{i}^{n} Oi \; Zi$$

where *Oi* is the frequency of occurrence of a given larvae group and *Zi* is the sampling depth. *Zi* was calculated as the middle point of the depth strata.

In order to compare the diversity of fish larvae taxa caught by the LHPR and Bongo nets, the species richness or the total number of different fish larvae taxa and the Shannon–Wiener diversity index were calculated for each sample.

To study the vertical distribution of the most frequent and abundant fish larvae taxa as a function of environmental factors, we build a Hurdle regression model (Gurmu, 1998), given that the concentrations of most taxa in the strata were zero-inflated and overdispersed. Hurdle regression model is a two-component model with a truncated count component for positive counts and a component that models the zero counts (Zeileis et al., 2008). The Hurdle regression model is simpler to interpret than other zero-inflated regression models, because the binomial probability model and the truncated-at-zero count data model are fitted separately (Welsh et al., 1996; Barry and Welsh, 2002). The zero Hurdle models or the probability of finding zero or positive values of larval abundances were adjusted to a binomial distribution with a logit link. The count model was fitted to a truncated at zero negative binomial distribution with a log link. The concentration of fish larvae taxa collected with the LHPR net in each station was grouped for several vertical strata: 0–10 m, 10–15 m, 15–20 m, 20–25 m, 25–35 m, 35–45 m, 45–55 m, 55–65 m, 65–85 m, 85–105 m and >105 m. The following predictors were used: temperature (°C), salinity, depth of