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Habitat association of larval fish assemblages in the northern Persian Gulf

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ABSTRACT

We examined the habitat use of fish larvae in the northern Persian Gulf from July 2006 to June 2007. Correspondence Analysis showed significant differences between hydrological seasons in habitat use and structure of larval fish assemblages, while no differences were found regarding abundance among coralline and non-coralline habitats. The observed configuration resulted in part from seasonal reproductive patterns of dominant fish influencing the ratio pelagic:demersal spawned larvae. The ratio increased along with temperature and chlorophyll-a concentration, which likely fostered the reproduction of pelagic spawner fish. The close covariation with temperature throughout hydrographic seasons suggests a leading role of temperature in the seasonal structure of larvae assemblages. Our results provide new insights on fish larval ecology in a traditionally sub-sampled and highly exposed zone to anthropogenic pollution, the northern Persian Gulf, and highlight the potential role of Khark and Kharko Islands in conservation and fishery management in the area.

1. Introduction

Understanding how fish larvae respond to space–time environmental conditions is essential to achieve adequate policies for the management of harvested populations. Analyses of observational data have shown that fish larvae dynamics is shaped by combined effects of environmental gradients, biological interactions and population connectivity. The former includes seasonal and inter annual variability of hydrographic structures that shape ichthyoplankton patterns (Perrier et al., 2012). Biological interactions relates to prey and predator densities, spawning patterns, i.e. time and location (Rakocinski et al., 1996), and food supply (Funes-Rodríguez et al., 2009), whereas population connectivity sculpt the rate of exchange among geographically distant subpopulations determining the relevant spatial scale at which populations are connected (Cowen et al., 2000). In this work we address the first issue.

Coral reefs are heterogeneous environments that encompass a variety of shelter areas for fish larvae. These ecosystems offer a large number of potential resource axes, such as feeding, refuge and breeding, which favor the life history success and shape behavioural patterns (Paris and Cowen, 2004; Gratwicke and Speight, 2005). These systems further support high diversity and are referred as valuable nursery areas for fish and invertebrates. In the northern Persian Gulf, little is known on ecological aspects of fish larvae in the Khark and Kharko Islands, despite their potential importance in recruitment and ultimately in stock management. Yet, fisheries research in this zone has been mainly focused on taxonomy and species richness (Rabbaniha, 1998, 2002; Dehghan et al., 2000), while drivers of larval assemblages and their seasonal changes in habitat use remain elusive. These issues are fundamental to gain understanding on fish ecology, whereas their quantification bears vast implications for a sustainable management of harvested fish in an area that is heavily exposed to anthropogenic stress, i.e. oil-related pollution. Indeed, the marine habitat in the northern Persian Gulf is particularly interesting as marine populations are heavily exposed to both hydroclimate forcing i.e. high levels of temperature and salinity stress, and habitat deteriorating due to the rapid development of the region, as well as the exposure to extensive oil extraction, transportation and refinement (Sheppard et al., 2010). Understanding how fish larvae respond

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to such stressors is therefore crucial for their adequate management. Here we examine larval fish assemblages, we assess their habitat associations and environmental factors favoring dominant larvae groups, and aim to provide a synoptic picture of space–time patterns in the Khark and Kharko Islands, northern Persian Gulf.

2. Materials and methods

2.1. Study area and data collection

The Khark and Kharko Islands are located in the northern Persian Gulf, Bushehr Province, Iran (29° 12′ to 29° 20′ N, and 50° 16′ to 50° 21′ E) (Fig. 1). Khark is a rocky island located about 57 km off the Bushehr Port, while Kharko is a smaler, sandy island surrounded by reefs patches about 60 km north-west off Bushehr. Sampling stations (maximum depth 32 m) covered both coralline and non-coralline sites, as well as the coastal area. Nine stations were located around the islands and three stations in coastal waters (Fig. 1). The sampled area included a variety of habitats that harbour a large diversity of marine life, including fish, molluscs, lobsters and sea birds (Zanjani, 2012).

Sampling was carried out monthly, from July 2006 to June 2007, always at the same tidal phase (low tide) in order to account for the potential effect of tidal currents on distributional patterns of larval fish assemblages. At each sampling station, temperature and salinity were recorded in the upper 32 m depth layer, while chlorophyll-a measurements were done using a chlorophyll-a sensor in the upper 30 m depth layer. Larvae samples were taken during daylight using a 61 cm diameter bongo net of 500 μm mesh, with a digital flow meter adapted to the net mouth to measure the water volume filtered. At each station, the bongo net was towed 10 min at a constant speed of 1 knot. Oblique tows were done from near the bottom to the surface.

Samples were fixed in 5% formaldehyde seawater immediately after towing and preserved in 10% ethanol. In laboratory, the developmental stage of larvae captured was registered. The scarcity of species-specific taxonomic keys for the region limited a high taxonomic resolution, therefore identification was done at the family level based on Leis and Rennis (1983) and Leis and Trnsky (1989). Adult habitat and spawning sites for the collected fish families were obtained from FishBase (Froese and Pauly, 2015). Fish data were sorted according to habitat types: coralline (5 stations), non-coralline (6 stations) and mouth of creek (1 station) (Fig. 1).

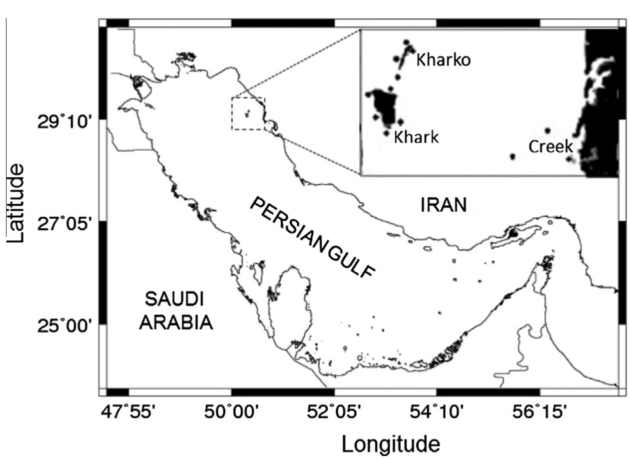

Fig. 1. Map of the Persian Gulf. The study area is located in the northeastern region. The inset shows the Khark and Kharko Islands and sampling stations.

2.2. Data analysis

To assess the spatial correlation of environmental conditions (i.e. temperature, salinity and chlorophyll-a) in the explored habitats we used the Mantel statistics (Mantel, 1967). The statistical significance of Mantel correlations was assessed by Monte Carlo permutation (1000 times). Hydrological patterns ascribed to temperature, salinity and chlorophyll-a were assessed by means of box-and-whisker plots to characterize the extent of monthly variations. Fish larval abundances were standardized to number of larvae per 10 m^2 and diversity was calculated throughout the year by means of Shannon diversity and evenness index.

Due to the non-normal distribution of data and the lack of variance homogeneity even after data transformation, we used the non-parametric Wilcoxon and Kruskal–Wallis tests to assess differences in the fish larvae abundance between hydrological seasons and habitats. Correspondence Analysis (CA) was used to evaluate the relative importance of habitats and seasonal environmental changes in larval assemblages. To compute CA we included only families with more than 2% of relative abundance (number of families used in the analysis = 10). CA was performed both seasonally and on a yearly basis.

The ratio of pelagic:demersal fish larvae was calculated as the log $(n1/n2)$, where $n1$ is the abundance of pelagic spawned larvae and $n2$ is the abundance of demersal spawned larvae. The index equals zero when the two groups show the same abundance, whereas positive values denote a higher abundance of pelagic spawned larvae and negative values indicate a dominance of demersal spawned larvae. This ratio broadly reflects the overall availability of nutrients in the marine system, and has been used as proxy of hypoxia events resulting from excess primary production and eutrophication, which negatively affect benthic/demersal fish (De Leiva Moreno et al., 2000).

Environmental windows (i.e. temperature, salinity) linked to the density of dominant families were assessed by means of a non-parametric test of habitat association, as in Molinero et al. (2009). The association between dominant fish families and environment windows was displayed as traffic light diagrams to qualitatively show the extent of overlapping between the preferred environmental ranges among families. Traffic light diagrams display a colour range from dark (quantile .90) to light grey (quantile .10). Statistical analyses were performed in R (R Development Core Team, 2008) and Matlab.

3. Results and discussion

3.1. Environmental conditions

No statistical differences were found in the environmental conditions relative to the habitats investigated, as revealed by the Mantel test (1000 iterations, $p < 0.05$), which measured the dissimilarity between the spatial locations, i.e. coralline, non-coralline, mouth of the creek. Instead, significant environmental changes were detected on the seasonal scale (Kruskal Wallis test, $p < 0.05$) driven by contrasting temperature variations, i.e. 40 °C in summer and 18 °C in winter (Fig. 2a). Salinity showed generally high values (42 ± 1.3; mean and standard deviation respectively), although a sharp decrease arose during the rainy season, in late summer (Fig. 2b). Chlorophyll-a ranged between 0.37 and 0.99 mg m^{-3}, with higher concentrations found in summer–autumn 2006 and spring 2007, although a large variability was observed (Fig. 2c). Likewise, conspicuous variability was observed in the monthly larval abundance, global average 7.9 ± 3.55 ind.10 m^{-2} (Fig. 2d).