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# Preferred larval fish habitat in a frontal zone of the northern Gulf of California during the early cyclonic phase of the seasonal circulation (June 2008)

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ABSTRACT

We analyze the larval fish habitats in the northern Gulf of California during the early stages of the cyclonic phase of the seasonally-reversing circulation (June 2008). The geostrophic current was cyclonic (~5–9 cm/s), and the pycnocline was slightly convex, suggesting a cyclonic eddy. The fish larvae distribution gradients showed four contiguous larval fish habitats: (*i*) A habitat located in the vertically well-mixed and most saline area of the Upper Gulf, which was dominated by the costal demersal species *Anchoa* spp. and *Gobulus crescentalis*. (*ii*) A habitat situated in the tidal-mixing frontal area on the south rim of the Upper Gulf, where the highest species number (>50% of the study) and the highest larval fish abundance were found. In addition to the dominant species in the former habitat, larvae of *Opisthonema* sp. 1, *Anisotremus davidsoni* and *Eucinostomus dowii* also dominated this habitat. Their distribution suggests retention associated with the front. (*iii*) A third habitat was defined in the deep area adjacent to the tidal mixing front, which was influenced by the incipient cyclonic eddy. Larvae of *Opisthonema* sp. 1 and *Etropus crossotus* were dominant, but with low abundance and frequency. (*iv*) A fourth habitat was observed in the southern, deeper portion of the northern Gulf, with the lowest fish larvae abundance, and characterized by the exclusive dominance of species like *Shyraena* sp. 1 and *Benthosema panamense*. These results suggest that the tidal-mixing frontal area is the preferred habitat for spawning and larval nursing of the fish species that inhabit the region. This contrasts with the unfavorable habitats in the deeper areas, which is an unexpected result in view of the presence of the cyclonic eddy, which potentially could be highly productive. This indicates that caution should be exercised in predicting an ecosystem organization of richness based on oceanographic mesoscale structures.

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## 1. Introduction

Larval fish distribution heterogeneity is strongly affected by the interaction of the spawning strategies (area, time and intensity) and mesoscale oceanographic structures like currents, eddies and fronts (Bakun, 1996; Reiss et al., 2000), which tend to favor concentration and retention of zooplankton organisms (Iles and Sinclair, 1982). The different combinations of spawning strategies and the effects of mesoscale structures result in diverse larval fish habitats (Leiby, 1986; Sánchez-Velasco et al., 2009). Those habitats with the highest larval fish abundance may indicate preferred larval fish habitats, where environmental conditions are most favorable for larval development, and the subsequent recruitment (e.g. León-Chávez et al., 2010; Moser and Smith, 1993; Sanvicente-Añorve et al., 1998).

The northern Gulf of California (NGC) (Fig. 1a) has been characterized as a productive region that supports high diversity and high abundance of fish species (e.g. Moser et al., 1974; Sánchez-Velasco et al., 2012). The NGC presents contrasting hydrodynamic environmental provinces (Lavín and Marinone, 2003) that may generate contiguous larval fish habitats with strong differences in larval abundance and well-defined hydrographic boundaries (Sánchez-Velasco et al., 2009). The most evident provinces of the NGC are the Upper Gulf, the wide mainland shelf, and the deeper part to the south (Fig. 1a), where Delfin basin is found (200–800 m depth). The Upper Gulf is the shallowest (<30 m depth) and most saline (up to 38 g/kg) region of the NGC (it is also the warmest (>31 °C) in summer and the coldest (<14 °C) in winter); it is characterized by strong tidal currents that cause well-mixed conditions (Álvarez-Borrego et al., 1975; Lavín et al., 1998), sediment resuspension and elevated turbidity (Álvarez and Jones, 2002). The current inverse-estuarine condition of the Upper Gulf is the

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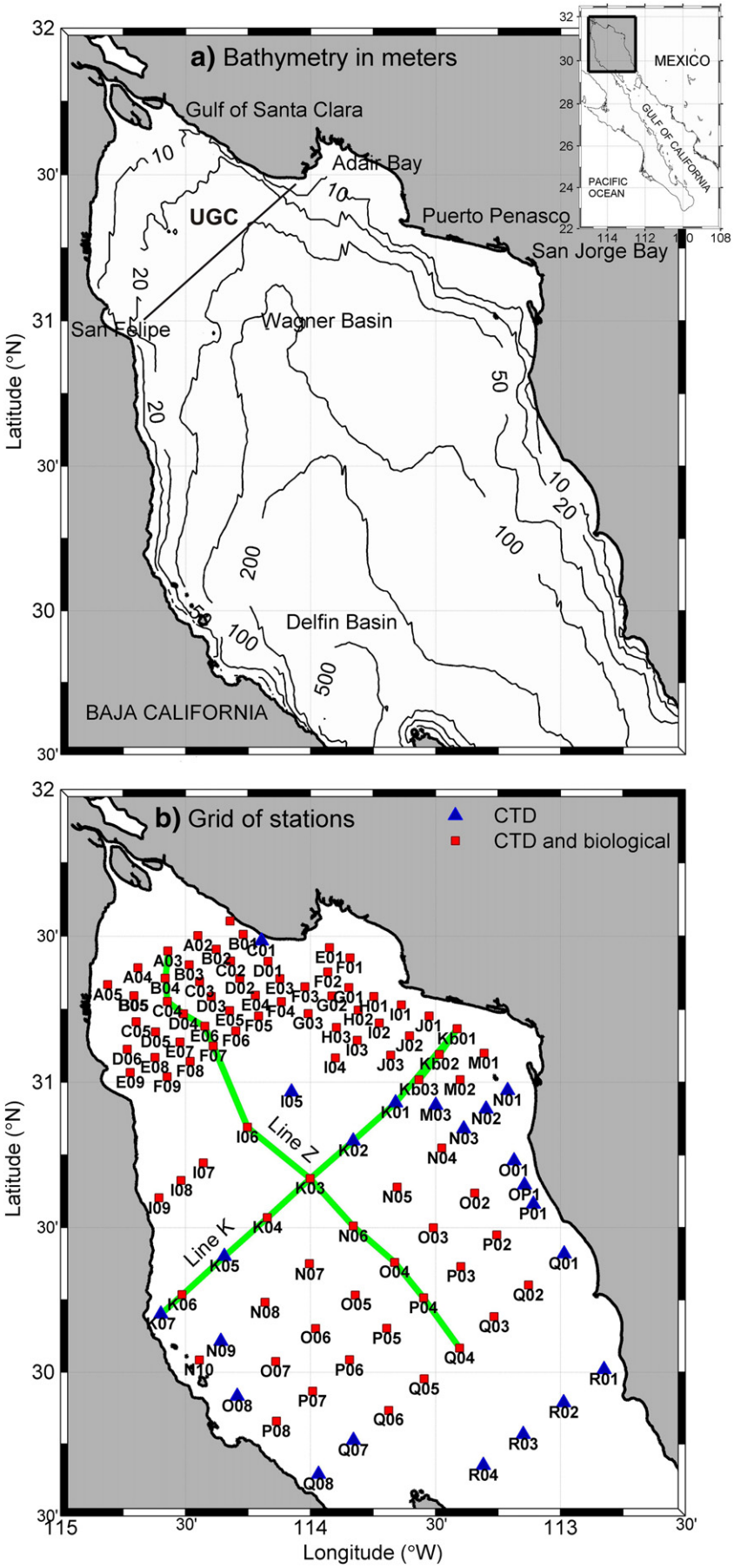


**Fig. 1.** a) Bathymetry of the northern Gulf of California, in meters. b) Sampling stations in the study area during June 2008. The Upper Gulf of California is the shallow area at the head of the Gulf. Black squares: CTD data and biological samples. Open triangles: CTD data only. Gray solid lines represent vertical transects. Line Z, along the axis of the Gulf, and line K, across-Gulf.

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