# INFLUENCE OF ENVIRONMENTAL FACTORS ON LARVAL TRANSPORT AND COASTAL RECRUITMENT SUCCESS IN THE SILVER MULLET, *Mugil curema*, IN

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## Introduction

Coastal and offshore environmental conditions in an upwelling zone of northeastern Venezuela were related to the reproduction and recruitment of silver mullet, *Mugil curema* Valenciennes, between March 1992 and July 1993.

The silver mullet is an offshore spawner with pelagic, oceanic larvae (Anderson, 1957; Collins and Stender, 1989) and it recruits to coastal lagoons and estuaries that act as juvenile nursery areas (Ibañez-Aguirre, 1993; Vieira, 1991). Different environmental conditions may affect each recruitment pulse, causing differential recruitment success.

Wind speed and direction may be an important physical factors influencing variability in recruitment of marine species. At weak or moderate levels, turbulence increases encounter rates between larvae and their prey and thus may affect the feeding, growth and ultimately the subsequent recruitment of larvae (Cury and Roy, 1989; Ware and Thomson, 1991; Mann, 1993). Wind direction drives oceanographic processes such as Ekman transport and the resulting upwelling event (Thompson, 1977; Mann and Lazier, 1991).

Here, we examine how both physical and biological factors influence coastal recruitment success in silver mullet. Specifically, we correlate offshore upwelling events with estimates of chlorophyll *a*, zooplankton abundance and the recruitment of juvenile mullet in the La Restinga Lagoon, Margarita Island, Venezuela. In addition, we use recorded weather observations to identify the seasonal environmental forces influencing recruitment variability.

## Methods and Materials

Measurements of rainfall, offshore phytoplankton and net and bottle zooplankton, winds, Ekman transport, sea-surface temperature were used to document the influence of upwelling on spawning and coastal recruitment. Seasonal changes of chlorophyll *a* caused by upwelling was also estimated using historical satellite images (1982-1986)(CZCS; Hovis et al, 1980)

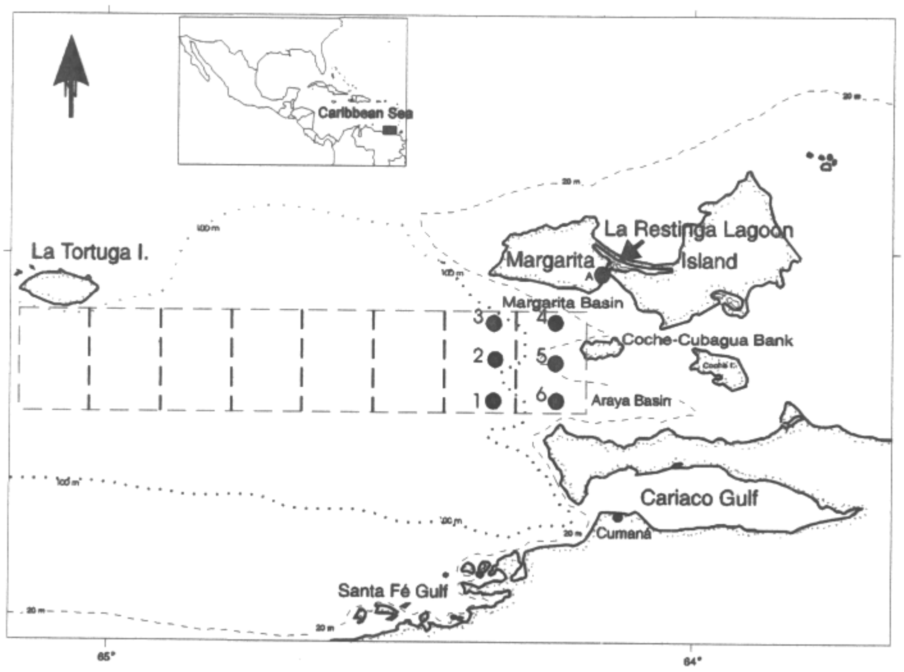


**Figure 1**. Locations of sampling stations (1 to 6) in the offshore shelf south of Margarita Island and sampling site A in La Restinga Lagoon, Margarita Island, Venezuela. Rectangle between Cubagua and La Tortuga Islands represent the zone where chlorophyll *a* concentrations were analyzed using CZCS images.

An upwelling index (UI) was calculated based on wind statistics from meteorological stations at Fundación La Salle, Margarita Island, and the Airport of Cumaná, following Bowden (1983). We used the UI as an expression of the Ekman offshore transport.

Wind series vectors (W) and upwelling indices (UI) between March 1991 and July 1993 were calculated with a Turbo-Pascal program using the daily means for the strength and direction of the wind.

Recruitment was determined from juvenile fish samples collected fortnightly in La Restinga Lagoon, Margarita Island, Venezuela. Adults were collected from commercial catches at three sites in north-eastern Venezuelan waters. Gonadosomatic indices, fecundity and gonadal observations helped to establish the time of reproduction. Enviromental conditions during successful offshore spawning were identifies by backcalculating the dates of hatching of juveniles successfully rescruited in La Restinga Lagoon. The age of these juveniles were estimated from counts of daily growth rings on otoliths.

**Results**

Fish with mature gonads were caught throughout the year but the reduction in the abundance of mature mullet in coastal fishery catches between September and December was probably the result of an offshore reproductive migration. Maximum abundances in the lagoon of juveniles measuring between 25-35 mm indicated that peak recruitment ocurred from March to June in both study years. The stimated of age of juveniles in the lagoon ranged from 50 to 240 days. Backcalculated ages of hatching revealed that successful recruitment was associated with hatching during wind induced upwelling events. Weekly estimates of coastal recruitment success (abundance of backcalculated hatchlings) were positively correlated with upwelling indices prevalent at the date of hatching of these recruits ($R2= 0.46$, $p<0.001$). Offshore sampling during the study years revealed higher levels of phytoplankton and zooplankton numbers in offshore areas and during upwelling events relative to inshore areas and in the spawning area of the species in Northeastern Venezuelan waters, based on satellite images, revealed peaks of phytoplankton biomass presumably associated with northeasterly winds conducive to upwelling.

**Discusion**

The magnitude and timing of chlorophyll *a* maxima were variable from year to year. Succesful recruitment arising from spawning at these times is associated with trophic advantages favouring larval survival and onshore transport of larvae in water masses at intermediate depths associated to upwelling. Spawning during periods of relaxed upwelling is associated with appereance of fewer, older recruits in the lagoon. Maximal periods of hatching leading to this successful recruitment, from late December-1992 to March-1993 coincided with moderate peaks in the upwelling index..

The timing and strength of upwelling can be quite variable. These variations may have profound effects on the food chain of the ecosystem. Prolonged spawning in silver mullet (Marin and Dodson, in preparation) may be an adaptation to overcome the unpredictability of upwelling. We suggest that recruitment into lagoons only represents a portion of the larvae that produced over a long period, which are successfully transported onshore.

Based on upwelling models (Peterson and Miller, 1975; Mooers et al, 1976; Jones and Halperm, 1981; Wolanski and Delesalle, 1995), we propose that the shoreward flow of deeper water transports demersal postlarvae of mullet. Okuda et al. (1978) reported a downwelling close to La Tortuga Island, which represented a compensating convection current. Sakuma and Larson (1995) provide evidence of an upwelling-associated shoreward migration of later stage flatfishes to nearshore zones. This, rather than mechanisms such as active swimming and tidal transport (Blaber, 1987), seems to be the main system of transport for larvae to estuarine nursery areas. Selection maximising survival of larvae and recruits appears to have resulted in an adptation for spawning during upwelling when trophic and transport advantages are maximal and recruitment to coastal nursery areas at the beginning of the rainy season when juvenile growth potential is maximal.

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