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Evaluating environmental forcing on nutritional condition of *Engraulis anchoita* larvae in a productive area of the Southwestern Atlantic Ocean

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ABSTRACT

The main goal of this study was to examine the nutritional condition of *Engraulis anchoita* larvae during the austral spring-summer seasons of 2010/2011 and 2012/2013 in highly productive waters in the southwestern Atlantic Ocean called El Rincón. RNA/DNA (RDs) index and derived index of Growth performance (Gpf) were used. Significant differences were observed in average RDs indices for 2010/2011 (5.27 ± 3.26) and 2012/2013 (0.81 ± 0.44). A difference in the years was also observed in Growth performance with higher values in 2010/2011 (2.45 ± 1.83) compared to 2012/2013 (−0.03 ± 0.25). Anchovy larvae captured in 2010/2011 were in good condition (Gpf > 1). During 2012/2013, extremely high larval densities were observed although Gpf values were very low indicating poor larval condition. Chlorophyll dynamics differed between sampled periods, with higher maximum values during spring 2012 as compared to 2010. Concerning chlorophyll concentrations showed a sharp decline in the values for the rest of the 2012/2013 season. We propose that the low larval growth and condition observed during 2012/2013 may have resulted from a decrease in chlorophyll concentrations together with very large larval densities which enhanced the competition for food within the larval population. Our results reinforce the idea that satellite ocean color products can be valuable tools for understanding variability in ecosystem dynamics and its effects on reproductive success in fish.

1. Introduction

The Argentine anchovy, *Engraulis anchoita* (Hubbs and Marini, 1935) is the most important pelagic fishery of the Southwest Atlantic Ocean in terms of biomass (Pájaro et al., 2009). There is wide interest in the study of this species due to its key role in the pelagic ecosystem, acting as the link between zooplankton and numerous species of commercial importance (Hansen, 2004; Sánchez and Ciechomski, 1995). *E. anchoita* spawns between 34 and 48°S, where two populations are distinguished, a northern and a southern one separated at approximately 41°S (Hansen, 2004).

This study focuses on the northern population, which finds suitable reproductive conditions in the area mainly due to the stability of the water column and high food availability (Sánchez and Ciechomski, 1995). Adults are found mostly in coastal waters (shallower than 50 m) where massive spawning occurs during the austral spring (Pájaro, 1998; Sánchez and Ciechomski, 1995). Anchovy eggs and larvae are present throughout the year with a main peak of abundance in the austral spring and summer (Sánchez, 1995). The patterns of abundance and spatial distribution of early developmental stages of this species are influenced by the oceanographic conditions (Brandhorst and Castello, 1971; Pájaro et al., 2011). Maximum larval densities are usually observed in proximity of the 50 m isobath within the area of “El Rincón” (Pájaro et al., 2008). According to Bakun’s fundamental triad statement (Bakun, 1996), this area exhibits adequate conditions for an increase in larval survival and recruitment, taking into consideration retention processes, water column stability and trophic enrichment that characterize this area (Auad and Martos, 2012; Pájaro et al., 2008; Viñas

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et al., 2013).

The large fluctuations often observed in pelagic fish biomass have been widely studied in fisheries biology and it is well known that diverse factors can affect the abundance of fish stocks. Several hypotheses have tried to explain mechanisms driving year-class strength during the early life of marine fish. The "match–mismatch" hypothesis (Cushing, 1990), an extension of Hjort's "critical period" hypothesis, proposed that the temporal overlap between the spring plankton bloom and larval production is critical for larval survival and subsequent recruitment. It is widely accepted that main causes of larval mortality are predation and starvation (Bailey and Houde, 1989), and although predation mortality is difficult to quantify, starvation mortality can be estimated from the assessment of the nutritional condition of the larvae. This approach allows the evaluation of the individual's physiological state, which in turn is a reflection of the environmental conditions in which the larvae were found. There are several indices for the assessment of the nutritional condition in fish larvae, with the RNA/DNA index (RD) being the most widely used (Chícharo and Chícharo, 2008). This method is based on the determination of the concentrations of nucleic acids and allows inferring functions related to tissue formation and the physiological condition of individuals (Ferron and Leggett, 1994). Since nucleic acids contents differ between larval tissues, reporting the analyzed tissue to calculate RD becomes crucial (Olivar et al., 2009). In the present study trunk muscle tissues were employed.

Here we propose the existence of a link between bloom progression and anchovy larvae nutritional condition. RNA/DNA index was employed as an indicator of the nutritional condition of anchovy larvae captured in the area of El Rincón during the austral spring-summer seasons of 2010/2011 and 2012/2013. Surface chlorophyll concentrations were examined as a predictor of food availability for larval *E. anchoita*. RNA/DNA index and derived growth indices were thus expected to be positively related to food availability in this nursery area. In addition, the abundance and distribution of eggs and larvae was examined in relation to the main oceanographic features of the study area.

2. Materials and methods

2.1. Study area

El Rincón (between 39 and 41°S, depth < 40 m) is a frontal area where fresh waters from the Negro and Colorado rivers meet high salinity waters of the San Matías Gulf advected from the south. Advection of continental shelf waters characterized by lower temperatures and intermediate salinities is also observed (Guerrero and Piola, 1997; Martos et al., 2004). The interaction between river discharge, high salinity waters from San Matías Gulf, and mid-shelf waters generate two adjacent frontal systems: a more coastal one where dilute waters meet saltier coastal waters and another system where high salinity waters meet mid-shelf waters (Pájaro et al., 2011). The second frontal system known as the Mid Shelf Front (MSF), is established during the austral spring (21 September-20 December) and summer (21 December-20 March) close to the 50 m isobath along the shelf of the Buenos Aires province separating vertically homogeneous coastal waters from stratified mid-shelf waters (Romero et al., 2006). El Rincón represents a favorable area for early development and survival of fish larvae. High nutrient concentrations that result in high phytoplankton and zooplankton concentrations serve as the main food for many species of ichthyoplankton (Viñas et al., 2002).

2.2. Sampling

Samples were collected during two research cruises conducted by the National Institute of Fisheries Research and Development (INIDEP) in the area of El Rincón during the austral spring and summer in two consecutive years 2010/2011 (S1) and 2012/2013 (S2) (S = survey).

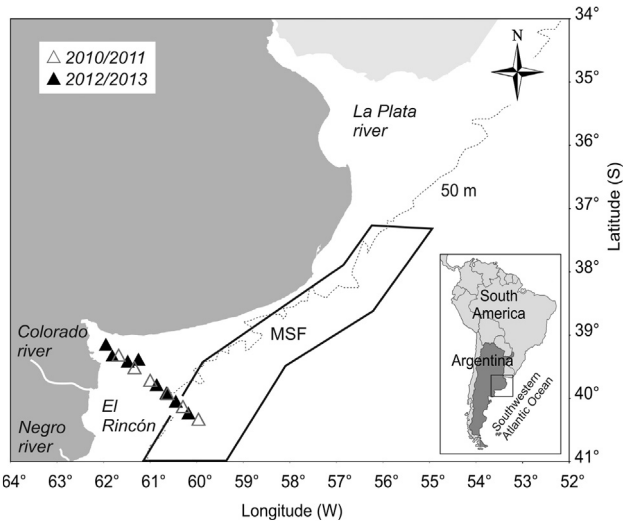

Fig. 1. Position of studied stations during 2010/2011 and 2012/2013 seasons. In gray are shown samplings performed in 2010/2011 and in black those in 2012/2013. The black polygon represents the Mid-Shelf Front (MSF) subregion.

Six and 8 stations were sampled in S1 and S2, respectively, along a 200 km section perpendicular to the coast in waters of the coastal zone between 6 and 70 m depth (Fig. 1).

During S1 (9–10 February 2011) ichthyoplankton was collected with a multinet at three strata: surface, thermocline (when it was detected) and near bottom. During S2 (7–8 December 2012) a Bongo net was employed. In both cases samplers were equipped with flowmeters in order to estimate the volume sampled. The different samplers were not intercalibrated; instead, anchovy eggs and larvae densities were arranged into broad density classes. At stations where the presence of anchovy larvae was observed, random individuals were selected for the analysis of nutritional condition and frozen in liquid nitrogen. Station and depth of provenance were recorded. The rest of the samples were fixed in a solution of 5% formalin in seawater. Additionally, vertical profiles of temperature, salinity, and fluorescence were recorded at each station using a Seabird SBE19 CTD profiler.

2.3. Chlorophyll estimation

Surface chlorophyll concentrations (mg/m^3) from MODIS onboard Aqua were examined as a proxy for the abundance of phytoplankton during the spring and summer. All available high-resolution (~1 km/pixel) level 2 data were processed with the standard flags and the empirical algorithm OC3M (O'Reilly et al., 2000), binned and mapped to a 2 km/pixel spatial resolution. Reprocessing version 2013.1.1 was used. Chlorophyll concentrations < 0.02 and > 30 mg/m^3 were excluded from all analyses. Previous *in situ* values of ~19 mg/m^3 have been reported for continental shelf and shelf-break locations in our study area (e.g., Almandoz et al., 2007; Bianchi et al., 2009; Garcia et al., 2008). Thus, to prevent overestimations we limited our results to values < 30 mg/m^3. All data were weighed equally and 5-day and monthly composites were generated for each spring-summer season analyzed (October-February 2010/2011 and 2012/2013). Data are distributed by the Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center.

Previous studies revealed that the spring phytoplankton bloom frequently occurred offshore of the 50 m isobath following the bathymetry south of 35°S. To examine the variability in the dynamics of the spring phytoplankton bloom, average chlorophyll concentrations for each 5-day period between October and February were calculated for the Mid-Shelf Front (MSF) subregion defined between 37°30′S and 41°S (black polygon in Fig. 1). Although spawning in *E. anchoita* extends