Oceanic Influence on the Distribution and Abundance of Bluntnose Flyingfish (Family Exocoetidae) Larvae in the Northern Gulf of Mexico

Influencia Oceánica para la Distribución y Abundancia de Chata Pez Volador (Familia Exocoetidae) Larvas en el Golfo Norte de Mexico

Influence des Processus Océaniques sur la Distribution et Abondance des Larves de Poissons Volants *Prognichthys occidentalis* (Famille Exocoetidae) dans le Nord du Golfe du Mexique

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EXTENDED ABSTRACT

Flyingfish are essential components of pelagic food webs, and these taxa are well represented in the diets of several apex predators that reside in coastal and offshore environments (Oxenford and Hunte 1999). Despite their importance, our understanding of their life history and ecology is limited, particularly studies investigating early life processes. Spatial and temporal trends in the distribution and abundance of fish larvae can be used to characterize the timing and location of spawning as well as environmental conditions that favor early life survival (Rooker et al. 2012). Therefore, establishing baseline data on the distribution and abundance of flyingfish larvae provides information that can be used to identify population trends and important spawning areas.

The Gulf of Mexico (GoM) is a model system for evaluating early life ecology of flyingfishes because high productivity associated with allochthonous nutrient inputs (Mississippi River) supports highly productive spawning and nursery areas for several pelagic fishes. In addition, the GoM is characterized by the presence of a dominant mesoscale feature (Loop Current), which frequently sheds cyclonic and anti-cyclonic eddies (Nürnberg et al. 2008). This combination of autochthonous and allochthonus drivers of production coupled with the unique oceanographic characteristics of the GoM make it an interesting location for investigating the early life ecology of flyingfish. The goal of the present study was to characterize the spatial and temporal trends in the distribution and abundance of flyingfish larvae in the outer shelf and slope waters of the northern GoM (NGoM).

Six ichthyoplankton surveys were conducted in the outer shelf and slope waters of the northern GoM during June and July of 2009 to 2011. Flyingfish larvae were collected with paired 2-m by 1-m neuston nets with mesh sizes 500 µm and 1200 µm towed for 10 minutes at a speed of 2.5 knots. All ichthyoplankton and associated zooplankton collected were stored in 50% ethanol and 50% seawater, and then transferred to 100% ethanol after 48 hours. In the laboratory, all flyingfish larvae were sorted using a Leica MZ stereomicroscope. Geographic information system (GIS) was then used to visually display the abundance of bluntnose flyingfish (larvae 1,000/m^2) across the sampling area.

Variation in mean density of larval bluntnose flyingfish for each cruise was analyzed using a full factorial two-way analysis of variance (ANOVA) with month and year as the main factors. Post-hoc differences among means of the main effects were examined using a Tukey's Honestly Significant Difference test (Tukey HSD).

Over the three years sampled, a total of 12,390 flyingfish larvae were collected from 385 stations in the NGoM. Bluntnose flyingfish (*P. occidentalis*) was the most common species, accounting for 76.9% (n = 9,533) of all flyingfish larvae collected. Mean density of bluntnose flyingfish ranged from 0.62 to 16.39 larvae 1,000/m^2, with an average of 7.05 larvae 1,000/m^2. Frequency of occurrence was high for flyingfish with larvae collected in every month and year sampled. Percent frequency of occurrence for bluntnose flyingfish ranged from 39.6% in July 2011 to 100% in June and July 2010.

Abundance of bluntnose flyingfish varied significantly among the three years surveyed (ANOVA, $F_{(2, 384)} = 16.966$, $p < 0.001$). Mean density of bluntnose flyingfish for years 2009 and 2010 (11.35 and 7.89 larvae 1,000/m^2, respectively) was significantly higher than the mean density for 2011 (1.91 larvae 1,000/m^2). Mean density also varied significantly between months sampled (ANOVA, $F_{(1, 384)} = 8.298$, $p < 0.004$), with densities in June (9.06 larvae 1,000/m^2) greater than July (5.04 larvae 1,000/m^2). A significant interaction was observed between month and year (ANOVA, $F_{(2, 384)} = 6.282$, $p < 0.002$) (Figure 1).

Spatial differences in the distribution and abundance of flyingfish larvae were detected among the six surveys (Figure 2). In 2009 and 2010, abundance of flyingfish appear consistent across transects, but in 2011 densities of flyingfish were variable with flyingfish absent from more stations than the previous two years. In June 2011, the abundance of flyingfish was higher in the 28°N transect, but in July abundance was greater in the 27°N transect. Additionally, larvae abundances generally increased in areas of negative sea surface height (Figure 2). Overall, densities were greater in areas with negative sea surface height anomalies (12.5 larvae 1,000/m^2) compared to areas with positive anomalies (6.2 larvae 1,000/m^2).

Bluntnose flyingfish larvae were commonly collected in our surveys and observed densities were relatively high, suggesting that this group represents an important component of the ichthyoplankton assemblage in the NGoM. Comparable assessments of flyingfish abundances in the GoM and other regions are rare; nevertheless, a study by Hunte et al. (1995) within the eastern Caribbean examined abundance of larval flyingfishes and found a relative density of bluntnose flyingfish at 0.04 larvae 1,000/m^2, which is markedly lower than mean densities observed in our study (7.05 larvae 1,000/m^2).

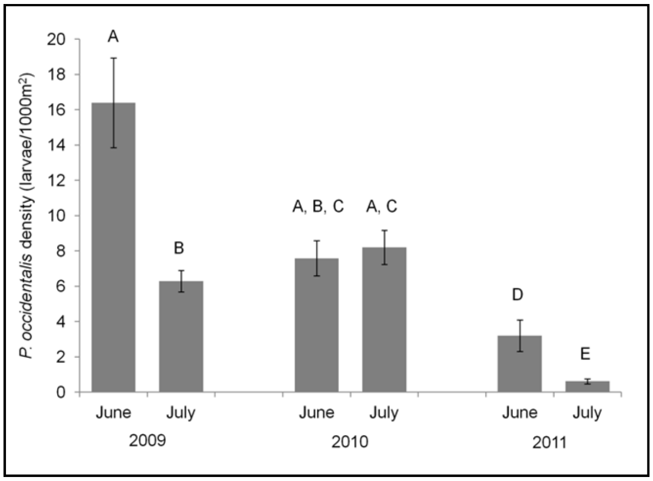

Figure 1. Mean density of bluntnose flyingfish (*P. occidentalis*) collected in June and July for each sampling year 2009 - 2011. Bars with different letters denote significant differences among months based on Tukey HSD post hoc groupings ($p < 0.05$). Error bars represent one standard error of the mean.

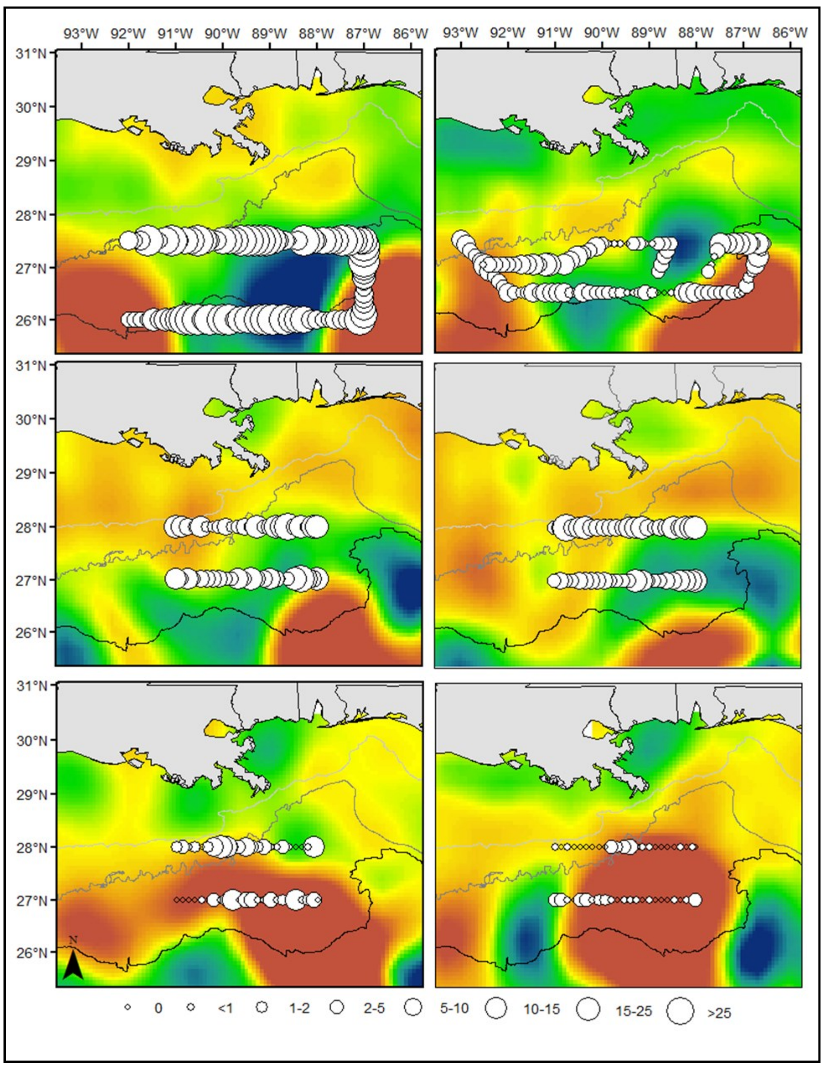

Figure 2. Spatial and temporal variability in the distributions of bluntnose flyingfish during summer ichthyoplankton cruises from 2009 (top), 2010 (middle), and 2011 (bottom) and June (left column) and July (right column). The location of the Loop Current during the sampling period is outlined in thick black. Density (larvae/1000 m^2) at each sampling station is denoted by circle size.

Temporal changes in abundance may be due to a variety of factors, including shifts in the spawning locations of adults (i.e. egg production) or variability in early life survival, both of which are influenced by oceanographic conditions (Rooker et al. 2012). Yearly differences in the abundance of larvae could be attributed to shifts in oceanographic features or conditions, particularly the location of the Loop Current. In 2011, the Loop Current penetrated farther north than the previous two years as shown in Figure 2 by the higher SSHA, potentially creating unfavorable spawning habitat for bluntnose flyingfish because of the warm, nutrient depleted waters associated with the Loop Current (Biggs 1992). The variability in oceanographic conditions, especially the Loop Current location, could lead to changes in the abundance of adult flyingfish which would impact the abundance of larval flyingfish within the NGoM. This study represents the first attempt to characterize the distribution and abundance of larval bluntnose flyingfish, and identify critical spawning and nursery areas for this species within the NGoM. The high abundance and broad distribution of this species highlights the importance of the NGoM as early life habitat, and suggests that flyingfish are an integral component of the pelagic ecosystem in this region.

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