The Distribution and Feeding Ecology of Larval Billfish in the Northern Gulf of Mexico

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ABSTRACT

Ichthyoplankton surveys were conducted in the summers of 2005 and 2006 to identify areas in the northern Gulf of Mexico with high larval billfish densities. Neuston net tows were conducted at 60 - 62 different sample sites along two transects at 27 and 28 degrees North latitude between 90 and 94 degrees West longitude. In 2006, our sampling efforts were concentrated around areas with similar conditions to areas where large numbers of larval billfish were caught the previous year. A total of 2,589 billfish larvae were collected from five cruises. The mean density of larvae per sample ranged from 0 – 53.82 larvae per 1,000 m^2. The size range of the larvae collected was 2.2 – 31.0 mm. The highest densities of billfish larvae were located at the fronts of anti-cyclonic eddies. An examination of the gut contents revealed that the diet of larval billfish mainly consists of cyclopoid copepods and ichthyoplankton. Our results provide confirmation that the Gulf of Mexico provides important nursery habitat for billfish larvae.

KEY WORDS: Billfish, Istiophoridae, early life history

Distribución y Ecología Alimentaria de las Larvas de Pez Vela en el Norte del Golfo de México

Durante los veranos de 2005 y 2006 se realizaron muestreos de ictioplancton para identificar áreas con altas densidades de larvas de pez vela en el norte del Golfo de México. Se realizaron arrastres con redes de neuston en 60-62 puntos de muestreo a lo largo de dos transectos a 27 y 28 grados de latitud Norte entre 90 y 94 grados de longitud Oeste. En 2006, nuestros esfuerzos de muestreo se concentraron en torno a áreas con condiciones similares a áreas en que se habían capturado números elevados de larvas en el año anterior. Un total de de 2589 larvas del marlinés fueron capturadas en 5 travesías. La densidad media de larvas por muestra osciló entre 0 y 53.82 larvas por 1000 m^2. El rango de tamaños de las larvas capturadas fue 2.2 – 31.0 mm. Las mayores densidades de larvas del marlinés se encontraron en los frentes de remolinos anticiclónicos. Una examen de los contenidos gástricos reveló que la dieta de las larvas del marlinés consiste principalmente en copépodos ciclopoides e ictioplancton. Nuestros resultados confirman que el Golfo de México proporciona un hábitat importante para las larvas del marlinés.

PALABRAS CLAVES: Marlinés, Istiophoridae, ciclo de vida temprano

INTRODUCTION

Billfish (family: Istiophoridae) found in the Gulf of Mexico include the blue marlin (*Makaira nigricans*), the white marlin (*Tetrapturus albidus*), and the sailfish (*Istiophorus platypterus*). These large pelagic predators occupy an important ecological niche in their environment as apex predators (Hoese and Moore 1998). Billfish also support a sport fishery that is valued at $200 million a year in the U.S. alone (Ditton and Stoll 2003). Because of their highly migratory behavior across vast expanses of open ocean, billfish are difficult to study, and as a result, basic information on billfish life history is limited. Such information is important in order to provide effective conservation and management decisions regarding these ecologically and economically important billfishes.

Probably the least known area of billfish life history is the early life stage. Basic information on early life history, such as the identification of nursery habitat, and ontogenetic changes in feeding habits, is currently lacking for billfishes. Identification of billfish nursery habitat is important for identifying the environmental characteristics such as optimal temperature, abundance of food, and potential predators, that allow the most successful recruitment of larval and juvenile billfish into the adult populations. The purpose of our research was to locate areas in the northern Gulf of Mexico with high densities of larval billfish that might serve as essential nursery habitat. Gut contents were also assessed to identify organisms that represent valuable prey items. The ultimate goal of the gut content study is to characterize the environmental conditions that allow the most successful feeding for larval billfish. This paper presents preliminary data on the distributions of larval billfish collected from surveys conducted during the summers of 2005 and of 2006 and is an assessment of the prey items consumed by larval billfish.

METHODS

Three research cruises were conducted in May, July, and September of 2005. Another two cruises were conducted in June and August of the following year. These cruises were planned to coincide with the peak spawning period of Atlantic billfishes (deSylva and Breder 1997). Sampling efforts in 2005 were concentrated along two transects on latitudes 27 and 28°N from longitudes 94 to 90°W (Figure 1). In 2006, our sampling efforts were concentrated around areas with similar conditions to areas where large numbers of larval billfish were caught the previous year. The sampling stations for 2006 remained in between latitudes 27 and 28°N but were moved slightly east of the previous year's locations (Figure 2).

For each cruise, we sampled approximately 60 stations placed 13 km apart. Each station was sampled with two 1x2 m neuston nets. One net had a 500 µm mesh and the other one had a 1,200 µm mesh. Both nets were fished simultaneously at 2.5 to 3.5 kts for approximately 10 minutes. The length of each tow was measured using a WAAS enabled GPS. A flowmeter was also placed inside each net to give a towing distance. After each collection, all ichthyoplankton and fish eggs were preserved in 1L jars of 100% ethanol. A YSI sonde was used to collect sea surface temperature, salinity, dissolved oxygen, and pH at each station.

In the laboratory, all billfish larvae were removed from the samples and stored in vials of 70% ethanol. All undamaged larvae were photographed and measured using Image Pro®. The stomach of each undamaged larva was then removed and the contents teased out. Prey items were photographed, measured and identified to the lowest taxa possible.

Billfish densities for each station were calculated as larvae per 1000 m^2 and were mapped with ArcGIS® software. Satellite images of the Gulf of Mexico portraying sea surface height were also overlaid on the map. These satellite images allowed us to see the oceanographic features that were present in the Gulf of Mexico during our sampling periods. These images were downloaded from the Colorado Center for Astrodynamics Research which maintains a website that archives daily images produced from the satellite *Jason* (http://argo.colorado.edu/~realtime/welcome/). From these images we were able to examine the role that the oceanographic features such as cyclonic and anti-cyclonic rings played in the distribution of larval billfish.

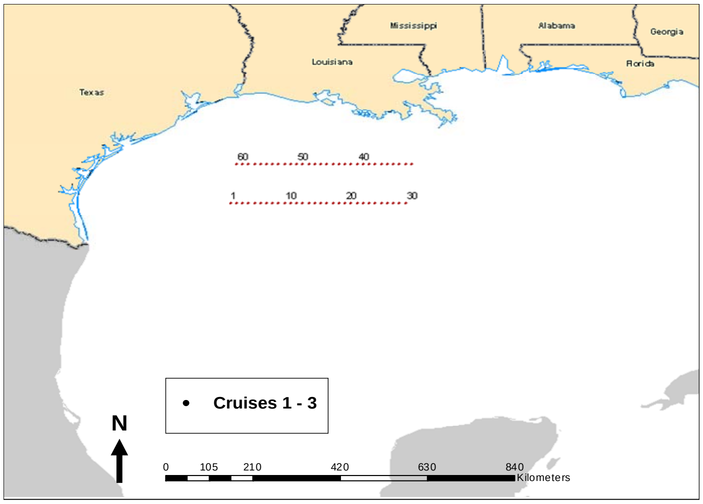

Figure 1. Stations sampled during cruises 1, 2, and 3 (May, July, and September 2005 respectively).

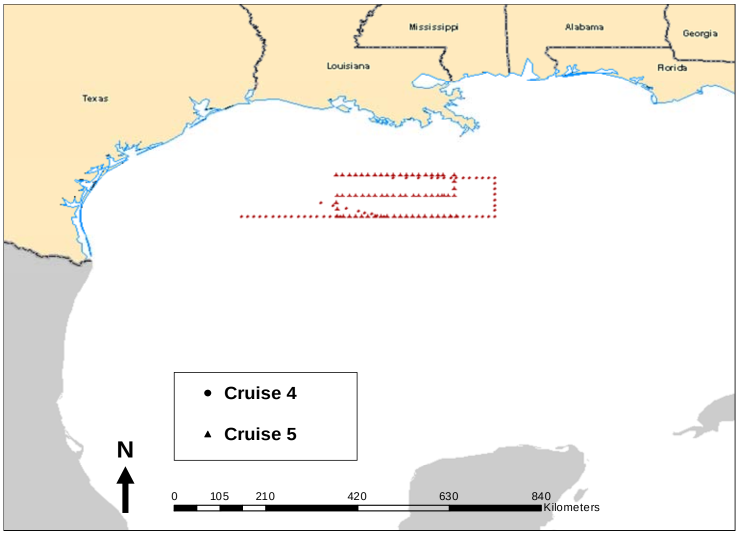

Figure 2. Stations sampled during cruises 3 and 4 (June and August 2006, respectively).

RESULTS

During the five cruises, a total of 287 stations were sampled; 167 of them produced billfish larvae, and a total of 2,587 billfish larvae were collected. The lowest catch total per cruise occurred in May of 2005 (n = 247), while the largest number of larvae caught (n = 918) occurred in July of 2005 (Figure 3). The density of billfish larvae for each station ranged from 0 – 53.82 larvae/1,000 m^2.

The overall average density for each station was 1.81 ± 0.11 larvae/1,000 m^2. The lowest density (0.67 ± 0.27 larvae/1,000 m^2) occurred in May of 2005, and the highest density (2.75 ± 1.08 larvae/1,000 m^2) occurred in July of 2005 (Figure 4). There was no significant difference in mean density of larvae among the five cruises (p = 0.18, ANOVA). Eighty-six percent of the billfish larvae from Cruise 1 were caught from stations 31 – 36 near the eastern end of the northern transect. The mean temperature of stations where billfish larvae were collected during Cruise 1 was 27.54° C. The mean temperature for stations during Cruise 1 where billfish were not collected was significantly lower at 25.96° C (p < 0.001, two sample t-test). When plotted on a map overlaid with the altimetry data from May of 2005, it appears that stations with billfish were in, or at the front of, an anti-cyclonic eddy (Figure 5). The highest density of larvae recorded in this study occurred at station 35 (28° N 90.533° W) during Cruise 2. In one 10 minute tow, 303 billfish larvae were collected from this station (52.83 larvae/1,000 m^2). Based on altimetry data, station 35 was located in between a cyclonic and an anti-cyclonic eddy when it was sampled in July 2005 (Figure 6).

The size range of the billfish larvae caught in all 5 cruises was 2.2 – 31.0 mm (mean = 5.56 ± 0.06 mm) (Figure 7). The smallest mean size for an individual cruise was for cruise 1 (4.13 ± 0.12 mm) while the largest billfish larvae were collected during cruise 5 (7.04 ± 0.16mm) (Figure 8).

A total of 803 larval billfish stomachs were examined for food items. Eighty-one percent of these stomachs contained at least one prey item, and 1906 prey items have been removed and identified. Seventy-one percent of these prey items are cyclopoid copepods of the Corycaeidae family. The two genera of corycaeid copepods found in the larval guts are *Farranula* and *Corycaeus*. The average prey size of these copepods was 739 µm. Copepod nauplii compose 26% of the prey items. These nauplii also appear to be from the corycaeid family, although identification down to the genus level was not possible. Three percent of the prey items were ichthyoplankton. Ichthyoplankton prey was on average 2.55 ± 0.14 mm in length and consisted of carangids, exocoetids, and istiophorids. The average size of piscivorous billfish larvae was 6.8 ± 0.26 mm.

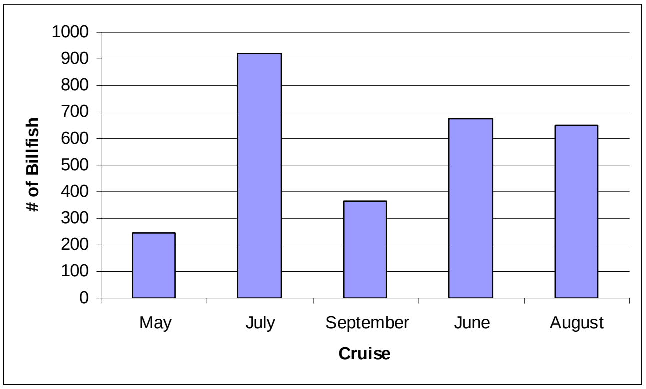

Figure 3. Total number of billfish larvae caught for each cruise

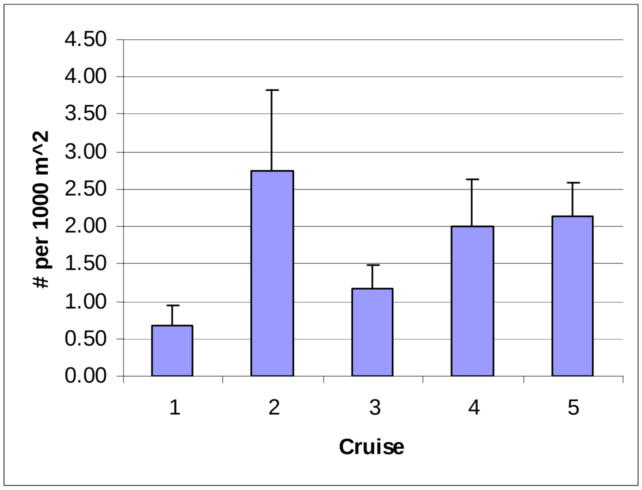

Figure 4. Mean and standard error of larval billfish density (# per 1000 m^2) for each cruise

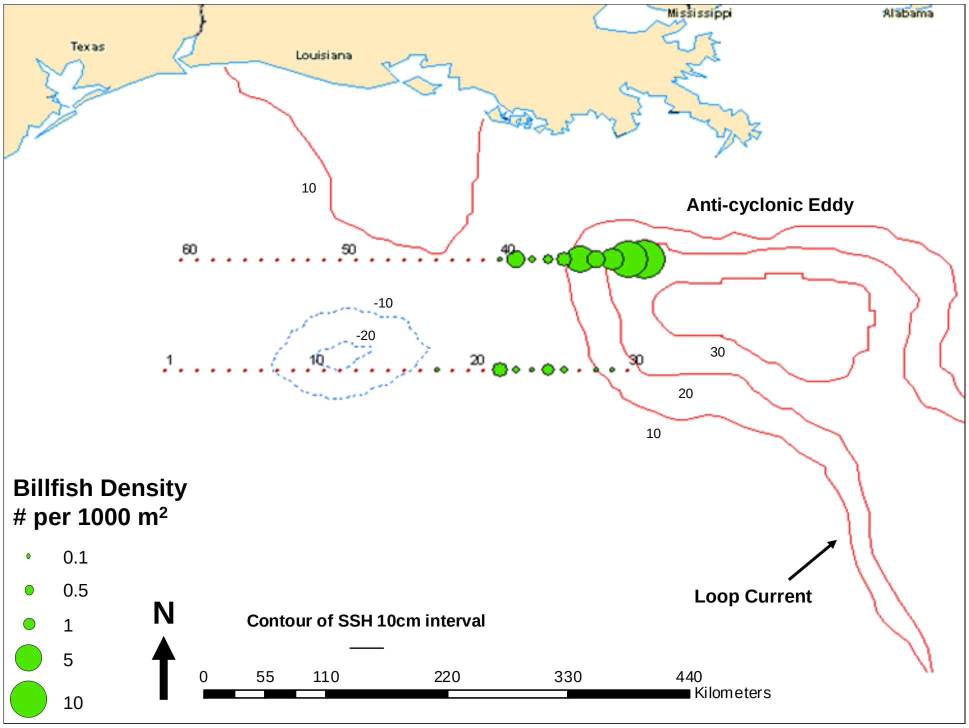

Figure 5. Map of larval billfish distribution (larvae per 1000 m^2) for cruise 1 plotted with the corresponding altimetry data. Solid contour lines indicate positive sea surface height, and dashed contour lines indicate negative sea surface height.

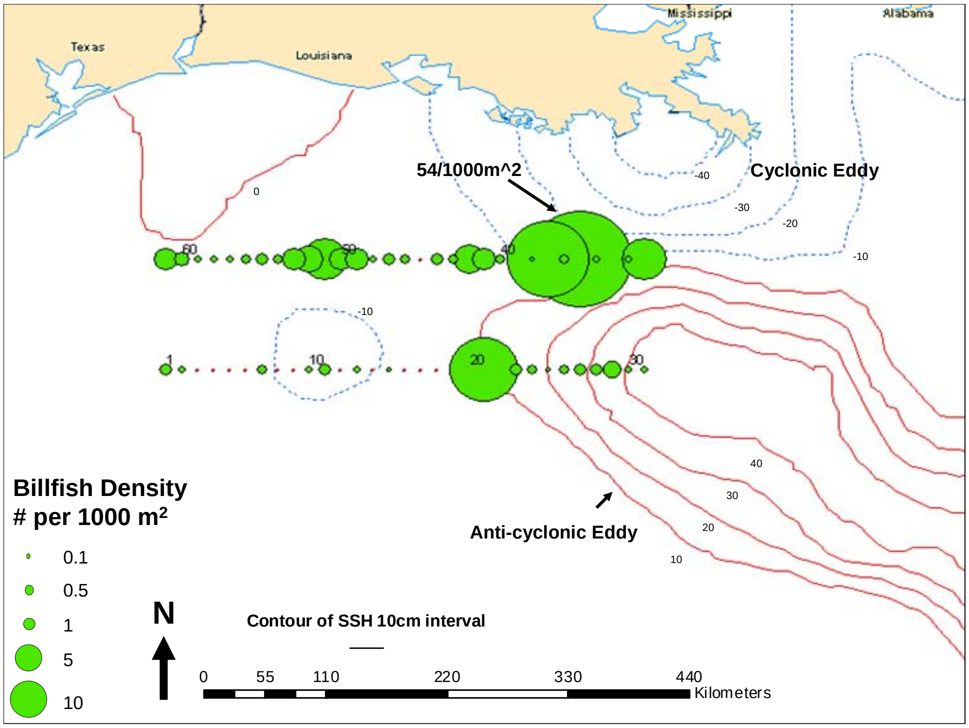

Figure 6. Map of larval billfish distribution (larvae per 1000 m^2) for cruise 2 plotted with the corresponding altimetry data. Solid contour lines indicate positive sea surface height, and dashed contour lines indicate negative sea surface height.

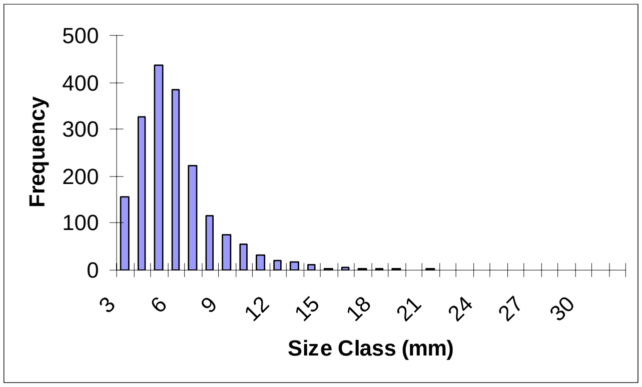

Figure 7. Histogram of size classes (in mm) for all billfish collected during the 5 cruises.

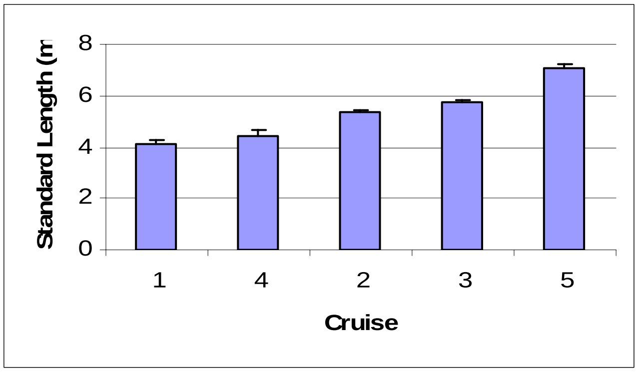

Figure 8. Mean standard length (mm) of billfish larvae for each cruise. Different letters indicate a significant difference in mean length among cruises.

DISCUSSION

The catch of 2,589 billfish were collected from 167 of the 287 stations sampled, represents one of the largest billfish larvae collections to date. Gonzalez-Armas *et al.* (2006) collected 83 billfish larvae from 275 stations in the Gulf of California. A total of 99 billfish larvae were collected from 67 stations in Exuma Sound, Bahamas in July of 2000 (Serafy *et al.* 2003). Post *et al.* (1997) collected 288 sailfish larvae from 315 samples in the Gulf Stream off of the coast of Miami. These projects sampled for billfish during assumed peak spawning times although the methods and sampling gear for some of these projects differed from this survey. For example, Post *et al.* (1997) conducted two minute tows rather than 10 minutes for the explicit purpose of trying to catch live billfish larvae. Gonzalez-Armas *et al.* (2006) looked for billfish in the neuston, but they used a 60 cm cone net instead of a 1 x 2 m neuston net.

Despite the apparent differences in catch numbers for each cruise, we found no significant differences in mean density per station between each cruise. This is because any variability in mean density between cruises was masked by the high variability in mean density among stations within cruises. Densities of billfish larvae for each station ranged from 0 – 53.82 larvae/1000 m^2 and seemed to be influenced by the presence of mesoscale oceanographic features. The mean temperature for stations where billfish larvae were caught in May 2005 was significantly higher than the mean temperature for stations where billfish were not caught. This warmer water is indicative of an anti-cyclonic eddy. These mesoscale oceanographic features are about 100 km in width and form when the northern most projection of the Loop Current pinches off as it makes a 180° degree turn (Sturges and Leben 2000). The Loop Current transports warm water from the Caribbean into the Gulf of Mexico via the Yucatan Strait. This makes the Loop current and the anti-cyclonic eddies warmer than the ambient water throughout most of the year (Sturges and Leben 2000). Anti-cyclonic eddies tend to cause a convergent flow of surface waters along their frontal regions (Bakun 2006). This may explain the association of billfish larvae with the anti-cyclonic eddy in cruise 1 (Figure 5).

There was no significant difference found between the mean temperature of stations with billfish and the mean temperature of stations without billfish for Cruise 2 in July of 2005. This is because the temperature of the Gulf of Mexico becomes more homogenized later in the summer and temperature differences between the Loop Current/ anti-cyclonic eddies and the ambient temperature are less recognizable. However, most of the billfish larvae for Cruise 2 were caught along the front of a large anti-cyclonic ring. Satellite altimetry images are useful for identifying oceanographic features, especially during the summer months when the features cannot be identified by sea surface temperature alone. In these images, anti-cyclonic rings are identified by their positive sea surface height, while cyclonic rings are identified by their negative sea surface height. The highest billfish density occurred in between a cyclonic and an anti-cyclonic eddy during July 2005 on Cruise 2. Such coupling of cyclonic and anti-cyclonic eddies is typical in the northern Gulf of Mexico (Biggs and Muller-Karger 1994). Anti-cyclonic eddies are considered oligotrophic and have been found to have no measurable nitrogen down to depths of 100 m (Biggs 1992), and as a result, these features are generally areas of low productivity. However, cyclonic eddies cause an upwelling of nutrients making them areas of high productivity (Zimmerman and Biggs 1999). The pairing of cyclonic and anti-cyclonic eddies may present a situation where nutrient rich water from the cyclonic eddies fuels primary productivity, which drives secondary productivity that is then concentrated in the frontal zone of the anti-cyclonic ring (Bakun 1996). This situation would create an abundant food source in the frontal zone for pelagic fish larvae such as billfish.

The size range of all billfish larvae collected was 2.2 – 31.0 mm and the mean size was 5.56 cm. Based on a non-linear regression analysis by Luthy *et al.* (2005) of relationship between standard length and age of sailfish larvae, the estimated ages of larvae ranged from 1 to 20 days, with a mean age of 7.6 days.

Starvation is believed to be a major source of mortality during the early life stages, especially for ichthyoplankton in an environment with sparse, patchy food sources (Cushing 1990). However, only 19% of the larval stomachs examined contained no prey items. This number is not completely unexpected as it is believed that starving larvae may become more vulnerable to predation, and starvation may occur so rapidly that malnourished larvae would die off before they could be collected (Houde 2002).

The most common prey item found in the larval billfish stomachs was corycaeid copepods *Corycaeus* spp. and *Farranula* spp. These cyclopoid copepods are commonly found in pelagic waters in the upper water column during the day (Lane *et al*. 2003, Owre and Foyo 1967). Billfish larvae appear to be initially planktivorous before switching to piscivory at a mean size of 6.8 mm. Based on the non-linear regression analysis used previously from Luthy *et al*. (2005), the estimated age of billfish larvae at the trophic shift to piscivory is nine days. Istiophorids are not the only pelagic fish to initially feed on zooplankton. Young and Davis (1990) found the primary prey item of albacore tuna (*Thunnus alalunga*) to be *Corycaeus* copepods. However, some pelagic fish larvae, such as king mackerel (*Scomberomorus cavalla*) and Spanish mackerel (*S. maculates*), appear to be piscivorous at first feeding (Finucane *et al.* 1990).

In conclusion, the catch of 2589 billfish larvae from 167 stations provides powerful support that the northern Gulf of Mexico is a billfish nursery. Eighty-one percent of the billfish larvae had food in their guts when captured; the most common prey were the epipelagic copepods *Farranula* sp. and *Corycaeus* sp. in the family Corycaeidae. The mesoscale oceanographic features present during the peak spawning period of several billfish species creates a situation where high densities of billfish are retained in areas with an abundant food supply.

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