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**SHORT COMMUNICATION**

# OCCURRENCE OF ATLANTIC TARPON, *MEGALOPS ATLANTICUS*, LEPTOCEPHALI IN THE MISSISSIPPI SOUND ESTUARY

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## INTRODUCTION

Atlantic Tarpon, *Megalops atlanticus*, Family Megalopidae, are large, migratory elopomorph fish that occur in tropical, subtropical, and temperate waters of the Atlantic Ocean, including the Gulf of Mexico (GOM) (Wade 1962, de Menezes and Paiva 1966, Crabtree et al. 1997), where they support valuable recreational fisheries (Crabtree et al. 1995, Shenker et al. 2002). Although there are restrictions on the harvest of Atlantic Tarpon in some parts of the United States, fishing pressure for human consumption still exists in parts of its range, including Cuba, Colombia, Mexico, Africa, and Caribbean islands (Garcia and Solano 1995, Stein et al. 2016). Evidence suggests that populations of Atlantic Tarpon have declined in many parts of its range and are now listed as "Vulnerable" with the International Union for Conservation of Nature (IUCN) (Adams et al. 2014).

In the GOM, Atlantic Tarpon reportedly spawn during summer months off southwest Florida and Yucatan, Mexico (Crabtree et al. 1997, Shenker et al. 2002). Larvae (leptocephali) are transported shoreward from offshore spawning grounds by ocean currents to coastal nursery habitats (Crabtree et al. 1992, Shenker et al. 2002), a process that lasts for 15–26 days on Florida's Atlantic coast based on age data from Shenker et al. (2002). Leptocephali are a slender, transparent larval form shared by other elopiform fishes (ladyfish, *Elops* spp.; bonefish, *Albula* spp.), marine eels (Order Anguilliformes), and spiny eels (Order Notocanthiformes) (Pfeiler 1986, Bishop and Torres 1999). The larvae undergo positive growth until arrival in estuarine habitats, which presumably prompts a period of negative growth, followed by the resumption of positive growth as juveniles (Wade 1962, Rickards 1968). Requirements for metamorphosis of Atlantic Tarpon leptocephali are unknown; however, Chen et al. (2008) suggested that low salinity estuarine waters trigger metamorphosis of Pacific Tarpon, *Megalops cyprinoides*, leptocephali. The development and metamorphic stages/phases of *Megalops* spp. leptocephali have been described in differing levels of detail by Wade (1962), Mercado and Ciardelli (1972), Smith (1980), Tsukamoto et al. (1997), and Tzeng et al. (1998).

Before this study, Atlantic Tarpon leptocephali collections from the GOM consisted only of offshore samples (Smith 1980, Crabtree et al. 1992, Crabtree 1995, Stein et al. 2016) and a single individual (27 mm SL) from coastal Louisiana (Tulane University Museum collection, accession number TU164723) (Stein et al. 2016). The report of spawning capable Atlantic Tarpon off Louisiana by Stein et al. (2012) represents the first evidence of this species spawning in the northern GOM. These findings and the collection of young–of–year Atlantic Tarpon from Mississippi coastal marshes in consecutive years (2006–2013) (Franks et al. 2013) prompted our investigation with the objective of documenting the recurring presence of Atlantic Tarpon leptocephali in nearshore waters of the Mississippi Sound estuary.

## MATERIALS AND METHODS

Atlantic Tarpon leptocephali were opportunistically collected from 4 Mississippi Sound locations (Figure 1) near the opening of tidal sloughs documented as habitat for early juvenile Atlantic Tarpon (Franks et al. 2013). Collections were taken adjacent to sandy beaches and fringing marshes using a rectangular–mouthed beam plankton (BPL) trawl (dimensions: 1.3 m × 0.76 m; 750 µm net mesh) fitted with a floatline and leadline, which was towed by hand approximately 120 m through the top 1 m of the water column. Collections were taken from 2006–2016 during summer daylight hours, and environmental data recorded included water surface temperature (°C), dissolved oxygen (mg/L), and salinity. The collections were immediately placed into sample jars and transferred on ice to the Gulf Coast Research Laboratory (GCRL), where leptocephali were sorted using a 1.7 mm sieve and sorting trays.

Leptocephali were identified as Atlantic Tarpon using morphological characteristics, including body length (mm), relative position of the dorsal and anal fins, and number of myomeres as described by Wade (1962), Mercado and Ciardelli (1972), Richards (2005), and Fahay (2007). Leptocephali were classified into developmental stages (Wade 1962), and further classified into phases per Mercado and Ciardelli (1972), wherein Stage 1 (Phases I–V) describes lar-

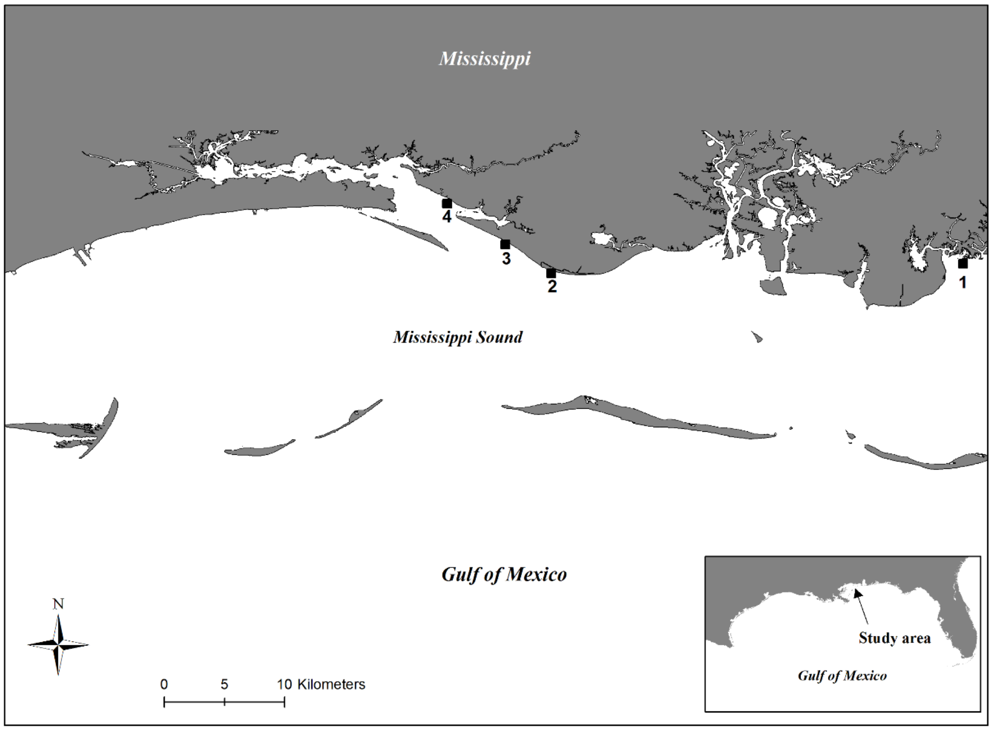


***FIGURE 1.*** *Atlantic Tarpon, Megalops atlanticus, leptocephali collection stations (black squares) on the Mississippi coast: (1) Grand Bay (30.357187 N, –88.439907 W), (2) Belle Fontaine Beach (N 30.348214 N, –88.748060 W), (3) Gulf Park Estates Beach (30.362305 N, –88.765628 W), (4) Ocean Springs East Beach (30.394283 N, –88.809883 W).*

vae undergoing an increase in length prior to the onset of metamorphosis, and Stage 2 (Phases VI–IX) describes metamorphosis during which leptocephali decrease in length. Ossification and advanced organogenesis further accompany Stage 2 development. Stage 3 (Phase X) describes juvenile growth after metamorphosis (Mercado and Ciardelli 1972). Larvae of one other elopiform species (*Elops saurus*) collected during sampling efforts were easily distinguished from M. *atlanticus* based on body length, myomere counts, and placement of dorsal and anal fins.

Leptocephali were measured for standard length (SL), fork length (FL), and total length (TL) to the nearest millimeter using a Zeiss Stemi 2000—C dissecting microscope with iSolutions Lite® computer imaging. Specimens were measured in fresh condition after capture and immediately preserved in 95% ethanol, apart from 4 leptocephali collected August–October 2013 that were observed alive in the field and transferred into temporary aquaria to be maintained in a laboratory setting. These 4 specimens were not measured after capture to reduce the risk of stress from excessive handling and initially placed in shallow glass trays with air stones. Survivors were transferred into recirculating 40 L aquaria and presented with newly hatched, enriched *Artemia* sp. nauplii throughout the larval rearing period. All larvae were held in individual aquaria maintained at approximately 28.0°C, a salinity of 25.0, and 7 mg/L dissolved oxygen. Observations were focused primarily on leptocephalus #2 to avoid unnecessary handling of the other specimens. General observations on behavior and growth under captive conditions, along with water quality, were periodically noted.

## Results

Ninety—nine Atlantic Tarpon leptocephali were collected during the study (Table 1). Ninety—two percent of these leptocephali were collected from stations 2 and 3 (Figure 1) during 150 targeted sampling trips (2013, n=110; 2016, n=40) conducted between July–October of 2013 and 2016, producing 40 and 51 specimens, respectively. Targeted sampling was concentrated primarily during high tide events coupled with a south wind. Larvae were collected at surface water temperatures and salinities that ranged from 24.1–34.1 °C and 6.3–28, respectively, and dissolved oxygen during collections ranged from 4.8–10.4 mg/L (Table 1). Additionally, one specimen was collected from Grand Bay National Estuarine Research Reserve (station 1, Figure 1) in 2006, and 7 specimens were collected from stations 2 and 4 (Figure 1) during routine standardized monthly BPL sampling between 2009–2015.

Measured specimens (n=89) ranged from 16.0–27.8 mm SL, with a mean of 23.2 mm SL (Table 1). The majority of those specimens ranged from 21.0–26.0 mm SL and were collected in August (36%) and September (42%). Seventy—seven leptocephali were identified as Stage 2 (Phases VI, VII; Figure 2A), i.e., during early metamorphosis (negative growth). Only 4 specimens were in pre—metamorphic Stage 1 (Phases IV, V). In addition to the 4 specimens maintained in captivity, 14 were not measured and/or staged because of bodily damage. The smallest leptocephalus (16.0 mm SL) was collected in July 2015 but not staged because of bodily damage. The largest specimen (27.5 mm SL) was collected in August 2013 and identified as Stage 2, Phase VI development.

Three of the 4 specimens maintained live for observations survived between one (leptocephalus #4: injured at capture) and 59 days. Leptocephalus #2 (Figure 2B), collected on 7 September 2013, lived for 38 days (SL at death: 15 mm, Stage 2, Phase IX), and leptocephalus #3, collected on 3 October 2013, lived for 59 days (SL at death: 17 mm, Stage 3, Phase X). Leptocephalus #1, collected on 6 Sep-

***TABLE 1.*** *Atlantic Tarpon,* Megalops atlanticus, *leptocephali collected from Mississippi coastal waters. Collection locations: 1—Grand Bay, 2—Belle Fontaine Beach, 3—Gulf Park Estates Beach, 4—Ocean Springs East Beach. *Live specimens included among these numbers; body length not recorded for live specimens. Stage and phase classifications from Wade 1962 and Mercado and Ciardelli 1972.*

| Date of Collection | Collection Location | Number of Larvae | Size Range, Mean (SL, mm) | Stage (Phase) | Envionmental Parameters Temperature (°C) | Salinity | Dissolved Oxygen (mg/L) |
|---|---|---|---|---|---|---|---|
| Aug 2006 | 1 | 1 | 24.0 (TL) | 2 (VII) | 30.5 | 28.9 | N/A |
| Sep 2009 | 2 | 1 | 23.0 | 2 (VII) | 27.6 | 18.0 | 7.4 |
| Oct 2009 | 2 | 1 | 26.0 | 2 (VI) | 28.5 | 18.0 | 9.6 |
| Jul 2012 | 2 | 2 | 22.5 – 24.1, 23.3 | N/A | 30.4 | 15.8 | 5.5 |
| Sep 2012 | 2 | 1 | 26.2 | 2 (VI) | 26.9 | 12.9 | 6.8 |
| Jul 2013 | 2 | 3 | 26.0 – 27.2, 26.6 | 2 (VI, VII) | 30.1 | 15.8 – 15.9 | 6.5 |
| Aug 2013 | 2 | 19 | 20.1 – 27.5, 24.1 | 1 (V); 2(VI, VII) | 29.1 – 34.1 | 13.4 – 21.4 | 6.4 – 8.2 |
| Aug 2013 | 3 | 5* | 23.1 – 25.7, 24.3 | 2 (VI, VII) | 29.1 – 33.1 | 14.5 – 16.1 | 6.5 – 8.0 |
| Sep 2013 | 2 | 10* | 19.9 – 22.5, 21.5 | 2 (VI, VII, VIII) | 29.1 – 32.5 | 17.3 – 17.9 | 7.2 – 7.9 |
| Sep 2013 | 3 | 2 | 19.2 – 21.9, 20.6 | 2 (VII) | 29.5 – 30.1 | 18.9 – 19.7 | 4.8 – 5.8 |
| Oct 2013 | 2 | 1* | N/A | N/A | 26.4 | 13.4 | 6.6 |
| Jul 2015 | 2 | 1 | 16.0 | N/A | 29.1 | 18.3 | 4.9 |
| Aug 2015 | 4 | 1 | 22.5 | N/A | 28.1 | 24.8 | 4.9 |
| Jul 2016 | 3 | 1 | 22.8 | N/A | 31.8 | 20.3 | 5.1 |
| Jul 2016 | 2 | 8 | 22.6 - 24.7 | 1 (V); 2(VI, VIII) | 32.0 | 21.8 | 7.2 |
| Aug 2016 | 2 | 10 | 20.9 - 25.0 | 2 (VI, VIII) | 26.1 - 30.1 | 6.03 - 13.9 | 5.5 - 10.4 |
| Sep 2016 | 2 | 28 | 18.1 - 25.1 | 2 (VII, VIII) | 30.1 - 34.1 | 19.7 - 25.5 | 6.5 - 8.2 |
| Oct 2016 | 2 | 4 | 21.5 - 26.6 | 2 (VI,V) | 26.6 - 27.6 | 26.1 - 26.5 | 7.0 - 7.4 |

tember 2013, is currently a live 4—year—old juvenile housed at the Institute for Marine Mammals Studies in Gulfport, Mississippi.

Developmental changes in leptocephalus #2 observed during the first 11 days in captivity included 1) a decrease in body length, 2) increased presence of star—shaped melanophores ventrally along the body, and 3) yellowish pigmentation on the head, ventral body, and caudal fin. The brain was visible as a white mass, and otoliths were observed posterior to the brain. The air bladder was elongated and appeared as a silvery oval. On the eighth day post—capture, the specimen began actively feeding on *Artemia* sp. nauplii and excreting waste. For the remainder of the observation period, there was increased pigmentation on the head and continued reduction in body depth and length.

## Discussion

In the present study, Atlantic Tarpon leptocephali were collected between July and October, primarily in August and September, and warrant special interest because they represent the first documented collections of Atlantic Tarpon leptocephali from coastal Mississippi waters. The lack of larvae < Stage 1: Phase V in our collections suggests that the onset of metamorphosis begins just prior to or at estuarine arrival, which agrees with the findings of Tzeng et al. (1998) for Pacific Tarpon leptocephali. Additionally, the larger leptocephali (>25 mm SL) in our collections exceed the maximum length for leptocephali collected inshore by Shenker et al. (2002; 22.1 mm SL) and those collected offshore by Eldred (1967; 22 mm SL), Smith (1980; 22 mm SL), and Crabtree et al. (1992; 24.4 mm SL) and fill an important data gap for tarpon leptocephali from the Gulf of Mexico.

Many marine larvae are transported long distances by ocean currents to nursery habitats (Johnson and Perry 1999), including elopiform larvae (McCleave 1993). The Loop Current provides a potential mechanism for transport of Atlantic Tarpon leptocephali into the northern GOM from spawning grounds in the southern GOM. Such transport was proposed for leptocephali of bonefish, *Albula vulpes*, collected off Louisiana (Thompson and Deegan 1982). However, results of the current study, combined with collections of early juvenile Atlantic Tarpon from the Mississippi Sound (Franks et al. 2013) in consecutive years, the capture of a spawning capable female from the northern GOM (Stein et al. 2012), and collections of 23 yolk—sac leptocephali (<5 mm notochord length) off the Louisiana coast (Stein et al. 2016), suggest the northern GOM is a spawning area for Atlantic Tarpon. Additional Atlantic Tarpon research is necessary to further understand the northern


***FIGURE 2.*** *Photographs of Atlantic Tarpon* Megalops atlanticus leptocephali *examined in this study. A. Deceased specimen (Stage 2, Phase VII, 20.8 mm SL) collected in September 2016 from Bellefontaine Beach. B. Deceased* Leptocephalus #2 *(Stage 2, Phase IX, 15 mm SL) 38 days post–capture.*

GOM's contribution to adult populations. The northernmost range of Atlantic Tarpon is limited mainly by temperature, and juveniles succumb to ambient water temperatures <12.0 ± 2.8°C (Mace et al. 2017). The Mississippi Sound estuary often experiences winter water temperatures ≤10 °C, and cold—kill events that included juvenile Atlantic Tarpon were documented in 1974 (n=6, 226–289 mm SL; Overstreet et al. 1974) and 2013 (n=33, 72–260 mm SL; Graham and Franks, unpublished data). With warming ocean temperatures driven by global climate change, it is feasible that the northern extent of the Atlantic Tarpon range will become more suitable for survival and growth, similar to other climate—driven distribution shifts (Fodrie et al. 2010, Muhling et al. 2011).

We provide the first report of Atlantic Tarpon leptocephali from the Mississippi Sound estuary and the largest known inshore collections of leptocephali from the northern GOM. Future studies of Atlantic Tarpon leptocephali from Mississippi estuaries will include otolith increment analysis, larval back—tracking models to estimate potential offshore spawning locations, and targeted sampling for smaller leptocephali. Better understanding of the early life history of Atlantic Tarpon will provide insights into triggers of metamorphosis, physiological responses to estuarine environments, habitat requirements, duration of the leptocephalus stage in northern GOM waters, and Atlantic Tarpon recruitment.

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