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ARTICLE

Recruitment of Age-0 Gray Triggerfish to Benthic Structured Habitat in the Northern Gulf of Mexico

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Abstract
Recruitment of age-0 gray triggerfish *Balistes capriscus* to benthic artificial reefs was documented by diver surveys from 2003 to 2007. Divers counted and estimated the sizes of all gray triggerfish that recruited to three types of artificial reefs (all in 20-m depths) ranging from 1.2 to 4.0 m^2 in area. Reefs were located in the Gulf of Mexico 28 km south of Dauphin Island, Alabama. Forty artificial reefs built in June 2003 were surveyed in October–December 2003 and May 2004; 20 artificial reefs built in October 2005 were surveyed in October and December 2005 and May, August, and December 2006; 40 artificial reefs built in July 2006 were surveyed in June 2007; and 30 artificial reefs built in August 2007 were surveyed in September, October, and December 2007. Recruitment patterns were similar in the fall and winter of 2003 and 2007. In 2005 significantly lower numbers of recruits were detected than in other years, which may have been caused by a major hurricane. Peak recruitment of age-0 gray triggerfish occurred from September to December. Based on known spawning seasonality and the first appearance of recruits in September in this study, gray triggerfish spend 4–7 months in the pelagic environment before recruiting to benthic habitat.

The gray triggerfish *Balistes capriscus* is a widely distributed species found throughout the western and eastern Atlantic Ocean, as far north as Nova Scotia and as far south as Argentina. Gray triggerfish distribution also extends into the Gulf of Mexico (Briggs 1958; Moore 1967). This species is primarily targeted and landed by recreational fishers but is also landed by the commercial fishery in the Gulf of Mexico (SEDAR-9 2006; GMFMC 2008). After completion of a stock assessment in October 2006, which showed an increase in landings across all sectors starting in 2000, gray triggerfish in the Gulf of Mexico were defined as overfished (SEDAR-9 2006). Due to stock assessment results, a rebuilding plan was created by the Gulf of Mexico Fishery Management Council and implemented by the National Marine Fisheries Service in August 2008.

Even though this species is widely distributed and economically important to fishers in the Gulf of Mexico, limited information is available on its early life history. Previous studies have documented spawning seasonality and found spawning as early as May and peaking in June and July in the Gulf of Mexico and South Atlantic Bight (Ingram 2001; Moore 2001; MacKichan and Szedlmayer 2007). Other studies have also shown a pelagic stage after hatching, which is closely associated with floating sargassum *Sargassum* spp. (Dooley 1972; Fahay 1975; Bortone et al. 1977; Wells and Rooker 2004). Seasonal peaks in the pelagic stage of gray triggerfish were similar among studies (e.g., July through August [Fahay 1975], August through October [Dooley 1972], and May through August [Wells and Rooker 2004]). Juvenile gray triggerfish showed larger sizes in the

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pelagic zone than other northern Gulf of Mexico reef fishes: 9–132 mm standard length (SL) from July to October (Dooley 1972; Fahay 1975; Bortone et al. 1977; Wells and Rooker 2004).

Adult gray triggerfish are closely associated with both natural and artificial reefs (Johnson and Saloman 1984; Frazer and Lindberg 1994; Vose and Nelson 1994; Kurz 1995; Ingram 2001; Lingo and Szedlmayer 2006). However, little information is available on the size and season when juvenile gray triggerfish settle out of the plankton and recruit to benthic structured habitats. Past studies have suggested that multiple bottlenecks occur in the early juvenile stages and that the shift from pelagic to benthic habitat represents a critical period (Doherty 1987; Richards and Lindeman 1987; Sogard 1997; Szedlmayer, in press). For example, during habitat shifts gray triggerfish may be more susceptible to predation because they encounter a new suite of predators on benthic reefs (Sogard 1997).

In this experiment, the size and season in which gray triggerfish leave the pelagic zone and settle on benthic artificial reefs in the northern Gulf of Mexico was examined. Jones (1991) defined recruitment as "the input of juveniles to the observed reef-based population." Throughout this study, we define recruitment as the season and size when juvenile gray triggerfish first appear on artificial reefs after settlement (Leis 1991).

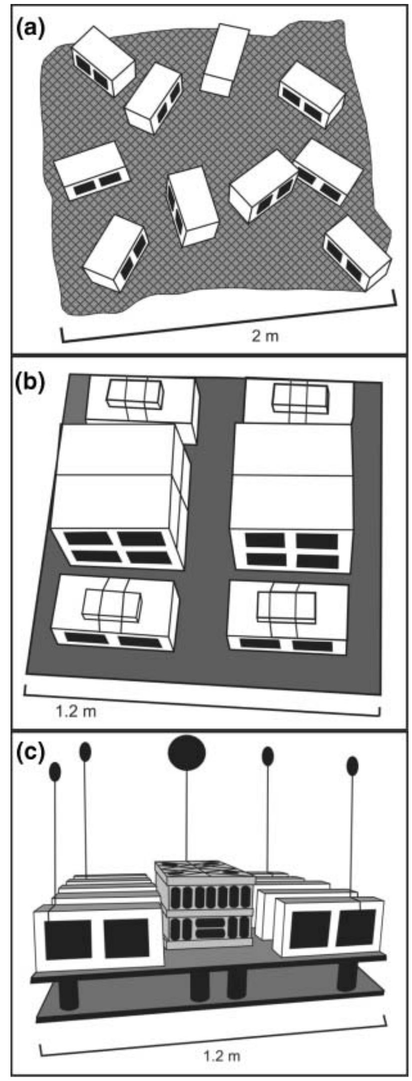

FIGURE 1. Artificial reef designs deployed in the northern Gulf of Mexico in **(a)** 2003, **(b)** 2005–2006, and **(c)** 2007.

METHODS

Three types of artificial reefs were built from 2003 to 2007 to study gray triggerfish recruitment to benthic reefs. All artificial reefs were placed in the Gulf of Mexico 28 km south of Dauphin Island, Alabama, in 20 m of water. All gray triggerfish were counted by two scuba divers and placed into size-classes with 25-mm increments. The census methods used by divers followed the methods described as the "point method" by Bortone et al. (1989). Two divers were positioned on each side of the artificial reef for 10–15 min to count and record the number of gray triggerfish. All of the artificial reefs built and surveyed were relatively small (1–4 m^2); however, if visibility was less than 2 m diver surveys were aborted.

Forty artificial reefs (2 × 2 × 0.2 m) were built 15–25 June 2003. Each of the 2003 artificial reefs consisted of 10 concrete blocks (41 × 20 × 20 cm) randomly attached to a polyethylene mat (4 m^2, mesh size 0.64 cm) via two 91-cm cable ties (Figure 1a). Ten artificial reefs were placed 30 m apart in four transects. Artificial reefs were visually surveyed by two scuba divers for gray triggerfish in the fall (4–5 October 2003), winter (21 November to 8 December 2003), and spring (5–20 May 2004).

Forty new artificial reefs (1.2 × 1.2 × 0.41 m) were built from 11 to 24 August 2005, but these were all were destroyed by Hurricane Katrina before surveys were completed. After the storm, an additional 20 artificial reefs were built on 10 October 2005. Each of the 2005 artificial reefs consisted of 12 concrete blocks (41 × 20 × 20 cm) attached with two 91-cm cable ties to plywood (1.22 × 1.22 × 0.006 m). Two sets of four concrete blocks each were stacked in the center of the board, and four blocks were secured on the outside edge (Figure 1b). Each reef also had four smaller concrete bricks (9 × 6 × 20 cm) placed on the top of the outside larger blocks and secured with 30-cm cable ties. Each reef was tied to a 1.8-m ground anchor via a 1.3-cm-diameter nylon rope, to reduce movement from storms. Ten artificial reefs were placed 30-m apart in two transects. All 2005 artificial reefs were visually surveyed by scuba divers for gray triggerfish in the fall (20 October 2005), winter (1 December 2005), spring (24 May 2006), summer (2 August 2006), and the following winter (13 December 2006).

An additional set of 40 artificial reefs were built 18–26 July 2006 using the same reef design as in 2005 (Figure 1b). All 2006 artificial reefs were visually surveyed by scuba divers for gray triggerfish from 6 to 11 June 2007.

A third reef design (1.22 × 1.02 × 0.42 m) was used in constructing 30 reefs from 1 to 9 August 2007 (Figure 1c).

Each of these reefs comprised 10 concrete half blocks (41 × 10 × 20 cm), and each block was attached to a plastic pallet (1.22 × 1.02 × 0.14 m) with four cable ties. Five blocks were arranged in rows on each side of the pallet, and a plastic crate (61 × 30.5 × 28 cm) was placed in the middle to increase reef complexity. The plastic crate had various hole sizes (12.1 × 3.2, 14 × 3.8, and 7.6 × 3.2 cm) on the top and sides. Four floats (12.7 × 5.1 cm) were attached to the reef with 1 m 0.64-cm-diameter nylon ropes at each corner of the reef. A larger circular float (15.2-cm diameter) was attached to the center of the reef with a 1-m, 0.64-cm-diameter nylon rope (Figure 1c). After the reef was deployed, it was secured to the substrate with a 1.8-m ground anchor and 1.3-cm-diameter nylon rope. Artificial reefs were placed in six rows with five reefs per row, with each reef 500 m from the other reefs. Ten different artificial reefs were visually surveyed by two scuba divers for gray triggerfish on 27 September, 26 October, and 7–10 December 2007.

Temperature, salinity, and dissolved oxygen were measured with a YSI 6920 meter (Yellow Springs Instruments, Yellow Springs, Ohio). Values reported were measured at 1 m above the bottom. Temperature data were also obtained from a National Oceanic Atmospheric Administration (NOAA) data buoy located 41 km south of Biloxi, Mississippi, to calculate mean surface water temperatures from 2003 through 2007.

In the few age and growth studies for gray triggerfish, size at age was highly variable (Johnson and Saloman 1984; Ofori-Danson 1989; Ingram 2001; Moore 2001; Bernardes 2002). From monthly visual surveys, age-0 and age-1 recruits were separated based on comparisons to previously reported age–length relations (Johnson and Saloman 1984; Ingram 2001; Moore 2001). A 1 June spawn date was applied based on observations of gray triggerfish spawning in June and July in the northern Gulf of Mexico (MacKichan and Szedlmayer 2007). Previous studies have also shown that gray triggerfish reach 200 mm fork length (FL) by age 1 (January), with an estimated growth rate of 0.95 mm/d (Ingram 2001; Moore 2001). In our study, to separate age-0 from age-1 gray triggerfish, the following size–age relations were applied: fish <100 mm FL were considered age-0 in August, fish <125 mm were age 0 in September, fish <150 mm were age 0 in October, fish <175 mm were age 0 in November, and all gray triggerfish <200 mm were age 0 in December. In January, all juvenile gray triggerfish on benthic artificial reefs were considered age 1.

Artificial reefs built in 2003, 2005, 2006, and 2007 were compared separately for number and size of gray triggerfish across survey periods (months). Abundance estimates were standardized to mean number of gray triggerfish/m^2. The 2003 and 2005 diver visual counts of gray triggerfish were analyzed with a repeated-measures analysis of variance (rmANOVA), whereas the 2007 counts were analyzed with a one-way ANOVA because 10 different reefs were sampled from each survey (not repeated). Mean abundance of age-0 and age-1 fish were compared separately for each survey with ANOVA. Mean fish size of age-0 gray triggerfish were compared among survey periods with

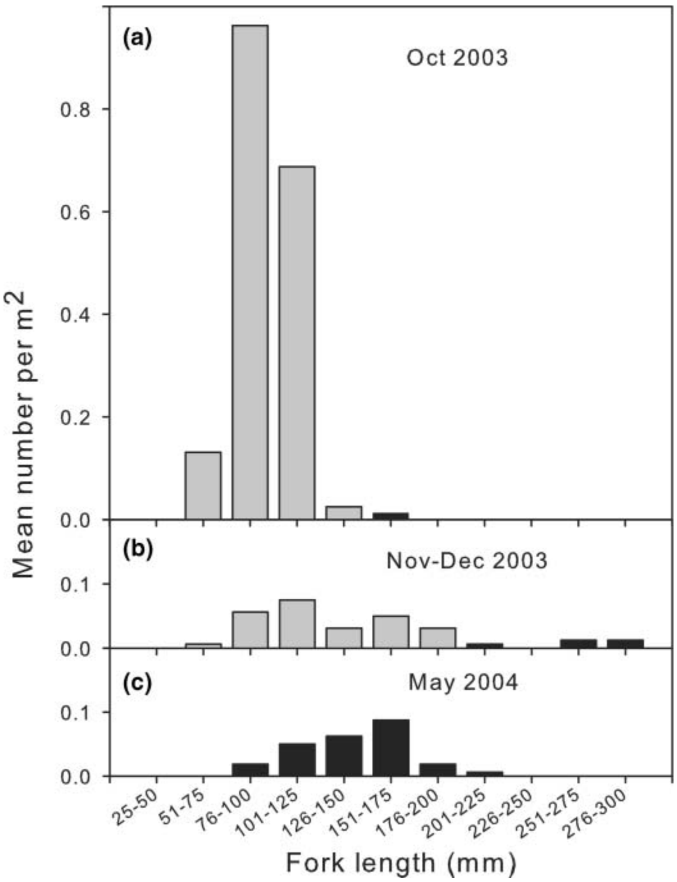

FIGURE 2. Length-frequency distributions of age-0 (gray bars) and age-1 (black bars) gray triggerfish on artificial reefs deployed in the northern Gulf of Mexico in 2003 and surveyed by divers in **(a)** October 2003, **(b)** November–December 2003, and **(c)** May 2004.

rmANOVA. Mean number of fish were compared across years for October and December surveys with a one-way ANOVA. Surface water temperatures were compared with temperatures taken at 1-m above the bottom by month and year with a paired *t*-test. All tests were considered significant at $\alpha = 0.05$. If significant differences were detected a Student–Newman–Kuels test was used to show specific differences (Zar 1999).

RESULTS

Peak densities of age-0 gray triggerfish were found on artificial reefs from September to December for all years, with the first recruits in September in the northern Gulf of Mexico (Figures 2–4). In 2003, significantly more age-0 gray triggerfish were observed in October (mean ± SE = 1.8 ± 0.3 fish/m^2) than in November–December (0.3 ± 0.05 fish/m^2; rmANOVA: $F_{1,39} = 33.6$, $P < 0.001$). In May 2004, age-0 gray triggerfish were not observed on artificial reefs (Figure 2). In 2005, significantly more age-0 fish were found on artificial reefs in December (0.3 ± 0.1 fish/m^2) than in October (0.04 ± 0.03 fish/m^2; rmANOVA: $F_{1,19} = 4.8$, $P < 0.05$). In May and August 2006, age-0 gray

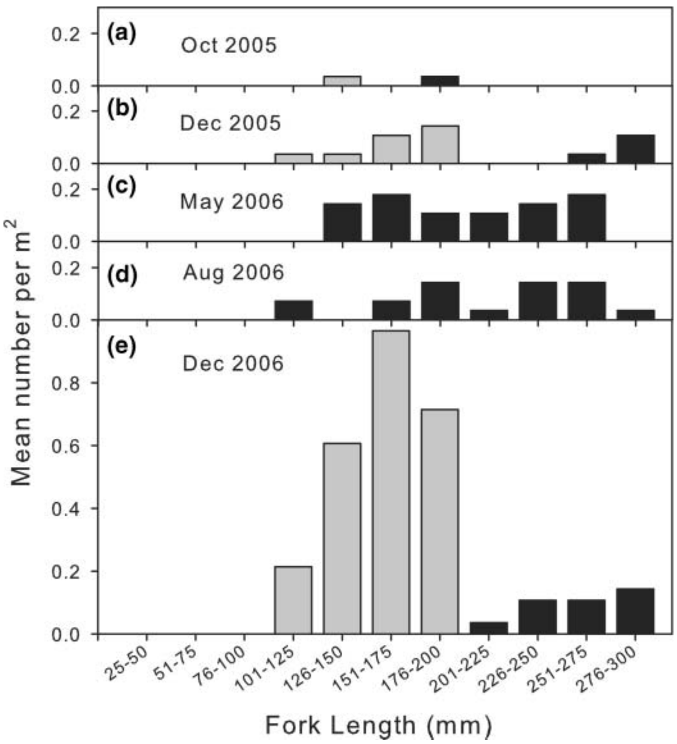

FIGURE 3. Length-frequency distributions of age-0 (gray bars) and age-1 (black bars) gray triggerfish on artificial reefs deployed in the northern Gulf of Mexico in 2005 and surveyed by divers in **(a)** October 2005**, (b)** December 2005, **(c)** May 2006, **(d)** August 2006, and **(e)** December 2006.

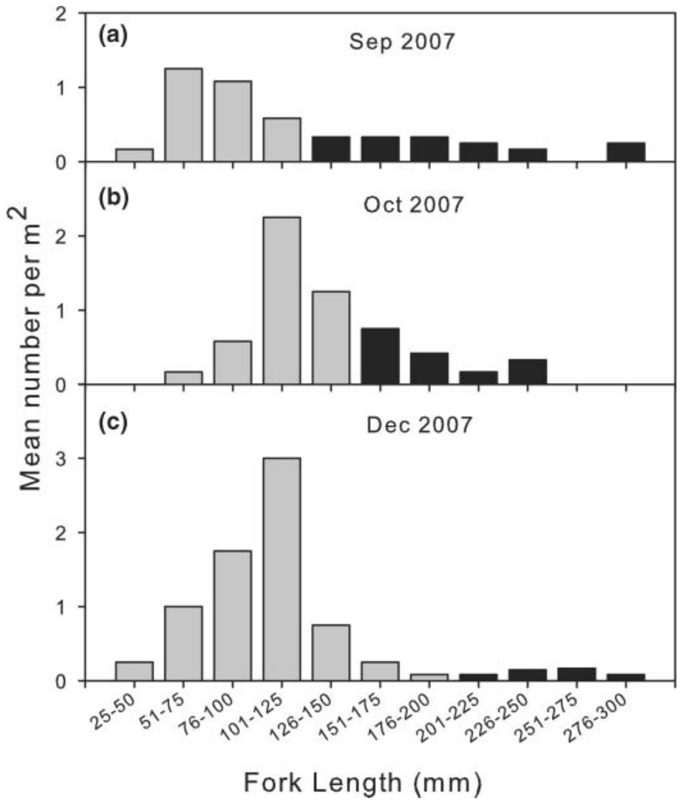

FIGURE 4. Length-frequency distributions of age-0 (gray bars) and age-1 (black bars) gray triggerfish on artificial reefs deployed in the northern Gulf of Mexico in 2007 and surveyed by divers in **(a)** September 2007, **(b)** October 2007, and **(c)** December 2007.

triggerfish were not observed on artificial reefs but did recruit to reefs by December 2006 (2.5 ± 0.3 fish/m^2; Figure 3). In 2007, significantly more age-0 gray triggerfish were found in December (7.1 ± 1.1 fish/m^2) than in September (3.1 ± 0.7 fish/m^2) or October (4.2 ± 0.6 fish/m^2; ANOVA: $F_{2,27} = 6.0$, $P < 0.01$; Figure 4).

In 2003 there were significantly (ANOVA for all years) more age-0 than age-1 gray triggerfish in October ($F_{1,78} = 43.8$, $P < 0.001$), as there were in November–December ($F_{1,78} = 17.5$, $P < 0.001$; Figure 2). In October 2005 only two gray triggerfish were observed. In December 2005, no significant differences were detected between age-0 and age-1 gray triggerfish ($F_{1,38} = 1.0$, $P > 0.1$; Figure 3). In December 2006, significantly more age-0 gray triggerfish were observed than age-1 fish ($F_{1,38} = 23.3$, $P < 0.001$; Figure 3). In 2007, no significant differences were detected in the numbers of age-0 and age-1 gray triggerfish in September ($F_{1,18} = 1.4$, $P > 0.1$). However, in 2007 significantly more age-0 gray triggerfish were observed than age-1 fish in both October ($F_{1,18} = 13.3$, $P < 0.01$) and December ($F_{1,18} = 30.3$, $P < 0.001$; Figure 4). Only age-1 gray triggerfish were observed in May 2004 (mean ± SE = 0.24 ± 0.04 fish/m^2; Figure 2), May (1.1 ± 0.2 fish/m^2) and August 2006 (1.3 ± 0.2 fish/m^2; Figure 3) and June 2007 (1.4 ± 0.2 fish/m^2; Figure 5).

Age-0 gray triggerfish length increased from initial recruits in fall to older recruits in early winter. In 2003, age-0 gray triggerfish were significantly smaller in October (mean ± SE = 95.9

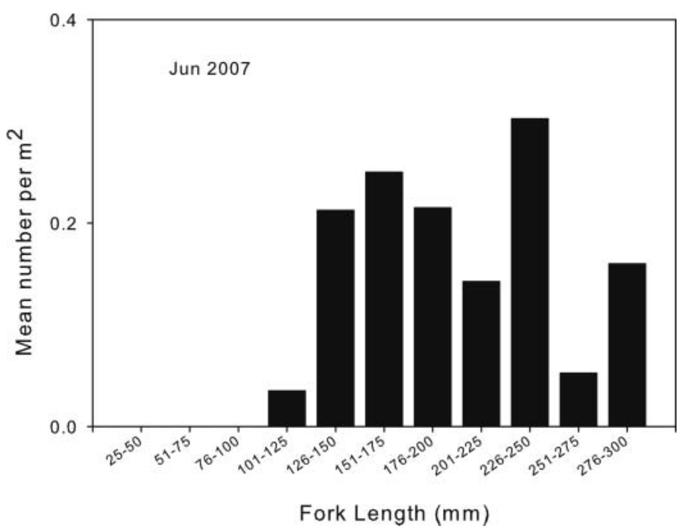

FIGURE 5. Length-frequency distributions of age-1 gray triggerfish on artificial reefs deployed in the northern Gulf of Mexico in 2006 and surveyed by divers in June 2007. No age-0 gray triggerfish were observed.

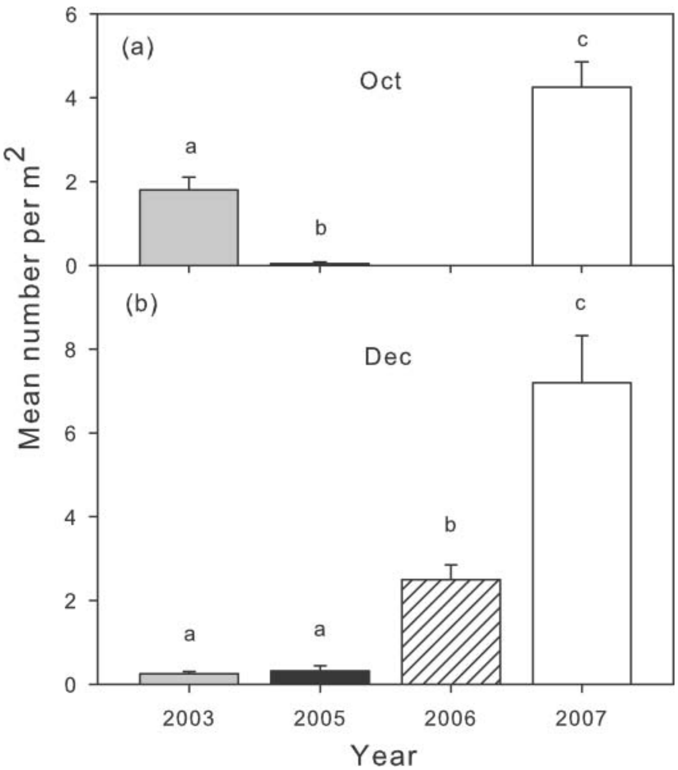

FIGURE 6. Comparison across years of the mean number of gray triggerfish observed on artificial reefs in the northern Gulf of Mexico in **(a)** October and **(b)** December. The error bars represent SEs; significant differences ($\alpha = 0.05$) within panels are denoted by different letters.

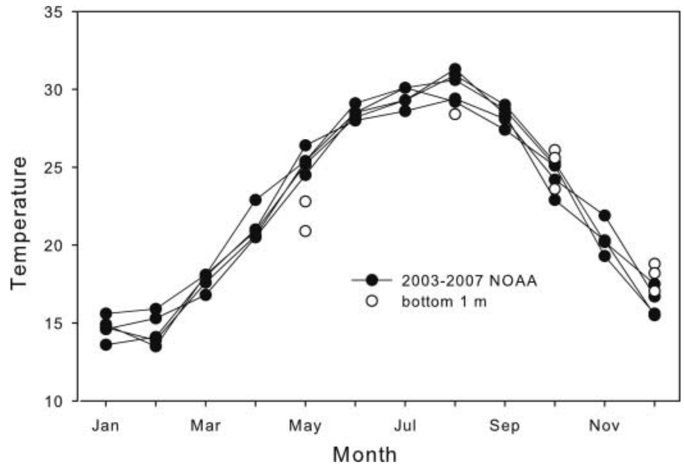

FIGURE 7. Across-year (2003–2007) mean surface water temperatures (°C) calculated from the National Oceanic and Atmospheric Administration's (NOAA) data buoy 41 km south of Biloxi, Mississippi, and from temperature data collected 1 m from the bottom in this study.

± 0.9 mm, range = 63–138 mm) than in November–December (128.1 ± 5.6, 63–188 mm; rmANOVA: $F_{1, 288} = 144.6$, $P < 0.001$; Figure 2). In 2005, the number of age-0 gray triggerfish was too low to make size comparisons. There was only one age-0 gray triggerfish surveyed in October 2005 (138 mm FL). In 2007, a significant increase in mean size was apparent from September (79.4 ± 3.5 mm, 38–113 mm) to October (114.5 ± 2.7 mm, 63–138 mm) followed by a decrease in December 2007 (101.9 ± 3.1 mm, 38–188 mm; rmANOVA: $F_{2, 170} = 27.7$, $P < 0.0001$; Figure 4).

Comparisons of size across years for age-0 gray triggerfish showed significant differences when compared by month. The mean size of age-0 gray triggerfish was significantly smaller in October 2003 than in October 2007 (ANOVA: $F_{1, 338} = 56.1$, $P < 0.001$). In December, age-0 mean size was significantly smaller in 2003 than in 2005 (mean ± SE = 165.3 ± 8.8 mm FL, range = 113–188 mm) and 2006 (159.3 ± 2.8 mm, 113–188 mm) but significantly larger than in 2007 (ANOVA: $F_{3, 200} = 57.0$, $P < 0.001$). In December 2005 and 2006, all gray triggerfish recruits were greater than 100 mm FL (Figure 3). For October, significantly more age-0 gray triggerfish were observed in 2007 than in 2003 and 2005 (ANOVA: $F_{2, 67} = 27.4$, $P < 0.001$; Figure 6a). For December, significantly more age-0 gray triggerfish were observed in 2006 and 2007 than in 2003 and 2005 (ANOVA: $F_{3, 86} = 73.5$, $P < 0.001$; Figure 6b).

Seasonal surface water temperatures were similar among years (2003–2007) and were not significantly different from bottom water temperatures taken during reef surveys (paired $t = 0.16$, df = 8, $P > 0.05$; Figure 7). Salinity and dissolved oxygen measures taken 1 m above the bottom showed little variation over the study period. Salinity ranged from 33.3‰ to 36.6‰ (mean ± SE = 34.6 ± 0.4‰, $N = 10$) and dissolved oxygen ranged from 4.8 to 8.8 mg/L (mean ± SE = 6.5 ± 0.5 mg/L, $N = 10$).

DISCUSSION

This study showed peak recruitment of age-0 gray triggerfish from September to December in the northern Gulf of Mexico. Fish were age 0 when they recruited to the benthic artificial reefs, based on our observations and previous seasonal information on spawning and pelagic stages. Gray triggerfish spawn as early as May, with peaks in June and July in the Gulf of Mexico and South Atlantic Bight (Ingram 2001; Moore 2001; MacKichan and Szedlmayer 2007). Past studies revealed high numbers in the plankton in late summer and fall (August–October), sizes ranging from 13 to 132 mm SL (Dooley 1972). Bortone et al. (1977) also found gray triggerfish in the plankton in the eastern Gulf of Mexico from May through October, their sizes ranging from 9 to 78 mm SL. A more recent study of sargassum mats in the northwestern Gulf of Mexico also found high abundance of gray triggerfish (13–106 mm SL) in the pelagic zone from May to August (Wells and Rooker 2004). Data from our study combined with these earlier studies indicate that most juvenile gray triggerfish have dropped out of the plankton by December, spending 4–7 months in the pelagic zone before recruiting to benthic substrate.

From the numbers of gray triggerfish collected via trawls in the Gulf of Mexico in October and November 1998, Ingram (2001) back-calculated the length-frequency of gray triggerfish at settlement, finding that they ranged from 40 to 160 mm FL with a mode of 70 mm. Those lengths were consistent with our estimated means of 95.9 mm FL (October 2003) and 114.5 mm FL (October 2007) for gray triggerfish on our artificial reefs. However, in our study, sizes of fish were estimated on a reef after recruitment had already occurred, and these fish probably settled at smaller sizes sometime before the visual census; in addition, the smallest recruits were 25–50 mm FL.

In contrast to Ingram's (2001) and our studies, aging studies of gray triggerfish off the Brazilian coast led Bernardes (2002) to conclude that they recruited to benthic habitat at age 1. However, these age-1 fish were similar in size (90–120 mm FL) to recruitment sizes of the age-0 gray triggerfish we observed in the northern Gulf of Mexico and reported in the South Atlantic Bight (Moore 2001). Bernardes' (2002) study of gray triggerfish was conducted in the Southern Hemisphere, where numerous differences in environmental factors could affect the growth rate and increment formation. Our study applied the age–length relation from Ingram's (2001) collections, which included 80 small gray triggerfish (<200 mm FL), and ages were not based on back-calculations.

Gray triggerfish showed similar recruitment patterns in the fall and winter 2003, 2006, and 2007; however, in 2005 recruitment was lower. Clearly, destruction of artificial reefs due to Hurricane Katrina affected our ability to quantify recruitment in our study area. After the first set of 2005 artificial reefs were destroyed, artificial reefs were rebuilt in October 2005, and surveys were taken at the end of the same month. These rebuilt 2005 reefs probably showed lower recruitment due to mortality or movement of juvenile gray triggerfish caused by Hurricane Katrina or artificial reefs may not have been in place long enough for full recruitment to have occurred.

Salinity and dissolved oxygen showed little variation across surveys. Szedlmayer and Conti (1999) showed similar salinity and dissolved oxygen readings in an earlier study from the same area. Bottom water temperatures taken during this study were similar to surface water temperatures from the NOAA data buoys and declined in the fall. These decreasing water temperatures in the fall (October and November) and winter (December) may be a cue for gray triggerfish to drop out of the plankton to benthic reefs.

Reef type and complexity may affect the annual recruitment of gray triggerfish (Shulman 1984; Lingo and Szedlmayer 2006; Piko and Szedlmayer 2007). In our study different artificial habitat types were used that may have influenced recruitment. Two differences in the 2007 artificial reef design compared with other years were (1) the vertical floats 1 m above the reef and (2) the plastic crate in the center of the reef between the concrete blocks. Thus, the 2007 artificial reefs were more complex than those of 2003, 2005, and 2006 reefs, and this increased complexity may account for the higher recruitment observed in 2007. However, these results should be taken with caution because the different reef types were not compared within the same year.

Our study showed a unique life history pattern for age-0 gray triggerfish compared with most other marine reef fish. In the northern Gulf of Mexico, gray triggerfish have a protracted pelagic stage and recruit to benthic reef structure as relatively large, older juveniles from September to December. Recruitment was consistent in September–December 2003, 2006, and 2007 but significantly lower in 2005, when lower densities of age-0 fish were probably caused by a major storm event.

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