Movement Patterns of Gray Triggerfish, *Balistes capriscus*, Around Artificial Reefs in the Northern Gulf of Mexico.

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
August 2, 2014

Keywords: VPS telemetry, Fine scale movements, Site fidelity

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ABSTRACT

Relatively little is known about the ecology of gray triggerfish, *Balistes capriscus* Gmelin, despite its importance to both sport and commercial fisheries. In particular, gray triggerfish habitat use is not well understood. Fine scale tracking would provide an understanding of habitat use for gray triggerfish which may help with the future management of this species. Thus, this study was an attempt to implant ultrasonic transmitters in gray triggerfish and track their fine scale movement patterns around artificial reefs in the northern Gulf of Mexico. Adult gray triggerfish (n = 17) were successfully tagged with transmitters and tracked using the VR2W Positioning System (VPS). Most (84.2 %) tagged fish successfully survived and were tracked for extended periods (1 to 57 weeks), with only three fish lost within 24 hours of tagging (here considered a tagging artifact). Tagged gray triggerfish showed diel movement patterns with home ranges (95 % KDE) and core areas (50 % KDE) significantly larger during the day than night. Fish also showed seasonal movement patterns that were positively correlated with water temperature. Gray triggerfish showed high site fidelity (mean distance from reef = 46.3 ± 1.3 m) and residency (79 % still present after 100 days) to release site reefs. This high site fidelity could have important implications for gray triggerfish management. This species forms spawning groups around artificial reefs with a single dominant male and several females. Due to this species high site fidelity, fisher removal of the dominant male may disrupt spawning success at greater rates than

previously considered. Also, the high site fidelity to artificial reefs further emphasizes the importance of structured habitat for gray triggerfish, and this new VPS tracking methods provided an important advancement for gray triggerfish movement studies.

Acknowledgments

This project was funded by Marine Resources Division, Alabama Department of Conservation and Natural resources, and is a contribution of the Alabama Agricultural Experiment Station and the School of Fisheries, Aquaculture, and Aquatic Sciences, Auburn University. I would like to thank my advisor, Stephen Szedlmayer, for his support and time throughout my time at Auburn. I also thank Mark Albins, Rachel Brewton, Lee Grove, Jessica Jaxion-Harm, Danielle Horn, Peter Mudrak, Maria Piraino, Claire Roberts, and Jay Williams for field and laboratory assistance and encouragement through this study. I would also like to thank my family for all of their love and support throughout my studies.

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Introduction

Gray triggerfish, *Balistes capriscus* Gmelin, is both a commercially and recreationally important species in the Gulf of Mexico (Hood and Johnson 1997; Simmons 2008). Gray triggerfish have become even more important in recent years due to intense fishing pressure on several other species. Short fishing seasons have been implemented for several species such as red snapper, *Lutjanus campechanus* (Poey), gag *Mycteroperca microlepis* (Goode and Bean), and greater amberjack, *Seriola dumerili* (Risso), in order to reduce fishing mortality and help rebuild their stocks. The shortened seasons have resulted in fishers targeting other fish species, especially gray triggerfish, which previously did not experience heavy fishing pressure (Vale *et al.* 2001).

Presently, gray triggerfish in the Gulf of Mexico is considered overfished and experiencing overfishing (SEDAR-9 2006). A management plan to rebuild the population was put in place in 2008 (NOAA 2012). Although the interest in gray triggerfish has increased due to their increasing value, many important life history parameters are still unclear. After hatching, gray triggerfish spend their first few months near the surface associated with *Sargassum* mats, *Sargassum natans* (Linnaeus) Gaillon, and *Sargassum fluitans* Børgesen, (Wells and Rooker 2004) after which they recruit to benthic structured habitats (Simmons and Szedlmayer 2011) and appear to show extended residency to these reef habitats (Ingram and Patterson 2001). They reach sexual maturity relatively early, by age two (Wilson *et al.* 1995; Hood and Johnson 1997). Unlike typical reef fish which are broadcast spawners, gray triggerfish display a haremlike mating system with a dominant male that builds nests in the sediment and spawns with several females (Simmons and Szedlmayer 2011). After spawning, they show parental care and tenaciously guard their nests until the eggs hatch (Simmons and Szedlmayer 2011).

Little is known concerning the importance of structured habitats for gray triggerfish, either artificial or natural reef structure. Due to recent advances in telemetry technology it is now possible to remotely carry out fine scale (m) movement studies of gray triggerfish around these reefs. Such studies will greatly improve our understanding of the importance of structured habitat for gray triggerfish and provide estimations of home range, habitat use, and residency.

Off the coast of Africa gray triggerfish move seasonally due to cold water temperatures (Ofori-Danson 1990). This pattern has not been reported for gray triggerfish in the Gulf of Mexico. Gray triggerfish may show seasonal movement patterns related to spawning behavior as large schools of gray triggerfish have been observed around reef structure at the start of the spawning season (personal observation). These aggregations were not observed later in the season (June and July) after fish had established a dominance hierarchy (Simmons and Szedlmayer 2012). These aggregations are unreported in the literature and information on their timing of formation, duration, breakup and purpose needs investigation.

Few studies have examined movement patterns in Balistidae. One of the earliest studies externally tagged 58 gray triggerfish off the coast of Florida (Beaumariage 1969). Only six gray triggerfish were returned with all recaptured at their release site. Ingram and Patterson (2001) externally tagged 206 gray triggerfish in the northern Gulf of

Mexico, and recaptured 42 fish (with eight fish recaptured more than once). Of these 50 recaptures, 67 % were at the site of release and 100 % were within 9 km. A similar study tagged 256 gray triggerfish on artificial reef sites off northwest Florida (Addis *et al.* 2007). Of the 40 recaptures, 58 % were on the site of release and 100% were within 10 km of the reef. The only previous study to use internal transmitters in Balistidae, tagged six ocean triggerfish, *Canthidermis sufflamen* (Mitchill), and monitored their presence with a satellite-linked acoustic receiver attached to a fish aggregation device (FAD) in the Indian Ocean (Dagorn *et al.* 2007). However, the fish were only detected around the FAD for 15 days.

In the present study, Vemco positioning system (VPS, Vemco Ltd, Nova Scotia) telemetry methods were used to assess the importance of structured habitat for gray triggerfish. These new VPS methods have proven successful with red snapper in the northern Gulf of Mexico, providing the ability to remotely and continually monitor the fine scale movement of several tagged fish (Piraino and Szedlmayer in press). These new VPS methods can provide very accurate fine scale movements (~ 1 m) and have the advantage of being able to estimate fishing mortality rates independent of fisher reported recaptures (Piraino and Szedlmayer, in press). For example, based on transmitter detection patterns at multiple receiver locations fishing mortality events can be identified without a reported recapture from fishers (Topping and Szedlmayer 2011a; Topping and Szedlmayer 2013; Piraino and Szedlmayer in press). The present study will first examine whether or not gray triggerfish can survive transmitter implantation and behave "normally" and if successful then apply VPS tracking methods to examine fine scale movements around artificial reefs (Piraino and Szedlmayer in press). Such information can then be used to examine important life history parameters of gray triggerfish that may help managers implement regulations to rebuild the Gulf of Mexico gray triggerfish stock.

METHODS

Study Area

Gray triggerfish were tagged on artificial reefs located 25 - 30 km south of Dauphin Island, Alabama, in the Hugh Swingle General Permit Zone. Two VPS study sites were set up on unpublished steel cage artificial reefs (4.4 x 1.3 x 1.2 m) site R34 (depth = 20 m) and site R44 (depth = 27 m; Figure 1). The VPS sites were surrounded by 22 additional steel cage artificial reefs at 1.3 - 1.7 km apart, each of which had 1 receiver (Figure 2).

Tagging Procedure

Adult gray triggerfish (> 250 mm fork length) were caught hook-and-line, weighed, measured, and anesthetized onboard the research vessel in a 70 L container of seawater and MS-222 (150 mg tricaine methanesulfonate L^{-1} seawater for 2.5 min). Fish tagging procedures followed Topping and Szedlmayer (2011a, 2011b). An individually coded acoustic transmitter (Vemco V13 - 1X – 069 - 1, 13 x 36 mm in length, 11 g in air) was implanted within the peritoneal cavity through a vertical incision on left ventral side of the fish, and the incision was closed with absorbable, sterile, plain gut surgical sutures (Ethicon 2 - 0 3.5 metric, Somerville, NJ, USA). For visual identification, all fish were also marked with individually numbered internal anchor tags (Floy tags, Seattle, Washington, USA). After surgery, fish were held in a 185 L container of seawater on the research vessel until they showed signs of recovery (active fin and gill movements).

Release Method

Initially, fish were released using cage release methods (Piraino and Szedlmayer in press). Once the fish had recovered it was placed into a circular cage (height = 40.6 cm, diameter = 60 cm) made from vinyl coated 12.5 gauge wire. Once the fish was in the cage, it was lowered to the bottom near (< 10 m) the reef. Tagged fish were allowed a 1 hour recovery period, after which SCUBA divers would open the cage and release the fish onto the reef. If the fish was not active and alert it was not released. This method was used for the first two gray triggerfish releases (T1 and T2). Due to the frequent presence of aggressive sandbar shark *Carcharhinus plumbeus* (Nardo), diver releases were discontinued.

All other tagged fish were released using a new cage release method that did not require SCUBA diver releases (L.J. Williams, J. Herbig, and S.T. Szedlmayer, Auburn University, unpublished data). Rectangular cages, 46 x 61 x 61 cm, were constructed using 13 gauge wire (Figure 3). After a fish showed signs of recovery, it was placed in the cage. The cage was lowered to the bottom near the reef (< 10 m). When the cage landed on the bottom, a door at one end opened. This allowed adequate protection for the tagged fish as well as the ability for the fish to leave the cage on its own initiative. Each cage and tagged gray triggerfish was allowed a minimum of 10 minutes to exit the cage. The cage was then retrieved after this recovery period and if the fish was still in the cage when it was brought to the surface, it was not released.

Effects of tagging

To the authors knowledge this study was the first attempt to implant ultrasonic tags in gray triggerfish. Thus, no reports were available on the effects of tagging gray triggerfish with internal tags. To examine tagging effects fish had transmitters implanted as above and were held in a closed seawater system. Adult triggerfish (> 250 mm FL) were caught hook-and-line from artificial reefs located in the Hugh Swingle Permit Zone, and tagged with transmitters (IBT- 96 - 5, 13 mm x 36 mm, 3.2 g in water; Sonotronics, Tucson, AZ, USA). All fish were also tagged with an external anchor tag. In addition to tagged fish, five gray triggerfish were held captive but not tagged (anchor tag or transmitter) for comparisons to captive tagged gray triggerfish. All gray triggerfish were injected with oxytetracycline dihydrate (OTC 0.40 g kg^{-1}) to mark otoliths and reduce infections. Fish were held in 0.7 x 1.5 m (1041 L) circular tanks that were part of an 11,000 - L closed seawater system. Water temperature was maintained at 19 - 22 ^{o}C and salinity between 34 - 37 ppt. Water quality (NH_3, NO_2, NO_3, and pH) was tested every 2 weeks. Fish were fed white, brown, or pink shrimp *Penaeus spp*. until satiation every 2 days.

Fine-Scale Tracking

Fine-scale movements of tagged gray triggerfish were monitored using the Vemco VR2W Positioning System (VPS). Each VPS site was set up using the same methods as Piraino and Szedlmayer (in press). Each site included an array of acoustic receivers (*n* = 5; Vemco VR2W) moored at 4.5 m above the seafloor on lines anchored to the bottom. Receiver positions were chosen to maximize detection ranges and assure continuous, simultaneous detection of each tagged fish by at least three receivers (Piraino and

Szedlmayer in press). At each reef site a receiver was positioned adjacent to the artificial reef (~ 20 m north, center receiver), and at four additional sites 300 m north, south, east, and west of center to maximize overlap of detection ranges. The overlap of the receivers ensures that multiple receivers were able to detect a tagged fish, making it possible to triangulate its location, with approximately 1 m accuracy within the receiver array. At each reef site, temperature loggers (*n* = 2, *Onset* HOBO, Bourne, MA, USA; U22 Water Temp Pro v2) were attached on the line of center receiver near the receiver and at the bottom, to monitor water temperature at 1 hour intervals. Synchronization transmitters (sync tags; Vemco V16-6x; 69 kHz; transmission delay: 540-720 seconds) were attached to the mooring lines 1 m above all receivers to synchronize the receiver clocks which is critical for accurate positioning of a tagged fish. A control transmitter was also placed within the array and the accuracy of the VPS was evaluated by comparing VPS-calculated positions with the known control transmitter position. Detection data were downloaded from the five receivers about every 3 months, processed by Vemco, which then reported fish positions.

In addition to the five receivers at each VPS site, single receivers (VR2W) were placed 1.3 - 1.7 km apart at 22 surrounding artificial reefs (Figure 2). These receivers were deployed so that emigration away from VPS sites (estimated by tracking patterns within the VPS sites) could be validated, as well as providing information on the direction, distance and timing of these emigrations. In addition, if tagged gray triggerfish established new residency on one of these surrounding reefs, residency time on these new reefs would be documented.

Data Analysis

Kernel density estimates (KDE) and area use were calculated using the R program (R program, Vienna, Austria). Kernel density estimates produce a probability distribution that a tagged gray triggerfish will be located within a certain area during a specified time period (Seaman and Powell 1996; Topping *et al.* 2005; Piraino and Szedlmayer in press). The R program was used to calculate the home range (95 % KDE = the area that the fish was located 95 % of the time), and the core area (50 % KDE, the area that the fish was located 50 % of the time). Seasonal effects on core area and home range were compared using a one way mixed model repeated measures analyses of variance (rmANOVA) with tagged fish as the random factor and season as the repeated measure (SAS program, Statistical Analysis Software program, Cary, NC, USA). The seasons tested were fall (September, October, November), winter (December, January, February), spring (March, April, May), and summer (June, July, and August). Monthly changes in core area and home range were also calculated for comparisons to mean monthly temperature changes. Diel patterns in core area and home range were compared by calculating area use by hourly periods and analyzed using a one-way mixed model rmANOVA with tagged fish as the random factor and hour as the repeated measure. When significant differences were detected, Tukey-Kramer tests was used to show specific differences. A linear regression model was used to test the effects of mean monthly water temperature on fish monthly area use. A linear regression was also used to compare fish size and fish area use. The mean distances that fish maintained from the artificial reef were calculated using the haversine formula outlined by Piraino and Szedlmayer (in press). A linear regression model was used to compare area use to mean fish distance from the reef. To estimate effects of tagging on gray triggerfish, fish survival over time (days) was compared between laboratory held control and tagged fish.

RESULTS

Laboratory Effects of Tagging

Tagged gray triggerfish (n = 11) and untagged gray triggerfish (n = 5) were held in a closed seawater system. There appeared to be higher (20 %) survival rate for control fish compared to tagged fish (10 %). However, there was no significant difference (t_{14} = 0.93, P = 0.37, power = 0.192) between the number of days survived and tagged or not tagged. Mean ± SE survival for tagged fish = 136 ± 42 days and untagged fish = 224 ± 108 days (Figure 4). At the time of writing the untagged fish had been held captive for 568 days and the tagged fish for 434 days. These fish were still alive and being monitored at the end of this study. From these data it is difficult to evaluate tagging effects due to low sample sizes, but it is apparent that tagged fish can survive over long periods. For example, on average fish survived for 136 days and over extended periods at least up to 434 days.

Fish Tagging on VPS Sites

Adult gray triggerfish (n = 17) were tagged and released on the two VPS sites. Tagged gray triggerfish were placed into groups based on their status (Table 1). Of the 17 tagged gray triggerfish, three (17.6 %) were lost within 24 hours and these loses were attributed to tagging effects. Among the remaining gray triggerfish, 14 (82.4 %) were successfully tracked on the VPS sites for 1 to 57 weeks (Figure 5). Of these remaining fish, two (14.3 %) were caught by fishers (16 and 22 weeks after release), one died (7.1 %, 2 weeks after release), five emigrated (28.6 %, 1 to 25 weeks after release), and six fish (42.9 %) were still present and actively being tracked at the end of this study.

Among the fish that emigrated from the VPS sites, four were detected on reefs surrounding the VPS sites. One tagged fish (T8) was detected on four different surrounding receivers (R45, R44, R37, R48) on 20 Nov 2013 immediately after tagging but then returned to its tagging site (R34) on the same day as released. This fish was then caught by a fisher 16 weeks after release at R34.

Tagged gray triggerfish T10, was immediately lost from the VPS array due to tagging effects. However, it was detected on R11 and R20 the same day that it left the VPS array after which it was not seen again.

Fish T4, emigrated from the VPS site (R44) on 4 March 2013, returned on 16 March 2013, and emigrated again on 17 March 2013. On 17 and 18 March 2013 fish T4 was then detected on R2, from 19 to 25 March 2013 it was detected on R45, on 26 March 2013 it was detected on R12, from 26 March through 6 May 2013 it was back on its original VPS site (R44), from 6 to 9 May 2013 it was detected on R12. Since leaving the R12 site on 9 May 2013, fish T4 has not been detected. Although tagged fish T4 moved from reef to reef, it was determined that this was not a predation event because T4 was tracked for over a month on the VPS site before leaving for the final time.

Fish T11 was tracked on the VPS site (R44) for 7 weeks then emigrated on 11 April 2013. It was not detected on surrounding sites. However, T11 returned to the VPS site (R44) on 22 May 2013 but soon emigrated. It returned to the VPS site (R44) on 9 June 2013 but again quickly left. Fish T11 was again detected on the VPS site (R44) on

12 June 2013 and quickly left again. On 18 June 2013 fish T11 was detected on both VPS sites (R44 and R34). Fish T11 then returned to its original VPS site (R44) on 22 October 2013 and remained there until 9 December 2013.

One fish, T13, experienced a natural mortality. The area use pattern of T13 became erratic and quite different from other gray triggerfish in May. The average home range of T13 was 665 m^2 for 10 days, but then in one day increased to 5121 m^2 and the following day it was 4537 m^2 (Figure 6). These were very large areas for a tagged fish to cover in one day: all other tagged gray triggerfish show smaller core areas and home ranges during the month of May. The transmitter of T13 was then recovered laying on the bottom 20 m north of the reef on 21 May 2013.

Seasonal patterns

Gray triggerfish core areas (50 % KDE) were significantly different among seasons (rmAnova, $F_{3, 60} = 8.88$, $P < 0.001$; Figure 7). Core areas were greater in the summer and fall compared to winter and spring ($P < 0.05$; Figure 7). Home range areas (95 % KDE) were not significantly different among winter, spring, and summer, but fall was significantly greater than winter and spring ($P > 0.05$; Figure 7). Both core area ($P < 0.05$, $R^2 = 0.33$) and home range ($P < 0.05$, $R^2 = 0.22$) showed a significant positive correlation with water temperature (Figure 8). There was a significant positive correlation between distance from the reef and hourly area use (core area: $P < 0.05$, $R^2 = 0.10$; home range: $P < 0.05$, $R^2 = 0.13$). A significant relation was not detected between fish size (FL mm) and core area use ($R^2 = 0.01$, $P > 0.05$) and although a significant relation was detected between fish size (FL mm) and home range little variance was accounted for in the regression ($P < 0.05$, $R^2 = 0.06$).

Gray triggerfish showed significantly different core areas around reefs across hourly time periods (rmANOVA, $F_{23, 905} = 12.50$, $P < 0.0001$; Figure 9). Core areas were not significantly different among night hours (1700 hours to 0500 hours). The core areas at night (1800 hours to 0400 hours) were significantly smaller than the core areas during the day (0600 hours to 1600 hours). The core areas among day hours (0600 hours to 1700 hours) were not significantly different. There was a trend of increasing core areas during the dawn hours (0400 to 0500 hours) and decreasing core areas during the dusk hours (1600 to 1700 hours).

Home range area use was significantly different among hour time periods (rmANOVA, $F_{23, 905} = 18.37$, $P < 0.0001$; Figure 9). Home range areas among night hours (1800 to 0300 hours) were not significantly different from each other. The home ranges during night hours (1800 to 0300 hours) were significantly smaller than the day (0500 to 1600 hours). Daytime hours (0500 hours to 0600 hours) were not significantly different from one another. Home range also showed trend of increasing movement during the dawn hours (0400 to 0500 hours) and decreasing movement during the dusk hours (1600 to 1700 hours).

DISCUSSION

Tagging Effects

A major objective of this study was estimating the effect of an implanted transmitter on gray triggerfish and if this species would be amendable to telemetry studies. Although this technique has been successful on other species such as red snapper (Piraino and Szedlmayer in press), gray triggerfish have a much small gut cavity, and can be very aggressive and it might be expected that untagged gray triggerfish may chase off a recovering tagged fish (Simmons and Szedlmayer 2012). The laboratory holding study was inconclusive concerning a comparison of tagged to untagged effects on survival mainly due to low sample sizes, but did show that gray triggerfish could survive over long periods with implanted transmitters.

In the present study, the field releases clearly showed that gray triggerfish could be tagged, would survive, and then provide long term fine scale tracking data. In support, SCUBA divers periodically observed tagged gray triggerfish on the artificial reefs and reported that the fish appeared healthy with no signs of infection or torn fins, were swimming up in the water column with the other fish, and were not hiding in the reef. Also supporting tagging methods were recaptures of tagged gray triggerfish during subsequent tagging trips, with all fish in excellent condition. In addition, it showed that tagged fish were feeding and competitive with non-tagged fish. Thus, the long term captive survival along with the successful field tagging and tracking shown in this study, has clearly shown that telemetry studies with gray triggerfish can be very successful. This is the first reported VPS telemetry study on gray triggerfish and as a relatively new method there are few studies using VPS on any species. Twelve out of 16 lingcod, *Ophiodon elongatus* Girard, were monitored using VPS and Vemco Radio Acoustic Positioning (VRAP) telemetry for 27 days and showed that the VRAP positions were less precise than the VPS positions (Andrews *et al.* 2011). In California, one gray smoothhound, *Mustelus californicus* Gill, and two shovelnose guitarfish, *Rhinobatos productus* Ayres, were tracked in a VPS array for 24 hours demonstrating that these species could successfully be tagged and tracked (Espinoza *et al.* 2011a). Building on an earlier study (Espinoza *et al.* 2011a), 22 gray smoothhound were tagged and tracked for a more extensive time period (5 to 145 days) and showed low site fidelity (< 10 % present for > 2 months; Espinoza *et al.* 2011b). Juvenile southern flounder, *Paralichthys lethostigma* Jordan & Gilbert, were tagged and tracked (n = 8) for almost a month in a Texas estuary and showed that movement was largely dependent on habitat type (Furey *et al.* 2013). Another study tagged and tracked five American lobsters, *Homarus americanus* Milne-Edwards, for a little over a month and showed that the presence of predators decreased movement (McMahan *et al.* 2013). Atlantic cod, *Gadus morhua* Linnaeus, were tagged and tracked (n = 22) around a wind farm for up to 251 days and showed high site fidelity (at least 50 % of fish present for 75 % of the time; Reubens *et al.* 2013). In the longest study to date (up to 694 days), red snapper (n = 17) were tagged and tracked and showed high site fidelity (> 88 % present for > 10 months) to artificial reefs in the Gulf of Mexico (Piraino and Szedlmayer in press). Thus the present study tracked fish far longer than most studies (up to 399 days).

Tagging effects in field releases were minimal with a low percentage (15.8 %) of fish lost within 24 hours or an 84.2 % success rate. The emigration rate due to tagging effects (15.8 %) in this study was similar to that reported in other red snapper telemetry studies at 17 % (Topping and Szedlmayer 2013) and 14.8 % (Szedlmayer and Schroepfer 2005). However, the present rate of fish loss due to tagging effects was much lower than shown in a more recent study with drop weight releases in red snapper (45.5 %; Piraino and Szedlmayer in press). However, Piraino and Szedlmayer (in press) developed a cage release method that significantly increased tagged fish survival to 92 %. Similar cage release methods were further refined in the present study, and all tagged gray triggerfish were released back to the reef site using cages, which accounts for the high survival observed in the present study. Another study had a 100 % success rate when they used a cage release method to tag and release 5 pink snapper, *Pristipomoides filamentosus* (Valenciennes), at 30 m (Parrish and Moffit 1992).

One tagged gray triggerfish (fish T13) suffered mortality about 2 weeks after tagging. Fish T13 showed relatively small area use until 13 - 14 May 2013 when area use increased dramatically (Figure 5). Area use then decreased followed by another increase on 17 May 2013. The transmitter then became stationary on 19 May 2013, and the tag was recovered by SCUBA divers about 20 m north of the reef on 21 May 2013. The sudden increase in area use followed by a stationary transmitter suggested that this was a predation event. Over the course of the study, SCUBA divers have observed several shark species around the VPS arrays, and during fish tagging several fish suffered predation mortality during hook and line retrievals. Both bull shark, *Carcharhinus leucas* (Müller & Henle), and sandbar shark, *Carcharhinus plumbeus* (Nardo), have been positively identified around the VPS arrays. In Piraino and Szedlmayer (in press), 28 % of tagged red snapper suffered mortality, a large percentage of which were most likely caused by predation. Previous estimates of mortality for externally tagged gray triggerfish have been low, 1.5 – 2.0 % (Ingram 2001; Ingram and Patterson 2001). However, these estimates were based on the condition of tagged fish released at the surface, and it is likely that mortality was actually higher due to predation as shown in Piraino and Szedlmayer (in press).

Residency and Site Fidelity

The present gray triggerfish study showed long term residency (up to 57 weeks) and close association with reef structure (mean distance from reef = 46.3 ± 1.3 m). Traditional tagging studies on gray triggerfish have also reported high site fidelity with 58.3 % (mean time at liberty 190 days; Ingram and Patterson 2001) and 67 % (mean time at liberty 161 days; Addis *et al.* 2007) of tagged gray triggerfish being recaptured at the site of release. The time at liberty for recaptured gray triggerfish in previous studies, was similar to the mean residency time (150 ± 125 days) of tagged gray triggerfish in the present study. However, past studies could not define home ranges, fine scale habitat area use, or define movements between mark and recapture. For example as shown in the present study, gray triggerfish can move away from release sites but return at a later time. Importantly the present study also addresses many of the other difficulties with conventional tagging, for example fisher non-reporting, tag loss, and incorrectly reported fish capture locations.

Tagged gray triggerfish also showed homing behavior with many tagged fish visiting another reef site within the VPS array then returning to the release site reef. In addition, two tagged gray triggerfish left and returned to the VPS site several times. Other reef fishes, such as red snapper, have also been shown to display homing tendencies emigrating as far away as 8 km and returning after being away for as long as 8 months (Topping and Szedlmayer 2011a; Piraino and Szedlmayer in press). Another reef fish, gag, *Mycteroperca microlepis* (Goode and Bean), displaced from reefs in the northern Gulf of Mexico moved 3 km within 10 days back to their original site of capture (Kiel 2004). Several species of rockfish, have also shown homing behavior when displaced; yellowtail rockfish, *Sebastes flavidus* (Ayres), moved up to 22.5 km after being displaced, and took up to 3 months to return to their original site of tagging (Carlson and Haight 1972), copper rockfish, *Sebastes caurinus* Richardson, and quillback rockfish, *Sebastes maliger* (Jordan and Gilbert) took 8 - 25 days to swim 500 m back to their original site of capture (Mathews 1990), and blindfolded black rockfish, *Sebastes inermis* Cuvier, traveled 1 km within 20 days to get back to their original site of capture (Mitamura *et al.* 2005). Both the blacksmith, *Chromis punctipinnis* (Cooper), and the senorita, *Oxyjulis californica* (Günther), have also shown homing behavior, with 80 % of displaced fish moving 0.5 km to return to their original site (Hartney, 1996).

Several fish (n = 5) emigrated from the VPS sites. It is difficult to specifically define the causes of emigrations but they are most likely linked to prey, spawning, or shelter availability (Mathews 1990). Among the gray triggerfish that emigrated, four were tagged before the spawning season (May - August), of which two (fish T4 and T9) left the VPS site during spawning season. Another fish (T11) left and returned to the

VPS site several times, also during the spawning season. Fish T11 and T9, were the smallest fish that were tagged and size may have affected competitive interactions with larger dominant males (Simmons and Szedlmayer 2012). The movement patterns of these two smaller fish (276 - 298 mm FL) fits the behavior patterns of subordinate males and suggested that fish may have left the VPS site to seek out spawning opportunities at other reef locations (Fricke 1980; Simmons and Szedlmayer 2012).

The use of artificial habitat in the northern Gulf of Mexico to manage important fisheries species is a contentious topic (Cowan *et al.* 2009; Gallaway *et al.* 2009). The addition of structured habitat in the form of artificial reefs may boost production by increasing shelter, prey, and habitat availability (Brickhill *et al.* 2005; Gallaway *et al.* 2009; Shipp and Bortone 2009). However, artificial reefs may simply attract fish and the higher catch rates may be driving fish stocks towards faster depletion (Brickhill *et al.* 2005; Cowan *et al.* 2009). High site fidelity and little movement would suggest suitable habitat while low site fidelity with large movements would suggest that artificial reefs are not suitable habitats and are merely attracting fish. The high site fidelity shown by gray triggerfish to the artificial reefs used for this study coupled with little time spent over open habitat while in the VPS array and homing behavior, shows that artificial reefs are important for gray triggerfish off the coast of Alabama. In addition, juvenile gray triggerfish recruit to artificial reefs from the plankton (Simmons and Szedlmayer 2011), they on feed reef prey items (Vose and Nelson 1994, Blitch 2000), and may experience higher growth rates on artificial habitat (Nelson 1985). Thus, artificial reefs in the northern Gulf of Mexico may be adding to the production of gray triggerfish.

Seasonal patterns

Tagged gray triggerfish remained close to the reef for the duration of the study but showed seasonal changes in area use. Home range areas and core areas of tagged gray triggerfish were greatest during the summer and fall seasons. In the northern Gulf of Mexico gray triggerfish spawn during the summer months with peak spawning occurring during June and July (Wilson *et al.* 1995; Ingram 2001; Simmons and Szedlmayer 2012). Typically there is one dominant male on an artificial reef that excludes subordinate males from the reef and it would be expected that gray triggerfish show more intraspecific aggression during the spawning season (Simmons and Szedlmayer 2012). Male redtail triggerfish, *Xanthichthys mento* (Jordan and Gilbert), chased off other males only during the spawning season (Kawase 2003), female blue triggerfish, *Pseudobalistes fuscus* (Bloch & Schneider), were aggressive towards any other triggerfish that came too close during spawning season (Fricke 1980), and female-female aggressive encounters were common during breeding season for red-toothed triggerfish, *Odonus niger* (Rüppell), (Fricke, 1980). Female gray triggerfish have also been documented chasing off other females interested in the same nest (Simmons and Szedlmayer 2012). These subordinate females may also spend more time avoiding the reef. In addition, guarding males and females actively chased other males and many potential egg predators e.g., red snapper away from reef sites (Simmons and Szedlmayer 2012) thus increasing home range estimates in the summer.

Seasonal habitat use was positively correlated with water temperature. Off the coast of Africa, gray triggerfish migrate seasonally due to cold water (Ofori-Danson 1990). Although tagged gray triggerfish did not migrate away from the reefs in the winter, their habitat use was reduced. Larger area use with warmer temperatures has also been shown for sheepshead, *Semicossyphus pulcher* (Ayres), which increased their home range between 300 m and 1 km (Topping *et al.* 2006). Spotted gar, *Lepisosteus oculatus* (Winchell), also showed an increase in movement due to an increase in temperature (Snedden *et al.* 1999). Red snapper in the northern Gulf of Mexico showed an increase in area use in the summer and Piraino and Szedlmayer (In press) suggested that reduced area use in the winter was the result of a lower metabolic rate and reduced foraging time. Red snapper have been documented to show seasonal diet shifts in support of a connection between reduced area use and foraging (Wells *et al.* 2008). Gray triggerfish may also show seasonal diet shifts and may be foraging less during the colder winter and spring seasons.

Tagged gray triggerfish showed diel movement patterns. Both core area and home range were significantly larger during the day (0600 to 1700 hours) than night (1900 to 0400 hours). Other *Balistids*, such as the fine scale triggerfish, *Balistes polylepis* Steindachner, the orangeside triggerfish, *Sufflamen verres* (Gilbert and Starks), and the black triggerfish, *Melichthys niger* (Bloch), retire during the nocturnal hours to rest in small holes (Hobson 1965; Kavanagh and Olney 2006). From an underwater housing unit Fricke (1980) noted that there were more redtoothed triggerfish, *Odonus niger* (Rüppell), up in the water column during the daytime and more triggerfish resting on the bottom at night. Gray triggerfish may display a similar pattern to other triggerfish species and rest in the reef at night. Acoustic telemetry studies of other species have also shown variable habitat area use due to diel patterns. For example, ocean whitefish, *Caulolatilus princeps* (Jenyns), used a larger area during the day than at night (Bellquist *et al.* 2008). Red snapper also showed a similar diel pattern where fish showed larger home ranges in the day compared to night (Piraino and Szedlmayer in press). In contrast, the painted comber, *Serranus scriba* (Linnaeus), showed no significant habitat use patterns related to diel periodicity (March *et al.* 2009), while other species, typically predatory species, are clearly more active at night (Hobson 1965; Danilowicz and Sale 1999). Red snapper on artificial reefs in the northern Gulf of Mexico showed diel shifts in foraging behavior (Ouzts and Szedlmayer 2003), and similar patterns might be expected for gray triggerfish based on their diel area use patterns. Using day and night SCUBA observations, gray triggerfish have been reported to be a diurnal species only foraging away from the reef during the daytime (Frazer and Lindberg 1994; Vose and Nelson 1994). Thus gray triggerfish likely show greater home ranges and core areas in the day due to foraging during daylight hours away from the reef and return back to the reef at night to rest.

Predation pressure may also play an important role in the observed diel patterns in gray triggerfish, as indicated by common sightings by SCUBA divers (9 out of 20 dives in two days in the present study) of the bull shark and the sandbar shark on the VPS sites. Both the bull shark and the sandbar shark increase their feeding activity at night (Driggers *et al.* 2012). Thus, gray triggerfish in the present study may be showing movements similar to other prey fishes, by decreasing movements and hiding in structure at night (Werner 1983; Piraino and Szedlmayer in press). A VPS study on the American lobster confirmed such a predator induced reduction in area use in the presence of predators (McMahan *et al.* 2013). Using underwater cameras, Simmons and Szedlmayer (2012) documented an attack by a sandbar shark on a nesting female gray triggerfish and the female gray triggerfish fled from the nest to shelter in the reef. This was the only time during their study that they observed a female leave her nest. Thus, it is likely that the gray triggerfish seek cover in the reef structure at night to reduce the risk of predation by sharks.

Conclusions

This is the first reported telemetry study on gray triggerfish around artificial reefs in the northern Gulf of Mexico. The present study showed a high success rate (84.2 %) of implanting transmitters and tracking gray triggerfish, demonstrating that acoustic telemetry can provide a major advance in the ability to estimate gray triggerfish habitat use. Tagged gray triggerfish showed high site fidelity (up to 57 weeks) on the same reef with little time over open habitat while on the VPS site. Fine scale movements of gray triggerfish showed diel patterns, with significantly greater home range and core areas during the day as compared to night periods. These diel patterns are likely linked to foraging behaviors and reducing the risk of nocturnal predation. Gray triggerfish core areas and home ranges also showed seasonal patterns with areas being larger during the summer and fall seasons compared to winter and spring seasons. These seasonal differences in core areas and home ranges were positively correlated with water temperature, but may also result from increased intraspecific territoriality during the summer months. In this study gray triggerfish were highly associated with artificial reefs in the northern Gulf of Mexico. As such, future attempts to increase this stock should consider habitat enhancement as an additional tool for management of this important species.

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TABLE 1: A summary of the tagging effort and status of tagged gray triggerfish. Fish (*n* = 17) were successfully tagged with acoustic tags and released on 2 VPS sites (R34 and R44) in the northern Gulf of Mexico.

Number of Fish	Status	Time
3	Lost due to tagging	0.14 weeks (< 24 hours)
2	Caught	16 and 22 weeks
1	Natural mortality	2 weeks
5	Emigrated	1-25 weeks
6	Present	16-57 weeks

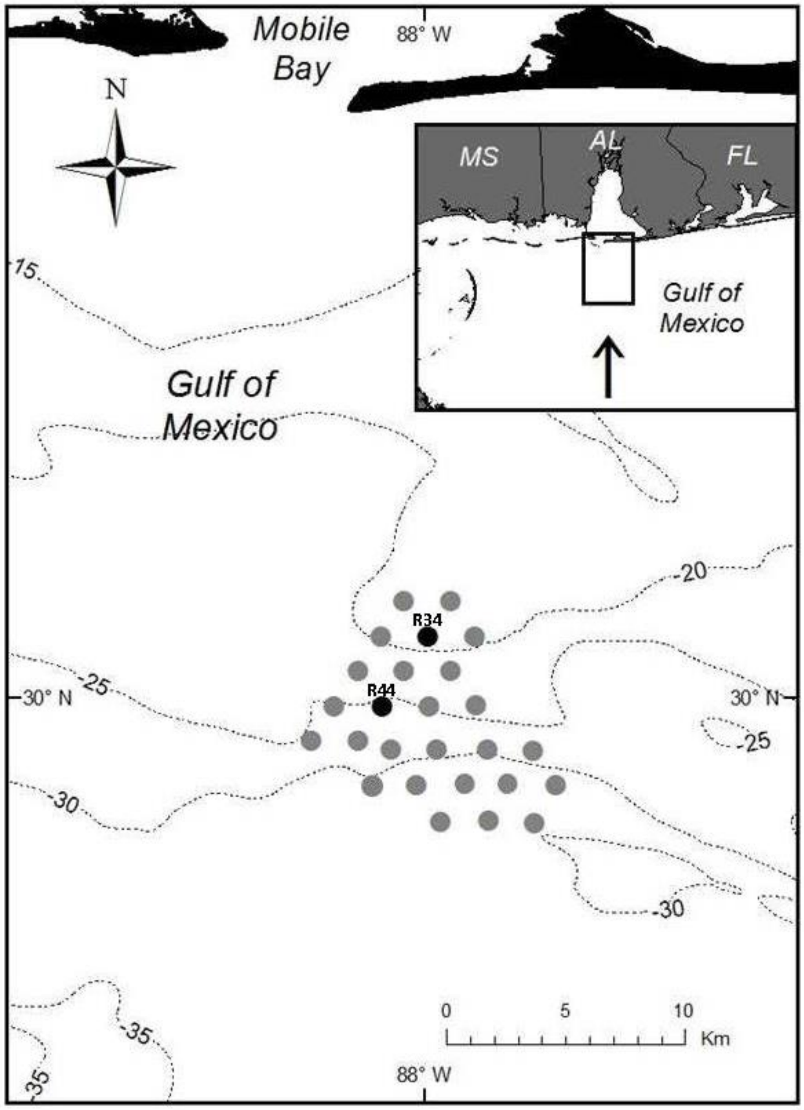

Figure 1: VPS study sites in the northern Gulf of Mexico. Black circles labeled R34 and R44 represent VPS sites were gray triggerfish were tagged and tracked. Gray circles represent surrounding sites where one receiver was positioned to monitor emigration and presence/absence.

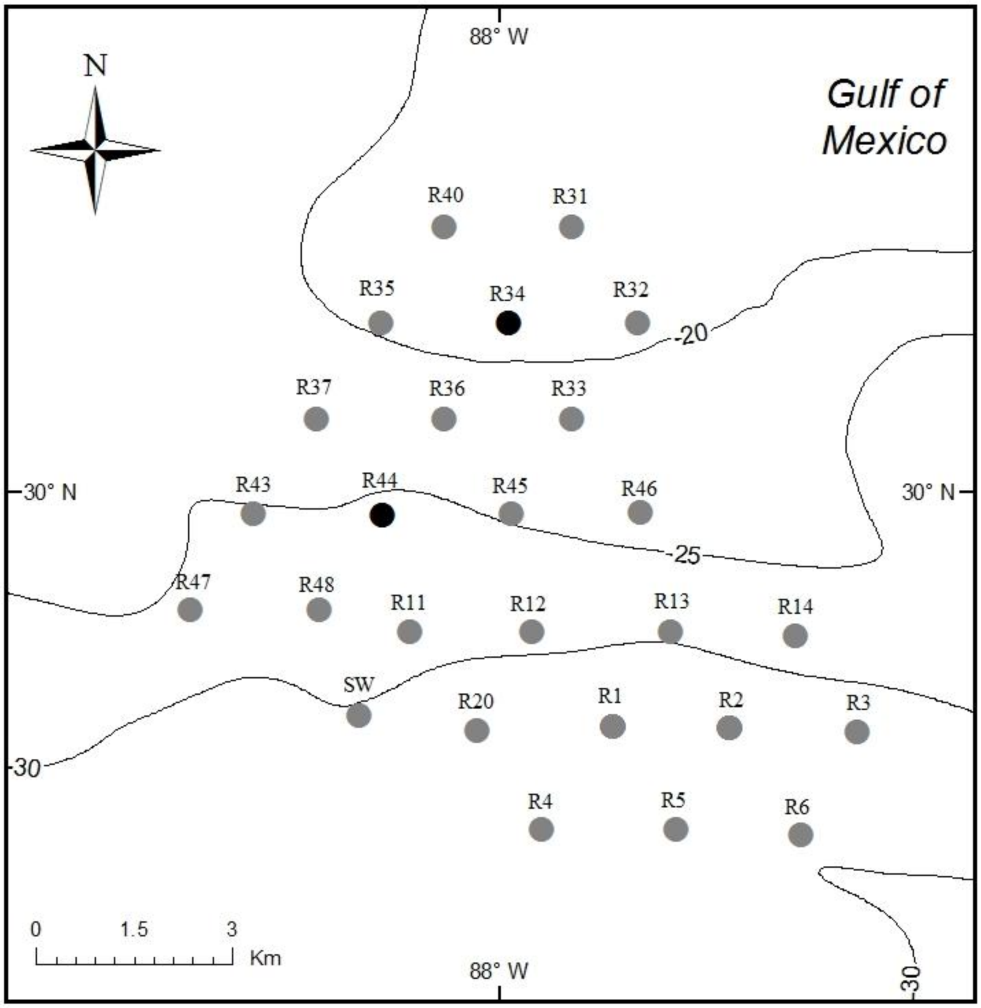

Figure 2: Release sites (R34 and R44) along with surrounding receiver-reef sites. The black circles represent VPS sites where fish were tagged. The gray circles represent the surrounding sites used to monitor emigration from other reefs.

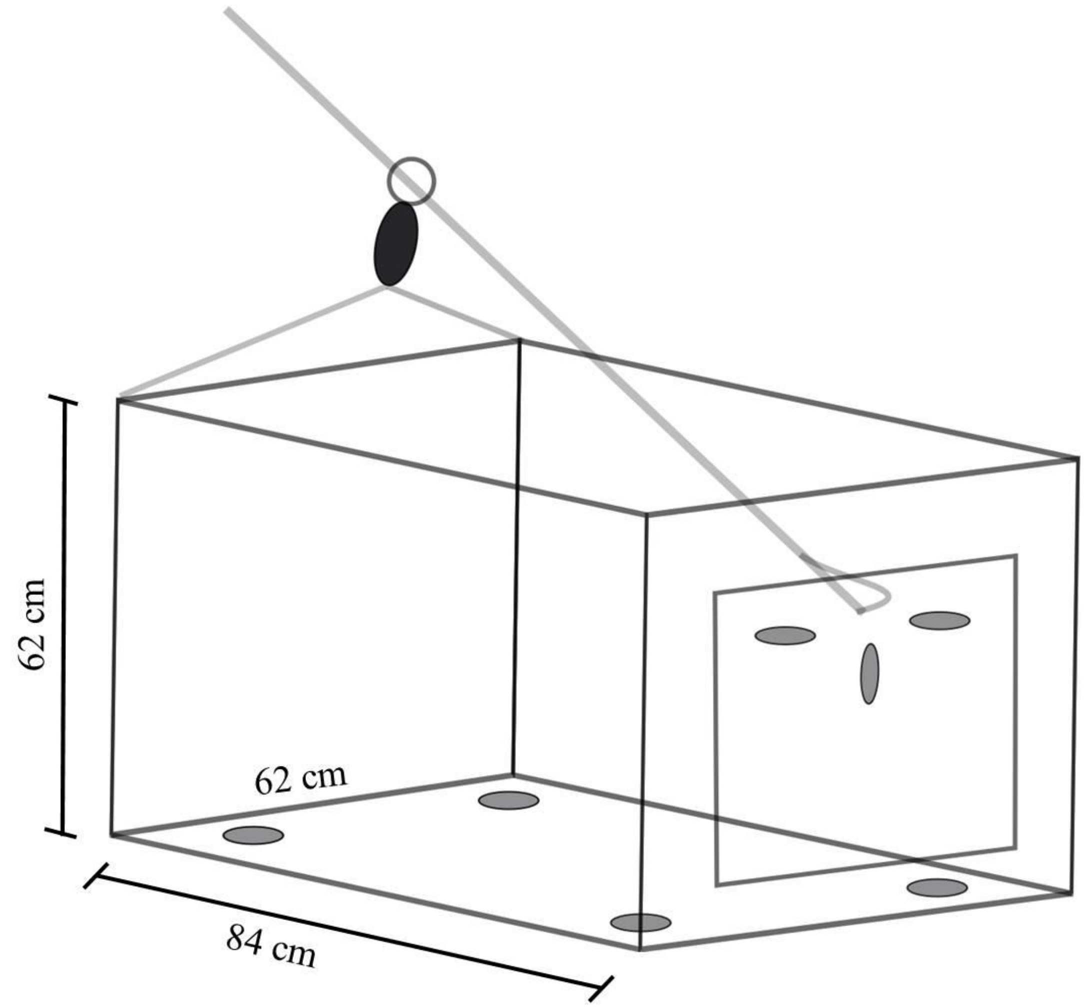

Figure 3: Release cage, 46 x 61 x 61cm, which was used to release tagged fish on VPS sites (L.J. Williams, J. Herbig, and S.T. Szedlmayer, Auburn University, unpublished data).

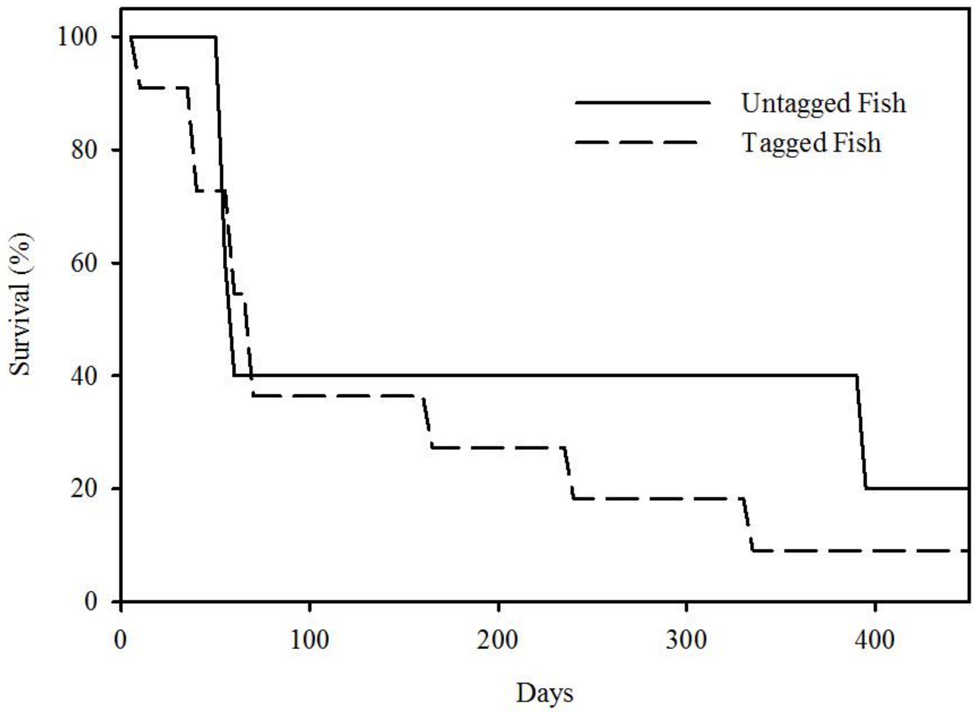

Figure 4: Survivorship of laboratory tagged fish.

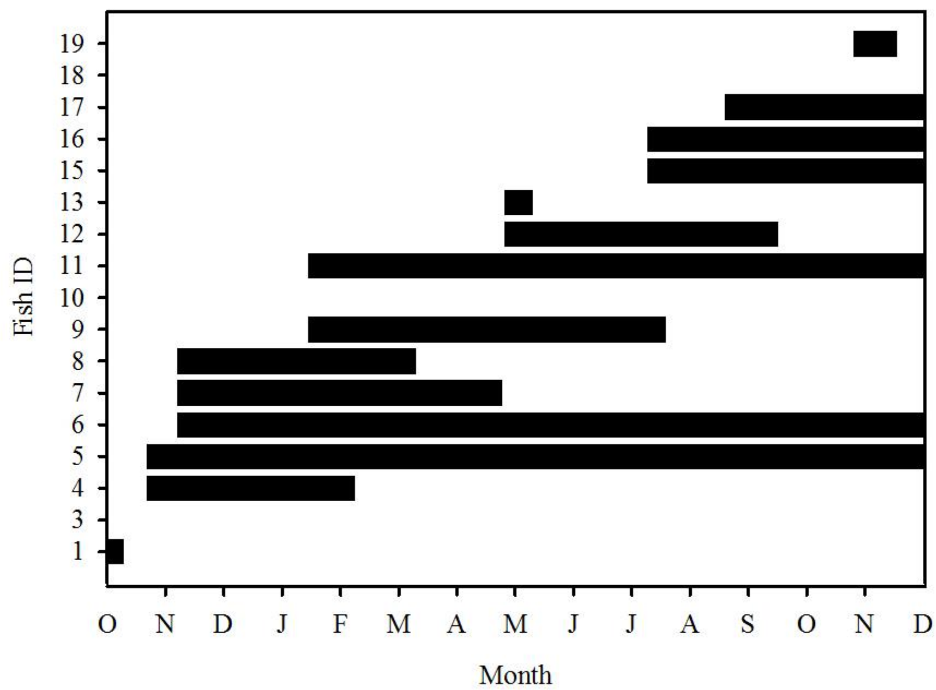

Figure 5: Tracking time intervals for each tagged gray triggerfish. Fish present until December were still being tracked at the end of this study.

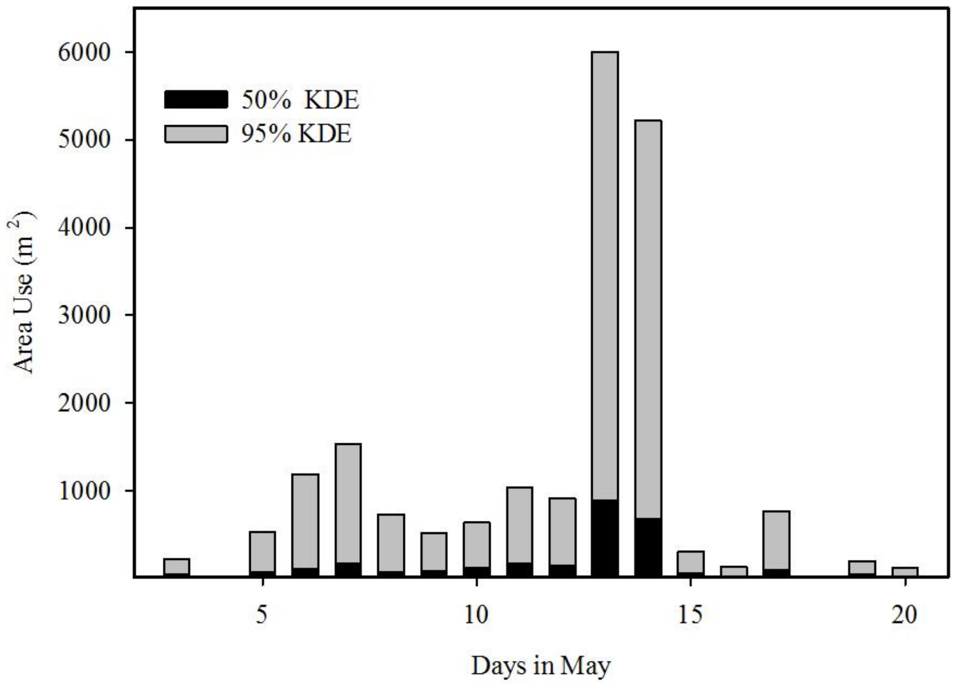

Figure 6: Area use of gray triggerfish T13 during the month of May. Divers retrieved the transmitter laying on the bottom on 21 May 2013.

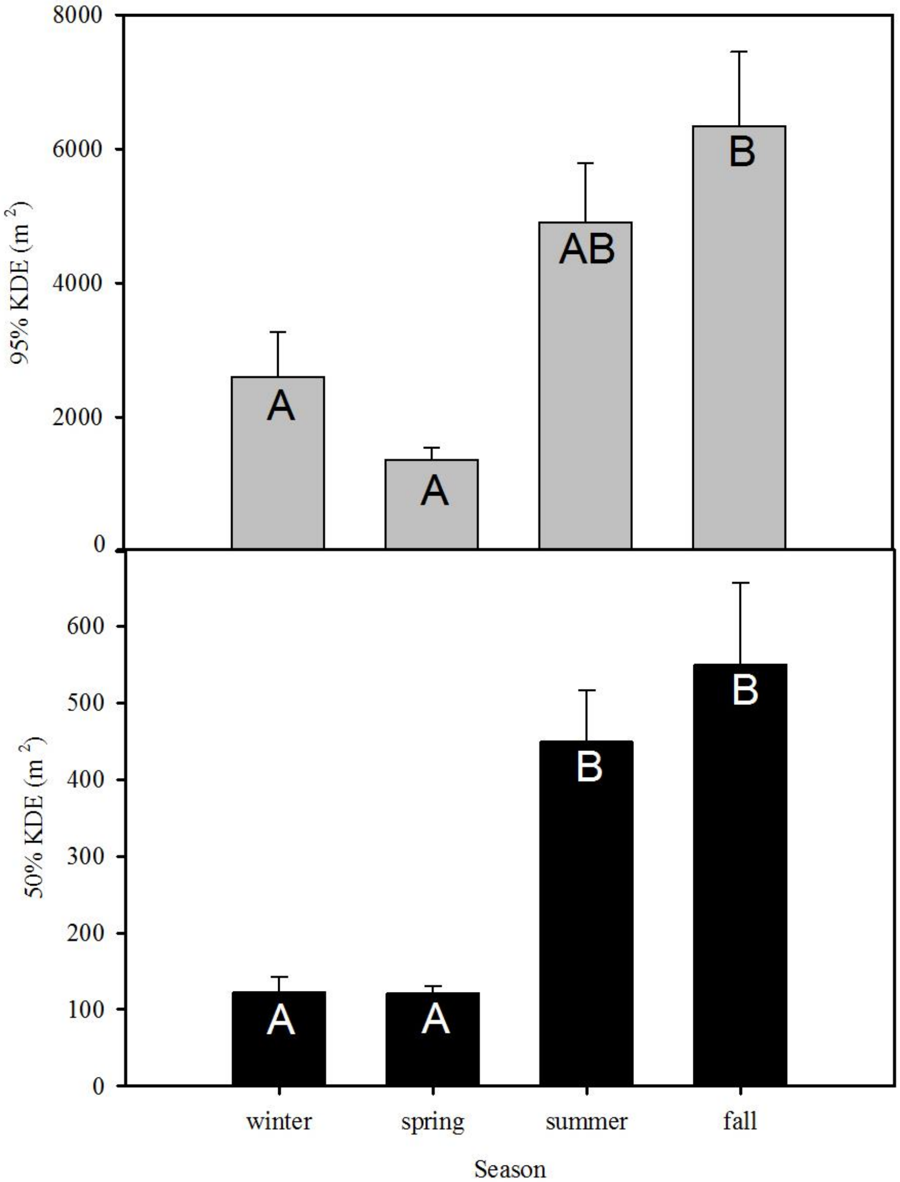

Figure 7: Mean ± SE seasonal area use by tagged gray triggerfish around artificial reefs in the northern Gulf of Mexico. Different letters show significant ($P < 0.05$) differences in area use.

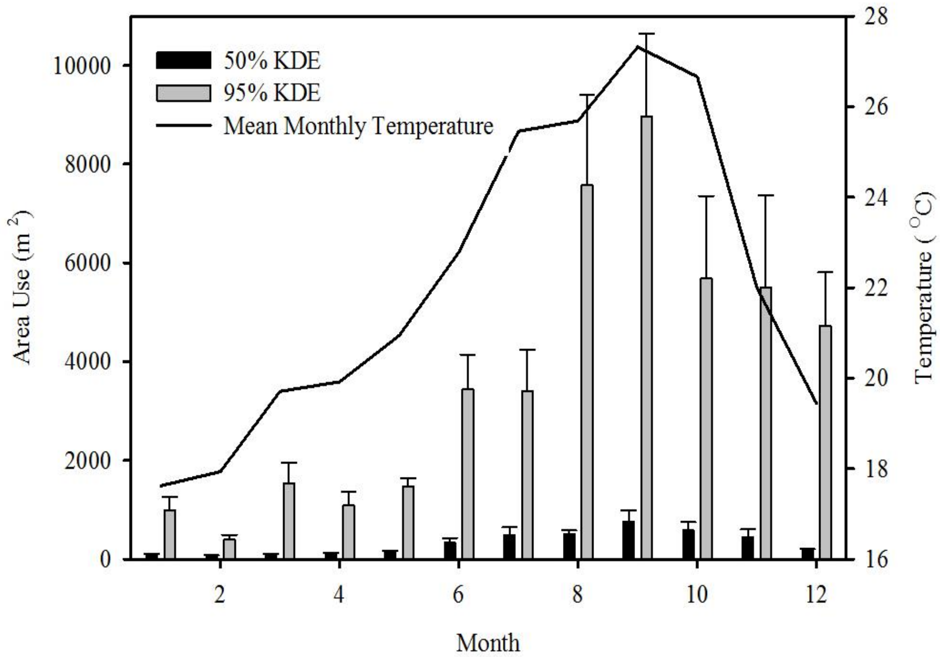

Figure 8: Gray triggerfish mean monthly area use correlated with average temperature. There was a positive correlation between mean monthly water temperature (black line) and area use.

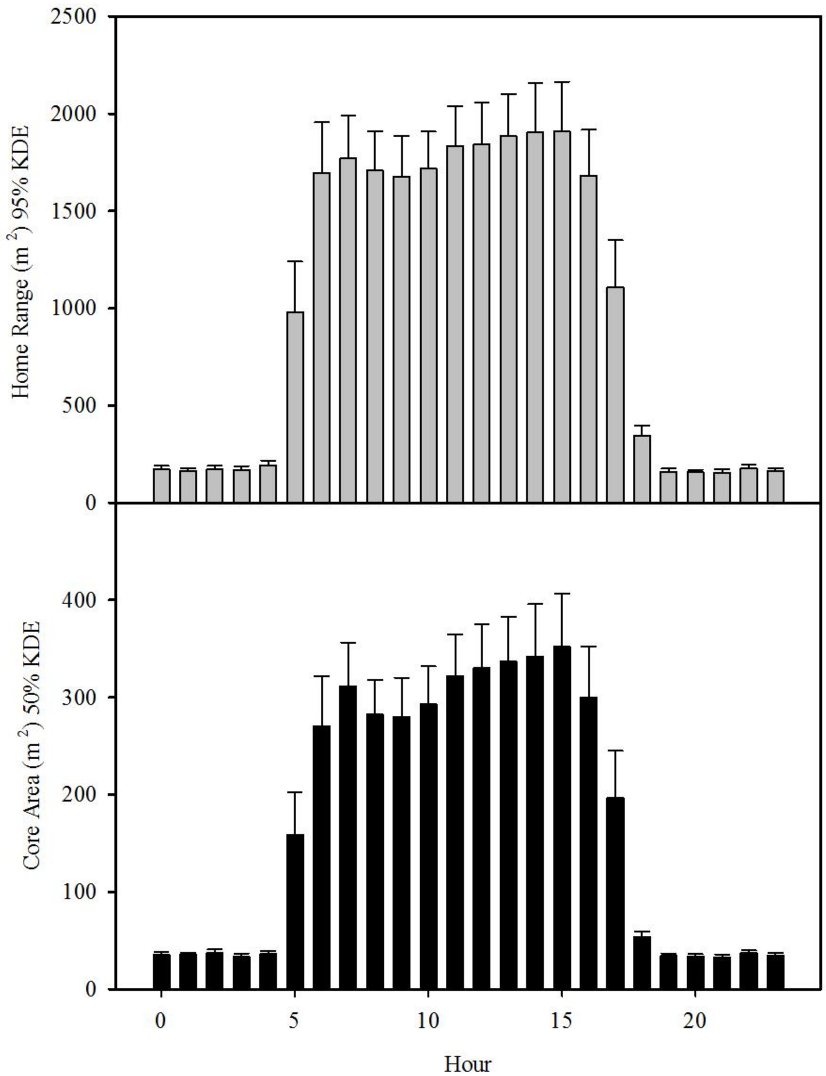

Figure 9: Gray Triggerfish diel patterns of area use for both home range and core area. Day hour areas were significantly larger (*P* > 0.05) than night hour areas.