Acoustic Telemetry of Shark Movements and Residency Near Artificial Habitats in the Northern Gulf of Mexico

Telemetría Acústica de Movimientos y Residencia de Tiburones Cerca de Hábitats Artificiales en el Norte del Golfo de México

Télémétrie Acoustique des Mouvements et de la Résidence des Requins à Proximité d'Habitats Artificiels dans le Nord du Golfe du Mexique

ASHLEY N. ALTOBELLI* and STEPHEN T. SZEDLMAYER
School of Fisheries, Aquaculture and Aquatic Sciences — Auburn University
8300 State Highway 104, Fairhope, Alibama 36526 USA.
*ana0027@auburn.edu

EXTENDED ABSTRACT

Many large coastal shark species have suffered major declines since the 1960's (Baum et al. 2003). Therefore, it is important to understand their movement patterns and essential fish habitats for future management efforts. The continental shelf in the northern Gulf of Mexico off coastal Alabama, U.S.A., presently has one of the largest artificial reef programs in the world with an estimate near 10,000 artificial structures (Szedlmayer S.T. and Mudrak P. A. 2017 unpublished side-scan sonar surveys). These artificial reefs offer increased habitat complexity compared to the surrounding seafloor and provide habitat for reef fishes (Lingo and Szedlmayer 2006, Redman and Szedlmayer 2009, Jaxion-Harm et al. 2018), but they have not been examined for their importance to shark species. The purpose of the present study was to use acoustic telemetry to quantify movement patterns of adult sharks around the artificial reefs of the northern Gulf of Mexico.

The study area consisted of 26 steel cage artificial reef sites. Each site contained a single receiver (VEMCO® VR2W), which provided presence-absence data for tagged sharks within a detection radius of 800 m. Each shark was caught with hook-and-line, inverted to induce tonic immobility, and a VEMCO® V16-6x transmitter was surgically implanted into the peritoneal cavity. Long-distance migrations were also recorded through the Integrative Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) network.

Residency indices (RIs; number of days detected divided by days at liberty) were calculated for each individual and compared among species (Analysis of Variance, ANOVA) (Table 1). Seasonal RI differences were compared with generalized linear mixed models. To quantify area of detections, a spatial evenness index (E) was calculated for each individual and compared among species with ANOVA (TinHan et al. 2014). Spatial evenness values close to zero indicate

Table 1. Residency Indices, spatial evenness, and migration distances for tagged sharks. Days detected is the total number of days that a shark was detected at any site. Days at liberty is the total number of days from the date tagged to the end of the study period. Residency Index (RI) is the days detected divided by days at liberty. Spatial evenness is indicated by E. The maximum distance is the distance in kilometers between the study area and the furthest position obtained from iTAG for that individual.

ID	Species	Date Tagged	Sex	Days Detected	Days at Liberty	RI	E	Max. Dist. (km)
S1	*Carcharhinus plumbeus*	9-Nov-2012	F	32	234	0.137	0.84	n/a
S2	*Carcharhinus plumbeus*	8-Jul-2013	F	7	1825	0.004	0.72	509
S3	*Carcharhinus plumbeus*	15-Aug-2013	F	229	1789	0.128	0.89	n/a
S4	*Carcharhinus plumbeus*	15-Aug-2013	F	n/a	n/a	n/a	n/a	n/a
S5	*Carcharhinus plumbeus*	15-Aug-2013	M	83	1789	0.046	0.93	512
S6	*Carcharhinus plumbeus*	3-Sep-2015	F	449	1040	0.433	0.12	1894
S7	*Carcharhinus plumbeus*	22-Jun-2016	F	8	747	0.011	0.34	n/a
S8	*Carcharhinus plumbeus*	9-Jun-2017	F	102	347	0.300	0.39	n/a
S9	*Rhizoprionodon terraenovae*	23-Nov-2012	F	4	1825	0.002	0.46	n/a
S10	*Rhizoprionodon terraenovae*	23-Jan-2013	F	18	1825	0.010	0.59	n/a
S11	*Rhizoprionodon terraenovae*	23-Jan-2013	F	2	1825	0.001	0.34	n/a
S12	*Rhizoprionodon terraenovae*	24-Jan-2013	F	6	1825	0.003	0.69	n/a
S13	*Rhizoprionodon terraenovae*	24-Jan-2013	F	89	1825	0.049	0.60	n/a
S14	*Carcharhinus leucas*	8-Jul-2013	M	1	1825	0.001	0.20	n/a
S15	*Carcharhinus leucas*	19-Jul-2016	F	12	720	0.015	0.63	858
S16	*Carcharhinus leucas*	20-Jul-2016	F	5	719	0.007	0.46	n/a
S17	*Carcharhinus leucas*	9-Jun-2017	F	3	395	0.008	0.33	n/a
S18	*Ginglymostoma cirratum*	17-Oct-2013	M	165	1726	0.096	0.67	856
S19	*Ginglymostoma cirratum*	27-Jul-2017	M	6	290	0.021	0.10	n/a

site preference and values closer to one indicate even detections among all sites.

Seven Sandbar Sharks (*Carcharhinus plumbeus*), five Atlantic Sharpnose Sharks (*Rhizoprionodon terraenovae*), four Bull Sharks (*Carcharhinus leucas*), and two Nurse Sharks (*Ginglymostoma cirratum*) were detected within the study area for periods of one to 449 days (Table 1). Residency indices were not significantly different among species ($F_{4,14}$ = 2.29, p = 0.12), however, Atlantic Sharpnose and Bull Sharks were rarely detected in the study area while Sandbar and Nurse Sharks were detected regularly. Bull Sharks showed significantly greater residency to the study area in summer ($F_{3,28}$ = 54.29, p < 0.001; Figure 1), and Sandbar Sharks showed greater residency in fall ($F_{3,65}$ = 3.81, p = 0.01; Figure 1). Residency did not differ among seasons for Atlantic Sharpnose Sharks ($F_{3,85}$ = 0.75, p = 0.52; Figure 1). Nurse Sharks (n = 2) were only detected during summer and fall, with one Nurse Shark (S18) repeating this seasonal residency pattern for all four years it was at liberty (Table 1).

One Bull Shark, one Nurse Shark and three Sandbar Sharks made long distance migrations (509 to 1894 km) away from the study area during their time at liberty. The Bull Shark (S15, female) was detected 858 km away in the Florida Keys in February of 2017 and 2018. The Nurse Shark (S18, male) was detected 856 km away in the Florida Keys in March and April of 2016, 2017, 2018, and along the Florida panhandle in winter of 2018. The first Sandbar Shark (S2, female) was detected 509 km away off Tampa, Florida in May 2014. The second Sandbar Shark (S5, male) was also detected off Tampa in winter of 2015, 2016, and 2017. The third Sandbar Shark (S6, female) was detected 1894 km away in the northwest Atlantic in May 2017, after migrating around the southern end of Florida and up the eastern United States coast. All five sharks that made confirmed migrations to other iTAG receiver arrays subsequently returned to the present artificial reef study area in the northern Gulf of Mexico after their absences.

Spatial evenness varied and was not significantly different among species ($F_{3,14}$ = 0.67, p = 0.59). However,

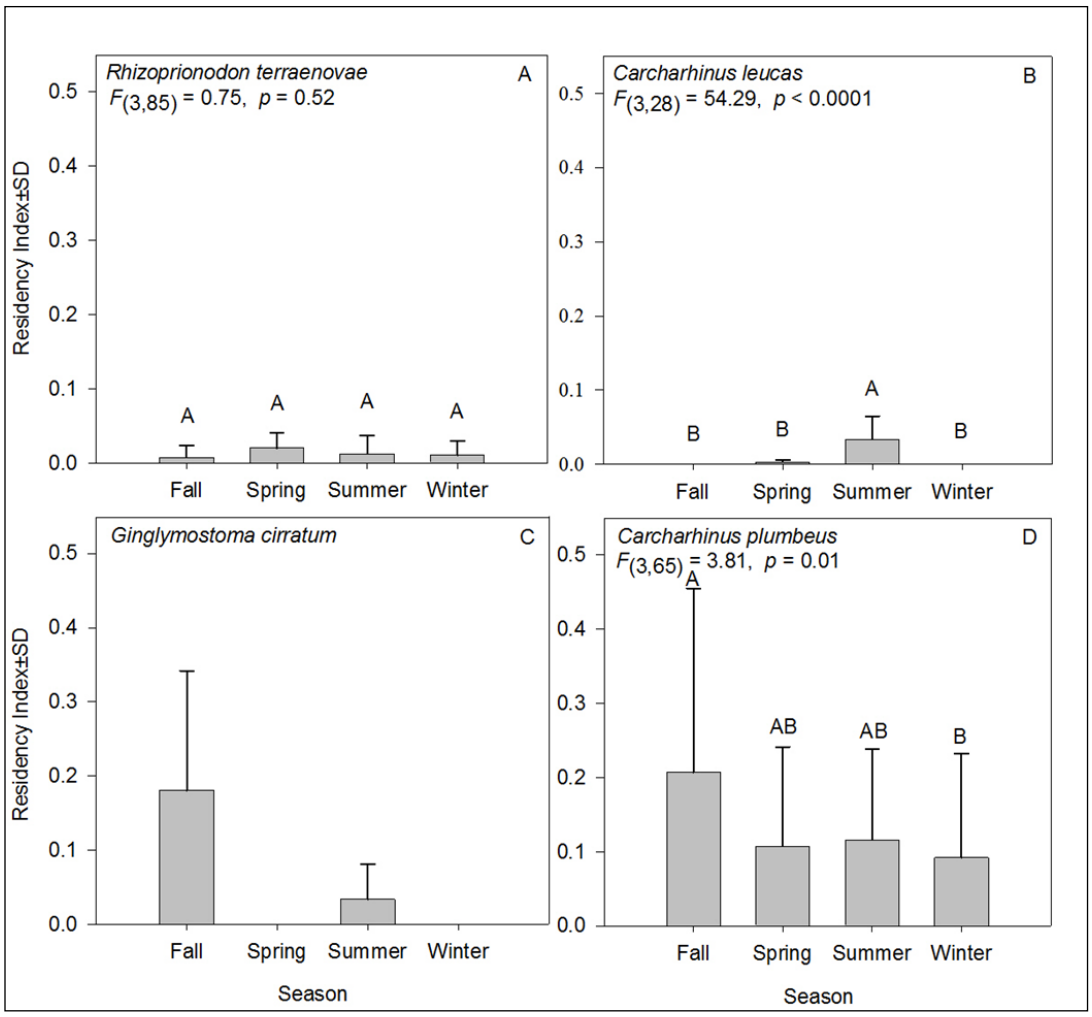

Figure 1. Comparison of seasonal residencies for Atlantic Sharpnose Sharks (A), Bull Sharks (B), Nurse Sharks ©, and Sandbar Sharks (D). Significant differences are indicated by different letters.

Nurse Sharks were detected in greater proportions in the northern shallower sites. The Nurse Shark that made annual migrations returned to these same sites each year. Also, one Sandbar Shark (S6) showed homing preference (E = 0.11; Table 1) for one particular site, which persisted for all three years it was at liberty. Ninety-four percent of the detections for this Sandbar Shark (108,752 total detections) were at the same site. This shark even returned to the same exact site, and remained there with high residency, after the 3,798 km round-trip migration to the northwest Atlantic.

Although Bull Sharks had low residency to the study area, there was a significant seasonal effect with detections only occurring during spring and summer. Most Bull Sharks (75%) in the present study were female and parturition for Bull Sharks occurs in summer (Clarke and Von Schmidt 1965), thus presence in the northern Gulf of Mexico may be linked to suitable nursery areas. Many locations along the northern Gulf of Mexico coast are considered nursery sites for Bull Sharks, including Mobile Bay which is located immediately north of the study area (Parsons and Hoffmayer 2007). Therefore, these female Bull Sharks may have been passing through the receiver areas on their way to give birth in these estuarine habitats. This type of directed movement may also explain their low residency to the study area.

Sandbar and Nurse Sharks were detected often in the present study, with some showing high residencies. Some individual sharks also displayed homing behaviors to the study area and to individual reefs, which persisted for many years (≥ 3 years) even after large-scale migrations. For Sandbar Sharks, the significantly greater residency during fall than in winter may have been related to increased prey availability on artificial reefs in the northern Gulf of Mexico in the fall (Jaxion-Harm et al. 2018). In addition, temperatures in the study area were significantly higher in the fall and likely increased metabolic rates, thus increasing Sandbar Sharks' need for prey (Gillooly et al. 2001). Fall also directly follows the parturition season for Sandbar Sharks, after which there would be an expected increased need for prey (Baremore and Hale 2012). Hence, these artificial reefs may serve as important foraging habitats for Sandbar Sharks.

Importantly, one Nurse Shark (S18) showed distinct annual migrations between the study area and the Florida Keys that repeated for three years. Other studies have reported Nurse Shark migrations and have shown movements from 292 to 541 km (Kohler and Turner 2001, Pratt et al. 2018). However, the present study observed repeated migrations for even greater distances up to 856 km. The timing of the Nurse Shark's presence (late summer through fall) was directly after mating season that occurs around June. Thus, this migration may be driven by an increased need for food items, as has been suggested by Pratt et al. (2018). The long-distance migrations, homing and long-term residencies observed in the present study indicated that the artificial reef areas in the northern Gulf of Mexico provided important habitats for at least the Sandbar and Nurse Sharks.

KEYWORDS: Shark migration, shark homing

ACKNOWLEDGEMENTS

We would like to thank the iTAG network and those who shared orphan detection data including Dr. Michael Arendt from the South Carolina Department of Natural Resources, Dr. Angela Collins from the University of Florida, Dr. Susan Lowerre-Barbieri from the University of Florida and Fish and Wildlife Research Institute, Dr. Jacob Brownscombe from Carleton University, and Dr. Aaron Adams from the Bonefish & Tarpon Trust.

LITERATURE CITED

Baremore, I.E. and L.F. Hale. 2012. Reproduction of the Sandbar Shark in the Western North Atlantic Ocean and Gulf of Mexico. *Marine and Coastal Fisheries* **4**(1):560 - 572.

Baum, J.K., R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, and P.A. Doherty. 2003. Collapse and conservation of shark populations in the Northwest Atlantic. *Science* **299**(5605):389 - 392.

Clark, E. and K. Von Schmidt. 1965. Sharks of the central Gulf Coast of Florida. *Bulletin of Marine Science* **15**(1):13 - 83.

Gillooly, J.F., J.H. Brown, G.B. West, V.M. Savage, and E.L. Charnov. 2001. Effects of Size and Temperature on Metabolic Rate. *Science* **293**:2248 - 2251.

Jaxon-Harm, J., S.T. Szedlmayer, and P.A. Mudrak. 2018. A comparison of fish assemblages according to artificial reef attributes and seasons in the northern Gulf of Mexico. Pages 23-45 in: S.A. Bortone (Ed.) *Marine Artificial Reef Research and Development: Integrating Fisheries Management Objectives*. American Fisheries Society 86. Bethesda, Maryland USA.

Kohler, N.E. and P.A. Turner. 2001. Shark tagging: a review of conventional methods and studies. *Environmental Biology of Fishes* **60**:191 - 223.

Lingo, M.E. and S.T. Szedlmayer. 2006. The influence of habitat complexity on reef fish communities in the northeastern Gulf of Mexico. *Environmental Biology of Fishes* **76**(1):71 - 80.

Parsons, G.R. and E.R. Hoffmayer. 2007. Identification and characterization of shark nursery grounds along the Mississippi and Alabama gulf coasts. *American Fisheries Society Symposium* **50**:301 - 316.

Pratt Jr., H.L., T.C. Pratt, D. Morley, S. Lowerre-Barbieri, A. Collins, J.C. Carrier, K.M. Hart, and N.M. Whitney. 2018. Partial migration of the nurse shark, *Ginglymostoma cirratum* (Bonaterre), from the Dry Tortugas Islands. *Environmental Biology of Fishes* **101**:515 - 530.

Redman, R.A. and S.T. Szedlmayer. 2009. The effects of epibenthic communities on reef fishes in the northern Gulf of Mexico. *Fisheries Management and Ecology* **16**:360 - 367.

TinHan, T., B. Erisman, O. Aburto-Oropeza, A. Weaver, D. Vazques-Arce, and C.G. Lowe. 2014. Residency and seasonal movements in *Lutjanus argentiventris* and *Mycteroperca rosacea* at Los Islotes Reserve, Gulf of California. *Marine Ecology Progress Series* **501**:191 - 206.