

Migratory Behavior and Habitat Use of Large Sharks in the Western Gulf of Mexico

Comportamiento Migratorio y Uso de Hábitat por Tiburones Grandes en el Oeste del Golfo de México

Comportement Migrateurs et Utilisation de L'habitat des Grands Requins dans L'ouest du Golfe du Mexique

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EXTENDED ABSTRACT

Large sharks are considered critical apex predators in many marine ecosystems around the world (Myers et al. 2007, Guttridge et al. 2012, Hammerschlag et al. 2015), yet the habitat requirements and migration patterns of these species remain poorly understood throughout much of their ranges. The growing demand for shark habitat use information has supported a proliferation of satellite biotelemetry studies (Hammerschlag et al. 2011). Unfortunately, few data exist on large shark movement patterns in the western Gulf of Mexico despite the multitude of anthropogenic pressures in the region, including indications of declines in the size of multiple large species landed via recreational fishers in the region (Powers et al. 2013, Ajemian et al. 2016).

In summer of 2014 and 2015, we initiated a satellite biotelemetry study to improve comprehension of migratory patterns and overall habitat use of two large shark species (Scalloped Hammerhead, *Sphyrna lewini*, $n = 5$; Tiger Shark, *Galeocerdo cuvier*, $n = 4$) relative to large habitat features (oil and gas platforms, natural banks, and artificial reefs) in the western Gulf of Mexico. Sharks were collected near an offshore production platform (MI-703) approximately 30 miles offshore of Port Aransas, Texas, USA at approximately 40 m depth. Individuals were captured on 1200-lb test hand-line gear with approximately 2 m of stainless steel wire, terminated in a 20/0 carbon steel circle hook baited with fresh dead or live fish.

Sharks were quickly worked up in the water alongside the research vessel to keep gills aerated with ambient seawater and minimize capture stress (Morgan and Burgess 2007, Morgan and Carlson 2011). All animals were measured, sexed, given an external ID tag, sampled for a fin clip (for genetics studies), and fitted with a Wildlife Computers Smart Position or Temperature transmitters (SPOT-258) along the leading edge of the dorsal fin. The SPOTs included copper wet-dry sensors for enhanced sensitivity, as well as an extra stiff antenna. Transmission rates were restricted to a maximum of 70 per day to prolong battery life. Prior to deployment, transmitters were coated in black antifouling paint (Interlux®) to minimize attachment of fouling organisms.

Animal position locations were downloaded weekly from Argos satellites (CLS America, Inc.). For suitable position estimates (location quality 0-3), underlying bottom depths were extracted from existing Gulf of Mexico bathymetry raster data sets in ArcGIS 10.0 (ESRI, Inc.). Additionally, point density rasters were created from each individual to explore spatial intersections with large habitat features (oil and gas platforms, natural banks, and artificial reefs). Density values were then extracted from the center points of each habitat feature existing within the convex polygon (i.e., spatial extent) of an individual's transmitted range. Mean proportional (regularized to the number of total positions) point density values were compared among individuals and habitats using a two-way analysis of variance (ANOVA).

Sharks tracks ranged from a few weeks up to 695 d (Table 1). Individuals demonstrated some important ecosystem connections between nearshore locales and deep open waters of the Gulf of Mexico (Figure 1). While Scalloped Hammerheads provided overall more frequent reports and fidelity to the Texas continental shelf, Tiger Sharks (in particular males) exhibited larger dispersal patterns over deeper depths, including one cross-basin venture towards the Campeche escarpment (Mexico) as shelf waters cooled in December 2014 and a subsequent return to the Texas shelf in late-winter 2015. Tiger Sharks, in particular females, also demonstrated use of NOAA-designated Habitats Areas of Particular Concern such as the south Texas hard banks and the Flower Gardens National Marine Sanctuary. These sex-based differences in movement patterns among Tiger Sharks are supported by previous studies of this species in other ocean basins (Holland et al. 1999; Lea et al. 2015).

Comparisons of mean proportional point densities (PPD) at large habitat features identified significant individual variation (two-way ANOVA, $F_{6,1300} = 3.56$, $p < 0.01$); however, this was found to be dependent on habitat type (two-way ANOVA, $F_{12,1300} = 2.99$, $p < 0.001$). Subsequent pairwise comparisons yielded significantly higher use of natural bank habitats over oil and gas platforms for both female Tiger Sharks Madeline ($t = 2.996$, $P = 0.008$) and Finley ($t = 3.009$, $P = 0.008$). While PPDs were highest around natural banks for the two males as well, these were not found to be significantly higher than other habitats ($p > 0.05$). Habitat use patterns among Scalloped Hammerheads was inconsistent, although one individual (Einstein) exhibited significantly higher mean PPD at platforms ($t = 6.955$, $p < 0.001$) and artificial reefs ($t = 3.673$, $p < 0.001$) when compared to natural banks.

Our work highlights the connected nature of many seemingly disparate habitats (nearshore to open ocean) within the Gulf of Mexico by large sharks and the importance of establishing satellite tagging programs for conservation and management purposes. Inter- and intra-species (i.e., sex-based) variation in habitat use highlight potentially different life history strategies employed by the two species, which in turn may exhibit contrasting levels of risk to offshore energy exploration in the Gulf of Mexico.

KEYWORDS: Shark, biotelemetry, Gulf of Mexico

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Table 1. Individual information from sharks tracked in the study (as of 10-2016).

Date	Species	Name	Sex	STL (cm)	Liberty Days
14-Jul-14	Scalloped Hammerhead	WYATT	M	220	480
16-Jul-14	Scalloped Hammerhead	HUNTER	M	275	22
12-Aug-14	Tiger Shark	SAM HOUSTON	M	311	190
12-Aug-14	Tiger Shark	MADELINE	F	282	695
2-Jun-15	Scalloped Hammerhead	HANS	M	225	14
2-Jun-15	Scalloped Hammerhead	EINSTEIN	M	225	504
5-Nov-15	Scalloped Hammerhead	BUDDY	M	238	257
5-Nov-15	Tiger Shark	JOSEPH	M	320	73
10-Nov-15	Tiger Shark	FINLEY	F	303	259

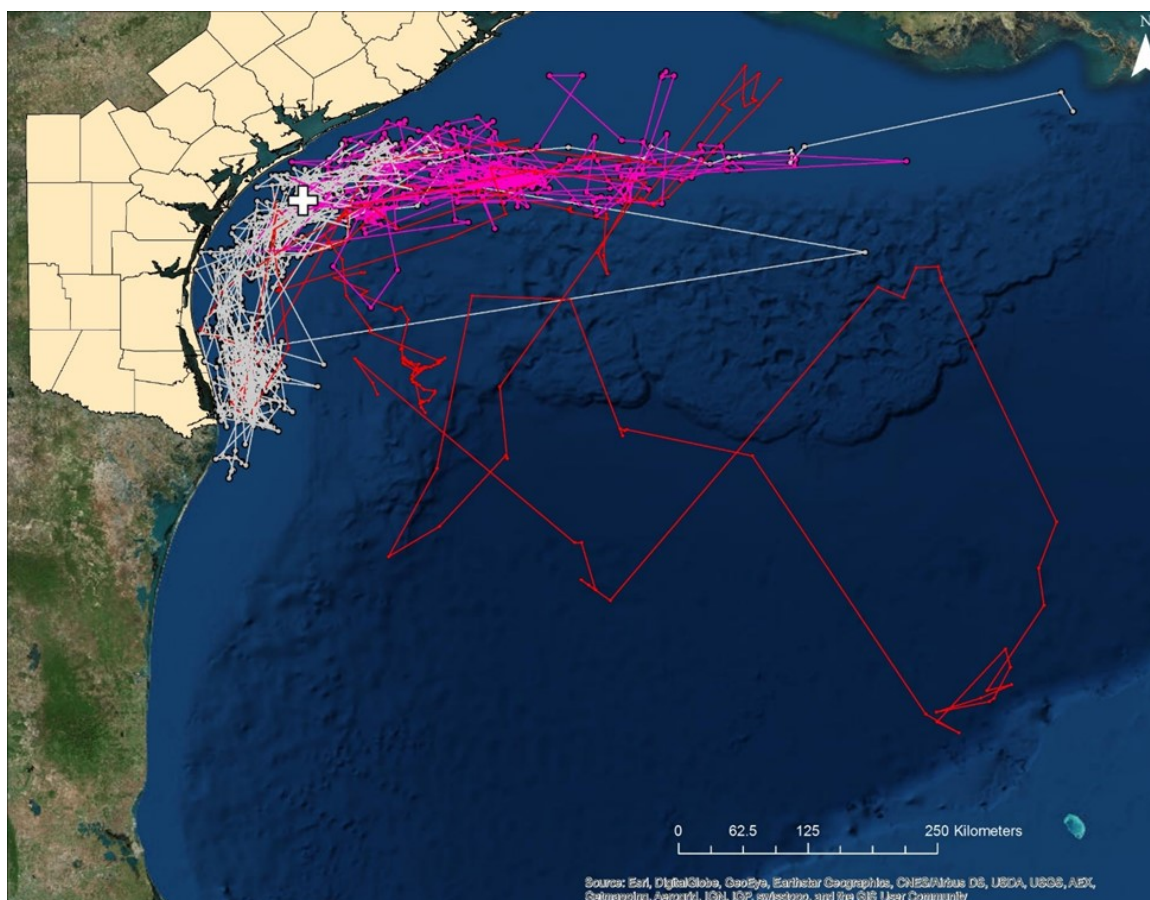


Figure 1. Dispersal patterns of large sharks tagged offshore of Port Aransas, Texas, USA from 2014 to 2016. Tracks are color coded by species and sex: Gray = Scalloped Hammerhead, Red = male Tiger Shark, Pink = female Tiger Shark.