Graduate Research Plan Statement

Shortfin mako sharks (*Isurus oxyrinchus*) and blue sharks (*Prionace glauca*) are both considered to be pelagic apex predators. Mako sharks is currently listed as endangered by the IUCN Red List, while blue sharks are listed as near threatened. While a national fishing ban was established for mako sharks in July 2022, there have been little efforts in actively reducing the fishing mortality of both species, as they are common bycatch in commercial fishing. Both species inhabit similar habitat in the Western North Atlantic Ocean. They follow similar seasonal migratory patterns, spending the warmer months in continental shelf waters at higher latitudes and traveling to offshore waters at lower latitudes in colder months[1, 3]. Both species also spend the majority of their time in the upper water column and have similar temperature preferences. Because blue and mako sharks occupy the same habitat at the same time, it is unclear how the two species display niche separation. A major physiological difference between mako and blue sharks is that mako sharks are regional endotherms and have body parts considerably warmer than ambient water temperature[5], whereas blue sharks are ectotherms. Unlike other endothermic sharks, mako sharks do not take advantage of their thermoregulatory capabilities to dive to cold, deep water[2]. These physiological differences also suggest some type of niche partitioning between blue and mako sharks. Most comparisons between mako and blue sharks has been based on satellite transmitters that provide geopositional data to conduct horizontal movement comparisons or depth and temperature data in the absence of accurate location information. Satellite telemetry tags that collect geopositional data, such as Wildlife Computers SPOT tags, are commonly used to turn geopositional data into movement patterns[6]. Further analysis on the generated tracks shows different behavioral patterns, where individuals stay in one place for an extended period of time (resident behavior) or move between locations (transient behavior)[4]. The generated tracks have been inlayed onto maps (fig.1) to represent the transition between resident and transient behavior. While previous studies have revealed transient and resident behavior using horizontal data, there has not been an extensive look into how these behavioral states relate to vertical movement. Recent advances in satellite telemetry now offer the opportunity to combine fine-scale depth records and highly accurate location data to investigate vertical and horizontal (three-dimensional) movements. I propose to use this technology to document fine-scale, three-dimensional habitat use of blue and mako sharks and to compare patterns of habitat use to evaluate niche partitioning between these two species.

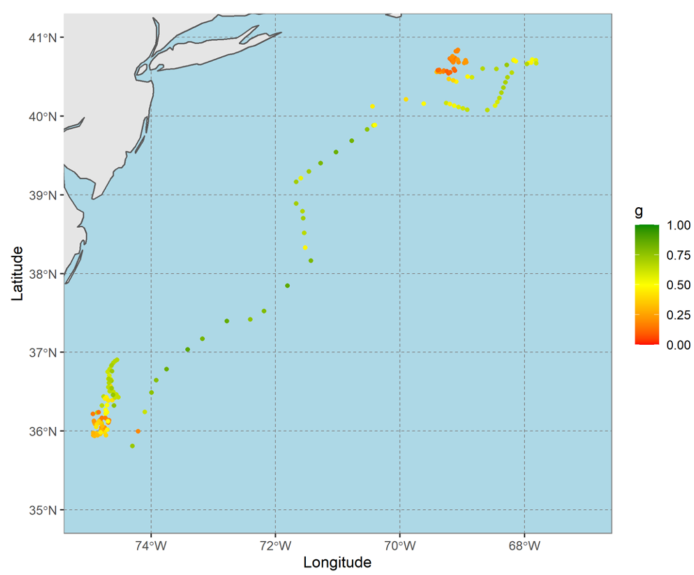

Fig. 1: Map of a mako shark track with behavioral states off the U.S. east coast. Behavioral states (g) are represented along a gradient from low values = resident behavior (red) to high values = transient behavior (green).

For this study, mako and blue shark individuals will be caught on rod and reel using circle hooks to minimize the effects of capture and handling and allow for an easier release. Each individual will have a Wildlife Computers SPLASH tag affixed to their dorsal fin. This research will describe the three-dimensional habitat use of both mako and blue sharks to test whether each species have different depth profiles due to their varying thermogenesis (Aim 1 and 2). It will also compare the three-dimensional movement of each species to the surrounding environmental conditions (Aim 3).

<u>Aim 1:</u> Behavioral patterns of mako and blue sharks will be categorized using horizontal geopositional track data. Behavioral states will be calculated with a state-space model using the "*foieGras*" package in RStudio[3]. **Understanding the behavioral states (transient vs resident) will provide a base understanding of three-dimensional habitat use.**

<u>Aim 2:</u> The 3-D habitat use of both mako and blue shakrs will be categorized by comparing the depth data collected by SPLASH tags with the behavioral states generated by geopositional data. This study will **test the hypothesis** that the vertical data will show different depth profiles for mako and blue sharks, with mako sharks displaying deeper depth profiles (i.e., expanded vertical niche) compared to blue sharks as a result of their ability to regulate internal core temperature. **This will be the first detailed description of three-dimensional habitat use of both species.**

<u>Aim 3:</u> The three-dimensional habitat use patterns will be compared to the environmental conditions, such as the relative location to the ocean floor or bathymetric features (underwater ridges, seamounts, guyots, and canyons). This will address whether the shallower depth constraints due to the continental shelf have any effect on the depth profiles. I predict that sharks will use a larger range of depth when off the continental shelf as compared to being on the continental shelf. Other conditions, such as currents, sea surface temperature, and salinity will also be compared to the depth profiles to see if there is any correlation. **This study will explore the effects of environmental conditions on the three-dimensional habitat use of both species.**

Intellectual Merit

A comparative behavioral study on mako and blue sharks will further current knowledge on both species' depth profiles. It will give greater insight on which niche of the water column both species mainly occupy. This research will also allow us to address the apparent lack of competitive exclusion between the two apex predators. Since both species follow similar migratory patterns and feeding ecologies, it is currently unclear how they coexist in the same regions.

Broader Impacts

Mako sharks are designated as endangered by the IUCN Red List due to being both a popular game fish and a large portion of bycatch in commercial fisheries. Even if fisheries mortality is minimized, mako shark populations may require decades to recover from overfishing due to life history traits such as few offspring, late maturity, and slow growth rate. Similarly, blue shark has been designated as near threatened with populations decreasing. This research will be published and can be used to reduce fishing mortality of both mako and blue sharks through advising effective population management. Additionally, the depth at which fishing gear is set in areas heavily used by both species could be modified to reduce bycatch, while maintaining high catch rates of the target species. Even slight modifications of management policy may enhance efforts to rebuild shark populations and to eventually reestablish sustainable fisheries for each species in the Western Atlantic Ocean.

References.

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