Vertical Habitat Utilization of Cuban Dogfish in the Exuma Sound

Mihir Edulbehram, Theo Mack, Mikey Petersen, Lizzy Soranno, Tessa Vetter
Advisors: Oliver Shipley, Flora Weeks

The ISLAND School

CAPE ELEUTHERA INSTITUTE
RESEARCH EDUCATION OUTREACH

Introduction

Due to the decline of shallow water fish stocks commercial fisheries are now largely active in deeper waters (Simpfendorfer and Kyne, 2009). Deep sea sharks are particularly vulnerable to fisheries exploitation as they are k-selected, meaning they mature, reproduce and grow slowly. As a result the potential rebound rate for deep sea shark species can be as low as 2.2% (Simpfendorfer and Kyne 2009). Despite their vulnerability, the logistical difficulties and expense of deep-sea research has yielded little life-history data for most species (Ramirez-Llodra et al., 2011), especially their fine-scale movement patterns. Therefore understanding their behavior is key to improving management and conservation.

Previous research has illustrated deep sea sharks exert diel vertical (daily) movements, residing at shallower depths during the nighttime and deeper depths during the daytime, and are more active during crepuscular (relating to twilight) periods of day (Nakamura et al. 2015). These behaviors may be associated with avoidance of predators and foraging habits, complemented by higher temperatures and light availability at shallower depths (Comfort & Weng 2014). Although some data exists surrounding the diel-vertical migrations of the larger deep sea shark species, for example, the bluntnose sixgill (*Hexanchus griseus*), there is little data available on the behavior of smaller mesopredatory species.

The Cuban dogfish (*Squalus cubensis*), characterized by a small flexible dorsal fins with a spine in front of the fin, is a small schooling species, found at depths ranging from 60m to over 1000m, in the western Atlantic Ocean, from North Carolina to Argentina (Bester 2009). Cuban dogfish are targeted for their squalene, an oil found in liver tissue, for the pharmaceutical industry. This species is therefore vulnerable to commercial fishing pressure.

Our study is aimed to assess the spatiotemporal behavior of the Cuban dogfish. With more information surrounding the vertical habitat patterns of deep-sea sharks we will be able to better understand movement and overall behavior, giving us an idea of their life history and impact on deep-sea island

Figure 1. Cuban dogfish (*Squalus cubensis*) are a small-bodied schooling species.

Objective

The purpose of this study was to investigate vertical habitat use in Cuban Dogfish, and the extent to which they exhibit diel-vertical behavior. This will lead to understand life history data which will help us to better understand their ecological role, and help manage deep-sea fisheries.

Study Site

The Exuma Sound is a deep-water inlet of the Atlantic ocean off the coast of Eleuthera (200km length, 50-75 km width), with a maximum depth of approximately 1600m (Brooks et al., 2015). The sound provides an accessible study site to perform deep-sea research due to its proximity to the Cape Eleuthera Institute (< 4 miles). Previous research here has highlighted the relative abundance of deep-sea sharks in this area (see Brooks et al., 2015) thus providing a unique opportunity to study their behavior.

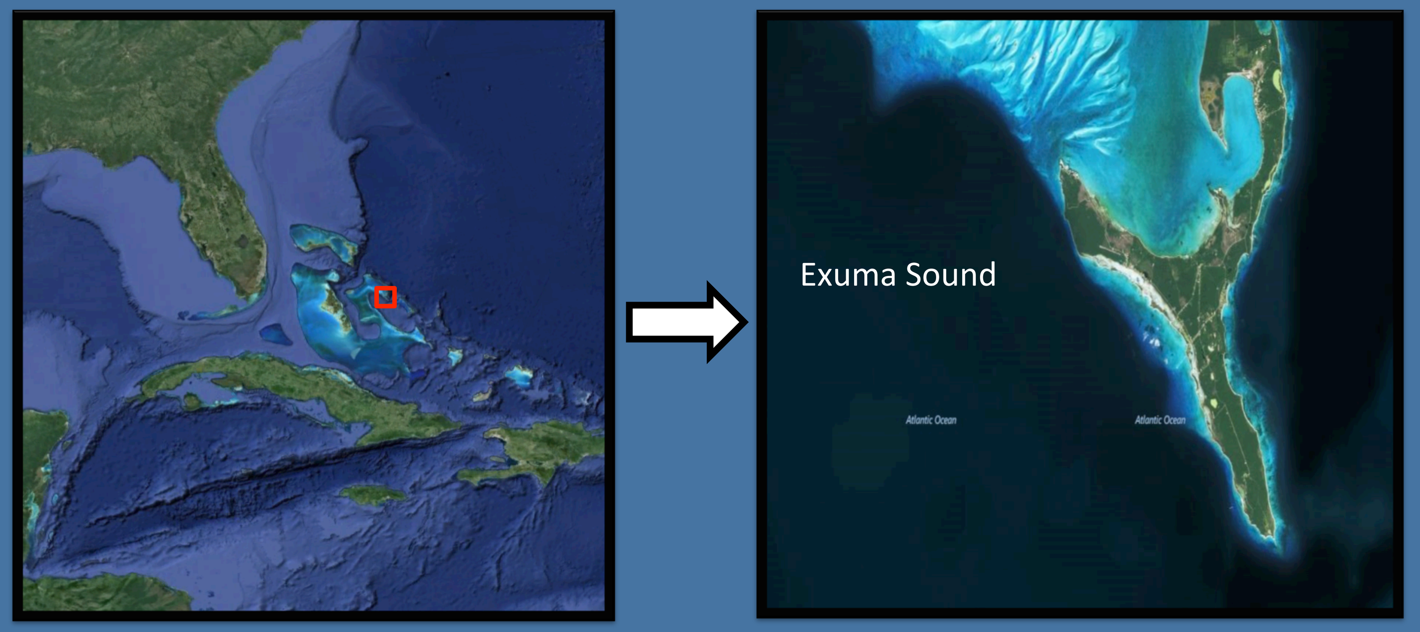

Figure 2. Satellite Image of the Exuma Sound in relation to the wider Caribbean

Materials and Methods

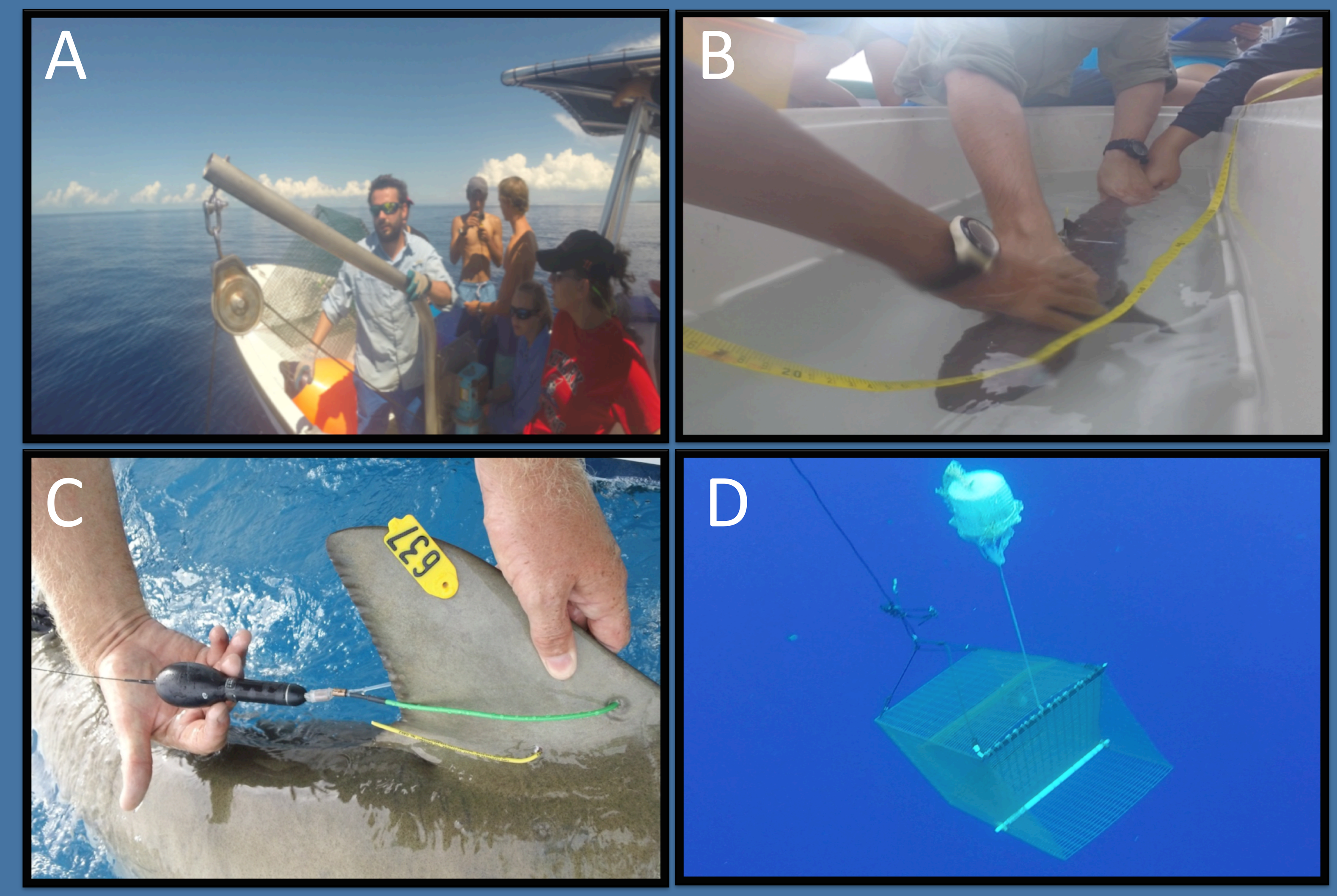

Figure 3. A) Sharks were captured using 800-1000m demersal longlines and were recovered using a pot hauler. B) Sharks were processed on the boat and its total length, pre-caudal length, fork length, sex, and maturity level were recorded. C) Sharks were tagged in the dorsal fin with a high-resolution X-tag which records depth and water temperature every two minutes for a two-week period. D) Sharks were placed in an anti-predation cage and lowered down to the ocean floor, allowing the sharks to exit.

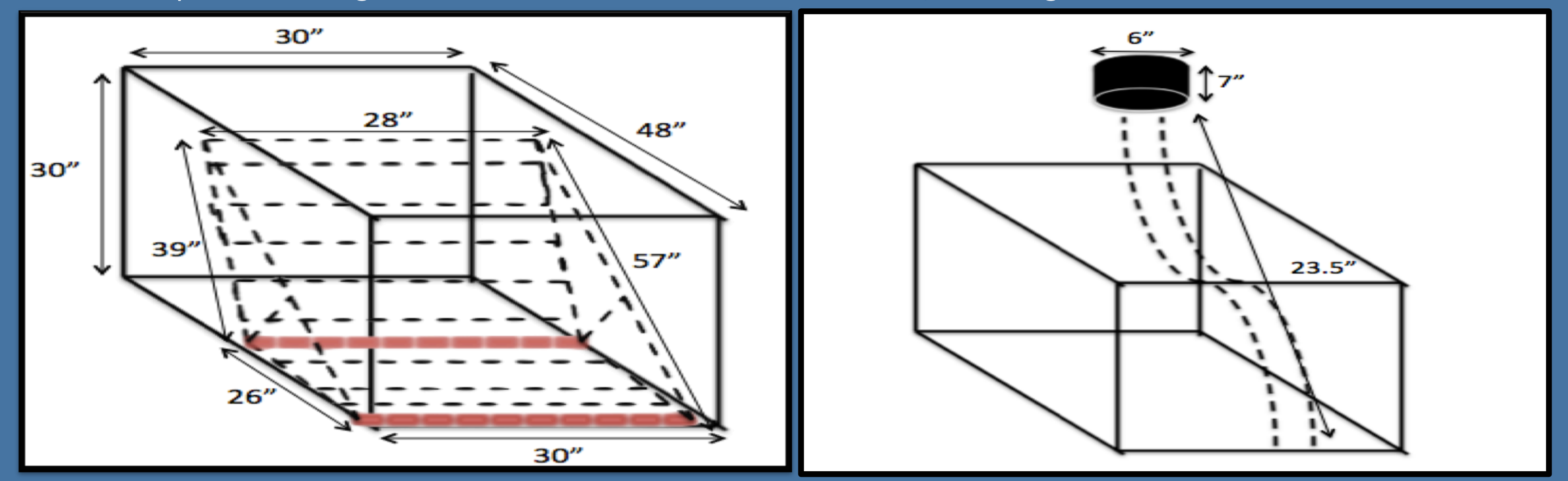

Figure 4. Previous studies have shown that deep-sea sharks can be vulnerable to post-release mortality (Brooks et al., 2015; B. Talwar, Unpublished Data). Our study utilized a newly designed cage to protect the animals during their descent. The cage is held closed by a parachute, which creates drag until the cage stops descending and then it allows the door to drift open and the animals to be released.

Results

Table 1. Summary data for the four Cuban dogfish (*Squalus cubensis*) tagged and reported in this study. All four were female, ranging in pre-caudal length from 54-71cm. The tags stayed on the sharks for between 8-14 days. There were two documented reasons for the tags to pop off: It would pop off if the memory was full (as seen in the two sharks that had their tags for 14 days) and it would pop off if it sensed a constant pressure (as seen in the sharks that had their tags for 8 or 10 days).

Shark Number	PCL (cm)	FL (cm)	TL (cm)	Sex	Stage	Sat Tag S/N	Sat Tag ID	Tag at Liberty (Days)	Reason for Pop-off	Percent of Data Received
1	49	54	62	F	IM	23479	150486	8	Constant Pressure	30%
2	56	61	70	F	M	23480	150487	14	Memory Full	65%
3	66	71	80	F	M	23484	150491	14	Memory Full	45%
4	49	55	63	F	IM	23485	150492	10	Constant Pressure	40%

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Vertical Movement Patterns

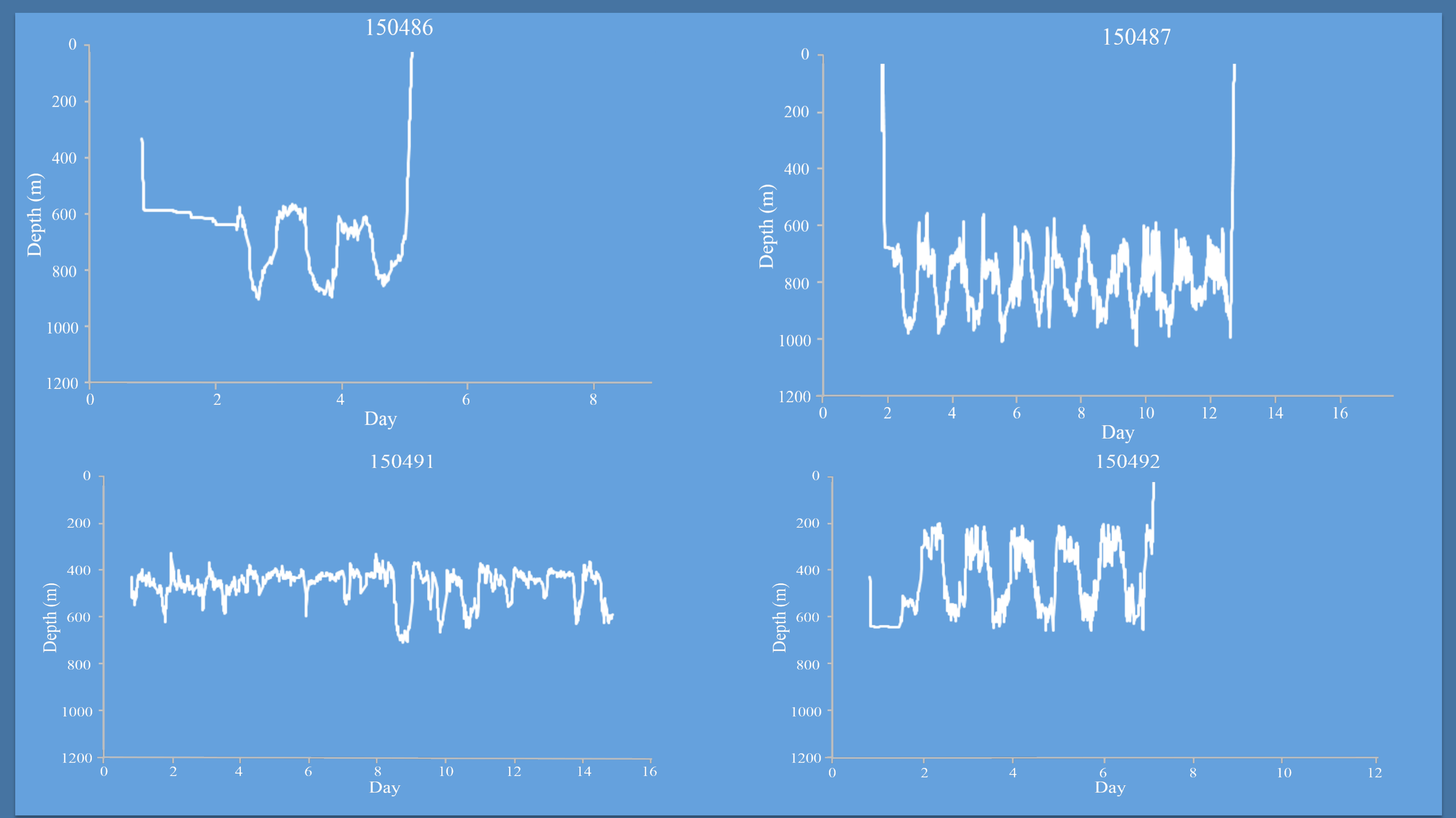

Figure 5. Daily depth migrations of four sharks captured.

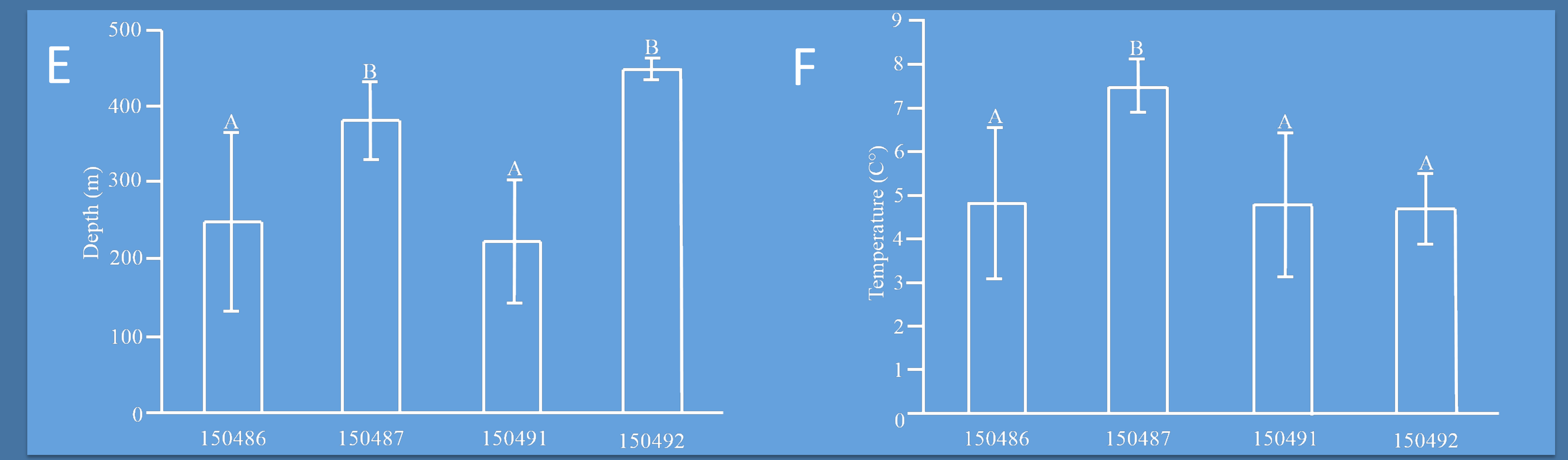

Figure 6. E) A statistically significant difference was observed between the migratory scope of the four Cuban dogfish (kruskal-wallis test, df=3, p<0.05). A *post-hoc* test revealed no significant difference between Shark 150486 (Mean=245.3 ± 115.52m S.D.) and Shark 150491 (mean=220.27 ± 78.91m S.D.) and between Shark 150487 (mean=381.42 ± 48.14m S.D.) and Shark 150492 (mean=450.05 ± 14.95m S.D.). F) A statistically significant difference was observed between the thermal gap of the four Cuban dogfish (kruskal-wallis test, df=3, p<0.05). A *post-hoc* test revealed no significant difference between the thermal gap of Shark 150486 (mean=4.81 ± 1.75˚C S.D.), Shark 150487 (mean=4.68 ± 0.8˚C S.D.), and Shark 150491 (mean=4.64 ± 1.68˚C S.D.). There was a significant difference in Shark 150492 (mean=6.99 ± 0.61˚C S.D.) from the other 3 sharks.

Discussion

Diel-vertical behaviors were observed across all individuals. These movements were associated with crepuscular daily periods (during twilight) with animals most active during dusk and dawn (Figure 5). The spatiotemporal behaviors observed may be associated with foraging or avoidance of predators, complemented by higher temperatures and light availability in shallower depths. The diel-vertical patterns of the Cuban dogfish are similar to diel-vertical behaviors displayed in other species such as bluntnose sixgill sharks (Comfort and Weng, 2014), highlighting homogeneity of this behavior across species. However, when compared to the bluntnose sixgill average minimum and maximum depths the Cuban dogfish inhabited were roughly 200m deeper. Although they are exerting a similar behavior, there is depth segregation, which could be indicative of niche partitioning, or active predator avoidance.

Intra-specific variations were observed in thermal gap and migratory scope between animals captured (Figure 6). The thermal gap and migratory scope highlight that these animals were migrating between varying temperatures and distances. Animals moved through a large thermal gap, suggesting an evolutionary adaptation to inhabit a broad range of temperatures. Observations were not dictated by size, suggesting that the migratory scope could be linked to following a preferred food source. It could therefore be argued Cuban Dogfish exhibit some degree of niche partitioning thus avoiding intra-specific competition regarding foraging. In addition foraging across variable depths may further facilitate ecosystem connectivity i.e. exerting top down controls across multiple habitats (pelagic and benthic components).

Utilizing technology that tracks the animal's location horizontally would add further rigor to our knowledge of deep-sea shark vertical migration through assessing the degree to which these animals exploit slope vs. pelagic food webs. On a broader scale, elucidating depth ranges of deep-sea sharks can help further restrictions for fisheries management based off of the depths the Cuban dogfish have been found at certain times of the day.

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