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Habitat use and diel vertical migration of bigeye thresher shark: overlap with pelagic longline fishing gear

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Abstract

Pelagic longliners targeting swordfish and tunas in oceanic waters regularly capture sharks as bycatch, including currently protected species as the bigeye thresher, *Alopias superciliosus*. Fifteen bigeye threshers were tagged with pop-up satellite archival tags (PSATs) in 2012-2014 in the tropical northeast Atlantic, with successful transmissions received from 12 tags for a total of 907 tracking days. Marked diel vertical movements were recorded on all specimens, with most of the daytime spent in deeper colder water (mean depth = 353 m, SD = 73; mean temperature = 10.7ºC, SD = 1.8) and nighttime spent in warmer water closer to the surface (mean depth = 72 m, SD = 54; mean temperature = 21.9ºC, SD = 3.7). The operating depth of the pelagic longline gear was measured with Minilog Temperature and Depth Recorders (TDRs), and the overlap with habitat utilization was calculated. Overlap is taking place mainly during the night and is higher for juveniles. The results presented herein can be used as inputs for Ecological Risk Assessments for bigeye threshers captured in oceanic tuna fisheries, and serve as a basis for efficient management and conservation of this vulnerable shark species.

Key-words: *Alopias superciliosus*; bycatch; fisheries; Temperature and Depth Recorders (TDRs), pop-up satellite archival tags (PSATs); sharks; susceptibility; vertical habitat.

1. Introduction

Pelagic sharks are captured by a wide range of commercial fisheries but are common as bycatch of pelagic longlines targeting tunas and swordfish (e.g., Petersen et al. 2009; Coelho et al 2012). Understanding the habitat use and foraging ecology of oceanic sharks is crucial, not only for assessing the fishing impacts to these apex predators, but also cascading impacts to marine ecosystems. For most shark bycatch species, knowledge on their biology, ecology and habitat use is still very limited, and this includes protected species as the bigeye thresher, *Alopias superciliosus*. Due to their conservation status, fishers are currently prohibited to retain bigeye threshers in the Atlantic (ICCAT 2009) and Indian (IOTC 2012) Oceans.

The bigeye thresher is a pelagic shark distributed worldwide in oceanic and neritic waters over continental and insular shelves (Gruber and Compagno 1981; Compagno 2001; Smith et al. 2008). Characterized by having an extremely low fecundity (usually two pups per reproductive cycle) and slow growth, this species is considered one of the most vulnerable pelagic sharks (Smith et al. 1998; Chen and Yuan 2006, Cortés 2008, Cortés et al. 2010). Although, the bigeye thresher is commonly caught in pelagic longline fisheries in all oceans, information on the species, habitat use and movement patterns is very limited, which complicates the provision of scientific advice for mitigation measures.

Over the past ~10 years, the use of pop-up satellite archival tags (PSATs) to study the movements and behavior of large highly migratory species like bluefin tuna, *Thunnus thynnus* (Block et al. 2005; Wilson et al. 2005); swordfish, *Xiphias gladius* (Abascal et al. 2015) and pelagic sharks (Kerstetter et al. 2004; Moyes et al. 2006; Campana et al. 2009; Stevens et al. 2010; Abascal et al. 2011) has been increasing. Currently, besides providing estimates of geo-location, PSATs can also collect and archive ambient water temperature, pressure (depth) and light levels. These tags are programmed to collect data for a period of time, after which the tags detach automatically or are shed, float to the surface and transmit the stored data to passing geosynchronous satellites of the ARGOS system (Musyl et al. 2011a). The downloaded data from PSATs can then be used to calculate overlaps (both horizontal and vertical) between the species distribution patterns and the depth of pelagic fishing gear, which can assist fishery scientists and managers to implement more precise management and conservation measures. Previous researchers have deployed PSATs on bigeye threshers, but most were in the Pacific and Gulf of Mexico, and sample sizes were small (n=1 to n=3) (Weng and Block 2004; Stevens et al. 2010; Musyl et al. 2011b; Carlson and Gulak 2012).

Given the paucity of information on vertical habitat use for the bigeye thresher shark and its vulnerability to oceanic longline fisheries, the main objective of this study was to provide information regarding the vertical habitat utilization patterns, particularly in terms of diel movements. The second objective was to calculate overlaps between the species vertical habitat utilization and the depths of hooks of pelagic longline fishing gear, specifically the surface longlines that are deployed targeting swordfish.

2. Material and Methods

2.1. Tagging protocol

PSATs used in this study were built by Microwave Telemetry Inc. (Columbia, MD, USA), and standard, X-tags and high rate (HR) tag models were used. The PSAT deployments were carried out by fisheries observers from the Portuguese Institute for the Ocean and Atmosphere, I.P. (IPMA) onboard vessels from the Portuguese pelagic longline fleet. Tag deployment and pop-up took place between August 2012 and December 2013, mainly in the tropical and sub-tropical region of the northeast Atlantic Ocean (Figure 1).

The PSATs were rigged with monofilament leaders (15 cm length) secured with copper crimps and encased in surgical silicone tubing. The copper crimps were at a distance from the tag sufficient to prevent any accidental contact with the PSATs detachment mechanism and were covered with the silicone tubing. An umbrella-type nylon dart (Domeier et al. 2005) was used to attach the tag laterally to the dorsal musculature below the first dorsal fin, using the methodology described by Howey-Jordan et al. (2013). The tags rigged in this way were tested and were positively buoyant in sea water. The pelagic longline gear used J-style hooks and either monofilament or wire leaders. Sharks were restrained alongside the vessel and measured (nearest ~10 cm) for fork length (FL) and the sex, GPS tagging location (latitude and longitude), date and time were recorded. The hooks were removed if possible. The tags were programmed for deployment periods between 1 and 6 months (Table 1).

The X-tags record data on depth and temperature every 2 min, daily minimum and maximum depths and temperatures, as well as the light levels and times of sunrise and sunset. The depth range of these tags is 0 to 1296 m with a resolution of 0.34 - 5.4m (via Argos) and 0.34 m (archived data) and the temperature range is -4 to +40°C, with a resolution of 0.16 - 0.23°C. After pop-up, the transmitting tags attempt to transmit one depth and temperature data-pair within each 15-30 minute period in the time series (depending on the length of the deployment period), as well as the full minimum and maximum daily depths and times of sunrise and sunset. Standard tags work in a similar way and have similar depth and temperature ranges and resolutions, but record and archive data at a lower time resolution. The HR tags record data every 5 min intervals and after pop-up attempt to transmit the entire time series of data. On those tags the depth range is 0 to 1296 m with a resolution of 1.34 (via Argos) and 0.34 m (archived data) and the temperature range is -4 to +40°C with a resolution of 0.16 - 0.23°C. Two of our deployed tags (one standard and one X-tag) were recovered and returned to the manufacturer for the full data download, so in those cases the full dataset was available (Table 1).

2.2. Depth of longline gear operation

In order to characterize the depth of pelagic longline operations, Minilog Temperature and Depth Recorders (TDRs) made by Vemco (Bedford, Nova Scotia, Canada) were deployed on 60 fishing sets. Six TDRs were used per fishing set and were programmed to record data at every 1 min interval, with a depth resolution of 1.2 m. TDRs were attached immediately adjacent to the hooks and were placed on all hooks between floats.

The fishing sets were carried out from commercial Portuguese longline vessels following the general practices of the European pelagic longline fleet that targets mainly swordfish. Deployment of gear typically starts in the late afternoon at ~ 17:00 hr, and haulback commences the next morning ~ 06:00 hr. The fishing gear consisted of a standard US-style polyamide monofilament mainline (Watson and Kerstetter 2006) with five branch lines between floats. Each branch line was around 18 m in length and was composed by two sections: a 9 m monofilament section (2.5 mm diameter) connected by a swivel to a 9 m monofilament gangion (2.2 mm diameter) with a J-style hook in the terminal tackle. Two different size options for the float line are typically used by this fleet: either 12 or 16 m. Therefore the study design took into account this variability of the fleet fishing strategy, with the TDRs equally deployed on sections using both sizes of float lines.

2.3. Data analysis

The percentage of habitat utilization in terms of time-at-depth and time-at-temperature were calculated and analyzed separately for daytime and nighttime. Sunrise and sunset were calculated taking into account the date (Julian day), latitude and longitude (Teets 2003), using library “RAtmosphere” in R (Biavati 2014). Habitat utilization was also analyzed separately for males and females, as well as for juvenile and adult specimens. The definition of juvenile and adult stages were based on the median size-at-first-maturity (L_{50}) reported by Fernandez-Carvalho et al. (2015), specifically 159.2 cm FL for males and 208.6 cm FL for females. The time-at-depth and time-at-temperature data were aggregated into 30 m and 2 ºC bins, respectively, based on the above analyses. These data were subsequently expressed as a fraction of the total time of observation for each shark, and the fractional data bins averaged across all sharks within each category.

The depth and temperature data were tested for normality with Kolmogorov-Smirnov tests with Lilliefors correction (Lilliefors 1967) and for homogeneity of variances with Levene tests (Levene 1960). Given the lack of normality in the data and heterogeneity of variances, time-at-depth and time-at-temperature were compared between daytime vs. nighttime, maturity stage (adults vs. juveniles) and sexes with nonparametric k-sample permutation tests (Manly 2007) using the library "perm" in R (Fay and Shaw 2010). For this, a Monte Carlo approach was used with the data randomized and re-sampled 9,999 times to build the expected distribution of the differences under a random distribution, which was then used to determine the significance of the differences in the time-at-depth and time-at-temperature for the sample.

In terms of estimating geographical locations, an attempt was made to estimate the most probable tracks using state-space models with the unscented Kalman filter (Lam et al. 2008), using library “ukfsst” in R (Nielsen et al. 2012). However, given the pronounced diel vertical movements observed on all specimens, the tags were not able to correctly record the daily sunrise and sunset times and it was not possible to estimate daily geographical positions.

The overlap between the species habitat and depth of fishing gear was calculated by analyzing the results from the TDRs and PSATs. The mean depth of the hooks were calculated, and the differences between hooks set with 12m or 16m float lines tested with permutation tests (Manly 2007). The 90% percentiles of the recorded hook depths were calculated and the depth distribution of the specimens PSAT data were overlapped with the depth distribution of the fishing gear in order to calculate the percentage of overlap time.

All statistical analysis for this paper was carried out with the R Project for Statistical Computing version 3.0.1 (R Core Team 2013). Plots were created using libraries “plotrix” (Lemon 2006) and “ggplot2” (Wickham 2009).

3. Results

3.1. Tag performance

Fifteen tags were deployed for this study and data from twelve tags were successfully transmitted, with two detaching early (Table 1). Two tags were recovered; one of a specimen recaptured by a commercial fishing vessel and another that was found on a beach in the Bahamas after drifting in the sea for more than one year after pop-up (Table 1). A total of 907 tracking days were registered, specifically 581 tracking days for females and 326 days for males, including adults and juveniles of each sex (Table 2).

3.2. Habitat use

A marked and constant diel vertical movement pattern was observed, with bigeye threshers spending most of the daytime in deeper and colder water (mean depth = 353 m, SD = 73; mean temperature = 10.7ºC, SD = 1.8) and the nighttime in warmer water closer to the surface (mean depth = 72 m, SD = 54; mean temperature = 21.9ºC, SD = 3.7) with those differences statistically significant (depth: permutation test differences = -280.83, p-value < 0.001; temperature: permutation test differences = -10.94, p-value < 0.001) (Figure 2). On occasions, the sharks performed rapid dives followed by rapid ascents (Figure 2). The maximum depth recorded was 955 m at 5.2ºC.

The patterns of habitat utilization for adults and juveniles followed the general trend of occupying shallower waters during the night and deeper waters in the day, but significant differences were noted. Specifically, the range of vertical habitat utilization was larger for the juveniles than the adults, with the juveniles staying in waters shallower than the adults during the night, but in deeper waters than the adults during the day (Figure 3). The mean depth during nighttime was 70 m (SD=54) for juveniles and 93 m (SD=49) for adults, while during the daytime the mean depth was 356 m (SD=71) for juveniles and 318 m (SD=86) for adults, with those differences significant (permutation tests: nighttime differences = -22.6, p-value < 0.001; daytime differences = 37.3, p-value<0.001). Similar results were obtained for the temperatures, with the mean temperature during nighttime 21.6ºC (SD=3.7) for juveniles and 22.5ºC (SD=3.7) for adults, while during daytime the mean temperature was 10.7ºC (SD=1.7) for juveniles and 11.6ºC (SD=2.6) for adults, with those differences also significant (permutation tests: nighttime differences = -22.6, p-value < 0.001; daytime differences = 37.3, p-value<0.001).

Differences between the sexes were also detected, as well as interactions between sex and maturity stages. During daytime adult males tended to be deeper than adult females, while juvenile males tended to be shallower than juvenile females (Figure 4). During nighttime both adult and juvenile males tended to be shallower than females (Figure 4).

In terms of vertical habitat utilization, for juveniles the modal depth class during daytime was 330-360m with 18.4% of the daytime spent there, while the modal depth class during nighttime was 30-60m where the sharks spent 49.9% of their time (Figure 5). The adults displayed a bimodal distribution for daytime, with a peak of 14.1% of the time spent at 240-270m and another peak with 16.9% of the time spent at 390-420m, while the modal class during nighttime was 60-90m where the sharks spent 29.8% of their time (Figure 5).

3.3. Overlap between habitat and fishing gear depth

The depth of hooks depended on the length of the float lines (Figure 6). The average hook depth of this fishery was 41 m (SD=15) and 48 m (SD=17), when using 12 m or 16 m float lines, respectively, with those differences statistically significant (Permutation test: observed differences = 6.68; p-value < 0.01).

The 90% percentile depth distribution of the hooks depth was 25 - 63 m and 30 - 70 m, respectively for the 12 m and 16 m float lines. When this distribution was overlapped with the species vertical habitat utilization, the overlap between fishing gear and species habitat use took place almost exclusively during nighttime. Moreover, the overlap was more marked for the juveniles. Specifically, during nighttime the overlap between the species vertical habitat and fishing gear deployment varied between 56.4 - 60.2 % for the juveniles and between 25.4 - 33.6 % for the adults (Table 3).

3.4. Horizontal movements

All specimens showed marked diel movements and spent most of the daytime at considerable depths and as such the satellite tags were not able to correctly detect sunrise and sunset times, as well as daylight duration. This hindered the estimation of accurate geo-location positions even after applying the state-space models. Therefore, only the known deployments positions and pop-up locations were used for the spatial analysis (Figure 1). The minimum distances traveled (straight lines between the tagging and pop-up locations) ranged from 94.6 to 1439.9 km (for 30 and 122 tracking days, respectively), with an average daily distance of 13.0 km/day, ranging from 2.3 to 27.0 km/day.

4. Discussion

The present paper provides the most comprehensive study on habitat use and movements of bigeye thresher sharks, based on a large set of specimens tagged with PSATs. We were able to tag and track specimens of both sexes, including juveniles and adults of each sex, and therefore the differences in vertical habitat utilization between sexes and maturity stages was observed and reported for the first time. Only a few studies have tried to determine vertical habitat utilization of bigeye thresher, but all tagged and analyzed a very limited number of specimens. Most have also detected the diel vertical movement pattern that we report in our study, but not the differences that we found in terms of differential habitat utilization by sex and maturity stage.

By analyzing data from TDRs deployed during commercial longline fishing sets we were able to calculate the overlaps between the species vertical habitat utilization and the depth of operation of longline fishing gear. For the particular fishery that uses shallow night set longlines targeting swordfish, the overlap is taking place almost exclusively during the night (when the fishery operates) and the juveniles are potentially more impacted than the adults, as the percentage of overlap time is greater for the juveniles than for the adults. However, it should be noted that we only calculated and reported the percentage overlap between vertical habitat utilization and depth of hooks not taking into account that the hooks were baited, typically with squid or mackerel (see Santos et al. 2012; Coelho et al. 2015; Amorim et al. 2015). Baits have attractant characteristics that may cause the specimens to change their behavior.

A previous study by Weng and Block (2004) analyzed two bigeye thresher sharks tagged with PSATs (one in the Gulf of Mexico and another in the Pacific Ocean close to Hawaii), and reported that, as observed in our study, both specimens showed diel movement pattern, with the majority of the nighttime spent closer to the surface and the most of the daytime spent bellow the thermocline (300-500m). In the eastern tropical Pacific, Nakano et al. (2003) used acoustic telemetry to actively track two bigeye threshers during 70 and 96 hr periods, and also reported diel vertical behavior. Moreover, Nakano et al. (2003) also detected the occasional quick dives that we observed in our study, and reported a maximum depth of 723 m, which is less than the 955m recorded in our study. In the Central Pacific, Musyl et al. (2011) tagged eight bigeye threshers with PSATs and analyzed data from three reporting tags, and also reported the same diel vertical movement patterns. Likewise, in Eastern Australia, Stevens et al. (2010) tagged one bigeye thresher for 14 days, that also presented this type of characteristic deep-daytime, shallow-nighttime behavior. By contrast, Carlson and Gulak (2012) analyzed one bigeye thresher tagged in the Gulf of Mexico, near or on the continental shelf of the USA, and reported that the specimen did not show evidences of pronounced diel movement patterns. Carlson and Gulak (2012) hypothesized that the lack of diel behavior exhibited in their tagged specimen might be related to bottom depth, given that it was moving closer to the continental shelf in shallower waters.

Diel behavior has been suggested to be related with foraging ecology for other pelagic species like swordfish, bigeye tuna (*Thunnus obesus*), blue shark, shortfin mako and common thresher (*Alopias vulpinus*) (Preti et al. 2008; Stevens et al. 2010; Musyl et al. 2011b). The daytime vertical migrations of bigeye thresher may therefore be described as a strategy to remain near prey organisms in the deep sound scattering layer (SSL), similarly to what has already been documented for swordfish and bigeye tuna, with possible vertical adjustments during the nighttime to lunar illumination (Musyl et al. 2003, 2011b). As determined from a diet study, it has been suggested that besides demonstrating the same general diel migrations as swordfish, bigeye thresher also forages on the same prey (Preti et al. 2008). In fact, though both species are predominately deep water species in the pelagic environment, they have a varied diet and may feed opportunistically across habitats in the mixed-surface layers, contrary to other pelagic sharks without this vertical mobility (Preti et al. 2008). Both swordfish and bigeye thresher have been described as presenting similar physiological adaptations for extended foraging in dark cold waters, like the presence of large eyes and cranial endorthermy (Weng and Block 2004; Preti et al. 2008). The bigeye thresher has a highly developed *rete mirabile* within the orbital sinus which suggests heat conservation in the eyes and brain enabling prolonged foraging periods beneath the thermocline (Weng and Block 2004).

From the 15 tags deployed, only three failed to transmit, representing a success rate of 80%. Hence, the performance of the PSATs used in our study can be considered high when compared to the reporting rates of 38% from Musyl et al. (2011b) and 50% from Carlson and Gulak (2012). Several factors can be attributed to the failure of PSATs namely, expiration of the battery, physical damage of the transmitter, detachment and sinking of the transmitter, death of the animal, biofouling, or failure of the release mechanism (Hays et al. 2007; Musyl et al. 2011a). Additionally, the success rate of PSATs also seems to be species-specific, and in particular related with the depth habitats of the tagged animals. Hammerschlag et al. (2011) carried out a revision of 48 studies using PSATs on sharks and reported an average rate of 10% tag failure. However, it is worth noting that several studies on species that also make deep dives presented lower reporting rates that our study, specifically for the basking shark, *Cetorhinus maximus* (Sims et al. 2003) and shortfin mako, *Isurus oxyrinchus* (Musyl et al. 2011b). On the other hand, in our study a 13% rate of premature release was observed, which is very low when compared with the average rate of 66% premature release reported for other sharks studies by Hammerschlag et al. (2011), or the 82% of tags detached before their scheduled pop-up date reported by Musyl et al. (2011a) for several species.

Some difficulties arose when using the satellite technology to estimate the geo-locations for this species, as other researchers have documented on deep-diving species (e.g., Musyl et al. 2003; Weng and Block 2004; Dewar et al. 2011; Musyl et al. 2011b). The fact that the bigeye thresher spends most of the daytime in deep waters poses a limitation as no geo-location could be obtained, other than the deployment and pop-up locations, as the extreme crepuscular diving transitions prevented the light-sensor on PSATs from recording sunrise and sunset.

The main conclusions of our study are that the bigeye thresher is using the vertical habitat with very constant diel movement patterns, with the specimens spending most of the daytime in deeper waters and the nighttime closer to the surface in shallower waters. Additionally, we were also able to find differences in the vertical habitat utilization when comparing adults and juveniles, with both maturity stages making the diel movements but staying at different depth classes. Consequently, the maturity stages are being affected in different ways by the pelagic longline fisheries. For the specific case of the shallow pelagic longline fishery that typically deploys night sets targeting swordfish, the impacts on the bigeye thresher are potentially higher for juveniles that have a higher percentage of overlap time.

The results presented in this work are novel and substantially increase the knowledge on the biology, ecology and habitat utilization of bigeye threshers in the pelagic environment, as well as the overlap and potential impacts with pelagic longline fishing gear. These results can be used as inputs for Ecological Risk Assessments for pelagic sharks captured in oceanic longline fisheries, and serve as a basis for more efficient management and conservation of this species. Moreover, this information can be used to establish more efficient bycatch mitigation measures, particularly in hot spot areas for juveniles of this vulnerable species.

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Tables

Table 1: Characteristics of tagged bigeye thresher sharks, *Alopias superciliosus*, and pop-up satellite archival tags (PSATs) used in this study, with information on specimen size, sex, tag type, planned duration, effective tracking days and % of transmitted data. FL=fork length.

ID	Tag model	Size (FL, cm)*	Sex	Tagging Date	Planned duration (months)	Tracking days	Transmitted data (%)
113777	Standard	155	Female	26-Aug-12	1	31	100
113778	Standard	135	Male	28-Aug-12	1	31	100
113782	Standard	160	Female	31-Aug-12	4	122	94
113783	Standard	130	Male	31-Aug-12	4	47	100**
119177	X-tag	140	Male	27-Sep-12	6	127	100**
120465	X-tag	180	Female	21-Aug-13	4	122	48
127995	X-tag-HR	215	Female	27-Sep-13	1	31	72
120466	X-tag	190	Male	16-Dec-13	4	121	55
127996	X-tag-HR	150	Female	17-Dec-13	1	33	79
127997	X-tag-HR	180	Female	19-Dec-13	1	30	80
120469	X-tag	195	Female	19-Dec-13	6	182	44
127994	X-tag-HR	170	Female	23-Dec-13	1	30	78

*: Sizes given are estimated within 10cm FL size classes; **: Recovered tags.

Table 2: Total tracking days of bigeye thresher sharks, *Alopias superciliosus*, per sex (males and females) and maturity stage (juveniles and adults).

Sex	Maturity stage		Total
	Adult	Juvenile	
Female	31	550	581
Male	121	205	326
Total	152	755	907

Table 3: Overlap, in percentage of time (%), between the vertical habitat of bigeye thresher sharks, *Alopias superciliosus*, and the depth of operation of shallow water pelagic longlines targeting swordfish.

Float line length	Daytime		Nighttime	
	Juveniles	Adults	Juveniles	Adults
12m	< 1.0	< 1.0	60.2	25.4
16m	< 1.0	< 1.0	56.4	33.6

Figure

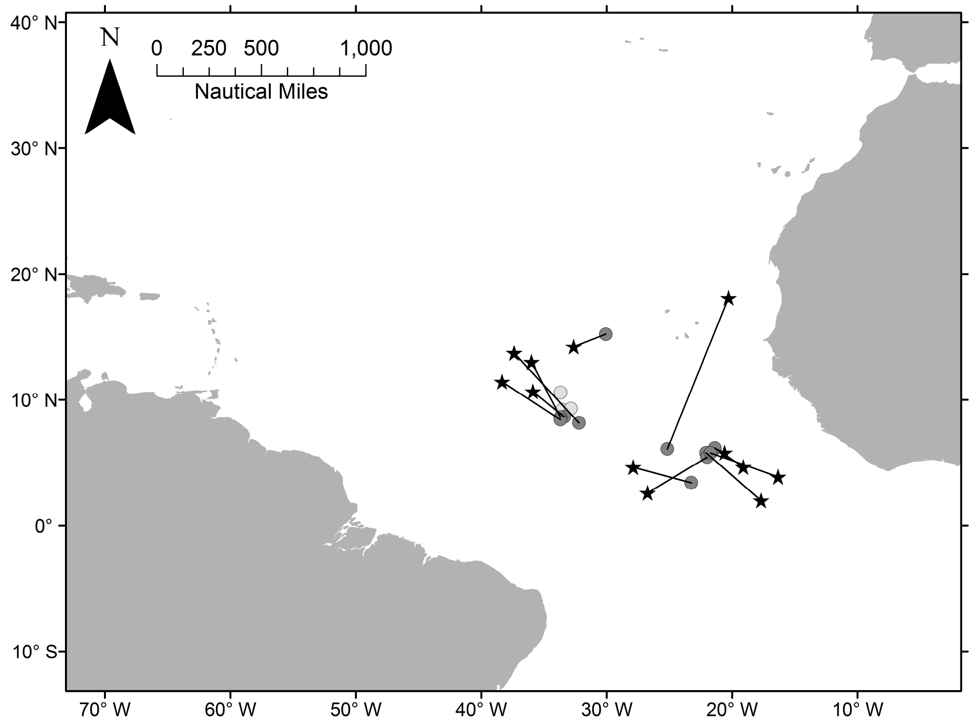

Figure 1: Tagging and pop-up locations of the bigeye thresher sharks, *Alopias superciliosus*, tracked with pop-up satellite archival tags (PSATs) in this study. The tagging locations of specimens with successful tag transmissions are represented in dark grey circles, the tagging locations of specimens with tags that failed to transmit are represented with light grey circles, and the pop-up locations are represented with black stars.

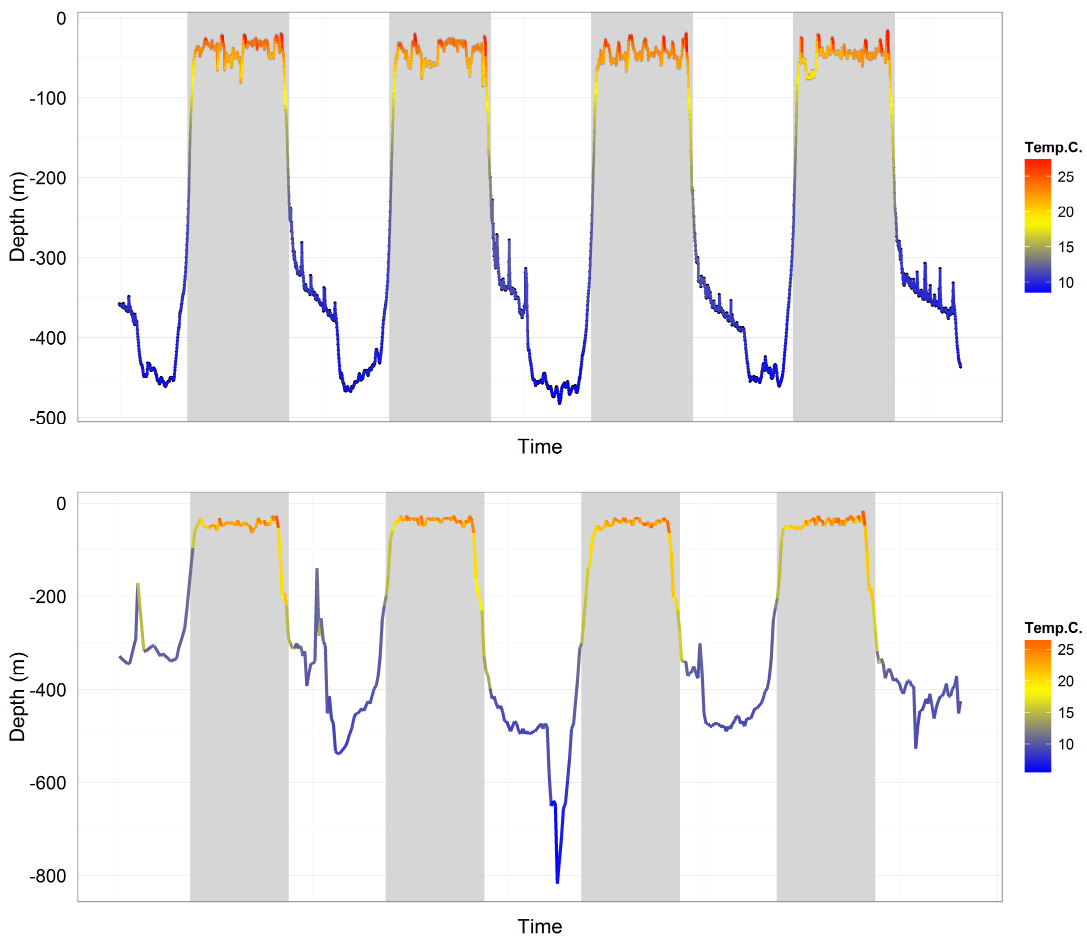

Figure 2: Details of diving behavior profiles of bigeye thresher sharks, *Alopias superciliosus*, tagged with pop-up satellite archival tags (PSATs). The plot on the top represents the most common diel behavior movements, with daytime spent in deep water and nighttime in shallow water. The plot on the bottom shows one occasional rapid deep dive and ascent. In both plots nighttime is shaded in grey.

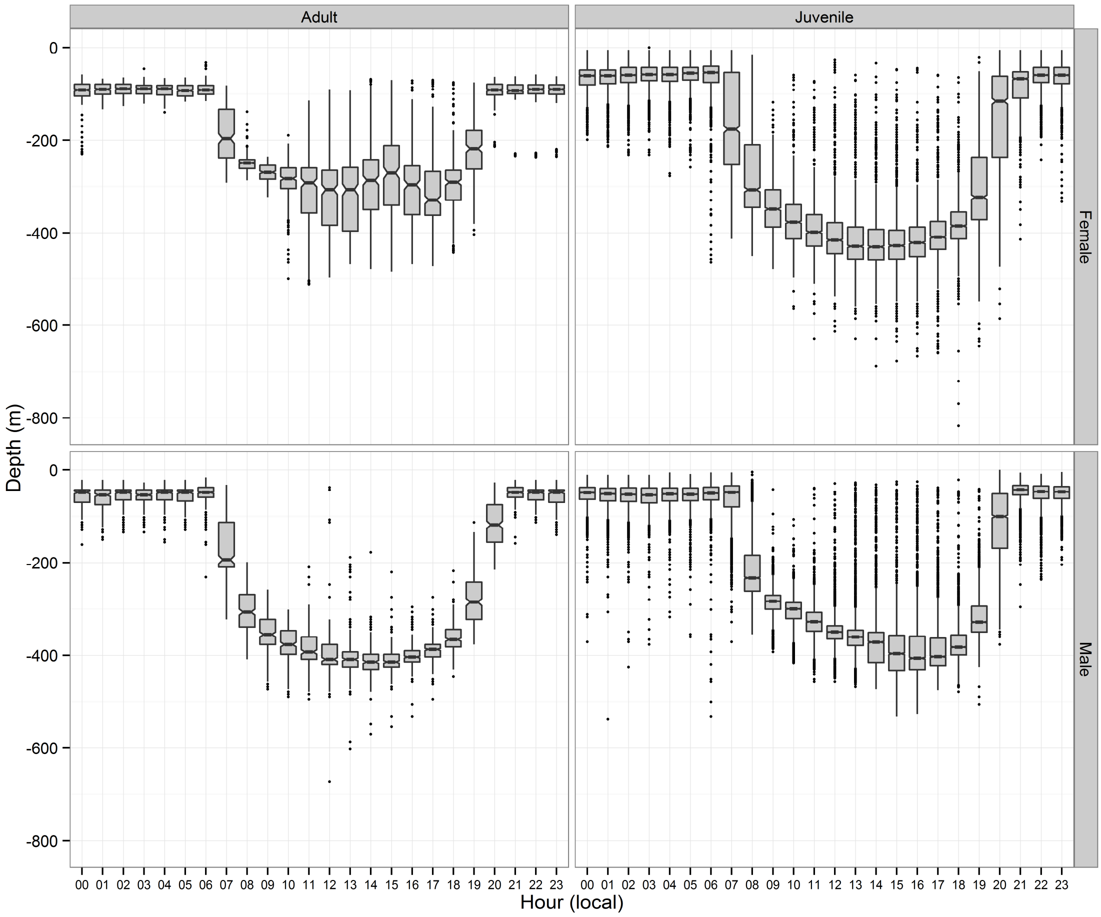

Figure 3: Bigeye thresher shark, *Alopias superciliosus*, habitat utilization with the data categorized in one hour time classes, separated by sex and maturity stage. The data represented is the median, the 1st and 3rd quartiles, the 95% confidence intervals of the median and the outliers.

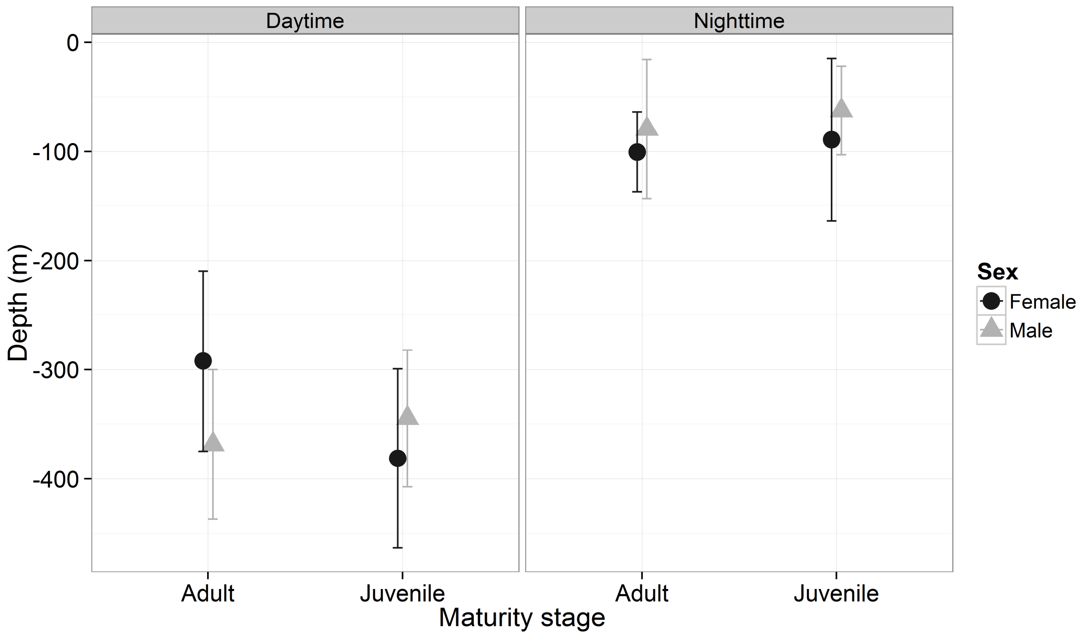

Figure 4: Mean depth of bigeye thresher sharks, *Alopias superciliosus*, separated by maturity stage (adult and juvenile) and sex (male and female), during daytime and nighttime. The error bars refer to the standard deviations.

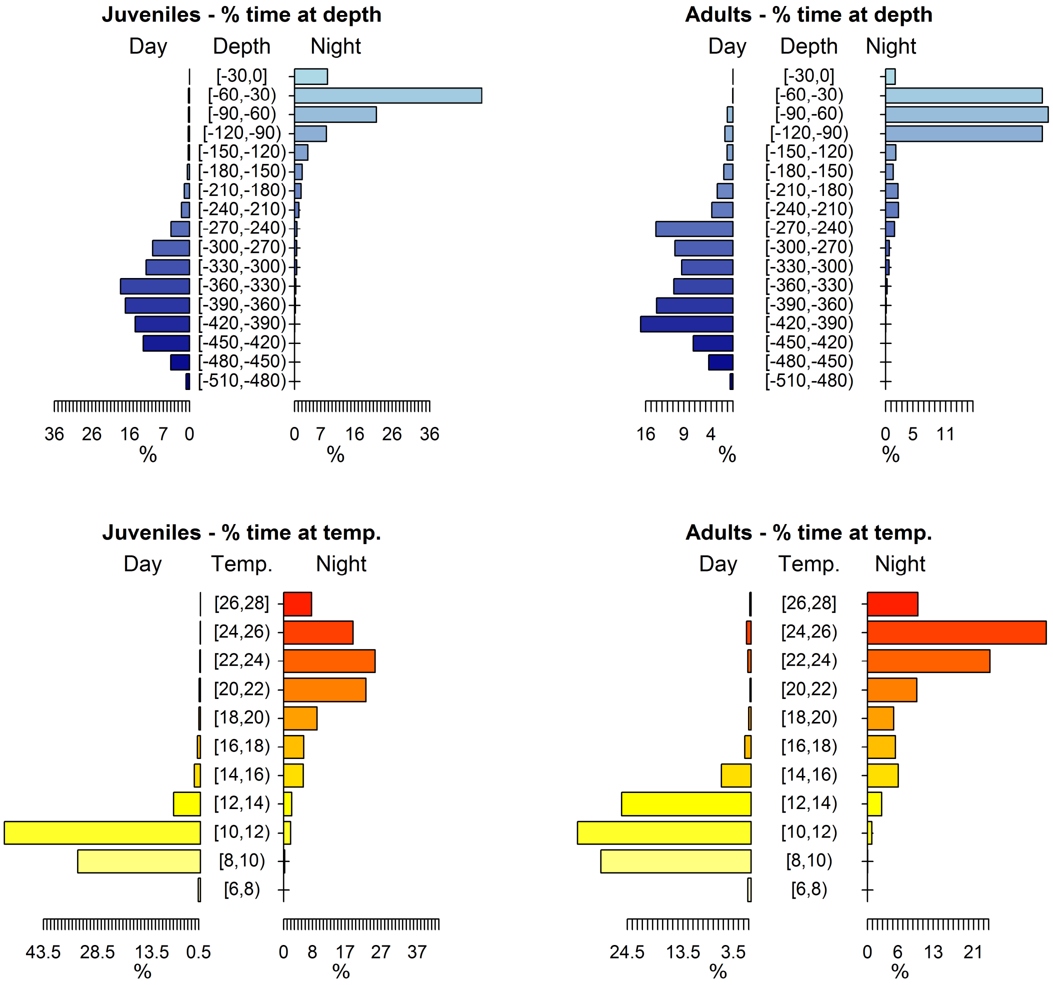

Figure 5: Habitat utilization for juvenile and adults bigeye thresher sharks, *Alopias superciliosus*, for daytime and nighttime in terms of depth and temperature. Depth classes are categorized in 30 m intervals and temperature classes in 2ºC intervals.

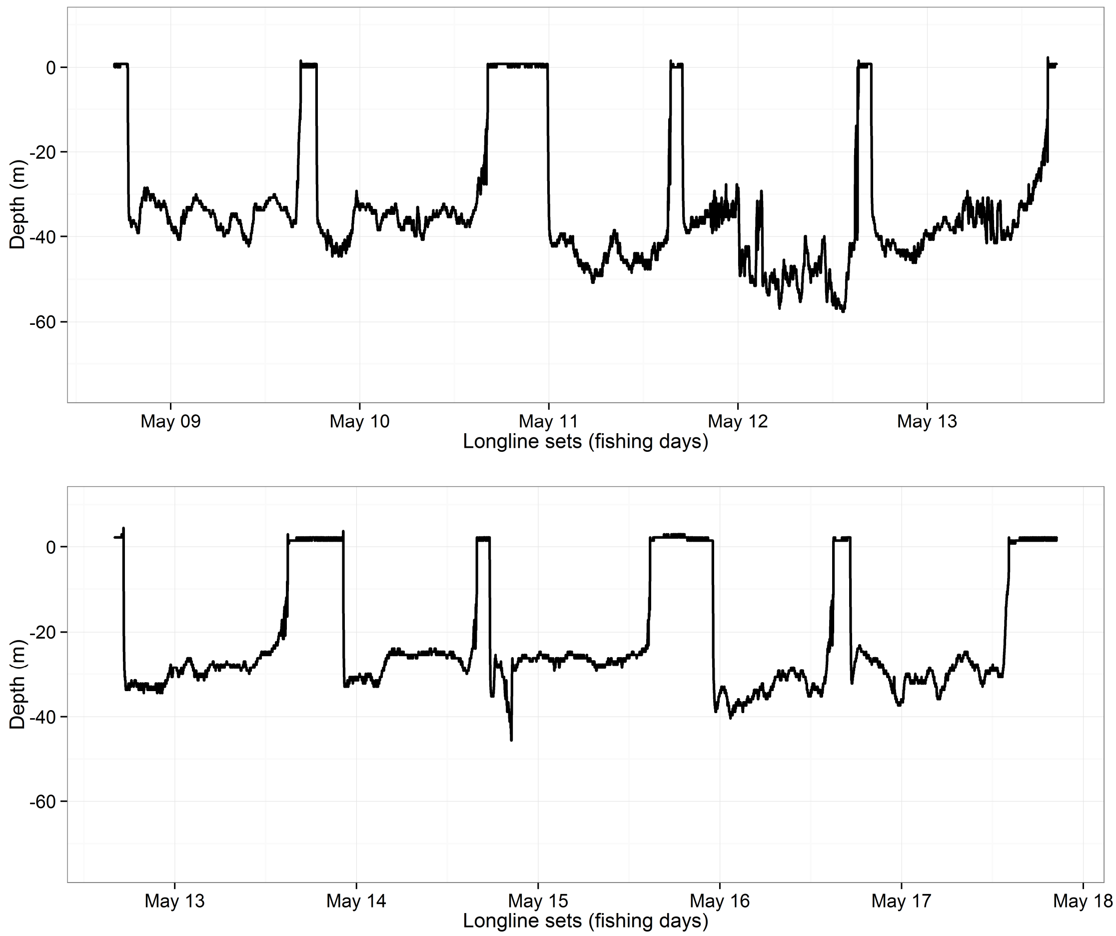

Figure 6: Examples of times series of temperature and depth recorders (TDRs) deployments on a traditional pelagic longline gear targeting swordfish, using 16 m (plot on the top) and 12 m (plot on the bottom) float lines. In these plots, each time series represents a sequence of 5 fishing sets (days).