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

Rui Coelho [a, b, *], Joana Fernandez-Carvalho [a, b], Miguel N. Santos [a]

[a] Portuguese Institute for the Ocean and Atmosphere, I.P. (IPMA), Avenida 5 de Outubro s/n, 8700-305 Olhão, Portugal
[b] Centre of Marine Sciences (CCMAR), University of Algarve, FCT, Ed. 7, Campus de Gambelas, 8005-139 Faro, Portugal

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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 = 10.7 °C, SD = 1.8) and nighttime spent in warmer water closer to the surface (mean depth = 72 m, SD = 54; mean temperature = 21.9 °C, 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.

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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

* Corresponding author. Portuguese Institute for the Ocean and Atmosphere, I.P. (IPMA), Avenida 5 de Outubro s/n, 8700-305 Olhão, Portugal.
E-mail address: rpcoelho@ipma.pt (R. Coelho).

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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 (Fig. 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 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 0–1296 m with a resolution of 0.34–5.4 m (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 min 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 0–1296 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 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.

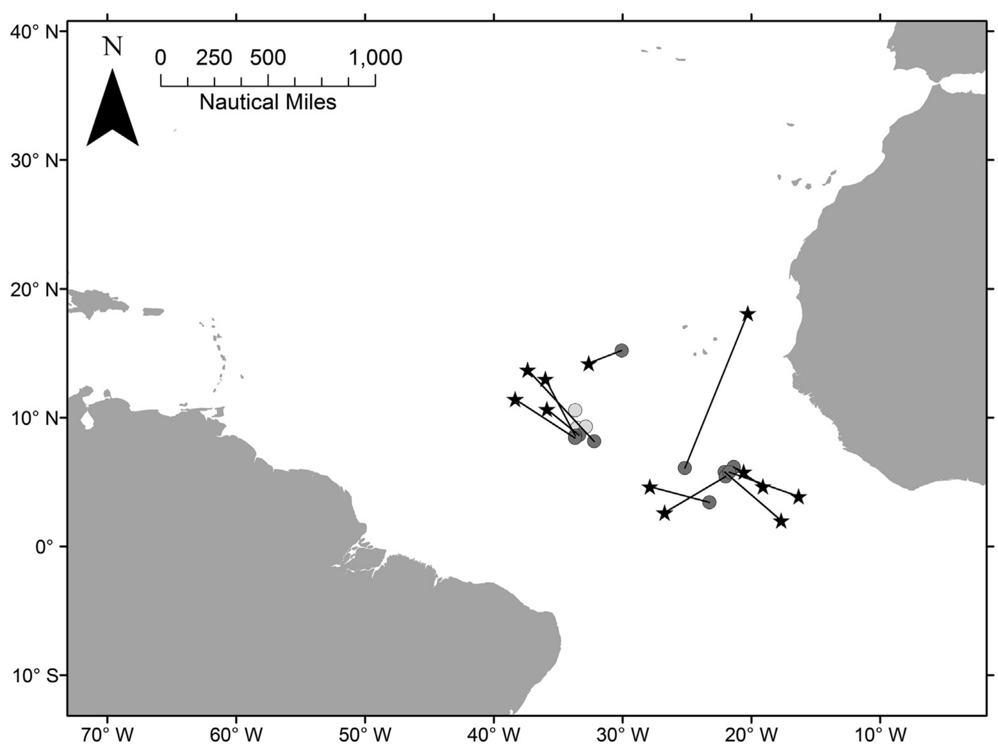

Fig. 1. Tagging and pop-up locations of the bigeye thresher sharks, *Alopias superciliosus*, tracked with pop-up satellite archival tags (PSATs) in this study. The tagging locations of specimens with successful tag transmissions are represented in dark grey circles, the tagging locations of specimens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

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