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HABITAT USE AND MIGRATIONS OF SHORTFIN MAKO IN THE ATLANTIC USING SATELLITE TELEMETRY

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SUMMARY

This paper provides an update of the study on habitat use for shortfin mako, developed within the ICCAT Shark Research and Data Collection Program (SRDCP). Currently, all phase 1 (2015-2016) tags (23 tags: 9 miniPATs and 14 sPAT) and 11 tags from phase 2 (2016-2018) have been deployed by observers on Portuguese, Uruguayan, Brazilian and US vessels in the temperate NE and NW, Equatorial and SW Atlantic. Data from 32 tags/specimens is available and a total of 1260 tracking days have been recorded. Results showed shortfin makos moved in multiple directions, travelling considerable distances. Shortfin mako sharks spent most of their time above the thermocline (0-90 m), between 18 and 22 °C. The main plan for the next phase of the project is to continue the tag deployment during 2018 in several regions of the Atlantic.

RÉSUMÉ

Ce document fournit une mise à jour de l'étude sur l'utilisation de l'habitat du requin-taupe bleu, élaborée dans le cadre du Programme de recherche et de collecte de données sur les requins (SRDCP) de l'ICCAT. A l'heure actuelle, toutes les marques de la phase 1 (2015-2016) (23 marques : 9 mini PAT et 14 sPAT) et 11 marques de la phase 2 (2016-2018) ont été apposées par des observateurs déployés à bord de navires portugais, uruguayens, brésiliens et américains dans les eaux tempérées du nord-est et du nord-ouest de l'Atlantique ainsi que dans le sud-ouest et l'Atlantique équatorial. Les données provenant de 32 marques/spécimens sont disponibles et un total de 1.260 jours de suivi a été enregistré. Les résultats ont montré que le requin-taupe bleu se déplaçait dans plusieurs directions, parcourant des distances considérables. Les requins-taupes bleus ont passé la majeure partie de leur temps au-dessus de la thermocline (0-90 m), entre 18 et 22 ° C. L'objectif principal de la prochaine phase du projet est de poursuivre l'apposition de marques en 2018 dans plusieurs régions de l'Atlantique.

RESUMEN

Este documento proporciona una actualización del estudio del uso del hábitat del marrajo dientuso, desarrollado en el marco del Programa de recopilación de datos e investigación sobre tiburones de ICCAT (SRDCP). Actualmente, todas las marcas de la fase 1 (2015-2016) (23 marcas: 9 miniPAT y 14 sPAT) y 11 marcas de la fase dos (2016-2018) han sido colocadas por los observadores en buques portugueses, uruguayos, brasileños y estadounidenses en el Atlántico noreste y noroeste templado y en el Atlántico suroccidental y ecuatorial. Los datos de las 32 marcas/ejemplares están disponibles y se han consignado en total 1.260 días de seguimiento. Los resultados mostraron que el marrajo dientuso se movía en múltiples direcciones, y que recorría distancias considerables. El marrajo dientuso pasa la mayor parte de su tiempo por encima de la termoclina (0-90 cm), entre 18 y 22º. El plan principal para la próxima fase del proyecto es proseguir con la colocación de marcas durante 2018 en varias regiones del Atlántico.

KEYWORDS
Habitat use; Movement patterns;
Satellite tagging; Shortfin mako; Sharks research program

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1. Introduction

In 2013 the ICCAT Shark Species Group developed the general guidelines of the Shark Research and Data Collection Program (SRDCP), aimed at the development and coordination of science and science-related activities needed to support provision of sound scientific advice for the conservation and management of sharks in the Atlantic. During the 2014 inter-sessional meeting, the Sharks Working Group updated the SRDCP, which was framed within the 2015-2020 SCRS Strategic Plan. The initial 3-year implementation of this Research Program focuses on biological aspects, ecology and fisheries of shortfin mako shark (*Isurus oxyrinchus*) that are relevant to the upcoming stock assessment of this important species.

Quantifying habitat use and migration patterns is important for management of fish populations and conservation planning. The knowledge of the movement patterns (i.e., use of space and activity patterns) is essential in understanding the behavior of a species as well as defining essential habitats. The need to understand whether fish are migrating between regions that can be undergoing different types and levels of fishing activity is also very important. Another important aspect is related with quantifying mortality. However, even though those issues are of great importance, there is still limited information on the stock structure and post-release mortality of most pelagic elasmobranchs at an ocean wide level. Using incorrect assumptions about the stock structure, movements and mortality can lead to biased conclusions about the level of fishing that is sustainable. Therefore, information about these processes should be incorporated into stock assessments.

In recent years, and especially due to advances in technology, satellite tagging has been increasingly used in several pelagic shark species, including lamniform sharks in the Atlantic, such as the porbeagle, *Lamna nasus* (e.g., Pade *et al.*, 2009), and the basking shark, *Cetorhinus maximus* (e.g., Sims *et al.*, 2003, 2006; Shepard *et al.*, 2006; Skomal *et al.*, 2009). By the contrary, the currently available information for the shortfin mako is still very scarce at a global level. The most comprehensive study to date was carried out by Vaudo *et al.* (2017) who analyzed data from 20 shortfin makos tagged in the NW Atlantic. Additionally, one specimen has also been tagged in the past in the SW Atlantic as part of a collaborative project between NOAA and DINARA (USA and Uruguay).

Given the wide range of information that can be gathered with satellite telemetry studies, within the ICCAT SRDCP, two studies using satellite telemetry were developed, specifically: 1) a study that uses satellite telemetry to gather and provide information on stock boundaries, movement patterns and habitat use of shortfin mako in the Atlantic; and 2) a study that uses satellite telemetry to determine post-release mortality of discarded specimens. This document presents the results of the habitat use study (1).

2. Materials and methods

2.1 Tag acquisition

Two models of tags were used: MiniPAT and Survivorship PAT (sPAT) tags built by Wildlife Computers (WC). The first tags acquisition process was completed during October-November 2015 by the ICCAT Secretariat, and the tags were then distributed to the participating Institutes in late 2015. In this first project phase, a total of 9 miniPATs and 14 sPATs were acquired (funds from 2015). Additionally, in late 2016, 12 additional miniPATs were acquired with the funds from 2016 for deployment during 2017-2018, during the second phase of the project. As one of the original miniPATs (2015) failed due to a depth sensor problem, the tag manufacturer provided one additional replacement tag. As such, for the second phase of the project a total of 13 miniPATs were available for deployment in 2017-2018. **Table 1** describes the numbers of tags acquired during the two project phases and their allocation for deployment as well as the current deployment status.

2.2 Tagging procedure

Tagging took place across a wide area of the Atlantic Ocean between 2015 and 2018, and was conducted onboard Uruguayan research vessel and vessels from the Portuguese, Brazilian and US pelagic longline fleet (**Figure 1**). The tag deployment was opportunistic when shortfin mako sharks were captured during the regular fishing operations. Sharks were either hoisted alongside the vessel or brought on board for tagging. An umbrella-type nylon dart was used to insert the tag laterally to the dorsal musculature below the first dorsal fin base, using the methodology described by Howey-Jordan *et al.* (2013). The entire tagging operation lasted a maximum of 2 minutes, and did not produce any additional injuries or damage to the specimens. Before tag attachment, tags were tested for accurate data collection, and were programmed to record information for periods between 30 and

120 days. In addition, the animals were sexed and measured for fork length (FL). Date and time were recorded, and the geographic tagging location (latitude and longitude) was determined by Global Positioning System (GPS).

2.3 Data analysis

Geographic positions at tagging were determined by GPS, while the pop-up locations of transmitting tags were established as the first point of transmission with an Argos satellite. In order to investigate movement patterns, the most probable tracks between tagging and pop-up locations were calculated from miniPATs light level data using astronomical algorithms provided by the tag manufacturers. To improve the geolocation accuracy, a state-space model incorporating a sea surface temperature field was applied using the Wildlife Computers GPE3 software (Wildlife Computers, 2015). In the case of sPATs, light sensors are not optimized for geolocation. Therefore, the distances travelled by the sharks tagged with sPATs were measured in straight lines between the tagging and the pop-up locations.

Vertical habitat use was only analyzed for sharks tagged with miniPATs. Vertical habitat use was investigated by calculating the percentage of time-at-depth and time-at-temperature, and was separately analyzed for daytime and nighttime. Sunset and sunrise were calculated using library “RAtmosphere” in R (Biavati, 2014), and took into account the date (Julian day), latitude and longitude (Teets, 2003). Time-at-depth and time-at-temperature data were aggregated into 30 m and 2°C 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. In the case of sharks tagged with sPATs, daily minimum and maximum depth and temperature from sPATs reports were analyzed for vertical habitat use.

All statistical analyses for this paper were carried out with the R language (R Core Team, 2016). Plots were created using libraries “plotrix” (Lemon, 2006) and “ggplot2” (Wickham, 2009).

3. Results and Discussion

3.1 Tag performance

Thirty-four tags (20 miniPATs and 14 sPATs) were deployed during this study (**Figure 1**), with data from thirty-two tags successfully transmitted. A total of 1260 tracking days was registered (**Table 2**).

3.2 Movement patterns

Estimated most likely tracks of sharks tagged with miniPATs are shown in **Figure 2**. For sharks tagged with sPATs, the tagging and the pop-up locations were connected with straight lines to become track segments (**Figure 3**). The distances travelled ranged from 30 km to 9035 km for 2 and 47 tracking days, respectively (**Table 3**).

In terms of movements, it is interesting to note that specimens tagged in the temperate NE Atlantic moved, predominantly, to southern areas off the Canary archipelago and West Africa. Generally, sharks tagged in the Equatorial region of the Atlantic moved easterly, with shark 167208 travelling more than 8900 km along the African west coast. The specimens tagged in the SW Atlantic off Uruguay followed oscillatory swimming patterns and tended to stay in the same general area. Finally, for sharks tagged in the temperate NW Atlantic no clear pattern in horizontal movements was observed. Specifically, shark 167204 moved north while shark 167203 moved south towards the Caribbean coastal waters and then returned north. Sharks tagged with sPATs in the NW Atlantic followed general southern movements.

This preliminary analysis confirmed that the shortfin mako has a wide geographic distribution and is found in both hemispheres from high-latitude temperate regions to tropical zones (Vaudo *et al.*, 2017; Abascal *et al.*, 2011). Horizontal movements showed shortfin makos moved in multiple directions and travelled long distances, confirming the species migratory nature (Compagno, 2001). The reasons for these movements are unknown, although several aspects related to foraging, reproduction and water temperature might explain them (Casey and Kohler, 1992; Holts and Bedford, 1993; Passarelli *et al.*, 1995; Petersen, 2007).

3.3 Vertical habitat use

Shortfin mako sharks swam through a depth range from the surface down to 620 m, with mean depth of 67.32 m. Water temperatures ranged between 8.10 and 29.90 ºC, with mean temperature of 19.57 ºC. However, sharks spent most of their time in depths above 90 m and preferred a range of water temperatures from 18 to 22 ºC, during both daytime and nighttime (**Figure 4**). The results described were consistent with previous studies (e.g., see Casey and Kohler, 1992; Loefer *et al.*, 2005; Stevens *et al.*, 2010; Abascal *et al.*, 2011; Vaudo *et al.*, 2016).

4. Contribution of SMA satellite telemetry data from other projects

The participating scientists and Institutes in this study had also other ongoing projects and initiatives that also included the deployment of satellite telemetry tags in SMA (see details in **Table 4**):

- *Project LL-Sharks:* 10 tags have been deployed on SMA specimens by Portuguese fishing vessels in the tropical NE and equatorial regions within the scope of Project LL-Sharks (*Mitigação das capturas de tubarões na pescaria de palangre de superfície*; Ref: 31-03-05-FEP-44; funded by PROMAR).

- *Project MAKO-WIDE*: Within project MAKO-WIDE - *A wide scale inter-hemispheric and inter-disciplinary study aiming the conservation of the shortfin mako shark in the Atlantic Ocean*; Ref: FAPESP/19740/2014; funded by FCT-Portugal and FAPESP-São Paulo, Brazil), we are in the process of acquiring 16 additional miniPAT tags, of which 10 will be deployed by Portuguese vessels in the NE tropical and temperate Atlantic and 6 will be deployed by Brazilian vessels in the SW Atlantic.

- *Project SAFEWATERS SC-07*: This project (*The provision of advice on the conservation of pelagic sharks associated to fishing activity under EU Sustainable Fisheries Partnership Agreements in the Atlantic Ocean*, under the Framework Contract MARE/2012/21, funded by the European Commission) deployed 5 miniPATs in SMA in the EEZ of Cabo Verde (tropical NE Atlantic).

- *NOAA (US-PRT-URY) collaboration project*: Within this collaboration project that involves scientists from NOAA (US), DINARA (Uruguay) and IPMA (Portugal), 9 miniPATs have been acquired by NOAA and are in the process of being deployed in the NW Atlantic. Additionally, one previous tag also from NOAA was deployed in 2014 by Uruguay in the SW Atlantic.

5. Project progress and future steps

Currently, all tags from the phase 1 and 11 tags from phase 2 have been deployed. Additional tags have also been deployed by national programs and projects that are cooperating with the ICCAT/SRDCP initiative.

The main plan for the next phase of the project is to continue the tag deployment during 2018 in the various regions of the Atlantic. The main deliverables and outcomes expected for these projects are SCRS papers. Specifically, an update is now presented in this paper and we plan to provide more detailed analyses and results on the project during the SMA ICCAT stock assessment meeting in 2019. Submission of the final results to peer-review journals are also envisioned pending agreement of all participants in the study.

6. Acknowledgments

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NOAA in US-Uruguay and US-Portugal-Uruguay collaboration initiatives. Rui Coelho is supported by an Investigador-FCT contract from the Portuguese Foundation for Science and Technology (FCT) supported by the EU European Social Fund and the Programa Operacional Potencial Humano (Ref: IF/00253/2014).

References

Abascal F.J., Quintans M., Ramos-Cartelle A., Mejuto J. 2011. Movements and environmental preferences of the shortfin mako, *Isurus oxyrinchus*, in the southeastern Pacific Ocean. Mar Biol 158: 1175–1184.

Biavati G. 2014. RAtmosphere: standard atmospheric profiles. R package version 1.1. Available from: https://CRAN.R-project.org/package=RAtmosphere.

Casey J.G., Kohler N.E. 1992. Tagging studies on the shortfin mako shark (*Isurus oxyrinchus*) in the western North Atlantic. Aust J Mar Freshwat Res 43:45–60.

Compagno L.J.V. 2001. Sharks of the world: an annotated and illustrated catalogue of shark species known to date, vol 2: Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). FAO species Catalogue for Fishery Purposes, no 1, vol 2, pp 269.

Holts D.B., Bedford D.W. 1993. Horizontal and vertical movements of the shortfin mako shark, Isurus oxyrinchus, in the Southern California Bight. Aust J Mar Freshwat Res 44:901–909.

Howey-Jordan L.A., Brooks E.J., Abercrombie D.L., Jordan L.K., Brooks A., Williams S., Gospodarczyk E., Chapman D.D. 2013. Complex movements, philopatry and expanded depth range of a severely threatened pelagic shark, the oceanic whitetip (*Carcharhinus longimanus*) in the western North Atlantic. PloS one 8:e56588.

Lemon J. 2006. Plotrix: a package in the red light district of R. R-news 6:8-12.

Loefer J.K., Sedberry G.R., McGovern J.C. 2005. Vertical movements of a shortfin mako in the western North Atlantic as determined by pop-up satellite tagging. Southeast Nat 4: 237–246.

Pade N.G., Queiroz N., Humphries N.E., Witt M.J., Jones C.S., Noble L.R., Sims D.W. 2009 First results from satellite-linked archival tagging of porbeagle shark, *Lamna nasus*: Area fidelity, widerscale movements and plasticity in diel depth changes. J Exp Mar Biol Ecol 370: 64–74.

Passarelli N., Knickle C., DiVittorio K. 1995. Isurus oxyrinchus: Florida Museum of Natural History. Retrieved June 17, 2018, from https://www.floridamuseum.ufl.edu/fish/discover/species-profiles/isurus-oxyrinchus/.

Petersen S., Nel D., Omardien A. 2007. Towards an Ecosystem Approach to Longline Fisheries in the Benguela: an assessment of impacts on seabirds, sea turtles and sharks. WWF Report Series - 2007/Marine/001.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from: http://www.R-project.org/.

Shepard E.L.C., Ahmed M.Z., Southall E.J., Witt M.J., Metcalfe J.D., Sims D.W. 2006. Diel and tidal rhythms in diving behaviour of pelagic sharks identified by signal processing of archival tagging data. Mar Ecol Prog Ser 328: 205–213.

Sims D.W., Southall E.J., Richardson A.J., Reid P.C., Metcalfe J.D. 2003. Seasonal movements and behaviour of basking sharks from archival tagging: no evidence of winter hibernation. Mar Ecol Prog Ser 248: 187–196.

Sims D.W., Witt M.J., Richardson A.J., Southall E.J., Metcalfe J.D. 2006. Encounter success of free-ranging marine predator movements across a dynamic prey landscape. Proc R Soc B 273: 1195–1201.

Skomal G.B., Zeeman S.I., Chisholm J.H., Summers E.L., Walsh H.J., McMahon K.W., Thorrold S.R. 2009. Transequatorial migrations by basking sharks in the western Atlantic Ocean. Curr Biol 19: 1019–1022.

Stevens J.D., Bradford R.W., West G.J. 2010. Satellite tagging of blue sharks (*Prionace glauca*) and other pelagic sharks off eastern Australia: depth behaviour, temperature experience and movements. Mar Biol 157:575-91.

Teets D.A. 2003. Predicting sunrise and sunset times. The College Mathematics Journal 34:317-21.

Vaudo J.J., Byrne M.E., Wetherbee B.M., Harvey G.M., Shivji M.S. (2017). Long-term satellite tracking reveals region-specific movements of a large pelagic predator, the shortfin mako shark, in the western North Atlantic Ocean. J Appl Ecol 54:1765-1775.

Vaudo J.J., Wetherbee B.M., Wood A.D., Weng K., Howey-Jordan L.A., Harvey G.M., Shivji M.S. 2016. Vertical movements of shortfin mako sharks *Isurus oxyrinchus* in the western North Atlantic Ocean are strongly influenced by temperature. Mar Ecol Prog Ser 547:163-175.

Wickham H. ggplot2: elegant graphics for data analysis. 1st ed. New York: Springer. 2009. Available from: https://CRAN.R-project.org/package=ggplot2.

Wildlife Computers. 2015. Data Portal's Location Processing (GPE3 & FastLoc-GPS) User Guide. Retrieved June 17, 2018, from https://wildlifecomputers.com/wp-content/uploads/manuals/Location-Processing-User-Guide.pdf

Table 1. List with the distribution of miniPATs and sPATS by the participating Institutes, for the 2 project phases. Current deployment status and additional notes are also provided.

Project Phase	Institute	Tag types and quantities	Tagging areas	Status of deployment
Phase 1 (2015-2016)	IPMA (Portugal)	6 miniPATs + 4 sPATS	Temperate NE	All tags deployed
	NOAA (US)	5 sPATs	Temperate NW	All tags deployed
	DINARA (Uruguay)	3 miniPATs + 5 sPATS	SW Atlantic	All tags deployed
Phase 2 (2016-2018)	IPMA (Portugal)	3 miniPATS	Tropical NE, Equatorial (E)	All tags deployed
	NOAA (US)	3 miniPATS	Temperate NW	2 tags deployed
	DINARA (Uruguay)	4 miniPATs	SW Atlantic	All tags deployed
	UFRPE (Brazil)	3 miniPATS	Equatorial (W)	2 tags deployed

Table 2. Total tracking days of shortfin mako sharks (*Isurus oxyrinchus*). N is the number of tags deployed for tag model.

Tag model	Tracking days
miniPAT (N=19)	946
sPAT (N=13)	314
Total	1260

Table 3. Characteristics of the tracks taken by shortfin mako sharks, *Isurus oxyrinchus*, with information on effective tracking days and distance travelled. Note that sPATs are marked with a star (*).

Tag ID	Tracking days	Distance travelled (km)
70638	30	1933
157339	121	3958
157340	2	30
157341	120	2131
157342	66	2396
157343	17	802
157344	2	347
157345	5	349
157346	-	-
157347	21	225
167199	33	1030
167201	120	4537
167202	18	1091
167203	47	9035
167204	73	6695
167206	10	1349
167207	36	5830
167208	117	8931
167209	85	4513
167210	23	1572
157365*	30	367

157366*	30	561
157367*	30	1171
157368*	30	104
157369*	29	530
157370*	30	476
157371*	1	33
157372*	30	270
157373*	30	278
157374*	-	-
157375*	30	1191
157376*	30	280
157377*	13	794
157378*	1	34

Table 4. Information from the tags deployed by participating national scientists and institutes with additional funds from other sources and projects.

Project	Tag ID	Tag model	Date	Planned (months)	Tracking days
LL-Sharks (EU.PRT)	136367	MTI Standard	10-Aug-15	2	-
	136368	MTI Standard	19-Aug-15	2	18
	136369	MTI Standard	24-Oct-15	2	61
	136370	MTI Standard	26-Oct-15	2	61
	136371	MTI Standard	27-Oct-15	2	61
	136372	MTI Standard	27-Oct-15	4	123
	136373	MTI Standard	28-Oct-15	4	43
	136374	MTI Standard	23-Dec-15	4	122
	136376	MTI Standard	29-Dec-15	4	68
	136375	MTI Standard	7-Feb-16	4	-
Safewaters SC07 (EU)	160177	miniPAT	02-Aug-16	4	121
	160178	miniPAT	24-Sep-16	4	10
	160179	miniPAT	06-Sep-16	4	3
	160180	miniPAT	20-Sep-16	4	121
	160181	miniPAT	19-Sep-16	4	3
NOAA (US-Uruguay) collaboration		MK10 PAT	14-Oct-14		72

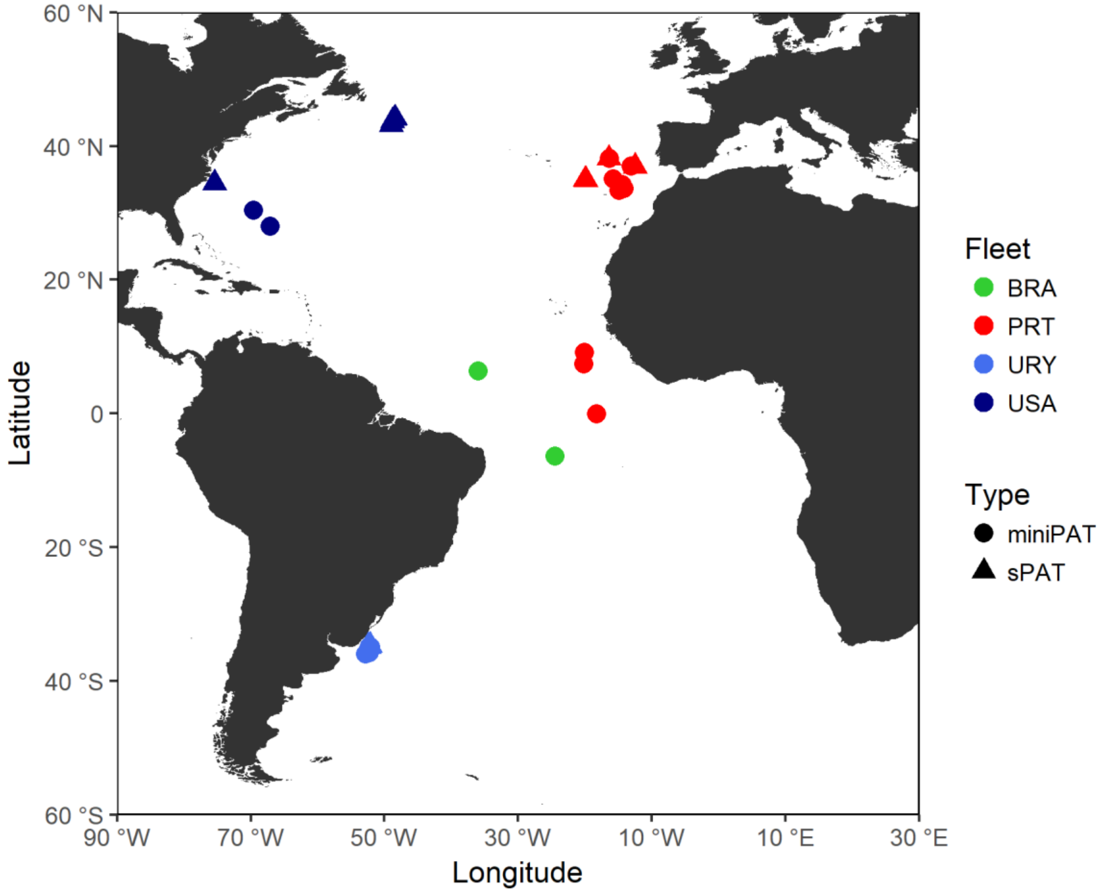

Figure 1. Location of the satellite tag deployments (miniPATs and sPATs) for shortfin mako sharks (*Isurus oxyrinchus*), within the ICCAT/SRDCP Project.

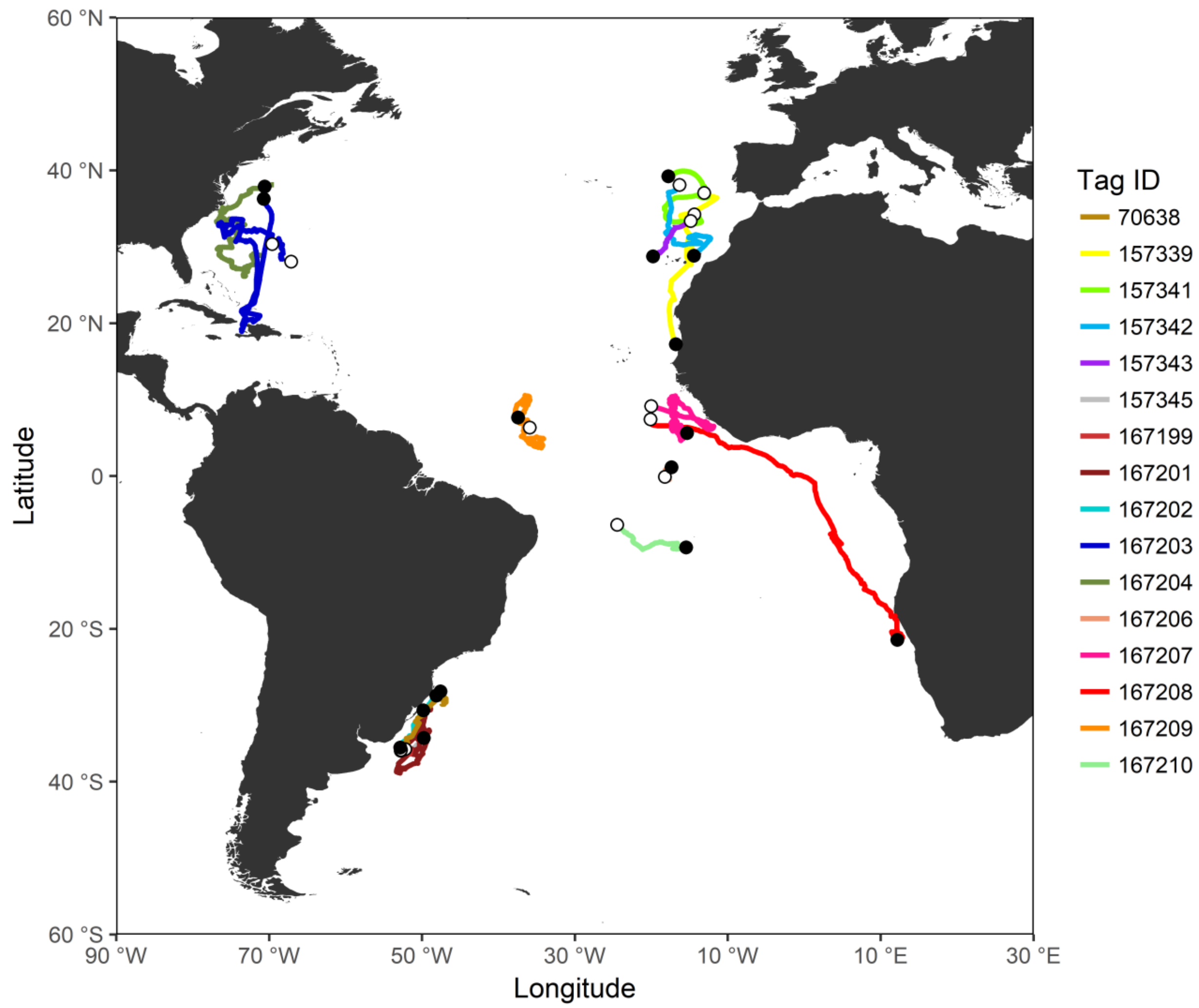

Figure 2. Most likely tracks of shortfin mako sharks (*Isurus oxyrinchus*) tagged with miniPATs. The tagging locations are represented with white circles and the pop-up locations are represented with black circles (see **Table 3** for details).

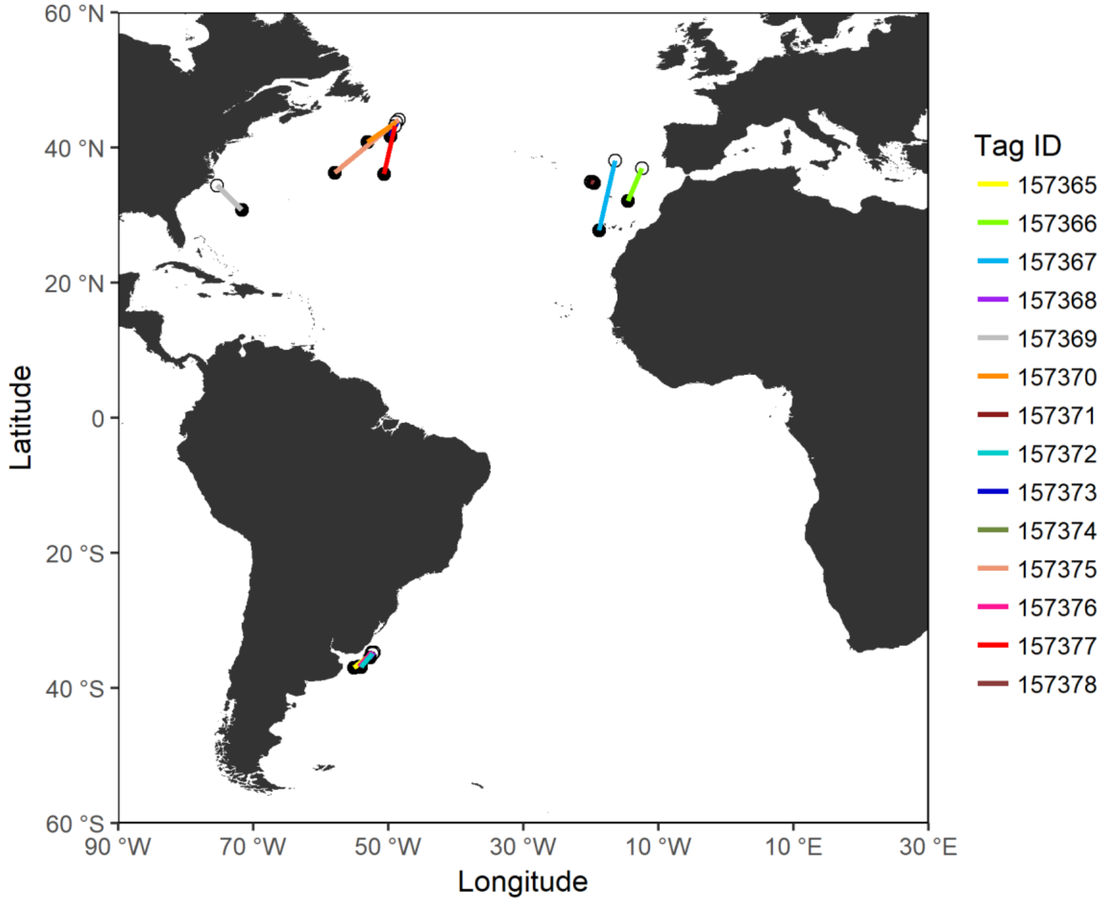

Figure 3. Strait line tracks of shortfin mako sharks (*Isurus oxyrinchus*) tagged with sPATs. The tagging locations are represented with white circles and the pop-up locations are represented with black circles (see **Table 3** for details).

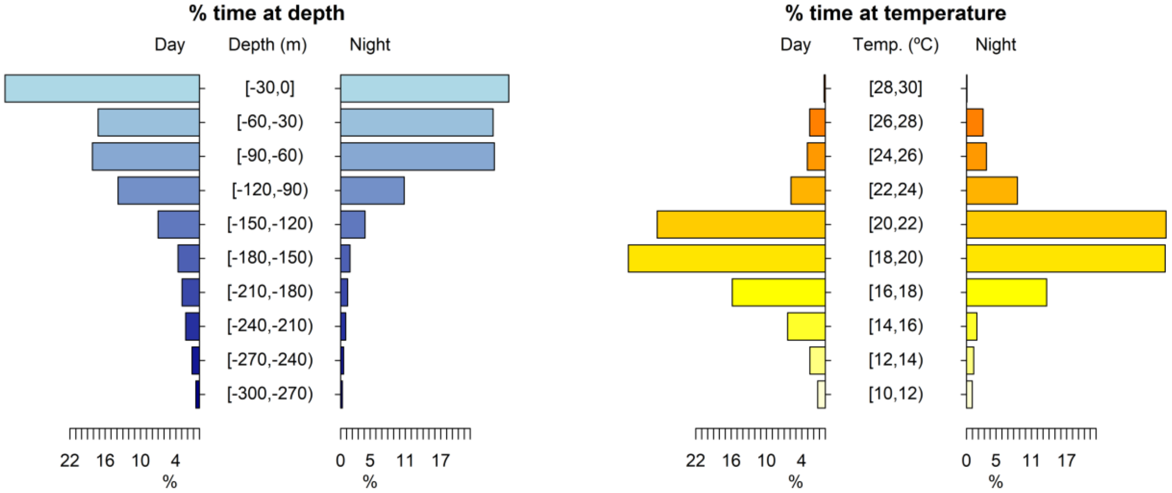

Figure 4. Vertical habitat use of shortfin mako sharks (*Isurus oxyrinchus*), for daytime and nighttime in terms of depth and temperature.