Post-release mortality of pelagic sharks caught by longliners – POREMO and ASUR projects

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Abstract

Pelagic sharks are occasionally caught incidentally by longliners operating in the Indian Ocean, among them species that are classified as vulnerable, endangered and critically endangered by IUCN and listed on CITES Annex II. Retention of some pelagic shark species is prohibited by IOTC (e.g. oceanic whitetip shark, thresher sharks) and despite the efforts made by fishing crew members to safely handling and releasing these sharks, post-release mortality (PRM) needs to be assessed. Projects POREMO (2018-2023) and ASUR (2020-2023) were dedicated to this task, the former solely on oceanic whitetip shark, and the latter on all shark species bycaught by longliners. Onboard observers deployed respectively 14 and 40 electronic popup tags on 6 shark species (blue shark – BSH, silky shark – FAL, oceanic whitetip – OCS, shortfin mako – SMA, scalloped hammerhead – SPL, smooth hammerhead – SPZ, tiger shark – TIG) bycaught and release by French and Portuguese longliners in the south-western Indian Ocean between 2018 and 2025. Based on 46 tags that reported data, we determined the overall PRM rate for each species and intended to explore the potential effect of tagging conditions, time spent on deck, hook type, hooking location, removal of hook, length of line trail, fish condition upon, length of the individual, and sex, on PRM. We found very few cases of mortality, hence high survival rate after release: 100 % for BSH, SMA, SPL and SPZ, 95 % for OCS, 75 % for FAL, and 67 % for TIG. Despite extensive information collected by observers, due to unbalanced samples, drivers of PRM could not be thoroughly investigated. However, we were able to show that time spent on deck impairs FAL survivability, and that J-hooks yield higher mortality in OCS. Overall, this study suggests that retention bans for sharks together with best practices for releasing sharks would be an efficient conservation measure.

Keywords

Selachii | Post-release mortality | Survival | Bycatch | Longline | Western Indian Ocean

1. Introduction

Pelagic sharks bycaught tuna and tuna-like fisheries are sensitive species generally classified as "Vulnerable", "Endangered", and "Critically Endangered" by the IUCN (IUCN, 2025) and listed on the CITES Appendix II prohibiting trade on this species (CITES, 2025). Various pelagic sharks are occasionally bycaught in the Indian Ocean by longline and purse seine fleets, among other fishing gears (IOTC, 2024). Pelagic sharks are particularly vulnerable to overfishing due to their characteristics of low reproductive rates, slow growth, and late maturity (Cortés, 2000).

IOTC prohibits the retention of thresher sharks since 2013 (Res. 12/09; Res. 25/08), and since 2014 whale sharks (Res. 13/05; Res. 25/08) and oceanic whitetip sharks (Res. 13/06; Res. 25/08) as an incentive conservation and mitigation measure to avoid the catch and promote the live release of these species. While retention ban measures are generally considered insufficient for the recovery of shark populations (Tolotti et al., 2015), it is crucial, for assessing the effectiveness of such measures and usefulness of efforts made by vessel to carefully handle and release sharks (Annex III of Res. 25/08), to assess the post-release survival rate of these species. Moreover, post-release mortality is necessary to estimate the total fishing mortality on a given species, which is required for stock assessment purposes (Bowlby et al., 2021).

The POREMO (*POst-RElease Mortality of Oceanic whitetip shark*) (2018-2023) and ASUR (*Connaissance et Amélioration de la SUrvie des Requins rejetés par les pêcheries palangrières pélagiques*) (2020-2023) projects, under the coordination of IRD (France) and with co-funding from both IRD (France) and the European Commission (as part of the "Data Collection Framework"), respectively addressed the post-release mortality of OCS that are unintentionally caught and released by longliners and purse seiners in the Indian Ocean (Bach et al., 2018; Bach et al., 2019; Bach et al., 2021; Sabarros et al., 2023), and pelagic sharks bycaught by French longliners in the Indian Ocean (Massey et al, 2023).

In this paper, we provide the results of the post-release mortality studies of pelagic sharks bycaught by longliners in the Indian Ocean, as part of the POREMO and ASUR projects. In addition to providing the overall mortality/survival rates of pelagic sharks released by longliners, we investigated the effect of the tagging condition, time spent on deck before release, hook type and location, condition of individuals upon release, length of individuals, and sex, on the post-release mortality.

2. Material and methods

2.1. Data

Popup satellite archival tags manufactured by Wildlife Computers (Redmond, USA) were employed to evaluate the post-release mortality of pelagic sharks released by longliners (Bach et al., 2018). Two distinct models, namely the survival PAT (sPAT) and the miniPAT from Wildlife Computers (Redmond, WA, USA), were used. Tags were rigged with a 12 cm stainless-steel tether and were affixed with Domeier, small or large Titanium anchors (Table 1) to be implanted at the basis of the first dorsal fin (Bach et al., 2018). Tags were programmed for a period of 30 or 60 days for sPATs, and 180 or 360 days for miniPATs (Table 1). At the onset of the POREMO project, 13 and 1 tags were respectively given to the purse seine observer program coordinators from France (IRD) and Portugal (IPMA) to be deployed on the respective longline fleets operating in the Indian Ocean (Bach et al., 2018). All 40 tags of ASUR project were planned to be deployed on French longliners. Tagging kits were provided to observers, including the protocol, tagging form, electronic tag (sPAT or miniPAT), tag applicator, and tagging pole (Bach et al., 2018). Information collected on the individuals on board longliners included the tagger's name, vessel name, date, geographic location, tagging conditions ("In water" or "On board"), time spent on deck (in min) if tagged on board, hook type ("Circle", "J-hook", "Teracima" or "Unknown"), hooking location ("Caudal fin", "Cheek", "Dorsal fin", "Eye", "Jaw", "Mouth", "Swallowed", "Throat" or "Unknown"), hook removed ("Yes" or "No"), length of line trail after cutting the branchline (in cm), fish condition at haulback and upon release ("Alive good", "Alive injured", "Alive moribund"), length of the individual (Fork Length in cm), and sex ("Female", "Male" or "Unknown") (Table 2; Figure 1). Table 3 shows the tag popup date (when it started transmitting data), the number of days at liberty, the tag release diagnostic ("Interval (full deployment)", "Premature", "Floater", "Too deep" and "No transmission"), and our assessment of whether the individual died after being released based of the examination of depth profiles (Figure S1; see section 2.2).

2.2. Analyses

Post-release mortality was assessed based on the depth profiles collected by electronic tags fitted on released sharks (Figure S1). Mortality was detected when the individual sank at depths below 1700 m or remained at the constant depth for 3 days above 1700 m (on the continental shelf for example). If a tag detached from an individual before the initially scheduled deployment time, possibly due to inadequate anchoring, the depth profile was examined to confirm whether the individual was exhibiting normal vertical movements.

Overall post-mortality rates by species tagged were calculated and provided in Table 4.

We then investigated for each species potential drivers of post-release mortality based on the data collected during tagging operation, notably tagging conditions (“In water” vs “On deck”), time spent on deck, hook type (“Circle”, “J-hook”, “Teracima” or “Unknown”), hooking location (“Caudal fin”, “Cheek”, “Dorsal fin”, “Eye”, “Jaw”, “Mouth”, “Swallowed”, “Throat” or “Unknown”), hook removed (“Yes” or “No”), length of line trail after cutting the branchline, fish condition at upon release (“Alive good”, “Alive injured”, “Alive moribund”), length of the individual, and sex (“Female”, “Male” or “Unknown”).

To examine the effect of time on deck on FAL mortality, we fitted a Bayesian logistic regression model using the *brms* R package (Bürkner, 2017). Mortality (0 = survived, 1 = died) was modeled as a binary response variable with time on deck (minutes) as a continuous predictor, assuming a Bernoulli likelihood. Given the small sample size (n = 4) and the presence of only a single mortality event, we specified weakly informative normal priors (mean = 0, SD = 2) for both the intercept and slope to regularize parameter estimates and avoid overfitting. Posterior distributions were estimated using Markov Chain Monte Carlo (MCMC) sampling with 2 chains and 2000 iterations per chain. Model predictions and 95% credible intervals were derived from the posterior predictive distribution and visualized across the observed range of time on deck (Figure 2).

To explore the effect of hooks in OCS mortality, we calculated mortality rates by type of hook (“Circle”, “J-hook”, “Teracima”, “Unknown”) (Figure 3).

3. Results

In POREMO and ASUR projects combined, 55 electronic tags – 43 sPATs and 12 miniPATs – were deployed by 8 scientific observers on 10 longliners flagged EU.FRA and EU.PRT between 2018 and 2023 in the western Indian Ocean (Table 2; Figure 1). Observers tagged 7 different shark species: 23 oceanic whitetip sharks (*Carcharhinus longimanus* – OCS) ranging between 81 and 200 cm FL, 11 blue sharks (*Prionace glauca*-BSH) between 150 and 250 cm FL, 6 shortfin makos (*Isurus oxyrinchus* – SMA) between 130 and 250 cm FL, 6 silky sharks (*Carcharhinus falciformis* – FAL) between 97 and 200 cm FL, 4 tiger sharks (*Galeocerdo cuvier* – TIG) between 150 and 250 cm FL, 3 scalloped hammerheads (*Sphyrna lewini* – SPL) between 150 and 250 cm FL, and 2 smooth hammerheads (*Sphyrna zygaena* – SPZ) between 170 and 250 cm FL (Table 2; Figure 1). Forty-seven (47) tags transmitted and reported data (86 %; Table 3).

Only 3 out of 55 tagged sharks succumbed following their release: 1 OCS (PTT#49014), 1 TIG (PTT#210110), and 1 FAL (PTT#210129) (Table 3; Figure S1). All 3 individuals died and sank immediately after release (Table 3; Figure S1). Among the 52 individuals that survived, 17 tags exhibited premature detachment (33 %; Table 3). The PRM rates for each species are: 33 % for TIG (n = 3), 25 % for FAL (n = 4), 5 % for OCS (n = 22), and 0 % for BSH, SMA, SPL, and SPZ (n = 9, 5, 3, and 1 respectively) (Table 4).

Among the 55 sharks tagged, all were “Alive good” at the time of hauling and were released in “Alive good” condition, expect for one SPZ (PTT#286261) and OCS (PTT#210095) that was “Alive injured”. Despite being injured, the female OCS of 99 cm FL survived (Table 3).

A large portion of sharks were not brought on the deck and were tagged “In water” by the vessel (78 %). For those that were brought and tagged “On board” (22 %), the time they spent on deck varied between 5 and 10 min (Table 3). The FAL (PTT#210129) that had spent 10 min on the deck, was release in “Alive good” condition but died immediately after release (Table 3; Figure S1). The Bayesian binomial regression shows that time on deck significantly impairs survivability above a threshold situated around 5 min (Figure 2).

Most individuals (65 %) were hooked in the mouth (n = 33), jaw (n = 1) or cheek (n = 1), while 22 % swallowed the hook (n = 6) or had it stuck in the throat (n = 6), and 4 % had their dorsal (n =1) or caudal fin (n = 1) (Table 3). Hook was not removed in 98 % (n = 52) of the cases (Table 3). The TIG (PTT#210110) that was caught up by the caudal fin, and which hook was removed, eventually died right away (Table 3; Figure S1). For those being released with a hook, the branchline was either completely removed (14 %; n = 7) or cut at a distance (86 %; n = 43), leaving a line trail ranging between 2 and 200 cm (Table 3).

Among the 22 OCS tagged, 11 were caught on circle hooks, 7 on J-hooks, 2 on Teracima hooks, and 2 unknown hooks (Table 3). The only OCS that died (PTT#49014) was caught on a J-hook (in the mouth), rising the mortality of OCS on J-hooks to 14 % (Figure 3).

4. Discussion

The rate of non-reporting tags (14 %) is comparable to other tagging experiments using electronic popup satellite archival tags (e.g., Musyl et al., 2011; Sabarros et al., 2015; Sabarros et al., 2023). Apart from actual technical component failure, tags generally do not report when they are unable to transmit data to satellites, potentially due to being situated under marine debris on the surface or being predated and therefore ingested by random predators (Sabarros et al., 2015).

A substantial portion of the tags (33 %) exhibited premature detachment from tagged individuals, a circumstance that can likely be attributed to poor anchoring. All tags expect one were rigged with Titanium anchors that are supposedly more difficult to implant than Domeier anchors (Bach et al., 2019). For comparison, tags deployed on OCS released by purse seiners in POREMO project were mostly rigged Domeier anchors to ease tagging operations by observers but a much larger proportion on the tags (62 %) detached prematurely (Sabarros et al., 2023). This suggests that even though Titanium anchors are supposedly harder to use, especially by observers that do not possess expert-level proficiency in tagging techniques, they hold better on sharks compared to Domeier anchors. Also, a couple observers deployed a more than half the tags (respectively 27 and 11), and thereby likely gained expert-level proficiency in tagging, which may also explain the overall higher retention found in this study. Nonetheless, premature detachments had no impact on our ability to assess mortality in all tagged sharks from POREMO and ASUR projects.

The highest post-release mortality was recorded for TIG with 33 %, although this estimate based on only 3 individuals. TIG are generally considered resilient (Ellis et al., 2016), as demonstrated in Afonso and Hazin (2014) and Gallagher et al. (2014) who reported 0 % post-release mortality for longline-caught TIG in the Atlantic Ocean. Surprisingly, the TIG that died in our study was not internally hooked; it had been caught by the caudal fin, the hook was subsequently removed, and the shark appeared to be in good condition at the time of release.

FAL exhibited the second-highest post-mortality rate, with 25 %, based on 4 individuals. The single mortality involved a relatively small specimen (110 cm FL) hooked in the mouth with a circle hook. This individual was brought onboard and remained out of the water for the longest duration among all tagged sharks (10 min) before released Despite appearing in good condition and swimming away upon release, depth profile data indicated that it sank rapidly thereafter. Post-release mortality of FAL caught by longliners has been reported as highly variable, averaging 16 % according to the meta-analysis by Musyl and Gilman (2019) based on Pacific Ocean data.

Among 22 OCS caught by French and Portuguese longliners and released alive in the Indian Ocean, only 5 % succumbed after release. This rate is lower than the 16.3 % estimated in Musyl and Gilman (2019) meta-analysis based on data from the Pacific Ocean. The low post-release mortality observed in our study may be explained by the fact that 61 % of individuals were released directly without being brought onboard and that 96 % were assessed as being in “Alive good” condition at release. The single OCS mortality involved a mouth-hooked individual caught with a J-hook (not removed), which appeared to be healthy and active at release but sank immediately according to the depth profile.

Because mortalities were rarely observed among individuals bycaught by longliners and tagged in POREMO and ASUR projects, our analyses of the potential factors driving post-release mortality were limited to 3 species: FAL, OCS and TIG. Moreover, the occurrence of only a single fatality in each species constrained the statistical power of the analyses, as the dataset was highly unbalanced (fatalities vs. survivals). The analyses that could be performed, as well as those that were not feasible, are summarized in Table 4. Below, we describe notable patterns identified for each species.

In longline operations, bycaught sharks can either be released when pulled by the side of the vessel or after being brought on board. When sharks are not brought on board, fishermen generally cut the branchline, leaving a more or less long line trail, and are not able to remove the hook. When brought on board, the hook can be removed, but not in all cases, depending on the dangerousness of such operation, for example when dealing with a large and agitated shark. In the case of FAL, we were able to show that individuals that were brought on board and that spent a certain time on board (> 5 min), had lesser chances of survival. This suggests that, to the extent possible, FAL should directly be released in water, without being brought on board, and if so, should be promptly release, within 5 min to maximize their survival chances.

The type of hook is known to influence catch rates and potentially mortality of species caught by longliners, positively or negatively, with patterns greatly varying among species (e.g., Ward et al., 2009). In our study, OCS caught with J-hooks had a higher post-release mortality rate (14 %) compared with individuals caught on other hook types (e.g., circle, Teracima), for which no mortality was observed. J-hooks are more likely than circle and Teracima hooks to lodge internally in the stomach, esophagus, or throat, where they can cause severe injuries and compromise survival. Nevertheless, the single OCS mortality recorded here involved an individual hooked with a J-hook, in the mouth, a location generally not considered life-threatening.

As noted above, hooking location can be critical when it results in internal or otherwise severe injuries (e.g., ocular damage). In our study, the single TIG mortality occurred in an individual hooked on the caudal fin with a circle hook, which was subsequently removed. Although such an injury would not typically be expected to be fatal, this shark nonetheless succumbed after release. This outcome may reflect an artifact of the observations rather than the actual cause of death, and thus the underlying reason for this mortality remains uncertain.

Most tagged sharks (except 2 individuals that were injured) were released in good condition, meaning that they were not injured and swam actively after release. This might be seen as a bias in tagging operations, where observers selected individuals with higher survival chances. However, the tagging protocol specifies the observers/taggers not to select tagging candidates based on their condition. This suggests that on longliners sharks that have survived until the moment of hauling the line, are generally release in good condition. Also, despite the tagging protocol describing in detail the different conditions modalities (moribund, injured, good), we cannot exclude that the assessment by an observer is somehow subjective.

Based on those results, we highlight the importance of following good practices for safely handle and release sharks that have been developed by IOTC (Annex III in Res. 25/08) to limit short term death due to injuries hauling and release operations by longliners, and therefore maximize their chances of post-release survival. This includes bringing the shark close to the vessel for release directly in water, dehooking if possible and if not cutting the line as close to the hook as possible.

5. Acknowledgements

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7. Tables

Table 1. Electronic tags rigging and configuration

PTT.Id	Serial Number	Tag Type	Tagware Version	Tether	Anchor	Deployment period (days)	Program
46286	17P0767	sPAT	2.4q	Stainless steel	small Ti	60	POREMO
46288	17P0768	sPAT	2.4q	Stainless steel	small Ti	60	POREMO
49011	17P0134	MiniPAT	2.4n	Stainless steel	small Ti	360	POREMO
49012	17P0398	MiniPAT	2.4n	Stainless steel	Domeier	180	POREMO
49014	17P0548	MiniPAT	2.4n	Stainless steel	small Ti	360	POREMO
49016	17P0554	MiniPAT	2.4n	Stainless steel	Ti	360	POREMO
49036	17P0578	MiniPAT	2.4n	Stainless steel	small Ti	180	POREMO
49037	17P0579	MiniPAT	2.4n	Stainless steel	Ti	180	POREMO
49047	23P1698	MiniPAT	2.5c	Stainless steel	small Ti	180	POREMO
49057	17P0595	MiniPAT	2.4n	Stainless steel	Ti	180	POREMO
49067	17P0596	MiniPAT	2.4n	Stainless steel	Ti	180	POREMO
49071	17P0610	MiniPAT	2.4n	Stainless steel	small Ti	180	POREMO
203635	20P1306	MiniPAT	2.4w	Stainless steel	small Ti	180	POREMO
203636	20P1325	MiniPAT	2.4w	Stainless steel	small Ti	180	POREMO
210090	20P0165	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210091	20P1959	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210092	20P1960	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210093	20P1961	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210095	20P1968	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210096	20P1969	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210097	20P1970	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210098	23P1672	sPAT	2.5c	Stainless steel	small Ti	60	ASUR
210099	20P1972	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210100	20P1973	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210101	20P1974	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210102	20P1975	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210103	20P1994	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210104	20P2266	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210105	20P2268	sPAT	2.5d	Stainless steel	small Ti	30	ASUR
210106	20P2271	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210107	20P2272	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210108	20P2273	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210109	20P2274	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210110	20P2275	sPAT	2.5d	Stainless steel	small Ti	30	ASUR
210111	23P2129	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210112	20P2278	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
210113	20P2279	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210114	20P2280	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210116	20P2282	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210117	21P1180	sPAT	2.4y	Stainless steel	small Ti	60	ASUR
210118	20P2284	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210119	20P2285	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210120	20P2286	sPAT	2.4x	Stainless steel	small Ti	30	ASUR
210121	21P1217	sPAT	2.4y	Stainless steel	small Ti	60	ASUR
210122	21P1220	sPAT	2.4y	Stainless steel	small Ti	60	ASUR
210123	21P1221	sPAT	2.4y	Stainless steel	small Ti	30	ASUR
210124	21P1222	sPAT	2.4y	Stainless steel	small Ti	30	ASUR
210125	21P1223	sPAT	2.4y	Stainless steel	small Ti	60	ASUR
210127	21P1278	sPAT	2.4y	Stainless steel	small Ti	60	ASUR
210129	21P1282	sPAT	2.4y	Stainless steel	small Ti	30	ASUR
260478	23P2177	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
260576	23P2174	sPAT	2.5d	Stainless steel	small Ti	60	ASUR
260577	23P2176	sPAT	2.5d	Stainless steel	small Ti	30	ASUR
260579	23P2178	sPAT	2.5d	Stainless steel	small Ti	30	ASUR
286261	25P0396	sPAT	2.5h	Stainless steel	small Ti	60	ASUR

Table 2. Electronic tags' deployment details

PTT Id	Tagged species	Deployment date	Latitude	Longitude	Tagger	Vessel	Country	Tagging conditions	Time on deck (min)	Fish condition at release	Hook type	Hooking location	Hook removed	Line trail (cm)	Fork Length (cm)	Sex
46286	OCS	01/06/2021	-20,19	54,811	Damien Naert	LE GRAND MORNE	EU.REU	In water		Alive good	Circle	Mouth	No	40	100	F
46288	OCS	27/05/2021	-20,517	54,03	Damien Naert	LE GRAND MORNE	EU.REU	In water		Alive good	Circle	Mouth	No	200	200	U
49011	OCS	07/11/2021	-22,53	41,307	Damien Naert	MANOHAL	EU.REU	In water		Alive good	J-hook	Mouth	No	50	180	F
49012	OCS	14/05/2018	-32,75	34,866	Jorge Encarnaçao	VALMITAO	EU.PRT	On board	5	Alive good	Unknown				195	F
49014	OCS	07/11/2021	-22,454	41,344	Damien Naert	MANOHAL	EU.REU	In water		Alive good	J-hook	Mouth	No	50	170	U
49016	OCS	02/10/2019	-20,992	53,727	Thibault Groult	SAINTE MARIE	EU.REU	On board	8	Alive good	Teracima	Mouth	No	25	171	F
49036	OCS	09/11/2021	-22,573	40,739	Damien Naert	MANOHAL	EU.REU	In water		Alive good	J-hook	Mouth	No	30	150	U
49037	OCS	22/12/2018	-21,033	54,75	Thibault Groult	LE GRAND MORNE	EU.REU	In water		Alive good	Teracima	Mouth	No	60	135	F
49047	OCS	17/07/2024	-23,365	40,731	Nicolas Guillon	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Mouth	No	100	150	U
49057	OCS	16/01/2019	-20,673	52,745	Thibault Groult	LE GRAND MORNE	EU.REU	In water		Alive good	Unknown	Mouth	No	30	120	U
49067	OCS	20/09/2019	-19,127	56,203	Thibault Groult	SAINTE MARIE	EU.REU	On board	10	Alive good	J-hook	Mouth	No	40	134	F
49071	OCS	24/03/2022	-23,06	39,884	Damien Naert	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Mouth	No	100	180	U
203635	OCS	27/05/2021	-20,675	54,096	Damien Naert	LE GRAND MORNE	EU.REU	In water		Alive good	Circle	Mouth	No	100	120	U
203636	OCS	30/11/2020	-20,35	54,132	Thibault Groult	LE GRAND MORNE	EU.REU	In water		Alive good	Circle	Cheek	No	5	200	F
210090	TIG	07/12/2024	-18,841	41,669	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Swallowed	No	150	200	F
210091	SPL	27/03/2025	-21,496	48,666	Nicolas Guillon	SAINTE MARIE	EU.REU	In water		Alive good	Circle	Mouth	No	150	250	U
210092	FAL	21/03/2023	-12,041	46,99	Nicolas Guillon	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	0	110	U
210093	OCS	28/03/2023	-11,78	46,584	Célya Martial	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	0	90	F
210095	OCS	05/04/2023	-11,805	46,421	Nicolas Guillon	CAP CLOE	EU.REU	On board	5	Alive injured	Circle	Throat	No	5	99	F
210096	SMA	12/06/2023	-22,415	54,07	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Mouth	No	50	200	U
210097	OCS	08/06/2023	-21,936	53,192	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Swallowed	No	20	100	U
210098	OCS	17/07/2024	-23,375	40,731	Nicolas Guillon	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Mouth	No	100	130	U
210099	TIG	01/06/2023	-28,541	54,608	Dorian Vincent	REDER MOR	EU.REU	In water		Alive good	J-hook	Mouth	No	50	150	U
210100	OCS	26/03/2023	-11,445	46,743	Nicolas Guillon	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	0	81	F
210101	BSH	10/06/2023	-22,451	52,658	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Mouth	No	30	180	U
210102	BSH	10/06/2023	-22,42	52,656	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Mouth	No	50	250	M
210103	OCS	10/06/2023	-22,404	52,66	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Mouth	No		180	U
210104	SPZ	12/06/2023	-22,441	54,17	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Mouth	No	20	170	U
210105	TIG	22/03/2025	-19,973	49,148	Nicolas Guillon	SAINTE MARIE	EU.REU	In water		Alive good	Circle	Swallowed	No	100	250	U
210106	OCS	20/03/2023	-11,502	46,625	Nicolas Guillon	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	5	100	U
210107	SPL	25/06/2025	-17,197	50,16	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Jaw	No	100	150	U
210108	SPL	27/03/2025	-21,513	48,681	Nicolas Guillon	SAINTE MARIE	EU.REU	In water		Alive good	Circle	Mouth	No	100	250	U
210109	FAL	21/12/2024	-20,366	55,865	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive good	Circle	Mouth	No	10	150	F
210110	TIG	01/04/2025	-21,234	48,772	Nicolas Guillon	SAINTE MARIE	EU.REU	In water		Alive good	Circle	Caudal fin	Yes		170	U
210111	SMA	03/08/2024	-24,327	40,037	Nicolas Guillon	LE CLIPPERTON	EU.REU	In water		Alive good	Unknown	Swallowed	No	100	150	U
210112	SMA	17/07/2024	-23,208	40,772	Nicolas Guillon	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Swallowed	No	150	130	U
210113	FAL	22/03/2023	-12,164	47,176	Nicolas Guillon	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	0	97	F
210114	BSH	22/05/2023	-20,461	54,658	Dorian Vincent	REDER MOR	EU.REU	In water		Alive good	J-hook	Throat	No	30	150	U
210116	BSH	21/05/2023	-20,848	54,943	Dorian Vincent	REDER MOR	EU.REU	In water		Alive good	J-hook	Mouth	No	100	250	U

210117	BSH	08/07/2022	-12,283	47,05	Damien Naert	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Throat	No	150	170	U
210118	FAL	21/05/2023	-20,628	54,841	Dorian Vincent	REDER MOR	EU.REU	In water		Alive good	J-hook	Throat	No	5	100	U
210119	BSH	26/05/2023	-21,635	55,226	Yoluène Massey	AMOR ATAO	EU.REU	In water		Alive good	J-hook		No	150	175	F
210120	BSH	14/06/2023	-21,699	54,38	Dorian Vincent	REDER MOR	EU.REU	In water		Alive good	J-hook	Throat	No			F
210121	BSH	05/08/2022	-12,278	47,258	Damien Naert	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Mouth	No	150	215	U
210122	BSH	08/07/2022	-12,475	47,023	Damien Naert	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Throat	No	100	180	U
210123	OCS	28/03/2023	-11,627	46,554	Nicolas Guillon	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	0	99	F
210124	OCS	27/03/2023	-11,946	46,862	Célya Martial	CAP CLOE	EU.REU	On board	5	Alive good	Circle	Mouth	No	0	91	F
210125	BSH	07/07/2022	-12,462	47,014	Damien Naert	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook		No	100	250	F
210127	BSH	31/07/2022	-23,351	55,243	Nicolas Guillon	LE BIGOUDEN	EU.REU	In water		Alive good	Circle	Mouth	No	2	170	U
210129	FAL	27/03/2023	-12,089	47,164	Célya Martial	CAP CLOE	EU.REU	On board	10	Alive good	Circle	Mouth	No	0	110	M
260478	SMA	23/07/2024	-24,07	39,733	Nicolas Guillon	LE CLIPPERTON	EU.REU	In water		Alive good	Unknown	Swallowed	No	150	150	U
260576	SMA	19/07/2024	-24,099	40,037	Nicolas Guillon	LE CLIPPERTON	EU.REU	In water		Alive good	J-hook	Dorsal fin	No	150	250	U
260577	FAL	17/10/2024	-23,718	41,101	Louis Wambergue	LE CLIPPERTON	EU.REU	In water		Alive good	Unknown		No	150	200	U
260579	SMA	17/10/2024	-23,668	41,102	Louis Wambergue	LE CLIPPERTON	EU.REU	In water		Alive good	Unknown		No	100	180	U
286261	SPZ	09/08/2025	-17,402	50,162	Nicolas Guillon	VETYVER 6	EU.REU	In water		Alive injured	Circle	Eye	No	100	250	U

Table 3. Electronic tags' popup and mortality assessment

PTT Id	Tag Type	Tagged species	Deployment period (days)	Deployment date	Popup date	Days at liberty	Diagnostic	Mortality
46286	sPAT	OCS	60	01/06/2021	01/07/2021	30	Premature	No
46288	sPAT	OCS	60	27/05/2021			No transmission	
49011	MiniPAT	OCS	360	07/11/2021	04/01/2022	58	Premature	No
49012	MiniPAT	OCS	180	14/05/2018	28/05/2018	14	Premature	No
49014	MiniPAT	OCS	360	07/11/2021	07/11/2021	0	Too deep	Yes
49016	MiniPAT	OCS	360	02/10/2019	01/12/2019	60	Premature	No
49036	MiniPAT	OCS	180	09/11/2021	08/05/2022	180	Interval (full deployment)	No
49037	MiniPAT	OCS	180	22/12/2018	26/01/2019	35	Premature	No
49047	MiniPAT	OCS	180	17/07/2024	06/08/2024	20	Premature	No
49057	MiniPAT	OCS	180	16/01/2019	25/01/2019	9	Premature	No
49067	MiniPAT	OCS	180	20/09/2019	17/11/2019	58	Too deep	No
49071	MiniPAT	OCS	180	24/03/2022	09/07/2022	107	Premature	No
203635	MiniPAT	OCS	180	27/05/2021	04/08/2021	69	Premature	No
203636	MiniPAT	OCS	180	30/11/2020	03/06/2021	185	Interval (full deployment)	No
210090	sPAT	TIG	60	07/12/2024	05/02/2025	60	Interval (full deployment)	No
210091	sPAT	SPL	60	27/03/2025	26/05/2025	60	Interval (full deployment)	No
210092	sPAT	FAL	30	21/03/2023			No transmission	
210093	sPAT	OCS	30	28/03/2023	10/04/2023	13	Premature	No
210095	sPAT	OCS	30	05/04/2023	06/05/2023	31	Interval (full deployment)	No
210096	sPAT	SMA	30	12/06/2023	07/07/2023	25	Premature	No
210097	sPAT	OCS	30	08/06/2023	09/07/2023	31	Interval (full deployment)	No
210098	sPAT	OCS	60	17/07/2024	15/09/2024	60	Interval (full deployment)	No
210099	sPAT	TIG	30	01/06/2023	02/07/2023	31	Interval (full deployment)	No
210100	sPAT	OCS	30	26/03/2023	29/03/2023	3	Premature	No
210101	sPAT	BSH	30	10/06/2023	11/07/2023	31	Interval (full deployment)	No
210102	sPAT	BSH	30	10/06/2023	10/07/2023	30	Premature	No
210103	sPAT	OCS	60	10/06/2023	09/08/2023	60	Interval (full deployment)	No
210104	sPAT	SPZ	30	12/06/2023	13/07/2023	31	Interval (full deployment)	No
210105	sPAT	TIG	30	22/03/2025			No transmission	
210106	sPAT	OCS	30	20/03/2023	20/04/2023	31	Interval (full deployment)	No
210107	sPAT	SPL	60	25/06/2025	21/08/2025	57	Interval (full deployment)	No
210108	sPAT	SPL	60	27/03/2025	26/05/2025	60	Interval (full deployment)	No
210109	sPAT	FAL	60	21/12/2024	19/02/2025	60	Interval (full deployment)	No
210110	sPAT	TIG	30	01/04/2025	01/04/2025	0	Too deep	Yes
210111	sPAT	SMA	60	03/08/2024	02/10/2024	60	Interval (full deployment)	No
210112	sPAT	SMA	60	17/07/2024	15/09/2024	60	Interval (full deployment)	No
210113	sPAT	FAL	30	22/03/2023	25/03/2023	3	Premature	No
210114	sPAT	BSH	30	22/05/2023	22/06/2023	31	Interval (full deployment)	No
210116	sPAT	BSH	30	21/05/2023	21/06/2023	31	Interval (full deployment)	No
210117	sPAT	BSH	60	08/07/2022			No transmission	
210118	sPAT	FAL	30	21/05/2023			No transmission	
210119	sPAT	BSH	30	26/05/2023	26/06/2023	31	Interval (full deployment)	No
210120	sPAT	BSH	30	14/06/2023			No transmission	
210121	sPAT	BSH	60	05/08/2022	06/10/2022	62	Interval (full deployment)	No
210122	sPAT	BSH	60	08/07/2022	06/09/2022	60	Interval (full deployment)	No
210123	sPAT	OCS	30	28/03/2023	05/04/2023	8	Floater	No
210124	sPAT	OCS	30	27/03/2023	06/04/2023	11	Premature	No
210125	sPAT	BSH	60	07/07/2022	08/09/2022	63	Interval (full deployment)	No
210127	sPAT	BSH	60	31/07/2022	30/09/2022	61	Interval (full deployment)	No
210129	sPAT	FAL	30	27/03/2023	27/03/2023	0	Too deep	Yes
260478	sPAT	SMA	60	23/07/2024			No transmission	
260576	sPAT	SMA	60	19/07/2024	04/08/2024	16	Premature	No
260577	sPAT	FAL	30	17/10/2024	10/11/2024	24	Premature	No
260579	sPAT	SMA	30	17/10/2024	16/11/2024	30	Interval (full deployment)	No
286261	sPAT	SPZ	60	09/08/2025			No transmission	

Table 3. Mortality and survival rates by species. PRM: post-release mortality; PRS: post-release survival

Species	N	N dead	N surv	PRM	PRS
BSH	9	0	9	0%	100%
FAL	4	1	3	25%	75%
OCS	22	1	21	5%	95%
SMA	5	0	5	0%	100%
SPL	3	0	3	0%	100%
SPZ	1	0	1	0%	100%
TIG	3	1	2	33%	67%

Table 4. Testable effects on each species' post-release mortality

Species	N	Mortalities	Tagging conditions	Time on deck	Hook type	Hooking location	Hook removal	Line trail	Condition upon release	Length	Sex
BSH	9	0	No	No	No	No	No	No	No	No	No
FAL	4	1	**Yes**	**Yes**	No	No	No	No	No	No	No
OCS	22	1	No	No	**Yes**	No	No	No	No	No	No
SMA	5	0	No	No	No	No	No	No	No	No	No
SPL	3	0	No	No	No	No	No	No	No	No	No
SPZ	1	0	No	No	No	No	No	No	No	No	No
TIG	3	1	No	No	No	**Yes**	**Yes**	No	No	No	No

8. Figures

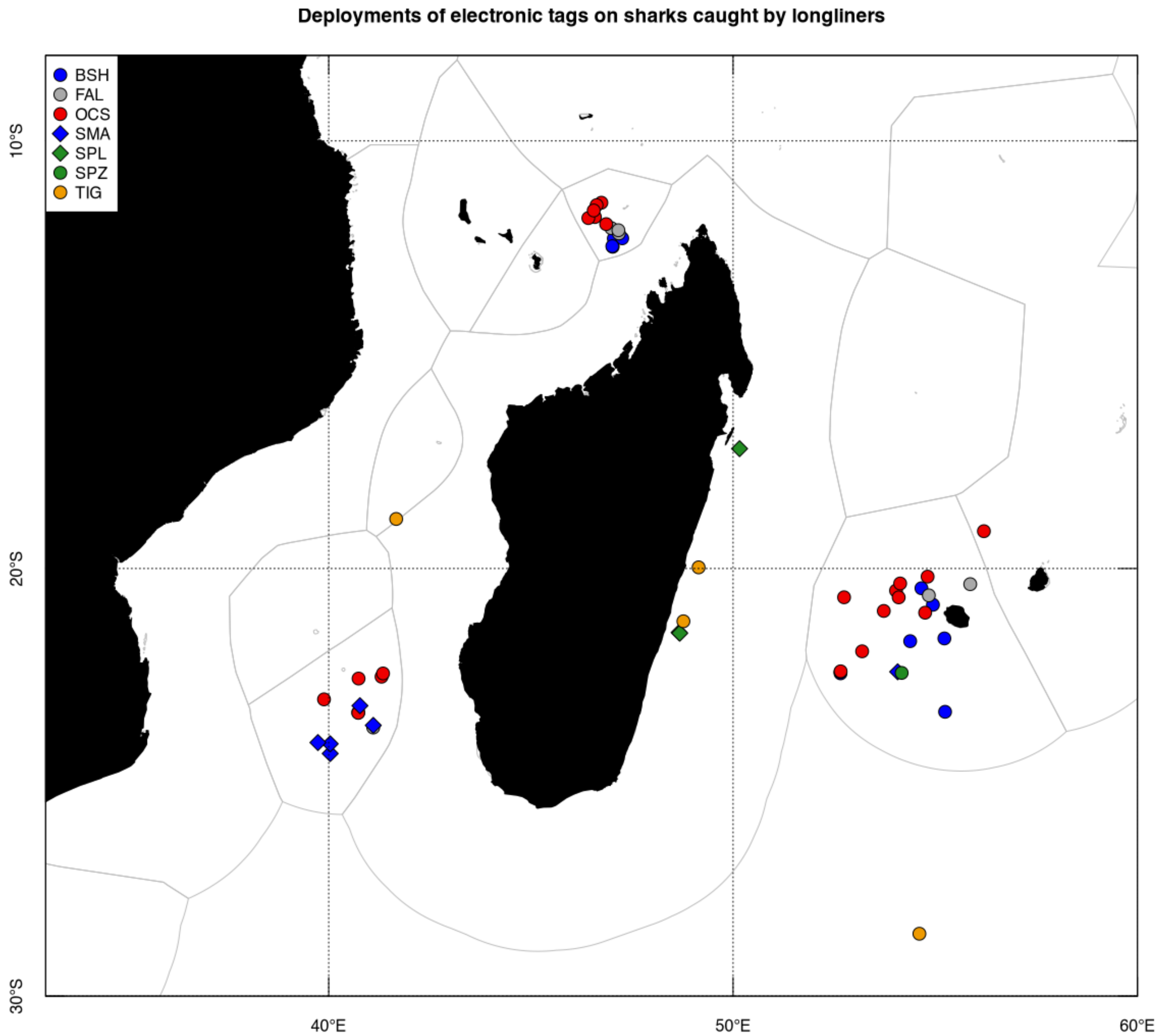


Figure 1. Map of tag deployments on pelagic sharks released by longliners in the western Indian Ocean between 2018 and 2025

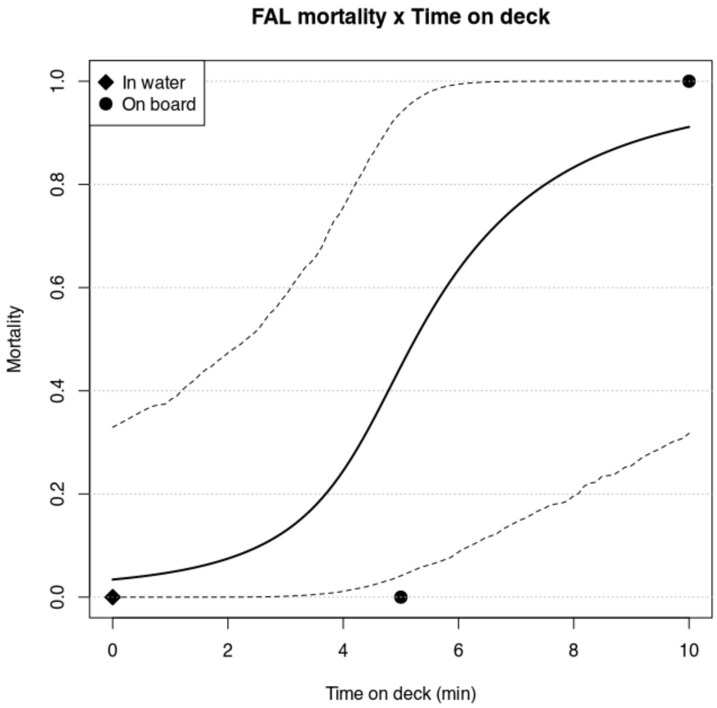


Figure 2. Bayesian binomial regression of the effect on time on deck on FAL mortality.

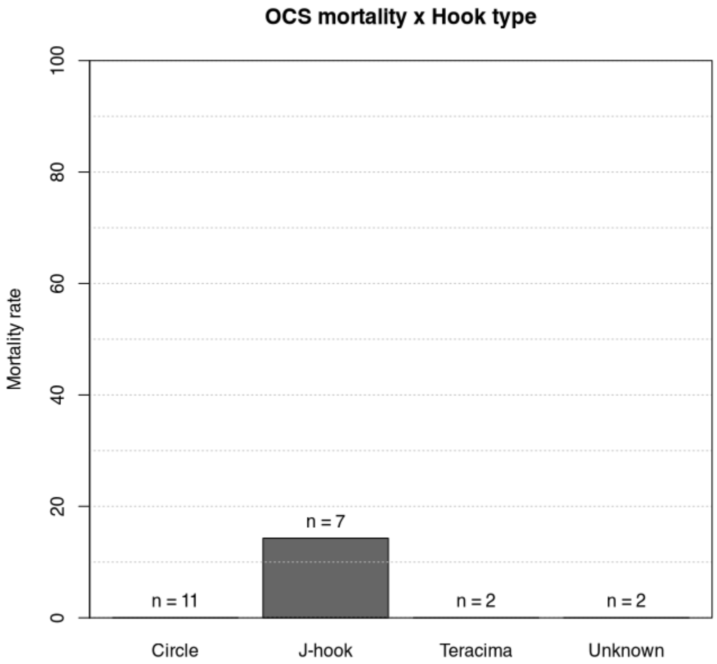
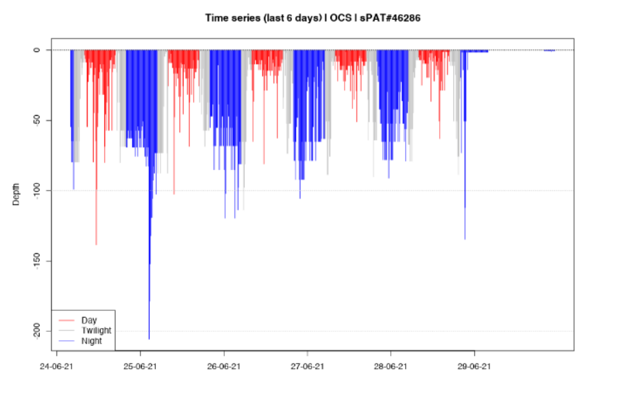
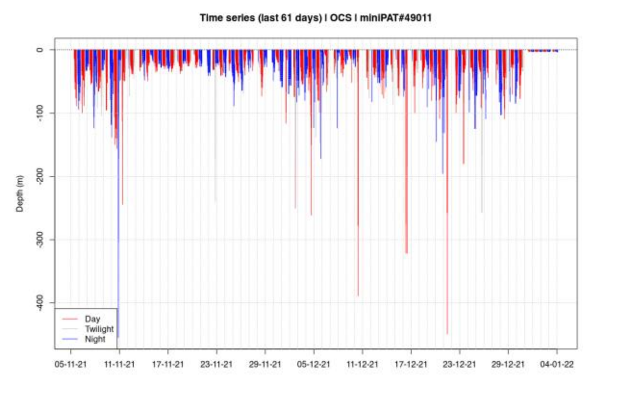
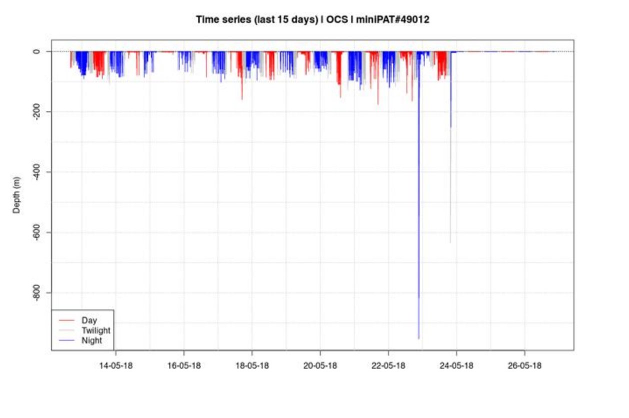


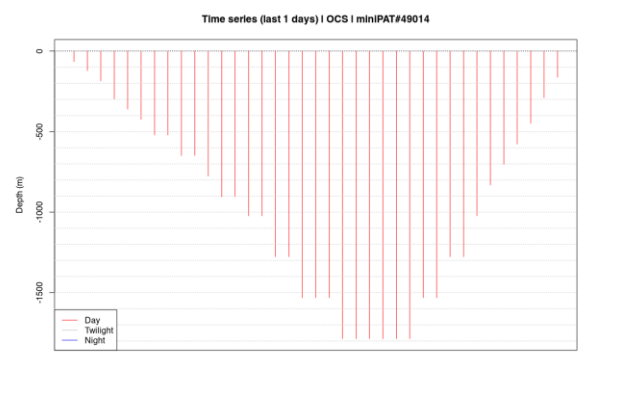
Figure 3. Post-release mortality rate of OCS by hook type

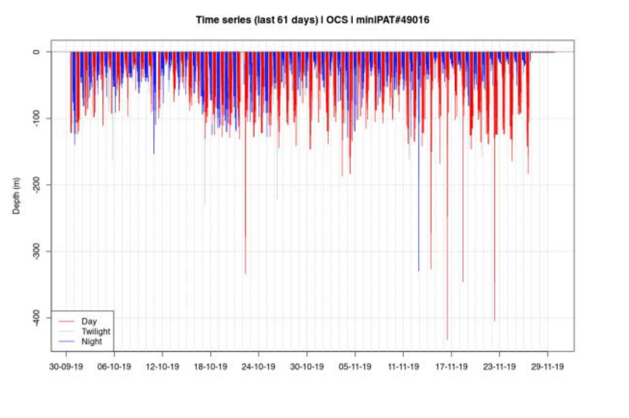
9. Supplementary material

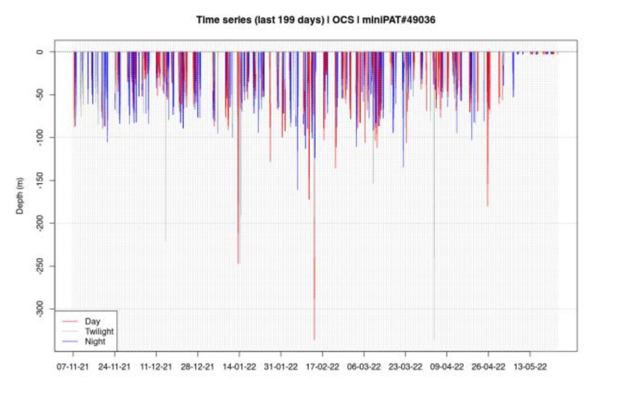


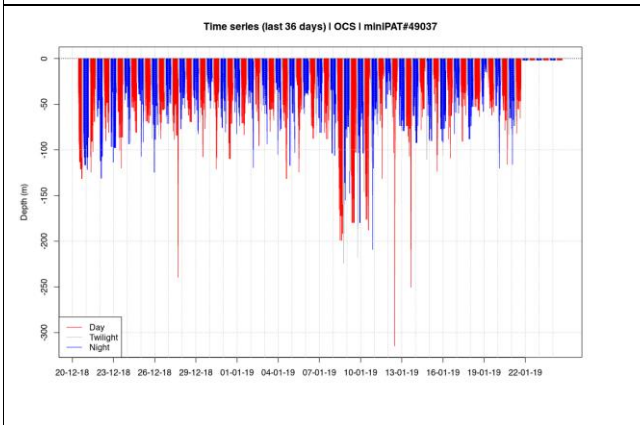


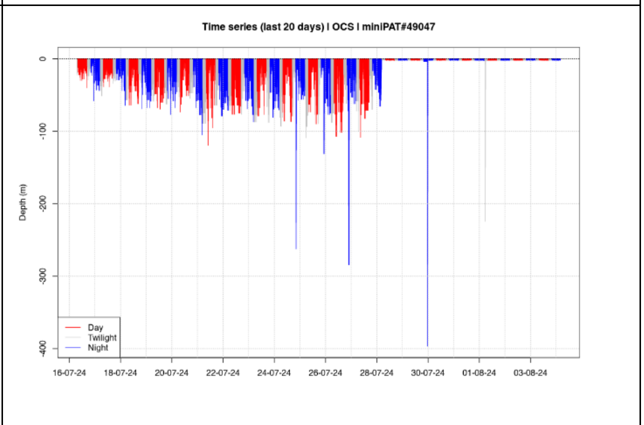


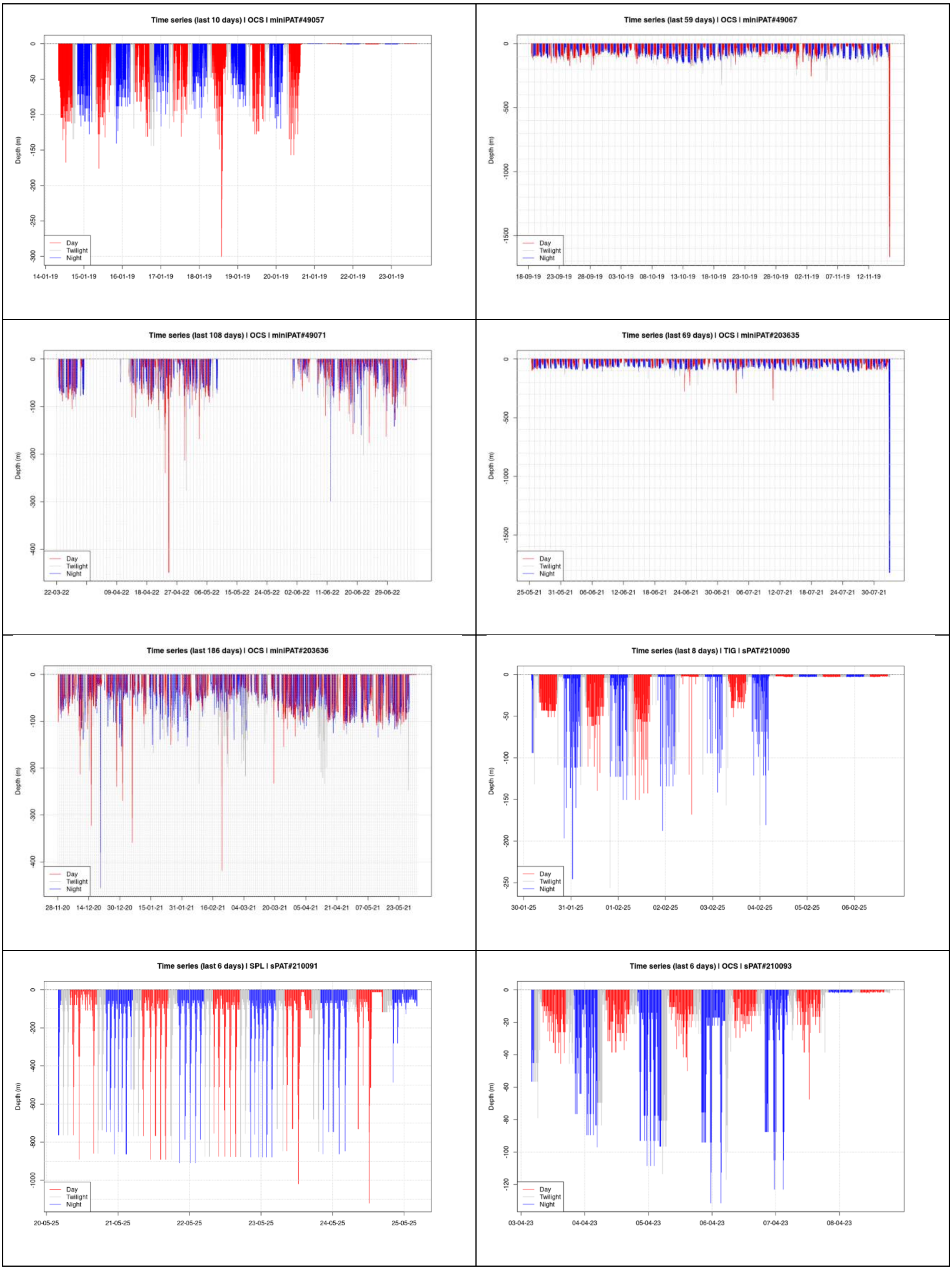


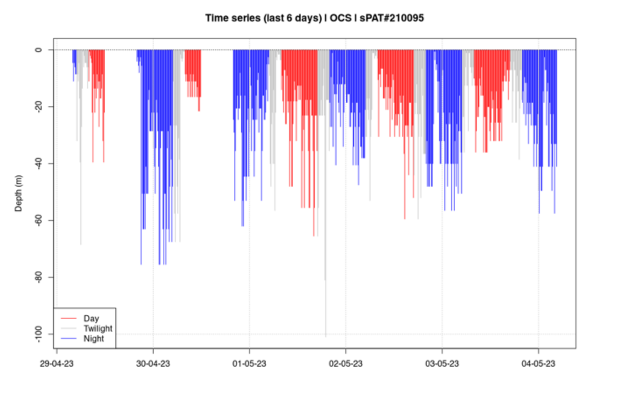


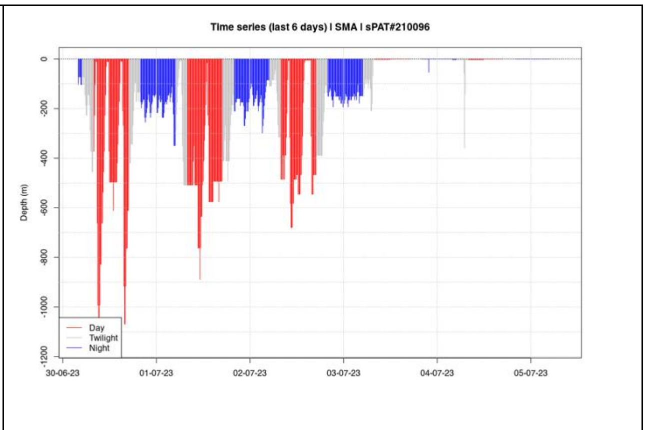


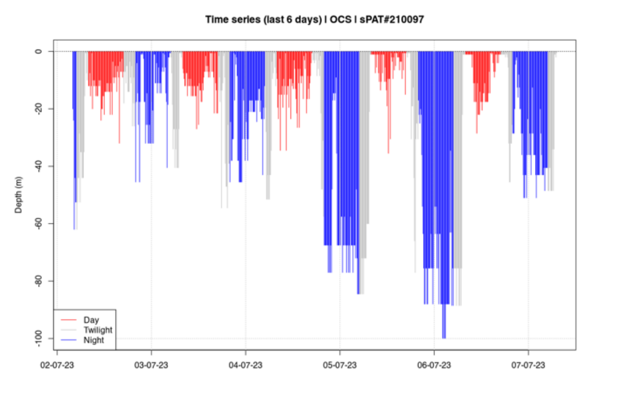


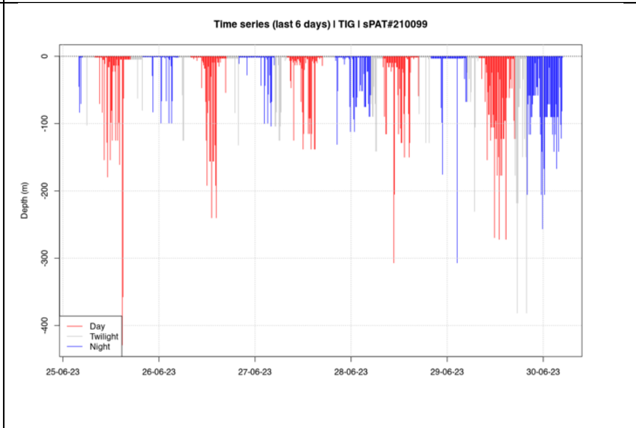


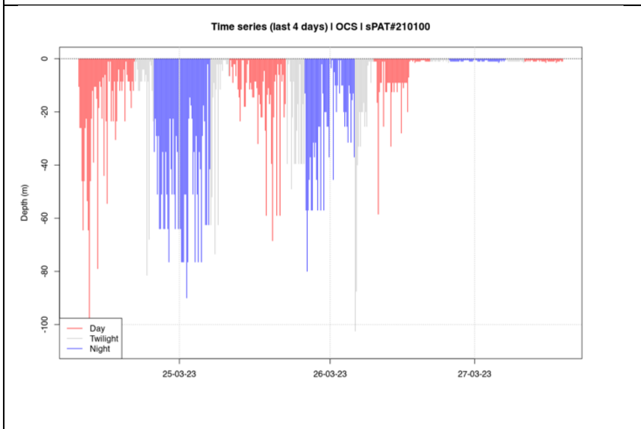

Time series (last 10 days) I OCS I miniPAT#49057
Time series (last 59 days) I OCS I miniPAT#49067
Time series (last 108 days) I OCS I miniPAT#49071
Time series (last 69 days) I OCS I miniPAT#203635
Time series (last 186 days) I OCS I miniPAT#203636
Time series (last 8 days) I TIG I sPAT#210090
Time series (last 6 days) I SPL I sPAT#210091
Time series (last 6 days) I OCS I sPAT#210093
Depth (m)
Day
Twilight
Night

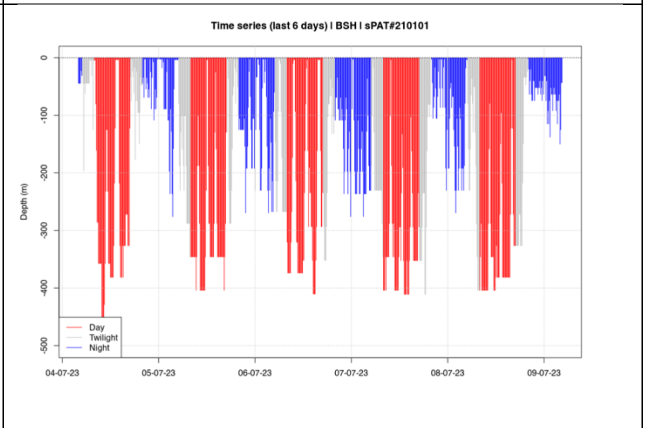

Time series (last 6 days) I OCS I sPAT#210095
Depth (m)
Day
Twilight
Night

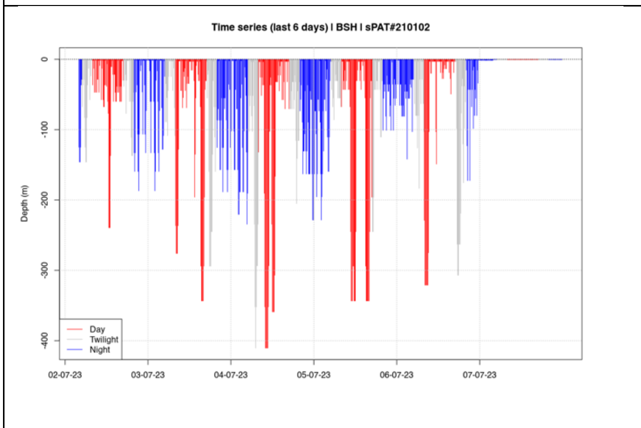

Time series (last 6 days) I SMA I sPAT#210096
Depth (m)
Day
Twilight
Night

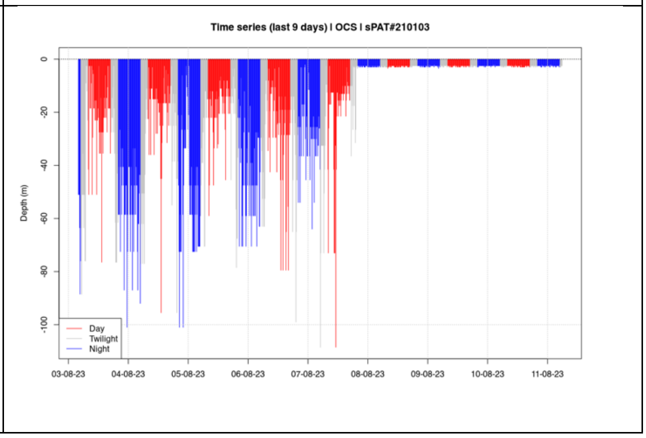

Time series (last 6 days) I OCS I sPAT#210097
Depth (m)
Day
Twilight
Night

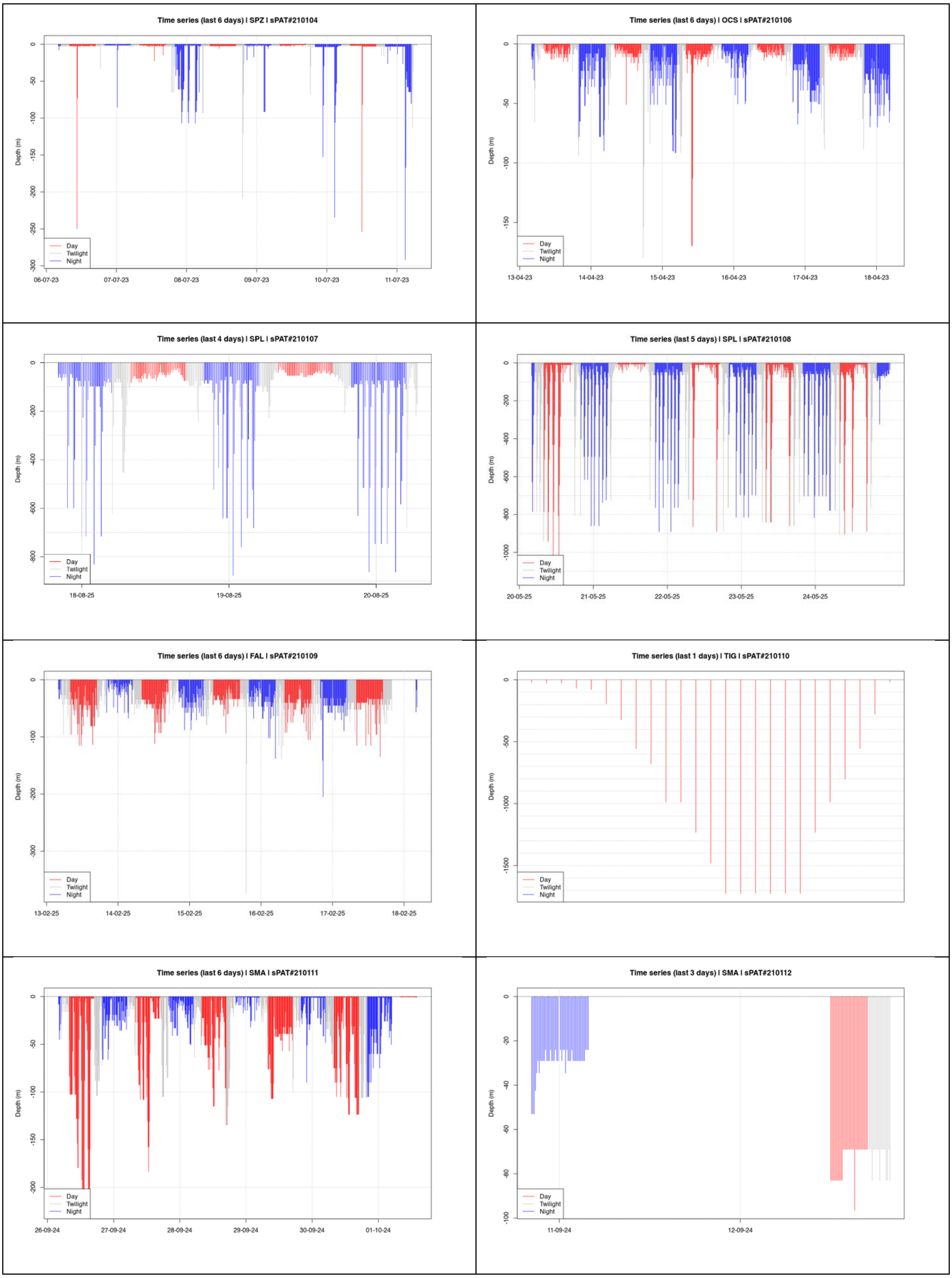

Time series (last 6 days) I TIG I sPAT#210099
Depth (m)
Day
Twilight
Night

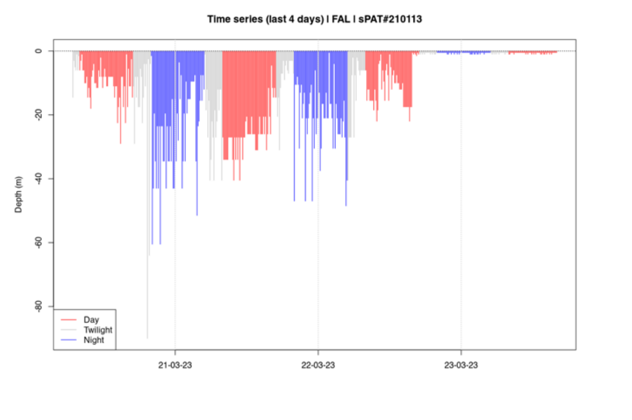

Time series (last 4 days) I OCS I sPAT#210100
Depth (m)
Day
Twilight
Night

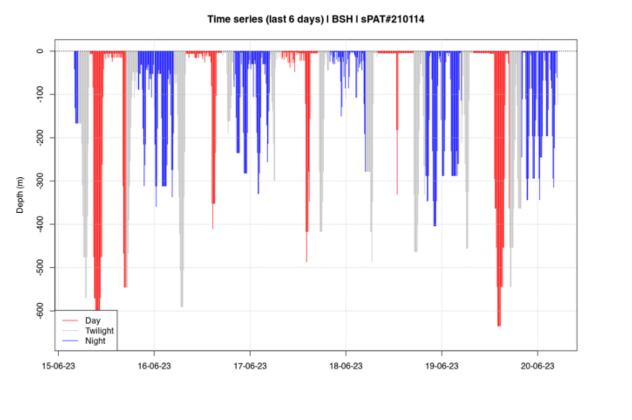

Time series (last 6 days) I BSH I sPAT#210101
Depth (m)
Day
Twilight
Night

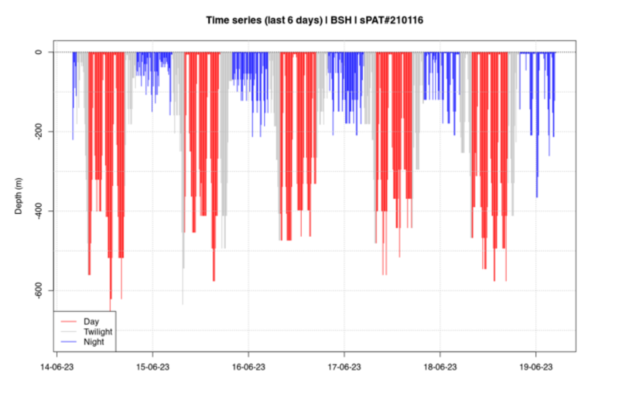

Time series (last 6 days) I BSH I sPAT#210102
Depth (m)
Day
Twilight
Night

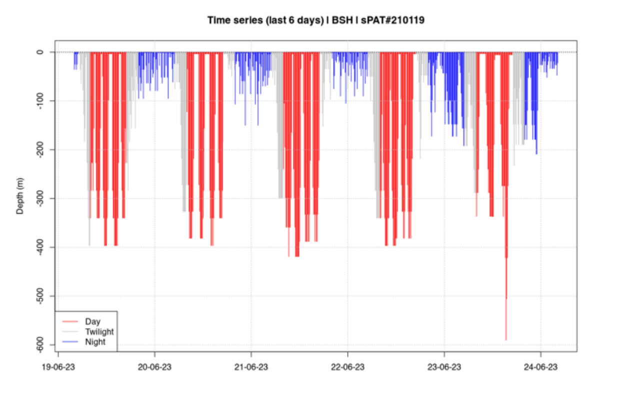

Time series (last 9 days) I OCS I sPAT#210103
Depth (m)
Day
Twilight
Night

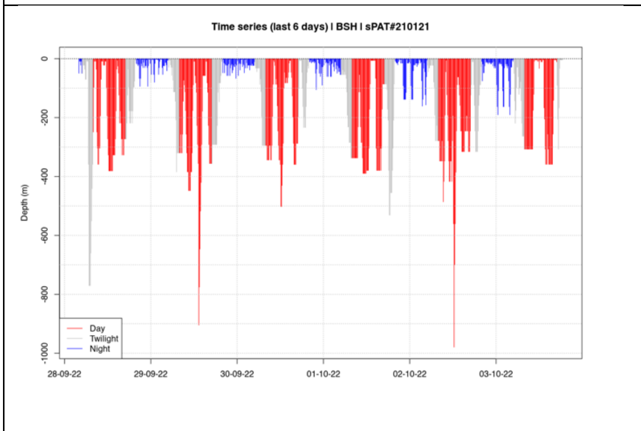

Time series (last 6 days) I SPZ I sPAT#210104
Time series (last 6 days) I OCS I sPAT#210106
Time series (last 4 days) I SPL I sPAT#210107
Time series (last 5 days) I SPL I sPAT#210108
Time series (last 6 days) I FAL I sPAT#210109
Time series (last 1 days) I TIG I sPAT#210110
Time series (last 6 days) I SMA I sPAT#210111
Time series (last 3 days) I SMA I sPAT#210112
Depth (m)
Day
Twilight
Night

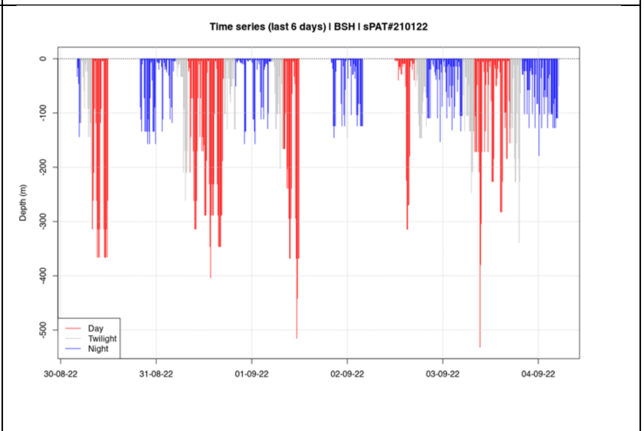

Time series (last 4 days) I FAL I sPAT#210113
Depth (m)
Day
Twilight
Night
21-03-23
22-03-23
23-03-23

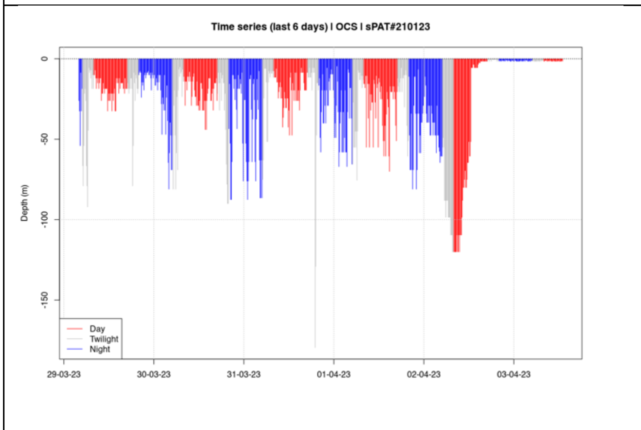

Time series (last 6 days) I BSH I sPAT#210114
Depth (m)
Day
Twilight
Night
15-06-23
16-06-23
17-06-23
18-06-23
19-06-23
20-06-23

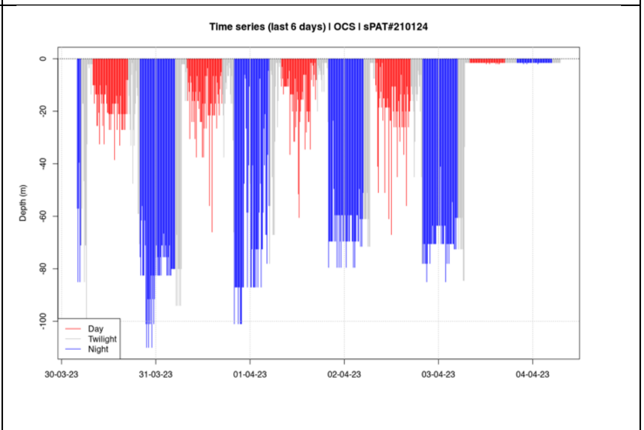

Time series (last 6 days) I BSH I sPAT#210116
Depth (m)
Day
Twilight
Night
14-06-23
15-06-23
16-06-23
17-06-23
18-06-23
19-06-23


Time series (last 6 days) I BSH I sPAT#210119
Depth (m)
Day
Twilight
Night
19-06-23
20-06-23
21-06-23
22-06-23
23-06-23
24-06-23


Time series (last 6 days) I BSH I sPAT#210121
Depth (m)
Day
Twilight
Night
28-09-22
29-09-22
30-09-22
01-10-22
02-10-22
03-10-22


Time series (last 6 days) I BSH I sPAT#210122
Depth (m)
Day
Twilight
Night
30-08-22
31-08-22
01-09-22
02-09-22
03-09-22
04-09-22


Time series (last 6 days) I OCS I sPAT#210123
Depth (m)
Day
Twilight
Night
29-03-23
30-03-23
31-03-23
01-04-23
02-04-23
03-04-23


Time series (last 6 days) I OCS I sPAT#210124
Depth (m)
Day
Twilight
Night
30-03-23
31-03-23
01-04-23
02-04-23
03-04-23
04-04-23

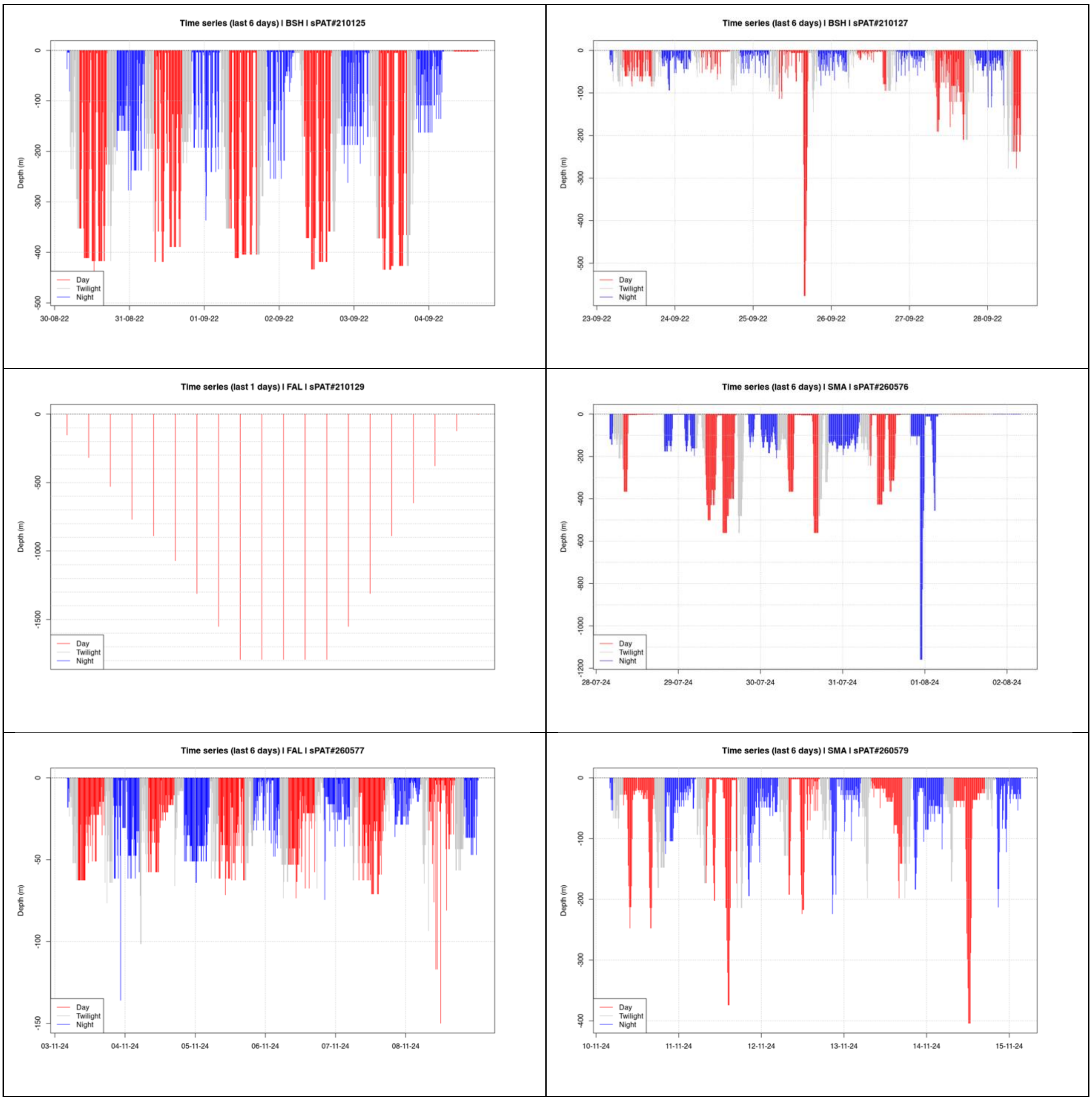


Figure S1. Depth profiles of tagged sharks used to estimate survival/mortality (N = 46)