Second progress report on the post release mortality of the oceanic whitetip shark (POREMO project) discarded by EU purse seine and pelagic longline fisheries

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ABSTRACT

In this second progress report we present briefly again the context of the project POREMO funded by EU France (FEAMP Mesure 77, Data Collection Framework) for the development of appropriate IOTC conservation measures for both targeted and non-targeted large pelagic resources exploited by open ocean fisheries. The POREMO project specifically aims to quantify the post release mortality of the oceanic whitetip shark caught as a bycatch in the EU tuna purse seine and pelagic longline fisheries in order to assess the retention ban measure taken as conservation and management measure (CMM) for this species as specified in the IOTC resolution 13/06. In this working paper we present activities done since the last WPEB-14 (2018) regarding in particular the deployment of both miniPATs and sPATs as well as some results on the survival of sharks after release reported by tags.

KEYWORDS

Post release mortality | Oceanic whitetip shark | Tuna purse seine fishery | Pelagic longline fishery | Pop-up archival tag | Survival pop-up archival tag | Indian Ocean | Conservation measures

1. Context

Appropriate mitigation measures in fisheries must be set up to preserve protected, endangered, threatened and protected (ETP) species to maintain both biodiversity and ecosystem sustainability. Many of PET species are more susceptible to overfishing than other species because their life history traits are mostly characterized by low reproductive potential with few offsprings and late maturity, low population growth rate, a slow growing and a high longevity. These traits characterize almost all shark species (Cortès, 2000). In the IOTC area of competence many pelagic shark species are either targeted or caught as bycatch by several gears (purse seine, pelagic longline, drifting gillnet, handline and pole and line) (IOTC-IOShYP01, 2014). Sharks caught as unwanted bycatch for many industrial fleets are discarded dead or alive. With the implementation of a regional observer program (IOTC Resolution 11/04 on a Regional Observer Scheme) more data are available to assess the status of shark. The release of shark alive has been considered as a relevant conservation measure for threatened and endangered shark species. Such considerations led to the adoption of four IOTC resolutions, one that applies to thresher sharks (IOTC Resolution 12/09 "*on the conservation of thresher sharks (Family Alopiidae) caught in association with fisheries in the IOTC area of competence*"), and one that applies to oceanic whitetip shark (OCS), (IOTC Resolution 13/06 "*on a scientific and management framework on the conservation of shark species caught in association with IOTC managed fisheries*").

Specifically with regards to OCS, IOTC Res. 13/06 specifies that "*CPCs shall prohibit, as an interim pilot measure, all fishing vessels flying their flag and on the IOTC Record of Authorized Vessels, or authorized to fish for tuna or tuna-like species managed by the IOTC on the high seas to retain onboard, tranship, land or store any part or whole carcass of oceanic whitetip sharks with the exception of paragraph 7 (dedicated for scientific purposes). The provisions of this measure do not apply to artisanal fisheries operating exclusively in their respective Exclusive Economic Zone (EEZ) for the purpose of local consumption*". While this ban retention alone may be insufficient to halt the decrease of the oceanic whitetip shark population (Tolotti et al., 2015), its effectiveness has not been assessed in the Indian Ocean. Thus, we need to deeper explore the survivorship rate of released OCS.

In the frame of the EU Data Collection Multi-Annual Program (EU DCMAP) project, the French government allocated to IRD a budget of 100K€ in 2017 to be dedicated to a pilot study focused on shark post release mortality (PRM) of sharks bycaught by EU fleets operating in the Atlantic and Indian oceans. The Observatory for exploited tropical pelagic ecosystems (Ob7) of IRD which is managing the DCMAP for tropical fisheries for France decided to focus this pilot study in the Indian Ocean. As recent information on PRM have been obtained for whale shark (Escalle et al., 2014) and silky shark (Poisson et al., 2014), this research was focused on the oceanic whitetip shark (OCS, *Carcharhinus longimanus*), a species commonly occurring as bycatch in EU purse seine (PS) and pelagic longline (LL) fisheries. The study covers purse seine fleets of Spain and France and pelagic longline fleets for Portugal and France and is coordinated by IRD (Bach et al., 2018). During an *ad hoc* discussion held during the 13^{th} WPEB in San Sebastian (Spain), it was agreed that this study coordinated by IRD will be an excellent contribution to the IOTC PRM work plan even acknowledging that some industrial PS and LL fleets releasing OCS as bycatch will not be covered in this PRM study.

2. State of the art

The fishing mortality of fishes subject to discard is the sum of 1) the at-vessel mortality (AVM) corresponding to the proportion of fishes dead at hauling or on the deck before being released at sea and 2) the post release mortality (PRM) corresponding to the proportion of fish released alive but not able to survive in the short term due to injuries during the catching, hauling or discarding processes (Davis, 2002; Poisson et al., 2014). It is often assumed that sharks show high capacity to recover following injury even though injury types have not been systematically collected (Chin et al., 2015).

Several tagging technics (conventional tags, acoustic tags, electronic tags) have been used to explore the post-release mortality of sharks in the field during both experimental and commercial fishing operations (see Ellis et al., 2017 for a review). Due to the limitations of conventional and acoustic tagging to quantify the exact degree of discard survival, recent studies consider expensive but efficient electronic tags (mainly pop-up satellite archival tags) (Moyes et al., 2006; Campana et al., 2009; Musyl et al., 2011; Capietto et al., 2014; Poisson et al., 2014; Escalle et al., 2016).

However due to the cost of PSAT, experiments prioritized the release of individuals prone to survive in order to collect important additional data aiming to analyze individual behaviors and the ecology of species. Recently, a new electronic tag design (survivorship pop-up archival tags - sPAT) that is cheaper (two times less expensive) than pop-up archival tags and dedicated to survivorship studies were developed to assess the survivorship of released individuals.

Meta-analyses published recently (Godin et al., 2012; Ellis et al., 2017) produced a synthesis of results for at vessel mortality (AVM) and post release mortality (PRM) from studies published from 2009 to 2015 for several species regarding different fisheries (Table 1).

For longline fisheries, shark AVM and PRM mortalities are highly variable between species (Gilman et al., 2008; Godin et al., 2012; Ellis et al., 2017) (Tables 1 and 2). The time spent hooked is an important factor to consider as soaking time can be potentially long. Both AVM and PRM vary with a range of biological attributes (species, size, sex and mode of gill ventilation) as well as the range of factors associated with capture (e.g. gear type, soaking time, catch mass and composition, handling practices and the degree of exposure to air and any associated change in ambient temperature). In general, demersal species with buccal-pump ventilation have a higher survival than obligate ram gills ventilators. Several studies have indicated that females may have a higher survival than males, but this might be confounded with size, as for many species females tend to achieve larger sizes than males. Certain taxa (including hammerhead sharks *Sphyrna spp*. and thresher sharks *Alopias spp.*) are particularly prone to higher rates of mortality when caught.

Some experiments have been carried out on purse seiners to assess the post release mortality of silky shark and whale shark. During three fishing cruises in the Indian Ocean 31 silky sharks (*Carcharhinus falciformis*) were tagged with satellite tags to assess their PRM (Poisson et al., 2014). The majority of individuals (95%) were brought on board using the brailer. Combining the proportion of dead sharks (AVM = 72%) and the mortality rate of those released (PRM = 48%), the overall mortality rate of brailed individuals was 85%. Few individuals (5%) were not brailed as they were entangled and disentangled during the hauling process. The survival rate of these entangled individuals reached 82%. However the combination of these two categories led to an overall survival rate of 19%. During a chartered cruise onboard a tuna purse seine vessel conducting typical fishing operations in the Pacific Ocean, the post-release survival and rates of interaction with fishing gear of incidentally captured silky sharks were investigated using a combination of satellite linked pop-up tags and blood chemistry analysis (Hutchinson et al., 2015). To identify trends in survival probability and the point in the fishing interaction when sharks sustain the injuries that lead to mortality, sharks were sampled during every stage of the fishing procedure. The total survival rate of silky sharks captured in purse seine gear was found to be less than 16%, a result similar to the one obtained by Poisson et al. (2014). In 2014, Escalle et al. (2016) deployed pop-up satellite tag on six large whale sharks (*Rhincodon typus*) (total length > 8 m) released after being encircled in the purse seine in the eastern tropical Atlantic Ocean. Results showed that all whale sharks survived at least 21 days (maximum duration registered was 71 days) after their release from the net and suggest that large whale sharks would exhibit low post release mortality if released following good practices.

Very limited information on AVM and PRM are available for gillnet fisheries (IOTC-IOShYP01, 2014) although it is considered that mortality of elasmobranchs for this gear is high. For example, even with short soaking times of about an hour, high AVM rates have been registered for *Carcharhinus limbatus* (58%) and *Sphyrna tiburo* (62%) (Hueter et al., 2006).

3. POREMO material

For this project it was decided to combine two types of tags: the survivorship PAT (sPAT) designed by Wildlife Computers to assess short term post release mortality (PRM) and programmed to pop-up at a maximum of 60 days after their deployment, and the miniPAT also from Wildlife Computers that is normally used for individual habitat study purposes programmed to pop-off 180 days after their deployment.

A total of 35 electronic tags (20 sPATs and 15 miniPATs) were purchased. Those tags were shared between several EU fleet/countries for deployment in both purse seine and pelagic longline fisheries.

4. Tag deployment

From the beginning of tagging operations in April 2018, 18 tags (of the 35) were deployed (Table 3), corresponding to 12 sPATs (of the 20) and 6 miniPATs (of the 15). For the purse seine fisheries (EU.France and EU.Spain), the rate of deployments has reached 66.7% and 33.7% of the deployment objectives for sPAT and miniPAT respectively. For the pelagic longline fisheries (EU.Portugal and EU.France), the the rate of deployments has reached 0% and 41.7% of the deployment objectives for sPAT and miniPAT respectively.

For the purse seine, the length of tagged individuals ranged from 136 cm to 200 cm total length (TL) and from 130 cm to 180 cm fork length (FL) either estimated or measured. For the pelagic longline, the length of individuals tagged ranged from 120 cm to 210 cm estimated FL (Table 4). The sex was determined for 11 individuals and females were dominant whatever the fishery, 7 females and 2 males for the purse seine and 2 females and no males for the pelagic longline (Table 4). When provided, the time on the deck lasted by the individuals before tagging ranged from 2 to 10 minutes for the purse seine and 10 minutes for the pelagic longline. The status of individuals at haulback was roughly evenly distributed between “alive injured” (22%), “alive” (22%) and “alive good” (22%) for the purse seine. For the longline no “alive injured” individuals have been tagged so far (Table 4). All tags were deployed with a Domeier’s anchor for the purse seine while the large titanium anchor was prefered for the pelagic longline. However, from the taggers feedback, it appears that Domeier-rigged tags are easier to deploy.

5. Pop-up diagnostic

For the purse seine fishery, except for one sPAT which not transmitted data (beacause it did not pop-off or due to a transmitting failure), the duration of deployments ranged between 3 days and about 60 days which corresponds to the programmed duration of a full deployment for sPATs (Table 5). Even for premature releases the duration up to

29 days was long enough to estimate post-released mortality based on satellite tag information. Amongst the 12 series of transmitted data, only one was considered due to an actual mortality after 3 days at liberty (Figure 1). The dead individual was "alive injured" priori to release after it ended up in the lower deck. However, a second individual caught during the same fishing set which also went through the lower deck, that was larger than the first one (180 cm total length compared to 145 cm), survived through the whole duration of the deployment (61 days). Therefore, for the 12 individuals (for which data were transmitted) released from purse seiners the survival rate reached 91.7 %.

For the longline fishery, amongst the 5 tag deployments only three were analyzed two of them premature pop-off after few minutes or two days. These premature pop-off were explained by the difficulties sometimes experienced when planting properly the large titanium anchor in the dorsal part of body of the shark due to the thickness of the skin. For the 3 others tags, days at liberty ranged between 9 and 35 days and although all these pop-offs corresponded to premature releases the duration was long enough to inform post-release mortality if it had occurred. For those individuals, no post-released mortality was observed therefore the survival reached 100%.

These optimistic results apparently provide a justification of the efficiency of the retention ban as a conservation measure for oceanic whitetip shark in the Indian Ocean. Until the final results are available, after the full deployment of all the remaining electronic tags over the next months and during 2020, the results presented here should be regarded as preliminary. Nonetheless, the optimistic results shown so far are encouraging and might be considered as incentives for fishermen to apply the best practices when they discard sensitive species like sharks, rays or sea turtles. However, more electronic tags, particularly for longline-caught OCS must still be deployed in order to obtain robust results on the post-release survival of this species in the Indian Ocean tuna fisheries managed by IOTC.

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Table 1. Summary of studies examining sharks at-vessel mortality (AVM) for pelagic longline fisheries. Data in parentheses corresponds to the number of individuals observed.

Shark species	AVM	Targeted species	Reference
Prionace glauca	4.5% (513)	Swordfish/ Albacore	(Megalofonou et al., 2005)
	0% (21)	Tuna	(Boggs, 1992)
	13.5% (7838)	Tuna	(Francis et al., 2001)
	12.2% (434)	Swordfish	(Francis et al., 2001)
	51.1% (92)	Swordfish	(Poisson et al., 2010)
	14.3% (30168)	Swordfish	(Coelho et al., 2012)
Isurus oxyrinchus	16.1% (31)	Swordfish/ Albacore	(Megalofonou et al., 2005)
	28.4 % (299)	Tuna	(Francis et al., 2001)
	35% (80)	Swordfish	(Beerkircher et al., 2002)
	35.6% (1414)	Swordfish	(Coelho et al., 2012)
Isurus paucus	30.7% (168)	Swordfish	(Coelho et al., 2012)
Lamna nasus	39.2 % (2370)	Tuna	(Francis et al., 2001)
Alopias vulpinus	6.3% (16)	Swordfish/ Albacore	(Megalofonou et al., 2005)
Alopias superciliosus	0 (1)	Swordfish/ Albacore	(Megalofonou et al., 2005)
	53.7% (82)	Swordfish	(Beerkircher et al., 2002)
	50.6% (1061)	Swordfish	(Coelho et al., 2012)
Alopias spp.	40% (6)	Tuna	(Boggs, 1992)
Carcharhinus plumbeus	0 (2)	Swordfish/ Albacore	(Megalofonou et al., 2005)
	26.8% (112)	Swordfish	(Beerkircher et al., 2002)
	36% (8583)	Shark	(Morgan and Burgess, 2007)
Carcharhinus longimanus	15% (26)	Tuna	(Boggs, 1992)
	27.5 % (131)	Swordfish	(Beerkircher et al., 2002)
	58.9% (17)	Swordfish	(Poisson et al., 2010)
	34.3% (281)	Swordfish	(Coelho et al., 2012)
Carcharhinus falciformis	66.3% (1446)	Swordfish	(Beerkircher et al., 2002)
	55.8% (310)	Swordfish	(Coelho et al., 2012)
Carcharhinus limbatus	88% (1982)	Shark	(Morgan and Burgess, 2007)
Carcharhinus obscurus	48.7% (679)	Swordfish	(Beerkircher et al., 2002)
	81% (662)	Shark	(Morgan and Burgess, 2007)
Carcharhinus signatus	80.8% (572)	Swordfish	(Beerkircher et al., 2002)
Galeocerdo cuvier	8.5% (2466)	Shark	(Morgan and Burgess, 2007)
	2.9% (36)	Swordfish	(Coelho et al., 2012)
Sphyrna lewini	61% (199)	Swordfish	(Beerkircher et al., 2002)
	91.4% (455)	Shark	(Morgan and Burgess, 2007)
	57.1% (21)	Swordfish	(Coelho et al., 2012)
Sphyrna mokarran	93.8% (178)	Shark	(Morgan and Burgess, 2007)
Sphyrna zygaena	71% (372)	Swordfish	(Coelho et al., 2012)
Pteroplatytrygon violacea	12% (8)	Tuna	(Boggs, 1992)
	1%	Swordfish	(Coelho et al., 2012)

Mantas and devil rays	1.4% (145)	Swordfish	(Coelho et al., 2012)
Myliobatidae	0% (19)	Swordfish	(Coelho et al., 2012)

Table 2. Summary of studies examining post-release mortality (PRM) of sharks for pelagic longline fisheries. Data in parentheses corresponds to the number of individuals observed.

Shark species	PRM	Targeted species	Reference
Prionace glauca	Healthy - 0% (10) Injured – 33% (27)	Swordfish & Tunas	(Campana et al., 2016)
Lamna nasus	Healthy – 10% (29) Injured – 75% (4)	Swordfish & Tunas	(Campana et al., 2016)
Isurus oxyrinchus	Healthy - 30% (23) Injured – 33% (3)	Swordfish & Tunas	(Campana et al., 2016)
Carcharhinus obscurus	Healthy – 11.1% (18) Injured – 66.6% (3)	Sharks	(Marshall et al., 2015)
Carcharhinus plumbeus	Healthy – 20% (10)	Sharks	(Marshall et al., 2015)

Table 3. Summary of the number of electronic tags (sPATs and miniPATs) deployed for each purse seine and pelagic longline fisheries by the end of July 2019.

	Available		**Total**	**Deployed**		**% deployment**	
Gear	**sPAT**	**miniPAT**		**sPAT**	**miniPAT**	**sPAT**	**miniPAT**
PS	18	3	21	12	1	66.7	33.3
LL	2	12	14	0	5	0	41.7
Total	20	15	35	12	6		

Table 4. Information regarding the electronic tag deployments (sPATs, and miniPATs) on oceanic whitetip sharks tagged and released from both purse seiners and pelagic longliners.

Tag Type	Serial Number	Anchor	Gear	Length (cm)	Length type	Length comment	Sex	Fish condition	Time on deck
sPAT	17P0574	Domeier	PS	164	TL	Measured	NA	Alive injured	10
sPAT	17P0631	Domeier	PS	145	FL	Estimated	NA	Alive injured	3
sPAT	17P0651	Domeier	PS	180	FL	Estimated	NA	Alive injured	3
sPAT	17P0673	Domeier	PS	164	TL	Measured	M	Alive injured	5
sPAT	17P0681	Domeier	PS	136	TL	Measured	NA	Alive good	5
sPAT	17P0712	Domeier	PS	160	TL	Estimated	F	Alive good	NA
sPAT	17P0720	Domeier	PS	200	TL	Estimated	F	Alive good	NA
sPAT	17P0722	Domeier	PS	145	FL	Estimated	F	Alive	NA
sPAT	17P0723	Domeier	PS	130	FL	Estimated	F	Alive	NA
sPAT	17P0726	Domeier	PS	200	TL	Estimated	F	Alive good	NA
sPAT	17P0727	Domeier	PS	150	TL	Estimated	F	Alive good	2
sPAT	17P0739	Domeier	PS	180	TL	Estimated	M	Alive good	3
MiniPAT	17P0480	Domeier	PS	165	TL	Estimated	F	Alive good	3
MiniPAT	17P0398	Domeier	LL	195	FL	Estimated	F	Alive good	NA
MiniPAT	17P0579	Ti	LL	135	FL	Estimated	F	Alive good	10
MiniPAT	17P0595	Ti	LL	120	FL	Estimated	NA	Alive good	10
MiniPAT	17P0678	Ti	LL	210	FL	Estimated	NA	Alive	NA
MiniPAT	17P0680	Ti	LL	210	FL	Estimated	NA	Alive	NA

Table 5. Position, dates of electronic tag deployments, pop-up, and at-release mortality diagnostic of oceanic whitetip sharks caught and released from purse seiners.

Tag Type	Serial Number	Deployment date	Latitude (°)	Longitude (°)	Pop-up date	Days at liberty	Diagnostic	Mortality
sPAT	17P0574	14/04/2019	-24.614	42.824	15/06/2019	62	Full deployment	No
sPAT	17P0631	18/11/2018	-3.441	47.722	21/11/2018	3	Too deep	Yes
sPAT	17P0651	18/11/2018	-3.441	47.722	18/01/2019	61	Full deployment	No
sPAT	17P0673	12/10/2018	-3.862	50.605	10/11/2018	29	Premature	No
sPAT	17P0681	27/08/2018	-3.415	53.053	26/10/2018	60	Full deployment	No
sPAT	17P0712	04/09/2018	0.172	51.220	05/10/2018	31	Premature	No
sPAT	17P0720	03/09/2018	0.008	51.609	02/11/2018	60	Full deployment	No
sPAT	17P0722	08/08/2018	-5.186	62.178	06/10/2018	59	Premature	No
sPAT	17P0723	09/08/2018	-5.303	61.054	17/09/2018	39	Premature	No
sPAT	17P0726	03/09/2018	0.008	51.609	-	-	Did not pop	NA
sPAT	17P0727	20/05/2019	-19.990	40.211	19/07/2019	60	Full deployment	No
sPAT	17P0739	08/05/2019	-14.917	44.092	24/06/2019	47	Premature	No
MiniPAT	17P0480	19/02/2019	6.683	55.583	10/04/2019	50	Premature	No

Table 6. Table 5. Position, dates of electronic tag deployments, pop-up, and at-release mortality diagnostic of oceanic whitetip sharks caught and released from pelagic longliners.

Tag Type	Serial Number	Deployment date	Latitude (°)	Longitude (°)	Pop-up date	Days at liberty	Diagnostic	Mortality
MiniPAT	17P0398	12/05/2018	-32.750	34.866	26/05/2018	14	Premature	No
MiniPAT	17P0579	20/12/2018	-21.033	54.750	24/01/2019	35	Premature	No
MiniPAT	17P0595	14/01/2019	-20.673	52.745	23/01/2019	9	Premature	No
MiniPAT	17P0678	11/05/2018	30.012	34.613	11/05/2018	0	Premature	NA
MiniPAT	17P0680	18/05/2018	31.667	37.400	20/05/2018	2	Premature	NA

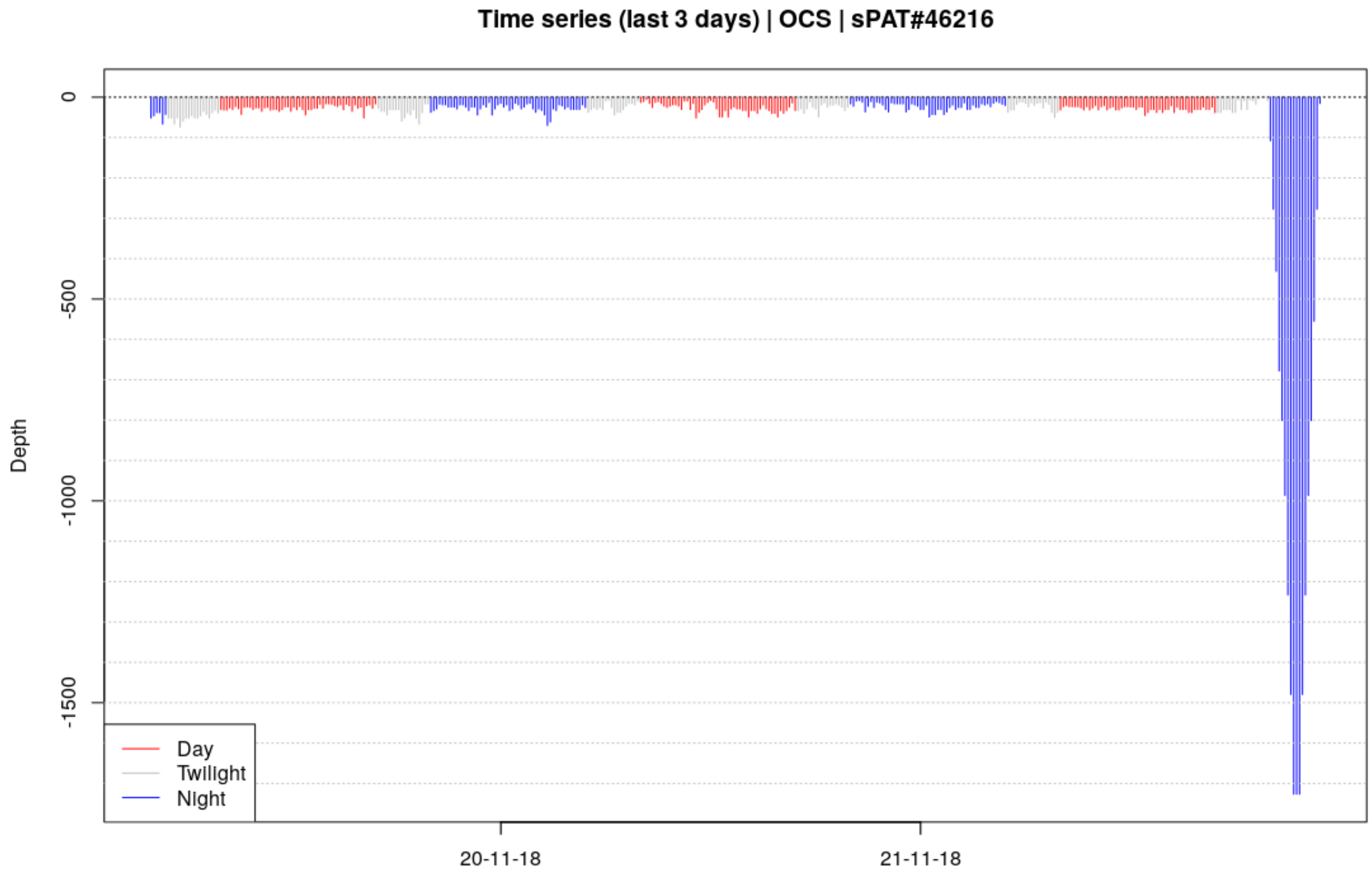

Figure 1. Depth data recorded by the sPAT (PTT: 46216) showing the death of the tagged individual at the beginning of the 4th night after the tag deployment. The dead individual reached the limit depth of 1700 m triggering the guillotine to release the tag.