An update on satellite tagging of billfish around the Indian Ocean via the FLOPPED project

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ABSTRACT

The FLOPPED project aims to investigate the reproduction zones of five billfish species in the Indian Ocean through a comprehensive data collection initiative, including satellite tagging data and biological sampling. Within the framework of this project, 100 satellite tags are to be deployed around the Indian Ocean, on blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Tetrapturus audax*), swordfish (*Xiphias gladius*), and sailfish (*Istiophorus platypterus*). Tagging and biological sampling were originally focused on six study sites, including Reunion, Mayotte, Mauritius (Rodrigues), Seychelles, Sri Lanka and Indonesia. However, due to logistical complications resulting from the global COVID-19 pandemic, we search for participants from a broader range of sites among our WPDCS colleagues to maximise the coverage and representativeness of this dataset. Here, we present on the first results of the 48 tags that have been deployed since the start of the project. Of these, 34 tags were deployed via a network of sports fishers using pole and line that were trained to tag by IFREMER and COOOL personnel in Reunion Island, Rodrigues, Seychelles and Mayotte. These tags were deployed on 23 blue marlin, 5 black marlin, 12 sailfish, 1 shortbill spearfish (*Tetrapturus angustirostris*). An additional 7 tags were deployed via an experiment whereby tags were deployed by a fisheries observer aboard a Portuguese longliner targeting swordfish and operating in the Indian Ocean south of Reunion Island. Swordfish were caught on the longline and tagged at haul-back if they were alive and considered to be in good condition. Tags were programmed to release from the fish ("pop") after 3 or 6 months. One of the 48 tags that were deployed is still attached to the fish, 3 tags popped after < 1 week due to a problem with the anchoring system, 3 tags popped after < 1 day, likely due to mortality and did not have sufficient data to calculate trajectories, 8 tags never transmitted a signal, and trajectories were estimated from 26 tags. The average duration of tag deployment was about 55% of the programmed time. Position estimates indicate that fish tagged in the south-western Indian Ocean tend to swim to the north-west Indian Ocean off Somalia. Some marlin appeared to have a northeastern trajectory, and one swam directly from Reunion to the southern tip of Madagascar. Marlin and sailfish appear to inhabit the top 200 meters during the day and restrict their depth range to the upper 50-100 m at night. In contrast, swordfish in the southern Indian Ocean appear to inhabit the top 600 meters during the day, and restrict their depth range to the top 200 m at night. While we were able to obtain some data from the

longline swordfish tagging experiment, the tagged fish experienced a high rate of mortality, likely due to extended time on the line. We note that our tagging protocol is a living document and is improved after evaluation of each event. We use our increasing experience to train a network of sports fishers, and we encourage any IOTC colleagues interested in participating to contact our team.

INTRODUCTION

The identification of spawning and nursery habitats for marine species is essential to define management measures. Indeed, it is during these younger stages that most of the natural mortality occurs (greater than 99%; Hjort 1914). In the case of billfish (swordfish, marlin, sailfish), larval survival is particularly critical since these species are very fertile (tens of millions of eggs per female) and thus low variations in larval survival will have a considerable impact on the abundance of the next larval cohort.

The state of these resources is of concern: marlins and sailfish are overfished and black and striped marlin are also subject to overfishing (status unknown for the black marlin since 2018). However, management measures are difficult to develop as these species are by-catch in fisheries that target tuna or swordfish. Swordfish, in contrast, is close to overfishing but is not currently overfished nor subject to overfishing.

In the framework of the management of swordfish species, the Indian Ocean Tuna Commission (IOTC) has established research priorities focused on these species. Among these, one of the highest priorities is the identification of areas and seasons of reproduction. Indeed, to date, no information is available on this subject for the three species of marlins (blue marlin, *Makaira nigricans*, black marlin, *Makaira indica* and striped marlin, *Tetrapturus audax*) and sailfish (*Istiophorus platypterus*). Some areas have been identified for swordfish (*Xiphias gladius*) as a result of IFREMER projects in southwestern the Indian Ocean (IOSSS, Longline Fisheries Program).

IFREMER, in partnership with the CNRS and the Comite régionale des pêches marines de La Réunion, developed a research project to provide knowledge on the areas and periods of reproduction of these billfish species and the abundance levels of spawning individuals. This project is funded under Measure 40 of the EMFF. To do so, this project will deploy 100 satellite tags on swordfish, marlin and sailfish in sites around the Indian Ocean over a period of three years.

METHODS

Tagging is led by experienced staff from IFREMER and COOOL who have worked to develop a detailed and regularly updated protocol to maximise the duration of tag deployment, while ensuring the safety, health and wellbeing of both the fish and the crew. Fish are caught by pole and line, and brought to the surface where they are assessed for their fitness for tagging (Table 1 for detailed criteria). The tags are deployed at the base of the dorsal fin (Figure 1). The position of the tag on an individual can have a substantial effect on the fitness of the individual, i.e., if a tag is badly placed, this can lead to injury and potential mortality. It is also important that a tag be placed correctly to ensure that it does not dislodge from its anchoring in the individual and is thus lost prior to the moment of programmed tag release. Fish are given time to recover and are then released.

Table 1. Criteria used to help determine whether a fish is fit to tag or not. If the fish is not fit, it is given time to recover alongside the boat, and released.

Fish fit to tag	Fish not fit to tag
Hook set in the mouth or the rostrum	Point of the hook sticking out around the eye (risk of eye perforation)
A "healthy/lively" fish, with calm and good swimming behaviour	Pale colored fish
Fish with vivid colors	Sign of bleeding in the gills
	Weakened fish, swimming poorly or not at all, moribund
	Fish hooked not in the mouth or rostrum (ex: gill, stomach, back...)
	Fish that does not have an external wound (ex: depredation)

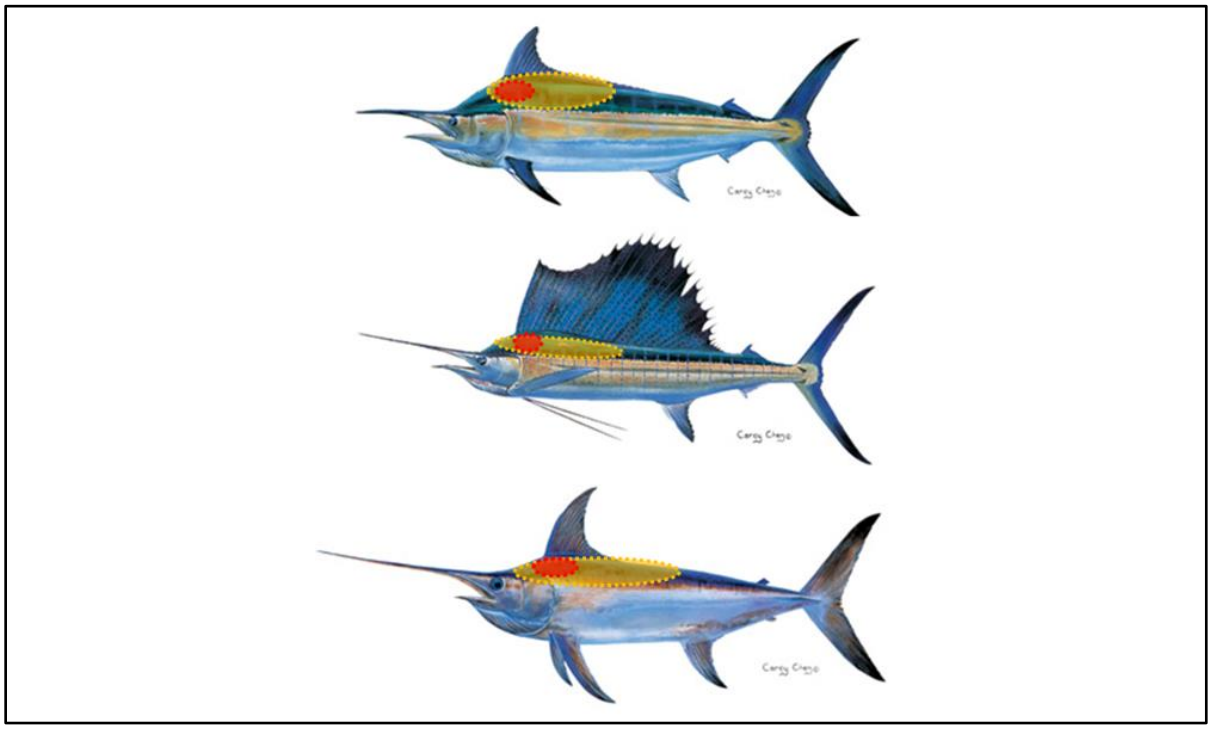

Figure 1. The ideal tagging zone is indicated by the red oval and the acceptable tagging zone is indicated by the yellow circle.

Due to the large number of tags that must be deployed in the course of this project, the FLOPPED team has worked to develop a network of sports fishers in the Indian Ocean to aid in tagging efforts. The FLOPPED team tries to provide hands-on training to the fishers, which then allows the fisher to tag independently.

Tagging events are recorded with a video and/or photos are taken of the fish to ensure a proper tag placement and for later evaluation to improve the tagging protocol.

Swordfish differ from the other species in that they tend to inhabit a much deeper zone, making them difficult to capture alive and in good enough condition to tag. We have begun testing different fishing strategies for capturing swordfish alive, including tagging of live individuals at the end of a commercial longline, and working with local fishers to test vertical longline techniques, similar to those deployed by Sepulveda et al. 2015 and Romanov et al. 2016.

Thus far in the project, we have made tagging expeditions to Rodrigues, Mayotte, and Seychelles and have tagged locally in Reunion Island. We have sent tags to sports fishers in Kenya, and to an observer of a Portuguese vessel targeting swordfish and sharks in the southern Indian Ocean. We have recently partnered with the University of Tasmania, who will aid us to deploy tags in Western Australia and Indonesia. We continue to look for partners to aid us in the deployment of these tags, especially in the northern parts of the Indian Ocean basin.

Tags were programmed to release between 3 and 6 months after deployment and record depth, temperature and light intensity. These tags are minipats by Wildlife Computers.

RESULTS

Since the project began, we have deployed 48 tags on 5 different species, including swordfish, sailfish, and black and blue marlin and a shortbilled spearfish in 5 different sites (in the waters around Reunion, Mayotte, Rodrigues, south of 25°S of Reunion, and Seychelles) (Table 2). Due to logistical issues, the tags sent to Kenya were not received by the Kenyan team and were sent back. One tag was deployed on a blue marlin in Seychelles at the very beginning of the FLOPPED project during the annual Seychelles Sports Fishing Club tournament. Tagging in Seychelles in 2019 was again planned for the annual tournament; however, inclement weather prevented the great majority of members from participating, and the only fish caught had to be released prior to being brought to the surface, as the line got caught in the propeller. Unfortunately, our ability to tag in 2020 and 2021 has been significantly affected by the global COVID-19 pandemic. However, some relaxations in travel restrictions have allowed us to travel to Mayotte to tag.

Table 2. Summary of the 48 tags that are currently deployed, or have popped from actual and potential tagging sites in the Indian Ocean. Species codes refer to blue marlin (BUM), black marlin (BLM), striped marlin (MLS), sailfish (SFA), shortbill spearfish(SSP), swordfish (SWO).

	BUM		BLM		MLS		SFA		SSP		SWO		Total / site
	At sea	Popped	At sea	Popped	At sea	Popped	At sea	Popped	At sea	Popped	At sea	Popped	
Rodrigues	0	7		4				3					14
Réunion	1	15		1				2		1			14
Kenya													0
Seychelles		1											1
South Reunion (Portuguese longliner)												7	7
Mayotte								6					6
Madagascard Nosy/be													0
	1	23	0	5	0	0	0	11	0	1	0	7	42

Total / species	**24**	**5**	**0**	**11**	**1**	**7**	

Of the 48 tags that have been deployed, 47 have released from the fish and only one is still deployed (Tables 2,4). The average duration of tag deployment was about 55% of the programmed time. The longest deployment was 180 days, or 6 months, which is the maximum duration programmed for the tags that have popped. Three tags were retained on the fish for < 1 day and did not have sufficient data to calculate positions or trajectories. Eight tags never transmitted a signal even after the programmed release date. Three tags released prematurely from the fish < 1 week after tagging due to issues with the anchoring system (Table 3).

Table 3. The percent of the time that the code for the release of the tags ("pop") was given by Wildlife Computers per species, and the possible explanations for the release. Too deep - the tag detected that it was getting dangerously close to its maximum structural depth. Floater/Premature - the tag stayed within four meters of a constant depth for more than one day. Pin broke - Some external force pulled on the tether and broke the pin. No information - no signal was ever sent by the tag. Interval - the tag ran to the configured end of the deployment and the animal survived. At sea - the tag is currently deployed and no information is expected.

Pop code	**BLM**	**BUM**	**SFA**	**SWO**	**Total**	**Potential reason for pop**
Too deep		5%		71%	15%	Likely mortality
Floater/Premature	40%	53%		14%	32%	Likely mortality, anchoring system issue
Pin broke	40%	21%			15%	Manufacturing error
No information	20%	11%	20%	14%	15%	Manufacturing error (battery)
Interval		11%	10%		7%	Released as programmed
At sea			70%		17%	

Table 4. Summary of tag duration, distance, and data transmission per site and species of the tags that have released from the fish. Captain indicates the captain responsible for the boat from which the tag was deployed. SWIO = Southestern Indian Ocean.

No.	**tagid**	**ptt**	**sp**	**tagsite**	**Captain/vessel**	**data transmitted?**	**dist**	**duration**
1	17P0764	46302	BUM	Seychelles	9G	Yes	3 556	11
2	18P0050	60928	SWO	South Reunion	Portuguese longliner	Missing deployment data		
3	18P0050	60932	BUM	REUNION	IRLINGER Eric	No signal transmitted		
4	18P0082	60929	SWO	South Reunion	Portuguese longliner	Not enough data		0,25
5	18P0092	60930	SWO	South Reunion	Portuguese longliner	Yes	579	27
6	18P0103	60931	SWO	South Reunion	Portuguese longliner	Yes	167	5

7	18P0251	60933	SWO	South Reunion	Portuguese longliner	No signal transmitted		
8	18P0325	60934	BUM	Reunion	Le BOZEC Pascal	Yes	658	6
9	18P0406	60935	BUM	Reunion	Le BOZEC Pascal	Yes	11 122	55
10	18P0409	60936	BUM	Reunion	Yann Guillou	Yes	5 461	90
11	18P0413	60937	BUM	REUNION	Le BOZEC Pascal	No signal transmitted		
12	18P0419	60940	SWO	South Reunion	Portuguese longliner	Yes		0,09
13	18P0455	60953	SWO	South Reunion	Portuguese longliner	No signal transmitted		
14	18P0740	64752	BUM	Reunion		Yes	3 576	91
15	18P0742	64768	BUM	Reunion	Le BOZEC Pascal	Yes	1 061	89
16	18P1067	66607	BLM	REUNION	Héas François	No signal transmitted		
17	18P1194	178417	BLM	Rodrigues	YANN COLAS	Yes	554	84
18	18P1808	181745	SFA	REUNION		No signal transmitted		
19	18P1896	181978	SFA	RODRIGUES	CYRIL FAURE	No signal transmitted		
20	18P1899	181980	BUM	Réunion	MAILLOT SANDRO	Yes	670	79
21	18P1955	181986	BUM	Rodrigues	CYRIL FAURE	Yes	2 950	137
22	18P1955	64752	BUM	Rodrigues	CYRIL FAURE	Yes	5 386	91
23	19P0001	195497	BUM	Reunion	CYRIL FAURE	Yes	2 662	125
24	19P0047	195503	BUM	Reunion	GIANNI	Yes	385	3
25	19P0197	195473	BLM	Rodrigues	CYRIL FAURE	Yes	2 238	74
26	19P0219	182267	BLM	Rodrigues	YANN COLAS	Yes	27	3
27	19P0426	195474	BUM	Rodrigues	YANN COLAS	Yes	141	7
28	19P0427	195475	SSP	Reunion	IRLINGER Eric	Not enough data		0,23
29	19P0585	195477	BLM	Rodrigues	CYRIL FAURE	Yes	4 180	93
30	19P0587	195479	BUM	Rodrigues	YANN COLAS	Yes	772	28
31	19P0697	195487	BUM	Rodrigues	YANN COLAS	Yes	627	26
32	19P0781	195492	BUM	Rodrigues	YANN COLAS	Yes	479	8
33	19P0786	195493	SFA	Rodrigues	CYRIL FAURE	Yes	6 853	180
34	19P0790	195513	BUM	REUNION	Héas François	No signal transmitted		

35	19P0794	195516	BUM	Reunion	CHANUT	Yes	723	14
36	19P0795	195517	BUM	Rodrigues	YANN COLAS	Yes	154	6
37			SFA	Mayotte	HERVE GAETAN	en cours		
38			SFA	Mayotte	HERVE GAETAN	en cours		
39			SFA	Mayotte	HERVE GAETAN	en cours		
40			SFA	Mayotte	HERVE GAETAN	en cours		
41			SFA	Mayotte	HERVE GAETAN	en cours		
42			SFA	Mayotte	HERVE GAETAN	en cours		

The experiment of tagging swordfish from the commercial longliner in the southern Indian Ocean was not successful in terms of fish mortality, and thus tag deployment duration. Swordfish were likely to have been extremely fatigued from remaining on the longline over several hours, and appear to have died not long after the tagging event as the depth of some of the just-tagged fish descended to great depths, indicating mortality and sinking (see Figure 3, SWO) and the tags popped not long after, resulting in very short trajectories (Figure 2).

Pole and line tagging of the other three species appear to be much more successful with the average tag duration of these events at about 60 days. Many of the two marlin species are marked in the southwestern Indian Ocean and then swim to the north western Indian Ocean; however there appears to be some movement to the northeast, and one blue marlin headed to the south of Madagascar. The tagged sailfish appears to first head south of Reunion, before turning around and swimming to the northwestern Indian Ocean.

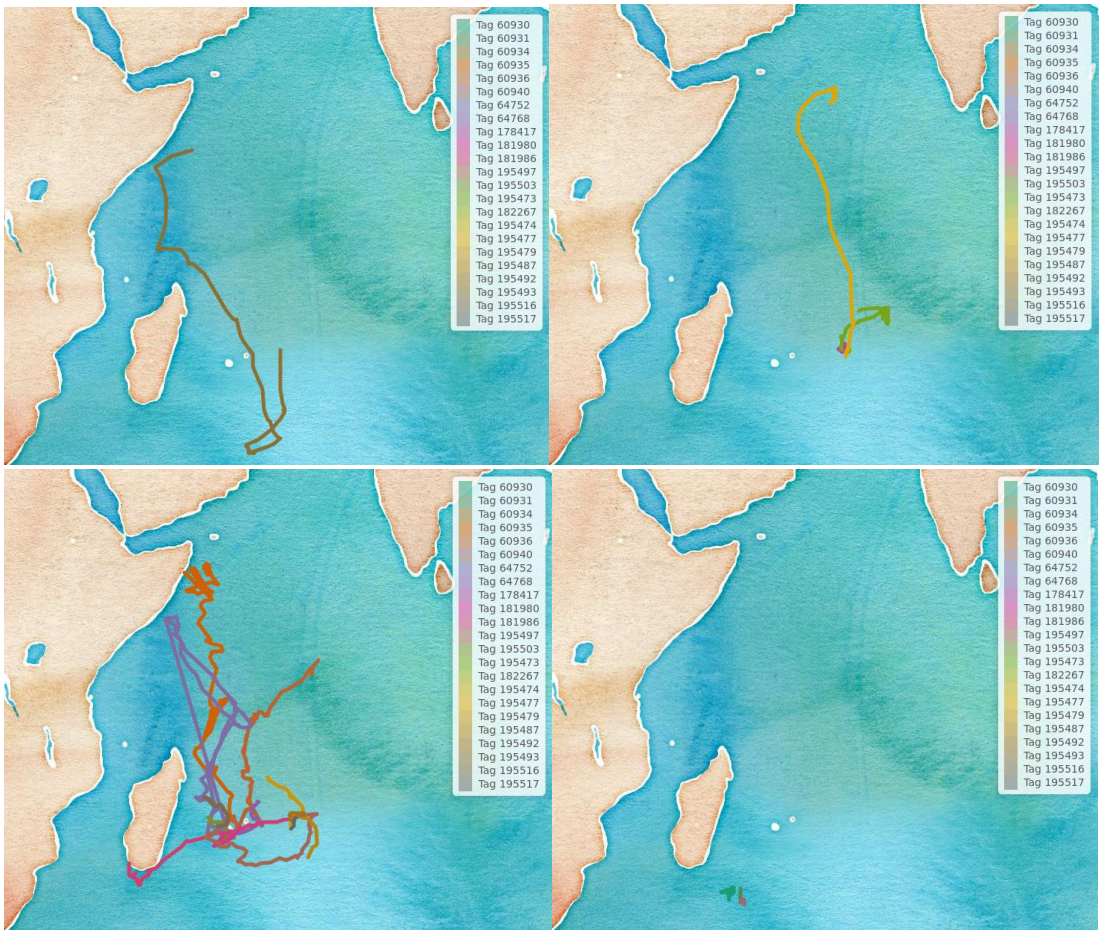

Figure 2. Trajectories of SFA (top left), BLM (top right), BUM (bottom left), and SWO (bottom right) tagged in this study. Species codes as in Table 2.

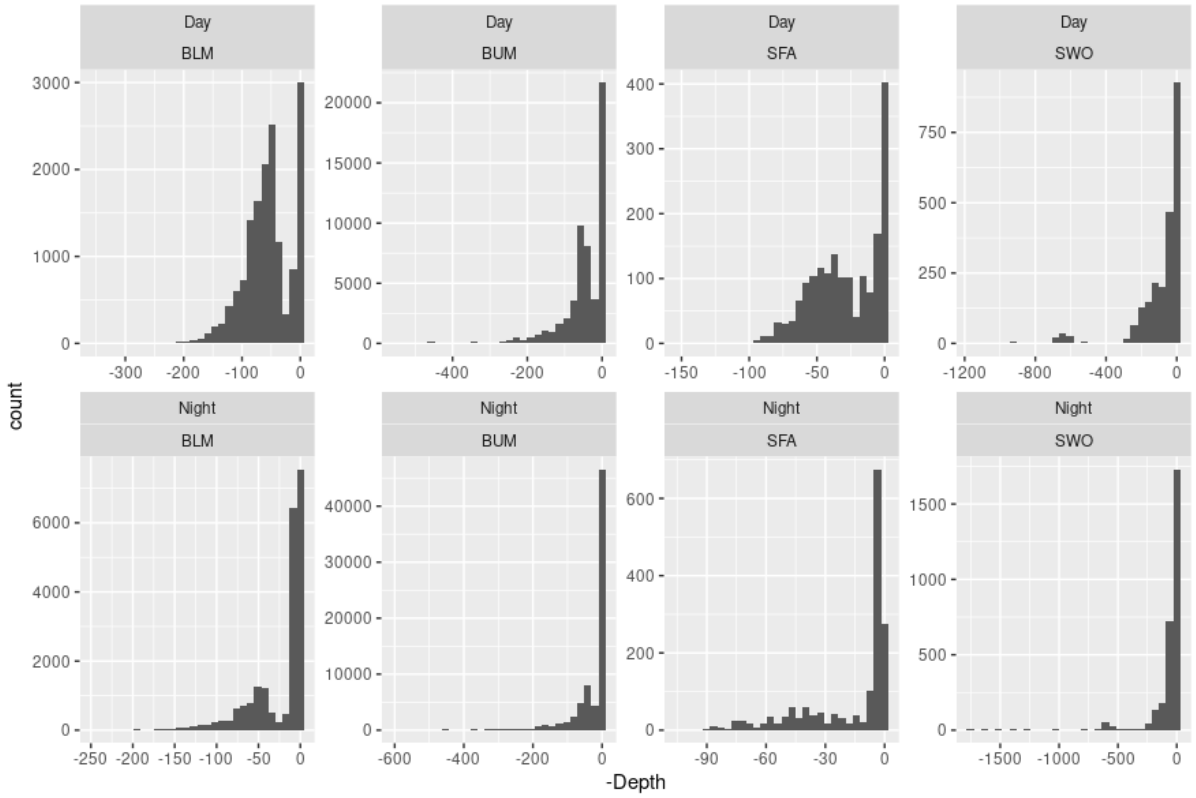

Figure 3. Frequency of depth (m) estimates during the day (top panels) and at night (bottom panels) for each of the tagged species. Species codes as in Table 2.

We see a similar pattern between black and blue marlin and sailfish inhabiting a range of depths up to 200 m during the day, with shallower and narrower depth distributions at night (Figure 3). Swordfish have a deeper distribution overall, with depths ranging up to 600 m during the day and shallower at night. Depths > 600 m in the figures are likely due to fish mortality and sink rather than a true depth range.

DISCUSSION

The FLOPPED project is a three-year project that will continue through 2021. These first results of the FLOPPED project come at the half-way point, and show that even due to restrictions from the global pandemic, we have still managed to deploy 40% of the tags planned, on 4 of the 6 species, and in 4 of the 6 sites targeted. More detailed analysis of the tagging data will continue. In combination with the biological information obtained via the sampling of captured billfish, we hope to better identify the reproductive grounds of these important species.

Though our results are on target in terms of the project objectives, COVID restrictions have impacted efforts to tag in some of the sites targeted at the beginning of this project. We feel that our protocol is well developed, and we are confident in our ability to train new fishers to aid in the tagging efforts. We encourage our WPDCS colleagues to approach us should they like to participate in the tagging and biological sampling efforts of the FLOPPED project.

ACKNOWLEDGEMENTS

We would like to thank the captains and the crew of the L'Oiseaux des Îles, Rod Fishing Club, Oringa, and the Seychelles Sports Fishing Club for their efforts, skill, and enthusiasm in successfully deploying these tags. We thank Malindi Club, Kenya for their willingness and enthusiasm to participate in this project. We thank C. Sepulveda and S. Aalbers of PIERS, Derke Snodgrass, Eric Orbesen, John Walters, and Matt Lauretta from NOAA for their kind advice in techniques to capture and tag swordfish. The FLOPPED project is funded by Measure 40 of the European Union's FEAMP funding.

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