Improving a protocol for satellite tagging of billfish

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Abstract

Satellite tags have been widely used to investigate the biology and ecology of marine species (e.g., migration, vertical movements, reproductive behavior, post-release mortality). The techniques used to tag the animals are substantially different depending on species and the experience of taggers. Tuna have been tagged onboard with manual sticks, spearguns, or harpoons. For billfish, the most common technique is to use a harpoon as these species can be dangerous to handle onboard, are difficult to bring onboard, and are very sensitive with high mortality rates once onboard. Here we present the key elements that can help to maximize the success of tagging from our experience on 84 tags on billfish in the Indian Ocean. We investigate the potential effect of different factors (tagger, handling time, fight time, position of the tag on the animal, …). We show that the position of the tag on the animal is critical for the subsequent retention time of the tag while other factors are less significant. The best position is determined to be below the first dorsal spine and above the lateral line. Retention time was XX times longer when targeting this area compared to other locations.

Introduction

Satellite tagging is an important tool to better understand species migration routes and breeding grounds, as well as population connectivity, all of which are extremely important for fish stock assessment (Nielsen et al. 2009; Hussey et al. 2015). The information collected by these tags thus has broad conservation and management applications (Hays et al. 2019). For example, they can be used to determine whether fish populations are shared between fishing nations or belong to territorial waters (Dwyer et al. 2019; Lennox et al. 2019).

Conventional satellite tags cost about 3500 euros each, so each tag represents a significant financial investment. However, there are a limited number of satellite beacon producers and their technology has not advanced significantly since the 1990s (Lutcavage et al. 2015). Similarly, deployment of these tags requires a significant investment, including costs associated with boat time, fishing expertise, and training. Due to the high cost of purchasing and deploying satellite tags, the number of possible deployments for most scientific studies is limited, leading to limited quantitative analyses from the data obtained. Therefore, it is very important that the tags are successfully deployed until the end of their attachment time on each fish.

The technical objective of the FLOPPED project (2019-2023) is to deploy 100 satellite tags (minipats) on billfish distributed throughout the Indian Ocean, with the scientific goal of better understanding the life history and population structure of these different species. However, tagging of billfish has little information or published protocols. A protocol for at-sea tagging of billfish using conventional (i.e., non-satellite) tags were published by Prince et al. in 2002, with no updates to this protocol in the last 17 years. To achieve the goals of the FLOPPED project, our technical challenges include the development and testing of detailed practical protocols for tag deployment on the different species. Our aim is to update the protocol published by Prince et al. 2002 for technological advances (i.e., satellite tags versus conventional tags), and to increase the number of species covered by the protocol in terms of species-specific tag placement procedures and Indian Ocean-specific fishing techniques.

In this paper, we focus on a particular aspect of the protocol, i.e. the position of the tag on an individual. The position of the tag can have a significant effect on their physical condition, i.e., if the tag is misplaced, it can lead to injury and post-release mortality (FAO 2017). It is also important that a tag is placed correctly to ensure that it does not become dislodged from its anchorage on the individual and is therefore lost before the time of scheduled release (Rouyer et al. 2019). Thus, one of the main aims to improve the tagging protocol is to identify the best location for a tag on an individual. We have performed dissections to identify the exact location where a tag anchor should be positioned, specifically between the dorsal spines for maximum tag retention on each individual. We verified this theoretical study with field studies that examine photographic evidence of the location of each tag and to determine where they were retained the longest.

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 FEAMP. The Company for Open Ocean Observations and Logging (COOOL)'s role in the project was to aid in the distribution and deployment of the tags. Here we provide the results on retention time of the 84 billfish tagged with a minipat thus far through the FLOPPED project.

Proposed protocol

Role of the crew

It is imperative that each member of the crew knows his or her role perfectly during a tag deployment. The ideal number of people on board is three or four. The captain maneuvers the boat during the fight with the fish; the angler fights and brings the fish to the boat; the troller is the person who reels in the last meters of line by hand. S/he is the one who "controls" and directs the fish to bring it to the side of the boat and present it to the tagger. The troller either grabs the bill of the fish or uses a "snooter" (a long stick with a lasso-like hoop at the end) to grasp the bill and control it along the boat while the tag is placed (e.g., Sepulveda et al., 2015). The snooter is not a common fishing tool and little information is available on the preferred specifications for billfish (e.g., its length; the material it is made out of , etc). Different snooters were manufactured and tested by our team to determine the best materials and specifications for marking. The tagger (also the captain if there are only three people), in coordination with the troller, will tag the fish with the tagging harpoon. S/he will optionally unwind a measuring tape to estimate the size of the fish and then help the troller to unhook the fish or to cut the leader if the unhooking of the fish is dangerous.

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.

Figure 1. The tagging procedure includes capture and haul-back.

Tagging technique

1 - A video should be taken for each tagging event to verify and analyze the procedure.

2 - Once the angler has fought and brought the fish boatside, it should be traced and driven alongside the boat so that it presents a large tagging target. It is generally best to move the boat slowly forward to allow for better control of the fish (Figure 2).

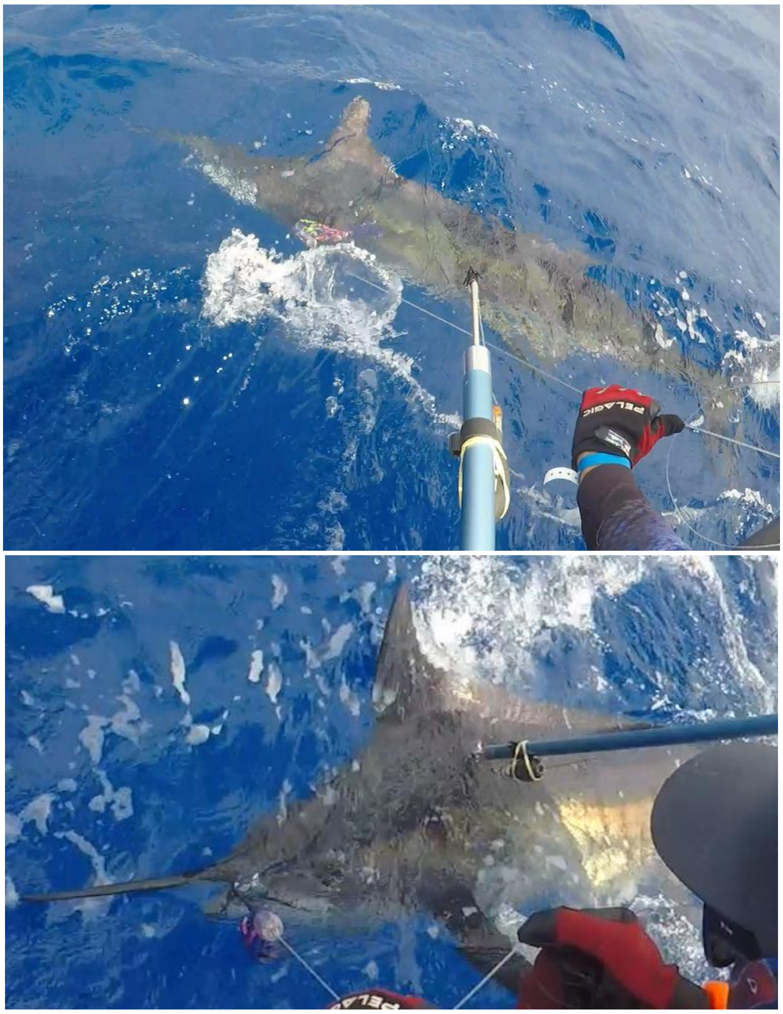


Figure 2. Fish is driven alongside the boat to present a large tagging target (top). The tagging harpoon targets a placement in the pterygiophores (see Figure 3) and the tag is deployed with a firm thrust (do not stab) (bottom).

3 - The fish are brought to the surface where they are assessed for their fitness for tagging (Table 1 for detailed criteria).

It is not recommended to tag fish that are very active or wild when brought near the boat as this can be very dangerous to the crew and the fish themselves, in addition to risking damage to the boat. Furthermore, the more active the fish, the more difficult it is to place the tag in the correct location. The entire tagging process, including the handling of the fish, becomes increasingly difficult in rough seas, which should also be taken into account when deciding to tag.

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)

4 - The rostrum of the fish should be held in the hand, preferably by a "snooter". The lasso is placed on the top of the rostrum, pulled tight, and the fish is held in place by tying the line to a cleat on the boat. The "Snooteur" allows the fish to be secured while submerged in the water during the tagging process, eliminating the need for a crew member to hold the rostrum of the fish, which can be dangerous. Once the fish is in the tagging position, the person handling the tagging harpoon (the tagger) must stand behind the person handling the fish (the troller) to allow a clean tagging action. The mark should be inserted into the fish in the pterygiophores (Figures 3 and 4) to maximize the chances of the mark holding. This requires access to the back of the fish. Sometimes the back of the fish is not accessible because it can turn sideways. It is the role of the troller to position the fish well.

4 - An attempt to apply the tag should be made only if the fish is calm or submissive. The tag should be placed well above the lateral line in the dorsal musculature, away from the head, gills, plates, eyes and other vital organs. Ideally, the anchoring system should be passed through the pterygiophores, which are extremely strong and allow for very good anchorage of the tag (Figure 3). This position of the tag will also promote rapid healing of the wound and minimize the risk of serious injury.

5 - The fish should be tagged with a firm, focused action. Simply place the tag against the side of the fish and push firmly (Figure 2 bottom). Do not stab. The depth of placement of the mark is determined by the length of the stainless steel applicator that extends beyond the tagging harpoon. This applicator should be about 7 cm long, even for the smallest billfish.

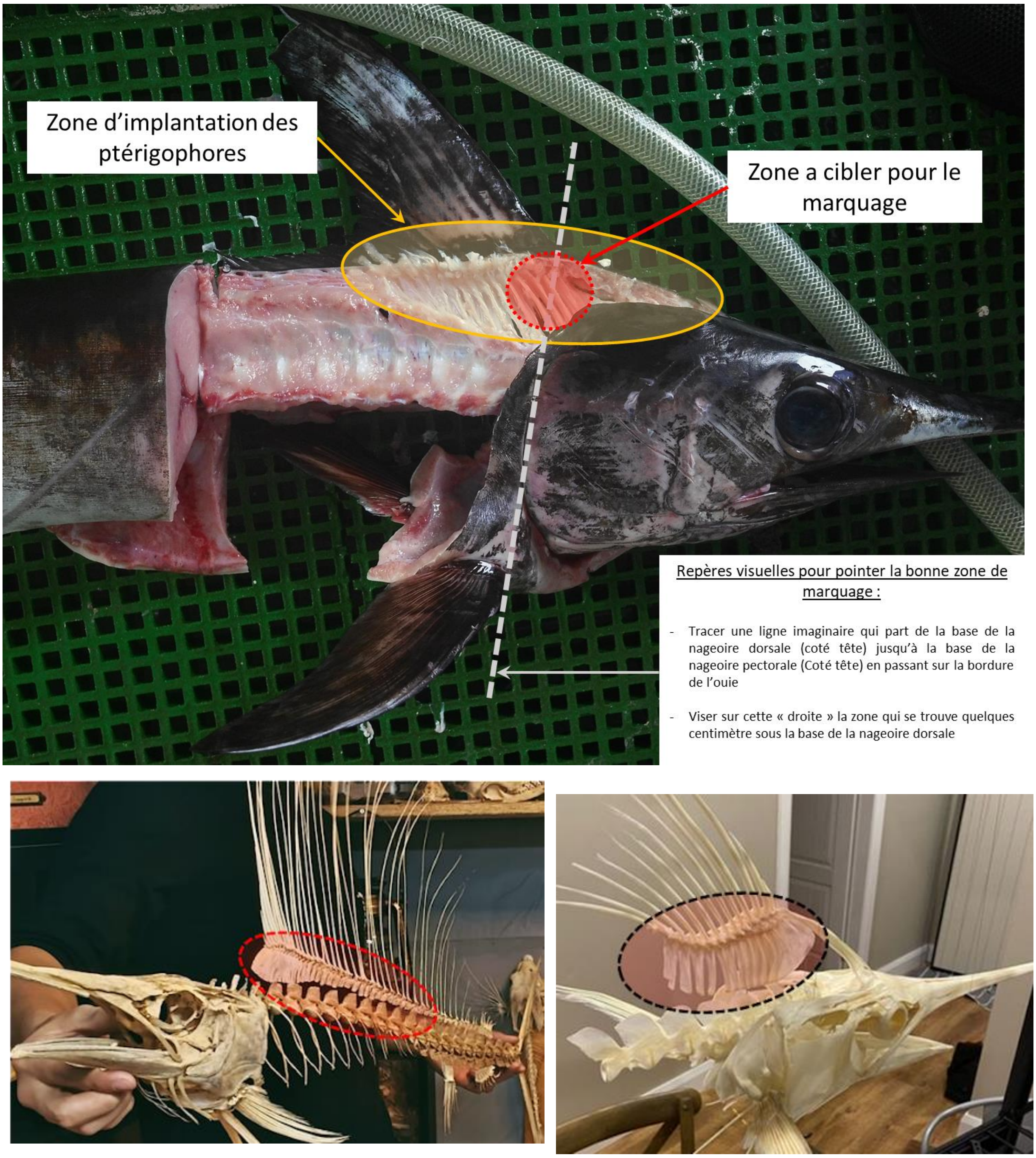


Figure 3. Zone within which to anchor the tag between the pterygiophores of swordfish (top), sailfish (bottom left) and marlin (bottom right).

6 - Before the release, the tagger should estimate the length of the fish (length of the fork of the lower jaw) by using a meter tape (optional).

7 - Once the tag is placed, the tagger must help the angler remove the hook if possible (a disgorger can facilitate this) or cut the line near the fish's mouth.

8 - Revive fish that appear to be exhausted or are having difficulty staying in a swimming position in the water. A commonly used approach for billfish is to hold the fish firmly by its submerged rostrum while the boat moves forward at 2 to 3 knots. This ensures a good flow of water over the gills of the

fish. The fish should not be released until it shows strong signs of life and improvement in skin color, which may take several minutes or more. Great care should be taken during this step, especially in bad weather. The use of a snooter is safer for this step than holding the bill by hand.

9 - Immediately fill out the tag information sheet and return the sheet and tagging video to the Ifremer and COOOL representative as soon as possible (Appendix 1).

Materials & Methods

Tagging was led by experienced staff from IFREMER and COOOL who have worked to develop a detailed and regularly updated protocol (see above) to maximize the duration of tag deployment, while ensuring the safety, health and wellbeing of both the fish and the crew. Marlin and sailfish were caught by pole and line. Swordfish tagged in this study were caught by longline and were tagged at haul-back, depending on their assessed fitness.

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, which were blocked at customs, as well as 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 helped us deploy tags in Western Australia. 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 12 months after deployment and record depth, temperature and light intensity. These tags are minipats by Wildlife Computers.

Trajectories were analyzed using the multiple modeled speeds (3km/hr, 5km/hr, 10km/hr, 15km/hr, 20km/hr) and the optimum speed was determined using the algorithm scoring delivered by Wildlife Computers analyses and additional criteria to ensure that the trajectory did not cross land and the trajectories themselves were reasonable relative to the biology of the animal. In general, the speeds selected were between 10-20 km/hr.

The effect of tag position on the duration of the deployment was analyzed using the tag position zones in Figure 4. Further variables that were also investigated included the weight of the fish, the tagger, the tagger workplace, the rigging and the species tagged.

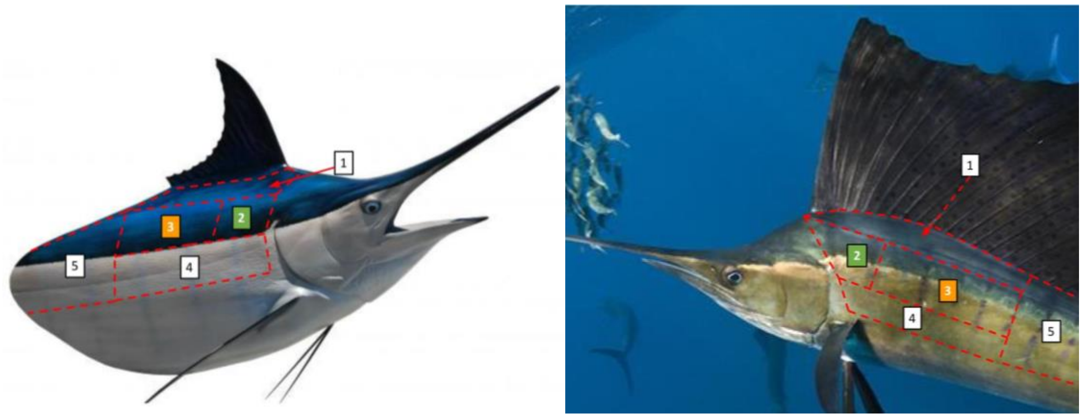
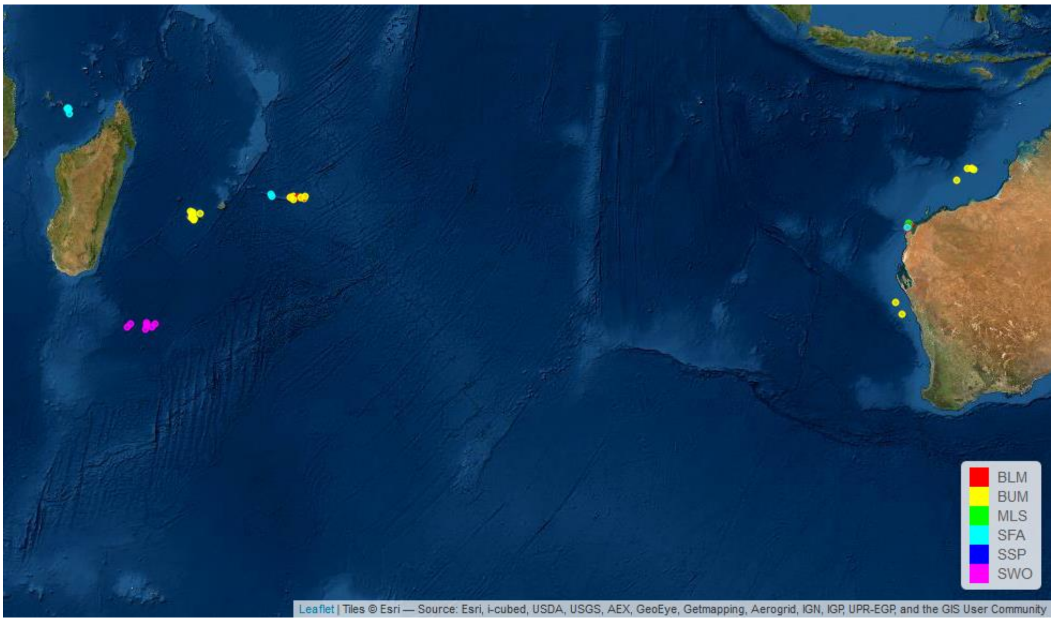


Figure 4. The tag position zones analyzed for marlins (left) and sailfish (right).

Billfish were tagged at 5 different sites: Australia, Rodrigues island, Reunion island, Mayotte and the south of Reunion island. Six species of billfish were tagged: blue marlin (*Makaira nigricans*), black marlin (*Makaira indica*), striped marlin (*Kajikia audax*), swordfish (*Xiphias gladius*), sailfish (*Istiophorus platypterus*) and shortbill spearfish (*Shortbill spearfish*). Fish were tagged between 5 January 2019 and 26 April 2022 (still some tag planning in the future) by 22 different taggers. In total, 84 billfish have been tagged. On the 84 tags deployed, 66 have already been released (79%) and 18 are still attached to the fish.

Table: Number of species tagged by tag site.

		TAG SITE					
		AUSTRALIA	SOUTH REUNION	MAYOTTE	REUNION	RODRIGUES	TOTAL
SPECIES	BLM	6	0	0	1	4	11
	BUM	12	0	0	19	7	38
	MLS	4	0	0	0	0	4
	SFA	10	0	7	3	3	23
	SSP	0	0	0	1	0	1
	SWO	0	7	0	0	0	7
	TOTAL	32	7	7	24	14	84



Map of the different tag sites.

Eight of the 66 popped tags (12%) were malfunctioning and haven't recorded the "pop date". So we removed these formers tags and conducted the analysis on 58 tags with the complete information. In order to evaluate the influence of the followings factors: weight, tagger, species, tag placement zone, tagger workplace and rigging on the retention time of the tags, one-way analysis of variance (ANOVA) and a Kruksal-wallis analysis of variance (Kruskal & Wallis, 1952) were performed. Then post-hoc pairwise multiple comparisons procedures were used: a Turkey-test (Turkey, 1949), following the ANOVA and a Dunn test (Dunn, 1964), following the Kruksal-Wallis anova.

Results

Of the 84 tags that were deployed, 66 were released from the fish and 18 are still deployed (Table Marks). The average duration of tag deployment was 58 days. The longest deployment lasted 180 days, or 6 months, which is the maximum programmed duration for tags that were released. Four tags remained on the fish for less than a day and did not collect enough data to calculate positions or trajectories. Eight tags never transmitted a signal even after the scheduled release date. Three tags were released prematurely from the fish <1 week after tagging due to an incorrect anchoring system. In summary, XX% of the tags released earlier than programmed due to mortality and XX% due to manufacturing error. The remaining XX% either released as scheduled or are still at sea.

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			17%	57%	15%	Likely mortality
Floater/Premature	40%	48%	25%	14%	36%	Likely mortality, anchoring system issue
Pin broke	40%	30%			19%	Manufacturing error
No information	20%	13%	33%	29%	21%	Manufacturing error (battery)
Interval		9%	17%		8%	Released as programmed
At sea			8%		2%	

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 57% of the just-tagged fish descended to great depths, indicating mortality and sinking (see Table 3, Figure 5, SWO) and the tags popped not long after, resulting in very short trajectories (Figure 2).

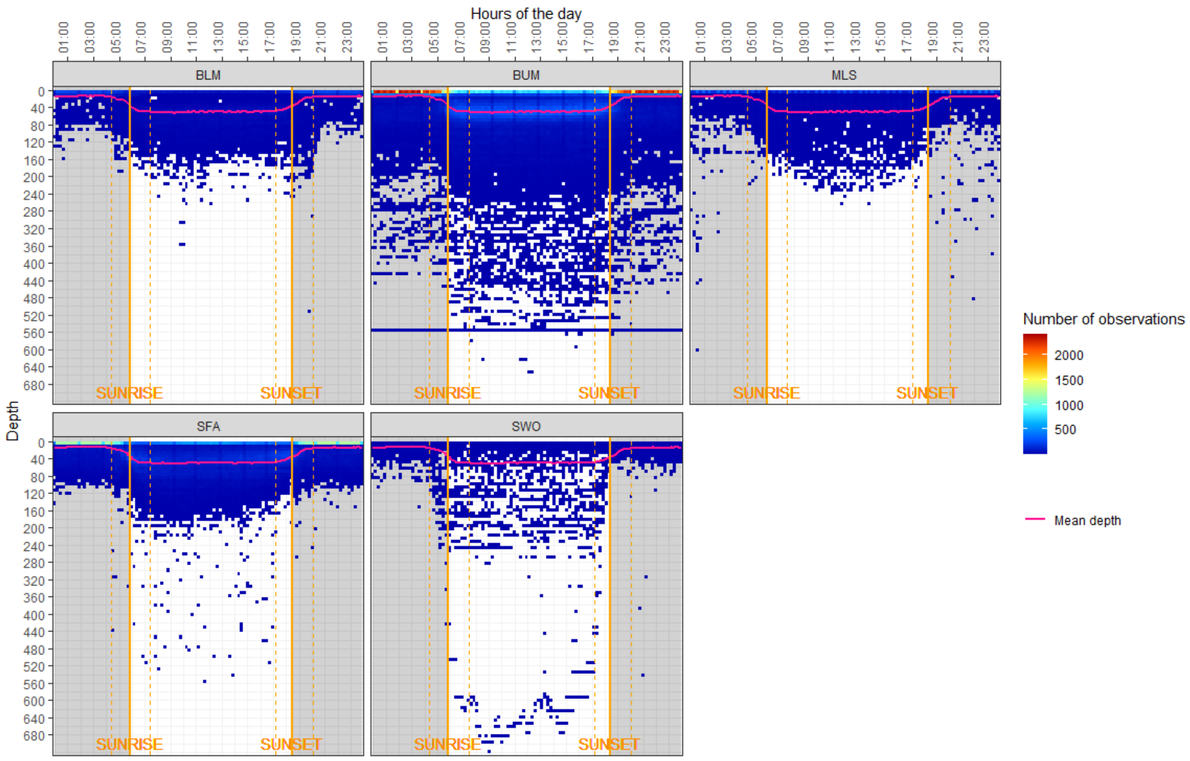


Figure 5. Frequency of depth (m) estimates during the day (top panels) and at night (bottom panels) for each of the tagged species. Species codes as in Table 2.

Pole and line tagging of the other three species are much more successful with the average tag duration of these events at about XX days. Many of the two marlin species are tagged 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.

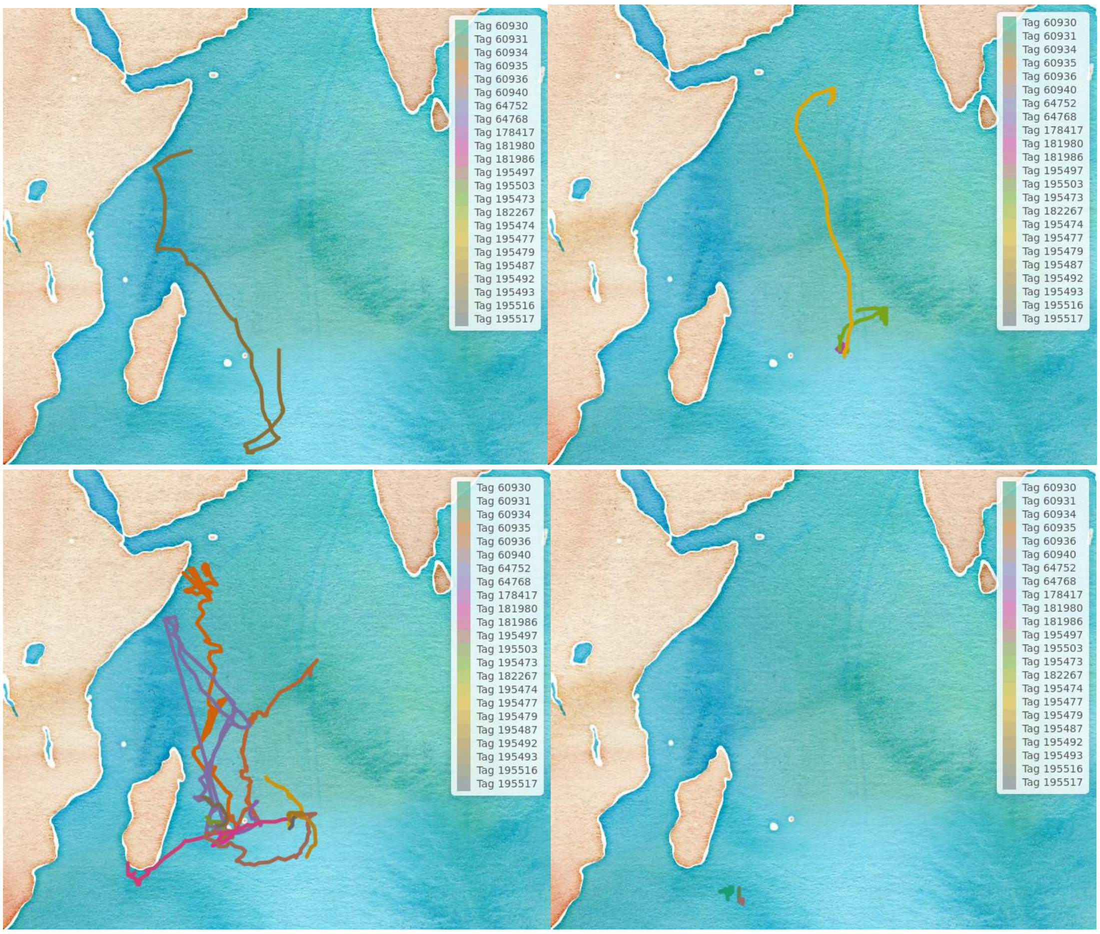


Figure 6. Trajectories of SFA (top left), BLM (top right), BUM (bottom left), and SWO (bottom right) tagged in this study. Species codes as in Table 2.

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 5). 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.

We analyzed several variables which could have affected the tag deployment duration, including tag position (Figure 7). The majority of tags were placed in zone 2 for all species (n=), followed by zone 1 and zone 3 (see Figure 4 for tag zones).

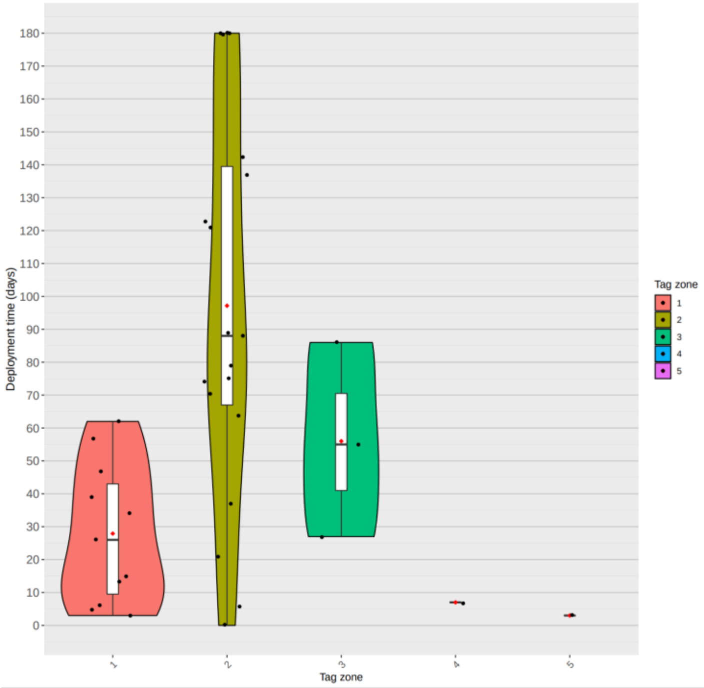


Figure 7. Deployment time of the by tagging zone (see Figure 4) for all species.

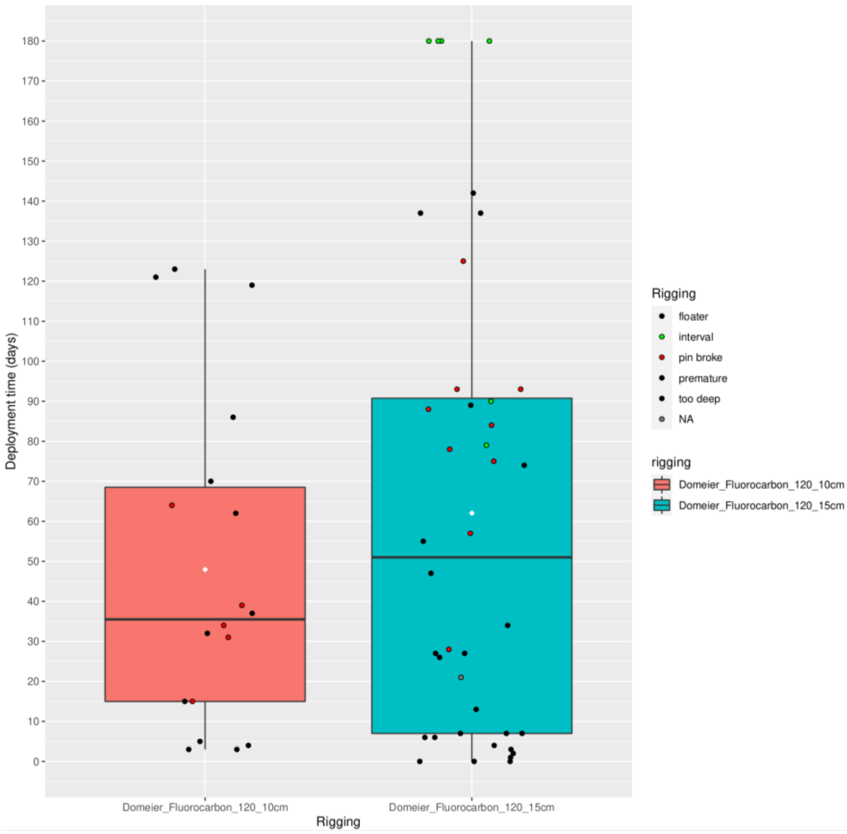


Figure 8. Deployment time based on rigging of the anchorage system. Dots indicate the deployment time of each tag; colors of the dots refer to the fate of the tag (see Table 3), barplots indicate the interquartile range of the deployment time between the two rigging systems. The horizontal black line indicates the median deployment time.

Only the factor "tag zone placement" showed a significant effect (*p=0.001*) on the retention time. Zone 1 et zone 2 being significantly different. The other factors analyzed didn't show any significant effect on the duration of the tag deployment.

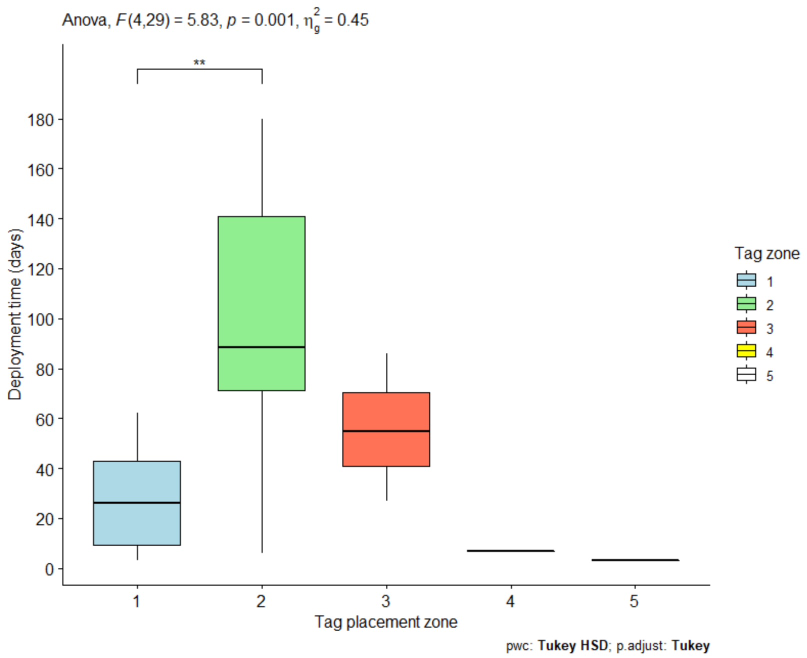


FIg: Results of the ANOVA for the effect of the tag placement zone on the deployment time.

Discussion

The development of precise protocols for fishing techniques and tag placement is necessary for each species and very little information exists in the literature. Our protocols aim to focus first on the safety of the tagging crew and second on the welfare of the fish. To do this, we identified tools and techniques to ensure and maintain the calmness of the fish during the tagging operation. For example, a "snooter" is a long stick with a lasso-like hoop at the end that is used to grasp the rostrum of a billfish and control it along the boat while the tag is placed (e.g., Sepulveda et al., 2015). The "snooter" is not a common fishing tool and little information is available on the preferred specifications for billfish (e.g., its length; the material it is made out of , etc). Different snooters were manufactured and tested by our team to determine the best materials and specifications for marking.

However, overall, the indicators of fish condition are unclear and are mostly focused on the activity of the fish (active or fatigued), hook placement (e.g., in the jaw, whether it has pierced the eye, etc.), and whether it is bleeding. Throughout this study, we will record fish observations to determine if there are key indicators of fish condition that predict post-release survival. In addition, we will work on the best way to resuscitate the individual, testing the time needed to re-oxygenate the fish before release. We need to identify the best tag placement for the health of the individual, as well as to maximize tag retention time. We will perform dissections to identify the ideal entry point for each species.

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