Preliminary results of an autonomous buoy prototype to count pelagic sharks at FADs

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Given the magnitude of the FAD-based fishery, bycatch from this fishing mode has generated conservation concerns. In particular, the silky (*Carcharinus falciformis*) and oceanic white tip (*Carcharinus longimanus*) sharks are the two major pelagic shark species that are incidentally captured at FADs (Dagorn et al., 2013). These shark species are both listed in the convention on International Trade in Endangered Species (CITES, Appendix II) and classified as Vulnerable and Critically Endangered by the international Union for Conservation of Nature (IUCN), with the oceanic whitetip shark recently listed as threatened under the United States Endangered Species Act (Young et al., 2018).

Over the last decade, research efforts have been directed towards finding bycatch mitigation methods to reduce fishing induced mortality of pelagic sharks in tropical tuna purse seine fishery. Studies investigating the mortality of silky sharks released from the purse seiners following good handling practices agreed that survival rates of released individuals was generally low (around 15 %) (Eddy et al., 2016; Hutchinson et al., 2015; Poisson et al., 2014). Other studies have subsequently explored technical mitigation measures by attempting to remove sharks from the net before reaching this survivorship bottleneck on the deck (Restrepo et al., 2016). Forget et al. (2015) also investigated the associative patterns and vertical distributions at FADs of targeted tuna species and major bycatch species, including silky sharks, in order to characterize and identify species-specific behavioral patterns that could help to improve the selectivity of the gear throughout the day. Silky sharks displayed similar associative patterns and a shallower vertical distribution than tunas, indicating few opportunities for technical mitigation solutions based on the time of the fishing set and the depth of the gear.

The fishing grounds of the tropical tuna purse seine fishery are extensive, getting remote information on FADs is crucial to fishers in planning and adapting their fishing strategy. Echo-sounders attached to FADs provide near real-time tuna biomass estimations at FADs and play an important role in the choice of the fishing area and the selection of FADs to visit. Similarly, real time information on the presence of Endangered, Threatened and Protected Species (ETP) species could be helpful to improve fishing selectivity by avoiding certain areas or specific FADs.

An autonomous buoy system prototype (“shark counter”) that has the capacity to detect and enumerate pelagic sharks at FADs automatically using cameras was developed. The automated detection system is based on a deep learning algorithm that was optimised for the shark counter buoy. The general design of the system consists of a floating collar on which the iridium communication system and the solar panels are fixed. The floater is connected to the lower camera platform with carbon fibber poles situated, approximately 1.3 m below the surface, on which 4 IP cameras are fixed (Figure 1). A waterproof housing containing the battery and the microcomputer is fixed onto the carbon poles. Once activated, the buoy will film 10 mins every hour. The shark detection algorithm processes the videos and outputs the number of

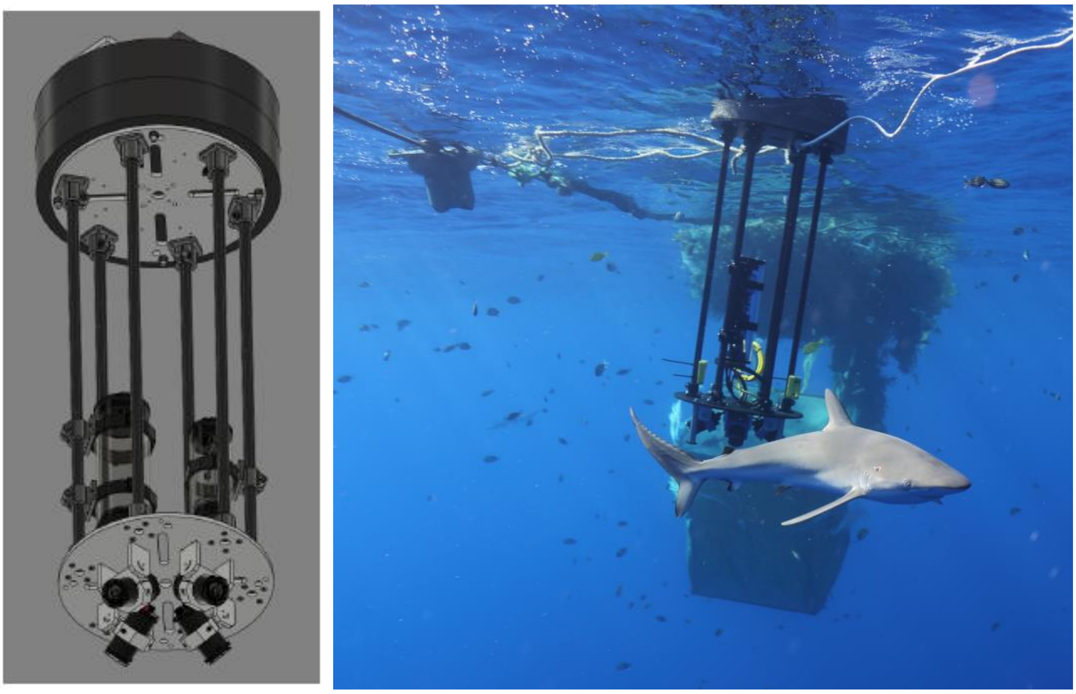

Figure 1: 3D CAD drawing of the shark counter buoy (left). Shark counter buoy attached to a drifting FAD during an experiment (right).

detected sharks per frame (Figure 2). A CSV file containing the buoy position, the time stamp of the counts, number of sharks per frame and the Nmax (maximum number of sharks per time step) are sent by Iridium and are accessible remotely.

A scientific cruise was conducted in the Seychelles onboard the *MV Tethys Supporter*, South of the Mahé plateau, in the Amirates basin within the EU INNOV-FAD project. The protocol to assess the performance of the shark counter buoy consisted of comparing the counts of the buoy to that of the reference shark counts established by scientists during UVCs. First, a UVC was conducted by the team of scientific divers at the FAD to estimate the number of sharks. The duration of the UVC was of 20 mins at 12 meters deep directly below the drifting FAD. Once the UVC was completed the shark counter buoys were switched on and the count cycles started.

This protocol was conducted on 7 drifting FADs during the cruise. The results summary are presented in the Table 1. The number of shark (Nmax) counted by the divers ranged between 2 and 16. A linear regression was used to compare the shark counts (Figure 3). The intercept of the linear regression was set to cross zero. Overall the shark count estimations by the shark counter buoy was about 50 % of that of the UVC reference count (Table 2, Figure 3).

Table 1 : Summary results of shark counts by UVC and the shark counter buoy.

Date	FAD #	UVC Shark count	Buoy shark count
16/04/22	1	4	2
18/04/22	2	2	2
19/04/22	5	4	2
21/04/22	6	5	3
22/04/22	7	12	6
23/04/22	8	16	7
24/04/22	9	7	3

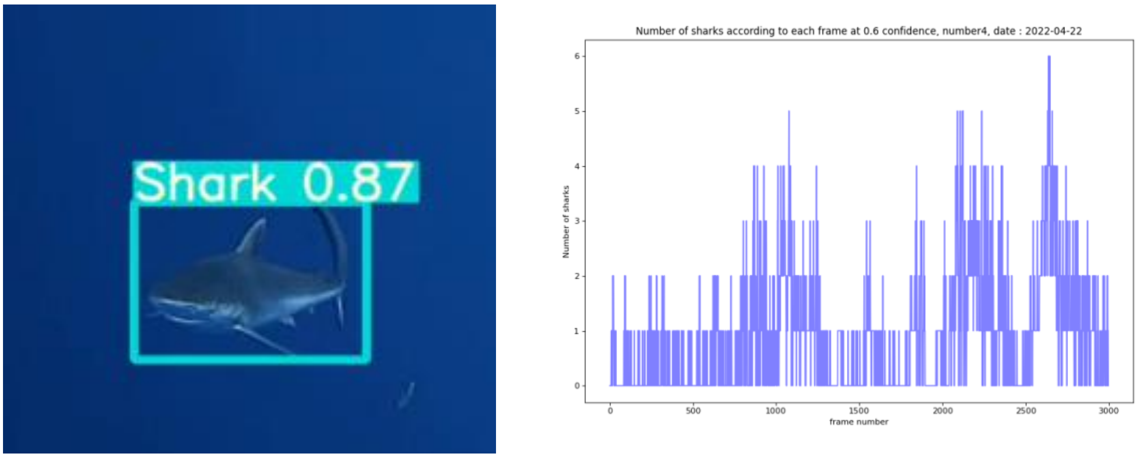

Figure 2: Vignette of a silky shark detected by the shark counter buoy and its detection confidence score (left). Shark counter buoy algorithm output time series with the number of detected sharks per video frame (right).

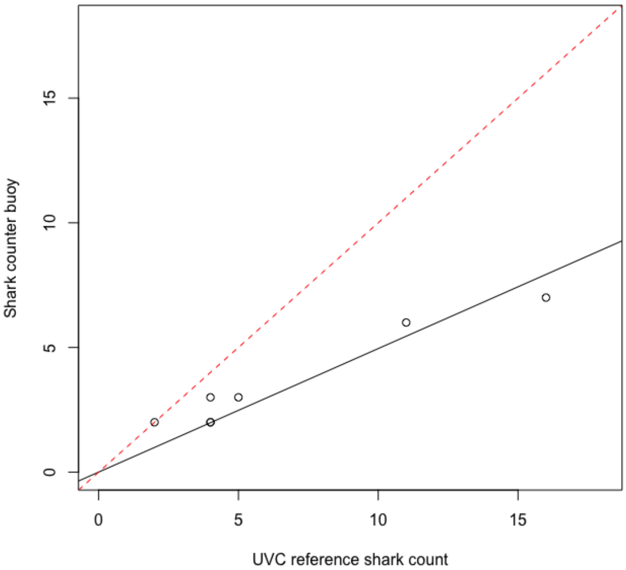

Figure 3: Estimated regression (solid line) and agreement 1:1 relationship (dashed red line) between the number of sharks recorded by the UVC reference shark count and shark counter buoy (N=7).

Table 2 : Summary results for regression statistics.

n	Coefficent	Std. Error	t-Statistic	P-value	R-squared
7	0.4956	0.0358	13.84	<0.001	0.96

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