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Remote electronic monitoring as a potential alternative to on-board observers in small-scale fisheries☆

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ABSTRACT

Small-scale fisheries can greatly impact threatened marine fauna. Peru's small-scale elasmobranch gillnet fishery captures thousands of sharks and rays each year, and incidentally captures sea turtles, marine mammals and seabirds. We assessed the ability of a dedicated fisheries remote electronic monitoring (REM) camera to identify and quantify captures in this fishery by comparing its performance to on-board observer reports. Cameras were installed across five boats with a total of 228 fishing sets monitored. Of these, 169 sets also had on-board fisheries observers present. The cameras were shown to be an effective tool for identifying catch, with > 90% detection rates for 9 of 12 species of elasmobranchs caught. Detection rates of incidental catch were more variable (sea turtle = 50%; cetacean = 80%; pinniped = 100%). The ability to quantify target catch from camera imagery degraded for fish quantities exceeding 15 individuals. Cameras were more effective at quantifying rays than sharks for small catch quantities ($x \le 15$ fish), whereas size affected camera performance for large catches ($x > 15$ fish). Our study showed REM to be effective in detecting and quantifying elasmobranch target catch and pinniped bycatch in Peru's small-scale fishery, but not, without modification, in detecting and quantifying sea turtle and cetacean bycatch. We showed REM can provide a time- and cost-effective method to monitor target catch in small-scale fisheries and can be used to overcome some deficiencies in observer reports. With modifications to the camera specifications, we expect performance to improve for all target catch and bycatch species.

1. Introduction

Overexploitation has long been identified as a major threat to global biodiversity (Diamond, 1984), especially in the marine biome (Knapp et al., 2017). Monitoring of biodiversity and exploitative activities has been identified as a major priority in conservation biology (Bawa and Menon, 1997) and new monitoring tools are being developed for a variety of biomes (e.g. Bicknell et al., 2016; Rist et al., 2010). Improved monitoring of the fisheries sector is of particular importance as global illegal, unreported and unregulated (IUU) fishing practices are estimated at 11–26 million tonnes per annum (Agnew et al., 2009).

Small-scale fisheries make a substantial contribution to global fish captures (Chuenpagdee et al., 2006), producing more than half of the world's annual catch and supplying most fish consumed in developing nations (Berkes et al., 2001). However, despite their importance to global catches, small-scale fisheries are often largely under-regulated (Berkes et al., 2001). Moreover, small-scale fisheries remain relatively unstudied compared to large industrial fisheries due to insufficient resources and poor infrastructure (Berkes et al., 2001; Lewison et al., 2004; Mohammed, 2003; Pauly, 2006), making it difficult to quantify their impacts on target and non-target species (Berkes et al., 2001; Lewison et al., 2004; Pauly, 2006).

Independent on-board observers have traditionally been used to monitor target catch (Alfaro-Cordova et al., 2017; Haigh et al., 2002; Mangel et al., 2013) and bycatch (Caretta et al., 2004; Gales et al., 1998; Rogan and Mackey, 2007) in fisheries, including some small-scale fisheries (Doherty et al., 2014; Mangel et al., 2010; Ortiz et al., 2016). However, use of on-board observers to quantify fishing activities can

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Fig. 1. The camera system developed by Shellcatch Inc. used in our study to monitor catch includes (i) a camera and GPS logger, (ii) a battery pack, (iii) a solar panel to charge the battery, and (iv) a metal frame to mount the camera to the boat. The position where the camera was installed depended on the vessel's configuration. Attachment locations included (a) guard rail (vessel 2); (b) cabin (vessel 3); (c) mast A-frame (vessel 5).

sometimes yield biased information, resulting from deployment effects (Benoît and Allard, 2009), observer effects (Benoît and Allard, 2009; Faunce and Barbeaux, 2011) and low fleet coverage (McCluskey and Lewison, 2008). Monitoring small-scale fisheries through observers poses a major challenge due to the large number of vessels, limited number of trained personnel, low enforcement and vigilance, and difficult working conditions, given the small size of vessels (Salas et al., 2007).

Some vessel monitoring system (VMS) technologies have been developed as an alternative or to supplement on-board observers. VMS is most commonly associated with Geographical Positioning Systems (GPS), but also incorporates other monitoring technologies. VMS is capable of providing data at high spatial and temporal resolution and has been installed in numerous fisheries (Campbell et al., 2014; Gerritsen and Lordan, 2010; Jennings and Lee, 2012; Witt and Godley, 2007), although to date, VMS has been mostly deployed in industrial fisheries, where it is sometimes mandatory (Bertrand et al., 2008). Several aspects of fishing activities can be monitored using VMS, including vessel position, operational characteristics, engine operation, and soak time (Kindt-Larsen et al., 2011; Lee et al., 2010; Vermard et al., 2010). Simple VMS technologies, such as GPS, have been deployed in some small-scale fisheries to monitor their activities (Metcalfe et al., 2016), whilst also providing some direct benefits to the fishermen such as improved navigation (Wildlife Conservation Society Bangladesh, 2016).

One increasingly popular VMS is the use of Remote Electronic Monitoring (REM) cameras, and represents one of the many applications of cameras in marine environmental research (Bicknell et al., 2016). Studies have been carried out to measure the effectiveness of REM systems at monitoring industrial fishing activities, including target catch (Ames et al., 2007; Hold et al., 2015; Kindt-Larsen et al., 2011; Stanley et al., 2009), bycatch (Kindt-Larsen et al., 2012; Pasco et al.,