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Hooking locations in sea turtles incidentally captured by artisanal longline fisheries in the Eastern Pacific Ocean

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ABSTRACT

Bycatch by longline fisheries, especially by artisanal small-scale fisheries, is one of the main conservation problems for some sea turtle populations around the world. Since 2004, a network of professionals under the "Eastern Pacific Regional Sea Turtle Bycatch Program" have been working with artisanal longline fishers in the Eastern Pacific Ocean (EPO) to reduce sea turtle bycatch and related mortality. Trials assessing circle hooks of different sizes and shapes, and different baits, have been conducted to determine the effectiveness in the reduction of sea turtle bycatch and changes in hooking location. In this paper, information from 1823 olive ridley sea turtles incidentally captured in the EPO were analyzed to assess how hook type (J, tuna hooks or circle hooks), hook size, bait type (squid or fish), turtle size and target species (tunas, sharks or mahi-mahi) affect hooking location on sea turtles. This were modeled with a Classification and Regression Tree using hooking location as a multinomial variable response (for 6 categories of hooking locations); and also as a binomial response (swallowed vs. non-swallowed) using a Generalized Linear Mixed Model (GLMM). Hook type and size, plus bait type, were the most important factors affecting hooking location, while turtle size and target species did not have any significant effect. J-hooks and tuna hooks had a much greater probability of being swallowed than circle hooks. In addition, as the hook size increased, the likelihood of swallowing it decreased. The use of fish bait in combination with larger circle hooks tended to produce higher proportions of external hookings. An increase in external or lower mandible hookings is preferred since these locations are assumed to be less dangerous for the animal's post-release survival, and because hooks and attached gear are easier to remove by well-trained fishermen.

1. Introduction

Bycatch is one of the most important issues affecting global fisheries management today (Hall et al., 2000; Soykan et al., 2008; Gilman, 2011). This problem becomes particularly sensitive when the non-target species incidentally caught are long-lived animals, have low reproductive rates and are threatened or endangered (Dayton et al., 1995; Lewison et al., 2004). This is the case of sea turtles when they interact with longline fisheries, one of the main causes for the decline of some sea turtle populations in the world (Camiñas et al., 2003; Deflorio et al., 2005; Gilman et al., 2006; Casale et al., 2007; Brazner and McMillan, 2008; Alessandro and Antonello, 2010).

Several studies have been conducted in a number of longline fisheries around the world assessing different measures to reduce the incidental capture of sea turtles (Bolten and Bjorndal, 2003;

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Shiode et al., 2005; Swimmer et al., 2005, 2010; Gilman et al., 2006; Baez et al., 2007; Wang et al., 2007; Brazner and McMillan, 2008). Of these, changes in bait type, and in the size, type and shape of hook seem to be the most promising (Largacha et al., 2005; Watson et al., 2005; Gilman et al., 2006; Gilman et al., 2007; Read, 2007; Brazner and McMillan, 2008; Sales et al., 2010). In particular, the use of mackerel bait in combination with large (size 18/0) circle hooks has been shown to reduce incidental capture of sea turtles by up to 90% in longline fisheries of the Western Atlantic and Hawaii (Watson et al., 2005; Gilman et al., 2007). However, due to differences in longline fisheries at regional and local levels, mitigation measures cannot always be readily adopted, and research needs to be conducted in each region and fishery before mitigation measures can be implemented in management plans (Gilman, 2011; Andraka et al., 2013). Furthermore, a thorough understanding of the socio-economic and political drivers of the region is essential to ensure the success of any proposed mitigation measure.

In the Eastern Pacific Ocean (EPO), bycatch of marine turtles is a priority conservation issue in many longline, trawl and gillnet fisheries (FAO, 2004; Wallace et al., 2010). In 2004, the "Eastern Pacific Regional Sea Turtle Bycatch Program" (EPRSTBP), was started in Ecuador based on the successful experiments carried out by the National Oceanic and Atmospheric Administration (NOAA) that showed a significant sea turtle bycatch reduction using circle hooks and fish bait (Watson et al., 2005). The main objectives of the EPRSTBP were: (1) to assess the benefits of using circle hooks in artisanal longline fisheries in the EPO; (2) the voluntary adoption by longline fishers of measures to reduce sea turtle bycatch; and (3) the training of fishers in on-board best sea turtle handling and de-hooking techniques (Andraka et al., 2013).

Since 2004, an interdisciplinary team of professionals from regional fishery management organizations, non-governmental organizations, governmental institutions and the fishing industry, has conducted trials in artisanal longline fisheries in nine Eastern Pacific countries from Mexico to Peru. The trials were designed to assess circle hooks of different sizes, shapes and different bait types, with the aim of confirming their efficacy in reducing capture rates, and in changing the hooking location in captured turtles, a factor directly related to post-release mortality. Andraka et al. (2013) analyzed and discussed some of the results obtained in the trials performed in these countries regarding the impact of circle hooks in the capture rate of sea turtles and found that the results for target and non-target species were not consistent for all fisheries analyzed, although circle hooks did reduce sea turtle hooking rates in most of the cases.

In addition to reducing sea turtle bycatch rates, circle hooks have been promoted as an alternative to traditional J-hooks to minimize injury in sea turtles accidentally captured in pelagic longline fisheries (Watson et al., 2005; Piovano et al., 2009). Due to their shape, circle hooks tend to slide along the jaw and they lodge near the commissure of the mouth or externally instead of being swallowed (Epperly et al., 2012), allowing for potentially easier removal, especially by fishers trying to recover their hooks. This, in conjunction with adequate hauling methods (using a net, instead of hauling the animal by pulling the line) and handling and hook removal techniques, could effectively reduce sea turtle post-release mortality (Parga, 2012; Swimmer and Gilman, 2012).

Apart from hook type, there are a number of variables that have been suggested to alter the location of hooks in incidentally captured sea turtles. After studies in a laboratory setting using circle hooks, Stokes et al. (2011) suggested that hook size and bait type were the two variables that most significantly altered hook location in loggerhead sea turtles (*Caretta caretta*). Analyzing these variables plus hook type, in data gathered over ten years by National Marine Fisheries Service Atlantic fishery observers, Stokes et al. (2012) concluded that under normal fishery conditions, hook type seemed to be the only factor significantly affecting hooking location. Moreover, Epperly et al. (2012) had similar results in experiments conducted with pelagic longline fisheries in the North Atlantic Ocean, with J-hooks having a greater probability of being swallowed than circle hooks. However, the authors were unsure if this greater gut-hooking rate could be attributed to the hook type or due to the size, since J-hooks used were smaller than the circle hooks.

In the present study hook type (J-hooks, Japanese-style tuna hooks -from now on "tuna hooks"- and circle hooks), hook size, bait type and turtle size were analyzed as factors affecting hooking location on sea turtles in real fishing conditions, using data gathered from the EPO artisanal longline fisheries in the past 8 years (2004–2011). The variable "target species" was also considered, because the characteristics of longline configuration, areas and seasons change according to the target species of each fishing trip (see Andraka et al., 2013 for further details). The effect that these changes in hooking location may have on turtle mortality will also be discussed based on current knowledge, as well as measures that can be adopted to increase the probability of sea turtle post-release survival.

2. Material and methods

Data were collected between 2004 and 2011 by trained observers of the EPRSTBP during trials conducted on standard commercial fishing trips in the artisanal longline fisheries in the EPO. During this period, a total of 3,529,699 hooks in 8996 sets were observed between 19°S–16°N and 70°W–100°W. The surface longline fisheries of this area include fisheries targeting mahi-mahi, tunas or sharks, and use different types of hooks such as J-hooks, tuna hooks and circle hooks, described by Mituhasi and Hall (2011) and Andraka et al. (2013). During the trial, comparisons between J-hooks or tuna hooks vs. circle hooks (12/0 through 18/0) were performed. J-hooks or tuna hooks and circle hooks were placed in an alternating pattern along the longline. Further details on the experiments and fisheries characteristics, such as vessel size, fishing season, targets, hooks per set, among others, can be found in Andraka et al. (2013).

More than one type of bait was used in some of the longline sets; in many cases it was bait obtained opportunistically, and it was hard to control its use. Because there was no detailed information on bait type for each hook, for the purpose of this work only those sets using one type of bait were included in the analysis. Thus, 4838 sets were considered in the analysis from a total of 8996 observed by the EPRSTBP between 2004 and 2011. The bait types were pooled into two categories for further analysis: squid (mainly *Dosidicus gigas* but also *Illex* sp. and *Loligo* sp. were employed) and fish (mainly *Opisthonema* spp., *Scomber japonicus*, *Auxis* spp. and *Sardinops sagax*).

Observers collected the information using standardized forms, including details on type and size of the hook, bait, curve carapace length (CCL), hooking location and entanglement of sea turtles accidentally captured. The analysis was focused only on olive ridley sea turtles (*Lepidochelys olivacea*), as this species is by far the most frequently captured in the region (71% of all turtles caught; Andraka et al., 2013).

2.1. Statistical analysis

Hooking locations were pooled into categories as follows: 'External': hooks on flippers, tail, carapace and neck; 'Tongue': hooks lodged in the tongue or glottis; and 'Swallowed': deep in the mouth, independently of whether the shank was visible or not. 'Lower jaw', 'Upper jaw' and 'Jaw joint' were not grouped, and each