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Abstract

Estimating bycatch is essential for monitoring the ecological impacts of a fishery in order to set management and mitigation priorities. Purse seine vessels targeting tropical tunas incidentally catch pelagic sharks (mainly silky and oceanic whitetip sharks), which are brought onboard and can be observed on the upper and lower decks. Currently, single onboard observers can only be efficiently stationed on one of the two decks, and thus often rely on information provided by the crew to complement their bycatch estimations. In this study, we used dedicated scientists strategically positioned during fishing sets in order to establish a reference count of captured sharks during conventional commercial fishing trips. We then assessed the accuracy of the counts made by (i) single observers onboard during the same fishing trips in the Pacific Ocean (where observers' main duty is to estimate catch of target species and bycatch estimation is of a lower priority) and the Atlantic Ocean (where observers' focus is on bycatch) and (ii) Electronic Monitoring System (EMS) in the Indian Ocean. A total of 74 fishing sets conducted during four purse seine fishing trips revealed that shark counts were underestimated for 50% to 100% of the sets, with the mean shark count underestimation, at the fishing trip level, ranging from 9% to 40% (onboard observers) and 65% for EMS. Given the importance of monitoring populations of vulnerable species, we strongly encourage specific studies during which the complementary counts of two onboard observers are used simultaneously to assess the accuracy of various EMS configurations, bearing in mind that single onboard observers appear to underestimate the number of captured sharks.

Introduction

Mitigating bycatch is a key component of the sustainability of any fishery under the ecosystem-based fishery management scheme (Pikitch et al., 2004). Quantifying the amount of bycatch is an essential step in order to assess impacts and set priorities for bycatch mitigation. Time series data of bycatch estimates are also important for tracking changes in the abundance of impacted species and for assessing the efficacy of mitigation techniques and conservation measures. This is especially pertinent for Endangered, Threatened or Protected (ETP) species such as pelagic sharks whose populations have been impacted by overfishing (Dulvy et al., 2008; Oliver et al., 2015; Queiroz et al., 2019). For each fishery, mitigation objectives depend on the level of bycatch and the population status of the bycatch species.

The shark bycatch rate of purse seine vessels targeting tropical tunas catch is relatively low; less than 1% by weight compared to tuna catches (Dagorn et al., 2013). However, the magnitude of the fishery (about 3.3 million tons annuelly, ISSF, 2020) generates concerns about its impact on pelagic sharks populations. The two main shark species caught by tropical tuna purse seine vessels are the silky shark (*Carcharhinus falciformis*) and the oceanic whitetip shark (*C. longimanus*) which are often found associated with drifting fish aggregating devices (dFADs) and other floating objects (Gilman, 2011). The populations of these two species have been harvested at such high levels (targeted by some fisheries or as incidental bycatch) that they are both listed in the Convention on International Trade in Endangered Species (CITES , Appendix II) and classified as Vulnerable worldwide by International Union for Conservation of Nature (IUCN), with the oceanic whitetip shark now listed as threatened under the United States Endangered Species Act (Young et al., 2018).

Every Regional Fishery Management Organization (RFMO) has observer programs to monitor the purse seine fishery, estimate catch of non-target species (including ETP species), and sometimes target species. These observers have numerous tasks including species identification and enumerating individuals interacting with the fishing gear. These tasks present a number of different challenges and depend on the characteristics of the fishery, e.g., the number of species and individuals caught per fishing event, as well as the size of the vessel and its configuration (Gilman et al., 2019). Tropical tuna purse seine vessels are usually large (up to 110 m long) and each fishing set usually brings tens of tons of tuna onboard, composed of targeted tuna species (skipjack- *katsuwonus pelamis*, yellowfin-*Thunnus albacares* and bigeye tuna *T. obesus*) and several non-target species. Brailing, the process by which the catch is brought onboard, usually occurs rapidly as it is essential for the crew to transfer the fish from the sack of the net to the refrigerated holds rapidly to maximize the quality of the catch. The speed of this process can make it difficult to identify all the species brought on board and to count individuals while the content of each brail (4–6 tons) is conveyed into the refrigerated holds in the lower deck. Another challenge faced by observers is that sorting and releasing bycatch can happen both in the upper and the lower decks of a purse seine vessel (Monteagudo et al., 2015). An observer can only be present on one of the two decks at time, and thus often relies on the help of crew members, located in different parts of the vessel, to complement their bycatch estimates. Some early work conducted by Hutchinson et al.(2015) highlighted that shark counts were generally underreported by both the observer and the vessel's logbook during a fishing trip in the Western Pacific Ocean. However, despite the key role of observer data in the ecosystem approach to fisheries, assessing the accuracy of such data has not been comprehensively assessed. In the last decade, the technological development leading to alternative observation systems, such as the Electronic Monitoring System (EMS), are gradually being implemented by several commercial fisheries. For EMS trials conducted in the purse seine fishery, the effectiveness of the systems has been evaluated by comparing estimations to that of onboard fisheries observer data (Ruiz et al. 2013, Briand et al. 2017), which has for now been considered as the reference counts.

The objective of this study is to investigate the accuracy of shark count estimations by single onboard observers and EMS on tropical tuna purse seine vessels. The approach here was to use the counts made by scientists strategically positioned onboard in order to have a reference count. The accuracy of the onboard observers and EMS was then assessed during each commercial fishing trip using the reference count established by the scientists.

Materials and Methods

Shark counts

Shark count comparisons were made for four commercial cruises onboard tropical tuna purse seine vessels conducted in the Western and Central Pacific (WCPO1, WCPO2), the Atlantic (AO) and the Indian (IO) Ocean (Table 1). During the WCPO1, WCPO2, and AO cruises, both scientists (2 or 3) and trained observers were present onboard. During each fishing set, scientists stationed on the upper deck, and the lower deck for vessels with a bycatch chute, counted sharks incidentally captured and brought onboard. These two independent counts allowed to investigate the accuracy of the counts made by the observer using the reference count established by the scientists. Following respective tuna RFMO (Regional Fisheries managerial Organization) sampling protocols, observers in the WCPO primarily focused on grab sampling of targeted tuna species and they also attempted to enumerate bycatch. In the AO, the observer primarily focused on the enumeration of bycatch. During the IO cruise, there was no observer but an Electronic Monitoring System (EMS) by Thalos (www.Thalos.fr) was installed onboard. Footage from two cameras was used for bycatch enumeration; one on the port side of the fishing deck and the other in the lower deck above the conveyor belt and the bycatch chute where individuals were sorted and released from the lower deck through the chute. Recorded footage was then analyzed by a trained and experienced observer to enumerate the number of sharks brought aboard the vessel. This allowed comparison of shark counts made by scientists and the EMS.

Data analysis

We investigated the differences in the shark counts using the Bland-Altman plot analysis (Altman and Bland, 1983). The Bland-Altman analysis is frequently used in studies investigating the agreement and proportional bias between two quantitative measurement methods by studying the mean difference between the two methods (Giavarina, 2015; Özgür, 2018). This graphical method was used to illustrate the difference between counts of the scientists considered as the reference count (K1) and those of the onboard observer or EMS (K2).

Scatterplots were made in which the X-axis represented the reference counts by scientists, and the Y-axis represented the difference (K1 – K2) of the two measurements. Additionally, the mean bias (mean of K1 – K2) and its confidence limits (limits of agreement) were projected (2*SE). The proportions of sets with the same counts (agreement), with underestimations or overestimations were computed as well as respective means and standard errors.

Only sets in which sharks were observed were included in this analysis.

Results

A total of 74 sets for which sharks were observed were used in the analysis: WCPO1 (n=16), WCPO2 (n=22), AO (n=15), IO (n=21). A total of 589 sharks were observed by scientists in the four cruises: WCPO 1 (n=205,) WCPO2 (n=67), AO (77), IO (240) (see Table 1).

Generally, onboard observers underestimated the number of captured sharks for most fishing sets (50%-81% of sets; Table 1, Figure 1). EMS data followed the same trend; the number of sharks in all sets was underestimated. Fishing sets with concurring shark counts varied between 12.5% and 26.7% for cruises with onboard observers. The accuracy was generally low as the mean bias varied from 9.5% to 40.1% for onboard observer counts and 64.7% for the EMS. Overestimations only occurred during WCPO1 (n=1) and WCPO2 (n=2) but influenced the mean bias. When only considering sets where shark counts were underestimated or in agreement, the number of sharks was underestimated between 44.9% and 53.1% for the three cruises with onboard observers and 64.7% with the EMS.

Table 1: Summary statistics of shark counts per cruise.

Cruise	Year	No. sets	No. sharks	% sets with agreement	% sets with underestimations	% mean of understimations	% sets with overestimations	% mean of overestimations	% mean bias
WCPO1	2012	16	205	12,5	81,3	44,9	6,3	NA	40,1
WCPO2	2013	22	67	36,4	50,0	46,3	13,6	100	9,5
AO	2016	15	77	26,7	73,3	53,1	0,0	NA	38,9
IO	2018	21	240	0,0	100,0	64,7	0,0	NA	64,7

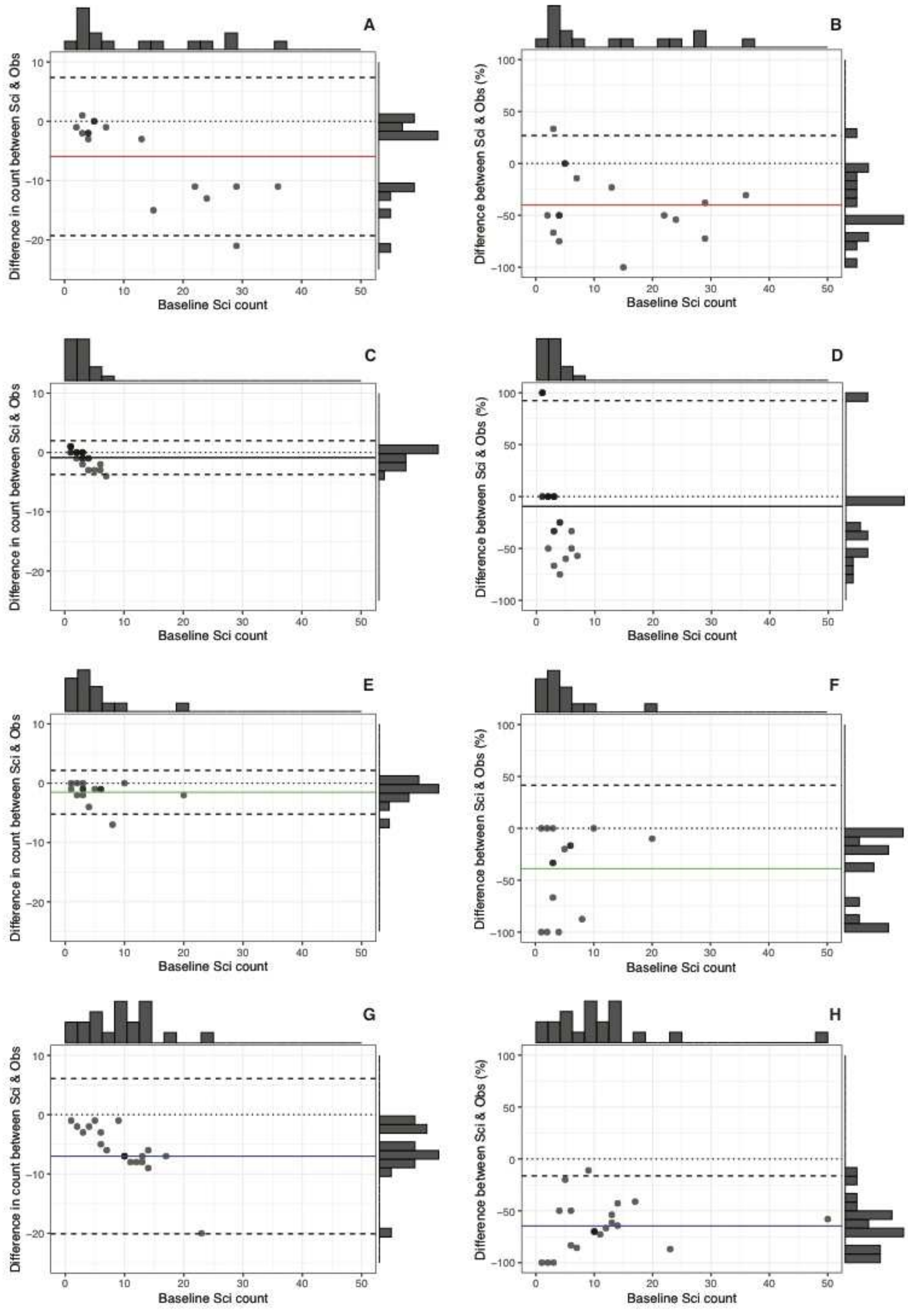

Figure 1: Bland and Altman plots illustrating the difference in shark counts by scientists (Sci) and observers (Obs) in numbers of sharks on the left (A,C,E,G) and by percentages on the right (B,D,F,H) per set for WCPO1, WCPO2, AO and IO EMS cruises. Solid lines represent the mean bias, dotted lines represent the limits of agreement (2*SE). The marginal histograms denote the frequency distributions of the X and Y variables.

Discussion

The results of this study suggests that single observers placed on purse seiner vessels underestimate the number of captured sharks. Underestimations occurred during most sets (between 50% and 81%, depending on the trip), and it is noteworthy that when there were more than 10 sharks, underestimations were systematic.

Shark bycatch is typically discarded at sea (in various condition states) as two of the main species encountered in purse seine fisheries are subject to no-retention policies in some RFMOs and are thus sorted from the rest of catch. This may occur on the upper or the lower decks of a tuna purse seine vessel (depending on the vessel's configuration). Often, sharks are not seen until they are on the conveyor belts of the lower deck; thus a single observer must rely on the help of the crew to provide, or complement, bycatch estimates from the location where he or she is not present. Moreover, in some regions (e.g., western and central Pacific Ocean), following RFMO requirements, the main duty of the observer is to estimate the catch composition of the target tuna species and bycatch estimation is a lower priority. The inaccuracy of shark counts increased substantially for sets with more than 10 sharks during all the cruises.

The magnitude of the shark count underestimations by the EMS analyzed in our study was greater than those measured during trips with single observers which is in accordance with the findings in Ruiz et al. (2017). It is possible that improvements of the EMS analyzed in this trip, through changes in the location of the cameras, could have improved the accuracy. However, the objective of this study was not to evaluate the design of the EMS, but rather to highlight the fact that EMS may also underestimate shark counts. It is very likely, however, that the performance of EMS could vary with different designs (e.g., number and location of cameras) and more studies are clearly required in order to assess the performance of various EMS configurations. Additionally, it is important to note that the taxonomic precision of the shark identification was greatly degraded as identification at the species, or genus, level was often not possible (30% of individuals, data not shown) with the EMS. This causes additional issues for the monitoring of ETP species bycatch using EMS.

While observers' duties and their locations on the vessel during the fishing operations can differ by ocean, the need to improve the accuracy of the number of sharks incidentally captured appears to be global. Technically, improvements appear to be simple: two observers onboard the same vessel (one on each deck), or a combination of a an observer and an EMS in complementary locations. However, considering the high cost of such an observation system, one approach could be to apply one of the two combinations described above during some commercial cruises, on a regular basis, in order to monitor the accuracy and, if possible, attempt to correct the bias obtained by single observers or EMS. The use of EMS has great potential to improve count accuracy (Gilman et al., 2019) by strategically positioning cameras in key locations such as the upper deck above brailing boom and the hopper, the starboard side where sorted bycatch are released on the upper deck, and above the bycatch chute in the lower deck for purse seine vessels that are equipped with one. However, while studies usually compare EMS with single observers (Briand et al., 2018; Gilman et al., 2019; Ruiz et al., 2017), we strongly encourage specific studies during which the complementary counts of two onboard observers are used simultaneously to assess the accuracy of various EMS configurations, bearing in mind that single onboard observers underestimate the number of captured sharks.

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