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Contribution to the Special 'Marine vertebrate bycatch: problems and solutions'

Leatherback bycatch in an eastern Caribbean artisanal longline fishery

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ABSTRACT: Overlap of small-scale fisheries with sea turtle high-use areas is of growing concern, but the extent to which these endangered species interact with fishing gear is rarely known. Structured face-to-face interviews with 22 longline vessel captains were used to make a rapid assessment of sea turtle bycatch by the artisanal longline fleet of Barbados in the eastern Caribbean. Extrapolated estimates suggested that an average of 284 sea turtles yr^{-1} were caught on 1 896 200 hooks, a bycatch per unit effort of 0.15. Based on extrapolation of the percentage of the observed vessels to the entire fleet, an estimated average of 374 sea turtles yr^{-1} are caught. The majority of captains (86 %) reported leatherback turtles *Dermochelys coriacea* to be the predominant species. The Barbados longline fleet operates in sea areas through which leatherbacks pass on their way to and from important nesting beaches in Trinidad and Tobago, Grenada, and the Guianas, and in which they reside during the pre-nesting period as well as throughout the nesting season. Although most sea turtles caught as bycatch were released alive, they often remained hooked with trailing lines. The majority of captains expressed their willingness to be trained in safe-handling and release of hooked and entangled turtles, to increase the probability of their survival.

KEY WORDS: Eastern Caribbean · Sea turtle · *Dermochelys coriacea* · Artisanal fishery · Survey

1. INTRODUCTION

Sea turtles must return to land to reproduce, and are therefore vulnerable to incidental capture in both offshore and nearshore fisheries (Casale et al. 2010, Wallace et al. 2010, Hamelin et al. 2017, Alfaro-Shigueto et al. 2018). There are numerous reports of interactions between the highly migratory leatherback sea turtle *Dermochelys coriacea* and fisheries that operate in oceanic and coastal areas (Lee Lum 2006, Alfaro-Shigueto et al. 2007, Fiedler et al. 2012, Hamelin et al. 2017). Adults of the northwest Atlantic population migrate between foraging grounds in the northeast and northwest Atlantic and the large breeding rookeries in Trinidad and Tobago, Grenada, and the Guianas (Georges et al. 2007, James et al. 2007, Witt et al. 2011, Dodge et al. 2014, Fossette et al. 2014), and they regularly move between rookeries within a single breeding season (Horrocks et al. 2016). Adult male and female leatherbacks, satellite tracked from Canada, migrate in late fall to specific high seas areas between 10–15° N and ~40–60° W before transiting to waters closer to the beaches where nesting takes place (Bond & James 2017). Females make their first nests in late March, and remain in the region until the end of August (Eckert 2006). Male leatherbacks begin their northward migration at the peak of the nesting season in May (James et al. 2005).

Fisheries bycatch, particularly in the vicinity of nesting beaches, has been identified as a potential driver of the declines in nesting seen in the Eastern Caribbean over the last decade (Northwest Atlantic

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Leatherback Working Group 2018). This has led to the recent re-classification of this population from Least Concern to Endangered (Northwest Atlantic Leatherback Working Group 2019). The very significant negative impact of the nearshore gillnet fishery off Trinidad on this important leatherback rookery has been reported previously (Lee Lum 2006, Eckert et al. 2008), but the population-level impacts of bycatch in artisanal longline fisheries in the region have not been documented.

Leatherbacks feed on gelatinous prey which inhabit the same productive waters that are attractive to longline fisheries (Fossette et al. 2010, Arocha et al. 2015). Turtles are attracted by the bait, after which they often become hooked or entangled in the lines. Although many turtles may be released alive, they are often injured and may still be hooked and/or trailing line. Fossette et al.'s (2014) examination of the highly seasonal overlap between longlining activity and leatherback density in the Atlantic shows the susceptibility of leatherbacks to bycatch in the Eastern Caribbean as being 'medium' from April–September and 'low' from October–March, based on seasonal differences in fishing intensity and on changes in the density of leatherbacks passing through the area to and from the rookeries in Trinidad and Tobago, Grenada, and the Guianas (Fig. 1; Fig. S1 in Fossette et al. 2014). Notably, Fossette et al.'s (2014) analyses were largely based on tracking data from animals on their post-breeding migrations, rather than pre-breeding migrations or while they were nesting within the region, and new offshore high-use areas where male and female leatherbacks aggregate prior to moving to nearshore coastal waters for breeding have since been identified (Bond & James 2017).

The first longlining vessels began fishing from Barbados in 1990. The Barbados fishery targets mainly yellowfin and bigeye tuna *Thunnus* spp., but also takes billfishes (swordfish *Xiphias gladius*; blue marlin *Mikaira nigricans*; and white marlin *Kajikia albidus*), Atlantic sailfish *Ostiophorus* spp., dolphinfish (dorado *Coryphaena hippurus*), albacore *T. alalunga*, and sharks (Walcott et al. 2009). Records of sea turtle bycatch are not logged by this fishery and observers have rarely accompanied fishing trips (but see Walcott et al. 2009). Therefore, the extent of sea turtle bycatch attributable to the fishery is unquantified. In an attempt to better understand the impact of the longline fishery on sea turtles, and in the absence of resources to implement an observer program, we initiated a rapid assessment approach using interview-based surveys. This can be a reliable method to provide estimates of the scale of bycatch in artisanal fisheries (see Alfaro-Shigueto et al. 2018). The primary objectives of this paper were to obtain an estimate of sea turtle bycatch in the Barbados artisanal longline fishery through a survey of vessel captains, to document the locations and seasonality of interactions between the fishery and sea turtles, particularly leatherbacks, and to report on the willingness of vessel captains to participate in actions to increase sea turtle survival post-release.

2. MATERIALS AND METHODS

Information on interactions between sea turtles and the longline fishery was collected in March 2015 through structured face-to-face interview surveys with 22 longline boat captains at the Bridgetown Fishing Complex, Barbados. Interviewing only the

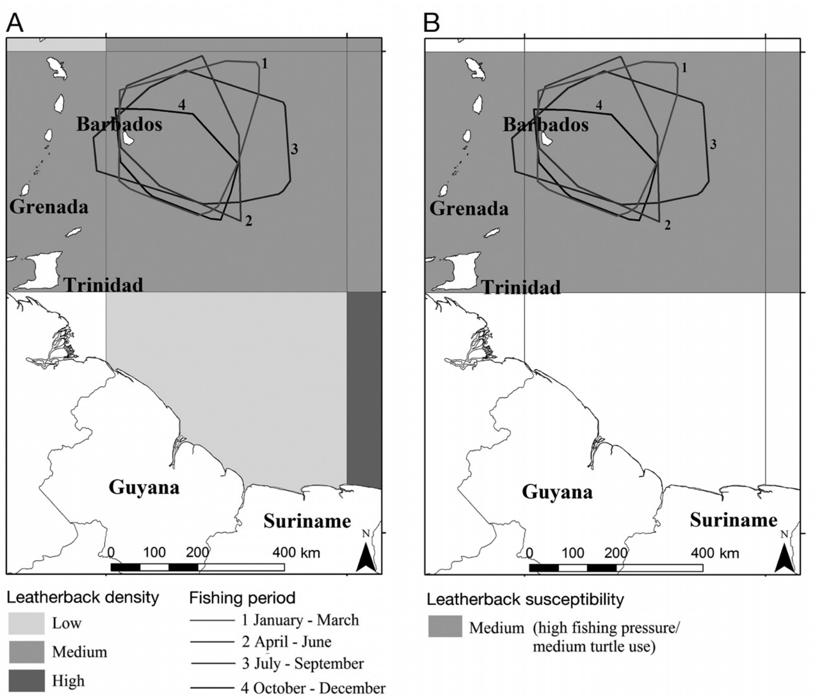

Fig. 1. Areas fished by 5 Barbados longline vessels during different quarters of the year between April 2014 and December 2016, superimposed on (A) leatherback sea turtle density pixels estimated from satellite tracks (adapted from Fig. 1b in Fossette et al. 2014) and (B) areas of susceptibility to bycatch where high fishing pressure overlapped with leatherback habitat use (adapted from Fig. 2 in Fossette et al. 2014)

captains avoided the potential of more than one member of the same vessel providing information. Given that there were 29 longline boats operating in 2015 (ICCAT 2016), our sample constituted 76% of the fleet. The 20–30 min interviews collected information on the fishing gear used, fishing practices employed, and interactions with sea turtles. Information on the seasonality of the fishery, the number of trips per year, and the number of sets (the setting and subsequent hauling of the line) made per trip was obtained. A previous study of the Barbados fishery has shown that a set line is allowed to soak for 6–13 h before retrieval, which can take 3–15 h depending on the length of line, sea conditions, and number of fish caught (Walcott et al. 2009). The numbers of turtles sighted or caught (leatherback or hard shelled), and the mortality of turtles caught were recorded. Finally, captains were asked questions about their handling of sea turtle bycatch and their willingness to participate in efforts to mitigate it. Follow-up interviews were conducted for further information, as required.

The annual number of sea turtles caught was calculated from the reported estimate of bycatch frequency per trip multiplied by the number of fishing trips vessels made each year. For comparison with the US and Venezuelan longline fleets operating in the same fisheries regions, the sea turtle bycatch per unit effort (BPUE), i.e. the number of turtles caught per 1000 hooks in the Barbados fishery, was also estimated.

In total, 5 Barbados vessels provided GPS data for their longline sets made between April 2014 and December 2016. The fishing areas identified for each vessel were then superimposed onto a map of leatherback density generated from satellite tracks of post-nesting adults in the Atlantic and onto a previously generated bycatch susceptibility map based on leatherback density and longline fishing activity in the Atlantic (Fossette et al. 2014).

3. RESULTS

3.1. Fishing effort and target species

Of the captains interviewed (n = 22), 86% reported that their boats fished year-round. Captains reported that their vessels made 6–36 trips yr^{-1} (mean ± SD: 22.7 ± 8.3 trips yr^{-1}), for a total of 499 fishing trips yr^{-1}. The vessels set an average of 7.6 ± 0.9 times $trip^{-1}$ (range: 6–10 sets) using monofilament nylon mainlines, varying in length from 35–65 km (mean: 42.4 km), with an average of 500 hooks $line^{-1}$ (range: 400–650 hooks $line^{-1}$). Most vessels fished at depths between 40 and 55 m (range: 33–101 m, SD: 14.4; Table 1). The hook type used by all vessels was the J-hook, within the size range of 6/0 to 8/0 (Table 1).

All captains targeted yellowfin and bigeye tunas and the majority also targeted billfishes. About half of the boats also landed sailfish, dolphinfish, and albacore, although these were caught incidentally. Some also reported fishing for flying fish *Hirundichthys affinis*, either to sell or to use as bait for longlining. Bycatch reported that was not landed included sea turtles and some sharks. Possession of sea turtles or their products has been prohibited in Barbados since 1998, but to date there are no regulations regarding the retention of sharks.

3.2. Sea turtle sightings and fishery interactions

The captains reported regular sightings and capture of sea turtles while fishing. All reported sighting sea turtles, either daily (33% of respondents), several times per trip (30%), or every 2–3 trips (37%). Sightings of >1 turtle at a time were not uncommon, suggesting that they were fishing in areas where turtles were aggregating in order to forage or to mate. All 22

Table 1. Comparison of the US, Venezuela and Barbados longline fisheries and estimates of sea turtle bycatch per unit effort (BPUE) in overlapping fishery areas. NCA: North Central Atlantic fisheries reporting area; CAR: Caribbean fisheries reporting area; TUN: Tuna North fishery reporting area. Data for USA from Witzell (1999) and Keene et al. (2007); data for Venezuela from Ortiz & Arocha (2004), Arocha et al. (2015) and Tavares (2005)

	USA	Venezuela	Barbados
Method of bycatch estimation	Observer program	Observer program	Interview survey
Target fishery species	Mixed (swordfish and tunas)	Tropical tunas and tuna-like species	Mixed (tunas and swordfish)
Hook type	Circle hooks (16/0–18/0)	J-tuna type (#3–4) and circle hooks	J-hooks (6/0–8/0)
Hook depth	57–77 m	20–90 m	40–55 m
Line setting time	Night	Day	Night and day
Months of highest bycatch	October–December	January–September	March–September
Fishery area	NCA; CAR; TUN	Caribbean; Guyanas-Amazonas	Fig. 1 in this study
Total BPUE	0.05[a]; 0.08; 0.03	0.003	0.15

[a]Estimated from Fig. 2 in Swimmer et al. (2017)

captains reported sea turtle bycatch, with turtles either being hooked or entangled in the line. Only one captain expressed a lack of confidence in differentiating hard shelled sea turtles from leatherback turtles, but of the others, 86% indicated that leatherbacks were the most frequently caught species. In total, 36% of captains reported one or more turtles caught per trip (with 7.6 sets trip^{-1} on average), and 64% reported one incidence of bycatch every 2–3 trips (every 15–23 sets). Many sets caught no turtles at all.

To provide a conservative estimate of total annual sea turtle bycatch by the 22 boats, we assumed only one turtle was caught per trip for those reporting one or more turtles per trip, and only one turtle per 3 trips for those reporting bycatch every few trips. The average turtle by-catch of each vessel was estimated to be 12.9 ± 9.0 turtles yr^{-1} (range: 2–36 turtles yr^{-1}). A conservative estimate of the average number of turtles incidentally caught by the 22 boats was 284 turtles yr^{-1} (range 44–792 turtles yr^{-1}), the majority of which were leatherbacks. Assuming the remaining 7 boats that were not sampled had similar bycatch numbers, this would extrapolate to 374 turtles yr^{-1} caught. In terms of BPUE, using an average of 7.6 sets of 500 hooks trip^{-1} and a total number of 499 trips yr^{-1}, approximately 1 896 200 hooks yr^{-1} are set by the 22 boats. With 284 turtles caught on 1 896 200 hooks, this suggests an annual average sea turtle BPUE of 0.15 turtles captured per 1000 hooks (range 0.02–0.42).

Entanglement in the mainline or branch lines (45% of incidents) or hooking around the mouth (45% of incidents) were the most common ways that turtles were reported to be caught, followed by swallowing of hooks (10%). Captains reported cutting entangled turtles from the mainline and then re-splicing the 2 ends. Reports of dead turtles being found on the hauled lines were uncommon, with all captains reporting that captured turtles were usually alive and active when released. Sea turtles with prior injuries were also reported. Of 8 captains who indicated that they had caught sea turtles with signs of previous injury, hook damage was most common (75%), followed by entanglement injuries (62%), and carapace damage (12%).

Most captains (75%) said that they never brought turtles aboard to remove fishing hooks or untangle the line, due to the size of the turtle caught. None possessed equipment to bring large sea turtles aboard safely, nor had they access to specialized line cutters. The lines were typically cut as close as they could get to the turtle, but in reality far enough from the point of attachment to the turtle that animals frequently trailed line at release (Fig. 2). None of the captains were aware of the potential danger to the turtle by releasing it trailing long pieces of line.

Fig. 2. Leatherback sea turtle hooked in the mouth immediately before line was cut at the boat (Photo by E. Czuchnicki)

3.3. Location and seasonality of bycatch

The 5 vessels that each provided GPS data for their fishing sets between April 2014 and December 2016 travelled an average distance of 473 km (range: 65–1300 km) from Barbados, depending on what satellite data identified as potentially good fishing areas. The GPS data are shown as polygons for the 4 quarters of the year in Fig. 1. The vessels primarily fished from NE–SE of Barbados, and between 10–15° N and 56–59° W, over an average total area of about 75 000 km^2. During July–September, vessels increased the area to the east that they fished, and some also included fishing areas to the west of Barbados. All polygons fell within the pixels identified by Fossette et al. (2014) as 'medium' leatherback density and 'medium' risk of susceptibility to bycatch in longline fisheries, based on fishing effort and leatherback density (Fig. 1).

Barbados captains reported higher sea turtle bycatch, especially of leatherbacks, between March and September (Fig. 3). Bycatch of turtles was rare between October and February.

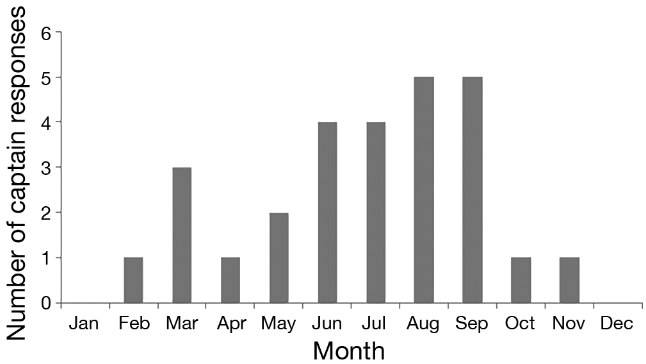

Fig. 3. Months in which captains reported their highest levels of sea turtle bycatch. Captains could report more than 1 mo

4. DISCUSSION

Assessment of the extent and the spatial distribution of bycatch is an essential element in the conservation of endangered sea turtles. Wallace et al. (2010) reported about 85 000 incidents of sea turtle bycatch over a 20 yr period globally, including 1384 incidents of longline bycatch in the Caribbean region. They noted that the figure was likely an underestimate by several orders of magnitude, because observers are typically employed in <1% of fleets and because the impact of small-scale fishing activities is rarely documented. Although Walcott et al. (2009) reported sea turtles as bycatch in the Barbados longline fishery, along with sharks, oil fish, rays, and pilot whales, they did not quantify its extent. In the absence of an observer program, this survey of captains of the longline fleet has provided a first rapid assessment (see Moore et al. 2010, Alfaro-Shigueto et al. 2018) of sea turtle bycatch for the Barbados fleet, and has provided an extrapolated annual average estimate of 374 turtles yr^{-1}, consisting mainly of leatherbacks, for the entire fleet.

Longline bycatch is reported throughout the range of leatherbacks that nest in the Eastern Caribbean and the Guianas (Fossette et al. 2014, Swimmer et al. 2017). The US Atlantic longline fleet catches leatherbacks from this stock (Stewart et al. 2016) within the North East Distant (NED) fisheries reporting area (Witzell 1999), as well as in fisheries reporting areas that are adjacent to the major nesting beaches, i.e. Caribbean (CAR) and Tuna North (TUN) (Swimmer et al. 2017). The 3 US fisheries reporting areas that overlap with the spatial data of the fishing area provided by the 5 Barbados vessels are the North Central Atlantic (NCA), CAR, and TUN. The BPUE for the US fleet was ~0.05 in NCA, ~0.08 in CAR, and ~0.03 in TUN (estimated from Fig. 2 in Swimmer et al. 2017; see Table 1), and included data after a mandatory change in gear to circle hooks reduced sea turtle bycatch substantially post-2004 (Swimmer et al. 2017). Two Venezuelan fisheries reporting areas also overlap with areas fished by the Barbados fleet (as shown in Fig. 1), the Caribbean and the Guyanas-Amazonas areas (Bjorkland 2011). A combined BPUE of 0.003 for the Venezuelan fleet in these 2 areas (which includes a third area, Sargasso, where no turtles were caught) was recorded (Table 1), with leatherbacks being caught more frequently than other species (Arocha et al. 2015).

Hsu et al. (2015) deduced that deep longlines set during the day were more effective for catching tunas, while shallow longlines set at night were more effective for catching swordfish. Since air-breathing sea turtles are more likely to be found at shallower depths, bycatch in swordfish-targeted fisheries may be greater (Lewison et al. 2004, Kaplan 2005). The estimates of BPUE for the 3 nations' longline fisheries (Table 1) are not directly comparable, due to variation in fishing effort and gear configurations and because of the different data collection methodologies, but the order of magnitude higher bycatch by the Barbados fleet over the Venezuelan fleet during similar months of the year with similar sized hooks may be at least partly attributable to the Venezuelan fleet targeting tunas with deeper set lines (Bjorkland 2011, Arocha et al. 2015), while the more mixed species Barbados fishery sets lines at shallower depths (<60 m; Table 1). Aside from use of the larger circle hooks, the US Atlantic fleet, which also has lower BPUE than the Barbados fishery, also fishes at greater depths than the Barbados fishery (Table 1).

Sea turtle BPUE is calculated from very rare events (Coelho et al. 2013) and we acknowledge the potential bias of BPUEs reported from low fishing effort, such as that reported by the Barbados fleet (Sims et al. 2008). Caution is also necessary when extrapolating from survey data, especially when the range in estimated numbers of turtles caught per vessel sampled is high (range: 2–36 turtles yr^{-1}). Although the lower end of the range of BPUE for the Barbados fishery is closer to the average BPUEs reported for other fisheries (Arocha et al. 2015, Swimmer et al. 2017), we consider it likely that the estimated average BPUE (0.15; Table 1) for the Barbados fleet is as high as it is because fishing activity overlaps with both high-use sea turtle areas (Fossette et al. 2014, Bond & James 2017) and water depths.

Walcott et al. (2009) reported that the preferred fishing areas of the Barbados fleet were southeast of the island, while data from the present study suggests that fishing is now occurring over a wider area, from the northeast to the south of Barbados (Fig. 1), and occasionally west of the island. Breeding leatherbacks of both sexes arrive in the Eastern Caribbean region prior to first nesting in March (Bond & James 2017) and some females remain until the end of the nesting season in August. Adults are therefore vulnerable to interactions with the Barbados longline fleet for 6–7 mo of the year. These include the months when Barbados captains report the highest turtle bycatch. Fossette et al. (2014) previously identified April–September as months when breeding leatherbacks may be most susceptible to capture, based on movements of satellite-tracked adults. The GPS data show that fishing sets overlap with migratory pathways (Fossette et al. 2014, Bond & James 2017), pre-nesting areas of adult leatherbacks of both sexes, and areas of high use by adult females during the mating period (see Figs. 3 & 4 in Bond & James 2017). This is substantiated by captains often reporting sightings of 2–3 turtles in the same area. Some leatherbacks of <100 cm carapace length were also described as bycatch. Juvenile leatherbacks overwinter in tropical waters (Eckert 2002, Dodge et al. 2014) and the few existing records of these size classes stranding include reports from the southeastern Caribbean. Barbados itself has recorded small leatherbacks stranding on its east coast beaches (Horrocks 1987).

Leatherbacks are more likely to be foul-hooked in he head, shoulders, flippers, or carapace than to swallow hooks, while hard-shelled turtles are more likely to be captured through hook ingestion (Watson et al. 2005, Gilman & Huang 2017). Gear used in the Barbados fishery is exclusively J-hook, while the Venezuela fleet uses both J- and circle hooks, and the US Atlantic fleet has used large (16/0 and 18/0) circle hooks exclusively since 2004 (Swimmer et al. 2017) (Table 1). These wider circle hooks have been shown to reduce bycatch primarily by reducing the chances of a turtle swallowing the hook (Gilman & Huang 2017), and although their use results in an overall reduction in bycatch of sea turtles (Watson et al. 2005, Sales et al. 2010, Reinhardt et al. 2017), bycatch of hard-shelled turtles may be reduced more than leatherbacks. Given that most Barbados captains also reported leatherbacks being more often foul-hooked and/or entangled in the lines rather than ingesting hooks, switching to circle hooks may not be the first priority to reduce bycatch impacts. Instead, the focus should be on training captains in best practices to reduce post-release mortality of live but foul-hooked/entangled turtles, and ensuring that they have the necessary tools on-board to do this. Captains reported cutting the line as close as possible to the animal while it was still in the water, but this often resulted in long trailing lines still attached. The level of post-release mortality in leatherbacks is unknown (Stewart et al. 2016), but the risk of subsequent entanglement may be significant in the Barbados fishery. Most captains indicated their willingness to be trained in best practices for safe handling, line cutting, and release of turtles (NMFS SEFSC 2010) and we recommend that this be the first priority for sea turtle bycatch mitigation in the Barbados longline fishery.

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