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Shark species identification from bite marks on a Short-finned Pilot Whale, *Globicephala macrorhynchus*

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ABSTRACT

A Short-finned Pilot Whale, *Globicephala macrorhynchus*, was found dead and with shark bites along its body on a beach in northeast Brazil. The present study aimed to identify the shark species responsible for the bites as well as to estimate its/their total length. Species identification was performed using the bite marks, which were of the same diameter, suggesting they were inflected by one or more Tiger sharks of similar size. The characteristics of the bites and the shape and distribution of the marks left by the teeth pointed to the Tiger Shark, *Galeocerdo cuvier*. The total length of the Tiger Shark or sharks was estimated at between 257 and 288 cm, based on the perimeter contour of each bite and the interdental distance inferred from the marks on the whale. This suggests that the bites were inflicted by one or more sub-adult specimens.

Descriptors: *Galeocerdo cuvier*; Bite wounds, Cetacean, Predation.

The Short-finned Pilot Whale, *Globicephala macrorhynchus*, is a delphinid of tropical and subtropical distribution known to be highly social, with pods of up to many hundred individuals (Jefferson et al., 2015). This species has been identified in events of individual or mass strandings (Olson, 2008). Rescued and released Short-finned Pilot Whales often strand again (Olson, 2008).

On July 12, 2020, a live Short-finned Pilot Whale measuring approximately 240 cm in total length (TL) stranded on a beach in northeastern Brazil, southwestern equatorial Atlantic (Uruaú Beach, Beberibe, Ceará State, Brazil). The whale was rescued and released back to the sea in an operation that ended the subsequent day. However, on July 16 (three days later), the same individual was found dead, with similar-sized half-moon bite marks along its body, on Prainha Beach, Aquiraz, Ceará State, Brazil (ca. 70 km away).

Several shark species can inflict half-moon bites on large cetaceans (Heithaus, 2001a), including Bull sharks (*Carcharhinus leucas*), Tiger sharks (*Galeocerdo cuvier*), White sharks (*Carcharodon carcharias*), and Dusky sharks (*Carcharhinus obscurus*) (Naessig and Lanyon, 2004; Weller, 2009;). All of these occur off the Ceará State coast (Jucá-Queiroz et al., 2008), where the predation event occurred, supporting

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the notion that the bite marks could have been inflicted by a shark. Moreover, since the bite marks were similar in size, it was inferred that a single or multiple sharks of similar size may have bitten the Pilot Whale. In this context, the present study aimed to characterize this predation event by identifying the shark species responsible and, estimating its/their total length (TL).

The data used for shark identification was obtained during the Pilot Whale's necropsy, when the following six photographs of bite marks were taken: caudal peduncle (bite ids. A, B, C, and D), dorsal fin (bite id. E), and lateral mandibular region (bite id. F) (Figure 1). The images were used to determine the species based on: (a) bite shape and size and (b) shape of teeth impressions, following Long and Jones (1996), Clua, Bescond and Reid (2014), and Clua and Reid (2018).

The photographs were used to estimate the shark's total length (TL; cm) applying two methods, both based on equations described by Lowry et al. (2009). One was based on bite circumference, which was estimated from the sum of linear elements measured along the contour of each bite. Since it was not possible to determine if the bite marks were inflicted by the upper ($y = 1.085x - 1.153$) or lower ($y = 1.100x - 1.215$) jaws, equations for each were applied equally. The other method was based on interdental distance (IDD), which was estimated from linear distances between tooth impressions ($y = 1.111x - 2.563$). All measurements of the digital photographs were carried out using a measurement tool applied to software tpsDig (version 2.31; http://www.sbmorphometrics.org/soft-dataacq.html).

The tooth impressions left on the tegument were relatively narrow and long, very close together, and parallel, with the marks of each tooth making a sharp angle and with some overlap, leaving skin flaps (bite ids. B, D, E; Figure 1). These characteristics alone suggest that one or more Tiger sharks were responsible. Comparatively, other regular predators of odontocetes found in the State of Ceará coast, *C. carcharias* and *C. leucas* (Heithaus, 2001b; Jucá-Queiroz et al., 2008), do not feature a bite and tooth morphology compatible with the marks observed in this study. Both *C. carcharias* and *C. leucas* leave pointed marks, and their teeth are relatively more separated than Tiger Shark teeth (Clua, Bescond and Reid, 2014). The *C. obscurus* is not considered a regular predator of odontocetes, being rarely involved in this predation (Heithaus, 2001b), and is therefore less likely to have inflicted the bites. Moreover, the marks were compatible with a Tiger Shark pattern. In the present study, the teeth impressions featured the typical flaps, usually left on the bitten tissue due to the Tiger Shark's wide, serrated, and slightly curved teeth (Clua and Reid, 2018).

Three estimated total length (ETL) values were obtained. ETL was calculated using bite circumference, based on the upper jaw equation (ETL = 257 cm) and the lower jaw equation (ETL = 263 cm). Finally, the last ETL value was calculated using interdental distance (IDD) (ETL = 288 cm) (Table 1). The ETL values were below the first-maturity size TL reported for this species (male TL = 292 cm; female TL = 290 to 320 cm; Whitney and Crow, 2007). Therefore, these values suggested that one or more sub-adult Tiger sharks were responsible for the bites.

It is possible that the one or more Tiger sharks performed most of the biting while the whale was positioned laterally at the waterline. The whale was presumably weakened after an attempted rehabilitation. In any case, a hemorrhage detected in the region of the whale's head after its second and final stranding suggests that the one or more Tiger sharks bit the whale either while it was still alive or recently dead.

This is the first record of a Short-finned Pilot Whale being predated by Tiger Shark. This builds on existing knowledge of interactions between sharks and cetaceans from Brazil (e.g. Bornatowski, et al., 2012), as well as from other parts of the world (e.g. Tucker et al., 2019).

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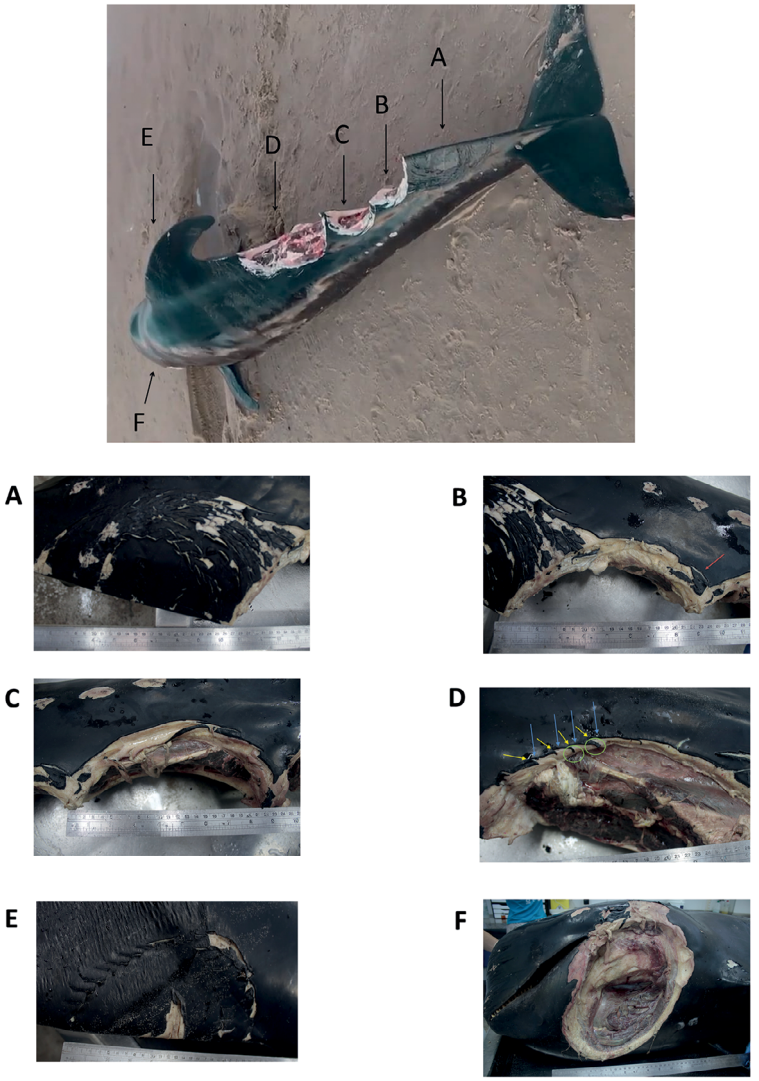

Figure 1. Photo of the Short-finned Pilot Whale, *Globicephala macrorhynchus*, stranded in northeastern Brazil, with indication of the bite marks. A- Area of multiple partial shark bite marks. B – Area of a complete shark bite with a 22 cm diameter. There is a narrow and long teeth impression (red arrow). C- Area of a complete shark bite with a 22 cm diameter. D – Area of a ripped shark bite of 31 cm; there are many tooth marks, with almost parallel teeth, sharp angles and skin flaps (blue arrows - almost parallel bite lines; yellow arrows - sharp angles; yellow circle – skin flaps). E- Area of an incomplete shark bite with a 22 cm diameter. F – Area of a complete shark bite mark with a diameter of 22 x 32 cm.

stranding and who later reported its second stranding and death. We also thank Michelle Charvet Proença for reviewing this manuscript.

AUTHOR CONTRIBUTIONS

M.L.S.B.L.: Conceptualization; Data curation; Formal Analysis; Investigation; Methodology; Visualization; Writing - original draft; Writing - review & editing;

V.L.C.: Conceptualization; Data curation; Investigation; Methodology; Supervision; Writing - review & editing;

L.G.P.: Investigation; Methodology; Writing - review & editing;

B.Q.: Investigation; Methodology; Writing - review & editing;

A.L.F.C.: Investigation; Validation; Writing - review & editing;

P.C.: Investigation; Validation; Writing - review & editing;

V.V.F.: Conceptualization; Investigation; Methodology; Supervision; Visualization; Writing - review & editing.

Table 1. Estimated total length (ETL, cm) of the one or more Tiger sharks that presumably predated a Short-finned Pilot Whale, based on bite circumference and interdental distance.

Bite Id. (see Figure 1)	Bite circunference (cm)	Interdental distance (cm)	Estimated total length (ETL) (cm)		
			Based on upper jaw	Based on lower jaw	Based on interdental distance
B	29.94	-	221.4	227.2	-
C	33.66	-	246.6	252.7	-
D	-	2.06	-	-	307.7
E	38.08	1.77	276.3	282.8	268.5
F	39.27	-	284.2	290.8	-
Average ETL (cm)			257.1	263.375	288.1

*Bite id. A was not included because it corresponded to an incomplete bite mark.

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