

Records of *Isistius* sp. (Elasmobranchii: Squaliformes: Dalatiidae), from the Azores archipelago, inferred by fresh bite marks in dolphins

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Abstract

The marine waters around the Azores archipelago have been studied for quite a long time. Deeper areas, however, were historically poorly accessible and only now previously unreported species are recorded regularly. Our monitoring efforts of the Azorean ichthyofauna have recently revealed two cases of indirect evidence of the presence of a cookiecutter shark (*Isistius* sp.). The evidence, documented photographically, was in the form of explicit bite marks on two dolphins representing two separate species: the Atlantic spotted dolphin, *Stenella frontalis* (Cuvier, 1829) and the short-beaked common dolphin, *Delphinus delphis* Linnaeus, 1758. The two dolphins swam close to Terceira Island. No specimens have yet been collected. The shape, and size of the wounds observed suggest that they were inflicted by a cookiecutter shark. The fresh state of the injuries suggests they were sustained recently in the proximity of the Azores.

Keywords

bite marks, cookiecutter shark, feeding behavior, new records, North Atlantic, species occurrence

Introduction

The parasitic feeding behavior of fishes is well known and was comprehensively assessed by Zidowitz et al. (2004) and Leung (2014). The review presented by Leung (2014) describes all parasitic feeding including ectoparasitism although this author categorizes sharks involved in this type of feeding as representing a modified form of piscivorism. Carrier et al. (2012) considered cookiecutter sharks (*Isistius* spp.) facultative ectoparasites.

Besides their ectoparasitic way of feeding on large fishes and marine mammals, they also prey on smaller fishes, squids, and crustaceans. The most speciose group of ectoparasitic fish are lampreys; others such as remoras are better known for their attachment ability to a vast guild of hosts in a more mutualistic than parasitic relation and which is considered as a commensal relation. Among elasmobranch fishes, cookiecutter sharks and possibly other dalatiid species, such as the kitefin shark, *Dalatius licha* (Bonnaterre, 1788), or the Portuguese dogfish,

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Centroscymnus coelolepis Barbosa du Bocage et de Brito Capello, 1864, are the only species showing this distinctive feeding behavior. Carlisle et al. (2021), however, have shown by analysis of biochemical tracers that large epipelagic prey constituted a relatively minor part of their overall diet, and that in turn, small micronektonic and forage species (meso- and epipelagic) are the most important prey group for cookiecutter sharks.

Two species of cookiecutter sharks are recognized as valid: *Isistius brasiliensis* (Quoy et Gaimard, 1824) and *Isistius plutodus* Garrick et Springer, 1964. They are small-sized representatives of the family Dalatiidae with a cosmopolitan distribution mainly in tropical to warm-temperate waters (Feunteun et al. 2018). The maximum reported length for *I. brasiliensis* is 42 cm for males and 56 cm for females (Ebert 2003). The less known and apparently rarer *I. plutodus* has been reported to reach 42 cm TL although similar maximum sizes should be considered (McGrouther 2009). *Isistius plutodus* is only known from fewer than 15 specimens collected mostly in inshore waters from the Pacific and Atlantic Oceans (Wenzel and López Suárez 2012). One was collected in open waters, north of the Azores, expanding the range of the species by 21 degrees of latitude to the North of its known range (Zidowitz et al. 2004). Two females were reported from the southwestern Atlantic by Stehmann and Kukuev (2015) and, more recently, additional records of offshore captures are known (South Atlantic, off Japan, see de Figueiredo Petean and de Carvalho 2018), though, due to its rarity, not nearly as many as *I. brasiliensis*. Even nearer coastal specimens have been caught in deep water or over high depths and still often well offshore or even around the island shelf.

Papastamasiou et al. (2010) characterized cookiecutter sharks as ectoparasitic predators, that leave distinct circular wounds on several types of prey ranging from fish to marine mammals and even underwater structures. These wounds often take on an oval to round shape, varying from superficial tooth punctures for partial bites to deeply incised scoops of flesh for full consumption (Papastamatiou et al. 2010; Grace et al. 2018). In the Azores' EEZ (Exclusive Economic Zone) 63 species of Chondrichthyes are confirmed to occur (Barcelos et al. 2021). Although specimens of *Isistius* spp. from these waters are not known to us, the Azorean Exclusive Economic Zone does fall within the area of distribution for both species (Jahn and Haedrich 1988; Zidowitz et al. 2004).

In this paper, we present evidence of the occurrence of *Isistius* sp. off the Azorean coasts, based on various visual observations made by the authors, who have extensive experience as guides in whale-watching operations and sea-going research, reinforced by photos of two dolphins with unhealed wounds. These kinds of bite marks are very common, in several species of cetaceans from tropical to temperate regions (Dwyer and Visser 2011). The here presented fresh bite marks, prove that *Isistius* species occur in these waters and are probably common (Muñoz-Chápuli et al. 1988; Zidowitz et al. 2004). A characterization of cookiecutter bites was simulated and

thoroughly discussed by Grace et al. (2023). This also allows observers to be more confident in observations of potential bites.

Methods

Selected photographs (approximately 100) of the Atlantic spotted dolphin, *Stenella frontalis* (Cuvier, 1829) (Fig. 1) and the short-beaked common dolphin, *Delphinus delphis* Linnaeus, 1758 (Fig. 2), obtained during more than 20 trips, were carefully analyzed, and compared with published data regarding cookiecutter bites (Wenzel and López Suárez 2012; Best and Photopoulou 2016; Grace et al. 2018). The reported sightings of *S. frontalis* on southern inshore waters (38°37.380'N, 027°14.640'W; 1500 m from shore) and *D. delphis* on the southwestern inshore waters (38°41.340'N, 027°21.540'W; 500 m from shore), off Terceira Island (Azores archipelago), were on waters more than 200 m deep.

The total lengths of the dolphins mentioned above, and maximum diameters of bite marks were estimated with *Mesurim 2* software (Cosentino 2020), following a protocol of two steps:

- Defining the scale with the reference object (known size) in the same optical settings of the camera and at approximately the same distance between the camera and the animal.
- Using the scale to measure the bite marks.

Our choice to use this method was made also upon the following issues:

- It is free and can be used directly from a browser, without the need for installation.
- A technician with extensive experience in using the software was present to help with the measurements.
- The software has already been used in other studies related to measurements in the sea (see Ter Halle et al. 2016).

Both cases are considered recent bite marks due to the lacerations with no visible healing processes.

Results

The two wounded dolphins (Figs. 1, 2) show fresh bite marks that fall within the pattern we determined in the Methods section and were photographed during whale-watching tours that took place in August 2022 and June 2023. The *Stenella frontalis* individual had an estimated total length (TL) of 160 cm and the bite mark a maximum diameter of 4 to 5 cm (± 1 cm). For the *Delphinus delphis* individual, its estimated TL of 200 cm with a bite mark of approximately 5 or 6 cm (± 1 cm) in its maximum diameter.



Figure 1. Atlantic spotted dolphin, *Stenella frontalis*, with a fresh bite mark, observed on 10 August 2022 at 38°37.380'N, 027°14.640'W (photo by João B Barreiros).



Figure 2. Short-beaked common dolphin, *Delphinus delphis*, with fresh bite marks, observed on 25 June 2023 at 38°41.340'N, 027°21.540'W. (photo by João B Barreiros).

Discussion

The Atlantic spotted dolphin is a migratory species associated with warm waters (Shirihai and Jarrett 2006; Carwardine 2019). This species arrives at Azorean waters in early March staying until mid-November (Silva

et al. 2014). Since the photos were taken in August, it is unlikely that the animals already had the wounds before arriving in Azorean waters.

The short-beaked common dolphin is a resident species in Azorean waters (Silva et al. 2014), being sighted year-round.

Many reports on their occurrence have been published through studies on bite marks. It is widely accepted that these bite marks, either recent or from healed scars, are proof of their occurrence as an indirect method, given their oceanic habitats and elusive nature (Papastamatiou et al. 2010). For instance, Souto et al. (2007, 2008) cite data of bite marks in cetaceans and sub-Antarctic fur seals from Bahia (northeastern Brazil). One especially interesting report describes cookiecutter bites on a great white shark, *Carcharodon carcharias* (Linnaeus, 1758) (see Hoyos-Padilla et al. 2013).

One case reported by Honebrink et al. (2011) describes the first known cookiecutter bite on a human, in this case, an open water swimmer in Hawaii. The wound had the typical form found in fish and measured 10 cm in diameter for a depth of ca. 4 cm (see also Grace et al. 2023 for the study of simulated cookiecutter bites). Although slightly smaller oval bite marks from 4–5 to 7 cm are given by Jones (1971), this case is within the expected range of measurements taken in fish markets (see Papastamatiou et al. 2010). An anecdotal report by Honebrink et al. (2011) states that cookiecutter sharks may swim in schools and threaten swimmers and other sea-going persons, especially when in pelagic areas during twilight and at nighttime. Estimating the occurrences of these sharks may help to avoid eventual incidents although none have been so far reported. Postmortem scavenging on a human body by *Isistius* was reported by Makino et al. (2004) and Ihama et al. (2009). Again, the shape of the bite marks was unequivocally attributed to cookiecutter sharks.

Given its more temperate distribution, although based on a few records, we think it is more probable that

Isistius plutodus instead of *I. brasiliensis* occurs in the Azores, also because one specimen was recorded north of the archipelago (Zidowitz et al. 2004).

With the estimation of the distribution, collection efforts can be made to capture some specimens of the sharks, which later, through DNA analysis, would allow the identification of the species.

Conclusion

Given the above results and available data discussed, it is indisputable that cookiecutter sharks are present in Azorean waters. Efforts are being made to collect more data on *Isistius* sp. bites within or close to the Azores' EEZ. We also aim to use eDNA to detect the presence of these species in the areas where the cetaceans were detained.

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