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Daggernose Shark: An Elusive Species from Northern South America

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The Daggernose Shark *Isogomphodon oxyrhynchus* is an endemic species of the northern coast of South America distributed from Trinidad and Tobago to Brazil's Amazon Coast. Due to increasing fishing efforts and its limited distribution range, the Daggernose Shark is one of the most endangered shark species in the world. Further threats arise from mangrove deforestation, pollution, and aquaculture caused by increasing human populations in coastal areas. The Daggernose Shark is highly associated to the turbid waters influenced by the Amazon and Orinoco estuaries. Furthermore, its morphological features associated to adaptations to these environments such as an elongated rostrum, small eyes, and long pectoral fins make it one of the most iconic shark species in the world. Finally, we report the capture of a young-of-the-year *I. oxyrhynchus* in a freshwater system in Northern Brazil—the first recorded in a non-marine environment.

The Daggernose Shark *Isogomphodon oxyrhynchus* is one of the most geographically restricted shark species in the world (Lessa et al. 1999). This medium-sized coastal species is endemic to the western Atlantic, living in a limited range from Trinidad and Tobago to the Gulf of Maranhão—the eastern limit of the Brazilian Amazon Coast (BAC; Lessa et al. 2016). The Daggernose Shark is a demersal species that inhabits shallow and turbid estuarine coastal waters (Lessa et al. 1999). The majority of the basic biological data available for this species comes from studies carried out in Maranhão state's coast during the 1980s and 1990s (Lessa 1997).

Reproductive data demonstrate its inherent fragility to human impacts such as fishing and habitat degradation. Females have a biennial reproductive cycle with a 12-month gestation and are believed to give birth during the wet season (January–June; Lessa et al. 1999). *I. oxyrhynchus* is a viviparous species, giving live birth to between one and eight pups per gestation period, and the fertility rate is not influenced by female size (Stride et al. 1992). No difference in embryo sex ratio has been observed so far. Average embryo size from back-calculated data indicate the size at birth to be 42.3 cm total length (TL), ranging between 38–43 cm (Compagno 1984; Lessa et al. 2000).

Length and growth data indicate that males mature between 5–6 years of age while females mature between 6–7 years (Lessa et al. 2000). Males that are 103 cm TL or higher are sexually mature, whereas a female's size at maturity is 113 cm TL (Lessa et al. 2000). The estimated maximum size ranges from 171.4–173.8 cm TL (Lessa et al. 2000). The estimated maximum age is 20 years, but no specimen that old has ever been caught. During the juvenile stage, individuals grow 14 cm per year. This growth slows to 10 cm per year after reaching sexual maturity (Lessa et al. 2000). Despite sexual differences in size at maturity, no difference in growth between sexes has been observed (Lessa et al. 2000).

However, significant sexual dimorphism for fin and head morphometric measurements have been demonstrated, possibly associated with copulation behavior (Martins et al. 2015). In some species, male sharks are known for biting a female's pectoral fins during copulation and as a result, there is a substantial amount of evidence indicating fin sexual dimorphism in order to withstand this behavior (Pratt and Castro 1990; Crooks and Waring 2013). Furthermore, when compared to other Carcharhinidae species, *I. oxyrhynchus* has one of the largest pectoral fin–body length ratios. Other interesting adaptations are the elongated flat and triangular snout, and the significantly small eyes (Compagno 1984). Definitive explanations for these traits have not been found so far, but this remarkable phenotype is speculated to be related to the highly turbid waters where it inhabits, as well as its foraging habits associated to preying upon benthic and nektonic organisms (Compagno 1984; Stride et al. 1992).

Despite the small amount of stomach samples with identifiable material, Almeida et al. (2011) demonstrate that the Daggernose Shark preys upon small and slender fishes. Most common prey items are *Anchoa spinifer*, *Stellifer naso*, *Nebris microps*, and *Eucinostomus* spp. It is worth mentioning that these species are highly abundant throughout the *I. oxyrhynchus* distribution range, in both juvenile and adult stages (Almeida et al. 2011). According to Compagno (1984), *I. oxyrhynchus* has greatly suited tooth and jaw morphology to catch small fish like the species mentioned above. However, its common prey items are also the target of small-scale fisheries throughout the BAC, thus there is growing concern for the Daggernose Shark's conservation.

Further conservation issues rise from fisheries productivity in Maranhão's coastal waters. Both fisheries dependent and independent studies have demonstrated that *I. oxyrhynchus* specimens are bycatch of the gillnet fisheries targeting *Cynoscion acoupa* and *Scomberomorus brasiliensis* more often than longline fishing (Stride et al. 1992; Lessa et al. 2016). The Daggernose Shark has been subjected to overfishing since the 1980s and catches collapsed in the mid-1990s (Lessa et al. 2016). Since then, total biomass of the species decreased by 90%, especially due to the hampered recruitment caused by elevated juvenile catches (Lessa et al. 2016). According to Stride et al. (1992), in the 80s and 90s, the largest amount of *I. oxyrhynchus* catches in Maranhão were composed of juveniles, the most vulnerable age class due to the small mesh sizes of the gillnets. Furthermore, recent genetic data provided evidence for low genetic diversity in Northern Brazil's population—another factor indicating the overfishing scenario (Rodrigues-Filho et al. 2009).

Overfishing, combined with the life history features of the species (e.g., low fertility and late sexual maturation) and its restricted geographical distribution, led to the inclusion of *I. oxyrhynchus* in the critically endangered category of the International Union for Conservation of Nature's Red List of Endangered Species (Lessa et al. 2006). Lessa et al. (2016) recently argued that the Daggernose Shark is in a quasi-extinction stage. Despite the urgent need for conservation measures among the countries where *I. oxyrhynchus* occurs, only Brazil has a national plan for shark conservation.

Despite Brazilian law prohibiting catching Daggernose Sharks since 2004, studies have demonstrated that the capture of *I. oxyrhynchus* continues to occur in the BAC (Rodrigues-Filho et al. 2012; Palmeira et al. 2013; Feitosa et al. 2018). This occurs due to the lack of law enforcement in fisheries activities, as well as social factors involving artisanal fishermen livelihoods, such as low income per capita and little or no education (Martins et al. 2018). Although the general assumption is that artisanal fisheries have a low impact on species extinction, it has and continues to cause dramatic declines in shark populations in northern Brazil (Barreto et al. 2017). Artisanal

fisheries also pose a major threat for Brazilian shark species conservation (Martins et al. 2018).

In addition, habitat degradation is also one of the major threats to the Daggernose Shark (Lessa et al. 1999; Dulvy et al. 2014). Due to the high organic matter availability, the mangrove forests are one of the richest ecosystems in the region and sustain a high diversity of plant, invertebrate, and vertebrate species (Schaeffer-Novelli et al. 1990; Vannucci 2001; Kristensen et al. 2008; Giarrizzo et al. 2011). Mangrove forests are the dominant ecosystem in the coast between Trinidad and Tobago and Northern Brazil (Blasco et al. 1996; Souza-Filho 2005). These areas are supported by an elevated river discharge dominated by the Amazon and Orinoco rivers and followed by several smaller ones.

Due to the importance of river output to nutrient cycling, the strong seasonal differences in rainfall are an important feature affecting species occurrence, reproductive patterns, and habitat use. In addition, nutrient cycling is also affected in both large (rainy and dry season cycle) and small (daily tide cycle) scales. Nevertheless, the increasing occupation of coastal areas has boosted mangrove deforestation, as well as water pollution caused by poor sewage treatment and aquaculture (Ferreira and Lacerda 2016).

Some elasmobranch species, such as the Bull Shark *Carcharhinus leucas* and Largetooth Sawfish *Pristis pristis*, are known to use coastal areas in northern South America, including estuaries and rivers affected by cyclical salinity changes (Thorson 1972; Cervigón and Alcalá 1999; Feitosa et al. 2017). Particular areas of the Amazon have a stronger influence of sea currents during the drought months with the occurrence of tidal bores (Kjerfve and Ferreira 1993). Saltwater intrusion is a major factor for sporadic occurrences of estuarine animals deep into freshwater systems (e.g. crabs, fishes, and shrimps). However, details about the elasmobranch fauna that continuously, frequently, or sporadically inhabit the Amazon's freshwater systems are still relatively unknown. Thus, unusual records of highly endangered species provide important information that can direct future research and new scientific questions that need to be addressed. These new data are especially important for highly endangered species such as *I. oxyrhynchus*.

A young-of-the-year Daggernose Shark specimen was captured approximately 110 km from the Pindaré River mouth in December 2016 (Figure 1). The specimen became tangled in the gillnet of an artisanal fishermen in the Viana Lake—one of the several freshwater lakes of the Pindaré-Mearim floodplain complex (−3.2502°, −45.0361°) within the Amazon territory of Maranhão state, Brazil (Figure 2). This uncommon event is thought to occur due to the tidal influence in the Pindaré-Mearim basin during the dry season (Kjerfve and Ferreira 1993). Records of specimens associated to estuarine areas since the Miocene epoch (Bessedik et al. 1984), and although juveniles were common in the Gulf of Maranhão estuaries during the 1980s and 1990s (Lessa et al. 1999), *I. oxyrhynchus* has never been recorded within river systems before. Hence, it is possible that this habitat could have been occasionally used

Figure 1. Young-of-the-year specimen of *Isogomphodon oxyrhynchus* caught by artisanal fishermen.

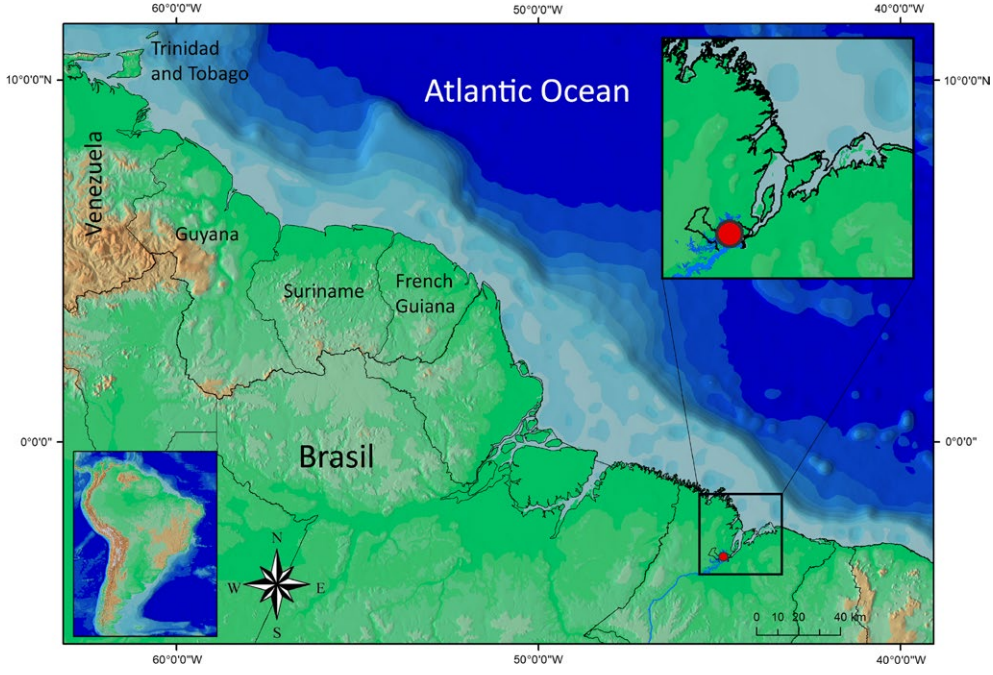

Figure 2. Global distribution range of the Daggernose Shark. The red dot indicates the capture location of the young-of-the-year specimen in the Pindaré River floodplain complex.

by the species over years, but no research focus towards investigating this has been undertaken.

Due to the Daggernose Shark's current conservation status, further studies will be difficult to carry out. Nevertheless, its interesting morphological features such as the unusually long snout, small eyes, and long pectoral fins make this species one of the most iconic sharks in the world. Understanding how these features evolved and interact with the environment could be key information for this species conservation and to unravel its phylogenetic relationships with other Carcharhinidae sharks. In general, the BAC is home to a great variety of endangered elasmobranch species, but *I. oxyrhynchus* might be the most critical one. We therefore recommend that future research should focus on the use of local ethnological knowledge to obtain potential historical records for the species in the area, as well as its habitat use patterns.

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