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Close to extinction? The collapse of the endemic daggernose shark (*Isogomphodon oxyrhynchus*) off Brazil

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HIGHLIGHTS

- The demography of *Isogomphodon oxyrhynchus* indicates a sharp decline in population.
- The juveniles were the most important for the sustainability of the species.
- The daggernose shark was one of the least resilient shark of northern Brazil.
- Fishing mortality was the cause of the daggernose shark collapse.
- The species is considered well on the way of extinction.

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ABSTRACT

The daggernose shark, *Isogomphodon oxyrhynchus* is endemic to the northern of South America from Trinidad and Tobago to Tubarão bay in Maranhão state (Brazil) where collapsed since the 1990's, due to several gillnet fisheries for teleost fishes, fisheries targeting sharks, including the daggernose shark, itself, and trawling for shrimp. Based on gillnets with meshes 80–>200 mm, we analyzed the intrinsic and extrinsic vulnerabilities of the species through different scenarios investigating the species' resilience. Samples were collected from December 1989 to September 1991, off the coast of Maranhão. Mortalities were $M = 0.188$ and $Z = 0.653$ for males and 0.725 in females. Only a scenario without fishing allowed for the population to remain in equilibrium. The survival of young specimens between 1 to 6 years was critical to sustainability according to elasticities that exceeded 70%. The intrinsic rebound (r_z) of 0.039, demonstrated the species low resilience. An unsustainable exploitation was revealed for different ages at first capture (t_c) when the maximal yield per recruit (*YPR*) provided F_{max} (0.15), below the actual $F = 0.47$ in 1991 when an exploitation rate $E = 0.72$ was obtained. Using data collected in 1980/1990 the species was globally categorized in 2006 as critically endangered (CR) similar to assessments in Brazil in 2004. After a three-generation period the species, which did not recover, is now collapsed matching the predicted quasi-extinction condition which claims for urgent and effective conservation measures.

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1. Introduction

The daggernose shark (*Isogomphodon oxyrhynchus*, Müller and Henle 1839) occurs along the northern coast of South America, in an area limited in the North by Trinidad and Tobago and in the South by the Tubarão bay in the Brazilian state of Maranhão (2°30′S/43°30′W), where the species has its southern most confirmed registration. The distribution area also includes Suriname, the Guyanas and the states of Amapá and Pará in Brazil (Bigelow and Schroeder, 1948; Lessa and Araújo-Filho, 1984; Barthem, 1985; Lessa et al., 1999; Léopold, 2004). Along the area the daggernose shark is also named "quati" or "pato" (Brazil) and "bécune" or "demoiselle" (French Guyane) (Fig. 1).

The species dwells in an area with a hot humid climate, in shallow and highly turbid waters derived from the drainage of numerous large rivers composing the Amazonian Estuary where muddy bottoms, covered by mangroves dominate along a well indented coastline with tides attaining a height of 7 m (Lessa et al., 1999; Léopold, 2004).

The range of distribution of the daggernose shark situated this species among the living sharks which occupy the narrowest areas in the world (Lessa et al., 2000) with records of occurrence to the south of Maranhão state in Brazil and to the north/west of Trinidad and Tobago, never confirmed (Casselberry and Carlson, 2015).

In the study area, the daggernose shark ranked fourth and first most abundant by-catch species in gillnets, the main gear targeting the Brazilian Spanish mackerel, *Scomberomorus brasiliensis* Collette, Russo and Zavalla-Camin (1978), and the weakfish *Cynoscion acoupa*, (Lacepéde, 1801), respectively, during the 1980's and 1990's. Overall, the species corresponded to about 10% of shark captures of the first quoted exploitation, reaching 71 kg/km^{-1} in the second (Lessa, 1986; Stride et al., 1992). The daggernose shark was also caught as a bycatch species in gillnets targeting the gillbacker-sea-catfish (*Sciades parkeri*), as a target in gillnets fisheries off the Amapá (Brazil) (Nascimento and Asano-Filho, 1999), in trawlings directed to *Penaeus* spp and in longlines all over the area (Frédou and Asano-Filho, 2006). In consequence, since the 1990's, catches have decreased in abundance by 90% (Lessa et al., 2006; Rodrigues-Filho et al., 2009; Almeida et al., 2014) leading the daggernose shark to be assessed by the IUCN as Critically Endangered-CR in 2006.

Although population data is lacking for Trinidad and Tobago, in the Guyanas and Suriname, the decline of the species in these countries should be similar to what happened in Brazil due to high fishing pressure over the targeted species. Also, the high value of by-products of teleosts (Almeida et al., 2014) and fins of sharks boosted gillnet fisheries.

The available information on the daggernose shark, apart from the taxonomic descriptions (Bigelow and Schroeder, 1948; Compagno, 1984) and paleontological records (Bassedick et al., 1984), is restricted to the northern Brazilian coast focusing on abundance (Lessa, 1986; Stride et al., 1992; Frédou and Asano-Filho, 2006), community studies (Lessa and Menni, 1994), reproduction (Stride et al., 1992; Lessa et al., 1999), age and growth (Lessa et al., 2000) and genetic studies by Rodrigues-Filho et al. (2009). Despite them, information about the resilience of the species is limited, not allowing the identification of the actual conservation status.

In the current study we analyzed the collapse of the daggernose shark in a large part of its habitat, off northern Brazil. For this, we proposed likely scenarios built using different levels of natural mortality with the aim of estimating intrinsic susceptibility. By employing age-based approaches (catch-curves and *YPR*) we analyzed the fishing mortality in the 1990's.

2. Material and methods

Data on the biology of *I. oxyrhynchus* was obtained on the west coast of Maranhão state (46°W to 43°40′00″W) (Fig. 1) where 1135 individuals were collected using gillnets from December 1989 to September 1991. Overall, data came from fisheries surveys, aimed at developing shark fishing, which was common place at that time (Stride et al., 1992). Also, data collected from 1987 to 1989 in artisanal fishing operations for *Scomberomorus brasiliensis* were used (Lessa et al., 1999).

Length frequency distributions using total length (TL) were established by sex with overall sexual proportion of 1 male: 1.26 females. Males ($n = 503$) were between 60.6 and 127 cm, the mean length ($\bar{x}$) being 98.7 cm, with standard deviation (SD) = 1.4 cm, and median size ($\tilde{x}$) 99 cm; whereas females ($n = 632$) measured from 58 to 160 cm, with the mean length $\bar{x} = 121.8$ cm, with standard deviation (SD) of 2.5 cm, and median size $\tilde{x} = 128$ cm.

Information on age and growth was provided through vertebral analysis (Lessa et al., 2000). The growth model was combined as there was no difference between sexes. The von Bertalanffy growth parameters were obtained: $L_\infty = 171.4$ cm; $K = 0.121$ and $t_0 = -2.612$ years. Maximal age ($t_{\max}$) in the study sample was 12 years, with first maturity achieved (t_{mat}) at 6.6 years. Furthermore, the ratio of embryos by sex was 1:1 and the size at maturity was estimated at 115 cm TL for females (Lessa, 1987; Stride et al., 1992; Lessa et al., 1999).

Stride et al. (1992) analyzing 53 pregnant females observed fecundity ranging from 1 to 8 embryos, leading to the mean of 4.85 embryos (SD = 1.56 embryos). The gestation period extends over one year, with a resting period seeming to occur between two successive cycles (Lessa et al., 1999). Thus, as for several species of the Carcharhinidae family, the reproductive cycle in the current study was 2 years. The fertility (m_x) of the species (*i.e.*: females embryos born of each pregnant female per year) resulted in a mean value of 1.21.

The instantaneous rate of mortality (Z) allowed for the estimation of intrinsic susceptibility and to infer the vulnerability of the population without fishing exploitation. For natural mortality (M), nine age-independent and two age-dependent methods were considered, all based on parameters of life history of the species. Weight–length relationship of females, used for obtaining (M) through the Peterson and Wroblewski approach was: $W = 0.0022TL^{3.1514}$($r^2 = 0.9692$; $n = 110$) (Lessa et al., 1999).