


BRIEF COMMUNICATION

Female wound records suggest mating periods for the Caribbean reef shark at an insular marine protected area from the Equatorial Atlantic Ocean

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Abstract

Despite being one of the most abundant, economically significant, reef-associated shark species, little is known about the reproductive aspects of the Caribbean reef shark (*Carcharhinus perezi*). In the present study the authors report the first evidence of mating wounds and scars in female Caribbean reef sharks at the Fernando de Noronha Archipelago, a remote marine protected area in the South Atlantic Ocean. Data from four females suggest this species mates mainly during the austral summer, between February and March. Given that the archipelago has been previously described as a nursery ground for the Caribbean reef shark, these results add information about the reproductive cycle of this species in the equatorial Atlantic Ocean.

KEYWORDS

copulation, elasmobranchs, life history, mating season, reproduction

The Caribbean reef shark (*Carcharhinus perezi*) is one of the most abundant reef-associated sharks found throughout the western Atlantic Ocean from North Carolina (United States of America) to Brazil (Carlson *et al.*, 2021). Due to the historic fishing pressure and to its life-history traits (e.g., relatively restricted distribution, habitat specialization and reproductive biology; Ebert *et al.*, 2021; Talwar *et al.*, 2022), the species has been recently listed as Endangered by the IUCN (Carlson *et al.*, 2021) and listed as Vulnerable by Brazil's National Red List (Ordinance no. 148 Ministério do Meio Ambiente, 2022). Despite the current conservation status, little is known about the Caribbean reef shark reproductive ecology across its distribution.

The Caribbean reef shark is a placental species with a very low reproductive output, which is characterized by long gestation and resting periods and few pups per litter, i.e., 3–6 pups per litter born after c. 1 year of gestation every 2 years (Ebert *et al.*, 2021). Previous studies indicate that the parturition period of the species occurs from

late January to possibly late April in two oceanic insular systems in the Southern Hemisphere (Garla *et al.*, 2006a, 2006b; B.S. Rangel, unpubl. data), and from June to November in the Caribbean, Northern Hemisphere (Talwar *et al.*, 2022; Tavares, 2009). Fresh mating wounds observed in the population from the Caribbean suggest that the mating period occurs mainly during the summer (Talwar *et al.*, 2022).

Identifying the reproductive seasonality of threatened elasmobranchs is crucial, especially due to their high vulnerability to anthropogenic impacts during this period, e.g., increased catch in commercial fisheries during reproductive aggregations (e.g., Bada-Sánchez *et al.*, 2019), higher incidence of abortion (e.g., Adams *et al.*, 2018) and pronounced responses to fishing-induced stress and higher mortality rates (e.g., Prado *et al.*, 2022). Thus, the objective of this study was to examine the occurrence of mating wounds and scars in female Caribbean reef sharks at the Fernando de Noronha Archipelago, a region previously described as a nursery area for this species (Garla *et al.*, 2006a, 2006b).

The Fernando de Noronha Archipelago is an isolated group of volcanic islands located 345 km off north-eastern Brazil (03° 51' S, 32° 25' W). The region is under the influence of the South Equatorial Current and experiences a warm tropical oceanic climate (Barcellos *et al.*, 2011). The seawater temperature and salinity are relatively steady year-round and average 26°C and 36‰, respectively. Part of the archipelago comprises a no-take marine protected area, which protects near-shore ecosystems up to the 50 m isobaths. The other part consists of a sustainable use area, *i.e.*, the Fernando de Noronha – Rocas – São Pedro and São Paulo Environmental Protected Area, where fishing is allowed with some restrictions. Shark fishing is prohibited in both areas (Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), 2017).

Female Caribbean reef sharks with mating marks were caught in March 2012, March 2016 and February 2020. Individuals were captured using bottom longlines and drumlines in waters ranging from 50 to 90 m depth. Longlines were composed of a 275-m-long braided polypropylene mainline with 8 mm in diameter equipped with 10 branch lines, which were attached to the mainline every 25 m with a snap. Branch lines were composed of a 5-m-long monofilament nylon line with 2.5 mm in diameter connected to a swivel, a wire leader 1 m in length and an 18/0 circle hook. Drumlines consisted of a

mooring with two attachment points: (a) a line running to the surface with a buoy and (b) a swivel connecting a 23 m monofilament ganglion line to a baited 18/0 circle hook. Both gears were checked every 90 min for shark presence. Upon capture, the sharks were either restrained in the water alongside the boat or placed aboard with their eyes covered and a hose with running sea water fitted into their mouth for ventilation. Sharks were sexed, measured for total length (L_T , in cm), tagged and then released.

This work was conducted under permits approved by the Instituto Chico Mendes para a Conservação da Biodiversidade (ICMBio #12064, #43305, #80761), and by the Committee on Ethics for the Use of Animals of the Instituto de Biociências da Universidade de São Paulo (CEUA #362/2020) and of the Universidade Federal Rural de Pernambuco (CEUA #23082.025519/2014). Also, the work did not involve anaesthesia, euthanasia or any kind of animal sacrifice.

Four captured females had mating wounds and scars. The first one captured on 7 March 2012, measured 237 cm L_T and showed healed bite scars throughout the body, including in the head region (Figure 1a). The second female, a 227 cm L_T female, was captured on 13 March 2018. This female had recent and deeper lacerations on the right side of the first dorsal fin (Figure 1b). The third female, measuring 221 cm L_T , was captured on 18 February 2020, and had recent

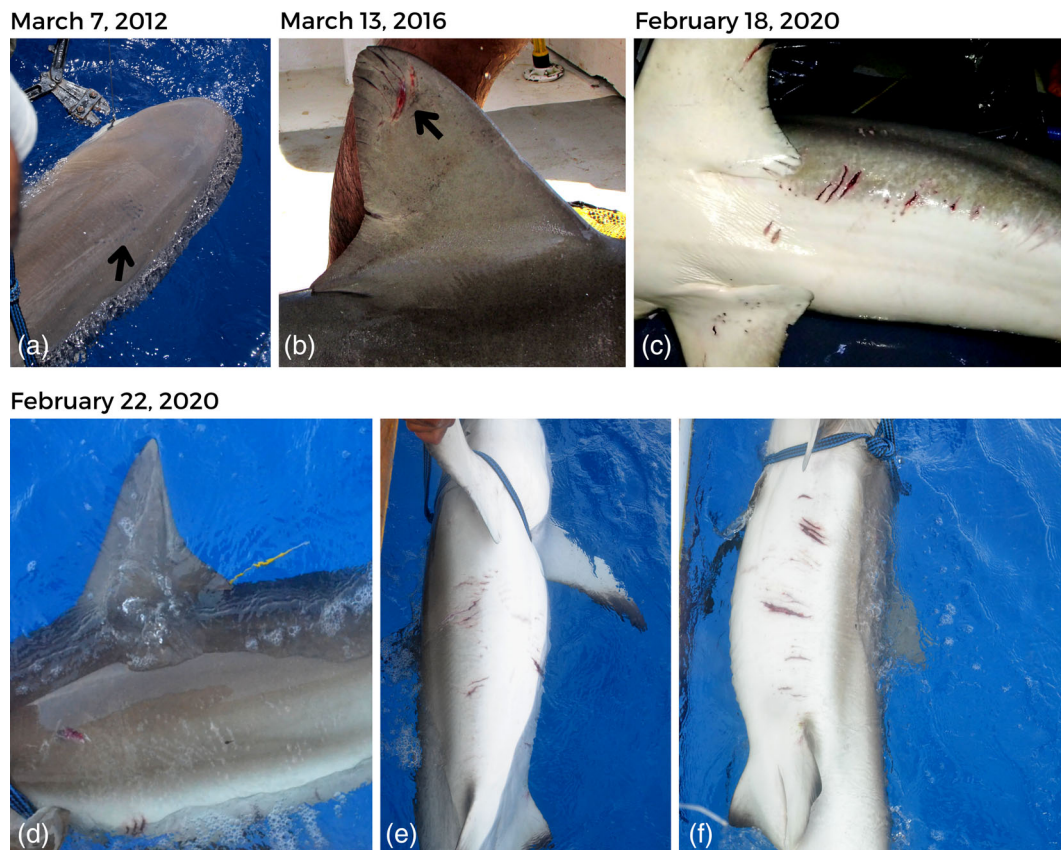


FIGURE 1 Mating scars observed on female Caribbean reef sharks *Carcharhinus perezii* sampled at Fernando de Noronha Archipelago. Arrows indicate the wounds observed in the first (a) and (b) second female. (c) Wounds are observed throughout the highlighted area of the body. (d–f) Mating scars observed in the fourth female. (d) Shallow scratches and one fresh, deeper laceration on the left flank. (e) Fresh and deeper wounds on the right side of the flank and on the (f) left side of the abdomen

wounds exposing integument and dermis on the left side of the belly and in both pectoral fins (Figure 1c). Lastly, a 216 cm L_T female was captured on 22 February 2020 and showed shallow scratches and one fresh, deeper laceration on the left flank (Figure 1d). Fresh and deeper wounds were observed on the right side of the flank (Figure 1e) and on the left side of the abdomen and pectoral fin (Figure 1f).

Based on the movement patterns of the Caribbean reef shark, which exhibit year-round residency at relatively small spatial scales throughout its southern distribution (e.g., Baremore *et al.*, 2021; Gallagher *et al.*, 2021; Garla *et al.*, 2006a, 2006b; Talwar *et al.*, 2022), it was expected that its entire life cycle, including reproductive process (i.e., copulation, gestation and parturition), would occur within the Fernando de Noronha Archipelago. Nonetheless, empirical evidence of all stages of the reproductive cycle is yet to be found. This study reports evidence that Caribbean reef shark mating activity can occur at the archipelago. Other shark species such as the nurse shark, *Ginglymostoma cirratum*, and the lemon shark, *Negaprion brevirostris*, are known to also use this area as a mating ground (Afonso *et al.*, 2016; Garla *et al.*, 2009).

Mating wounds on female Caribbean reef shark have been previously documented in the Caribbean population, suggesting that the mating season occurs mainly during the boreal summer (June–July) but possibly extend into September (Brooks *et al.*, 2013; Maljković & Côté, 2011; Talwar *et al.*, 2022). This study's findings corroborate these previous studies and suggest that mating activities occur mainly during the austral summer (January–March). Despite the fact that first female described had fully healed scars (Figure 1a), it is possible that the bites were inflicted a few weeks before the capture. This is because carcharhinid sharks show high capacity for wound healing, e.g., complete healing of bite wound observed within 40 days in the *Carcharhinus melanopterus* (Chin *et al.*, 2015). Taken together, these data suggest that the reproductive cycle of this species in the Equatorial Atlantic Ocean is similar to that found in the Caribbean population, and possibly extends throughout its distribution in the Southern Hemisphere.

All the females sampled in the present study were larger than 200 cm L_T , corroborating the observations made in other studies for Caribbean reef shark sexual maturity (Talwar *et al.*, 2022 and references therein). Finally, the data of this study are not sufficient to infer the entire reproductive cycle, despite the fact that adult females with no evidence of mating marks were captured during the same research expedition as females with mating marks. Therefore, more extensive studies are needed. For instance, sex steroid hormone quantification over a 2-year period coupled with ultrasound examinations would help to understand whether the reproductive cycle in the Fernando de Noronha Archipelago follows the pattern observed for the Caribbean population (Carlson *et al.*, 2021; Talwar *et al.*, 2022).

In conclusion, this is the first study reporting mating activity in Caribbean reef sharks in Brazilian waters, reinforcing the importance of this remote protected oceanic archipelago for conservation plans for this endangered species. The results also add evidence that the Fernando de Noronha Archipelago is used by multiple shark species

for reproductive purposes. It is important to mention that although sharks are protected within the no-take area, they are exposed to interactions with artisanal and recreational fishing within the sustainable use area. Therefore, future studies should also assess the efficiency of the no-take marine reserve to protect sharks, especially during critical life-cycle stages (e.g., during pregnancy and mating period).

AUTHOR CONTRIBUTIONS

Conceptualization and data curation: all authors; roles/writing – original draft: B.S.R.; formal analysis: B.S.R., A.S.A. and R.C.G.; methodology: B.S.R., A.S.A. and R.C.G.; writing – review and editing: B.S.R., A.S.A. and R.C.G.

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