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BRIEF COMMUNICATION

A safe haven for potential reproductive aggregations of the critically endangered Brazilian guitarfish (*Pseudobatos horkelii*)

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Abstract

Brazilian endemic batoid elasmobranch populations have declined dramatically in the past 40 years due to anthropic activities (*e.g.*, overfishing). The Brazilian guitarfish, *Pseudobatos horkelii*, included in the IUCN red list of endangered species [Critically Endangered (CR)], has been captured as by-catch by trawling fishing boats to the edge of extinction. Despite governmental conservation initiatives, the species is still caught and commercialized along the Brazilian coast. In this study, the authors report three rare aggregation events for the Brazilian coast of *P. horkelii*, inside the only nearshore no-entry Brazilian marine protected area. Strategies for its protection are also discussed.

KEYWORDS
Endemic elasmobranch, Marine Protected Areas, Overfishing, Rays and Sharks, Reproductive aggregations, Southwestern Atlantic

1 | INTRODUCTION

Elasmobranchs (sharks and rays) play a critical role in marine ecosystems through predation (Heithaus *et al.*, 2008; Machovsky-Capuska & Raubenheimer, 2020), comprising one of the most distinctive evolutionary radiations among marine predatory lineages (Derrick *et al.*, 2020). The slow life history of elasmobranchs (*e.g.*, late maturity, long gestation, low fecundity and slow growth) results in high longevity, small population growth and low natural mortality (Martins *et al.*, 2018; Stevens *et al.*, 2000). Unfortunately, these traits make elasmobranchs low resilient to human

activities (Cortés, 2002; García *et al*., 2008). In the past four decades, human activities (*e.g*., industrial fishing) in marine ecosystems have increased significantly (Steneck & Pauly, 2019). As a consequence, at least 25% of all species of sharks and rays are on the verge of extinction because of overfishing (Dulvy *et al*., 2014; Martins *et al*., 2018). Among all elasmobranchs, four families are considered to be at high risk of extinction: Pristidae (Sawfishes), Squatinidae (Angel sharks), Rhynchobatidae (Wedgefishes) and Rhinobatidae (Guitarfishes) (Martins *et al*., 2018; Moore, 2017).

Reports of severe population declines of the Rhinobatidae family have positioned the guitarfishes as a top priority for conservation (de-Franco *et al*., 2012; Martins *et al*., 2018). The Brazilian guitarfish *Pseudobatos horkelii* (Müller & Henle 1841) is a "critically endangered" (CR) (Pollom *et al*., 2020) batoid elasmobranch, endemic to the Southwestern Atlantic coast, with an effective niche ranging from Rio de Janeiro State to Argentina (Kotas *et al*., 2017; Martins *et al*., 2018, 2021; Cruz *et al*., 2021). From 1972 to 2002, scientific fisheries independent surveys ["catch per unit effort" (CPUE)] conducted along the Brazilian coast reported a 92% decline in the abundance of the Brazilian guitarfish. The complex reproductive biology of *P. horkelii* (*e.g*., diapause, slow embryonic development and yolk-sac viviparity) combined with an intensive overexploitation have driven the Brazilian guitarfish populations to the edge of extinction (de-Franco *et al*., 2012; Martins *et al*., 2021; Vooren *et al*., 2005). Despite restrictions on capture and commercialization imposed by the Brazilian government (IBAMA, 2004), the Brazilian guitarfish is still captured and commercialized, misidentified as *Pseudobatos percellens* (Walbaum 1792) "near threatened" (NT) or even the Trigonorrhinidae *Zapteryx brevirostris* (Müller & Henle 1841) "vulnerable" (VU) (IUCN, 2021; Pollom *et al*., 2020). Molecular studies conducted with 267 samples originated from the coast of Bahia State (central Brazilian coast) to Rio Grande do Sul (Southern Brazilian coast), collected from commercial fishing boats, revealed that 56% of all samples were positively identified as *P. horkelii* (see de-Franco *et al*., 2012).

The species uses the coastal area to giving birth between late spring and early autumn, after which mating, ovulation, fertilization and spawning occur, before starting migration to deeper areas, and the newborns/young-of-the-year (YOY 20–40 cm long) remain in the shallow nursery areas in their first year life cycle (Lessa & Vooren, 2007; Vooren *et al*., 2005).

Considering that fisheries adequate management and monitoring remains nearly non-existent in Brazil for decades (Caltabellotta *et al*., 2019), low cost and efficient initiatives for the conservation of the endangered Brazilian guitarfish are urgent. Conservation strategies focused on "fish spawning aggregations" (FSAs) involving fishers, scientists, resource managers and conservationists, applying small investments in management, can offer significant benefits in a short time-scale to the conservation of marine species (Erisman *et al*., 2017). Such efforts are efficient; nonetheless, the space–time record determining where and when FSAs of species occur is fundamental for the implementation of these conservation strategies (Erisman *et al*., 2017). Unfortunately, reports of FSAs of *P. horkelii* are nearly nonexistent for the Brazilian coast. In this study, the authors report three underwater observations on aggregation events of the Brazilian guitarfish inside the only nearshore no-take marine protected area in the Brazilian coast, and discuss strategies for the conservation and management of the Brazilian guitarfish.

2 | MATERIALS AND METHODS

2.1 | Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

(1) Were fishes collected as part of faunal surveys? No; (2) Were fishes killed during or at the end of your experiment (*e.g*., for tissue sampling)? No; (3) Were surgical procedures performed? No; (4) Did the experimental conditions severely distress any fishes involved in your experiments? No; (5) Did any procedures (*e.g*., predation studies and toxicity testing) cause lasting harm to sentient fishes? No; and (6) Did any procedure involve sentient, un-anaesthetized animals that were subjected to chemical agents that induce neuromuscular blockade, such as muscle relaxants? No.

2.2 | Study area

Arvoredo Biological Marine Reserve, hereafter AR MPA, is located in the vicinity of Florianópolis Island, Santa Catarina State, southern Brazil (Lat. −27.278714°; Lon. −48.375083°), with sea water temperatures ranging from 28 to 16°C. Coastal and insular reefs in this region present similar geomorphology, characterized by steep granitic rocky reefs that end in sandy bottoms, generally 12–15 m deep (Anderson *et al*., 2014). AR MPA has been designated a no-take marine protected area since 1990 and encompasses 17,800 ha. In 2000, AR MPA officially became a no-entry area, where harvesting and human presence are strictly forbidden by law (researchers and managers excepted) (Anderson *et al*., 2014). The no-take core of the MPA area encompasses three islands: Deserta; Galé and the northern portion of Arvoredo Island (Figure 1). The southeastern portion of Arvoredo Island is part of the buffer zone where recreational diving is allowed (Figure 1). AR MPA is the only nearshore MPA in the south-southeastern coast of Brazil, protecting fragments of the Atlantic rainforest and marine biodiversity. According to the latest checklist of marine fish recorded inside AR MPA, 278 species inhabit the archipelago (Anderson *et al*., 2015).

2.3 | *P. horkelii* aggregation records

Photographs were taken during routine reef fish surveys on Rancho Norte (Arvoredo Island no-take portion). Since 2008, a monitoring programme has been conducted in AR MPA to evaluate the effectiveness of the MPA (Anderson *et al*., 2020). Sampling expeditions are conducted annually, in the morning, during the Austral summer (from December to March) (see Anderson *et al*., 2020).

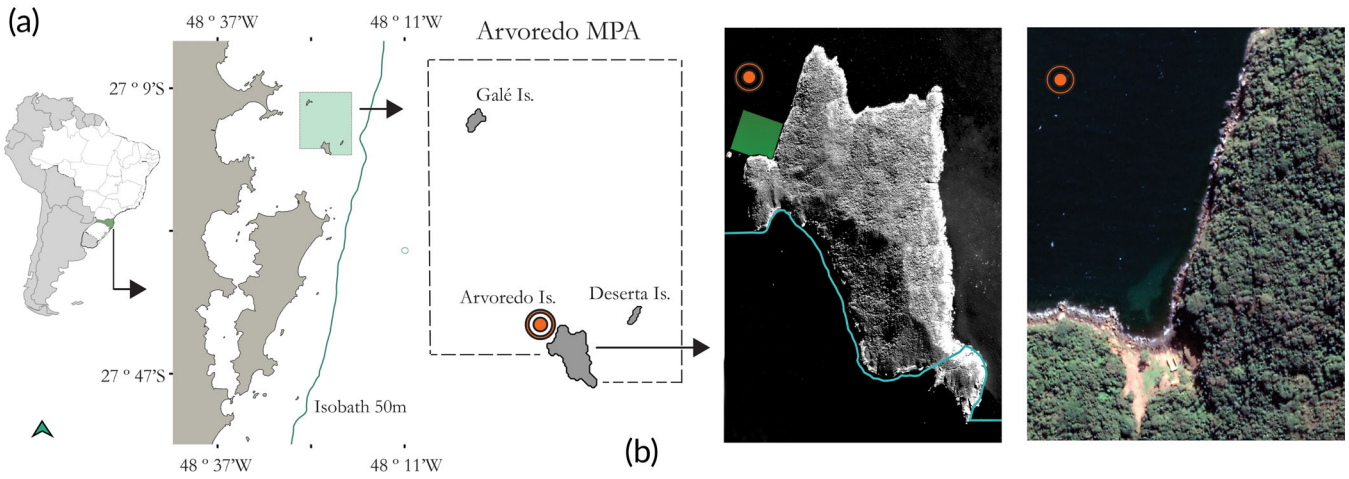

FIGURE 1 (a) Santa Catarina State; the light green polygon represents the limits of AR MPA. (b) AR MPA schematic representation with the position of the three major islands: the orange circle represents Arvoredo Is. The high-resolution image on the right is a zoomed view of Arvoredo Is.; the light green polygon represents the Rancho Norte site and the limits where *Pseudobatos horkelii* has been detected (13 ha. area). The light blue line represents the no-take area border. On the right corner is a zoomed image of the Rancho Norte site where all *P. horkelii* aggregations were recorded

3 | RESULTS

3.1 | The Brazilian guitarfish FSAs' records

On 4 February 2014 (Austral summer) during routine ichthyofauna surveys of UVC, the first record of a *P. horkelii* aggregation was photographed at Rancho Norte (AR MPA no-take zone, located at the northern portion of Arvoredo Is.) (Figure 1). Twenty-five individuals were recorded, motionless, scattered in a sandy substrate, in interface with the rocky reef, from 8 to 12 m depth, with bottom temperature 25°C (Figure 2a). On account of good water visibility (aprox. 15 m) at the period, *P. horkelii* individuals showed reluctant behaviour facing the diver's approximation and could not be photographed all clustered as when they were first sighted (Figure 2a). A few individuals were juveniles (35 cm TL), mostly adults ranging from 80 to 100 cm TL.

On 15 December 2018, the second record was reported, also, during routine surveys. Fifteen specimens were reported, motionless, scattered in small clusters of two to three individuals in sandy substrate at depths of 5–7 m and temperature aprox. 24°C (Figure 2b), and photographs were obtained from the ICMBio (Brazilian Government Institute responsible for the MPA's management) team which recorded this sighting.

On 10 December, 2019, a third and much larger aggregation of *P. horkelii* was photographed also at Rancho Norte. Individuals were registered by researchers during routine ichthyofauna UVC surveys. At least 50 large (mostly ranging from 80 to 120 cm TL) motionless individuals were counted and photographed all clustered in a sandy substrate from 5 to 12 m depth, with bottom temperature 24°C (Figure 2c).

4 | DISCUSSION

4.1 | Potential reproductive aggregations

This is the first report of an aggregation ground for this endangered species in a no-take MPA along the Brazilian coast. In February 2014, despite anecdotal reports from divers who spotted the individuals clustered, and considering the photographic evidence only, it is not possible to positively determine if individuals of *P. horkelii* were aggregated for mating. Nevertheless, the large aggregation recorded on 10 December 2019 comprised two size classes of adult individuals which could indicate both sexes (*e.g.*, mature males' size at first maturity is smaller than mature females) (Caltabellotta *et al.*, 2019; Vooren *et al.*, 2005). Chaikin *et al.* (2020) reported reproductive aggregations of *Glaucostegus cemiculus* (Blackchin guitarfish) to Mediterranean Israeli coast (Eastern Levantine basin) with impressive environmental and seasonal similarities to the records presented herein [see Chaikin *et al.*, 2020, appendix (3b)]. The two events observed are from the same place and within the seasonal period of the reproductive processes of the species in southern Brazil, and in both cases were recorded small size interval between large individuals (Caltabellotta *et al.*, 2019). Therefore, these aggregation records may characterize Rancho Norte shallow reefs as a recurrent aggregation environment for *P. horkelii* individuals, considering that, after the adults departures to deeper waters, the YOY could remain in such inshore environments. Thus, AR MPA can be regarded as a safe haven for potential reproductive aggregations of the CR Brazilian guitarfish, which demands reinforcements in monitoring, considering that illegal fisheries are known to occur inside AR MPA (Anderson *et al.*, 2014).

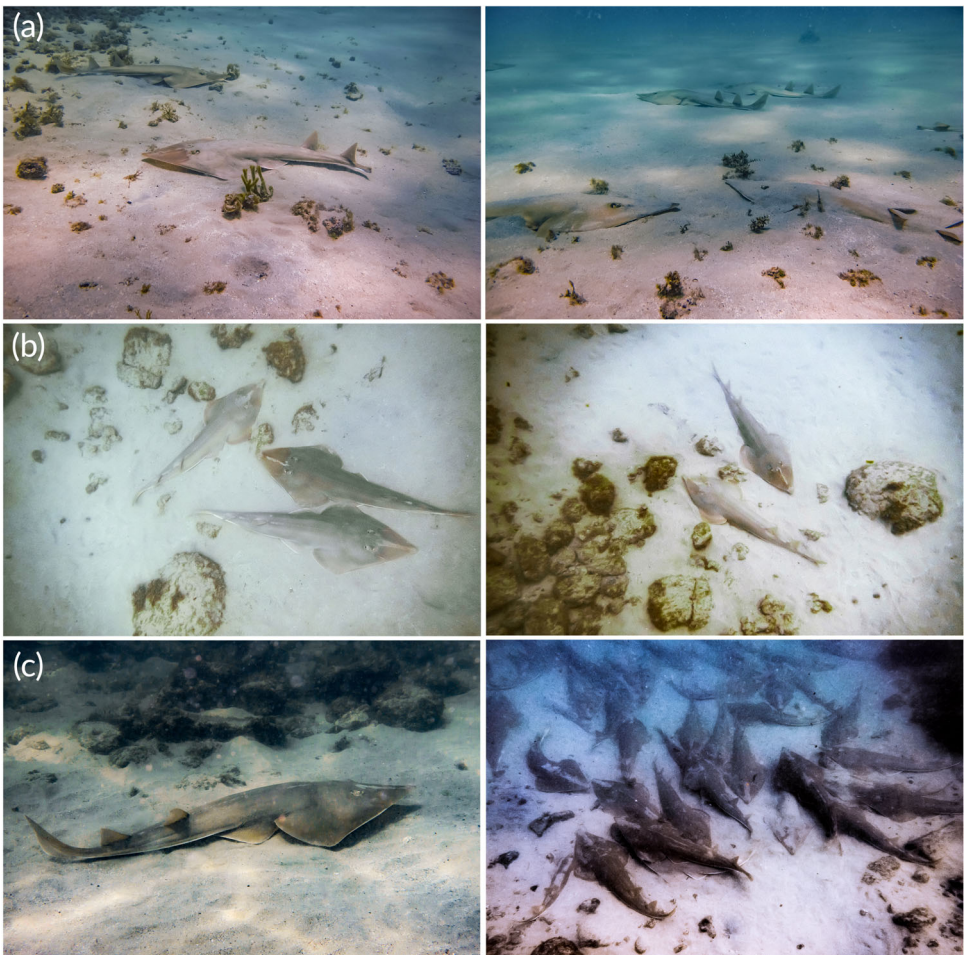

FIGURE 2 (a) The first *Pseudobatos horkelii* aggregation on 4 February 2014 at Rancho Norte (AR MPA no-take zone, northern portion of Arvoredo Is). Photographs were taken with the water visibility at aprox. 15 m; water bottom temp. 25°C and 10–18 m depth. (b) Second *P. horkelii* aggregation on 15 December 2018 at Rancho Norte (AR MPA no-take zone, northern portion of Arvoredo Is). Photographs were taken at depths of 5–7 m and were kindly authorized for use by the ICMBio staff. (c) Third and much larger *P. horkelii* aggregation on 10 December, 2019 at Rancho Norte (AR MPA no-take zone, northern portion of Arvoredo Is). Photographs were taken with the water visibility at aprox. 5 m; water bottom temp. 24°C and 5–12 m depth)

4.2 | Conservation strategies

The protection and monitoring of areas where reproductive aggregations occur can offer disproportional recovery of fish stocks (Erisman *et al*., 2017). Considering the small area inside the no-take core of AR MPA used for aggregations (13 ha.) (Figure 1), a low-cost monitoring programme focused on the Brazilian guitarfish seasonal reproductive behaviour could benefit the species and repopulate adjacent areas (Erisman *et al*., 2017). One example of successful recovery of marine fish biodiversity because of programmes and initiatives focused on protection of sites where aggregations occur is the Cabo Pulmo national Park in Mexico (Aburto-Oropeza *et al*., 2011; Erisman *et al*., 2017; Rowell *et al*., 2019). Researchers reported an impressive 463% in tons per ha^{-1} increase in biomass from 1999 to 2009 (Aburto-Oropeza *et al*., 2011). The implementation of a specific monitoring programme focused on the Brazilian guitarfish seasonal aggregation in AR MPA is urgent. AR MPA is under a recategorization process to become a park, and the increase in the presence of recreational divers could cause detrimental effects to *P. horkelii* future aggregations.

In AR MPA, the authors also recorded in 1 h. dive, seven individuals of an endangered butterfly ray, *Gymnura altavela* (Linnaeus 1758) in that same site in 2018 (ICMBio staff, pers. obs.), which further reinforces the importance of Arvoredo for the conservation of elasmobranchs. Considering that in the region there are several species of rays (Anderson *et al*., 2015; Hayata *et al*., 2018; Kotas *et al*., 2017) including endangered ones, it is hoped that with more effective management and surveillance, AR MPA and its surroundings will serve as a sanctuary for rays. The identification of other nearby areas that can serve as aggregation grounds for *P. horkelii* and other rays is also essential.

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