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Evidences of Seasonal Aggregations and Breaching Behaviour of Blacktip (*Carcharhinus limbatus*) and Spinner (*C. brevipinna*) Sharks in a Southwest Atlantic Marine Protected Area

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ABSTRACT

This study indicates a seasonal aggregation behaviour in Blacktip (*Carcharhinus limbatus*) and Spinner (*C. brevipinna*) sharks over 6 years of data in Ilha Grande Bay, a warm temperate bay in Rio de Janeiro, Brazil. Observations from visual surveys, drone footage and Baited Remote Underwater Video (BRUV) deployments revealed mixed-species aggregations, reaching a maximum of 113 individuals, and recorded the first instances of breaching behaviour of sharks in the Southwest Atlantic. These aggregations occurred seasonally during austral autumn and winter in a shallow cove near a nuclear power plant, partially within a no-take marine protected area. Understanding these behaviours provides valuable insights for effective management and conservation strategies in the region.

1 | Introduction

Aggregation is defined as a group of individuals gathered in a certain location attracted by environmental resources and not necessarily motivated by social organization (Allaby 2010). Specifically for elasmobranchs, McInturf et al. (2023) define aggregation as "the co-occurrence of two or more individuals in space and time due to the deliberate use of a common driver". Even though sharks are often considered solitary animals, many studies have reported aggregations (Klimley and Nelson 1981; Heupel and Simpfendorfer 2005; Kajiura and Tellman 2016; McInturf et al. 2023). These events have been indicated to be driven by reproduction (Sims 2006), feeding (e.g., Heupel and Simpfendorfer 2005; Hoffmayer et al. 2007) and refuge (e.g., Klimley 1993; Heupel and Simpfendorfer 2005), which can present seasonal (Domeier and Nasby-Lucas 2007; Dudgeon et al. 2008; Kajiura and Tellman 2016) and diel patterns (Economakis and Lobel 1998). Defining the causes and types of aggregation in sharks to enhance predictive power can be an important tool for developing effective management strategies.

Understanding breaching behaviour in sharks and whether there is a correlation with aggregations is also complex. Breaching has been reported for different elasmobranch species (Castro 1996; Curtis and Macesic 2011). In a recent review, Klimley et al. (2024) associated breaching behaviour with several hypothesized functions, including parasite removal, clearing of gill rakers, expulsion of faeces or internal parasites, courtship, attraction or repulsion of conspecifics and interspecifics, evasion from conspecifics, feeding, concentrating or stunning prey and birthing. Investigating this behaviour could also provide insights into the drivers of shark aggregations and habitat use.

The requiem shark family (Carcharhinidae) comprises 12 genera and at least 56 described species distributed worldwide across continental shelves and offshore regions, dominating tropical waters (Ebert et al. 2021). Many species in this family are targeted by fisheries—commercial, subsistence and recreational—for their meat and fins (Ebert et al. 2021), including in the Southwest Atlantic (Ferrette et al. 2019). Approximately one-third of these species are classified as threatened by the IUCN Red List of Threatened Species (IUCN 2024).

The two requiem shark species investigated in this study—the Blacktip shark and the Spinner shark—are often caught as secondary targets or bycatch in Southwest Atlantic fisheries. The Blacktip shark, *Carcharhinus limbatus* (Valenciennes 1839), is a cosmopolitan species found in tropical and subtropical waters, primarily on continental shelves and also in offshore areas, though it is not considered oceanic (Ebert et al. 2021). In Brazil, the species is present along the entire coast and at oceanic islands. It can grow up to approximately 2.55 m, with mature males measuring 1.4–1.8 m and females 1.5–1.8 m, while newborns measure around 55–65 cm (Gadig 2001). Heavily harvested in commercial and artisanal fisheries (Gadig et al. 2002; Domingues et al. 2013), *C. limbatus* is currently categorized as vulnerable by the IUCN Red List (Rigby et al. 2020b) and nearly threatened by Brazil's national list (ICMBio 2024). The Spinner shark, *Carcharhinus brevipinna* (Valenciennes 1839), inhabits warm temperate and tropical waters in the Atlantic, Mediterranean and Indo-West Pacific, favouring continental and insular shelves and inshore areas (Ebert et al. 2021). In Brazil, it is more commonly observed along the southeast coast (Gomes et al. 2010, 2019) and is also frequently caught by small-scale fisheries (Gadig et al. 2002). The species can grow up to 2.7 m, with mature males measuring 1.5–2 m and females 1.7–2.1 m, while newborns measure 60–75 cm (Gadig 2001). It is classified as vulnerable by both the IUCN Red List (Rigby et al. 2020a) and the Brazilian national list (ICMBio 2024). Both species are viviparous, with a yolk-sac placenta (placental viviparity), producing up to 10 embryos per pregnancy in *C. limbatus* and up to 15 in *C. brevipinna* (Gadig 2001). Their schooling behaviour, reproductive mode and tendency to inhabit inshore waters increase their susceptibility to fisheries pressure. Identifying and protecting areas where aggregations occur are critical not only for the conservation of these species but also for effective fisheries management.

Both species have been reported to form aggregations and exhibit breaching behaviour. Aggregations of *C. limbatus* have been recorded in Southeast Florida (Castro 1996; Kajiura and Tellman 2016), where breaching behaviour has also been observed (Castro 1996; Ritter and Brunnschweiler 2003). Additionally, aggregations have been reported in the Gulf of Mexico (Heupel and Simpfendorfer 2005) and North Carolina (Schwartz 2013). Aggregations of *C. brevipinna* are likely underreported in the literature due to the difficulty of distinguishing them from *C. limbatus*, often resulting in misidentifications (Branstetter 1982; Bowers and Kajiura 2023). Nevertheless, they have also been reported in Southeast Florida (Aubrey and Snelson 2007) and observed breaching in North Carolina (Schwartz 2013). Aubrey and Snelson (2007) indeed suggested that juvenile aggregations of these species may be mixed, indicating that some recorded *C. limbatus* aggregations could include *C. brevipinna* as well.

The Southwest Atlantic Ocean lacks studies on shark aggregations and has no reports on breaching behaviour. The objective of this study is to report aggregations of Blacktip sharks (*C. limbatus*) and Spinner sharks (*C. brevipinna*) in a Southwest Atlantic coastal bay, recording the breaching behaviour of sharks for the first time in the Southwest Atlantic and discussing the environmental characteristics driving these events.

2 | Material and Methods

The Ilha Grande Bay (IGB) is located in the south region of the Rio de Janeiro state (23°06 S, 44°42 W), Southeast Brazil (Figure 1). This bay presents a water surface area of 470 km^2 and has two ocean entrances on either side of the 193 km^2 island (Kjerfve et al. 2021). A narrow channel of 2.3 km wide and approximately 35 m deep divides IGB into the west and east portions. The coastal area is highly jagged with narrow rocky reefs bordering the whole coast from the surface to the sandy bottom. The local water is influenced by winds and tides with a mean amplitude of 1.6 m (Nogueira et al. 1991) and receives a significant contribution of freshwater from the rivers in some locations (Neves et al. 2016). Sea surface temperature in IGB varies from 24.4°C to 28.4°C in summer and 24°C to 26°C in winter (Creed et al. 2007).

Economic activities in the IGB include tourism, power generation (thermonuclear power plants), shipyards, private marinas, oil terminals, a commercial port and recreational and commercial (artisanal and industrial) fisheries. The Tamoios Ecological Station, a no-take marine protected area, covers part of the bay and includes 29 islets, islands, rocks and slabs and their respective marine surroundings in a 1-km radius (Figure 1a).

The area where sharks were recorded is a small area within the IGB called Piraquara de Fora Cove (approximately 3 km^2), with the influence of input of warm water from the nuclear plant, and part is protected by the Tamoios Ecological Station (Figure 1). Shark abundances were estimated in 2016 and 2017 by visual sightings from the surface and Baited Remote Underwater Videos (BRUVs); in 2020, 2021 and 2022 by drone surveys; and in 2023 and 2024 by BRUVs and drone surveys. The number of jumps per day was recorded using visual sightings and drones

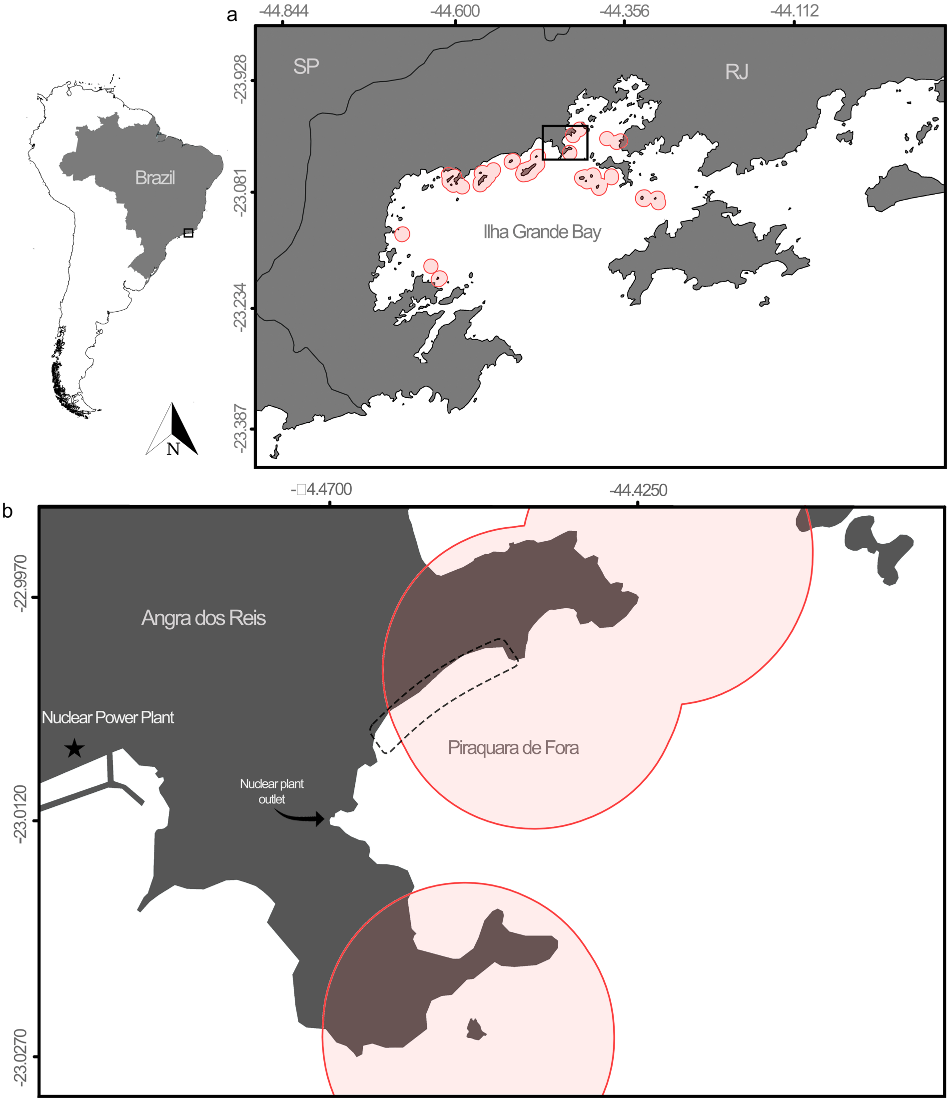

FIGURE 1 | Map of the study area (Ilha Grande Bay) showing Tamoios Ecological Station (shaded in red) (a), and the area covered by Baited Remote Underwater Video (BRUV) samplings and drone belt transects (dashed polygon) in Piraquara de Fora Cove (b). The map also indicates the location of the Nuclear Power Plant and its warm water outlet.

during the expeditions (Table 1). The frequency of spins during each jump was observed in order to describe the behaviour.

Visual sightings were based on observations from the surface from 8 to 17h, and the maximum number of individuals observed at the same time within the Piraquara de Fora Cove along the day was recorded.

BRUV deployments were conducted along the coast of Piraquara de Fora Cove (Figure 1b) at depths ranging from 2 to 10m. Each deployment lasted 60min, with 1kg of smashed sardines used as bait. The abundance was estimated based on the maximum number of individuals in a single frame (MaxN) (Langlois et al. 2020). BRUV hardwares used in 2016 and 2017 were composed of aluminium structures coupled with GoPro Hero3+cameras set up to 60 frames per second at 1080 pixels. The BRUV hardware used in 2024 consisted of a polyvinyl chloride (PVC) frame with GoPro Hero 10 camera set up to 30 frames per second at 1080 pixels. Two BRUV hardwares equipped with 360°cameras were deployed in July 2024.

Drone surveys were conducted along a belt transect approximately 1.2km long and 300m wide along the coast of the bay, twice a day (Figure 1b), counting all individuals observed within the transect. Some drone flights were conducted at lower altitudes to aid species identification. However, abundance estimates were calculated by combining both species due to the difficulty of distinguishing them at the standard survey altitude. The aerial observations were conducted using DJI Mavic Air 2 and DJI Mavic 2 drones (DJI Co., Shenzhen, China). The Mavic Air 2 is equipped with a 1/2in. CMOS sensor is capable of capturing 12 MP still images and recording 4K video at 50 fps. The videos captured with the Mavic Air 2 were recorded in 4-K resolution at 50 frames per second, ensuring detailed and fluid high-definition footage. The DJI Mavic 2, used alongside the Mavic Air 2, features a 1-in. CMOS sensor on its Hasselblad L1D-20c camera, allowing for 20 MP still images and recording 4K video at 30 fps. It also offers GPS and GLONASS positioning and advanced obstacle avoidance systems, making it highly reliable for aerial observations. The combination of these two drones allowed for flexibility and efficiency in capturing high-quality

TABLE 1 | Number of jumps and the maximum abundances of the mixed aggregations of Blacktip (*Carcharhinus limbatus*) and Spinner (*C. brevipinna*) sharks by method used in each expedition in Piraquara de Fora Cove.

Date	Method	Samples	Maximum abundance	Jumps
17 July 2016	BRUV	5 deployments	0	4
	Visual	Observations from 8 to 17 h	15	
18 July 2016	BRUV	5 deployments	0	3
	Visual	Observations from 8 to 17 h	12	
25 June 2017	BRUV	11 deployments	0	5
	Visual	Observations from 8 to 17 h	30	
26 June 2017	BRUV	11 deployments	2	2
	Visual	Observations from 8 to 17 h	26	
25 May 2020	Visual	Observations from 8 to 17 h	10	1
31 May 2020	Visual	Observations from 8 to 17 h	10	0
8 June 2020	Visual	Observations from 8 to 17 h	15	3
24 June 2020	Drone	2 belt transects	18	2
25 June 2020	Drone	2 belt transects	15	3
10 July 2020	Drone	2 belt transects	35	6
11 July 2020	Drone	2 belt transects	40	5
12 July 2020	Drone	2 belt transects	60	4
13 July 2020	Drone	2 belt transects	65	6
25 July 2020	Drone	2 belt transects	25	3
27 July 2020	Drone	2 belt transects	50	3
27 May 2021	Drone	2 belt transects	70	4
11 July 2021	Drone	2 belt transects	55	4
13 July 2021	Drone	2 belt transects	15	2
14 July 2021	Drone	2 belt transects	65	6
15 July 2021	Drone	2 belt transects	65	7
25 May 2023	Drone	7 belt transects	113	1
	BRUV	12 deployments	0	
22 June 2023	Drone	3 belt transects	61	0
	BRUV	12 deployments	4	
27 July 2023	BRUV	12 deployments	0	0
1 August 2023	Drone	3 belt transects	34	0
3 August 2023	Drone	4 belt transects	43	0
1 September 2023	Drone	1 belt transects	12	8
	BRUV	2 deployments	0	
21 September 2023	Drone	3 belt transects	0	0
28 September 2023	BRUV	17 deployments	0	0
11 October 2023	Drone	3 belt transects	0	0

(Continues)

TABLE 1 | (Continued)

Date	Method	Samples	Maximum abundance	Jumps
31 October 2023	Drone	2 belt transects	0	0
	BRUV	8 deployments	0	
10 November 2023	Drone	3 belt transects	0	0
27 February 2024	Drone	1 belt transects	0	0
	BRUV	12 deployments	0	
23 April 2024	Drone	4 belt transects	5	0
	BRUV	11 deployments	0	
14 May 2024	Drone	2 belt transects	8	0
28 May 2024	Drone	4 belt transects	48	2
	BRUV	5 deployments	0	
	Pelagic BRUV	5 deployments	2	
25 June 2024	BRUV	15 deployments	0	2
	Pelagic BRUV	4 deployments	1	
4 July 2024	Drone	3 belt transects	6	0
24 July 2024	Pelagic BRUV with 360° camera	2 deployments	1	2

aerial footage in remote field locations, with both drones offering stabilized gimbals to ensure smooth and professional results even in moderate wind conditions.

Additionally, water temperatures and salinities profiles across the water column were recorded with a SonTek CastAway® CTD (Conductivity, Temperature and Depth) during BRUVs samplings of 2017 along the coast of Piraquara de Fora Cove in four different sampling points. The equipment is synchronized with time and location via its built-in GPS receiver, with latitude and longitude recorded both before and after each profile. The device is deployed from the surface and free-falls at a rate of approximately 1 m/s to the ocean bottom, collecting data at a rate of 5 Hz (five times per second).

Species were identified according to Branstetter (1982), Gadig (2001), Gomes et al. (2010, 2019) and Ebert et al. (2021). Despite their morphological similarity, the two species can be distinguished by the shape of the snout, in which *C. limbatus* has a shorter pointed snout, while *C. brevipinna* has a longer pointed snout (Branstetter 1982; Gadig 2001). They also differ in the origin of the first dorsal fin: In *C. limbatus*, the first dorsal fin origin is slightly behind the axil of the pectoral fins, while in *C. brevipinna*, the first dorsal fin origin is located above or just behind the apex of the inner margin of the pectoral fins (Branstetter 1982; Gadig 2001; Gomes et al. 2010, 2019). Furthermore, *C. brevipinna* exhibits prominent labial furrows, longer than those of any other *Carcharhinus* species (Ebert et al. 2021). Individuals recorded in the videos were also examined for sex based on the presence or absence of claspers and for visible abdominal distention, which may indicate pregnancy (Porcher 2005).

Additionally, one individual was found dead stranded on the coast and underwent a necropsy. The Projeto Tartaruga Viva (Living Turtle Project) collected the specimen of *C. limbatus*, and the veterinarian in charge conducted an anatomopathological examination. The analysis included type of preservation, external examination and internal examination highlighting the main macroscopic findings. This report was included in the study to document the event and provide insights into the factors driving the aggregations.

3 | Results

Two species have been identified by the drone images, Blacktip shark (*Carcharhinus limbatus*) and Spinner shark (*C. brevipinna*) (Figure 2a,b), in mixed aggregations of different sizes with up to 113 individuals (Figure 2c,d). Seven out of 149 BRUVs recorded 10 appearances in the cameras, with the maximum number of shark individuals recorded in the same frame (MaxN) of one. Of these, only four could be identified due to limited water visibility, all of which were *C. limbatus* (Figure 2e,f).

Sightings of aggregations were in the Piraquara de Fora Cove, concentrated in the northern area (Figure 3).

C. limbatus and *C. brevipinna* aggregations were recorded in autumn and winter months in the IGB (July 2016, June 2017, May to July 2020, May and July 2021, May to September 2023 and April, May and July 2024), with counts ranging from 5 to 113 individuals (Figure 4a and Table 1). Drone surveys accounted for most of the shark observations, while the efficiency of BRUVs was impaired by the low visibility (< 1.5 m) at the bottom of the study site. Of the 10 shark records from BRUVs, all were *C. limbatus*, with three identified as females, while the sex of the other seven could not be determined. One of these females was presumably pregnant (Figure 2e). Breaching behaviour was recorded

FIGURE 2 | Individuals of *Carcharhinus limbatus* (a) and *C. brevipinna* (b) recorded by drones in the Piraquara de Fora Cove, Angra dos Reis, RJ, during aggregation events. Drone images with smaller (c) and larger aggregations (d). Baited Remote Underwater Video (BRUV) images with the individuals of Blacktip shark (*C. limbatus*) recorded (e, f), with a female presumably pregnant (e). Videos in the Supporting Information.

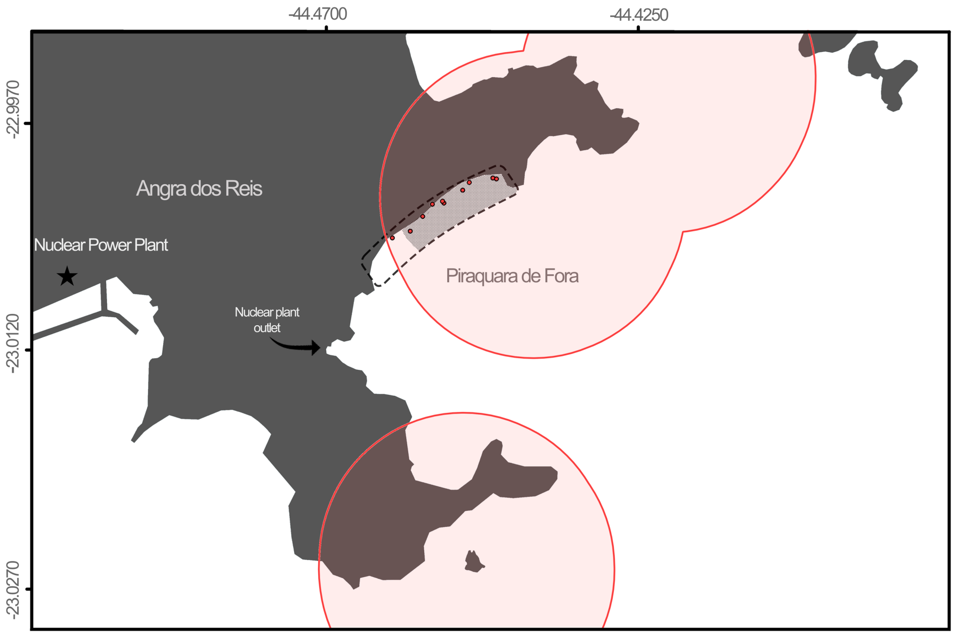

FIGURE 3 | Locations of the 10 Blacktip shark (*Carcharhinus limbatus*) records captured by Baited Remote Underwater Videos (BRUVs) (red dots) and the area of mixed aggregations (shaded area) of Blacktip and Spinner sharks (*C. brevipinna*) identified through drone belt transects (dashed polygon) in Piraquara de Fora Cove, Ilha Grande Bay, RJ, Brazil.

in 63% of sampling expeditions in May–July and in September (Figure 4b and Table 1). Breaches are not very frequent, with the maximum of eight jumps in a day (Table 1). In each jump, sharks spin approximately one to three times (Figure 5). Additionally, one shark was recorded pursuing a prey of *Mugil* spp. near the surface.

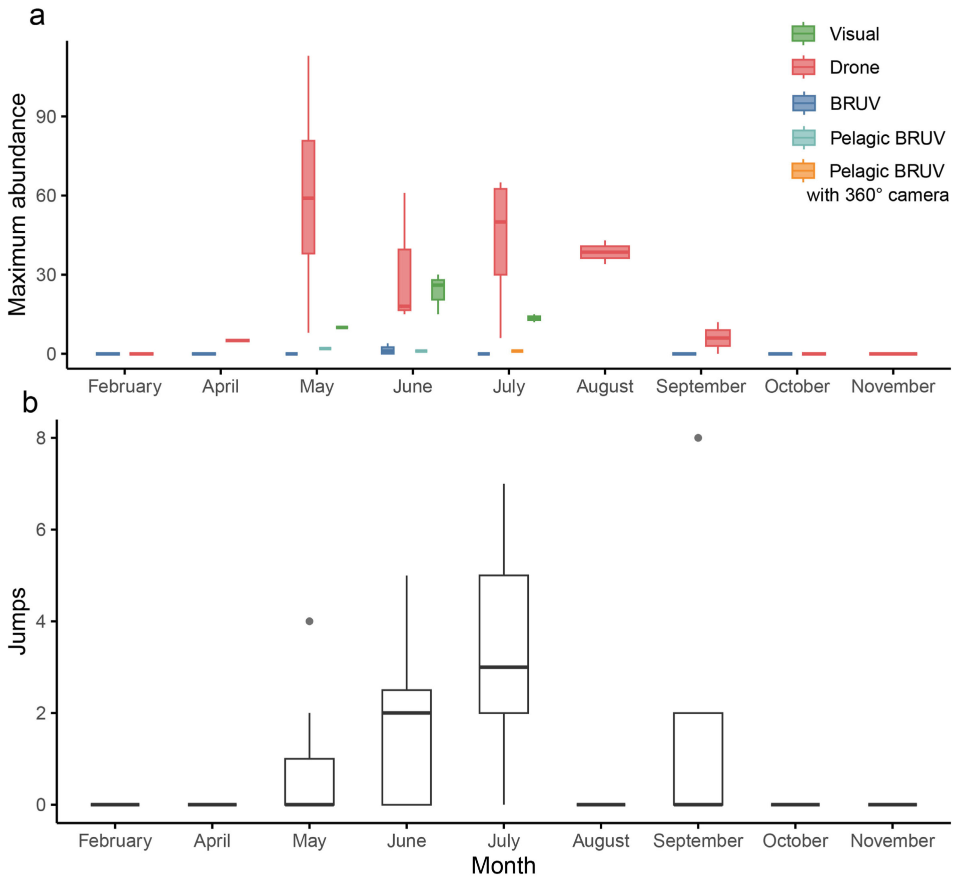

FIGURE 4 | Variation in the maximum abundance of mixed aggregations of *Carcharhinus limbatus* and *C. brevipinna* (a) and the frequency of jumps (b), observed in Piraquara de Fora Bay by month, combining the years analysed (details in Table 1).

FIGURE 5 | Images with the sequence of the breaching behaviour of one Blacktip shark (*Carcharhinus limbatus*) in Ilha Grande Bay, RJ, Brazil (complete video in the Supporting Information).

Results from the CTD showed a steeper thermocline in the southern region of the bay, decreasing as it moves northwards. In the southern sampling point, nearest to the nuclear plant outlet, the temperature ranged from 21.7°C to 27.1°C from the bottom to the surface (Figure 6a). The sampling point moving northwards ranged from 22.2°C to 26.7°C (Figure 6b); the next two sampling points both ranged from 21.8°C to 24.8°C (Figure 6c,d).

The dead, stranded individual of *Carcharhinus limbatus* was found on 11 June 2020 and was kept frozen until the

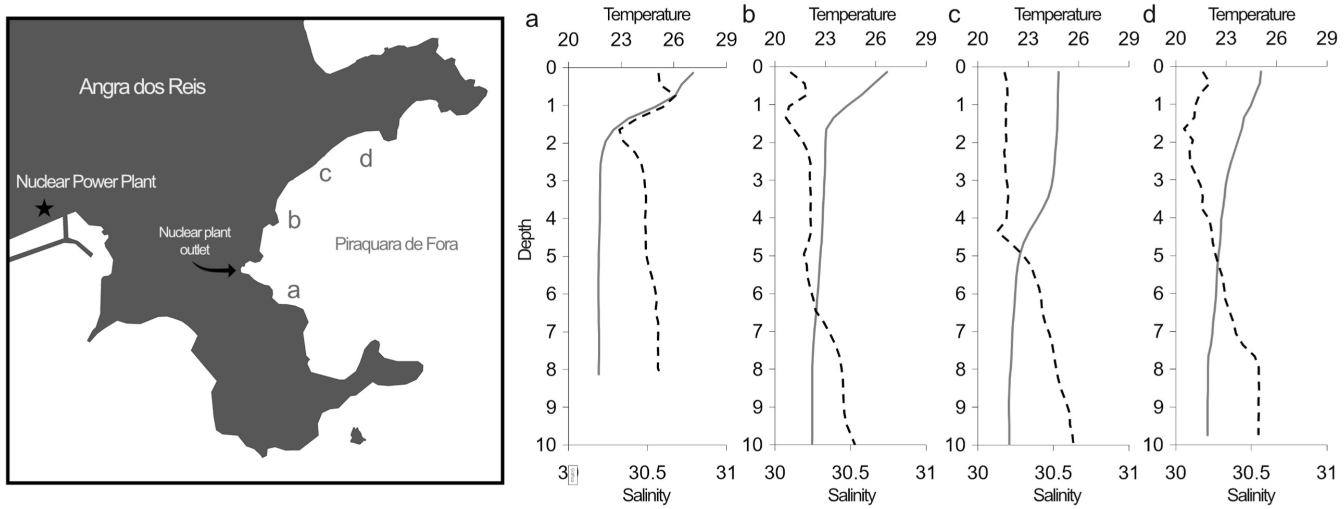

FIGURE 6 | Temperature (continuous line) and salinity (dotted line) data by depth in four sites in the Piraquara de Fora Cove, Angra dos Reis, RJ, Brazil.

anatomopathological examination conducted by the Projeto Tartaruga Viva necropsy team on 19 June. The shark measured 2.4 m in total length and exhibited an extensive, irregular reddish (hemorrhagic) area with abrasions on the ventral region, apparently caused by post-mortem pooling (*livor mortis*). It also had a small, straight lesion reaching the muscular layer on the right pectoral fin, as well as extensive damage to the anal fin and the lower lobe of the caudal fin. The major viscera showed no abnormalities or lesions. There were no clear signs of interaction with fishing gear or the presence of macroscopic ectoparasites. The individual was identified as a pregnant female, containing five foetuses measuring 260–280 mm in total length. The cause of death could not be determined, and no food content was found in the gastrointestinal tract. Photographs documenting the findings are included in the Supporting Information.

4 | Discussion

Our results report the first aggregation events of Blacktip sharks (*C. limbatus*) and Spinner sharks (*C. brevipinna*) in the Southwest Atlantic Ocean (Piraquara de Fora Cove, IGB, Rio de Janeiro), along with observations of their breaching behaviour. Although the monitoring methods varied over the years, data from 6 years consistently indicated seasonal aggregation events in the region. The aggregations, which reached up to 113 individuals, were observed during the austral autumn and winter months, starting to be recorded in April and disappearing in September, with peaks of abundance in May to August, indicating a seasonality in the use of the area.

The seasonality in the life cycle phases of both species has been observed in other regions of the world, with distinct migratory patterns and seasonal occurrences in specific areas associated with different life stages (Simpfendorfer and Milward 1993; Castro 1993, 1996; Allen and Cliff 2000; Gadig et al. 2002; Heupel and Hueter 2002; Yokota and Lessa 2006). The seasonal pattern of occurrences in Piraquara de Fora Cove reflects this behaviour and could be linked to a specific life stage. Monitoring sharks in the bay would be important to determine the sex and maturity stages of the individuals, potentially shedding light on the reasons behind the seasonal use of the area.

Although *C. limbatus* and *C. brevipinna* frequently exhibit schooling behaviour (Rigby et al. 2020a, 2020b), the highly coastal aggregations reported here have only been observed within the specific small cove of Piraquara, in contrast to adjacent areas in the region. Seasonal movements of Blacktip and Spinner sharks have been highly correlated with temperature (Kajiura and Tellman 2016), indicating their sensitivity to temperature changes. While the entire bay experiences warm waters during winter and bottom water temperatures in Piraquara are similar (~22°C) to those recorded further from the thermal outfall (Dias and Bonecker 2008; Kjerfve et al. 2021), heated water is discharged daily into Piraquara de Fora Cove due to the nuclear power plant's cooling process. This discharge leads to a 3°C increase in surface water temperature near the thermal outfall compared to points further north within the cove, according to our CTD profiles. This temperature variation could influence microhabitat selection in the warmer coastal waters of Piraquara de Fora Cove, as elevated temperatures are known to enhance metabolic and physiological functions, including digestion and somatic growth (Bernal et al. 2004). However, fishers reported shark aggregations in IGB before the establishment of the nuclear power plant (Neves. L.M., pers. obs). The elevated temperature may now be drawing individuals, previously observed throughout the bay, to aggregate specifically in this cove. In line with this, Zemah-Shamir et al. (2022) and Bigal et al. (2024) also observed aggregations of Carcharhinidae sharks near warm water discharges from power plants, suggesting that such thermal anomalies can significantly alter the distribution and behaviour of these species. Therefore, further investigation is necessary to clarify the drivers of these aggregations and to analyse historical shark records from fisheries data. This will help assess the effect of warm water discharge on this behaviour in the cove.

The attraction of pregnant females to warmer waters helps explain sexual segregation in some shark species (Speed et al. 2012). It is hypothesized that environments with higher temperatures provide energetic benefits that promote embryo development and shorten gestation periods (Economakis and Lobel 1998; Bernal et al. 2004). *C. limbatus* exhibits a well-defined parturition period in late spring to early summer in the Southwest Atlantic (Bornatowski 2008; Santander-Neto et al. 2020), and pregnant individuals of *C. brevipinna* have been captured between June and July (Fogliarini et al. 2024), suggesting that pregnant females may seek warmer waters in the study area during winter. In this study, we assessed the sex of four specimens of *C. limbatus*: a stranded individual with an analysed reproductive system and three individuals observed in the BRUV images, all of which were females. The stranded specimen was gravid, while one individual recorded by BRUV was also likely gravid, suggesting that reproduction may be a potential driver of the aggregation. However, further research into the sexual composition and reproductive stages of individuals is needed to better understand this phenomenon.

Breaching behaviour in *C. limbatus* (Ritter and Brunnschweiler 2003; Brunnschweiler 2005; Schwartz 2013) and *C. brevipinna* (Schwartz 2013) has been documented in various regions across their distribution range (Klimley et al. 2024) but not in the Southwest Atlantic Ocean. There is no consensus on the causes of this behaviour in sharks, with many authors attributing it to feeding attempts. In the review by Klimley et al. (2024), breaching behaviour of requiem sharks was associated with feeding, cleaning and evasion functions, in that order of importance. In our study, leaps of one individual in a single occasion were observed targeting prey, specifically a mullet from the genus *Mugil* (Actinopterygii, Mugilidae). According to Klimley et al. (2024), spinner and blacktip sharks often leap out of the water or lunge chasing prey such as sardines (*Clupeidae* spp.) or anchovies (*Engraulidae* spp.) that form schools near the surface. However, Schwartz (2013) suggests that the jumping and leaping behaviours of these species may also be linked to rapid, sharp temperature changes in ocean waters, as both *C. brevipinna* and *C. limbatus* can detect such changes with high sensitivity. Breaching can be also linked to sharks' need to regulate body temperature, particularly in areas with significant water temperature fluctuations (Schwartz 2013; Klimley et al. 2024). This behaviour likely aids in maintaining optimal metabolic rates by facilitating heat exchange, allowing sharks to escape warmer surface layers and reduce thermal stress before returning to cooler depths (Klimley et al. 2024). The nuclear plant outlet creates a vertical and horizontal temperature contrast, resulting in a steep thermocline where surface temperatures can be up to 10° higher than those at the bottom. This abrupt temperature shift, maybe combined with feeding attempts, may explain why these jumps are observed exclusively in this small bay within the Southwest Atlantic. However, given that we observed only one instance of feeding attempts and lacked monitoring of control areas without abrupt temperature changes, the drivers of breaching behaviour in the region require further investigation.

4.1 | Implications for Conservation

Mainly due to the large home range of most shark species, few marine protected areas have been specifically designed and/or effective for the protection of the group (MacKeracher et al. 2019). However, it is possible to design effective protected areas for sharks if it encompasses areas where known aggregations occur (Hyde et al. 2022). Our study highlights the seasonal significance of Piraquara de Fora Cove for *C. limbatus* and *C. brevipinna*, both categorized as endangered species, emphasizing the urgent need to protect this area from fisheries. While understanding and predicting shark aggregations is complex and influenced by various environmental factors, these aggregations are crucial considerations in conservation planning for these species. Although Piraquara de Fora Cove is already partially protected by the Tamoios Ecological Station, a no-take MPA, expanding protection to cover the entire bay, is critical, especially during winter when aggregations are most frequent. This report could also prompt discussions on designating this region as an Important Shark and Ray Area (ISRA) (IUCN 2021), given the likely significance of the cove for these species. ISRAs include areas where aggregations (one species) or assemblages (two or more species) of sharks occur regularly or predictably, either year-round or seasonally, regardless of the aggregation's current function (Hyde et al. 2022). Recognition as an ISRA could draw attention from decision-makers to the importance of maintaining a favourable conservation status for sharks in this area.

5 | Conclusions

Our results indicate seasonal mixed aggregations of Blacktip (*C. limbatus*) and Spinner (*C. brevipinna*) sharks during the autumn and winter months in Piraquara de Fora, a small cove in Ilha Grande Bay, Rio de Janeiro state, Brazil. Additionally, this study documents the first record of breaching behaviour in sharks for the Southwest Atlantic. We suggest that these aggregations are primarily driven by the attraction to warm waters for thermoregulation during winter. Regarding the breaching behaviour, one individual was observed using this strategy to capture prey. However, it also appears to be influenced by abrupt temperature changes—both horizontal and vertical—within the cove, potentially serving an evasion function as described by Klimley et al. (2024). While further studies are necessary to accurately determine the drivers of aggregation and breaching behaviour in Piraquara de Fora Cove, the conservation importance of this area for these species is strongly indicated.

Author Contributions

Fernanda Andreoli Rolim: conceptualization, investigation, funding acquisition, writing – original draft, methodology, validation, visualization, writing – review and editing, formal analysis, data curation. **Pedro Furtado Costa Rodrigues:** conceptualization, investigation, methodology, validation, writing – review and editing, formal analysis, data curation. **Otto Bismarck Fazzano Gadig:** conceptualization, investigation, writing – review and editing, methodology, validation, visualization, formal analysis, data curation. **Fábio dos Santos Motta:** conceptualization, investigation, funding acquisition, writing – review and editing, validation, methodology, formal analysis, data curation. **Marco Antonio Light Slerca:** conceptualization, methodology, data curation, formal analysis, writing – review and editing. **Nathan Lagares Franco Araujo:** investigation, writing – review and editing, formal analysis. **Leonardo Mitrano Neves:** conceptualization, investigation, funding acquisition, writing – review and editing, validation, visualization, methodology, formal analysis, project administration, supervision, data curation.

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Ethics Statement

This is an observational study, and the Research Ethics Committees of the respective universities confirmed that no ethical approval was required. Permits for video recordings were granted by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) and acknowledged in the acknowledgments section.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated during the current study are all available in the manuscript.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.