



Interactions between whale sharks, *Rhincodon typus* Smith, 1928 (Orectolobiformes, Rhincodontidae), and Brazilian fisheries: The need for effective conservation measures

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ABSTRACT

This study reports three interaction events between the whale shark (*Rhincodon typus*) and fisheries in Brazilian waters. Two events were described as incidental captures in a gillnet fishery on the northern coast of Rio de Janeiro State, in southeastern Brazil. The last event took place at the Royal Charlotte Oceanic Bank (RCOB), in the southern region of Bahia State, where five fishermen filmed their interaction with a juvenile specimen. For one of the incidental captures, the fish was landed and consumed by locals, and for the other, the shark was released. In the RCOB, the fishermen touched the whale shark with their hands, wooden sticks and even rode on it. In addition, 74 interviews were conducted with fishermen from Bahia about sightings and possible interactions with *R. typus*. According to statements made by the fishermen, although not frequent, the conduct reported for the RCOB occasionally takes place in the region. Evaluating information of this nature is important to support government plans that regulate fishing activities in order to reduce incidental captures and the harassment of whale sharks. Encouraging the participation of fishermen in a collaborative monitoring program for *R. typus* may be a good way to better understand the threats to the species at a reduced cost, particularly for developing countries, such as Brazil.

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1. Introduction

The whale shark, *Rhincodon typus* (Smith, 1828), is the largest living elasmobranch in the world, reaching 20 m long, and has a cosmopolitan distribution in all tropical and warm temperate seas

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from 30°N to 30°S [1]. This species is unmistakable because of its broad head and mouth with a truncated snout, and clear circular spots disposed longitudinally over its entire body [2]. It is a filter feeder and consumes a wide variety of planktonic and nektonic organisms, including small crustaceans (copepods, sergestids and euphausiids), fish larvae and small schooling fish [3,4] that are generally caught near the surface [5]. In the presence of humans, *R. typus* often becomes curious [6], and the attraction of humans to this species is often reciprocated. Its large size and non-threatening behavior result in reliable and profitable tourism activities at feeding aggregation sites, making *R. typus* one of the top three most popular species of sharks in the ecotourism industry [7].

However, injuries and harassment associated with ecotourism can harm and disrupt the natural behavior of this shark [3,6], which has led to the development of codes of conduct and regulations to protect whale sharks from being disturbed [8]. For example, in the Ningaloo Reef of NW Australia, changes in feeding and swimming behavior in the presence of humans have been observed since the enforcement of the “Tourist compliance to a Code of Conduct for Whale Sharks” [9]. In recent years, this type of intervention has become even more urgent, due to numerous videos published in the media worldwide that show humans touching and even riding these sharks. For this reason, it is crucial to develop comparative studies that analyze the behavior of *R. typus* in the presence and in the absence of harassment [6,9] in order to assess the magnitude of the impact of these interactions.

Globally, the whale shark is considered endangered [10], particularly due to being targeted in fisheries and because of incidental catches in nets [11,12]. For example, Akhilesh et al. [13] reported capture by gillnets as a major cause of *R. typus* landings in coastal India. Furthermore, the trade of liver oil and fins has been an incentive to catch these sharks and is recognized as the main conservation challenge for this species [14]. Also, the pressure of harpoon fisheries for whale sharks in Southeast Asia is well documented and considered a great threat to the species [15,16]. Currently, the whale shark is the marine species that has the highest potential value in international luxury markets, putting it at extreme risk of extinction [17].

In Brazil, considering the 3.5 million km² of exclusive economic zone (EEZ), reports of whale sharks are scarce, comprising only 119 observations [18,19]. The species seems to occur throughout the coast and around oceanic islands, but to date, little data is available on its biology and ecology in the region [20,21]. Fishing, transportation, storing and management of *R. typus* are prohibited in Brazil [22]. Consequently, environmental authorities have the challenge of controlling by-catch of whale shark while not interfering with legal fishing of non-threatened species.

In this context, information about whale shark mortality will help in the assessment of human related impacts on the species at a regional level. The aim of the present study was to evaluate the impact of lethal and non-lethal interactions between whale sharks and commercial fisheries in different regions of coastal Brazil.

2. Materials and methods

Information about whale shark fisheries was recorded along the coast of the municipalities of Carapebus (22°15'S, 41°37'W) and Quissamã (22°10'S, 41°23'W), in northern Rio de Janeiro State, southeastern Brazil, and on the Royal Charlotte Oceanic Bank (RCOB) (15°39'33"S, 37°58'21"W / 16°16'23"S, 37°56'47"W), in southern Bahia State, northeastern Brazil. The first region is under influence of the Brazil current and the Cabo Frio upwelling system, where highly productive deep waters flow along the coast due to the predominance of north/northeast winds [23]. The RCOB is part of the northern boundary of the Abrolhos region, an area with the highest marine biodiversity in a coral reef complex in the South Atlantic Ocean [24]. It is a shallow platform of 8,400 km², with an irregular surface [25], and has rectangular geomorphological formations where the continental shelf extends 100 km east-west and 50 km north-south [26]. The study area and where each event occurred are outlined in Fig. 1.

A database including information on the occurrence of *R. typus* along the coast of Rio de Janeiro was created using records gathered from the literature, newspapers, media reports, and our own data of two incidental captures obtained directly from fishermen and locals from Rio de Janeiro (mainly Quissamã) between February 1983 and October 2012. The lengths of the individuals were

visually estimated or obtained using a tape measure.

Data on the interaction at the RCOB were collected from a 09 min 18 s video recorded by one of five fishermen onboard a vessel, as well as from semi-structured interviews with all crew members. Additionally, data from 74 interviews with fishermen from Ilhéus, Una and Canavieiras, whom were shown a whale shark photograph, were added to the database. The interview questions were asked in order to investigate the awareness and attitudes of the respondents concerning the close sightings of whale sharks and their possible interactions with this elasmobranch species. Before each interview, respondents were assured of their anonymity.

3. Results

On 02 February 2001, a whale shark (10.8 m long) was captured in the gillnets of an artisanal fishery approximately seven nautical miles off the coast of Carapebus, in northern Rio de Janeiro State. The shark was dragged by three boats and landed by fishermen in Quissamã (an adjacent municipality). In fact, the shark was towed and landed due to the suspected value of its fins; however, neither the whale shark nor its fins had high commercial value at the time and the specimen was consumed by locals (Fig. 2A).

In the second event off Rio de Janeiro, on 19 July 2012, a specimen of *R. typus* (approximately eight meters long) was captured by two boats operating gillnets around four nautical miles off the coast of Quissamã (Fig. 2B). In this particular case, fishermen dove and cut their gillnets to release the fish, showing a lack of interest in its commercial value. Both captures were carried out by the gillnet fishery fleet of Barra do Furado, from Quissamã. The gillnets (70 mm) used during the incidental captures of the specimens were about three kilometers long.

A total of 18 individuals were reported along the coast of Rio de Janeiro State between February 1983 and July 2012, including records from the present study and the list provided by Gomes et al. [27]. The records were distributed throughout the seasons of the year (Table 1), occurring every month except October and December.

The interaction in Bahia State took place in October 2011 between 03:00 pm and 05:00 pm, while the sea was calm. The informants were fishing with hooks and lines, 17 miles offshore and 85 m deep, in the RCOB. They reported that the shark was foraging on small fish and shrimp associated with the hull of the vessel, demonstrating knowledge about the diet of the species. In the video, the shark's mouth is stained with the boat's paint, which indicates a potential risk related to the interaction of these animals with boats.

Fishing activity was completely interrupted by the crew while the video was being recorded. The fishermen were highly excited, splashing the water, touching the animal and even poking it with a wooden stick (Fig. 3) to see the shark's reaction. On several occasions, the shark swam towards the fishermen when a hand or an object was in the water.

Three out of five fishermen stepped on and even rode the animal during the episode. No awareness reaction of fishermen was observed regarding risk of injury during the interaction. According to the fishermen, they had seen people swimming near whale sharks in television shows or movies and this had encouraged them to interact closely with the fish.

In the remaining interviews, three fishermen affirmed to have ridden a whale shark and the same number reported seeing fellow fishermen riding the species at least once. In addition, twelve fishermen stated they had touched whale sharks with a hand and / or other objects (pieces of wood, lead sinkers). Although not commonplace, it can be seen that cases of whale shark harassment

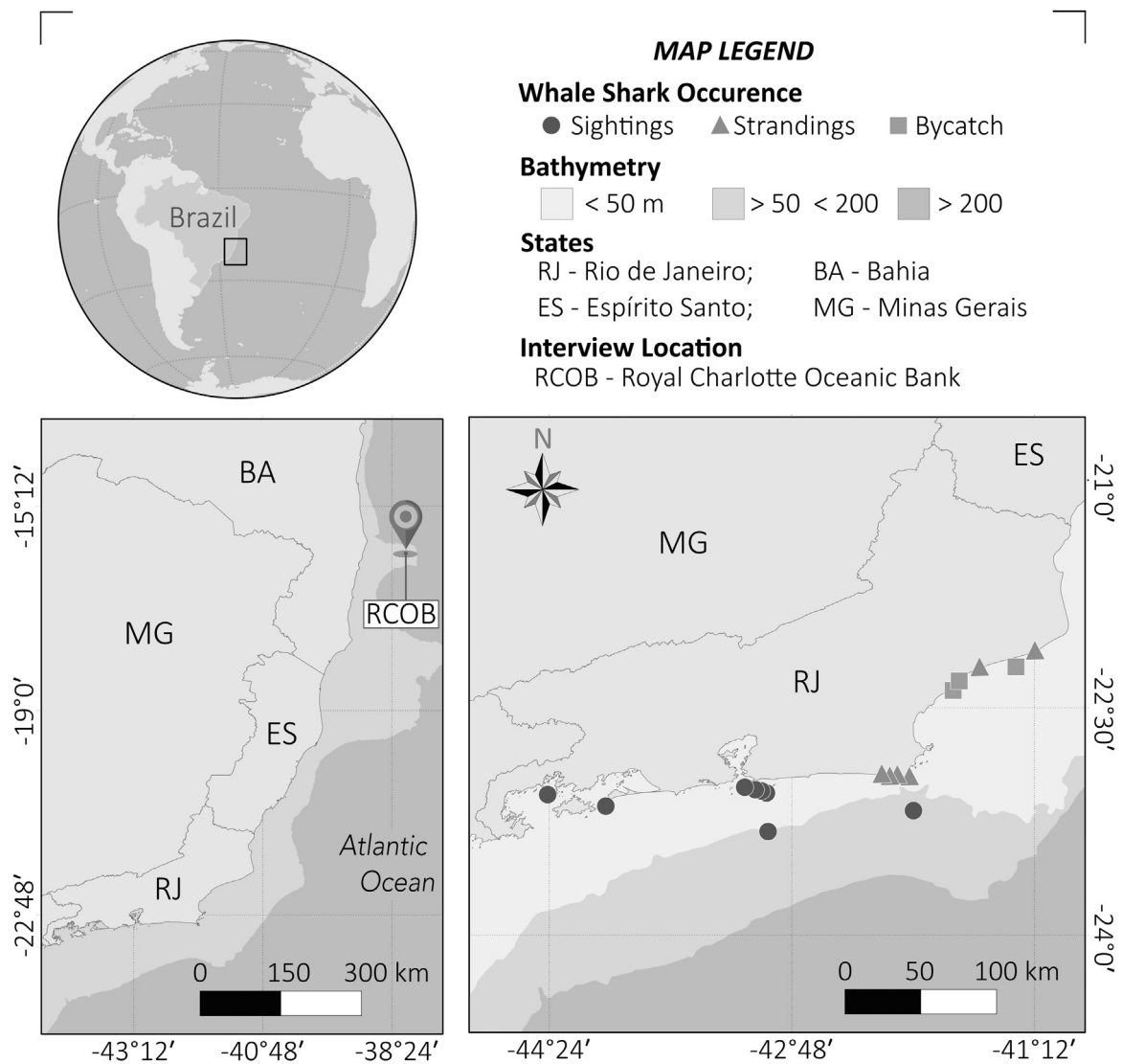


Fig. 1. Brazilian areas where the interactions occurred.

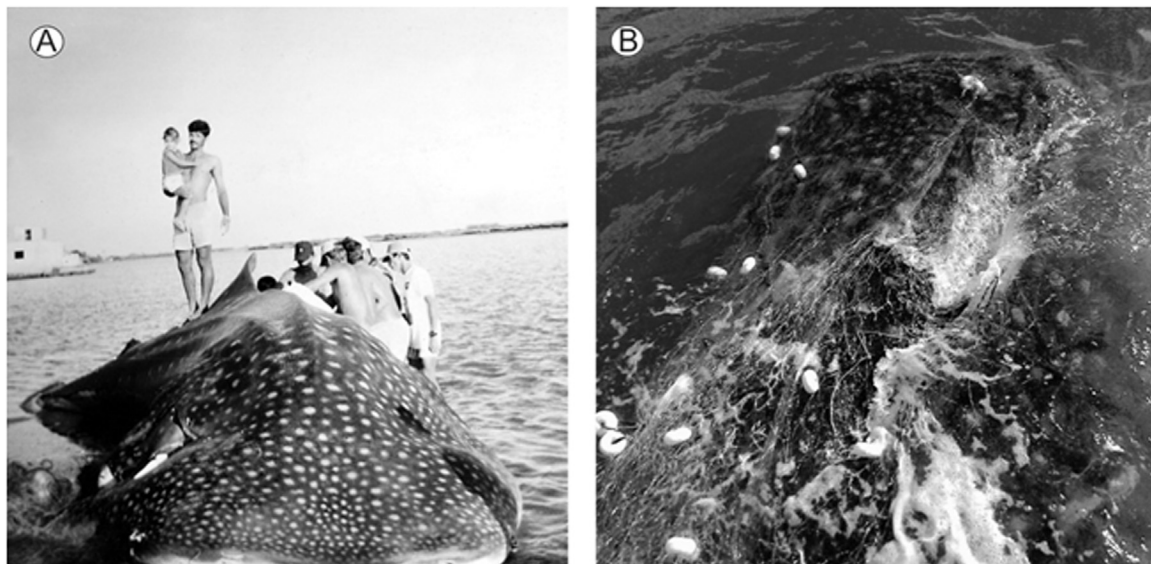


Fig. 2. Two whale sharks *Rhincodon typus* (Smith, 1828) incidentally captured by the gillnet fishery at northern Rio de Janeiro, south-eastern Brazil: (A) Whale shark captured on 02 February 2001; (B) Whale shark captured and released on 19 July 2012.

Table 1

Published and new records of the whale shark *Rhincodon typus* Smith, 1828 in Rio de Janeiro State, south-eastern Brazilian coast. Table informs records dates, localities, record type and source. Published and new records of the whale shark *Rhincodon typus* Smith, 1828 in Rio de Janeiro State, south-eastern Brazilian coast. Table informs records dates, localities, record type and source.

Date	Locality	Record type	Source
February 1983	Rio de Janeiro	Sighting	[27]
27 March 1984	Arraial do Cabo	Stranded carcass	[20]
March 1987	Arraial do Cabo	Stranded alive and released	Present study
November 1991	Macaé	Sighting	[20]
February 1992	Rio de Janeiro	Sighting	[20]
21 May 1993	Arraial do Cabo	Stranded alive and died	[20]
27 May 1993	Arraial do Cabo	Stranded alive and released	[27]
June 1994	Rio de Janeiro	Sighting	[27]
November 1994	Rio de Janeiro	Sighting	[27]
18 March 1995	Angra dos Reis	Sighting	[27]
3 June 1995	Arraial do Cabo	Stranded carcass	[28]
16 August 1997	Angra dos Reis	Sighting	[27]
28 August 1998	Macaé	Stranded carcass	[27]
2 January 2001	Quissamã	Incidental capture by gillnet	[27]
2 February 2001	Carapebus	Incidental capture by gillnet	Present study
April 2005	Arraial do Cabo	Sighting	[27]
17 December 2011	Rio de Janeiro	Sighting	Present study
19 July 2012	Quissamã	Incidental capture by gillnet	Present study



Fig. 3. Whale shark (*Rhincodon typus*) touched by fisherman with a wooden stick at the Royal Charlotte Oceanic Bank, Bahia State, Brazil, on October 2011. Image credits: Milton dos Anjos.

by local fishermen are not isolated. These participants strongly believe that these types of interactions do not have the potential to harm the animals. Furthermore, most respondents ($n=56$; 75.7%) reported that they had seen whale sharks in the region.

The range in total length of the animals sighted varied from two to fourteen meters. Only one fisherman reported an incidental catch of one individual of this species over 30 years ago. All participants reported that, regionally, these sharks are not captured often, mainly due to their size and because the meat is poor in quality.

4. Discussion

Some studies have recorded the participation of Brazilian small-scale fishermen in selling shark fins [29–31]. Once in the international shark fin market, this by-product is exported to some countries in Asia, used as display in shark fin soup restaurants and can reach very high values [32]. However, there are no records that whale shark fins are being marketed in Brazil.

An incidental catch of *R. typus* in a gillnet and the commercialization of the specimen was recorded by Faria et al. [33], which took place on January 2009, in Fortaleza, Ceará. In this case, the captain of the vessel was prosecuted by Brazilian environmental authorities (IBAMA), although he claimed ignorance of Instruction No. 5 [34], which prohibited the capture and transport of the species when the incident happened. Given this fact, it appears that environmental awareness interventions targeted at fishermen could clarify the conservation status of *R. typus* in Brazil.

It should be mentioned that the fishing ground near Barra do Furado is located adjacent to Restinga de Jurubatiba National Park. Our records are the first detailed information on incidental captures of *R. typus* with gillnets off the Rio de Janeiro coast, in the South Atlantic Ocean. Fishing activities in northern Rio de Janeiro are fairly well documented (e.g. [35]). Di Benedetto et al. [36] described the incidental capture of small cetaceans from the area, particularly Guiana (*Sotalia guianensis*) and Franciscanas (*Pontoporia blainvillei*) dolphins by gillnet fisheries. However, specific information about the small fishing fleet of Barra do Furado is limited.

It is crucial to implement actions in order to reduce incidental capture of whale sharks by artisanal fisheries in Brazil, mainly because most reports are of dead specimens captured incidentally by small-scale fishery nets [20]. A whale shark release, as reported in the present study, was described by Gomes et al. [27], which took place in Arraial do Cabo, Rio de Janeiro, and was an animal that had been caught in a gillnet. Shahid et al. [37] reported the successful release of twelve whale sharks from fishing nets in the Arabian Sea between January 2013 and June 2015. This success was attributed to the previous training the fishermen had in anticipation of incidental captures. In fact, Hsu et al. [12] argue that management regulation would be more effective if there were educational programs for fisherman and the general public about *R. typus* and the importance of its conservation. Recently, the United States implemented a compliance guide, called “Fishing Restrictions related to the Oceanic Whitetip Shark, the Silky Shark and the Whale Shark”, to restrict incidental captures of these species on the Central and West coasts of the Pacific Ocean [38]. According to this document, all vessels operating in the country are forced to delay the deployment of seine fishing nets when whale sharks are seen within the fishing area and to take all necessary actions to release any entangled individuals alive.

The movement patterns of whale sharks along the coast of Rio de Janeiro State seem to be associated to local currents, which provide highly productivity waters [5,39,40]. However, a considerable number of sightings of *R. typus* were recently reported around the mid-oceanic area of St. Paul's Rocks (0°55'N, 29°20'W), which is not highly productive [18,41]. These studies reported the use of the waters around St. Paul's Rocks as a resting point on their unknown migratory route in the Atlantic. In our review, the majority of *R. typus* records are from the northern part of Rio de Janeiro State ($n=11$), a region under the influence of an upwelling system. During the spring and summer seasons, greater densities of zooplankton are recorded in the region, as well as large densities of phytoplankton [42,43], but the waters could be considered highly productive throughout the year. According to Table 1, the records of *R. typus* along coastal Rio de Janeiro do not show defined patterns in response to upwelling periods. Several studies conducted in different areas around the world highlight the relationship between whale shark occurrence patterns and highly productive waters (e.g., [13,44–46]).

Although the RCOB is a region that historically stands out as a productive commercial and recreational fishing zone, there is a considerable gap in scientific studies about this region. This is the first record of a whale shark in the area. On the video, the animal was apparently in ram-feeding position [2], a strategy adopted for

low prey densities [47]. Indonesian fishermen have similarly reported the presence of whale sharks ram-feeding near their vessels and chasing schools of small fish [48]. According to Stewart [49], some individuals end up injured due to contact with fishing boats during such displays. Whale sharks have also been observed being hand-fed by fishermen [2] and being attracted to the concentration of small fish in local fishermen nets in the Papua Province of Indonesia [49]. In Brazil, Andrades et al. [19] suggested a potential attraction of whale shark to oil platforms, where zooplankton aggregations often occur.

Despite the fact that the fishermen were not conscious about the imminent risk of injuries during the interaction episodes, published reports show that whale sharks often dive away, change direction and demonstrate banking behavior when an interaction occurs during feeding activities [9]. Their reaction varies widely, with some animals showing no signs of stress or aggression [1], while others show defensive behaviors [6]. In addition, Norman [50] suggests that in Ningaloo Marine Park, Australia, a region where there is an ecotourism industry based on swimming close to whale sharks, the average interaction time declined along three consecutive years (19.3 min in 1995, 14.2 min in 1996 and 9.5 min in 1997), which is probably because these fish have become less tolerant of human contact.

In fact, the fishermen reported that all sightings were of solitary animals. This makes the ecological knowledge shared by these fishermen especially relevant, given there are still notable gaps in the scientific knowledge about whale shark ecology when not in feeding aggregations [2].

The reasons the fishermen had for not catching whale sharks (mainly size and poor meat quality), demonstrate they were not aware of the federal law prohibiting the capture of *R. typus* in Brazil.

5. Conclusion

The occurrence of whale sharks off the coast of Rio de Janeiro State is well known, and our review of these incidents suggests the species uses highly productive waters along the northern coast of Rio de Janeiro as a feeding ground. Both events of incidental capture of *R. typus* obtained from our non-systematic data collection suggest that this kind of negative interaction may be underestimated. The distribution and migration routes of *R. typus* off the southeastern Brazilian coast should be better studied by systematic surveys and interviews with fishermen, especially to build a hotspot map of the interactions with fisheries.

Based on the mutual curiosity between fishermen and *R. typus*, as supported by this study and various cases reported in the media, it is reasonable to presume that harassment of this species occurs in different regions of the world. Thus, because science has not accurately predicted the potential implications of these interactions on the species, it is necessary to adopt outreach and awareness programs for fishermen in order to educate them about what to do when sighting whale sharks.

Information of this nature is fundamental to support governmental plans to regulate fishing activities in order to reduce incidental capture and any potential harm derived from harassing whale sharks. Promoting the participation of fishermen in a collaborative monitoring program, may be a good way to better understand the risks involved (on the behavior and ecology of the species) at a reduced cost, particularly for developing countries, such as Brazil.

Conflicting interests

The authors declare there are no conflicting interests.

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