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REPORT OF INJURIES IN BATOIDS CAUGHT IN SMALL-SCALE FISHERIES: IMPLICATIONS FOR MANAGEMENT PLANS

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Abstract: Despite of the ecological importance of several batoids caught as bycatch, little attention is given to the individual resilience in risk assessments. The report of physical condition is imperative for a realistic understanding of the impacts caused by fishing, as a way to reduce the negative consequences of bycatch and improvement of management protocols. In this context, the present study provides an analysis of injuries observed in nine species of batoids caught by small scale fisheries by adopting a non-lethal approach. Levels of injury were determined according to severity and the relation between fishing time and injury/mortality was assessed. Results showed that injury levels and release condition were strongly influenced by fishing effort and time until release, with fishing effort lower than 110 min related with minor injuries, lower capture mortality rates (10.6%) and better release conditions. Since the frequency of batoids in small scale fisheries as accompanying fauna is high, the cooperation between researchers, fishermen and authorities is essential to reduce the negative consequences of bycatch. Based in the data presented here, we recommend that management plans establish fishing effort times and immediate release in areas of ecological importance for endangered species, thus helping to promote batoids conservation.

Keywords: bycatch; conservation; elasmobranch; impacts of fishing; lesions.

INTRODUCTION

Batoids, as well as sharks, exhibit biological traits (*e.g.*, late maturity, long life spans and long gestation periods) that make them extremely vulnerable to fishing practices (McEachran & Carvalho 2002, Molina & Cooke 2012). Recently, the impacts of bycatch are getting more and more attention (McEachran & Carvalho 2002, Thorpe & Frierson 2009), being considered a major threat to batoids and sharks, with more than 70% of the species being directly affected (Molina & Cooke 2012). Currently, the recommendations to reduce the impacts of fishing over endangered species are the establishment of areas where fishing is prohibited, fishing gear adaptations and use of repellents (Molina & Cooke 2012, Hart & Collin 2015). Additionally, fishing regulation requires that species caught as bycatch to be released regardless the animal's state (alive, injured or dead; Molina & Cooke 2012).

Despite elasmobranchs being extremely sensitive to capture, several species are brought on board alive (Moyes *et al.* 2006, Marshall *et al.* 2012). However, the effects of air exposure and stress of capture/handling may compromise the post-release recovery, thus reducing the efficiency of release protocols (Cedrola *et al.* 2005). That way, for a better understanding of the negative impacts of bycatch, the biological aspects of each species needs to be considered as a way to define the best strategy for conservation. Even with the ecological importance of many species caught as bycatch being well defined (Pina & Chaves 2009), few studies reporting survival rates, endurance and recovery are considered in risk assessments (Gallagher *et al.* 2014a, 2014b). So, understanding the physical consequences of capture is imperative to determine the aspects of commercial fishing that can be improved to reduce the lethal and sublethal effects of capture for species with no commercial interest (Serafy *et al.* 2012). Based on this premise, the present study brings a detailed description of external physical injuries in batoids caused by gillnet capture in small-scale fisheries, contributing that way for the improvement of management practices and conservation plans.

MATERIAL AND METHODS

Perequê Beach is inserted at Guaibe Sector, a Marine Protected Area located in the São Paulo coast, Southeastern Brazil (23°56'20.6"S, 46°10'27.6"W, *datum* WGS84; Figure 1), hosting a community of artisanal fishermen of great representativeness,

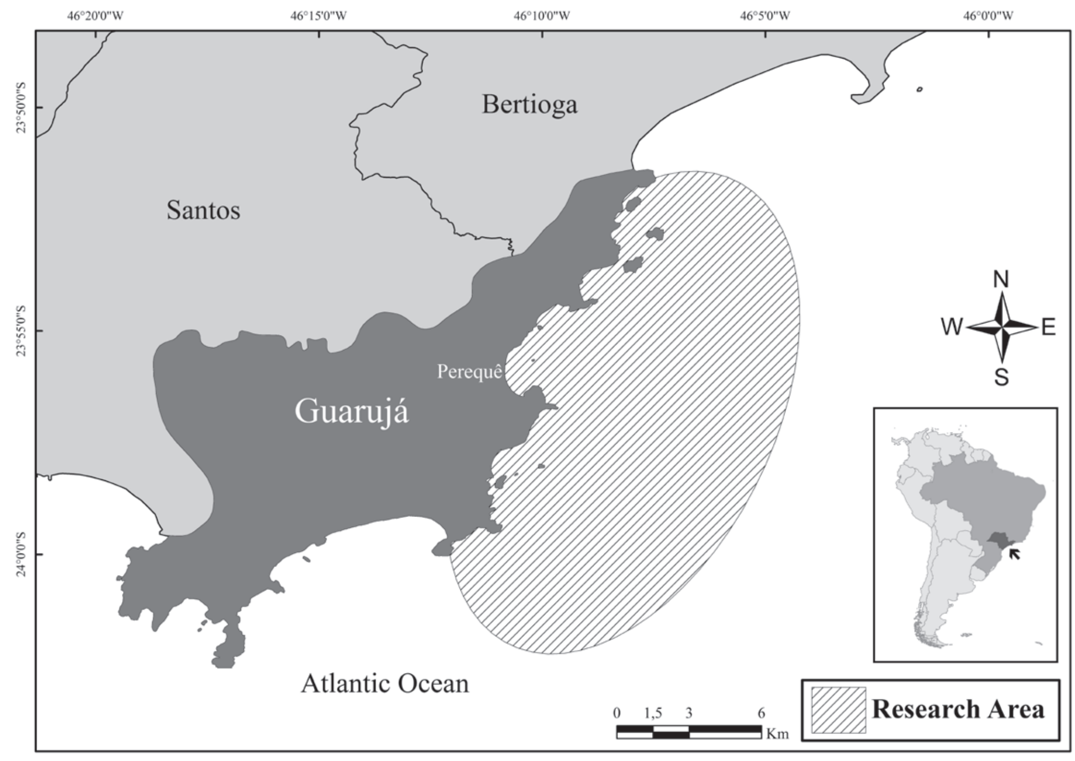

Figure 1. Area of trawlers and batoids capture. Perequê Beach is a Marine Protected Area located in the Central coast of São Paulo, Brazil.

with a fishing fleet of approximately 300 small vessels. Twelve field trips were conducted in order to track 37 shrimp trawl hauls, between December 2014 and November 2015. Commercial fishing was monitored onboard of a 11 m long vessel (60 HP) equipped with two-nets otter trawls (two meters high, nine meters wide, mesh 20 mm distance between opposite knots in the sleeves and body and 16 mm distance between opposite knots in the bagger), under governmental permit (SISBIO 48271-1). Short distance trawlers were performed in the shallow continental shelf (isobaths between 10-20 m, between points 23°51’46.7”S, 46°05’57.2”W and 24°01’13.8”S, 46°12’08.1”W, *datum* WGS84). The activities started at dawn, returning in the same day. The fishing effort was divided into drags (~ 110 min).

Animals caught as bycatch were identified following Figueiredo (1977), McEachran & Carvalho (2002), Vooren & Klippel (2005) and Gomes *et al.* (2010). The sex of individuals was verified, and they were measured (in centimeters) - total length (TL) and disc width (DW) and weighted (in grams) - total weight (TW). After injuries evaluation, the animals were tagged with external plastic tags - TBA type (T-bar anchor). Batoids with less than 25 cm in TL were not tagged but were recorded. After the procedure, the animals were released. The batoids were separated into neonates, juveniles and adults, criteria adopted based on Rudloe (1989), Capapé *et al.* (1992), Vooren & Klippel (2005), and Gomes *et al.* (2010) (Table 1).

External injuries were registered and classified as: (1) absent or small, < 10 mm injuries and/or contusions representing level 1 injuries; (2) moderate, 11-20 mm injuries and/or contusions representing level 2 injuries; and (3) extensive, > 20 mm injuries and/or contusions representing level 3 injuries (Figure 2). The classification was adapted from Mandelman *et al.* (2013) and Rudders *et al.* (2015). To standardize the classification, all the observations were made by the same researcher. The mean time of fishing effort (~ 110 min) was calculated by summing the total time of all trawls (~ 4050 min) and dividing by the total number of trawls (N = 37). With the mean obtained, two categories were created: (1) fishing effort higher than the mean and (2) fishing effort lower than the mean. The injury occurrence (%) of each category was compared in both fishing effort times, to evaluate the influence of time in the injuries level.

RESULTS

Ninety-four batoides from nine species were analyzed: *Pseudobatos horkelii* (Müller & Henle, 1841), *P. percellens* (Walbaum, 1792) (Rhinopristiformes, Rhinobatidae) and *Zapteryx brevirostris* (Müller & Henle, 1841) (Rhinopristiformes, Trygonorrhinidae); *Hypanus guttatus* (Bloch & Schneider, 1801) and *Dasyatis hypostigma* Santos & Carvalho,

Table 1. Measures criteria (in centimeters) used by species of batoids for age classification. Total Length (TL) and Disc Width (DW).

Species / Measures criteria	Neonates (cm)	Juveniles (cm)		Adults (cm)		References
		Male	Female	Male	Female	
Hypanus guttatus **(DW)**	15 - 20	21 - 39	21 - 74	40	75	Gomes *et al.* (2010)
Dasyatis hypostigma **(DW)**	10 - 12	13 - 29		30		Gomes *et al.* (2010)
Gymnura altavela **(DW)**	25 - 30	31 - 77	31 - 67	78	68	Capapé *et al.* (1992), Gomes *et al.* (2010)
Rhinoptera bonasus **(DW)**	30 - 40	41 - 69	41 - 64	70	65	Gomes *et al.* (2010)
Rioraja agassizii **(DW)**	-	< 32	< 40	32	40	Oddone *et al.* (2007), Gomes *et al.* (2010)
Narcine brasiliensis **(DW)**	9 - 12	13 - 24	13 - 28	25	29	Rudloe (1989), Gomes *et al.* (2010)
Pseudobatos horkelii **(TL)**	20 - 29	30 - 74	30 - 89	75	90	Vooren & Klippel (2005), Gomes *et al.* (2010)
Pseudobatos percellens **(TL)**	14 - 17	18 - 44	18 - 45	45	46	Gomes *et al.* (2010)
Zapteryx brevirostris **(TL)**	13 - 16	17 - 42	17 - 41	43	42	Gomes *et al.* (2010)

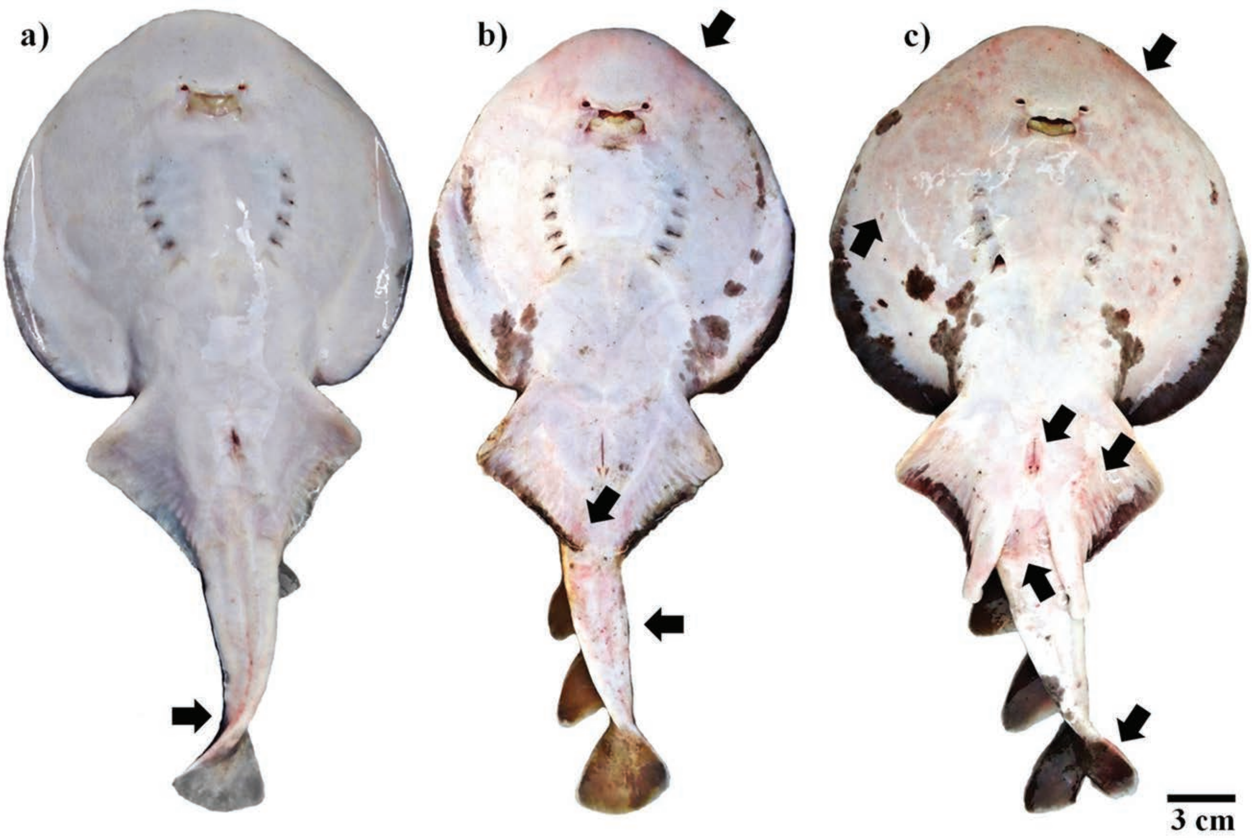

Figure 2. Levels of injuries observed in *Narcine brasiliensis* (Rajiformes, Narcinidae). (a) Level 1 – lesion absent or small; (b) level 2 – lesion moderate; (c) level 3 – lesion extensive.

2004 (Myliobatiformes, Dasyatidae); *Narcine brasiliensis* (Olfers, 1831) (Rajiformes, Narcinidae); *Gymnura altavela* (Linnaeus, 1758) (Rajiformes, Gymnuridae); *Rhinoptera bonasus* (Mitchill, 1815) (Rajiformes, Rhinopteridae) and *Rioraja agassizii* (Müller & Henle, 1841) (Rajiformes, Arhynchobatidae) (Figure 3).

Several external lesions were observed, caused mostly by compression, friction and collisions with the fishing net. Among them, the most common were bruises (observed in all levels) being classified by size and body location (Figures 4a, b, c). Lacerations and perforations of the disc were among the most critical injuries (classified as level 3) being common in *H. guttatus* (Figure 4d), *P. percellens* (Figure 4e) e *N. brasiliensis* (Figure 4f). Compression marks and scratches were observed in *Z. brevirostris* (Figure 4g). One case of eye injury was recorded for R. bonasus, suggesting friction with the fishing net probably while attempting to escape (Figure 4h), hypothesis reinforced by the lesions observed in the rostrum of *P. horkelii* (Figure 4a). In addition, fractures were observed in the tail of *Z. brevirostris* (Figure 4f).

From 94 animals analyzed, 59.5% (N = 56) exhibited none or minor injuries (level 1), 24.5% (N = 23) exhibited moderate injuries (level 2) and 16% (N = 15) exhibited severe injuries (level 3) (Figure 5a). The *R. agassizii* species (N = 1) only exhibited level 1 injuries (Figure 5b). In *P. horkelii* (N = 43), *Z. brevirostris* (N = 12) and *P. percellens* (N = 5), most of injuries were level 1, while in *G. altavela* (N = 2) and *N. brasiliensis* (N = 26), injuries level 1 and 2 were observed with the same frequency (Figure 5b). Finally, *H. guttatus* (N = 2), *D. hypostigma* (N = 2) and *R. bonasus* (N = 1) only exhibited level 3 injuries (Figure 5b).

The mean time for fishing effort was approximately 110 min. In the category 1 (lower fishing effort, < 110 min; N = 51), 66.5% of the animals exhibited level 1 injuries (N = 34), 21.5% level 2 (N = 11) and 12% level 3 (N = 6). In the category 2 (higher fishing effort, > 110') (N = 43) an increase in injuries of level 2 (28%) and level 3 (21%) was observed (Figure 6).

Among the 94 batoids analyzed, 32% of the

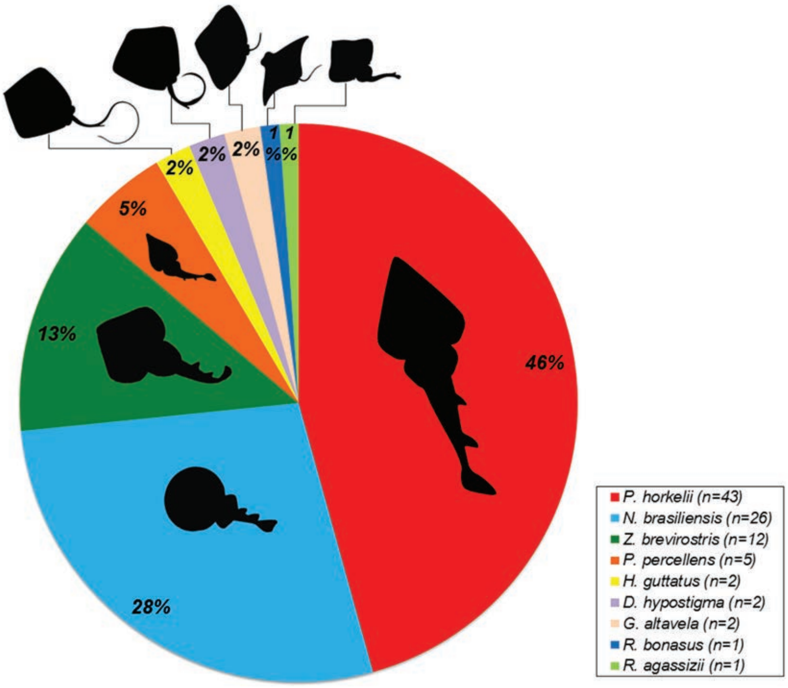

Figure 3. Record of species and abundance of batoids in the bycatch of shrimp fishery at Perequê beach, between December 2014 and November 2015.

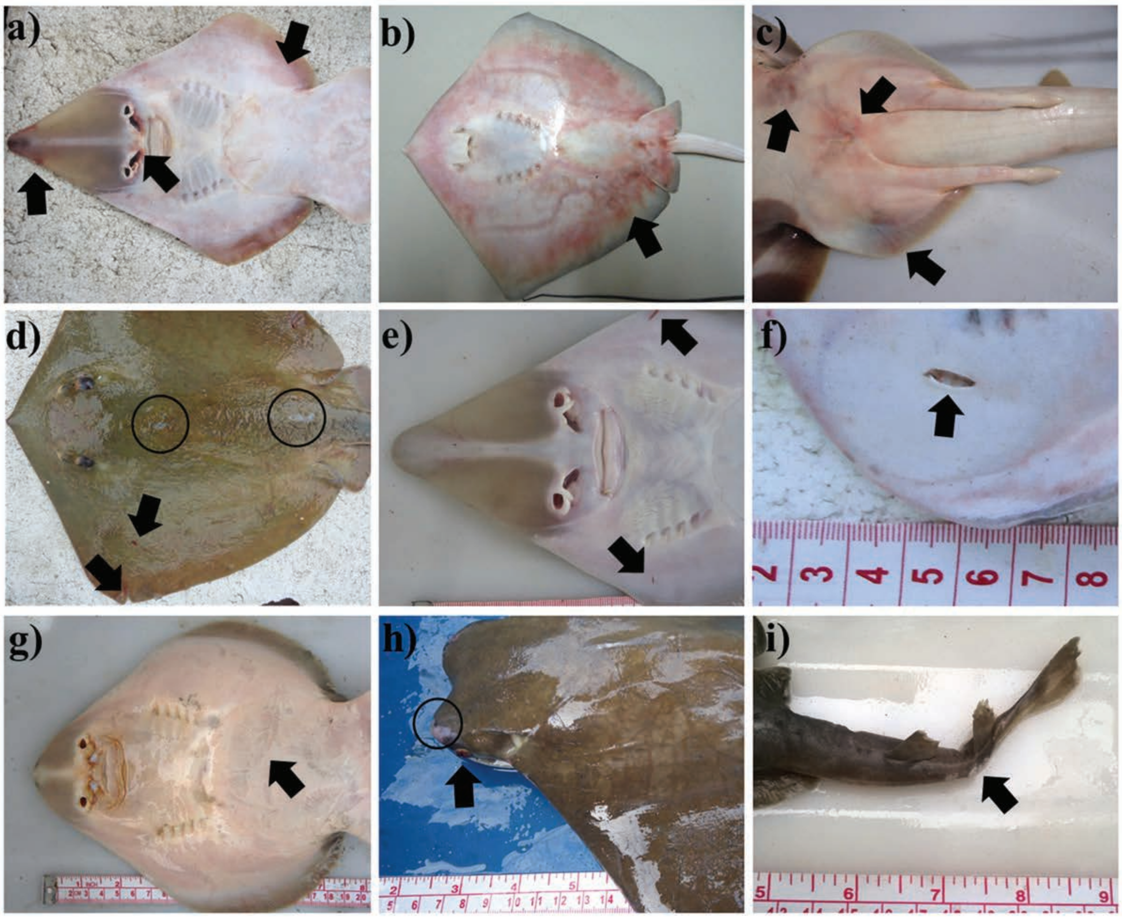

Figure 4. Types of injuries (a) bruises in the rostrum, nasal region and ventral region *Pseudobatos horkelii*; (b) bruises in the ventral region in *Hypanus guttatus*; (c) The arrows indicate the bruises in the pelvic fin of a *Zapteryx brevirostris*; (d) lacerations an perforations (arrows), loss of mucus (circle) in Hypanus guttatus; (e) perforations in *Pseudobatos percellens*; (f) Perforations in *Narcine brasiliensis*; (g) Compression marks in *Zapteryx brevirostris* (arrow); (h) Injury (contusion) in the eyes of *Rhinoptera bonasus* (arrow), loss of mucus (circle); (i) Fractures in the tail in *Z. brevirostris* (arrow)

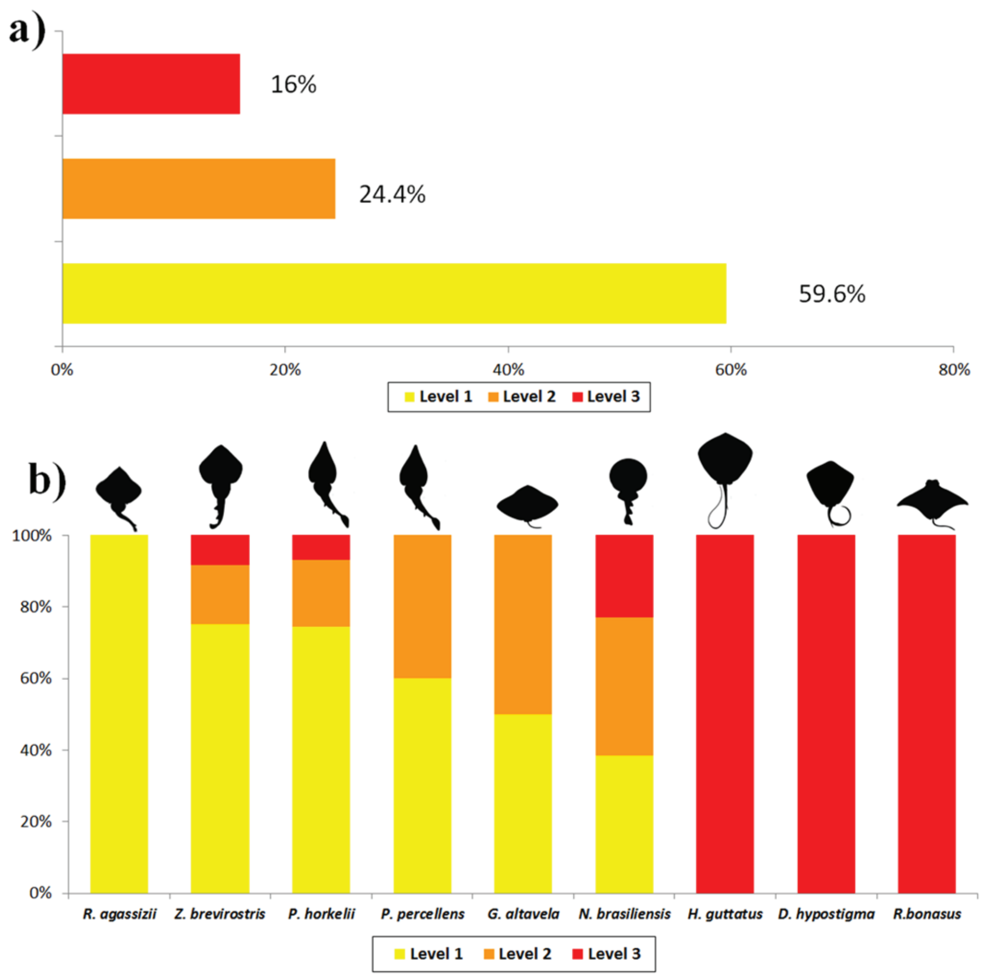

Figure 5. (a) Quantitative analysis of injuries observed; (b) Qualitative analysis of injuries observed during bycatch of batoids in small-scale fisheries of shrimp fishery at Perequê beach, between December 2014 and November 2015.

injuries occurred in neonates (N = 30), 44% in juveniles (N = 41) and 24% in adults (N = 23). At all life stages, level 1 injuries were more common, followed by level 2 and 3, respectively (Figure 7a).

Neonates from five species were caught. Only one neonate of *Z. brevirostris* and *P. percellens* were caught, both exhibiting level 1 injuries (Figure 7b). In *P. horkelii* (N = 22), most of injuries were level 1 (Figure 7b). In *N. brasiliensis* (N = 5), the most common injuries were level 1 and level 3 (Figure 7b). Only one neonate of *R. bonasus* was caught, exhibiting level 3 injuries (Figure. 7b).

Juveniles from seven species were caught. *Pseudobatos horkelii* (N = 21) and *N. brasiliensis* (N = 14) exhibited all injuries level, however with higher occurrence of levels 1 and 3 (Figure 7c). In *G. altavela* (N = 2) one animal exhibited level 1 and one exhibited level 2 injuries (Figure 7c). In *R. agassizii*, one animal was caught exhibiting level 1 injuries. One individual of *P. percellens* was registered with a lesion of level 2. Finally, one individual of *H. guttatus* and *Z. brevirostris* were caught, both exhibiting level 3 injuries (Figure 7c).

Adults from five species were caught. Most adult specimens of *Z. brevirostris* (N = 10) and *P. percellens* (N = 3) exhibited level 1 injuries (Figure 7d). The three levels of lesions were observed in *N. brasiliensis* (N = 7), of which 57% were level 2 lesions (Figure 7d). Two *D. hypostigma* and one *H. guttatus* were caught, all presenting level 3 injuries (Figure 7d).

During this survey, the mortality rate was 10.6% (N = 10). 60% of the animals that died exhibited level 3 injuries and 20% exhibited level 2. Between animals that died during the capture, 30% were *P. horkelli*, 30% *N. brasiliensis*, 20% *P. percellens* and

10% were *Z. brevirostris* and *H. guttatus*. Neonates showed the highest mortality rates (60%), followed by juveniles (40%). There was no mortality among adults.

DISCUSSION

In all animals analyzed in the present study some level of injury was observed. Capture mortality was more pronounced in neonates and juveniles, as was the severity of the external lesions observed. Additionally, the level of injuries had a strict relation with fishing effort time, indicating that this is a factor that needs to be considered in management plans. Among the nine-species caught as bycatch in the region, one is classified as Critically Endangered (*P. horkelii*), three as Vulnerable (*G. altavela, R. agassizi* and *Z. brevirostris*), two as Near Threatened (*P. percellens* and *R. bonasus*) and three as Data Deficient (*H. guttatus*, *D. hypostigma* and *N. brasiliensis*) (IUCN 2015). That said, constant monitoring and education programs with the fishermen brings not only valuable information for risk assessments, but may encourage compensatory release of endangered species, thereby reducing the impacts of bycatch in areas of ecological relevance where fishing is still permitted.

Reports on survival and post-release recovery are scarce (Barker & Schluessel 2005, Molina & Cooke 2012, Gallagher *et al.* 2014a), as are detailed description of external injuries caused by capture. Normally, the capture process leads the animal to an attempt to escape, causing exhaustion, muscle fatigue, hypoventilation and external/internal physical trauma, thus generating physiologic alterations that may reduce the resilience and survival in short (Skomal & Mandelman 2012) and/or long term (*e.g.*, development and reproduction) (Gallagher *et al.* 2014b).

Contusions (bruises), the most common injuries observed in the present study, are the quickest way to evaluate the negative effects of capture in elasmobranchs. Based on our findings, it seems that such injury is directly related to fighting behavior during capture and may represent superficial, deeper lesions or even internal bleeding. That way, even being classified as level 1 injury, such trauma needs to be carefully evaluated since it may be a valuable indicator of the impacts of the fishing apparatus on the species commonly caught. So, the evaluation of extension, color and location of the bruises, allied to the use of injury classification guides may be a promising approach to access fishing impacts in animals incidentally caught and released alive.

Guitarfishes are easily recognized by the differentiated body shape, with a pronounced snout. It is believed that the snout is used for foraging, boost in swimming and hydrodynamics (Wueringer *et al.* 2012). Both *Pseudobatos* species analyzed in the present study exhibited contusions in this region, suggesting the use of the structure in an attempt to escape. Due to its thinness, the

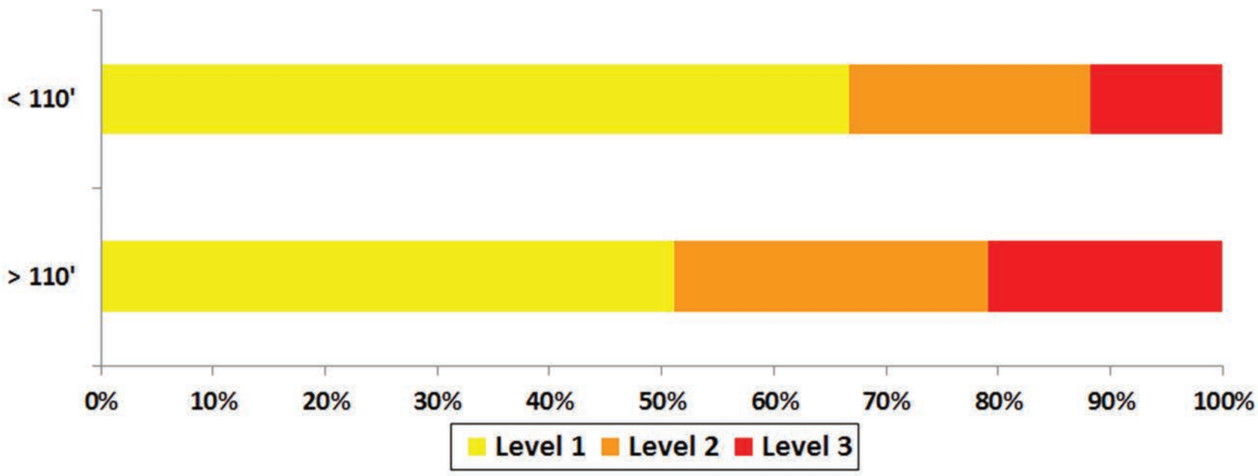

Figure 6. Influence of mean trawling time (fishing effort), observed during batch bycatch on shrimp fishing, below or above 110 minutes at the three injury levels (Level 1 - lesion absent or small; Level 2 - lesion moderate; Level 3 - extensive lesion)

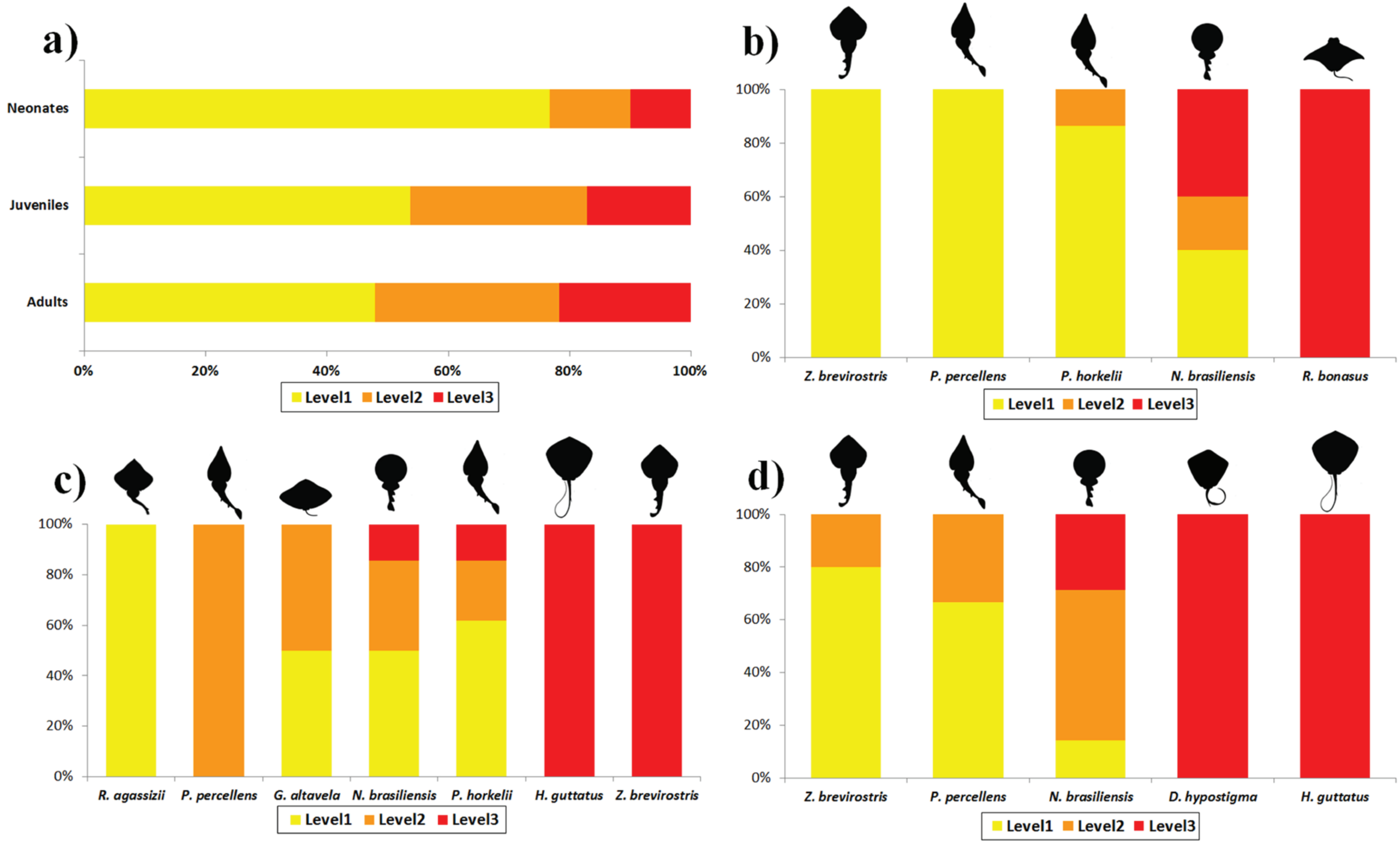

Figure 7. (a) Level of registered injuries related to stage of life of batoids (Level 1 - lesion absent or small; level 2 - lesion moderate; level 3 - extensive lesion); (b) Injury levels in neonates by species; (c) injury levels in juveniles by species; (d) Injury levels in adults by species.

snout constantly passes over the fishing net spaces, reducing the ability to move of the animal. Such restriction may be one the possible causes of high mortality observed in guitarfishes. That way, to reduce the catch and mortality of this highly endangered group, management protocols should consider such interaction between body shape and fishing apparatus, thereby reducing the negative impacts of bycatch at places of occurrence of these species.

In an opposite way, in batoids lacking the elongated snout (*i.e.*, stingrays), the contusions were observed in other body parts such as the ventral region and pelvic/caudal fins. Additionally, lacerations and disc perforations, probably caused by contact with other organisms were observed. Thorns of catfish (Siluriformes, Ariidae), thorns and chelipeds of crabs (Decapoda, Portunidae) and shrimp's snouts (Decapoda, Penaeidae) were found inserted in the disc of several stingrays sampled. It is likely that the perforations observed are related to the reduced thickness of the pectoral fins of stingrays when compared to guitarfishes. . It is important to mention that the damages caused by the by incidental capture in *N. brasiliensis* deserve special attention, due to being an endemic species, therefore, more susceptible to population declines. These batoids have characteristic organs of electric discharge, capacity particularly worrisome, since the fishery management based on the compensatory release can be compromised, due to the fear of possible incidents (electrical shocks) during the handling, fact that can reduce the cooperation of fishermen. Additionally, external damages can reduce the effectiveness of electrical discharges, since the electric organs are located in the pectoral fins. In fact, studies performed with injured *N. brasiliensis* held in captivity confirmed the reduced ability to proper respond to external stimulus, thus impairing the individual defense and predatory capacity (N. Wosnick *et al.* unpublished data).

Sharks and batoids are equipped with efficient sensory systems, molded over and 400 million years of evolution (Collin 2012, Hart & Collin 2015). The vision in elasmobranchs is of utmost importance in interactions with the environment, especially in prey location. Pelagic batoids have a higher reliance on vision than benthic species (*i.e.*, guitarfishes) which depend more on electroreception (Wueringer *et al.* 2012, Bedore *et al.* 2014). In the present study, one *R. bonasus* (pelagic species) exhibited serious eye damage caused by friction with the fishing net. Despite having been released alive, it is possible that this animal will face the negative effects of the injury as total or partial loss of vision, affecting your ability of escape and hunting. Such damage was rare and not seen in the guitarfishes caught. That is probably due to the fact that guitarfishes have the ability to retract the eyes into the orbital cavity. This ability has the same function as the nictitating membrane or ability to roll eyes on some species of sharks, which provides protection during predation (Gruber & Schneiderman 1975, Tricas & McCosker 1984, Ritter & Levine 2004). For batoids, such capacity may present an advantage facing the incidental capture, since it allows a higher degree of eye protection.

Finally, one *G. altavela* was recorded with the thorn ripped, presenting bleeding at the injury location. The seasonal replacement of thorns is reported for some species of batoids. However, it is not possible to infer that the loss induces a rapid substitution (Lowe *et al.* 2007). That said, even if the animal survives after release, the loss of the thorn might bring negative consequences, thus affecting long-term survival by reducing the defense ability.

In addition to the external injuries, batoids caught as bycatch are often air exposed for long periods. The effect of such exposure even for short time can lead to physiological disruptions, such as extracellular acidosis, homeostatic loss, reduced cardiac output, hypoxia, and gill collapse (Ferguson & Tufts 1992, Gingerich *et al.* 2007) thus reducing the survival and recovery. Despite the presence of external physical traumas in the batoids sampled in the present study, mortality caused by capture was low (10.6%). However, post-release survival was not determined. Both species of *Pseudobatos* sampled in the present study exhibited high mortality rates, corroborating data from personal monitoring, where the mortality of capture reached 100%. Even with similar life habits, body shape and evolutionary history, *Pseudobatos* species are extremely vulnerable when compared to *Z. brevirostris* (same family), with reports of survival up to six hours out of water and post-capture recovery of 100% during winter (N. Wosnick *et al.* unpublished data).

The survivability facing capture is also strongly affected by the animal's life stage. This study demonstrates that the mortality was higher in neonates (60%) followed by juveniles (40%). The high mortality in adults (females) is commonly observed during pregnancy (N. Wosnick *et al.* unpublished data). Both cases may be explained by the high metabolic demands required during growth (neonates and juveniles) and pregnancy (French *et al.* 2007). Responsiveness facing the stress of capture becomes reduced in periods such as those mentioned above since much of the metabolic gain is directed to growth and maintenance of pregnancy (viviparity) (Adams *et al.* 2018). It is also possible that the high mortality is related to the reduced size of neonates and juveniles, since the weight of the net, trawl movement and collision with substrate seemed to be more harmful in smaller animals.

It is worth considering some important study limitations that could be accounted for in future studies. First and probably most important, since the survey was carried out onboard of commercial vessels in partnership with fishermen, it was not possible to monitoring the animals for post-capture mortality. Thus, future studies linking field observations, non-lethal methodologies and post-capture monitoring are imperative for the assessment of species-specific mortality rates and recovery ability. Second, despite the sample size being considered high for non-lethal surveys, we are aware that for some species the number of individuals analyzed is low. This can be problematic in statistical terms, however, since the present study aimed to only describe the injuries observed, the individual analyzes become important, since each animal will respond in a way to the stress of capture. Finally, the lack of financial resources prevented us from analyzing post-release survival, not allowing a more in-depth discussion of the possible consequences of the lesions described. Thus, raising funds for future acoustic tagging studies will allow a better understanding of the process as a whole.

Despite still poorly adopted in Brazil, the use of non-lethal evaluation on field in partnership with fishermen may be an effective measurement to reduce the impacts of scientific sampling. Additionally, the understanding of the impacts caused by small-scale fisheries in elasmobranchs is necessary and urgent, since this fishing sector is responsible for the capture of animals in important life-stages (pregnancy and growth). Moreover, the assessment of external injuries, is an approach that despite being rarely used, bring new insights in a fishing context that will help the improvement of management plans, especially for endangered species or species with low or no commercial value, thus guaranteeing the commitment of fishermen to release practices as a way to reduce the impacts of bycatch.

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