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# DO PHYSICAL INJURIES AFFECT ELECTROPERCEPTION? A CASE STUDY ON THE BRAZILIAN ELECTRIC RAY, NARCINE BRASILIENSIS (OLFERS, 1831)

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## ABSTRACT

The present study aimed to analyze the possible consequences of body deformities caused by fishing in the electroreceptive system of *Narcine brasiliensis*. Results demonstrated that the ability to detect low electrical stimuli was affected, as well as the ability to respond properly to higher signals. We discuss the results as they relate to ecological consequences, especially for benthic species that heavily depend on the electrosensitive system for efficient foraging and predator avoidance/defense.
Keywords: batoids; Torpediniformes; endemic ray; sensory behavior; compensatory release.

## RESUMO

O presente estudo teve como objetivo analisar as possíveis consequências das deformidades corporais causadas pela pesca no sistema eletro-perceptivo da raia treme-treme, *Narcine brasiliensis*. Os resultados demonstraram que a capacidade de detectar baixos estímulos elétricos foi afetada, bem como a capacidade de responder adequadamente aos sinais mais elevados. Discutimos os resultados com foco nas consequências ecológicas das injurias externas, especialmente para espécies bentônicas que dependem fortemente do sistema eletro-perceptivo para o forrageio eficiente e defesa contra predadores.
Palavras-chave: batoides; Torpediniformes; raia endêmica; comportamento sensorial; soltura compensatória.

## INTRODUCTION

External injuries caused by fishing are common in batoids, and its negative influence on physiological traits depends on their extent and severity (Poisson *et al*., 2014; Wilson *et al*., 2014). Among the most commonly observed injuries in incidentally captured rays, contusions in the ventral portion of the body are the ones with the highest occurrence (Rodrigues *et al*., 2018). However, profound cuts, fractures, and partial or total loss of body parts are also observed. Despite the growing interest in quantifying the stress caused by commercial capture, little is known about its long-term effects and the recoverability of externally injured specimens. Such a knowledge gap becomes particularly challenging for bycatch species with low commercial value which are released alive through management protocols, whether by ethical choice of fishermen or local/national legislation (FAO 2014).

The Brazilian electric ray *Narcine brasiliensis* (Olfers 1831) is an endemic species of the Western Atlantic, being commonly captured as bycatch by artisanal fisheries (Nunes *et al*., 2005; Bornatowski *et al*., 2009). Narcine spp. exhibit an oval-shaped disc, two dorsal fins of similar size, a well-developed caudal fin, and a characteristic lateral caudal curvature (Gomes *et al*., 2010). It is a small-sized ray, reaching up to 49 cm in total length with sexual maturity occurring with about 25 cm (TL) in males and 30 cm (TL) in females (Gomes *et al.,* 2010). According to fishermen, this species has no commercial value and its release is considered a great challenge and often an annoyance, since electric discharges performed by the animals during handling are very common (personal communication). Although release is frequently performed, the physical state in which live animals are returned is unknown, as well as the effects of injuries caused by the fishing apparatus on recovery, survival, and subsequent behavior.

Elasmobranchs exhibit an elaborate ampullary electroreceptor system sensitive to low-frequency stimuli (Hueter *et al.,* 2004). This sensory is composed of a series of sensory units called Ampullae of Lorenzini, which are connected to the environment through external pores and subdermal canals and to the central nervous system through fibers and nerves (Helfman *et al.,* 2006). The ampullae are multifunctional and mostly located in the ventral portion of the animal's body (Hueter *et al.,* 2004). Due to its location, electroperception is particularly important for prey detection in benthic species, such as the Brazilian electric ray (Last *et al*., 2016).

There is an absence of studies determining the non-lethal but still potentially harmful effects that external injuries caused by commercial capture might pose to elasmobranchs. Our study is based on the possible influences that external injuries on the ventral body portion, even if healed, may have on the electrosensory system in *N. brasiliensis*, a benthic species that heavily relies on ampullae proper functioning not only for foraging but also for predator defense.

## MATERIAL AND METHODS

The study was conducted in partnership with Paranaguá Aquarium, where the animals are held in a 250 L tank with salinity kept at 32 PSU and temperature at 20°C. Water quality is maintained througth the use of biological and mechanical filters, partial water exchange every 30 days and constant monitoring of pH and ammonia levels. Both adult males monitored in the present study were incidentally caught by artisanal fishermen on 2014 and donated to the aquarium, where they are kept on display since then. While one male was donated in perfect conditions (hereafter referred as healthy specimen), the other individual exhibited several lacerations caused by the fishing apparatus (hereafter referred as impaired specimen). Both animals were healthy at the time of the experiments, however, the impaired ray still presented significant modifications of disc shape and several scars along the body (Figure 1a).

The artificial electric impulse was generated through a metallic dipole system buried in the substrate of the enclosure. The apparatus was connected to a multimeter for quantification of the stimulus generated at each stage of the experiment. To evaluate the influence of amperage (µA) on animal response, network frequency was kept constant at 60Hz and the electric tension at 12V. The protocol used in the present study was adapted from McGowan & Kajiura (2009). Fifteen impulse generation events were carried out for each animal with individual durations of 5 minutes and 2-minute intervals between each set. Experiments were performed only for three days to avoid conditioned response. The animals were filmed and photographed throughout the experiment and behavioural data were collected for further analysis. This work was approved by the Ethics Committee on Animal Use (CEUA-UFPR 132 #776/2014).

The behaviors displayed by both the impaired and healthy specimen were categorized to obtain a behavioural scale, where the most evasive conduct, *i.e.* an abrupt swimming in the opposite direction, was considered as the negative lower limit (-3); the most attractive behaviorism, *i.e.* biting the equipment until it was turned off, was considered as the positive upper limit (6); and the lack of movement while exposure was the zero threshold (Figure 1b). The remainder scaled behaviors consisted in: *a)* repulsion:

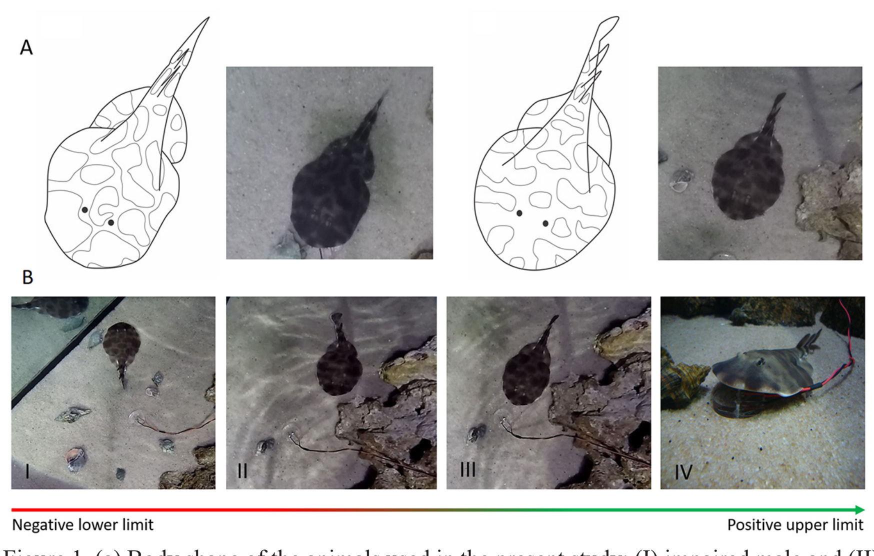


Figure 1. (a) Body shape of the animals used in the present study; (I) impaired male and (II) healthy male. (b) Behavioural scale. (I) Abrupt swimming in the opposite direction as negative lower limit; (II) Lack of movement while exposure as zero threshold; (III) Investigative behavior toward the signal as a positive response; (IV) Biting the equipment until it was turned off as positive upper limit.

swimming away when the signal was changed from 6 to 12 µA (-2); slowly swimming away (-1); and *b)* attraction: slowly swimming towards the equipment (1); investigated it without biting (2); swimming around the apparatus (3); biting it once (4); and biting the equipment four times (5). Due to the low number of observations, a Fisher's exact test was used to inspect for possible significant differences between the 2 specimens during exposure to the different voltages. The relationships between the respective time took to answer the stimulus (seconds) for each specimen and their corresponding distances from the dipole were investigated with linear relationships. Additionally, a two-sample student's T-test was used to assess whether the answering time significantly differed between both males rays. All analyses were performed in the R software (version 3.4.2) and the significance level was set at 0.05.

## RESULTS

The impaired *N. brasiliensis* remained still and did not answer to any 6 µA stimulus, except for a smooth movement of its tail and pectoral fins in a single occasion. However, it was attracted by the 12 µA stimulus (Figure 2a). On the other hand, while the healthy specimen was attracted only by the 6 µA amperage, it was repulsed by the stronger current (Figure 2b) and significantly differed from the injured ray on this regard (Fisher's test; p-value < 0.001). Significant positive relationships were observed between the time to answer and the distance from the dipole, with both rays answering faster when closer to the equipment (Fig. 2c-2d). Besides, although the healthy specimen answered a bit faster to the stimulus (mean = 20.06 s) than the injured ray (mean = 24.91 s), such a difference was found not to be significant (t = 0.93; degrees of freedom = 17.10; p-value = 0.364).

## DISCUSSION

Here, we presented for the first time the possible influences of external injuries and body deformity on the electroperception capacity in a benthic electric ray. Up to the present moment, all studies with electrical rays aimed to elucidate morphological and functional aspects of the electric organs (Mathewson *et al*., 1958; Bennett *et al.,* 1961; Macesic & Kajiura 2009), however, nothing was yet known about the electroperception capacity in Torpediniformes, nor how both systems (*i.e*., electroperception and electrogenesis) interact. *N. brasiliensis* can generate electricity through its main and accessory electric organs, both located within their pectoral fins. Despite its electrogenic capacity, this species uses electric organ discharges (EODs) only for predator defense and intraspecific communication (Macesic & Kajiura 2009). Thus, foraging and prey capture

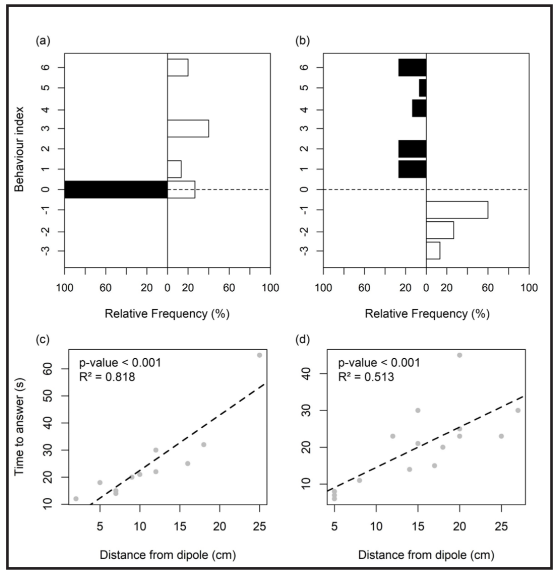


Figure 2. Behavioural scale of the impaired (left panels) and healthy (right panels) *N. brasiliensis*. Black and white bars in (a) and (b) respectively represent the relative frequencies of 6 µA and 12 µA amperages. The dashed lines depict the zero threshold, i.e. specimen immobile, in (a) and (b); and the corresponding fitted linear models in (c) and (d).

are performed exclusively by the synergy between electroperception and feeding kinematics (Dean & Motta 2004).

Regarding the electroperception system of *N. brasiliensis*, the present study corroborated its use not only for foraging (indicated by attraction followed by bites in the apparatus in 6 µA), but also detection of potential predators (indicated by evasive escape in 12 µA), at least for the healthy male. The injuries in the impaired male seemed to affect its ability to detect signal strength, but not its general capacity of signal detection (speed response *vs.* distance from the emitting source). It is possible that the injuries and subsequent body deformity presented by the impaired male has generated a morpho-functional noise that reduced its electroperception capacity. More specifically, it is known that any movement performed by the animal itself generates noises, which can be neutralized by specific behaviors during foraging (*i.e.* electric rays hold the disc rigid while hunting for prey (Montgomery & Bodznick 1999). Therefore, due to the reduced swimming capacity caused by the partial loss of both pectoral fins, it is possible that the impaired male must perform additional pectoral movements during foraging, causing electrical noise that exceeded the artificially emitted signal. This could also explain why the impaired male responded positively to the higher amperages, indicating that the noise generated by the pectoral movement did not overlap with higher stimuli.

Such interference becomes particularly problematic in the context of compensatory release, particularly for species commonly caught as bycatch, since negative effects caused by interaction with the fishing apparatus may compromise post-release survival by altering proper response of the animal in its natural habitat. More specifically, the sub-lethal effects of commercial capture also embrace alterations in the behavior patterns (Skomal 2007; Skomal *et al*., 2007), leading the animal to respond inefficiently to stimulus generated by prey and predators. Under natural conditions, an animal that is unable to modulate perceptual capacity can lose its predatory potential, as well as become vulnerable to direct predation.

Some valid points should be considered in future studies of this nature. Our sample size was low, so, complementary studies are necessary to validate not only the influence of injuries on the electroreceptive capacity, but also the ability of these animals to detect amperage-dependent signals. Furthermore, complementary studies using multifunctional signals (*e.g*. amperage, frequency and voltage) can bring new functional, behavioural and evolutionary perspectives of a sensorial capacity that modulates important aspects of the behavior and ecology of elasmobranchs.

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