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Research Article

Behavioral responses of *Sotalia guianensis* (Cetartiodactyla, Delphinidae) to boat approaches in northeast Brazil

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ABSTRACT. Boat engines increase the noise levels of the oceans, alter the acoustic environment of cetaceans and diminish their efficiency to echolocate. This study aims to determine if Guiana dolphins (*Sotalia guianensis*) are influenced by boat approaches. A land-based survey was conducted to record behavioral responses and count surfacing events of Guiana dolphins during 293 observation sessions from February to November 2014 in Pontal Bay, Ilhéus, Brazil. Ninety-eight behavioral responses to boat approaches of 93 dolphin groups were classified as negative (interruption or alteration of activity) or neutral (no response). The dolphins presented a neutral response to 90% of boats without engine approaches, 48% negative responses to inboard motorboat approaches, and 76% negative responses to outboard motor boat approach. Resting groups demonstrated 14 negatives and four neutral responses. Groups engaged in forage-feed activity presented ten negative and seven neutral responses while traveling groups exhibited 14 negative and 36 neutral responses. The average rate of surfacing events was significantly superior ($P < 0.001$) in the absence of boats (1.83 ± 0.90 surfacing events ind^{-1} min^{-1}) than in their presence (1.34 ± 0.92 surfacing events/individual/minute). Guiana dolphins are exposed to an increasing number of anthropic perturbations and the evaluation of its behavioral responses to approaching boats is the first step to comprehend the real impact of boat encounters. Our results may contribute to the development of management strategies in estuarine areas to increase the conservation of the Guiana dolphins.

Keywords: *Sotalia guianensis*, Guiana dolphin, behavior, surfacing events, dolphin-boat, estuary, Brazil.

INTRODUCTION

The traffic of motorized boats is one of the primary sources of disturbance for cetaceans (Nowacek *et al.*, 2001; Lemon *et al.*, 2006). Motorboats increase the noise level in the ocean and change the acoustic environment of cetaceans (Hildebrand, 2005). For example, toothed whales are affected by sound interference, as they echolocate to perceive the surrounding environment and to find their prey. Furthermore, toothed whales produce a complex vocal repertory to communicate (National Research Council, 2003; Au, 2004; Hildebrand, 2005). The boat traffic may drive this species off from areas they use to forage, rest, or reproduce (Parsons, 2012; Rako *et al.*, 2013) and consequently reduce the time they allocate to these activities (Gill *et al.*, 2001; Bejder *et al.*, 2009). In addition, sound disturbances may affect hearing abilities of toothed whales either temporarily or permanently (Richardson & Würsig, 1997) and cause stress (Miksis *et al.*, 2001; Romano *et al.*, 2004; Hildebrand, 2005). Stress leads to metabolic rate variations, with an increase in energy production necessary for diving and swimming speed (Christiansen *et al.*, 2014). In long-term, these changes may alter the survival and reproduction rates of the cetaceans' populations (David, 2002; Lusseau, 2003; Brock *et al.*, 2013; Merchant *et al.*, 2014).

Toothed whales react to boat encounters with short-term behavioral changes in an attempt to minimize their

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impact (Lusseau, 2006). For example, killer whales (*Orcinus orca*) swim faster (Williams *et al.,* 2014); Guiana dolphins (*Sotalia guianensis)* breath at a decreased frequency (Santos *et al.*, 2013) and increase breathing synchrony (Tosi & Ferreira, 2008); Hawaiian spinner dolphins (*Stenella longirostris*) perform a higher whistle activity (Heenehan *et al*., 2017) and bottlenose dolphins (*Tursiops truncatus*) alter their activity more frequently (Constantine *et al.,* 2004) in the presence of boat. These short-term behavioral changes can lead to long-term alterations including population decline (Bejder *et al.*, 2006) and abandonment of an area, as evidenced in a population of bottlenose dolphins in New Zealand (Lusseau, 2005). Some studies suggest that toothed whales identify boats as threats and perform antipredator tactics such as escape or local abandonment, regardless of the noise produced by the boat engines (Nowacek *et al.,* 2001; Lusseau, 2003; Constantine *et al.*, 2004; Dans *et al.*, 2012). The behavior of toothed whales might be affected by the physical presence and movement patterns of boats without engine (Lusseau 2006; Williams *et al.*, 2011; Pirotta *et al.*, 2014). As dolphins need to communicate in turbid waters (Van Parijs & Corkeron, 2001), the continuous approach of noisy boats promotes adjustments in their habitat usage and behavior (Bryant *et al.,* 1984; Morton & Symonds, 2002).

According to the IUCN, *S. guianensis* is classified as Data Deficient (Secchi, 2012). However, the species is classified as 'vulnerable' in the list of Brazilian species threatened by extinction (Instituto Chico Mendes de Conservação da Biodiversidade, 2014) once a decline of the population's size is expected due to increasing anthropogenic activity in coastal regions. Guiana dolphins occupy coastal waters, bays, and estuaries (Flores & Silva, 2009) with individuals residing in the same area for several years (*e.g.,* Rossi-Santos *et al.,* 2007; Hardt *et al.,* 2010; Cantor *et al.,* 2012).

In Ilhéus (State of Bahia, northeastern Brazil), Guiana dolphins share with tourists and fishing boats the estuary of the Cachoeira River called Pontal Bay, where they form foraging groups of up to eight individuals (Santos *et al.*, 2010). The aim of this study was to determine if and how boats provoke short-term behavioral responses in Guiana dolphin groups. For this purpose, we investigated if: 1) the number and type of boats influences the period that dolphins remain in the bay, 2) the behavioral responses of dolphins to boat approaches differs according to the boat type, 3) the number of surfacing events is associated with the type of the boat approach and the behavioral response of dolphins, 4) the number of surfacing events and behavioral response is modulated by the activity of the group prior to the boat approach.

MATERIALS AND METHODS

Study area

The study was conducted in a 0.76 km^2 estuarine area of the Cachoeira River (the Pontal Bay) located at Ilhéus, in the State of Bahia, Brazil (Fig. 1). Most of the estuary is shallow, except for the bed of the river, where the depth reaches 17 m (Diretoria de Hidrografia e Navegação, 2003). The frequency of boats in the Pontal Bay increases from December to February, especially at weekends. Recreational and fishing boats often pass through, but rarely with the purpose to observe dolphins. In addition, fishing vessels do not use gill nets within the bay area.

Data collection and analysis

One observer conducted the data collection from February to November 2014. To guarantee the randomness of data collection, four observation days were drawn applying the following requirements: three days during the week and one during the weekend. We performed two observation sessions per day, each comprising three hours, being one in the morning (7:00-10:00 h) and the other in the afternoon (14:00-17:00 h).

Data were assessed exclusively in stable weather conditions (*i.e*., no precipitation and sea states ≤2 on the Beaufort scale). Monitoring was conducted from two land-based positions: point A (39º2'15.17"W, 14º48'9. 48"S) and point B (39º1'43.29"W, 14º48'40.41"S) (Fig. 1). The size of the observation range areas was similar (0.7 km^2 and 0.6 km^2, respectively). Both points were close to key bay piers and allowed an overview of the study area. The point of observation for each session was defined from a simple random sampling with a replacement before the beginning of the data collection. Continuous scans were conducted, both with naked eye and binoculars (Lugan Ocean Xtreme 7×50) to detect boats and dolphins.

A group was defined as a set individuals swimming in an apparent association, close to each other, up to three body lengths apart (Queiroz & Ferreira, 2008), in the same direction, and often engaged in the same activity (Shane, 1990). When a group was detected, the observer recorded the size of the group, its main activity and its behavioral response to every boat approach. The observer annotated the time at the start and end of the observation period in order to calculate the permanence of the group in the area (min). The observation of a group ended when its components could no longer be detected by the observer.

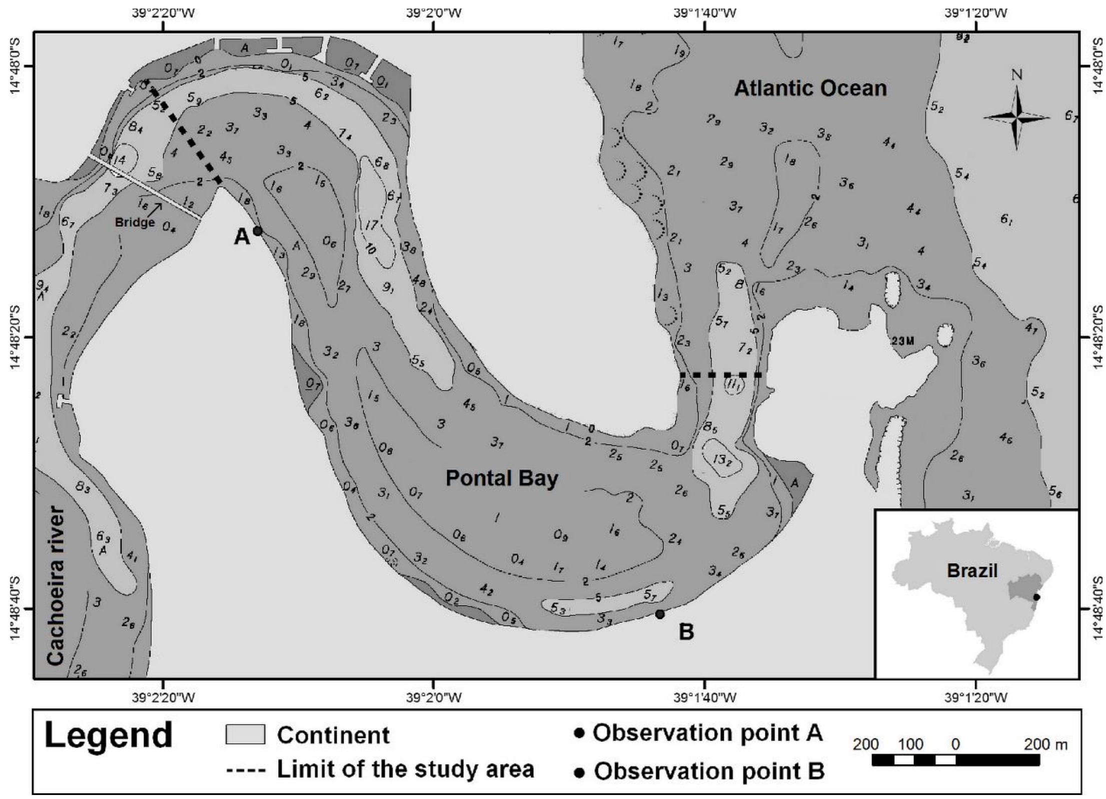

Figure 1. Pontal Bay in Ilhéus, Bahia, Brazil. Dashed lines indicate the limits of the study area. The land-based observation points are indicated by the letters A and B. Bathymetry of Pontal Bay based on the nautical chart 1201 (Diretoria de Hidrografia e Navegação, 2003).

The tide direction (*i.e.*, ebbing or flooding tide) and amplitude were registered to evaluate the influence of the tide on the presence of Guiana dolphins in the bay even in boat traffic situations. We calculated the tide amplitude at the start of the observation period of a group by applying Miguens (2000) correction tables to the high and low tide tables of the Brazilian National Oceanographic Database (BNDO) (Diretoria de Hidrografia e Navegação, 2014). We applied General Linear Model (GLM) to estimate the influence of six variables (Table 1) on the permanence time of Guiana dolphins.

We recorded with a voice recorder every time a dolphin rose to the surface (surfacing event) and identified each surface behavior in the absence (control) and presence (encounter) of a boat. This was possible because the groups were small (mean = 4, see results). An encounter occurred when a boat was at a distance of fewer than 100 m from the closest dolphin. The 100 m distance of encounter definition was based on Valle & Melo (2006) and Santos *et al.* (2013) studies on *S. guianensis*. Encounter distance was estimated visually since the duration of surfacing events of Guiana dolphins are too short for telemeter use. The known distance between the observer and four fixed objects to each land-based point were systematically used to minimize the visual estimation error between the Guiana dolphins and the boat. During an encounter, the observer recorded the instant of the closest distance between the boat and a dolphin to compare the behavioral and surfacing events before and after that moment.

The analyses were carried out in an R environment (version 3.0.2) (Development Core Team, 2013) and are described in Table 1.

Boat classification

Boats were classified into three types: boats with an inboard motor (IM), represented by small fiber or wood fishing boats with engine power ranging from 15 to 33 HP and larger trawling activity fishing boats (120 HP); boats with an outboard motor (OM), represented by aluminum boats (15 to 25 HP), fiber boats (40 to 150 HP), and jet skis (130 to 260 HP); and boats without a motor (WM) represented by canoes, stand up paddleboards, kayaks and small sailing boats.

Surfacing events

We counted every surfacing event, which was mostly breathing events but not consistently confirmed as such due to the small blows produced by dolphins. These

Table 1. Statistical analyses performed. Variable types: explanatory (EV), response (RV), Boat types: with an inboard motor (IM), with an outboard motor (OM), without motor (WM).

Goal	Analysis	Variables
Estimate the influence of environmental variables on the permanence time of Guiana dolphins	General Linear Model (GLM) with Poisson's distribution	EV: tide amplitude, tide direction (flooding/ ebbing), boat number (WM/IM/OM) RV: Guiana dolphins permanence time in view of the observer
Investigate if the Guiana dolphin group response is affected by different approaching boat types	Heterogeneity chi-square test	EV: boat type (WM/IM/OM) RV: Response type (negative/neutral/positive)
Test if the number of the surfacing events carried out by Guiana dolphins varies on the boat presence	*t*-test	EV: boat presence or absence RV: Surfacing Index
Test if the number of surfacing events varies according to the boat type	Analysis of variance	EV: boat type (WM/IM/OM) RV: Surfacing Index
Test if the number of surfacing events varies according to the response type	Analysis of variance	EV: response type (negative/ neutral/positive) RV: Surfacing Index
Evaluate if the number of surfacing events varies in relation to the group activity type before the encountering	Analysis of variance	EV: main group activity before the closest boat approaching (forage-feed/rest or travel) RV: Surfacing Index
Evaluate if the response type depends on the main group activity	Heterogeneity chi-square test	EV: main group activity before the closest boat approaching (forage-feed/rest or travel) RV: response type (negative/neutral/positive)

surfacing events were recorded for up to 10 min before (B) and 10 min after (A) the closest approaching moment of a boat for comparison purposes. The time of the first and last surfacing event was recorded to calculate 1) the mean frequency of surfacing events per individual and per minute (Santos *et al.*, 2013), and 2) the Surfacing Index (SI). We employed the variable SI for the first time in the literature. The SI was defined by B minus A, the difference between the mean number of surfacing events per individual and per minute before (B) minus after (A) the moment that the boat was the closest to the group.

Predominant activity

A scan sampling was carried out every five minutes to define the prevailing activity of the group, *i.e.*, the activity of at least half of the individuals per scan sampling (Mann, 1999; Lusseau, 2003). We recorded three predominant activities: rest, forage-fed, and travel, as defined by Flach *et al.* (2008).

Behavioral responses to boat approaches

The response of a group after the moment of a boat's closest approach was categorized as negative, neutral, or positive (Pereira *et al.*, 2007). The response was classified as negative when the animals interrupted or altered its predominant activity, neutral when the Guiana dolphins did not change their activity and positive when the Guiana dolphins approached the boat performing an aerial behavior or wake riding.

If a boat left the encounter area (100 m from the group) and another boat came closer than 100 m from the group, another encounter was recorded. We did not record the responses of a group when more than one boat was less than 100 m from the dolphins.

RESULTS

Sampling effort

Data collection was conducted during 293 sessions (127 at land-based point A; 166 at land-based point B) from February to November 2014, yielding a total of 879 h of monitoring. We detected 93 groups (32 at land-based point A; 61 at land-based point B) in 84 sessions (28.8% of the sessions; 29 at land-based point A; 55 at land-based point B), involving a total of 21 h and 46 min of observation (2.43% of sampling effort). Group size varied from 1 to 10 (mode = 3; mean = 4.09 ± 2.28), and each group was monitored from 1 min to 2 h and 24 min (mean: 16 min; SD: 20 min). An average of 4.91

boats (SD: 3.40 boats) was recorded per hour, totaling 1487 IM, 1030 OM, and 1800 WM, independently of the presence of the Guiana dolphins.

Influence of boats and tide dynamics on the permanence time of Guiana dolphins

Results of the GLM indicate that the time of permanence of the dolphin groups is explained ($P < 0.05$) by tide amplitude, tide direction, the number of WM per session, and the number of IM per session (Table 2).

Guiana dolphins remained for a longer period in Pontal Bay during lower tide (E = -0.293; $P < 0.001$) and when the tide was flooding (E = 2.991; $P < 0.001$), compared respectively to the time the individuals stayed in the bay during flooding and ebb tide. The groups remained for longer periods in the area when there were more WM per session (E = 0.019; $P < 0.001$) and shorter periods when there were more IM per session (E = -0.025; $P < 0.001$). The permanence time of the groups was not significantly influenced by the number of OM per session ($P = 0.313$).

Guiana dolphins' behavioral response according to the approaching boat type

Ninety-eight boat approaches were recorded, including 31 IM, 26 OM, and 41 WM. Sixty responses of dolphin groups to boat encounters were neutral (62.2%) and 38 (38.8%) were negative. No positive responses were observed.

The number of neutral responses (n = 37; 90.2%) to WM encounter was significantly higher than the number of negative responses (n = 4; $\chi^2 = 28.9$; df = 1; $P < 0.001$; 9.75%). There were no significant differences in the numbers of neutral (n = 16; 51.6%) and negative responses (n = 15; 48.4%) to IM encounter ($\chi^2 = 0.032$; df = 1; $P = 0.86$). The number of negative responses (n = 19; 76%) to OM encounter was significantly greater than the number of neutral responses (n = 6; $\chi^2 = 6.76$; df = 1; $P = 0.009$; 24%) (Fig. 2).

Effect of boat presence, boat type and behavioral response type on the mean of surfacing events

The average number of surfacing events was significantly higher ($t = 3{:}41$; df = 163, $P < 0.001$) in the absence (1.83 ± 0.90 surfacing events ind^{-1} min^{-1}); than in the presence of boats (1.34 ± 0.92 surfacing events ind^{-1} min^{-1}).

Surfacing events were counted during 78 encounters (with 31 WM, 26 IM, and 21 OM) and SI was not significantly different among the three types of boats (F = 2.065; $P = 0.13$, $R^2 = 0.027$).

Table 2. Explanatory variables, estimate coefficients E and *P*-values of a GLM test to evaluate the influence of tide and boats on the permanence of Guiana dolphins in Pontal Bay, Ilhéus, Bahia State, Brazilian northeastern from February to November of 2014. WM: without motor, IM: inboard motor, OM: outboard motor.

Variables	E	*P*
Tide amplitude (m)	-0.293	<0.001
Ebbing tide	0.114	0.065
Flooding tide	2.991	<0.001
n WM	0.019	<0.001
n IM	-0.025	0.001
n OM	0.005	0.313

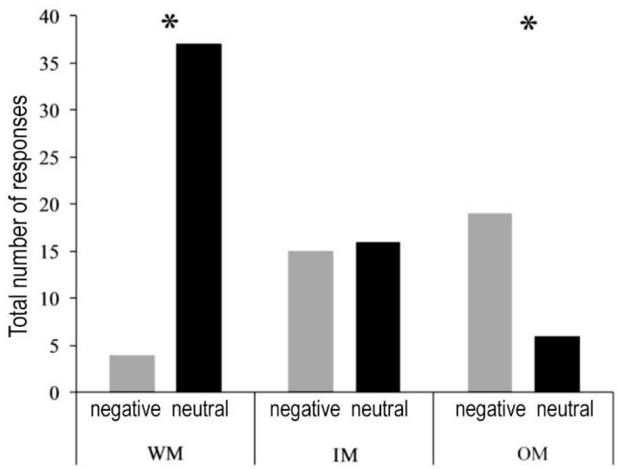

Figure 2. The frequency of negative and neutral responses of Guiana dolphins to boat approach (WM: without a motor; IM: inboard motor; OM: outboard motor) in Pontal Bay in Ilhéus, Bahia State from February to November 2014. *Indicate significant ($P < 0.05$) differences between neutral and negative responses.

Considering the total encounters with surfacing events recorded (n = 76) encounters with negative responses accounted for 27, while those with neutral responses totalized 49. The number of surfacing events decreased (SI > 0) more after encounters with boats producing a negative responses than boats causing a neutral response (F = 6.79; $P = 0.002$; $R^2 = 0.17$) (Fig. 3).

Effect of behavioral activity on boat encounter responses and surfacing events

The activity of the dolphins was determined before and after 85 of the 98 encounters with boats. Boats approached 50 groups of dolphins while traveling (58.8%), 18 at rest (21.2%), and 17 during forage-feed behavior (20%). The dolphins' activity changed after boat encounter, in which more groups were observed in

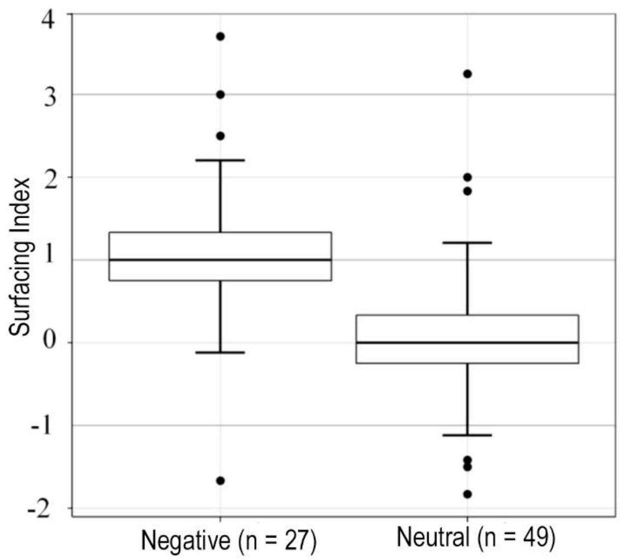

Figure 3. The relation between Surfacing Index and the type of response of Guiana dolphins to boat approach in Pontal Bay, Ilhéus, Bahia State, from February to November 2014 (n = number of approaches). The dark center bars represent the median, the boxes 50% of the data set values and the whiskers 1.5 interquartile range.

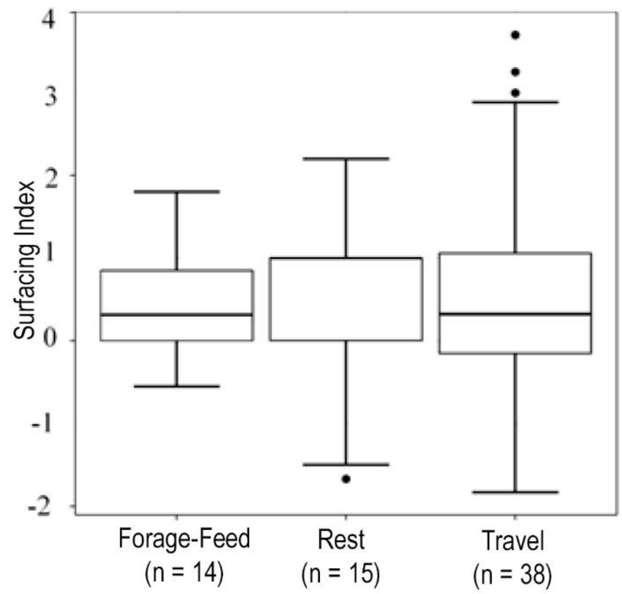

Figure 4. The relation between Surfacing Index and the main activity carried out by Guiana dolphins before boat approach in Pontal Bay, Ilhéus, Bahia State, from February to November 2014 (n = number of approaches). The dark center bars represent the median, the boxes 50% of the data set values and the whiskers 1.5 interquartile range.

travel (n = 71, 83.5%) and fewer in for forage-feed (n = 10) and rest (n = 4).

A boat approaching a group in travel caused significantly more neutral (n = 36) than negative responses (n = 14; χ^2 = 9.68; df = 1; P = 0.001). When a boat approached a resting group, the response was significantly more frequently negative (n = 14) than neutral (n = 4; χ^2 = 5.55; df = 1; P = 0.01). When engaged in forage-feed activity, dolphins' response to boat approach was negative (n = 10) or neutral (n= 7; χ^2 = 0.52; df = 1; P = 0.46). The activity carried out by a group before encountering a boat did not influence the Surfacing Index (SI) value (F = 0.028; P = 0.97, R^2 = 0, see Fig. 4).

DISCUSSION

Santos *et al.* (2010) concluded in a previous study that the tide is an important environmental variable that affects the use of the area by the Guiana dolphins in Pontal Bay, so that the ecological and structural features of the Pontal Bay may also influence the behavior of Guiana dolphins. In our study, flooding and low tide are associated with an increased permanence time of the groups in the area. These tidal characteristics may support the dolphins to obtain energy with less effort since low water column facilitates fish captures (Monteiro-Filho, 1995; Lodi, 2003). A greater frequency of dolphin groups in shallow areas (1 to 3 m) has been observed in other populations of Guiana dolphins (*e.g.*, Geise *et al.*, 1999; Edwards & Schnell, 2001; Flores & Bazzalo, 2004; Bazzalo *et al.*, 2008). In addition, the relation between inboard motor boats and the short permanence of dolphins might be indirectly associated with the tide. Most of the inboard boats are professional fishing boats that leave and enter the estuary when the tide is not low, in a way they are not in traffic in the estuary during low tide.

Groups of Guiana dolphins were observed for shorter periods in Pontal Bay when the number of inboard motor boats was high, while outboard motor boats did not influence the dolphins' permanence time. The frequency levels of motor noise increase with the power (Erbe, 2002) and speed of the boat (Arveson & Vendittis, 2000) and outboard motor boats emit a greater intensity of noise at higher frequencies. Assuming that the noise caused by the boats' traffic is the primary disturbance for dolphins, it is expected that a greater number of outboard motor boats would lead the groups to shorten their stay in the study area. Surprisingly, we did not observe such phenomenon.

Our study presented a similar frequency and group size of Guiana dolphins in the Pontal Bay in comparison to the visual monitoring conducted in 2006 (see Santos *et al.*, 2010 the presence of Guiana dolphins was registered in 28,7% of sessions, with mean of group size = 3.75 ± 1.59). Boat traffic probably increased during the last decade due to a pronounced urbanization around the Pontal Bay. However, the estuary is associated with an abundance of food resource for the dolphins by providing excellent availability of organic matter (Souza *et al*., 2011). Guiana dolphins may face the actual traffic of boats and the energetic cost of the negative responses to boat approaches in the estuary because they have no option than to frequent this critical habitat to forage-feed and rest.

Guiana dolphin groups showed negative responses in most of the encounters with an outboard motor boat. Conversely, boats without motor provoked negative responses only three times, suggesting that they rarely disturb the dolphins.

Motorboat traffic might mask the communication of Guiana dolphins, once the sound frequency rate they emit overlap with the noise created by boat engines in Dolphin Bay (Albuquerque & Souto, 2013): outboard motor engines of 40 to 150 HP produce noise similar to the frequency rate of the whistles of the Guiana dolphin, as also reported for the population of Ilhéus (Lima & Le Pendu, 2014). Boat speed was associated with negative response to boat approaches in Chinese white dolphin (*Sousa chinensis*) in Hong Kong (Ng & Leung, 2003) and in bottlenose dolphins around Lampedusa Island (Papale *et al.*, 2011). Ng & Leung (2003) also found that slow boats did not cause immediate stress in dolphins. Furthermore, Papale *et al.* (2011) reported only neutral responses when boats without motor approached dolphins, supporting the hypothesis that noise intensity would be a determining factor causing negative responses in coastal dolphins. However, the real physiological effect that this disturbance may cause in cetaceans is still in debate (*e.g.*, Miksis *et al.*, 2001; Romano *et al.*, 2004; Wright, 2006; Christiansen & Lusseau, 2015).

Traffic of recreational boats, such as motorboats and jet skis, is common in Pontal Bay. These boats have less predictable and frequent erratic trajectories, which may have a greater adverse effect on dolphins' behavior when compared to boats with more directional movements (Nowacek *et al.*, 2001). Although tourism does not occur targeted the species in the region, these recreational boats are often seen changing their direction toward Guiana dolphin groups, inducing the animals to change their direction or escape.

Guiana dolphins did not show positive responses to boat approaches in the Pontal bay, as reported in an open sea area for the same population (Izidoro & Le Pendu, 2012). Unlike other species (*e.g.*, Chinese white dolphin: Bearzi *et al.*, 1999; Ng & Leung 2003; bottlenose dolphins: Arcangeli & Crosti 2009; Papale *et al.*, 2011), Guiana dolphins do not show positive responses when encountering a boat and often avoid their proximity (Lodi, 2003).

Fewer surfacing events were performed by the dolphins in the presence of any boat type. Increased dive time during motorboat encounters was evidenced for this same population in the Port of Malhado, Ilhéus (Santos *et al.*, 2013) and for different cetacean species: Chinese white dolphins (Ng & Leung, 2003), Irrawaddy dolphins (*Orcaella brevirostris*, Kreb & Rahadi, 2004), and bottlenose dolphins (Arcangeli & Crosti, 2009). These animals react to boat proximity with escape strategies, rising fewer times to the surface to reduce their exposure (Frid & Dill, 2002; Pirotta *et al.*, 2014), and moving away from the source of disturbance (Lusseau, 2003). The Surfacing Index did not differ when compared encounters with each type of boat but the number of surfacing events decreased at negative responses. This result evidences the importance of using more than one parameter for evaluation of the boats' traffic effect.

Forage-feed and rest rate diminished by half after boat encounter, while travel frequency increased. Miller *et al.* (2008) and Arcangeli & Crosti (2009) found the same pattern of activity change in bottlenose dolphins. Interruption of forage-feed in the presence of boats was also observed in *Delphinus* sp. in New Zealand (Stockin *et al.*, 2008; Meissner *et al.*, 2015), bottlenose dolphins in Italy (Miller *et al.*, 2008; Papale *et al.*, 2011), and in Guiana dolphins in Dolphin Bay (Rio Grande do Norte State, Brazil) (Carrera *et al.*, 2008). Due to interruption of feeding activity, the energy acquisition may be negatively influenced (Lusseau *et al.*, 2009; Symons *et al.*, 2014).

As observed in bottlenose dolphins (Lusseau, 2003, 2004; Constantine *et al.*, 2004; Arcangeli & Crosti, 2009), the rest-activity was more sensitive to encounters, with a sudden change to travel activity. Interruption of rest was also observed in other species, such as *Delphinus* sp. (Stockin *et al.*, 2008) and *Stenella longirostris* (Courbis & Timmel, 2009; Tyne *et al.*, 2015). Interruption of rest-activity affects the dolphin's energy recovery and may result in a greater impact on dolphin species that rests in estuarine areas, in which great human disturbance is found (Arcangeli & Crosti, 2009; Tyne *et al.*, 2015).

Interruption of activity may have energetic implications for dolphins: a quick escape results in greater energy expenditure, and the 'interruption of hunting' culminates in less energy acquisition (Ng & Leung, 2003). Thus, frequent interruptions of activities may significantly change energy budget, interfering with the individual's health and the maintenance of the population (Williams *et al.*, 2006).

The permanent abandonment of an area by Guiana dolphins in Nicaragua was attributed to the increased boat traffic frequency (Edwards & Schnell, 2001). The significant proportion of negative responses reported in this research and the current increase in boat traffic due to the construction of a bridge have not resulted so far in a decline in dolphin frequentation by the dolphins (Le Pendu, *unpubl. data*).

However, an intensification of the exposure to disturbances may force the dolphins to leave the area and lead to population decline (*e.g.*, Bejder *et al.*, 2006; Azevedo *et al.*, 2017). On the other hand, in Pipa Bay (Rio Grande do Norte State, Brazil), Tosi & Ferreira (2008) showed that simple control of boat traffic could minimize the adverse impacts on short-term dolphins' behavior.

Studies on behavioral responses of cetaceans associated with anthropogenic impacts such as noises are considered as priority investigations (Hildebrand, 2005). Consequently, such studies should be conducted to provide information on the acoustic aspects of the sound levels emitted by each type of boat (*e.g.*, Van Parijs & Corkeron 2001; Buckstaff, 2004) to enable the development of management strategies (Erbe, 2002).

In order to establish these guidelines, we should evaluate how behavioral responses are determined by variables that could not be controlled in our study, such as distance, boat speed, and engine noise intensity (Courbis & Timmel, 2009; Albuquerque & Souto, 2013).

An initial step to minimize the impacts of human activities on dolphins is the implementation of voluntary conduct regulations in the Pontal bay. According to Duprey *et al.* (2008), this method is very efficient when associated with environmental education, dissemination in the media and consider local culture and subsistence needs. Skippers of tourist outboard motor boats, such as jet skis, should be oriented not to follow the animals, reduce their speed, and put the engine into neutral when close to Guiana dolphins. The approach type should also be considered to minimize the effect of human activities on the dolphins. Filla & Monteiro-Filho (2009) verified that direct approaches within less than 50 m of the Guiana dolphins were responsible for almost the total of negative reactions. Restrictions concerning the speed and number of motorized boats in the traffic area must be developed, ensuring a sustainable use of the bay by the local population, especially fishers.

As shown by Cruz *et al.* (2016) study on space patterns' of Guiana dolphins in the Pontal Bay, the outboard motor is the boat category that widely shares a common area with the dolphins and affects their spatial behavior. Human population is growing around Pontal bay and the traffic of recreational boat may increase in the near future. The cumulative effect of short-term responses may be crucial to the survival of these animals and their reproduction success. Thus, evaluating these responses is the first step to understand the real impact of boat encounters on this population. Our findings indicate the presence of short-term changes in the Guiana dolphins' behavior and may be applied to foster measures that ensure the survival and conservation of this population of Guiana dolphins.

Nonetheless, long-term harmful effects may occur with an increased frequency of boat traffic in the area. Long-term and large-scale studies are essential to track the variations in the distribution and abundance of these cetaceans (*e.g.*, Arcangeli *et al.*, 2016). Furthermore, the Guiana dolphins that inhabit Pontal bay face other sources of noise pollution (*e.g.*, bridge construction, dredging processes), water pollution through waste disposal, household waste, and more broadly, habitat loss.

Ethnobiological studies (*e.g.*, Costa *et al.*, 2012) must also be conducted to evaluate the possibility of change in the species population by virtue of the increased boat traffic in the region due to the knowledge of local fishermen.

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