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Research Article

Surface patterns of *Sotalia guianensis* (Cetacea: Delphinidae) in the presence of boats in Port of Malhado, Ilhéus, Bahia, Brazil

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ABSTRACT. Interactions with boats can cause several behavioural changes in cetaceans. The purpose of this research is to analyse if Guiana dolphins, *Sotalia guianensis*, change their surfacing patterns in the presence of different boat categories, and their contact distances to boats at Port of Malhado, Ilhéus, Bahia, Brazil. Data were collected from a fixed point from September 2008 to August 2009 and totalled 362.6 h of sampling effort and 213.22 h of effective effort. The number of dolphin breathing events was recorded during one minute periods, every time a boat passed nearby, and the same measurements were performed during periods of boat absence (control). Dolphin group composition was classified into groups with calves and groups without calves. Boat types were classified as inboard motor (IM), outboard motor (OM), ships (S) and without a motor (WM). Distances between the dolphins and passing boats were classified as near, intermediate and far. In total, 365 samples of one minute observations in absence of boats, and 379 observations in their presence were collected. Inboard motorboats had the highest occurrence in the study area (n = 478) and in interactions with Guiana dolphins (n = 260). However, outboard motorboats were mainly responsible for the reduction in surface patterns with an average of 1.82 and median of 2.2. In groups with calves, the number of breaths decreased significantly with an average of 2.13 per minute. There were no significant variations concerning the distances in the breathing pattern for any of the boat categories. The variation in the *S. guianensis* breathing pattern in the presence of boats may be a strategy of boat avoidance or a response to the difficulty of communication between animals.

Keywords: guiana dolphin, *Sotalia guianensis*, breathing and interactions, Bahia, Brazil.

Patrones superficiales de *Sotalia guianensis* (Cetacea: Delphinidae) con la presencia de embarcaciones en el Puerto de Malhado, Ilhéus, Bahía, Brasil

RESUMEN. Las interacciones con embarcaciones pueden causar cambios de comportamiento en los cetáceos. El propósito de esta investigación es analizar si los delfines costeros, *Sotalia guianensis*, modifican su patrón de afloramiento para respirar, en presencia de diferentes categorías de embarcaciones y de la distancia de contacto con las mismas en el puerto de Malhado, Ilhéus, Bahía, Brasil. Los datos se obtuvieron desde un punto fijo, de septiembre 2008 a agosto 2009, totalizando 362,6 h de esfuerzo de muestreo y 213,2 h de esfuerzo efectivo de observación. El número de salidas a la superficie fue contabilizado durante períodos de un minuto, cada vez que pasaba una embarcación, y también durante la ausencia de embarcaciones. La composición de los grupos de delfines se clasificaron como: grupos con crías y grupos sin crías. Los tipos de embarcaciones fueron clasificadas como: con motor central (CM), con motor fuera de borda (OM), barcos (S) y sin motor (WM). Las distancias entre los defines y las embarcaciones que pasaban se clasificaron como: cerca, intermedia y lejana. En total se efectuaron 365 observaciones de un minuto en ausencia de embarcaciones y 379 en su presencia. Los barcos de motor central fueron los más frecuentes (n = 478) en el área de estudio y en interacción con los delfines (n = 260). Sin embargo, las embarcaciones con motor fuera de borda eran las principales responsables de la disminución de los patrones superficiales con un promedio de 1,82 y una mediana de 2,2. En los grupos con crías, el número de subidas a la superficie se redujo significativamente con un promedio de 2,13 por minuto. No hubo variaciones significativas con respecto a las distancias en el patrón de subida a la superficie con ningún tipo de embarcación. La variación de este comportamiento de *S. guianensis* en presencia de embarcaciones puede ser una estrategia de evasión de embarcaciones o una respuesta a la dificultad de comunicación entre los animales.

Palabras clave: delfin costero, *Sotalia guianensis*, respiración e interacciones, Bahia, Brasil.

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INTRODUCTION

The interaction between cetaceans and boats can cause direct impacts, such as collisions that cause injuries and even death (Laist *et al*., 2001; Vanderlaan & Taggart, 2007), and indirect effects, such as changes in behavioural patterns (Mattson *et al*., 2005; Lusseau, 2006). Research conducted on coastal species of Delphinidae has identified behavioural changes in the presence of boats. For example, research on the species *Tursiops truncatus,* demonstrates changes in their surfacing patterns (Janik & Thompson, 1996; Nowacek & Wells, 2001; Lusseau, 2003), an increase in the breathing synchrony of groups (Hastie *et al*., 2003), and erratic movements (Lusseau, 2006). Hector's dolphins, *Cephalorhynchus hectori*, increased the cohesion of groups (Bejder *et al*., 1999) and decrease group size in the presence of several boats simultaneously (Nichols *et al*., 2001). These short-term changes can cause long-term reactions, such as avoidance of certain areas by groups of dolphins (Lusseau, 2005).

The types, quantities and proximities of boats can cause different reactions in dolphins. According to Janik & Thompson (1996) and Constantine *et al.* (2004), dolphin watching boats cause the greatest impact.

The Guiana dolphin, *Sotalia guianensis*, is a small species of Delphinidae observed in bays, estuaries, and protected coastal waters. *S. guianensis* is geographically distributed along the western Atlantic coast of south and Central America, from southern Brazil (27°35'S, 48°35'W) to Nicaragua (14°35'N, 83°14'W), and possibly Honduras (15°58'N, 79° 54'W). The main threats to *S. guianensis* are related to accidental capture in fishing nets, water pollution, seismic activity, oil spills, habitat destruction and boat traffic (Flores & Da Silva, 2009).

Research on the interaction between *S. guianensis* and boats, has been performed along the Brazilian coast (Santos-Jr. *et al*., 2006; Valle & Melo, 2006; Pereira *et al*., 2007; Araújo *et al*., 2008; Carrera *et al*., 2008; Filla *et al.*, 2008; Tosi & Ferreira, 2008).

In Port of Malhado, Ilhéus, a population of *S. guianensis* can be observed during the entire year, with a lower occurrence in the summer (Izidoro & Le Pendu, 2012). There are no dolphin watching tours, but there are fishing boats, recreational boats, ships and tugboat traffic. Therefore, our aim is to determine if Guiana dolphins show changes in their surfacing patterns in the presence of different boat types and at certain proximities.

MATERIALS AND METHODS

Study area

The Port of Malhado (14°46'08"S, 39º01'33"W) is located in the Trincheiras Bay, city of Ilhéus, on the southern coast of Bahia, Brazil (Fig. 1). Research was conducted from a fixed point, as well as in other locations, where *S. guianensis* have been studied (*e.g.*, Santos *et al*., 2000; Araújo *et al*., 2001), and where it was possible to conduct observations without interfering with their natural behaviour (Azevedo *et al*., 2009). The fixed point was 5.06 m above sea level and located at the end of the Malhado pier. The end of the pier is directed towards the true north and is approximately 2.3 km in length; the tidal range in the port is 2.4 m (Andrade, 2003), and the bottom sediment consists of fine sand. The observations were made with the naked eye in a 300 m radius visual field and in an area of 1.5 ha, defined with the aid of an electronic theodolite from the fixed point (Fig. 1).

The study area was chosen because it is a traffic region for tugboats, recreational, fishing and cargo boats. These boats use the area for transiting with a defined route around the extremity of the Malhado pier (Fig. 1). The study area was also chosen due to the daily presence and permanence of *S. guianensis* over the entire year, and because of the dolphin's proximity to the observation point, which allowed for better visual data collection.

Data collection

Data were collected from September 2008 to August 2009 using weekly surveys of 8 h a day (from 08:00 to 16:00 h), totalling 48 field days and 362.2 h of sampling effort (total observation time). Observations were made in sea states ≤ 2 on the Beaufort scale. Because the dolphins are small, the distance from the observer was approximately 300 m, and the height of the observation point was approximately 5 m.

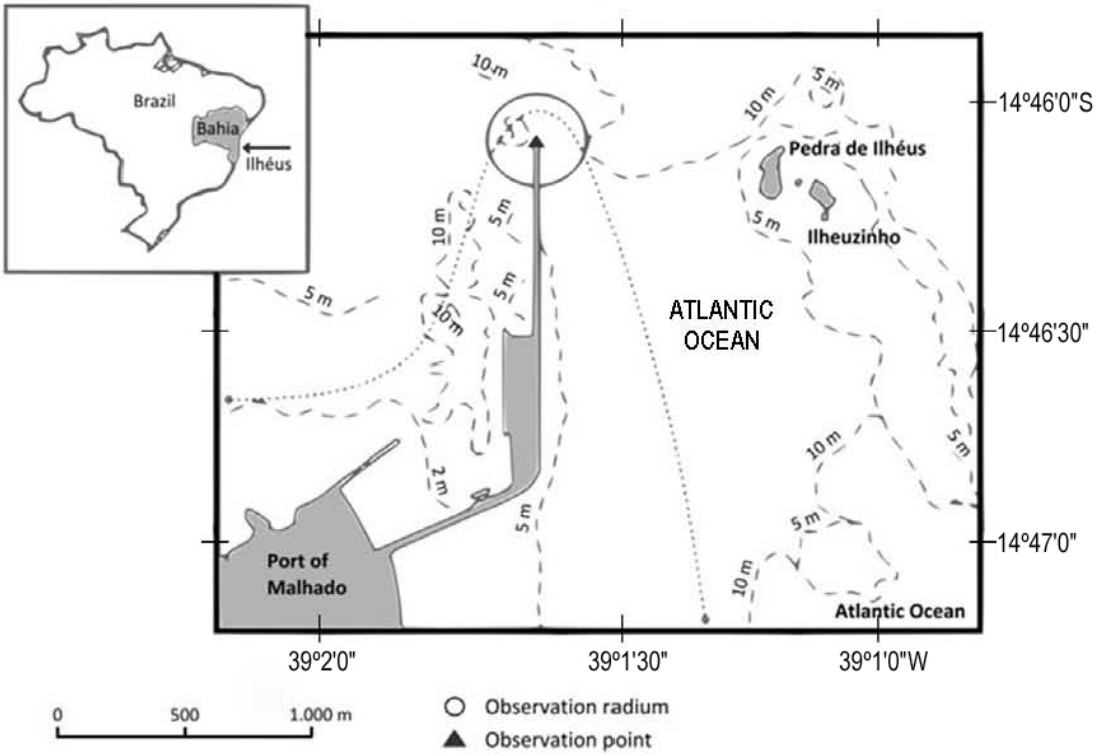

Figure 1. Port of Malhado, located in the coast of Ilhéus, Bahia, Brazil. The triangle represents the fixed point in the extremity of the port pier and the circle represents the amplitude of the observation field with a radium of 300 m. Dashed line represents the trajectory of boats.

The surface pattern was taken as group surfacing, because the dolphins could not be individually identified. A group was considered as the aggregation of two or more individuals in apparent association that were close to each other (Azevedo *et al*., 2005, 2007). Initially, the size and composition of the group was recorded and classified into two categories: groups with calves and groups without calves. The age classes were categorised based on the proportional size of the dolphins and colour pattern. Calves were always accompanied by one or more adults. They had a medium body size or were smaller than adults and have grey-pinkish colour, with darker shades on the dorsum, head and rostrum. Adults were considered as all individuals larger than 120 cm with a more defined grey colour and only a light-coloured belly (based on Randi *et al*., 2008; Rosas & Barreto, 2008).

After determining the group size, the number of breathing events of all individuals during a period of one min was recorded. Timing began when the initial individual surfaced to breathe and was considered complete when a period of one minute passed. Thus, knowing the group size and the total number of rises in the group, it was possible to calculate the average breathing per individual and per min. The surface pattern was obtained independently with the presence and/or absence of vessels (control).

Interactions between Guiana dolphins and boats were recorded when boats were observed to be travelling in an area in which dolphins were present. These interactions were recorded by the "all occurrences" sampling method for dolphin groups (Mann, 1999). Even when there were no dolphins during the passage of boats, the type of boat and time was recorded. Data concerning the quantity, type of boat and the distance between the dolphins and boats were also obtained. The type of boats were classified into four categories: boats with an inboard motor (CM), represented by fishing boats and all other motorized wooden boats; boats without a motor (WM), represented by paddle canoes, sailing canoes and catamarans; boats with an outboard motor (OM), represented by motorboats, sailing boats, flying boats, inflatable boats and jet skis; and ships (S), represented by cargo ships and tugboats.

The distance measurement between the dolphins and passing boats was set from a sighting pilot using an electronic theodolite as a method to improve the accuracy of a visual estimate. Distance categories were created following Araújo *et al*. (2008). Thus, comparisons between port systems were possible. An interaction between dolphins and a boat occurred when dolphins were approximately 150 m away from a boat. The distance was classified into three categories: far, when the boat was between 75 and 150 m away from the dolphins; intermediate, when the boat was 25 and 75 m away; and near, when the boat was less than 25 m away. To compare behavioural changes according to vessel proximity, distance categories were classified by a visual estimation in each observation. The maximum distance considered was 300 m, from the observation point to where the dolphins and the vessel were.

Data analysis

Data were properly recorded in a database, and the Biostat 5.0 program was used for statistical analyses. It was calculated the average ($\bar{x}$) median (Md) and standard deviation (SD) of the surface pattern related with categories and distances of vessels and composition of groups. Normality was tested, and the data were nonparametric. To test for significant differences between the average number of surfacing per individual, per minute with or without (control) the presence of vessels, a nonparametric Mann-Whitney test was used. A Kruskal-Wallis test evaluated significant variations in the average number of breaths associated to vessel categories, group composition and distance to the dolphin groups. Data obtained in the presence of more than one boat were discarded from the analyses. The significance was set as $\alpha = 0.01$. Statistical analyses were not performed on group composition, vessel categories and the approximate distances to dolphin groups due to the large variation in the number of samples.

RESULTS

Guiana dolphins were sighted during 42 days of observations (87.5% of total field days), which totalled 213.22 h of effective effort. The number of dolphins simultaneously present in the area ranged from 1 to 12 individuals with a mean group size of 3.76 (SD = 1.81) and a modal size of two individuals. In 73% (n = 543) of the observations, the presence or absence of calves was determined; 40% (n = 217) of groups had calves and 60% (n = 326) of groups were without calves.

A total of 855 vessels were recorded travelling in the study area. The inboard motorboats were the most frequent (n = 478), followed by outboard motors (n = 178), boats without a motor (n = 118) and ships (n = 81). Interactions between Guiana dolphins and boats were observed during 49.9% of all present boats (n = 427), where 260 boats were inboard motorboats, 66 were outboard motorboats, 62 were without a motor, and 39 were ships.

A total of 744 observations of group breathing were counted by minute; 365 observations occurred in the absence of boats, and 379 occurred in their presence. Most interactions occurred in the presence of only one boat (n = 340). On a few occasions (n = 39), there was more than one boat interacting with dolphins, with a maximum of three boats present simultaneously.

The average number of breaths per individual, per minute was significantly lower (Z = 4.91; $P < 0.0001$) in the presence of boats ($\bar{x} = 2.25$; SD = 1.05; Md = 2) in comparison to control ($\bar{x} = 2.59$; SD = 1.03; Md = 2.5).

There was variation in the surfacing pattern according to boat category. In the presence of outboard boats, the average surface pattern was 1.82 (SD = 0.98; Md = 2.2), which was significantly lower in comparison to an average of 2.64 (SD = 1.03; Md = 2.5; $P < 0.0001$) for boats without a motor, and the control ($P < 0.0001$). The average number of breaths in the presence of inboard motorboats was 2.27 (SD = 1.06; Md = 2.2), also significantly lower when compared to the control ($P = 0.0001$). In the presence of ships, the breath average was 2.1 (SD = 0.81; Md = 2) and there was no significant difference ($P > 0.001$) (Fig. 2).

Despite the wide variation in the number of samples, it was observed that the number of surfaces to breathe was lower in groups with calves for all vessel categories at a near distance, except for ships, in which the average number in the near distance category was 2.1 and 2.0 in intermediate distance. In groups without calves, the results did not show an increased surfacing pattern (Table 1).

In groups with calves, the number of breaths per individual was significantly lower in the presence of vessels (n = 118; $\bar{x} = 2.13$; SD = 1.04; Md = 2) than in the control (n = 99; $\bar{x} = 2.66$; SD = 0.98; Md = 2.6) ($P = 0.0001$). In groups composed exclusively of adults and juveniles, there was no significant difference in surfacing patterns with the presence (n = 183; $\bar{x} = 2.26$; SD = 1.06; Md = 2) or absence of boats (n = 143; $\bar{x} = 2.49$; SD = 1.12; Md = 2.5) ($P = 0.039$) (Fig. 3).

Most boats were observed near the dolphins (n = 127), followed by far (n = 95) and intermediate distances (n = 89). Distance was not determined in 30 events because dolphins submerged during the boats passage and then surfaced when the boat had already

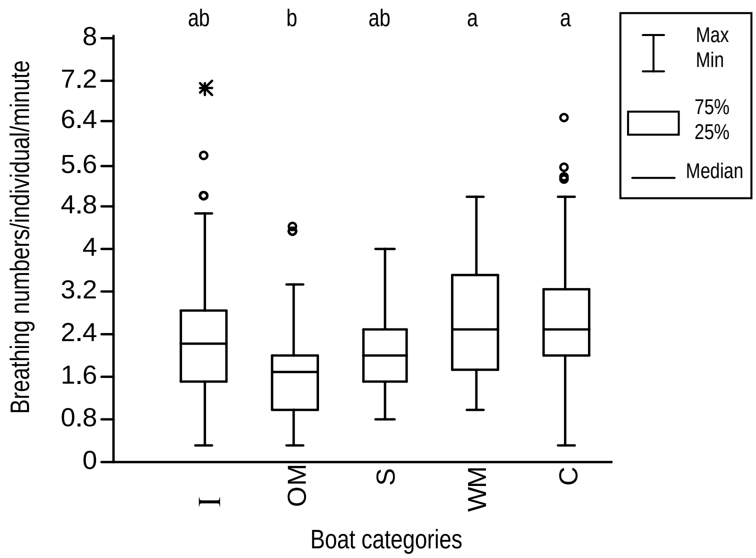

Figure 2. *Sotalia guianensis* average number of breathing per minute per individual, according to categories of boats (IM: inboard motor, OM: outboard motor, S: ship, WM: without motor, and C: control-without boats) in the Port of Malhado (Ilhéus, Bahia, Brazil). Where are values 1.5 times higher than the 3^{rd} quartile and *are values three times higher than the value of the 3^{rd} quartile). Different letters means differences between treatments (Tukey's test, $P < 0.01$).

Table 1. Number of records (n) and average number of breathings to surface per minute. individually, according to the categories of boats, distances and composition of group.

Distances	Inboard motor				Outboard motorgroups				Ships without motor							
	with calves		without calves		with calves		without calves		with calves		without calves		with calves		without calves	
	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
Near	1.8	29	2.3	48	1.8	7	1.5	6	2.1	3	2.5	11	2.3	6	1.7	7
Intermediate	2.3	18	2.1	35	2.1	4	1.9	5	2.0	1	2.0	2	2.6	4	3.5	1
Far	2.4	15	2.5	26	2.3	4	1.8	4	2.3	1	2.6	5	3.4	5	2.8	12
Undetermined	6		3		4		2		0		2		2		0	

passed. The average number of breaths per individual, per minute according to distance was 2.1 at near distances (SD = 0.97; Md = 2), 2.2 at intermediate distances (SD = 1.05; Md = 2) and 2.5 at far distances (SD = 1.1; Md = 2.25). There was no significant difference for the distance categories between the dolphins and any type of vessels ($P < 0.01$).

DISCUSSION

The results obtained in this research indicate that *S. guianensis* shows variation in their surfacing pattern when interacting with different categories of boats. The results shows a decrease in the number of breaths in the presence of boats compared to the absence of boats, and breaths were lower in the presence of outboard and inboard motorboats. Although analyzing other behavioral changes, Izidoro & Le Pendu (2012), also in Port of Ilhéus, showed more indifferent behaviour responses by dolphins, in the presence of boats. However, they could observe that the animals escaped in some situations of the passages of fishing and recreation boats.

The change in surfacing pattern in the presence of boats has also been noted for this species by Valle & Melo (2006), at Praia de Pipa - Rio Grande do Norte,

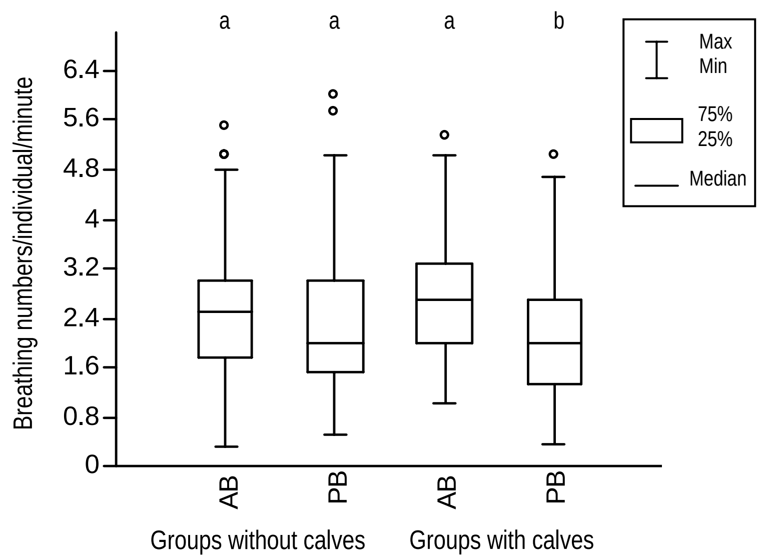

Figure 3. *Sotalia guianensis* average number of breathings per individual per minute, according the composition of groups considering the presence of boats (PB) and the control - absence of boats (AB) in the Port of Malhado (Ilhéus, BA, Brazil). Where are values 1.5 times higher than the 3rd quartile. Different letters means differences within composition of groups.

Brazil, and by Pereira *et al.* (2007) in the north bay of Santa Catarina, Brazil.

Other dolphin behavioural changes related to the interaction with different categories of vessels have also been reported for *S. guianensis*, such as increased group cohesion (Valle & Melo, 2006; Tosi & Ferreira, 2008), decreased foraging activity (Carrera *et al.*, 2008), deviation from boats (Pereira *et al.*, 2007) and changes in acoustic behaviours (Filla *et al.*, 2008).

In the present study, if the underwater motor sounds were the reason for changing the dolphins' time on the surface, why were there no differences between motored boats (inboard and outboard) and either boat without motors, or in the absence of boats? As reported for other species, noise pollution was potentially not the only factor that affected the surfacing behaviour of Guiana dolphins. Reactions to different boat types have also been reported for other dolphin species. For *Tursiops truncatus*, jet skis cause prolonged submersion of individuals, which is associated with the high speed of the boat, undefined motion and the noise produced by the motor (Mattson *et al.*, 2005). The Irrawaddy dolphin (*Orcaella brevirostris*) decreases its breathing pattern in the presence of motorized canoes (<40 hp), high-speed boats (40-200 hp) and towing ships (>1000 hp) (Kreb & Rahadi, 2004). For *Sousa chinensis*, speedboats and inflatable boats have the most impact (Ng & Leung, 2003).

The vessel category that travels in areas where the Guiana dolphin performs its activities could change its behaviour and even social communication (Rezende, 2008). In contrast, Araújo *et al.* (2008) observed a predominance of neutral reactions to all types of boats. These authors suggested that the reactions were neutral because the speed and direction of the boats were constant. All reports of *S. guianensis* interactions and observations from tourist boats reported negative reactions by the dolphins (Santos Jr. *et al.*, 2006; Valle & Melo, 2006; Pereira *et al.*, 2007; Tosi & Ferreira, 2008).

At Port of Malhado in Ilhéus, Guiana dolphins are not targets for dolphin watching tourism, and boats only use the area for passing through with a constant speed, a pre-defined route, and spend a short time interacting. These conditions could be an explanation for the absence of significant variation in the surfacing pattern for most categories of boats (ships and boats without a motor), although there was a significant difference for outboard and inboard motorboats. An alternative explanation could be that because the dolphins inhabit the port area, they live under daily boat traffic, which causes habituation to passing boats and a resulting tolerance from hearing damages. Erbe (2002) suggested the hypothesis of temporary or permanent hearing loss due to boat exposure for *Orcinus orca*. Pereira *et al.* (2007) suggest this hypothesis as a possible cause of the decline in negative behavioural responses and the increase in neutral reactions to boats for *S. guianensis* in North Bay, Santa Catarina. Outboard motorboats move faster and produce more noise, whereas inboard motorboats and ships have slower displacement and the motor produces low noise. It is possible that Guiana dolphins have more negative reactions in the presence of outboard motorboats. According to Erbe (2002), the fastest motorboats can be heard by *O. orca* at a distance of 16 km and can cause behavioural responses of orcas at 200 m; slower boats can be heard by orcas at a distance of 1 km and cause behavioural reactions at 50 m.

At Pipa beach, Valle & Melo (2006) observed that when outboard motorboats were switched off, or remained at low rotations, the Guiana dolphins tended to approach the boat or show neutral reactions. According to Mattson *et al*. (2005), the prolonged time underwater in the presence of outboard motorboats can be a strategy for boat avoidance or even a response to communication difficulty.

There is a differential response to interactions with the vessels due to the presence of calves in the group. The average number of breaths was lower when the group had calves. It is necessary to investigate the difference between the two groups to determine whether the difference between them is related to boat avoidance. The direction of vessel traffic must also be considered when studying interactions with cetaceans. In this study, as similarly reported by Araújo *et al.* (2008), the vessels only passed through the area and spent a short time interacting with the dolphins. The distance from boats did not interfere in the surfacing pattern of the dolphins. However, the results from Pipa Beach (Valle & Melo, 2006) and North Bay, Santa Catarina (Pereira *et al.*, 2007), showed behavioural variations in the dolphins relative to the distance of dolphin watching tourism vessels, where the boats followed the animals for a longer period of time. The proximity to the animals, the increased noise and the risk of damage caused by collision could explain these differences in results regarding the distance to vessels and traffic patterns. The Port of Malhado is an important area for dolphins and boat traffic can be a threat to the dolphin population. Some conservation measures should be enacted, including determining an area for vessel passage other than the area used most by dolphins and limiting the use of boats with an outboard motor in the area.

For a more comprehensive analysis of behavioural changes caused by vessels in *S. guianensis* at Port of Malhado, it is necessary that other reactions are analysed, such as group cohesion up-down movements in the area, the change in group composition during the day and other changes in behavioural states, such as foraging and socialization periods.

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