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RESEARCH ARTICLE

Environmental factors related to group size and habitat use of Guiana dolphins from São Marcos Bay, Amazon coast

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Abstract

Environmental changes can affect the social structure and disrupt habitat use of marine mammal species. An impact on the social dynamics of dolphins, including group size structure, may attenuate the feeding success and increasing predation risk, especially considering species exhibiting small home ranges, which impose particular habitat dependency and high vulnerability to environmental changes. In this regard, the Guiana dolphin (*Sotalia guianensis*, Van Benéden, 1864) is a particularly endangered species due to its coastal distribution and considerable small home range. The aim of this study was first to conduct a spatial assessment of the dolphin groups sighted in the São Marcos Bay (SMB; Northeastern Brazil), one of the most important port areas in Brazil. The results show an overlap between the distribution of the dolphin groups and the port activities area, which includes the loading zone at the main port area and the navigation channel used by large cargo ships and other vessels. Also, a GLM regression was conducted to identify the best combination of selected variables that best predict the group size of the dolphins. The predictor variables included: salinity, sea surface temperature, depth, water transparency, distance from the main port area, and the feeding activity of the groups sighted. The results indicated that larger dolphin groups were found in areas closer to the main port area and were associated with foraging activities. Therefore, the results suggest that this dolphin population might be exposed to threats linked to the port activities, which may include noise pollution, vessel collision, and chemical pollution.

Keywords Amazon coast · Brazil · Environmental change · Group size · Guiana dolphin · *Sotalia guianensis*

Introduction

Environmental changes and human-related threats can affect habitat use and disrupt the group composition of dolphins' species that are highly dependent on social interactions (Acevedo-Gutiérrez 2018). An impact on the social system of top predators such as dolphins may trigger population instability and decline, which can negatively affect the trophic dynamic of the environment and break up important ecosystem functions (Midgley 2012).

One of the social traits that can be straightly affected by environmental changes is group size (Sarabia et al. 2017). Cetaceans display high intra- and inter-specific variability in social aggregation, which depends on habitat characteristics and ecological factors that determine the best group size and its dynamics to maximize the survival rate (Blasi and Boitani 2014). For example, offshore species tend to form large groups as a social mechanism to minimize the risk of predation and to deal with less regular prey availability. Conversely, coastal species tend to form smaller groups as prey resources are generally more predictable and the predation risk is comparatively reduced (Acevedo-Gutiérrez 2018). Living in groups provides numerous advantages at individual and population levels. Breaking this socio-evolutionary property may lead to survivorship problems, especially for species exhibiting small home ranges, which impose particular habitat dependency and high vulnerability to environmental changes (Acevedo-Gutiérrez 2018). In this regard, the Guiana dolphin, *Sotalia guianensis* (Van Benéden 1864) is a particularly endangered species due to

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(1) its coastal distribution, typically inhabiting waters up to 30 m deep (Flores et al. 2018), and (2) its considerable small home range (Flores et al. 2018). The Guiana dolphin, subject species of this scientific investigation, is a small coastal delphinid (maximum length about 2 m) that occurs exclusively along the Western Atlantic coastal waters, from Santa Catarina (27°S, Brazil) to Honduras (14°N, Central America) (Flores et al. 2018). This species exhibits a high preference for estuarine and protected shallow waters throughout its distribution (da Silva et al. 2010).

Among other threats (e.g. bycatch and marine pollution), habitat loss and modification caused by a number of anthropogenic activities on coastal ecosystems are growing challenges for the populations of *S. guianensis*, especially those located in areas with high level of urbanization, with intense tourism, and with heavy port activities (Moura et al. 2014).

Although considerable scientific efforts have expanded the knowledge about this coastal dolphin, the scarcity of basic information is still persisting in several areas along its geographical distribution, which justifies the classification of the species as "data deficient" by the red list of the International Union for the Conservation of Nature (Secchi 2012; Moura et al. 2014). The Amazon coast, including the São Marcos Bay (Maranhão state), is a region where scarcity of information about *S. guianensis* is still an important conservation challenge, although there are pieces of evidence showing that this species is relatively common in this region (Garri et al. 2008; Siciliano et al. 2008). Few observations carried out in the aforementioned bay also indicate that anthropogenic activities such as fishery may be a potential threat for the conservation of this small cetacean in the region (Garri et al. 2008).

In light of the information about the threats over *S. guianensis* and their potential to unbalance the species functional traits, (here group size), we aim to investigate how selected variables affect group size structure in an intense Port area in northern Brazil.

Materials and methods

Study area

The São Marcos Bay (SMB), together with its neighbor São José Bay, forms the Maranhense Gulf geologic system, which includes small rivers, several islands, enclosed estuaries, complex mangroves, straits, inlets, and tidal flats (El-Robrini et al. 2006). The SMB, spread approximately 100 km in length and measure about 23,600 km^2 in its main area (Rodrigues et al. 2016). At the mouth of the bay, the approximate width is 55 km, narrowing to 15 km in its central part and expanding its width again in the interior section, reaching 25 km (El-Robrini et al. 2006). The SMB is an estuarine system, dominated by mangroves, and its hydrodynamics are influenced by the discharge of three rivers (Grajaú, Mearim, and Pindaré) and by a substantial exchange with the ocean waters (González-Gorbeña et al. 2015). The hydrodynamic of the bay is also characterized by large variations of semidiurnal tides, whose maximums can reach 7.2 m in large equinoctial syzygy tides. However, the maximum tidal amplitude is typically less than 5.5 m (El-Robrini et al. 2006).

The bathymetry of the bay shows depth reaching 97 m in its central channel, which facilitates the navigation of heavy cargo ships to transport minerals from the port complex located in bay, which includes the Port of São Luis, the Port of Itaqui, the Ponta da Madeira Terminal (PMT), and the Alumar terminal (González-Gorbeña et al. 2015). The PMT, for example, is the national leader in volume of cargo transport, with an annual movement of 120 millions tons of minerals, including, among other products, iron ores, steel and aluminum mills (Camelo et al. 2010).

Study design and data collection

The SMB was surveyed for the occurrence of dolphins and environmental sampling activities in two periods, comprising 25 days of fieldwork in total. The first sampling period was carried out from the 10th to the 19th of December 2013 and the second one from the 7th to the 21st of January 2014. The fieldwork was conducted using a wooden fishing boat of 15 m long, using an active search and visual census technique (Santos and Rosso 2007), keeping a boat speed varying from 15 and 18.5 km/h. The survey path followed a "zig-zag" configuration of linear transects to maximize chances of encountering dolphins (Santos and Rosso 2007). Each day of survey activities started alternately from each extremity of the transect path (Fig. 1).

Two trained observers were positioned at opposed sides of the boat prow, each covering approximately 90° of the onward view along the path.

For every Guiana dolphin groups sighted, information about their characteristics and also about the environment condition at the specific sighting location and time were recorded. The information collected about the dolphins included group size and the presence of calves. For this study we considered the information of group size valid only when (1) the observers were close enough to the dolphins (around 100 m distance), and (2) when the time of observation was superior of 5 min. Normally, photos taken from the dolphins were later analyzed in order to better estimate the size of the groups and to reduce uncertainties of this assessment.

For each sighting location, a number of environmental variables were measured, including sea surface temperature-SST (°C), salinity (ppm), water transparency (cm) and depth

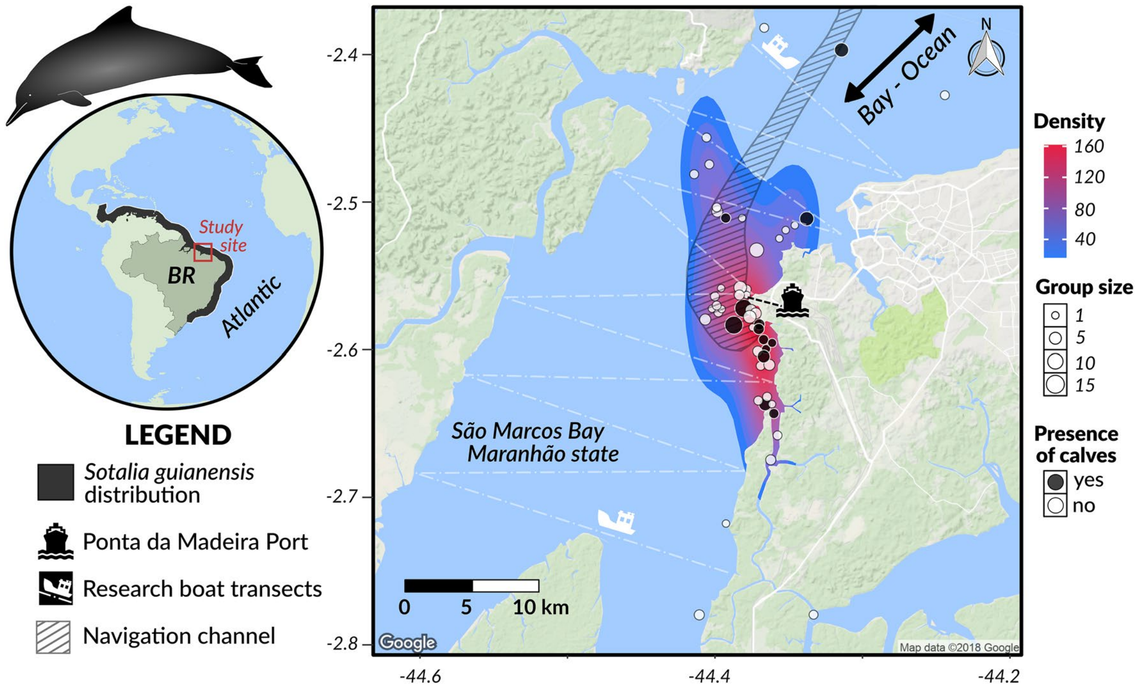

Fig. 1 Synoptic map showing the distribution of observations of the Guiana dolphins sighted discriminated by group size and presence/absence of calves at the São Marcos Bay. The figure also presents the (1) the line-transect path surveyed, (2) the navigation channel used by large vessels to access the ports (González-Gorbeña et al. 2015), and (3) the kernel density estimation for the distribution of sightings

(m). These variables typically determine the habitat characteristics of cetacean species, and variations in such conditions may affect their distribution and movements (Tobeña et al. 2016).

Depth data were collected using a portable echo-sounder with a 0.1 m precision. SST was measured with an alcohol thermometer in the water surface. Salinity was inferred by using a handheld refractometer. Finally, water transparency was estimated with a radius Secchi disk graduated in centimeter.

Data on the foraging activity of the dolphins were also collected, as feeding behavior is generally linked to group size of Guiana dolphins (Oliveira et al. 2013). The groups sighted were classified as performing foraging activities when the majority of the dolphins were engaged on feeding behavior, which was determined by rapid surfaces swimming, frequent direction changes, fish chases, and observations of fish catches (Pennino et al. 2013).

Furthermore, in order to check if the port activities conducted at the loading zone at the Ponta da Madeira Maritime Terminal (PMT) may influence the dynamics of the dolphin groups, the rectilinear distances (in km) between the PMT and every group sighted were later quantified and treated as a variable. Information about sea conditions (Beaufort scale: 1–5), geographical coordinates; date and time were also recorded. The field activities were conducted with sea Beaufort scale under 3.

Data analysis

A descriptive spatial assessment of the dolphin groups sighted was conducted in order to identify patterns in the distribution of the dolphins in the SMB. For the purpose of the spatial distribution analysis a heatmap was produced, where the gradient was calculated using a 2-dimensional kernel density estimate, based on bivariate normal distributions. The spatial probability density estimation was computed using the "kde2d" function from the R "MASS" package using default settings (Venables and Ripley 2002) and plotted with the "stat_density2d" and "ggplot" functions from the R package "ggplot2" (Wickham 2016). The sightings of Guiana dolphins in the map are discriminated by the group size and by the presence/absence of calves. The map was elaborated by using the R package "ggmap" (Kahle et al. 2019). Geographical elements of importance for this study were also plotted on the map, which includes the Ponta da Madeira Maritime Terminal (PMT), and the boat survey transects undertaken during the fieldwork campaigns.

Generalized linear models (GLMs) were used to detect which set of variables may be related to the group size of Guiana dolphins monitored in this study. Group size was included as a response variable under the influence of the following fixed predictor variables: (1) water depth (in m), (2) salinity (ppm), (3) water transparency (in cm), (4) SST (in °C), (5) foraging activity, and (6) distance from the main area of the Ponta da Madeira Maritime Terminal (PMT; in km). Prior to the GLM procedure, a detailed data exploration was performed to check for outliers, collinearity, and overdispersion as suggested by Zuur et al. (2009).

The GLM models were constructed step-by-step by reducing the full model, which initially included all the predictor variables (Tavares et al. 2015), using the negative-binomial as the best error distribution, followed by graphical diagnostics (Zuur et al. 2009). Given the relatively small number of observations and the number of explanatory variables considered in the modeling approach, the Akaike's Information Criterion with small-sample correction (AICc) was used for the model selection. The lowest AICc scores indicated the models with the best performances and the set of predictor variables that contributed to the model evaluation (Burnham and Anderson 2002). Adjusted deviance explained by the final selected model was calculated using "Dsquared" function from the R package "modEvA" (Barbosa et al. 2016).

Results

A total of 52 groups of Guiana dolphins (174 individuals in total) were sighted during about 178 h of field effort along 25 days of sampling activities in the SMB (Table 1). On average, the dolphin' groups were composed of 3.35 dolphins, ranging from 1 to 15 individuals. Calves were present in 27% of the groups sighted. In 85% of the groups presenting calves, only one calf was recorded.

Table 1 presents summary statistics of the environmental data collected at the locations where the dolphin groups were recorded. The mean SST measured in the SMB was 26.4 °C. On average, the dolphin groups were recorded in waters of 20.4 m deep, varying from 2.4 to 47 m. Values for salinity ranged from 28.0 to 36.0 psu (mean = 31.85) and the measurements for water transparency indicates a substantial turbid environment in general, with mean values of 19.17 cm of visibility (Secchi disc). The linear distances between the spatial location of dolphin groups sighted and the PMT were also measured and ranged from 0.2 to 23.1 km.

Table 1 Descriptive statistics for the environmental variables, the time of observation per group of dolphins sighted, and for the group size of Guiana dolphins

Parameters	Mean	Range	SD
Time of observation per group (min)	18.8	2–80	16.7
Dolphins per group (n)	3.3	1–15	3.0
Calves per group (n)	0.6	0–3	0.6
Distance from port (km)	6.6	0.2–23.1	6.2
Sea surface temperature–SST (°C)	26.4	24.0–27.1	0.67
Depth (m)	20.4	2.4–47.0	10.1
Salinity (psu)	31.85	28.0–36.0	2.63
Water transparency (cm)	19.17	10.0–31.0	4.96

The spatial assessment shows that most dolphin' groups were sighted in waters near the PMT, as the kernel density analysis and distribution of the sightings suggest (Fig. 1). Some groups were also recorded in the inner and outer part of the bay. In consonance with the overall spatial configuration of the data points, the groups presenting calves were also found in waters close to the PMT. The spatial distribution of the dolphin groups indicates that dolphins may use regularly the navigation channel used by large cargo ships to access the PMT.

The selected GLM model (explaining 65.93% of the variation present in the data) included the following predictor variables correlated with the group size of Guiana dolphins: distance from the PMT and foraging activity (Fig. 2, Table 2). The model showed a negative relationship between the group size and the variables distance from PMT, while the response variable showed a positive association with foraging activities. More specifically, the GLM model suggests that the dolphins tend to occur in larger groups in waters closed to the PMT for foraging purpose.

Discussion

In general, the group sizes of the Guiana dolphins observed in the SMB were fairly small and consistent with the populations living in protected estuarine areas and bays (Azevedo et al. 2005; Santos and Rosso 2007), contrasting with those Guiana dolphin populations inhabiting open coastal areas and open bays, which exhibit substantially larger groups (de Souza et al. 2008; Tardin et al. 2013).

Our descriptive spatial assessment shows an overlap between the distribution of the Guiana dolphin groups and the port activities area, which includes the loading zone at PMT and the navigation channel, used by large cargo ships, tugboats and other vessels. Also, larger groups of dolphins were commonly sighted near the PMT. Izidoro and Le Pendu (2012), as a comparative illustration, reported that the occurrences of *S. guianensis* were also frequent near the port of Ilhéus, Baía State (Brazil), although more frequently when large cargo ships where absent.

The spatial distribution of the dolphins and the human-related activities conducted at the SMB suggest that the population of *S. guianensis* using the bay may be under substantial human-related pressure. For example, given the observed high density of sightings in the navigation channel, problems such as boat collision (Van Waerebeek et al. 2007; Tardin et al. 2013) and noise pollution (Marega-Imamura et al. 2018; Pais et al. 2018) may be important anthropogenic

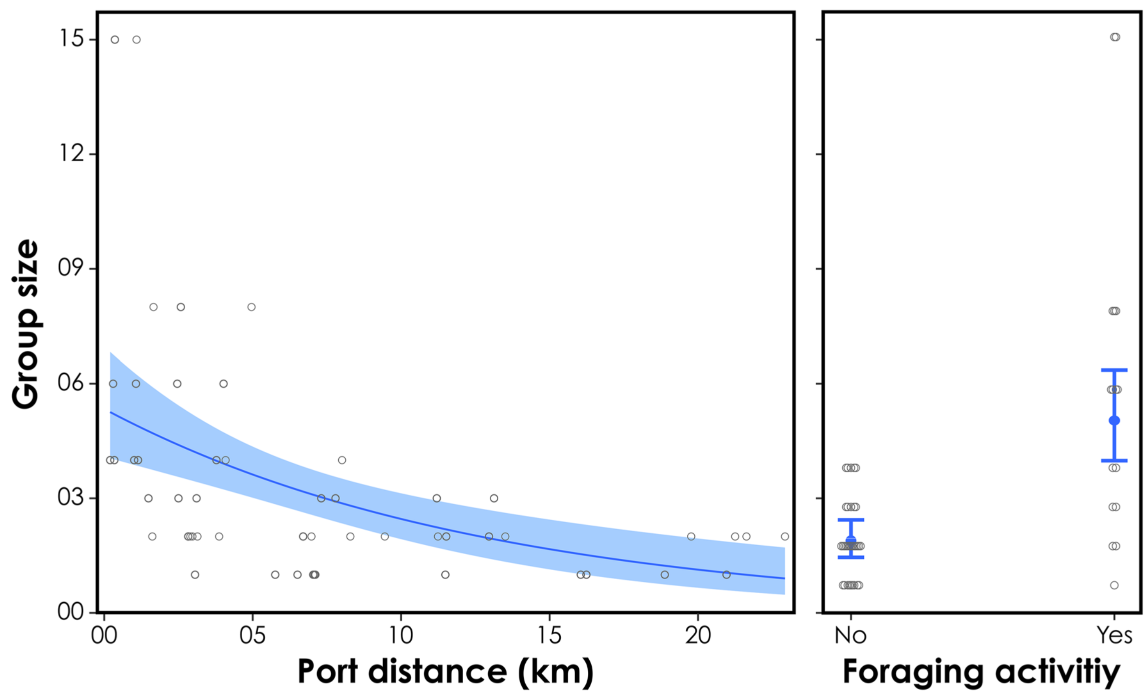

Fig. 2 Results of the generalized model showing the two most important predictor variables for explaining the variability in the group size of Guiana dolphins. The subplot **a** presents the predicted curve for the variable port distance (95% confidence bands) and the subplot **b** displays the predicted mean group size (95% confidence interval) when foraging is active in the group or not

Table 2 Summary statistics for preferred GLM model fits

Response variables	AICc	Parameter	Estimate ± SE	*p* value
Group size	191.91	α	1.2216 ± 0.1475	< 0.001
		βPortDist	− 0.0658 ± 0.0158	< 0.001
		βForagYes	0.8938 ± 0.1557	< 0.001

For each model, the associated Akaike's information criterion (AIC) indices are presented; along with the parameters estimates for intercept "α" and slope "β", their respective standard error, and *p* values

factors affecting the species at SMB. Another threat that might emerge from the aggregations of *S. guianensis* near the PMT may be related to the dolphins' exposure to harmful levels of persistent toxic chemicals (including Al, Cd, Pb, Hg, tributyltin and polychlorinated biphenyls), as the study conducted by Carvalho-Neta et al. (2012) may suggest. Those authors found that high levels of chemical contaminants in areas close to the PMT were associated to branchial lesions and other enzymatic responses in catfishes (*Sciades herzbergii*), a species typically consumed by dolphins of the genus *Sotalia* inhabiting the estuarine areas from the Amazon coast (Beltrán-Pedreros and Pantoja 2006).

Our GLM model results suggest that Guiana dolphins occur in larger groups more likely for foraging purposes and in waters closer to the PMT. In general, group size formation in dolphin species is a socio-evolutionary development mostly linked to foraging efficiency, to resource defense, and to a defense mechanism against predators (Acevedo-Gutiérrez 2018).

Previous studies have demonstrated that Guiana dolphins forage typically in groups and in a cooperative and coordinated manner to maximize feeding efficiency (Rossi-santos and Flores 2009; Tardin et al. 2011; Oliveira et al. 2013).

Although large group formation may increase the foraging efficiency of the Guiana dolphins using the SMB, their spatial distribution closer to the PMT is likely to pose some risk to the population due to the port-related activities. For example, noise activities associated with the port activities at the PMT may disrupt the dolphin's communication, crucial for feeding efficiency (Wisniewska et al. 2018). Dolphins living in a habitat with high water turbidity, such as at the SMB, may rely especially on acoustic communication to interact with the environment and with the group members (Herzing and Johnson 2015; Leão et al. 2016). In high turbid waters, the dolphins might be highly sensitive to noise pollution associated to the port activities and vessels, which can affect important social interactions and vital activities such as foraging ability (Jensen et al. 2009; Nachtigall et al. 2018).

Conclusion

This study indicates that the Guiana dolphins inhabiting the São Marcos Bay (SMB) are most regularly found in waters near the Ponta da Madeira Terminal (PMT). Also, the spatial distribution of dolphins in the bay considerably overlaps with the navigation routes of large vessels that use the port for loading with materials. Furthermore, the regression model suggests that *S. guianensis* occurs in larger groups in waters closer to the PMT more likely for foraging. The results bring new scientific information about habitat use and group characteristics of a species fairly unknown along the Amazon coast and especially in the SMB. Moreover, this study highlights the necessity to investigate whether and how the port-related activities at the PMT may affect the dolphins' communities using the SMB.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Acevedo-Gutiérrez A (2018) Group Behavior. In: Wursig B, Thewissen JGM, Kovacs KM (eds) Encyclopedia of marine mammals, 3rd edn. Elsevier Academic Press, California, pp 428–435
Azevedo AF, Viana SC, Oliveira AM, Van Sluys M (2005) Group characteristics of marine tucuxis (*Sotalia fluviatilis*) (Cetacea: Delphinidae) in Guanabara Bay, south-eastern Brazil. J Mar Biol Assoc U K 85:209–212
Barbosa AM, Brown JA, Jimenez-Valverde A, Real R (2016) Package "modEvA": model evaluation and analysis version. Compr. R Arch. Netw., pp 1–45
Beltrán-Pedreros S, Pantoja TM (2006) Feeding habits of *Sotalia fluviatilis* in the Amazonian Estuary. Acta Sci Biol Sci 28:389–393
Blasi MF, Boitani L (2014) Complex social structure of an endangered population of bottlenose dolphins (*Tursiops truncatus*) in the Aeolian Archipelago (Italy). PLoS One 9:e114849
Burnham KP, Anderson DR (2002) Model selection and multimodel inference. Springer, New York
Camelo GR, Coelho AS, Borges RM, Souza RM (2010) Teoria das filas e da simulação aplicada ao embarque de minério de ferro e manganês no terminal marítimo de Ponta da Madeira. Cad do IME Série Estatística 29:1–16
Carvalho-Neta RNF, Torres AR, Abreu-Silva AL (2012) Biomarkers in catfish *Sciades herzbergii* (Teleostei: Ariidae) from polluted and non-polluted areas (São Marcos' Bay, Northeastern Brazil). Appl Biochem Biotechnol 166:1314–1327
da Silva VMF, Fettuccia D, Rodrigues ES, Edwards H, Moreno IB, Moura JF, Wedekin LL, Bazzalo M, Emin-Lima NR, Carmo NAS, Utreras V (2010) Report of the working group on distribution, habitat characteristics and preferences, and group size. Lat Am J Aquat Mamm 8:31–38
de Souza AS, Torres JPM, Meire RO, Neves RC, Couri MS, Serejo CS (2008) Organochlorine pesticides (OCs) and polychlorinated biphenyls (PCBs) in sediments and crabs (*Chasmagnathus granulata*, Dana, 1851) from mangroves of Guanabara Bay, Rio de Janeiro State, Brazil. Chemosphere 73:S186–S192
El-Robrini M, Marques VJ, Silva MA, El-Robrini MHS, Feitosa A, Tarouco JEF, Santos JHS, Viana JR (2006) Maranhão. In: Muehe D (ed) Erosão e progradação do litoral Brasileiro. IBAMA-MMA, Brasília, pp 87–130
Flores PAC, da Silva VMF, Fettuccia DC (2018) Tucuxi and Guiana dolphins: *Sotalia fluviatilis* and *S. guianensis*. In: Wursig B, Thewissen JGM, Kovacs KM (eds) Encyclopedia of marine mammals, 3rd edn. Elsevier Academic Press, California, pp 1024–1027
Garri RG, Magalhães FA, Tosi CH, Júnior TBL (2008) Conservação dos Cetáceos no Maranhão. In: Selbach J, Leite JRSA (eds) Meio ambiente no Baixo Parnaíba: olhos no mundo, pés na região. EDUFMA, São Luis, pp 135–150
González-Gorbeña E, Rosman PCC, Qassim RY (2015) Assessment of the tidal current energy resource in São Marcos Bay, Brazil. J Ocean Eng Mar Energy 1:421–433
Herzing DL, Johnson CM (2015) Dolphin communication and cognition: past, present, and future. MIT Press, Cambridge
Izidoro FB, Le Pendu Y (2012) Estuarine dolphins (*Sotalia guianensis*) (Van Bénéden, 1864) (Cetacea: Delphinidae) in Porto de Ilhéus, Brazil: group characterisation and response to ships. North West J Zool 8:232–240
Jensen FH, Bejder L, Wahlberg M, Soto NA, Johnson M, Madsen PT (2009) Vessel noise effects on delphinid communication. Mar Ecol Prog Ser 395:161–175
Kahle D, Wickham H, Jackson S, Korpela M (2019) Ggmap: spatial visualization with ggplot2. v.3.0.0, pp 1–65
Leão DT, Monteiro-Filho ELA, Silva FJL (2016) Acoustic parameters of sounds emitted by *Sotalia guianensis*: dialects or acoustic plasticity. J Mammal 97:611–618
Marega-Imamura M, Carvalho GH, Le Pendu Y, da Silva PS, Schiavetti A (2018) Behavioral responses of *Sotalia guianensis* (Cetartiodactyla, Delphinidae) to boat approaches in northeast Brazil. Lat Am J Aquat Res 46:268–279
Midgley GF (2012) Biodiversity and ecosystem function. Science 335:174–175
Moura JF, Hauser-davis RA, Lemos L, Emin-Lima R, Siciliano S (2014) Guiana dolphins (*Sotalia guianensis*) as marine ecosystem sentinels: ecotoxicology and emerging diseases. Rev Environ Contam Toxicol 228:1–29
Nachtigall PE, Supin AY, Pacini AF, Kastelein RA (2018) Four odontocete species change hearing levels when warned of impending loud sound. Integr Zool 13:160–165
Oliveira ECS, Tardin RH, Poletto FR, Simão SM (2013) Coordinated feeding behavior of the Guiana dolphin, *Sotalia guianensis* (Cetacea: Delphinidae), in southeastern Brazil: a comparison between populations. Zoologia 30:585–591
Pais FDS, Cardoso RP, Rossi-santos MR, Wedekin LL, Silva FJL, Monteiro-Filho ELA, Leão DTM (2018) Anthropogenic noise and Guiana dolphins (*Sotalia guianensis*) in Brazil: ecological and conservation concerns. In: Rossi-Santos MR, Finkl CW (eds) Advances in marine vertebrate research in Latin America. Springer, Cham, pp 321–366
Pennino MG, Mendoza M, Pira A, Floris A, Rotta A (2013) Assessing foraging tradition in wild bottlenose dolphins (*Tursiops truncatus*). Aquat Mamm 39:282–289

Rodrigues CAL, Ribeiro RP, Santos NB, Almeida ZS (2016) Patterns of mollusc distribution in mangroves from the São Marcos Bay, coast of Maranhão State, Brazil. Acta Amaz 46:391–400

Rossi-santos MR, Flores PAC (2009) Feeding strategies of the Guiana dolphin *Sotalia guianensis*. Open Mar Biol J 3:70–76

Santos MCO, Rosso S (2007) Ecological aspects of marine tucuxi dolphins (*Sotalia guianensis*) based on group size and composition in the Cananéia Estuary, southeastern Brazil. Lat Am J Aquat Mamm 6:71–82

Sarabia RE, Heithaus MR, Kiszka JJ (2017) Spatial and temporal variation in abundance, group size and behaviour of bottlenose dolphins in the Florida coastal Everglades. J Mar Biol Assoc U K 98:1097–1107

Secchi ER (2012) *Sotalia guianensis.* IUCN Red List Threat. Species. https://doi.org/10.2305/IUCN.UK.2018-2.RLTS.T181359A144232542.en

Siciliano S, Emin-lima NR, Costa AF, Rodrigues ALF, Magalhães FA, Tosi CH, Garri RG, da Silva CR, Silva JS (2008) Revisão do conhecimento sobre os mamíferos aquáticos da costa norte do Brasil. Arq do Mus Nac 66:1–21

Tardin RHO, Especie MA, Nery MF, D'Azeredo FT, Simão S (2011) Coordinated feeding tactics of the Guiana dolphin, *Sotalia guianensis* (Cetacea: Delphinidae), in Ilha Grande Bay, Rio de Janeiro, Brazil. Zoologia 28:291–296

Tardin R, Galvão C, Espécie M, Simão S (2013) Group structure of Guiana dolphins, *Sotalia guianensis* (Cetacea, Delphinidae) in Ilha Grande Bay, Rio de Janeiro, southeastern Brazil. Lat Am J Aquat Res 41:313–322

Tavares DC, Guadagnin DL, Moura JF, Siciliano S, Merico A (2015) Environmental and anthropogenic factors structuring waterbird habitats of tropical coastal lagoons: implications for management. Biol Conserv 186:12–21

Tobeña M, Prieto R, Machete M, Silva MA (2016) Modeling the potential distribution and richness of cetaceans in the Azores from fisheries observer program data. Front Mar Sci 3:1–19

Van Waerebeek K, Baker AN, Félix F, Iñiguez M, Sanino GP, Secchi E, Sutaria D, van Helden A, Wang Y (2007) Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Lat Am J Aquat Mamm 6:43–69

Venables WN, Ripley BD (2002) Modern Applied Statistics with S. Springer, New York

Wickham H (2016) Ggplot2—elegant graphics for data analysis. Springer, New York

Wisniewska DM, Johnson M, Teilmann J, Siebert U, Galatius A, Dietz R, Madsen PT (2018) High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). Proc R Soc B 285:20172314

Zuur A, Ieno EN, Walker N, Saveliev AA, Smith GM (2009) Mixed effects models and extensions in ecology with R. Springer, New York