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Behavioural seasonality of the estuarine dolphin, *Sotalia guianensis*, on the north-eastern Brazilian coast

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This study tested the association between variation in precipitation and behavioural seasonality in *Sotalia guianensis*, at the Curral inlet (6°13'00"S 35°3'00"W) in north-eastern Brazilian coast. From October 1999 to September 2003, observations were carried out four days a month. Behaviours were registered instantaneously each five minute interval. The observation period consisted of six hours into the daytime (0600 to 1700 h). Two observers inspected the area simultaneously, from a fixed location at the top of the cliff. During June to November, socialization (Md_{JN}=1.524; Md_{DM}=0.667; *U*=–2.848; *P*=0.004) and forage (Md_{JN}=3.268; Md_{DM}=1.762; *U*=–2.881; *P*=0.004) were significantly higher than from December to May, although the number of individuals (Md_{JN}=6.000; Md_{DM}=5.000; *U*=–1.395; *P*=0.163) did not change over the year. Such behavioural seasonality was not associated with dry/rainy periods (number of individuals: Md_{RS}=5.000; Md_{DS}=6.250; *U*=–1.672; *P*=0.095; socialization: Md_{DS}=0.947; Md_{RS}=1.464; *U*=–0.858; *P*=0.391; and forage: Md_{DS}=3.017; Md_{RS}=2.292; U=–1.506; *P*=0.132). These results support behavioural seasonality in an equatorial odontocete population.

INTRODUCTION

While in higher latitudes climate fluctuations affect the behaviour of odontocetes, in lower latitudes such an effect does not occur (Shane et al., 1986; Read, 1990; Urian et al., 1996). Considering the few studies carried out in such equatorial regions and the minimal climate variations, cetacean behavioural rhythms are not expected in these places.

Sotalia guianensis (van Bénéden, 1864), the focused species in this research, is of interest because of its wide latitudinal occurrence (from 15°N to 27°S, Geise et al., 1999) in several places on the Brazilian coast, including subtropical regions. Like most other small cetaceans, the behaviour of *S. guianensis* is synchronized with environmental cycles. An example is the variation in number of individuals and/or forage activity over the year because of fluctuations in food availability (Geise et al., 1999; Hayes, 1999; Di Benedito et al., 2001; Araújo et al., 2001; Lodi, 2003) or use/overlap of areas by different species of dolphins associated with prey migration (Flores & Bazzalo, 2004; Wedekin et al., 2004; Daura-Jorge et al., 2005). Despite this, little is known about the behavioural changes in species from equatorial regions, where environmental changes are minimal. In equatorial regions, the rainy period is one of the most relevant climatic factors to the behavioural seasonality of terrestrial animals (Moore et al., 2005; Schradin & Pilay, 2006; Thorup et al., 2005).

In the present study, we tested the association between variation in precipitation and behavioural seasonality (number of individuals, socialization and forage) in an equatorial population of *Sotalia guianensis*.

MATERIALS AND METHODS

This study was carried out at the Curral inlet (6°13'36"S 35°3'00"W), an area of about 1 km in length, located in Pipa beach, northern Brazilian coast (Figure 1). The line delimiting the observation area is about 1000 m long and its longer distance from the beach is about 400 m in the central area. The inlet extremities are composed of rocky (sedimentary) formation, which reaches from the bottom through the extension of beach and reaches the 'falésia' (a kind of cliff up to 30 m high). Maximum depth is 5 m and the bottom is exclusively

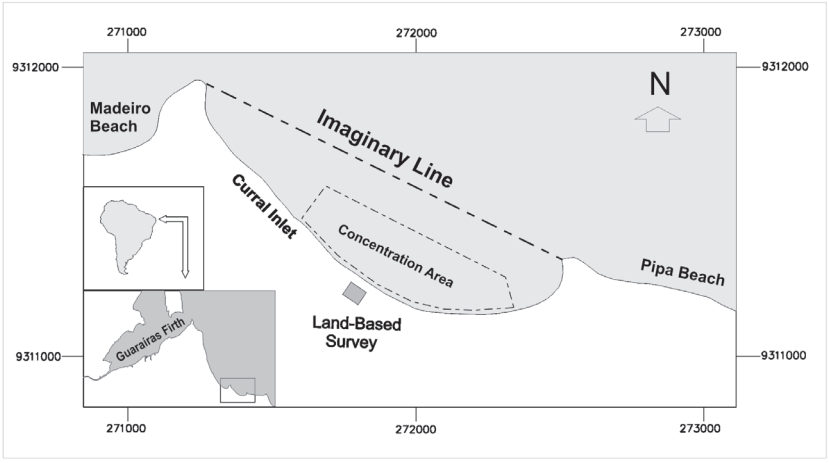

Figure 1. Study area (Curral inlet, Pipa, Rio Grande do Norte, Brazil).

composed of sand. The right side is protected from wind (<1.0 on the Beaufort scale) and coastal streams, where environmental conditions fluctuate much less than in the left side. The study area is also influenced by the estuary of Guaraíra lagoon, which is located about 5 km to the north (Figure 1).

Four observations were performed per month, from October 1999 to September 2003. Each observation period lasted six hours and was distributed along the daylight period (from 0600 to 1700 h). Behaviour was registered instantaneously every five minutes. Two observers registered simultaneously the area by means of binoculars (10x50 mm). They were positioned always in the same place on a high cliff-top. Numbers of individuals and the frequency of behaviours were registered for the dolphins in the observation area.

For such a goal, observations were carried out continuously, although registration was restricted to the five-minute intervals. Such a methodology prevented repeated quantification of the same individual. Despite each individual being carefully observed, we considered the behaviour displayed by most of the individuals in the longest period of time in the inlet, as suggested by Mann (1999).

The frequencies of the following behaviours were registered (from Mann, 2000):

Socialization (according to Acevedo-Gutiérrez et al., 2005; Daura-Jorge et al., 2005): any activity not considered forage. These activities included physical contact among conspecifics (agonistic or associative behaviours) and jumps out of the water exposing totally or partially the body, irrespective of the animal position.

Forage (based on Monteiro-Filho, 1995; Monteiro et al., 2006): any activity associated with food acquisition.

For quantification of the daily number of individuals, it was considered the maximum number of individuals counted that day. For behaviours, it was computed as the frequency of behaviour per hour of observation each day.

For quantification of precipitation, 0.50 mm^3 was considered the precipitation quantity that determines one day of rain, as described by the Instituto Nacional de Meteorologia (INMET), 1999. Therefore, the rainy season (RS) occurred from March to August, with the precipitation median above 0.50 mm^3; the dry season (DS) occurred from September to February (precipitation median below 0.50 mm^3). Precipitation data were obtained from Empresa de Pesquisa Agropecuária do Rio Grande do Norte (EMPARN) and the Department of Geography of the Universidade Federal do Rio Grande do Norte (Figure 2D).

Data showed non-normal distribution (Kolmogorov–Smirnov test) and were then analysed by the Mann–Whitney *U*-test. The significance level was set at α=0.05.

RESULTS

Frequency of *Sotalia guianensis* was registered every observation day (N=192), ranging from 3 to 12 animals (Md=6.00). The median of these frequencies changed over the year, considering the four years of the present study, as shown in Figure 2A. However, comparison of the higher and lower maximums (Md_{JN}=6.000; Md_{DM}=5.000; *U*=–1.395; *P*=0.163) showed no significant change (Figure 3). The maximum number of individuals in one day was also not different significantly between the dry and the rainy seasons (Md_{RS}=5.000; Md_{DS}=6.250; *U*=–1.672; *P*=0.09 5) (Figure 3).

Similarly, frequency of socialization (Md_{DS}=0.947; Md_{RS}=1.464; *U*=–0.858; *P*=0.391) and forage (Md_{DS}=3.017; Md_{RS}=2.292; *U*=–1.506; *P*=0.132) were not affected by dry or rainy season (Figure 3). On the other hand, socialization (Md_{JN}=1.524; Md_{DM}=0.667; *U*=–2.848; *P*=0.004) (Figure 2B) and forage (Md_{JN}=3.268; Md_{DM}=1.762; *U*=–2.881; *P*=0.004) (Figure 2C) behaviours were significantly more frequent from June to November and less frequent from December to May (Figure 3).

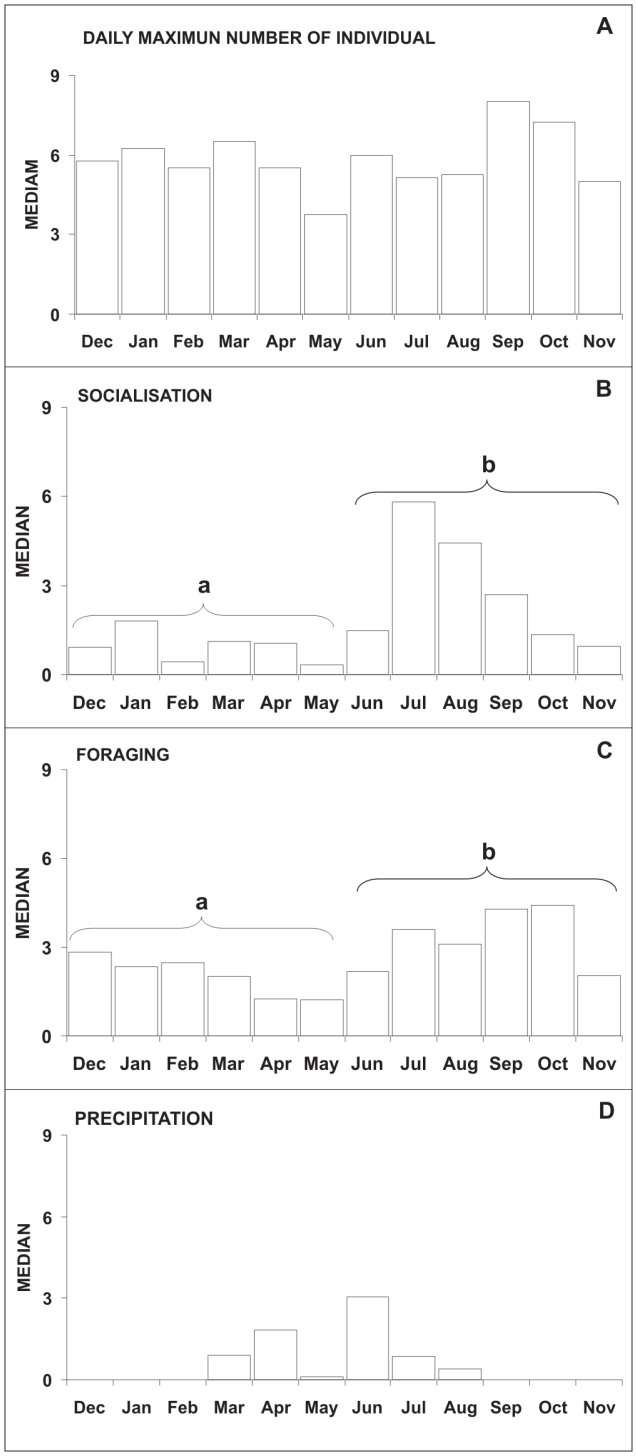

Figure 2. Median values of the investigated behaviour quantified in four years. (A) Daily maximum number of individuals; (B) socialization; (C) forage; and (D) precipitation (mm^3) in the Curral inlet, Pipa, north-eastern Brazilian coast. The lower case letters indicate a statistically significant difference among groups (*P*<0.05).

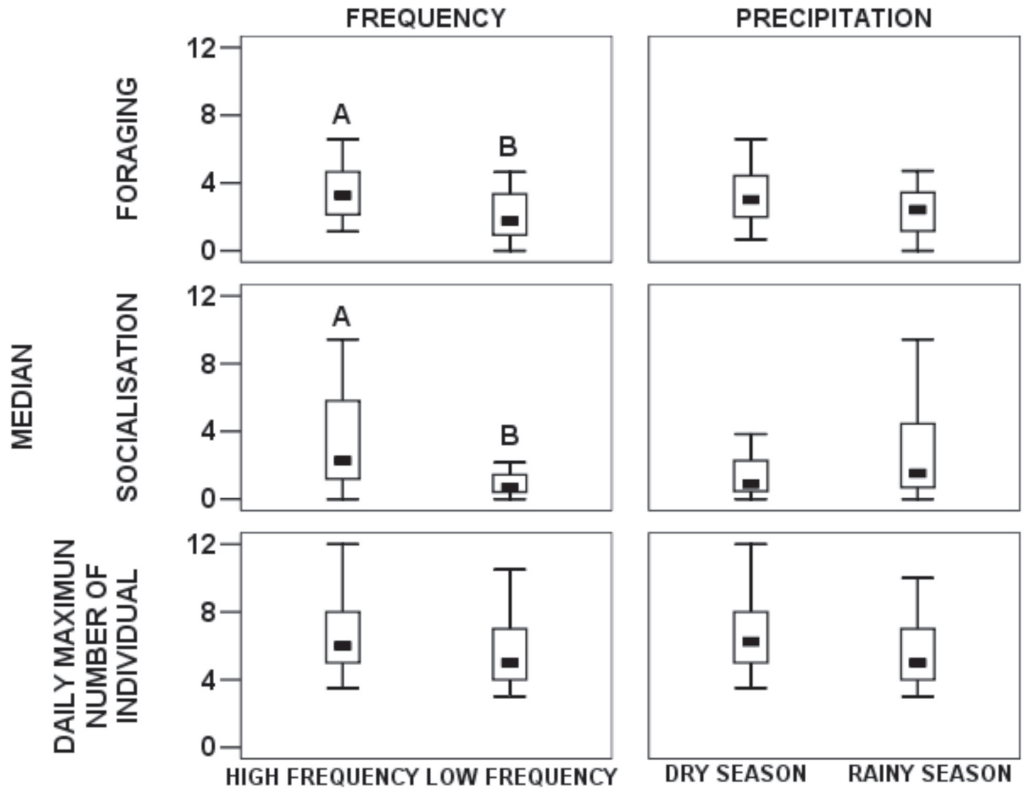

Figure 3. Maximum number of individuals/day, socialization activity and forage according to higher or lower frequency over the year and precipitation period. Upper case letters indicate a statistically significant difference between groups ($P<0.05$).

DISCUSSION

In the present study we showed that there is no marked seasonality in the frequency of *Sotalia guianensis* throughout the year and also between dry and rainy seasons. Socialization and forage activities were also not affected by these seasons. On the other hand, socialization and forage frequencies showed cyclic patterns over the year. As these changes were not associated with rainy or dry seasons, other environmental fluctuations may be implicated.

Araújo (2001) reported that *S. guianensis* is present in the Curral inlet over the whole year, showing no seasonal variation of the biological parameters, including no change in the number of individuals and forage activity between dry and rainy seasons. The present study partially corroborates these observations, because no effect of rainy and dry seasons is described, but a peak of socialization and forage is described. Hayes (1999) argues that *S. guianensis* occurs mainly in the rainy period in the equatorial region in Fortaleza, CE, Brazil. However the author does not mention the significance of these data. Thus we cannot know if that behaviour is seasonal or just a casual consequence. *Sotalia guianensis* occurs annually and the number of individuals varies seasonally in Paraty, south-eastern Brazilian coast, because of the nutrient concentrations which are greatly affected by rain and the upwelling provoked by the central streams of the South Atlantic (Lodi, 2003).

In fact, in high latitudes the changes in climatic factors affect the animals mainly by driving them to anticipate behaviourally the seasonal change (Neave & Wright, 1968; Similä et al., 1996; Clapham, 2000; Iñiguez, 2001). Latitude has been considered an important factor in studies on other species of odontocetes, from the polar to subtropical areas (Shane et al., 1986; Wilson et al., 1997; Defran & Weller 1999; Iñíguez, 2001). In low latitude areas, mild climate fluctuations do not interfere significantly with the behaviours of the small cetaceans (Read, 1990; Urian et al., 1996). However, seasonal variation in precipitation is a relevant factor even in equatorial regions, as also detected in the present study.

Despite the extensive literature on *S. guianensis* in Brazil, most of these studies are concerned with subtropical areas only. Excepting rain, several environmental factors are noted as important to individuals to cope with environmental pressure. Thus, temporal variation of forage in *S. guianensis* in south Brazil is considered as determined by variation in food resources over a wide distribution area (Flores & Bazzalo, 2004; Daura-Jorge et al., 2005). The extension of the use area depends on endogenous and exogenous factors, which may determine behavioural seasonality (Shane et al., 1986; Read, 1990; Flores & Bazzalo, 2004). In some cases, spatial overlap between species is a consequence

of overlap of food availability or of other non-seasonal factors (Di Benedito et al., 2001; Wedekin et al., 2004; Acevedo-Gutiérrez et al., 2005), or even of the low feed productivity of the area (Flores & Bazzalo, 2004). Accordingly, decrease in the food availability during April to September expands the useful area for occupation, while the increase of food availability, from October to May, decreases the same area (Wedekin et al., 2007), thus indicating behavioural flexibility to environmental changes.

Salinity is another factor that should be considered for the behavioural dynamic of *Sotalia* considering migration for feeding. As seasonal variations may affect fertilization, development and hatch in some salmonid and Mugilid species (Holliday & Blaxter, 1960; Holliday, 1965; Lee et al., 1981), the behaviour of *S. guianensis* may be a consequence of change of the fish spatial distribution as they are potentially prey. Although salinity changes little in pelagic regions, in coastal areas such changes are more drastic. The hydrological and nutritional output from river and estuary waters to the ocean drastically affects salinity. This could affect fish distribution near the coast (Laevastu & Hayes, 1989). Such an effect was reported in the Pacific Ocean, where migration was caused by low salinity water coming from rivers to the coast (Seckel & Waldron, 1960).

Such an effect of salinity might occur in the Curral inlet. Freshwater from rain and Guaraíra Firth (Figure 1) could decrease salinity and thus affect some fish species distribution, so that *S. guianensis* could migrate for feeding. In fact, in the present study, we detected a shift in the peak of forage and socialization matched with the rainy peak (Figure 2B–D).

On the other hand, annual behavioural variations may reach a seasonal pattern because of the environmental stability of this region, expressing only a few peaks over the year (Geise et al., 1999; Di Benedito et al., 2001; Azevedo et al., 2007). Furthermore, environmental stability may also contribute to the animals staying in the area throughout the year, thus implicating a diffuse pattern of occurrence (Read, 1990; Santos et al., 2001) and so corroborating the wide flexibility of behaviour to environmental challenges.

We believe that the behavioural seasonality described here for socialization may be a function of forage seasonality. Considering that the increased forage implies increased capture efficacy and/or feeding availability, the animals could be replacing time for food searching with other activity, such as socialization. Time spent in socialization is related to food availability or success levels after forage (Neumann, 2001). This author states that animals are engaged in social activities for a longer time in periods of higher food availability.

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