Behavioral patterns and movement intensity of *Sotalia guianensis* (P. J. van Bénéden) (Cetacea, Delphinidae) in two different areas on the Brazilian coast

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ABSTRACT. The behavioral patterns of the estuarine dolphin, *Sotalia guianensis* (P. J. van Bénéden, 1864), were compared between two populations along the Brazilian coast: Caravelas (Bahia), along the eastern coast, and Norte Bay (Santa Catarina), along the southern coast. Applying the focal-group sampling in both areas, information such as the geographic position (UTM) of groups and predominant behavioral patterns were obtained. Geographic positions were used to calculate the total distance traveled by estuarine dolphin groups on each observation day. Since the distance traveled varies with time, the daily mean speed of the dolphin's group was used as an index of movement intensity. Two comparable and easily recognizable behavioral patterns were considered: travelling and foraging. Overall movement intensity and behavioral pattern frequency were similar between both areas. However, a seasonal variation was observed in both parameters in Norte Bay, while in Caravelas these parameters were homogeneous throughout the year. Variation in the behavior of the estuarine dolphin was consistent with variations in environmental factors, such as water temperature.
KEY WORDS. Behavior; estuarine dolphin; Caravelas estuary; Norte Bay; spatial requirements.

RESUMO. **Padrões comportamentais e intensidade de movimentos de *Sotalia guianensis* (P. J. van Bénéden) (Cetacea, Delphinidae) em duas diferentes áreas da costa brasileira.** Os padrões comportamentais do boto-cinza, *Sotalia guianensis* (P. J. van Bénéden, 1864), foram comparados entre duas populações da costa brasileira: Caravelas (Bahia), na costa leste, e Baía Norte (Santa Catarina), na costa sul. Utilizando o método de grupo-focal em ambas as áreas, informações como posições geográficas (UTM) do grupo e padrão comportamental predominante foram coletadas. A posição geográfica foi utilizada para o cálculo da distância total percorrida por um grupo de botos-cinza em cada área de observação. Como a distância é uma medida que varia com o tempo, a velocidade média diária do grupo de botos foi usada como um índice de intensidade de movimento. Dois padrões comportamentais comparáveis e facilmente reconhecíveis foram considerados: deslocamento e forrageamento. A intensidade de movimentos e a freqüência dos padrões comportamentais foram similares entre as duas áreas. No entanto, foi observada uma variação sazonal dos dois parâmetros para a Baía Norte, enquanto em Caravelas estes parâmetros foram homogêneos ao longo do ano. A variação no comportamento do boto-cinza acompanhou a variação de fatores ambientais como a temperatura.
PALAVRAS-CHAVE. Baía Norte; comportamento; estuário de Caravelas; fatores ambientais; requerimento espacial.

Variation of ecological factors may influence behavioral patterns of individuals, social groups or a population that inhabits an area (KREBS & DAVIES 1993). This influence is largely documented for species of terrestrial mammals, such as primates, whose behavior may be influenced by availability of food resources in a variety of ways (OATES 1987). Food resources in the marine environment may present a complex pattern of distribution and abundance in space and time (*e.g.* LAEVASTU & HAYES 1981), and we should expect that marine predators may also respond, behaving in different manners, according to availability of food resources. In fact, the behavior of small cetaceans has been linked to diverse environment cycles and variation (*e.g.* WÜRSIG & WÜRSIG 1979, 1980, WELLS *et al.* 1980, SHANE *et al.* 1986, BRÄGER 1993, BALLANCE & PITMAN 1998). A great part of these environment cycles and variations are indirect factors that may influence prey abundance and/or distribution.

According to SHANE (1990b), behavioral flexibility of cetaceans can be studied from at least three viewpoints: (1) individuals from the same population with differences in behavior; (2) diverse behaviors with a common function; and (3) different behaviors for the same function developed by separated populations in distinct habitats. The present work approaches the last perspective comparing the behavior characteristics of two populations of the estuarine dolphins, *Sotalia guianensis* (P. J. van Bénéden, 1864), on the Brazilian coast: one off the eastern coast of Brazil, in a typical tropical environment; and the other off the southern coast of Brazil, in a subtropical environment, at the southern limit of distribution of this species (SIMÕES-LOPES 1988).

The estuarine dolphin has a wide distribution along the Brazilian coast, inhabiting mainly protected coastal waters such as bays and estuaries (BOROBIA *et al.* 1991). Studies on the behavior and ecology of *S. guianensis* along the Brazilian coast are fragmented and focused on single populations (*e.g.* MONTEIRO-FILHO 1995, GEISE *et al.* 1999, FLORES 1999, SANTOS *et al.* 2000, ARAÚJO *et al.* 2001, CREMER *et al.* 2004, DAURA-JORGE *et al.* 2004, 2005). Where the species is studied, the use of different methods in each area along its distribution, limits the potential for comparative approaches and its testability. Therefore, this species' responses to environment variation remain unknown.

The aim of the present work is to compare the behavior patterns and movement intensity of two *Sotalia guianensis* populations in different areas of the Brazilian coast, in order to test if the species has different behavior strategies to cope with different environmental conditions related to both the space and time axis.

MATERIAL AND METHODS

Study areas

Norte Bay is located between Santa Catarina Island and the mainland, southern Brazil (27°30'S, 48°32'W). It is a coastal bay delimited by rocky shores, sandy beaches, and small patches of mangrove forests, which are probably responsible for increasing the marine productivity of the area. It presents a mean depth of 3.5 m, rarely exceeding 10 m (in both south and north channels) and the temperature varies markedly throughout the seasons (Laboratório de Cultivo de Moluscos Marinhos, Universidade Federal de Santa Catarina – data gathered in 2000 and not published, Fig. 1). Caravelas Estuary (17°00'S, 39°30'W), eastern Brazil, is located in the coastal waters of the Abrolhos Bank, an enlargement of the Brazilian continental shelf. This region is characterized by an open coast protected by banks of coral reefs and with a predominance of sandy beaches and large mangroves. Influenced exclusively by the Brazil Current, this coast is a typical tropical ecosystem with a high diversity of species (NONAKA *et al.* 2000) and low production (EKAU & KNOPPERS 1999). The Caravelas Estuary system is the second largest mangrove forest of Brazil's northeast region, with an area of approximately 66 km² (HERZ 1991). It presents a low temperature variation throughout the seasons (Instituto Baleia Jubarte – data gathered since 2002 and not published, Fig. 1).

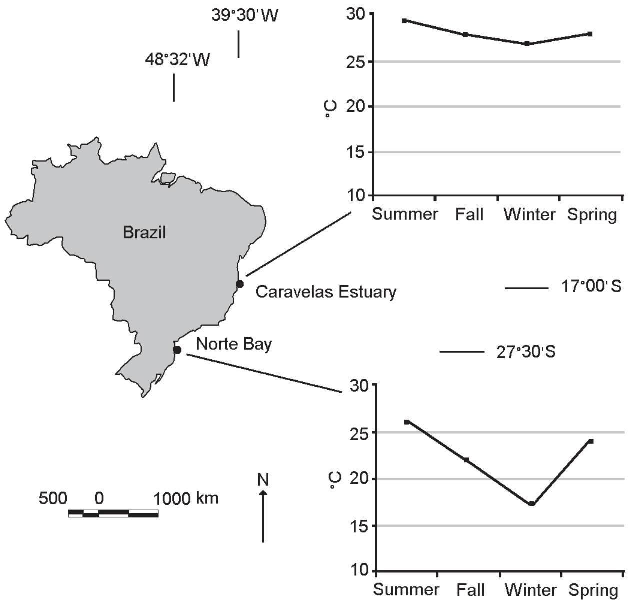


Figure 1. Geographic location of Caravelas Estuary and Norte Bay study areas on the Brazilian coast, with seasonal variation of mean temperatures (°C). Source of temperature data: Laboratório de Cultivo de Moluscos Marinhos (Norte Bay) – data gathered in 2000 and not published; Instituto Baleia Jubarte (Caravelas) – data gathered since 2002 and not published.

Data gathering and analysis

Using the focal-group sampling (LEHNER 1996) in both study areas, data such as geographic position (GPS) and predominant activity sampling (see MANN 1999) – denoted here as predominant behavioral patterns, or simply behavior – of the groups were registered at every five-minute interval, totalling 155 hours of direct observation for Norte Bay, and 133 hours for Caravelas Estuary (Tab. I). Experienced researchers performed the observations. Although different in each area, they had the same training during preliminary observations and were always the same in the whole period of study.

The behavioral patterns considered in the present work were adapted from SHANE *et al.* (1986), as follows: foraging (FO) – short and asynchronic dives, abundant aerial events, movements in varying directions (except for cooperative feeding) and, many times, the presence of seabirds; the dolphins could be either in the same area, or moving in a defined direction; and travelling (T) – moving steadily in one direction, with synchronised dives. Other behavioral patterns, such as resting and socializing, were excluded from our analyses due to small frequency of occurrence.

The geographic positions were plotted in digitized nautical charts from each region using ArcView GIS 3.2 (Environment Systems Research Institute – ESRI). As a result, maps were generated with all records of daily continuous movement tracks

Table I. Sampling characteristics, total frequency of each behavior and mean of the index of movement intensity in both study areas between hot and cold seasons. (DO) Direct observation, (FO) foraging behavior, (T) travelling behavior, (IMI) index of movement intensity.

	Season	Days	DO (h)	FO	FO%	T	T%	IMI
Norte Bay	Hot	19	81.1	877	90.04	97	9.96	2.375
	Cold	17	70.4	722	85.44	123	14.56	3.229
	Total	36	151.5	1599	87.91	220	12.09	–
Caravelas	Hot	36	48.0	503	87.32	73	12.67	2.694
	Cold	54	87.1	943	90.23	102	9.77	2.786
	Total	90	135.1	1446	89.20	175	10.80	–
Total	All	126	286.6	3045	88.52	395	11.48	–

of estuarine dolphin groups for each area. Then, using the ArcView extension "Animal Movement Analyst Extension" (HOOGE & EICHENLAUB 1997), the total distance travelled by the group for each day of observation was calculated. As the distance travelled by dolphin groups is a variable that may change with time, the daily mean speed of the groups was used as an index of movement intensity (IMI). Only the sequential data without sampling interruption were considered, thus avoiding distortions of the index.

Frequency variation of behavioral patterns and IMI were compared between areas and within the same area in different seasons. The overall IMI analyses were tested using the Mann-Whitney test, whereas the relative frequency of the behavioral patterns were analysed through the Chi-square test (5%, SOKAL & ROHLF 1995). The seasons were grouped in hot season (Norte Bay – spring 2001/2002 and summer 2002/Caravelas – spring 2002/2003 and summer 2003) and cold season (Norte Bay – fall 2002/2003 and winter 2002/Caravelas – fall 2002/2003 and winter 2002/2003).

RESULTS

The frequencies of behaviors were similar between Norte Bay and Caravelas ($\chi^2 = 1.298$; df = 1; p = 0.254), and foraging was the most common behavior in both areas. However, in Norte Bay the frequencies of behaviors were different between cold and hot seasons ($\chi^2 = 8.573$; df = 1; p = 0.003). Travelling frequency was higher in cold season than in hot season, while foraging frequency was higher in hot season than in cold season. Contrasting the seasonal pattern verified in Norte Bay, the frequencies of behaviors were constant throughout the year in Caravelas ($\chi^2 = 2.976$; df = 1; p = 0.084; Tab. I and Fig. 2).

The overall index of movement intensity was similar between the two areas (Mann-Whitney: U = 1692.00; Z (U) = 0.3614; p = 0.717; Fig. 3). As the results about behavioral patterns indicated, a seasonal variation on movement intensity was detected only in Norte Bay (Mann-Whitney: U = 85.00; Z (U) = 2.424; p = 0.015), while in Caravelas this variation was not observed (Mann-Whitney: U = 1101.00; Z (U) = 0.1105; p = 0.911). The IMI of Norte Bay was significantly higher in cold

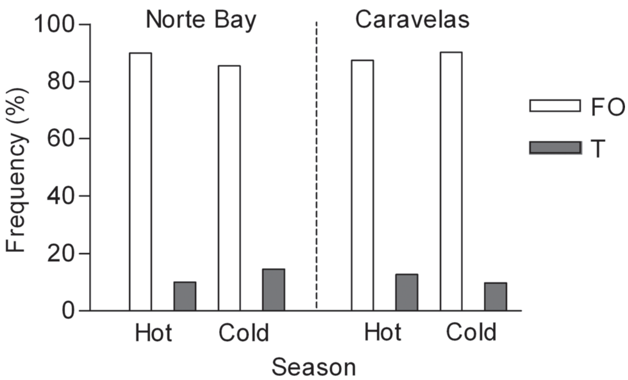


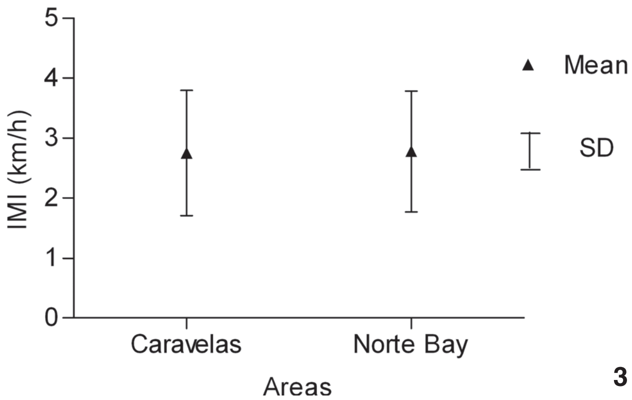
Figure 2. Relative frequency of foraging (FO) and travelling (T) in both study areas between hot and cold seasons.

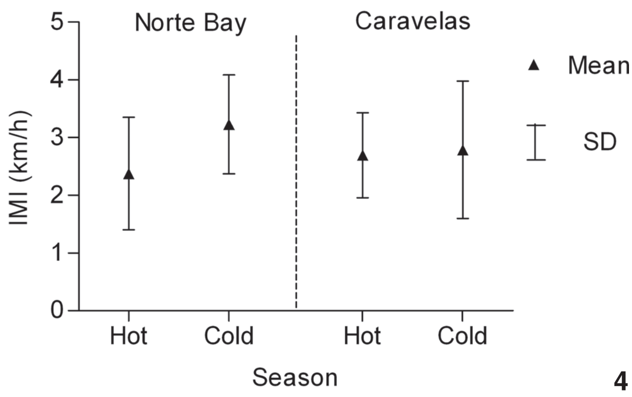
seasons (mean = 3.23km/h) than in the hot season (mean = 2.37km/h). This seasonal variation was not observed in Caravelas, where the index was similar between hot (mean = 2.69) and cold seasons (mean = 2.78) (Tab. I and Fig. 4).

DISCUSSION

Both populations of *Sotalia guianensis* presented distinct seasonal patterns of movement intensity and behavioral frequencies. As it had been observed in previous studies of movement intensity (DAURA-JORGE *et al.* 2004), behavior (DAURA-JORGE *et al.* 2005) and spatial use (WEDEKIN *et al.* 2007), our results show that the Norte Bay population has higher spatial requirements during cold seasons, moving more intensively and frequently. This pattern was not observed for Caravelas, where estuarine dolphins have the same behavior frequencies and movement intensity throughout the year.

Distinct ecological conditions between Norte Bay and Caravelas may account for the observed variations in the behavioral responses of the two populations studied. Ecological differences between two habitats are usually the result of several interacting factors, such as water temperature, transparency, salinity, tides, currents, light, depth and habitat struc-





Figures 3-4. Index of movement intensity (IMI) of *Sotalia guianensis* for both study areas (3) and in hot and cold seasons of Norte Bay and Caravelas. (SD) standard deviation.

ture. In the absence of available data on these factors, the use of temperature as a surrogate for environment variability is quite common. Water temperature is an easily measurable parameter and an excellent indicator of changes in ecological and environmental conditions (Laevastu & Hayes 1981). The temperature range of an area is also correlated with latitude, increasing from lower to middle and high latitudes, tropical to sub-tropical and temperate environments (Stevens 1989). Moreover, the temperature is positively correlated with species diversity of a habitat, indicating a latitudinal gradient of species diversity, well documented for marine and terrestrial assemblages of animals (see Stevens 1989). Comparing the diversity of fish species in different estuaries along the north-south coast of the Western Atlantic, Vieira & Musick (1993) observed that lower latitudes (tropical estuaries) tend to have more species and more equitability among them than temperate and subtropical areas.

In Norte Bay, the annual range in the temperature may promote (through distinct processes depending on the species involved) a strong seasonality of dominant prey items of the estuarine dolphin. For example, the low temperatures occurring during the fall trigger the reproductive migration of mullet (*Mugil platanus*; Günter, 1880) northward along the southern Western Atlantic (Vieira & Scalabrini 1991). The presence of this important fishing resource in certain periods of the year, a potential prey item of the estuarine dolphin in Norte Bay, may influence the behavior of this species, which responds by moving more intensively and frequently in order to capture this highly mobile prey. The influence of mullets on the behavior of the estuarine dolphin has already been suggested (*e.g.* Araújo *et al.* 2001, Flores & Bazzalo 2004). Other fish species from the family Engraulidae (such as *Cetengraulis edentulus*; Cuvier, 1828 – see Daura-Jorge *et al.* 2004), Clupeidae and/or Scianidae, all potential prey items of the estuarine dolphin, may also play a major role in determining the seasonal patterns observed in Norte Bay. The same may not be the case of Caravelas, which is located at a lower latitude and influenced by a wider range of ecosystems, such as mangroves, coral reefs and open waters, presenting a higher diversity of fish species but without a marked dominance of one single species in certain periods (Nonaka *et al.* 2000).

Comparing different populations of *Tursiops truncatus*, Würsig *et al.* (1991) suggested that in habitats with well-defined local abundance of some prey, the behavior patterns and habitat use by dolphins also tend to be well defined. On the other hand, when the habitat shows a higher species diversity without a specific dominant prey, these behavioral patterns become diffused or non-existent. Comparatively, the tropical waters of Caravelas may be characterized as a more diverse and uniform habitat in terms of prey, while Norte Bay presents a predictable and well-defined pattern, caused by dominance of certain species in specific periods of the year.

Associations between temperature and behavior patterns of cetacean have already been observed (*e.g.* Shane 1990a, Bräger 1993). Shane (1990a) noted that *Tursiops truncatus* increases the time spent in feeding activity when the temperature falls. Bräger (1993) registered a similar pattern with the same species, suggesting the necessity of higher energetic requirements due to the decrease of the water temperature. Another explanation suggested by the author was that the time that dolphins spend feeding increases in the fall in response to the decreasing prey abundance due to fish emigration during that season. This relation between behavioral responses of small cetaceans and the dynamic of its prey is also well documented by other authors (*e.g.* Wells *et al.* 1980, Shane *et al.* 1986, Selzer & Payne 1988, Reilly 1990, Jaquet & Whitehead 1996, Fiedler *et al.* 1998, Acevedo-Gutierrez & Parker 2000).

A better knowledge on the diet of the estuarine dolphin (including seasonal variations of prey ingested by different populations), the dynamics of prey abundance and distribution and, finally, the influence of the diverse physical-chemical parameters of the water in the biotic components would help to unravel and explain processes involving the complex associations between the physical environment, prey and predators in these coastal areas. The standardization of methodologies used in different areas would help future comparisons in dolphin studies.

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