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Habitat use by marine tucuxis (*Sotalia guianensis*) (Cetacea: Delphinidae) in Guanabara Bay, south-eastern Brazil

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Data on habitat use by marine tucuxis (*Sotalia guianensis*) were collected in Guanabara Bay (GB), south-eastern Brazil, over a two-year period. Diurnal activities of marine tucuxis were dominated by behaviour related to feeding/foraging (58% of all recorded time). Dolphins spent more time in feeding/foraging activities in the morning with a secondary peak in late afternoon. Dolphins were seen in waters of 2 to 35 m (11.63±6.05; median=12.0). Depths used by *S. guianensis* groups significantly differed from depths available in GB (Kolmogorov–Smirnov test; Z=5.72; $P<0.001$). Most groups (69.8%) were sighted in depths between 5.1 and 15.0 m. Dolphins occupied an area of 136.9 km^2, which represents about 42% of the entire water surface of GB. Individuals selected areas within GB and avoided the most degraded ones, which suggests that habitat degradation may affect *S. guianensis* distribution. Diurnal distances travelled by individuals ranged from 3.3 to 27.2 km in a same day. Dolphins found in main channel and adjacent waters moved along the north–south axis of GB throughout the day and covered distances three times greater than dolphins which concentrated their activities in north-eastern areas.

INTRODUCTION

Marine tucuxis (*Sotalia guianensis* Van Beneden, 1864) are small delphinids which inhabit coastal waters in South and Central Americas, from southern Brazil to Nicaragua, with possible records in Honduras (Flores, 2002). Many studies about diurnal activities of marine tucuxis have been conducted, which have contributed to improve the knowledge on behaviour and ecology of this species. For several *S. guianensis* populations, feeding/foraging behaviours were the most frequent in diurnal dolphin activities (e.g. Edwards & Schnell, 2001; Santos, 2004). The species seems to prefer waters shallower than 5 m. For example, Edwards & Schnell (2001) reported that, in coastal waters of the Cayos Mosquito Reserve (Nicaragua), groups of *S. guianensis* were mostly seen in waters shallower than 2 m and only rarely were they observed in waters deeper than 5 m. However, a few studies reported that dolphins usually are seen in water deeper than 5 m (e.g. Santos, 2004).

The Guanabara Bay (GB) in Rio de Janeiro State, south-eastern Brazilian coast, harbours a resident population of marine tucuxis (Azevedo et al., 2004). Despite being a highly degraded area, GB supplies food and breeding grounds, and tucuxis are found year-round at this site (Azevedo et al., 2004). The marine tucuxis are seen in aggregations up to 50 dolphins, but usually the groups have two to 10 members (Geise, 1989; Azevedo et al., 2005). Calves are sighted throughout the year and some individuals have been observed in the bay for at least eight years (Azevedo et al., 2004).

Marine tucuxi behaviour has been studied in GB since the 1980s. Previous studies reported feeding and travelling as the most frequent activities (e.g. Geise, 1989). Dolphins seem to use waters deeper than 5 m, avoiding the shallowest areas, and some dolphins leave the area during night (Geise, 1989). Recently, Azevedo et al. (2005) reported that group size of marine tucuxis in GB was not affected either by the dolphins' behaviour or by water depth. Although much information concerning the ecology of *S. guianensis* in GB is already known, patterns of habitat use still need to be investigated. The present study was conducted to examine daylight behaviour and spatial distribution of marine tucuxis in GB.

MATERIALS AND METHODS

The Guanabara Bay (22°50'S 43°10'W), located in Rio de Janeiro State, south-eastern Brazil, has a total extension of 30 km, with an entrance 1.8 km wide and a total surface water of 328 km^2 (Figure 1). The mean depth of the bay is 5.7 m but along the main channel, which follows the central south-north axis, depths reach an average of 20 m. This bay has features of an estuarine system and the freshwater contribution derives from 35 rivers, which flow into the bay, and from sewage input (Kjerfve et al., 1997; Perin et al., 1997). GB is surrounded by a metropolitan complex and is highly degraded due to habitat loss, overfishing, harbour activities, inputs of metals and organochlorines, among others (Kjerfve et al., 1997; Perin et al., 1997).

Thirty-nine boat surveys were conducted in GB from October 2002 to September 2004. All surveys were carried out under adequate sea conditions (Beaufort sea state ≤2), in small (4.5–6.0 m) outboard-powered boats, usually between

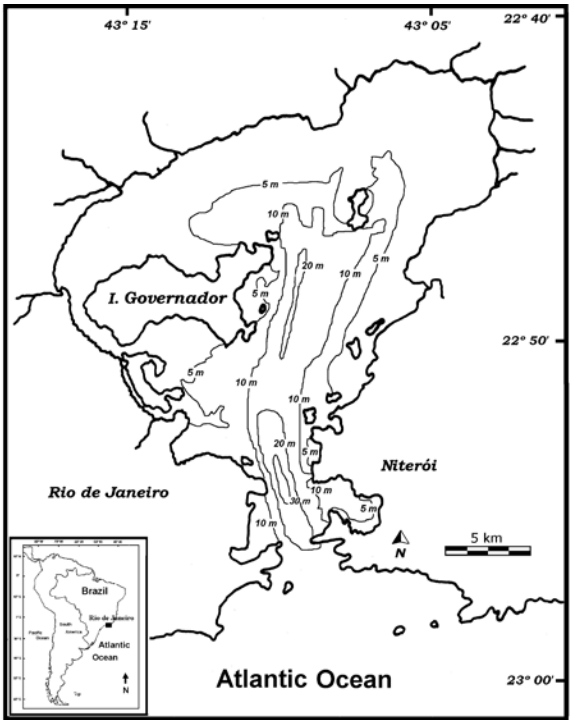

Figure 1. Map of Guanabara Bay (22°50'S 43°10'W), south-eastern Brazilian coast.

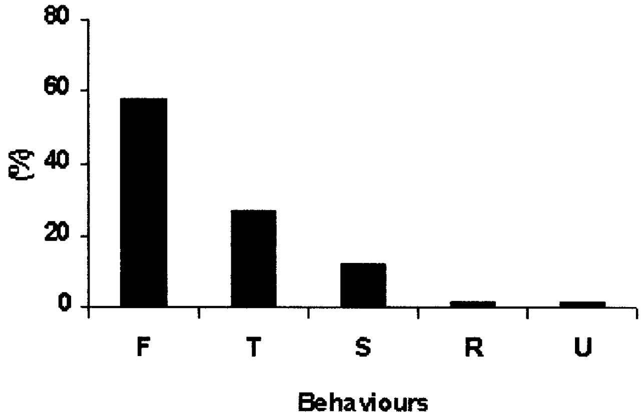

Figure 2. Percentage of occurrence of the daylight activities developed by marine tucuxis in Guanabara Bay (Brazil), between October 2002 and September 2004. (F), foraging/feeding; (T), travelling; (S), socializing; (R), resting and; (U), unknown.

0700 and 1800. At each survey we followed a different boat course in order to cover different sites of the GB, at different day times. The study area was divided into six sub-areas and each day we started the observations at a different sub-area, randomly selected. Zigzag routes covered each sub-area, in order to sample them randomly and to avoid oversampling sections or isobaths.

Instantaneous sampling focal-group behavioural data (*sensu* Altmann, 1974) were collected every five minutes. Focal-groups were solitary animals and aggregations of two or more dolphins in apparent association within 30 m from each other. Each focal-group had at least one recognizable dolphin, which could be distinguished from all other individuals in the group due to natural marks on its body. Photo-identification techniques have been applied in studies with tucuxis from GB since 1995 (Azevedo et al., 2004). Some individuals have prominent natural marks on the body (e.g. cut on back, half tail fluke, nick or cut on dorsal fin, anomalous pigmentation), which allowed us to recognize them using the naked eye.

Observations of focal-group activities began when animals were assumed to have become habituated to the presence of the boat. We considered that there was no interference with dolphin behaviour when animals did not interrupt their behaviour or move away from the area due to the boat's presence. For each focal-group, we recorded group size, composition, spatial geometry, surface behaviour, location and time of day. Surface behaviour was classified into five broad categories: travelling, foraging/feeding, socializing, resting and unknown (*sensu* Shane, 1990; Azevedo et al., 2005). The location of each focal-group was obtained with a GPS, and water depth was estimated from the nautical chart DHN No. 1501 of the Brazilian Navy. Trying to maximize data representativeness, we avoided oversampling groups during surveys by following each focal-group for a maximum period of two hours. After that, another group was sampled.

Consecutive observations of the same group could lead to non-independence of data. Trying to minimize this problem, we randomly chose one activity observation per focal-group per hour to perform the statistical analysis. The Chi-square test was performed to examine activity distributions through day time, season and tide state (ebb or flood). The Kruskal–Wallis single factor analysis of variance by rank was used to compare water depths where diurnal activities occurred.

We estimated the availability of water depths and mean depth of GB also based on the nautical chart DHN No. 1501. The nautical chart was divided into squares of 30" of latitude and longitude (N=401), and water depth in each vertex was used as a proxy of water depth available. The Kolmogorov–Smirnov test was performed to examine differences between depths available and those occupied by marine tucuxis. The Mann–Whitney rank sum test was performed to investigate differences in water depths used by marine tucuxis during morning (0700 to 1159) and afternoon (1200 to 1759).

Additionally, the positions of focal-groups were used to estimate the area range of *S. guianensis* using the CALHOME software (Kie et al., 1996). Because some focal-animals were sighted in different sub-areas during a single day, movements of individual dolphins were estimated based on their first and final positions in a given day. The focal-animals were not re-sampled; we only collected their positions in order to access individual movements and distance travelled.

RESULTS

Approximately 166 h were spent in direct observations. From a total of 1990 observations, 238 focal-group activities were randomly chosen. Daylight activities of marine tucuxis were dominated by behaviours related to feeding/foraging, which were observed during 57.9% of all recorded activities (Figure 2). Travelling was the second most frequently observed behaviour (27.3%) and socializing was the third (12.2%). Resting and unknown categories were infrequently

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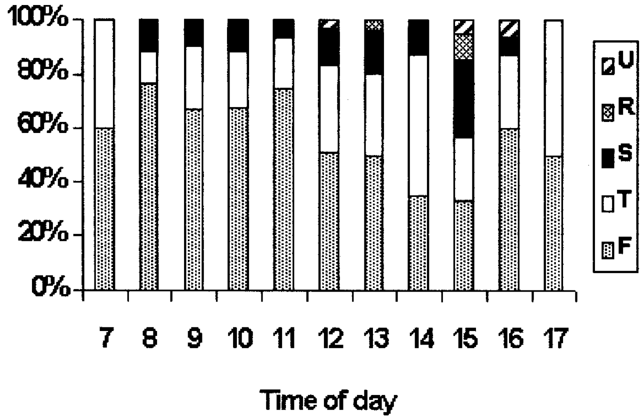

Figure 3. Observation frequencies of the activities of marine tucuxis during daylight hours in Guanabara Bay (Brazil), between October 2002 and September 2004. (F), foraging/feeding; (T), travelling; (S), socializing; (R), resting and (U), unknown. X-axis values represent intervals of one hour. For example: 7 includes information between 0700 and 0759.

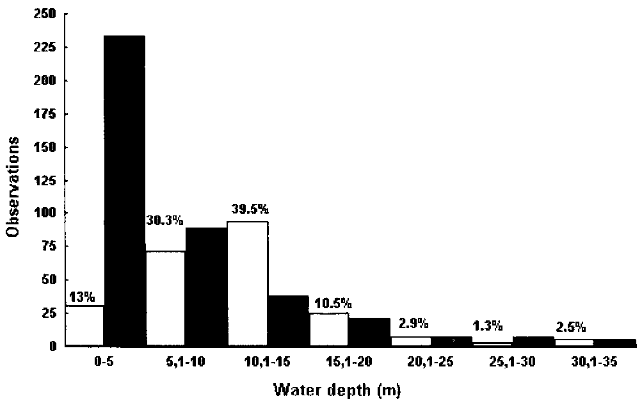

Figure 4. Distribution of the water depths available in Guanabara Bay (■) and of the water depths where marine tucuxis were observed (□), between October 2002 and September 2004.

seen (1.3 % for both). Dolphins changed their activities throughout the day and differences were found between morning and afternoon (χ^2_3=14.81; *P*<0.01). Dolphins spent more time in feeding/foraging activities in the morning, decreasing in early afternoon with a second peak in late afternoon (Figure 3). Travelling and socializing behaviours had an inverse pattern and were more frequent in the afternoon. The feeding/foraging peak occurred in austral summer and the travelling peak was in austral winter, but there were no interseasonal changes in frequencies of behaviour occurrence (χ^2_9=9.45; *P*>0.05).

Dolphins were seen in waters 2 to 35 m deep (11.63±6.05; median=12.0). Most groups (69.8% of the 238 observations) were sighted in depths between 5.1 and 15.0 m. The use of areas shallower than 5 m corresponded to 13.0% of all observations. The mean depth of GB was estimated to be 6.51 (±6.75 m) (N=401; median=4.2; range=0.5–35 m). Depths used by *S. guianensis* groups significantly differed from depths available in GB (Kolmogorov–Smirnov test; Z=5.72; *P*<0.001) (Figure 4).

Dolphins occupied an area of 136.9 km^2 (Kernel 95%), which represents about 42% of the entire water surface of GB. Dolphin activities were concentrated in the main channel and adjacent areas, and in shallow waters located in the north and north-east of GB. No dolphin was sighted in the west and north-west sites.

Groups preferred to use deeper water in the afternoon than during the morning (Mann–Whitney test; *U*=4760; N_1=118; N_2=120; *P*<0.001). Marine tucuxis performed different behaviours independent of water depth and dolphins did not seem to select water depth for any specific behaviour (Kruskal–Wallis test, $H_{3,235}$=2.835; *P*=0.418). The tide state also did not affect dolphin behavioural frequencies (χ^2_3=5.48; *P*>0.05).

Individual diurnal distances travelled varied and dolphin movements ranged from 3.3 to 27.2 km in a single day. Dolphins found in main channel and adjacent waters moved along the north–south axis of GB throughout the day and covered distances (18.5±0.8 km; median=17.8 km) three times longer than dolphins which concentrated activities in north-eastern areas (6.9±0.2 km; median=8.4 km) (Mann–Whitney test; *P*<0.001). These individual preferences were maintained throughout the study and several dolphins were never seen in main channel waters, whereas others never used the north-eastern areas. Only a few dolphins were seen in both areas.

DISCUSSION

Sotalia guianensis spent most of their day time in feeding/foraging activities. This is a tendency that has been observed in previous studies on species' behaviour in GB (e.g. Geise, 1989) and other localities (Edwards & Schnell, 2001; Lodi, 2002; García & Trujillo, 2004; Santos, 2004). Other coastal dolphin species, such as *Sousa chinensis* and *Tursiops truncatus*, also spend most of their diurnal activities in feeding/foraging behaviours (Bräger, 1993; Bearzi et al., 1999; Karczmarski & Cockroft, 1999).

In general, the distribution of behaviour varied during the course of the day. This fact has not been previously reported for *S. guianensis*, but it is one frequently observed in other dolphin species (Shane, 1990; Bräger, 1993; Karczmarski & Cockcroft, 1999). Diurnal variability in abundance and distribution of prey for marine tucuxis in GB may have caused fluctuations in dolphin behaviours throughout the day, by affecting feeding/foraging activities. However, we do not have information regarding prey availability for these dolphins in GB, and thus cannot evaluate how it may affect the behavioural patterns exhibited.

Dolphins were rarely seen in resting behaviour, a pattern already observed for other coastal dolphins (Karczmarski & Cockcroft, 1999), as well for *S. guianensis* (Edwards & Schnell, 2001; Lodi, 2002; Santos, 2004). Resting behaviour represents less than 5% of the diurnal activities of the dolphins. Two reasons may be responsible for the low frequency of resting observations in *S. guianensis*. One is that our observations did not include night-time. For *T. truncatus*, Mate et al. (1995) found evidence of resting at night instead of day. Another reason is that eventually the methodologies applied to sample marine tucuxi behaviours may not be adequate to quantify resting in this species.

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We expected that tidal cycle and water depth would also influence dolphin activities, but we did not find differences in dolphin behaviours related to both factors. Tide influence on dolphin behaviours seems to be stronger in enclosed bays (Karczmaski & Cockcroft, 1999). But, GB has a semi-diurnal tide pattern, with low amplitude and no spatial variation (Kjerfve et al., 1997), which may account for the lack of effect on *S. guianensis* behaviours at this site.

The preference of marine tucuxis for water depths varies among study areas. Several studies have reported sightings in places shallower than 5 m (e.g. Edwards & Schnell, 2001; Lodi, 2002; Flores & Bazzalo, 2004). In contrast, in other areas *S. guianensis* seems to prefer waters deeper than 5 m (Simão & Polleto, 2002; Santos, 2004). Differences found among sites may be related to habitat characteristics. In GB, species preference for deeper water seems to be related to water quality and, probably, marine tucuxis' prey distribution. Dolphin activities were concentrated in the main channel and adjacent waters, where water renovation, dissolved oxygen concentrations and fish abundance are highest (Kjerfve et al., 1997; Jablonski et al., 2006). *Sotalia guianensis* individuals selected sites in GB and occupied less than half of available space. Dolphins showed preferences for waters between 5 and 15 m deep. However, marine tucuxis were also seen frequently in waters less than 5 m deep, which suggests that shallow waters are important sites for marine tucuxis in GB. The shallowest parts used by marine tucuxis are located in the north and north-east of GB. These sites are the most preserved areas in the Bay, with less human activity and larger mangrove margins (Kjerfve et al., 1997; Perin et al., 1997). Other shallow waters located in the west and north-west areas of GB are intensely degraded. Both areas have the greatest sewage discharge (industrial and domestic), the lowest dissolved oxygen concentrations and the lowest renovation water ratios (Kjerfve et al., 1997; Perin et al., 1997). In the west and north-west areas we did not observe any dolphins, which suggests an effect of habitat degradation on *S. guianensis* distribution in GB.

Individual movements of *S. guianensis* are poorly known. Distances moved by dolphins in GB were similar to those reported by Flores & Bazzalo (2004), who studied the species in Baía Norte, southern Brazil. In GB, perhaps some individuals which use preferentially the main channel leave GB during night time, as suggested by Geise (1989) and the use of deeper water in the afternoon is related to their diurnal movements. During the morning, focal-groups were usually found in northern areas of the main channel, where the waters are shallower. On the other hand, in the afternoon most groups moved along the main channel to near the GB entrance, where the waters are deeper.

Our findings revealed important information about marine tucuxi habitat use in GB, and contribute to improved knowledge about relationships between behaviour and ecology in *S. guianensis*. Spatial distribution revealed that habitat degradation has a strong influence on distribution of the dolphins in GB. Once daytime activities of the species were dominated by feeding/foraging, the abundance and the distribution of dolphins' prey may be main factors that affect marine tucuxis' spatial distribution. Delphinids show a complex pattern of habitat use, in which physical and biological features affect ecological aspects, including behaviour and spatial use (Connor, 2000). However, this is a short-term study and additional information is needed for the better understanding of habitat use by *S. guianensis* in GB.

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