Abstract - Marine tucuxi dolphins (*Sotalia fluviatilis*) studied in Baía Norte, southern Brazil, exhibited very small overall home ranges with daylight movements in consistent water depths of around 3m. Mean overall home range areas calculated through two methodologies were similar, measuring 13.83km² ± 1.92 using the Minimum Convex Polygon method and 15.22km² ± 0.66 through the kernel estimator. Mean core areas calculated by kernel were extremely small [mean = 1.49km² at 50% UD (utilization distribution) and 0.87km² at 25% UD levels]. The geographical distributions of home ranges and core areas overlapped extensively at both 50% UD and 25% UD. Daylight movements ranged from 0.16 to 28.97 km/day (mean = 5.65 ± 0.56km/day, SD = 5.36) with mean minimum rate of movement of 2.6 ± 0.2km/h (SD = 2.02). Daylight movement patterns varied seasonally with higher values of distance moved and rate of movement in winter and winter and autumn, respectively. The marine tucuxi home ranges and daylight movement patterns presented here are smaller than much of what is known for other coastal small cetaceans. The percentage of overall home range within the limits of a protected area designated for the tucuxis could be considered moderate to high depending on the estimator used (54.06% or 5.9km² by MCP and 74.71% or 11.35km² using the kernel). Nevertheless, core areas are completely within the protected area. Conservation implications of these findings include the need to: (i) create a buffer zone to the south of the existing protected area which will encompass the overall home range of the tucuxis; (ii) establish constant, adequate enforcement of fishery and boat traffic regulations in the core areas; and (iii) regulate boat traffic and aquaculture farming in important areas which are not yet subject to specific regulations.

Keywords: marine tucuxi, *Sotalia fluviatilis*, home range, movement patterns, southern Brazil, conservation.

Introduction

Home range is an important ecological aspect of an animal population and it has been broadly considered as “… that area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as part of the home range” (Burt, 1943). Home range size is an important ecological feature, as it is indicative of the space required by an animal to meet its needs under a given set of constraints, including resource availability. The minimum area polygon (also known as the minimum convex polygon or MCP hereafter) is maybe the most widely used and simplest method to measure home range size. It is obtained by constructing a convex polygon which connects the outer locations of an animal distribution (see Jenrich and Turner, 1969 and also reviews in Garrot and White, 1990). Alternatively, for performing statistical analyses, the concept of ‘utilization distribution’ has been applied which expresses the relative amount of time or location points that an animal spends or had in any place over time (e.g., see Hayne, 1949; Jenrich and Turner, 1969; Van Winkle, 1975). The kernel estimator is one the best methods for estimating the ‘utilization distribution’ by means of nonparametric statistics (e.g., reviewed in Silverman, 1986 and Norton, 1987). Many other methods have been developed since then, but the MCP and the kernel remain the most popular and comparable approaches (see reviews in Van Winkle, 1975; Norton, 1987 and White and Garrot, 1990).

Home ranges of the tucuxis (*Sotalia fluviatilis*) have not been reported previously and its movement patterns have been only scarcely assessed (Da Silva and Best, 1996; Flores, 2002). Marine tucuxi daily movements entering and leaving some localities were assessed without calculating or presenting values of distance or speed traveled (Andrade et al. 1987; Geise 1991; Oliveira et al. 1995; Geise et al. 1999). Because of its distribution in the coastal waters of South and Central America, the marine ecotype of the species is threatened from a variety of human induced sources such as habitat farming in important areas which are not yet subject to specific regulations.

Keywords: marine tucuxi, *Sotalia fluviatilis*, home range, movement patterns, southern Brazil, conservation.
loss, pollution, fish stock depletion and mainly by incidental catches (Da Silva and Best, 1996; Flores, 2002). Thus, baseline information on its ecology, including data on home ranges and movement patterns is important for conservation.

In Baía Norte, southern Brazil, the austral limit of distribution for the species, the marine tucuxi (*Sotalia fluviatilis*) has been studied over the last 12 years (e.g., Flores, 1992; 1999; 2003). This paper examines the movements and home ranges of dolphins over a seven-year study period. Conservation implications regarding the studied population are also discussed in the light of legal protection given to this population by Brazilian federal laws.

**Material and Methods**

**Study area**

Baía Norte and surrounding waters (27°23' – 27°35'S, 48°33' – 48°30'W), located on the southern Brazilian coast (Figure 1), are very shallow with depths usually less than 12m, except at the North channel (around 14m) and the strait connecting to South Bay (more than 25m). These coasts are a mosaic of Atlantic Rain Forest remnants, sand beaches, rocky shores, small salt marshes, mangroves and urban developments mainly in and around Florianópolis city to the southern part of the bay.

Three species of small cetaceans have been sighted in Baía Norte. The marine tucuxi is found year round almost on a daily basis and over long term periods (> 10 years) in a resident, small population which has been studied since the early 1990s (Flores, 1999; 2003). The bottlenose dolphin (*Tursiops truncatus*) is much less frequent (Flores 2003) and the franciscana (*Pontoporia blainvillei*) is rarely sighted in the study area, being seen only twice during 1993 to 1997 (Flores *et al*., 2000).

Potential predators for the marine tucuxi have been recorded in Baía Norte or nearby. A ~1.70m tiger shark (*Galeocerdo cuvieri*) was caught in a gillnet on July 2001 (identified by photographs of the fresh animal) near Ratones Is., Baía Norte, about 5km from the tucuxis’ area of distribution (P.A.C. Flores, pers. obs.). An established shark fishery targeted at various species including the bull shark (*Carcharhinus leucas*) takes place near the Arvoredo Archipelago (e.g., CEPSUL – IBAMA 1998; UNIVALI 2001, 2002). During austral summer 2001 a group of about eight orcas (*Orcinus orca*) including two adult males were seen...
and filmed also near Arvoredo Archipelago (footage provided by José Luis, Schooner Vento Sul, Florianópolis, SC). This archipelago is located about 25km northeast of the tucuxis’ home range. A stranded orca was recorded in 1979 about 100km north the study area (Bittencourt, 1983) and an adult male was sighted on May 1991 off Laguna, Sta. Catarina (Simões-Lopes and Ximenez, 1993) some 120km south of Baía Norte.

The Environmental Protection Area of Anhatomirim (EPAA) is a multiple-use conservation unit created by Brazilian Federal Decree # 528 of 20 May 1992 with “the main purpose to ensure protection to the wild resident population of the marine dolphin Sotalia fluviatilis and its feeding and breeding areas”. It is located in the northwestern continental part of Baía Norte (Figure 1), comprising 4,750-ha from which approximately 3,090-ha is marine waters. Later specific regulations were applied to tourism boat traffic in a small sector of the EPAA (Directive 58-N of January 1998).

Field procedure

Descriptions of boat based surveys and observation sampling of the marine tucuxi in Baía Norte have been provided by Flores (1999). Using a small inflatable boat (5m, 30hp four stroke outboard engine since 1996) surveys have been conducted throughout the study area. Boat based work was conducted up to 5 days/week and no more than one survey was undertaken in a given day. Some days were dedicated to systematic surveys while others combined surveys, photo-identification, and behavioral observations. Because sea conditions may deteriorate after noon, the time spent engaged in the surveys varied. Two types of surveys were conducted, always without following a regular, established course: focal group survey and “random survey”. During focal-group surveys the same animals are observed and usually photographed until the end of the survey. “Random surveys” are conducted when survey effort is resumed after leaving a sighting. This may occur when: (i) it is concluded that most individuals were photographed, (ii) the initial 5 min. of sampling is obtained, and/or (iii) weather or sea state conditions are poor or deteriorating. In all three cases, surveys were usually resumed after a dolphin sighting to increase chances of having other sightings in the same survey. Once a group of dolphins was encountered, environmental variables were measured at the initial dolphin sighting location and then dolphin data were determined and recorded at 5 minute intervals. Dolphin data included time of day, location of dolphins, number of individuals in the group, group composition (adult, juvenile, calf, female), behavioral activity, and birds in association during feeding behavior. Photographic identification then was started whenever appropriate.

Photographs were taken with a 70-300-mm (f 4.0-5.6) zoom lens mounted on a 35mm camera equipped with a motorized film winder. A variety of film was used (Kodak Plus-X 125 ASA black and white, Kodak T-Max 400 ASA black and white, Ektachrome 64 ASA slide, Fujichrome Provia 100 ASA slide, Fujicolor 200 and 400 color print) but mostly ISO 400 black and white. As many animals as possible were photographed in each sighting. Individuals were identified primarily from scars, notches and marks on the dorsal fins, but also secondarily from distinctive scars and marks on the flanks and head. Photographic identification effort (or photographs taken) was not evenly distributed during the study (Flores, 1999, 2003). Sighting locations were determined through both nautical charts (nº1903 of the Division of Hydrography and Navigation, Brazilian Navy) and by a Global Positioning System (GPS) handheld device.

Definitions

The encounter with either a group or solitary animals during the course of a survey was defined as a ‘sighting’ and thus represents the sampling unit. A group of dolphins refers to an aggregation of dolphins within visual range of the survey team and usually engaged in the same general activity or behavior pattern. A group may contain individuals of all age classes.

Seasons were defined by the Austral calendar as follows: Autumn, 21 March – 20 June; Winter, 21 June – 20 September; Spring, 21 September – 20 December; Summer, 21 December – 20 March. A tucuxi was defined as an adult female if a calf accompanied it on at least five consecutive sightings. “Probable male” was defined as any large animal heavily scarred and with no calf in any photograph taken, similarly to what has been described for bottlenose dolphins by Smolker et al. (1992) and Tolley et al. (1995), recognizing that these assumptions have not been tested for tucuxi, and may lead to incorrect gender assignments.

Data analysis

Data from sightings from 1996 to 2002 were used for home range estimates while data including both sighting locations as well as focal group sampling during 2001 and 2002 has been used in movement assessment. Home ranges were calculated using the MCP and the kernel estimator, both methods subtracting any landmasses. Through the Kernel estimator were calculated the home range or overall ranging area (95% utilization distribution - UD) and the core area at two different levels (50% UD and 25% UD). Typically, a reliable estimation of home range is obtained with 100 or more locations (Samuel and Fuller, 1996) and this has proven to be the case in Atlantic bottlenose dolphins T. truncatus in Sarasota, USA (Owen et al. 2002). One way of defining how many locations are required is to plot home range area versus sequentially obtained locations until the home range size reaches an asymptote (Harris et al., 1990). This was applied to our data set and the asymptote was reached at around 30 locations using the kernel estimator. The kernel estimator was used to calculate marine tucuxi home ranges we used only the thirteen individuals with the largest photographic records (ranging...
from 33 to 53 locations out of the 173 group sightings obtained for 1996-2002). Gender assignation of these individuals was evenly distributed. Dolphins #A05, B04, C04, D01 and T'sM are presumed females, dolphins #D02, ‘Parceiro’, ‘Dude’, ‘Caroço’ and ‘Narizota’ were classified as ‘probable males’, while individuals #A06 and SB (Shark Bite) were not assigned gender. Dolphin ‘Tippy’ was a calf and later a juvenile during the study and no gender was assigned. Seven adult individuals (dolphins #A05, A06, B04, Tippy’s Mom or T’sM, C04, D01 and D02) were photographed every year since 1996, one adult was seen since 1997 (SB). Two adults (‘Parceiro’ and ‘Dude’) were recorded from 2000 to 2002 and two other adults (‘Caroço’ and ‘Narizota’) only during 2001 and 2002. One individual (‘Tippy’) first identified as a calf of female T’sM in 2000 was sighted from 2000 to 2002, including after leaving its mother in July 2002 and has become a juvenile.

Daylight distance moved was calculated by measuring the straight, shortest distances of subsequent GPS readings every five minutes throughout a focal group sampling from the first to the last time of each dolphin sighting (always avoiding land masses). Daylight rate of movement was estimated by dividing the total distance moved during a given day by the total time of direct observations of dolphins (focal group sampling).

The mean focal sampling time or direct observation for the movement pattern assessment was 2:16h (SD=1:10) and was evenly distributed throughout the seasons (Kruskal-Wallis P = 0.582, H = 1.9542). Dolphins were observed from 6:30AM to 5:00PM.

Movements were calculated on a daily basis and then combined and compared by season and between years. Home range and movements were calculated through ArcView 3.1 with the help of the extensions Spatial Analyst 1.1 and Animal Movement 2. Statistical analysis was performed using BioEstat 2.0. Differences in home ranges from the two estimators as well as among genders through the two methods were tested with Mann-Whitney U tests at P<0.05 (Zar, 1999). Movements were tested among seasons through the Kruskal-Wallis and between years using the Mann-Whitney U tests at P<0.05 (Zar, 1999).

**Results**

**Home ranges**

The mean overall home range area was 13.38km² ± 1.92 using the MCP. The mean kernel home range at 95% UD was 15.22km² ± 0.66 and the core areas were 1.49km² at 50% UD and 0.87km² at 25% UD levels. Home ranges varied from 5.39 to 21.57km² by MCP and 12.59 to 19.57km² through kernel (Table 1). Overall home ranges did not differ between the two methods employed (Mann-Whitney U test, P = 0.898).

There was an extensive, almost complete overlap in home ranges for all individuals through both methods, including the core areas at both the 50% and 25% UD (Figures 3-9). Overall kernel home ranges were split in two areas for nine
HOME RANGES AND MOVEMENT PATTERNS OF *SOTALIA FLUVIATILIS* IN BAÍA NORTE, SOUTHERN BRAZIL

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individuals (Figures 3-9). These were two females (#A05 and D01 – Figures 3-4), the calf/juvenile ('Tippy' – Figure 5), all five ‘probable males’ (#D02, ‘Parceiro’, ‘Dude’, ‘Caroço’ and ‘Narizota’ – Figures 6-8), and an adult with no gender assignment (SB – Figure 9).

Home ranges of females were larger than of ‘probable males’, both through the MCP (females mean = 14.31km² ± 3; probable males mean = 8.97km² ± 3.1) and the kernel (females mean = 15.91km² ± 1.2; probable males mean = 14.09km² ± 1.1). However, no significant differences were found between females and ‘probable males’ using both methods (Mann-Whitney *U* test, *P* = 0.0758 for MCP and *P* = 0.1745 for kernel).

The mean area of home ranges within the limits of the EPAA was 5.9km² (54.06% of overall home range) by MCP and 11.35km² (74.71%) through the kernel estimator (Table 1). Both the 50% and 25% UD core areas of kernel estimator were completely within the EPAA for all individuals (Figures 3-9).

**Movement patterns**

Daily distances moved ranged from 0.16km to 28.97km/day (mean = 5.65km ± 0.56, SD = 5.36km) and were not significantly different (Mann-Whitney *U* test, *P* = 0.327) between years (year 2001 mean = 6.73km ± 1.36, SD = 6.5km and 2002 mean = 5.29km ± 0.59, SD = 4.91km). However, distance moved differed among seasons (Kruskal-Wallis test, *P* = 0.0018). Differences were statistically significant (Tukey test) between summer and autumn (*P* = 0.0063), summer and winter (*P* = 0.0002) as well as winter and spring (*P* = 0.0219).

Movement patterns clearly followed the 3-m depth contour in the western sector of the bay (Figure 10), regardless of distance moved, rate of movement or season. Deeper water movement was rare and limited to 5m, except for two excursions over 8-10m deep waters in winter and spring. Similarly, they moved to the eastern bay sector only twice, during winter (Figure 10). All 60-80 individuals in the sighted group performed these extreme movements.

**Discussion**

**Home ranges**

No significant differences were found between home range sizes using the MCP and the kernel methods for 13 individual marine tucuxis in Baía Norte. However, MCP values varied more (5.39 to 21.57km²) than those from kernel (12.59 to 19.57km²) and such variation is likely to result from the intrinsic definitions of each method and

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**Table 1.** Home ranges of individuals calculated by the minimum convex polygon (MCP) and the kernel estimator as overall at the 95% UD (Utilization Distribution) and core areas at the 50% and 25% UD.

<table>
<thead>
<tr>
<th>INDIVIDUALS</th>
<th>PRESUMED GENDER</th>
<th>MCP</th>
<th>KERNEL AT 95 % UD</th>
<th>KERNEL AT 50 % UD</th>
<th>KERNEL AT 25 % UD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A05</td>
<td>♀</td>
<td>7.21</td>
<td>17.17</td>
<td>1.47</td>
<td>0.87</td>
</tr>
<tr>
<td>A06</td>
<td></td>
<td>20.15</td>
<td>16.06</td>
<td>1.25</td>
<td>0.84</td>
</tr>
<tr>
<td>B04</td>
<td>♀</td>
<td>21.57</td>
<td>15.97</td>
<td>1.58</td>
<td>0.94</td>
</tr>
<tr>
<td>Tippy</td>
<td></td>
<td>17.64</td>
<td>14.09</td>
<td>1.52</td>
<td>0.92</td>
</tr>
<tr>
<td>T’sM</td>
<td>♀</td>
<td>15.17</td>
<td>13.57</td>
<td>1.58</td>
<td>0.94</td>
</tr>
<tr>
<td>SB</td>
<td></td>
<td>19.75</td>
<td>17.72</td>
<td>1.77</td>
<td>1.03</td>
</tr>
<tr>
<td>C04</td>
<td>♀</td>
<td>20.06</td>
<td>19.57</td>
<td>1.73</td>
<td>0.95</td>
</tr>
<tr>
<td>D01</td>
<td></td>
<td>7.52</td>
<td>13.28</td>
<td>1.59</td>
<td>0.79</td>
</tr>
<tr>
<td>D02</td>
<td>♂</td>
<td>21.19</td>
<td>18.39</td>
<td>1.76</td>
<td>0.95</td>
</tr>
<tr>
<td>Parceiro</td>
<td>♂</td>
<td>6.85</td>
<td>13.35</td>
<td>1.39</td>
<td>0.8</td>
</tr>
<tr>
<td>Dude</td>
<td>♂</td>
<td>6.03</td>
<td>12.59</td>
<td>1.26</td>
<td>0.74</td>
</tr>
<tr>
<td>Caroço</td>
<td>♂</td>
<td>5.39</td>
<td>12.75</td>
<td>1.24</td>
<td>0.74</td>
</tr>
<tr>
<td>Narizota</td>
<td>♂</td>
<td>5.39</td>
<td>13.35</td>
<td>1.29</td>
<td>0.77</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>13.39</td>
<td>15.22</td>
<td>1.49</td>
<td>0.87</td>
</tr>
<tr>
<td>SE</td>
<td></td>
<td>1.92</td>
<td>0.66</td>
<td>0.05</td>
<td>0.03</td>
</tr>
</tbody>
</table>

The mean overall rate of movement did not vary significantly from year to year, with an overall rate of 2.63km/h ± 0.21 (SD = 2.02), 2.86km/h ± 0.54 (SD = 2.59) in 2001, and 2.56km/h ± 0.22 (SD = 1.82) in 2002 (Mann-Whitney *U* test, *P* = 0.950). Rate of movement differed through the seasons, however (summer: mean = 1.38km, SD = 1.32; spring: mean = 2.33km, SD = 1.84; autumn: mean = 2.56km, SD = 1.30; winter: mean = 2.93km, SD = 1.54; Kruskal-Wallis test, *P* = 0.0018). Differences were statistically significant (Tukey test) between summer and autumn (*P* = 0.0063), summer and winter (*P* = 0.0002) as well as winter and spring (*P* = 0.0219).
the different periods of time in which individuals were seen. For example, nine dolphins have the kernel home range areas split into two polygons because of the density of locations in the core areas. The calculated areas of these home ranges were clearly smaller than the actual values thereby biasing the mean area at the 95% UD (15.22km² ± 0.66) which would be a little higher. Nevertheless, the maximum values were very similar in each method (21.57km² with MCP and 19.57km² by kernel). It would be at least conservative then to recognize that an appropriate mean value of home range area would stand between the means found (MCP mean = 13.38km² and kernel mean = 15.22km²).

Though its weaknesses are widely recognized, the MCP estimator is still being used and remains one of the most commonly applied techniques because of the validity for comparison to previous studies and its ease of calculation (Samuel and Fuller, 1996; Seaman et al., 1999). The kernel density estimator is considered one of the best methods, though yet not applied to many studies (Seaman and Powell, 1996). However, as stated by these authors, as computer programs become more widely available and easy to use, there has been an increased interest in and utilization of the kernel estimator. Having data from both estimators would then facilitate comparisons of the results of this study to others. Furthermore, it would help compare

Figure 3. Home ranges of two presumed female marine tucuxis (#A05 - top, and B04 - bottom) in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP - right) methods.
between methods and decide which would be better suitable to the study case. Home range estimates of marine tucuxi in Baía Norte reported here are likely to represent actual values as the studied population has been shown to have a very discrete, restricted distribution pattern, based on a larger data set collected over 10ys (Flores, 1999; 2003). Additionally, this population ranges over a small area of about 40km² (Bazzalo and Flores, in preparation). In spite of the fact that other tucuxis have been studied within 200km north of Baía Norte (Cremer, 2000), none of the dolphins identified in Baía Norte have been identified at any other tucuxi research site.

The marine tucuxi overall home range, as well as the core areas at both levels 50 and 25% UD are extremely small when compared to those of other small cetaceans. Home ranges in small cetaceans vary in size and such differences are considered to be a function of various factors including body size, physiological requirements, habitat heterogeneity and predation pressure (e.g., see reviews in Connor, 2000 and also Forcada, 2002). Coastal bottlenose dolphins in Sarasota, Florida, have mean overall ranges of 162.58 ± 24.21km² and cores areas of 28.74 ± 9.17km² at 50% and 9.30 ± 3.06km² at 25% UD levels (Owen et al., 2002). Home ranges of 27 Indo-Pacific humpback dolphins (Sousa

Figure 4. Home ranges of two presumed female marine tucuxis (#C04 – top, and D01 – bottom) in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP – right) methods.
Mangroves are key components of very productive ecosystems, which support high concentrations of nutrients, zooplankton, fishes and other fauna (Cintrón and Schaeffer-Novelli, 1983). Over 185 species of 60 different families of fishes are found in Brazilian mangroves (Avelline, 1980). Several of these fishes, such as the white mullet (*Mugil curema*), the southern anchovy (*Lycengraulis grossidens*), the Atlantic cutlass fish (*Trichiurus lepturus*) and the whitemouth croaker (*Micropogonias furnieri*), among others, are prey items of the marine tucuxi in Baía Norte (Emerim, 1994) and elsewhere (Borobia and Barros, 1989; Di Benedetto, 2000; Santos *et al*., 2002; Santos and Haimovici, 2001; Zanelatto, 2001). Baía Norte coastline has four mangroves where several of these prey items have been recorded, including white mullets, southern anchovies, Atlantic cutlass and whitemouth croaker fishes (*e.g.*, Clezar *et al*., 1998; Marcon, 2000). Most of these fish species are found year round as juveniles in different total lengths, thus indicating that these mangroves are important nursery grounds (*e.g.*, Clezar *et al*., 1998; Hostim-Silva *et al*., 1998; Ribeiro *et al*., 1998; Marcon, 2000). This also suggests these mangroves are important suppliers of food resources, which would sustain this dolphin population, but nothing is known of the specific fish communities in

![Figure 5. Home ranges of a presumed female ('Tippy's Mom' or #T'sM – top) and its calf/juvenile ('Tippy' – bottom) marine tucuxis in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP – right) methods.](image-url)
the bay area. Such studies are needed to contribute to a better understanding of the home range size in marine tucuxis in Baía Norte.

The similarity in size and overlap in areas of home ranges of all individuals including females, ‘probable males’, a calf/juvenile and the two individuals not assigned gender are interesting. Such traits are characteristic of rare cetacean populations living in productive systems and forming stable groups, such as the orcas in British Columbia, Canada (e.g., Bigg et al., 1990; Ford et al., 1994). As group dynamic analyses unfold, a similar stability of the marine tucuxi in Baía Norte is being revealed with long-term residency and site fidelity (Flores, 2003), as well as stable associations both in the short and long term (Flores, unpublished). Recent findings of a closed population of bottlenose dolphins living in low-productivity systems show an unprecedented stability (Lusseau et al., 2003) and the ecological constraints which shape marine tucuxi home range, movements and social structure in Baía Norte need to be fully investigated (Flores, 2003).

From the 13 individuals discussed here, three (#A05, A06 and C04) have been seen in the area since 1993, while another three animals (#B04, D01 and D02) have been present from 1994 onwards (Flores, 1999; 2003). They as well as other individuals are year round and long-term residents of a very well-defined, small area with high degrees of site fidelity.

Figure 6. Home ranges of two marine tucuxis (#A06 – top, and D02 – ‘probable male’, bottom) in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP – right) methods.
(Flores, 2003) and stable individual associations (Flores, unpublished). Such characteristics combined with the home range results presented here have implications for various conservation issues, which are discussed later.

Movement patterns

The results presented here for distance traveled and rate of movement, should be considered underestimates, because it was not possible to follow marine tucuxis throughout 24h periods and all combined data were used regardless the activity pattern (travelling, feeding, feeding/travelling, socializing and resting) or diurnal variation in activity. However, distance moved or traveled in a day reached its maximum value of 29.97km. This is comparable to coastal bottlenose dolphins. Bottlenose dolphins daily distance moved or traveled varies with study site and techniques applied. Satellite or radio tagged individuals may range up to 30km a day (e.g., Mate et al., 1995; Irvine et al., 1981) while individuals tracked from theodolite only during daylight hours ranged 73km (Würsig and Würsig, 1979).

Several factors may influence the higher values found for distance moved and daylight rate of movement in winter and autumn (winter mean = 6.49km, SD = 5.21 and autumn mean = 6.69km, SD = 5.41; winter: mean = 2.93km, SD = 1.54 and autumn: mean = 2.56km, SD = 1.30, respectively).

Figure 7. Home ranges of two ‘probable male’ marine tucuxis ('Caroço' – top, and 'Narizota' – bottom) in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP – right) methods.
These probably include prey availability (patterns of distribution, occurrence and schooling), marine tucuxi energetic demand to maintain body temperature, and boat traffic. Tucuxis have been seen feeding (chasing, capturing and even tossing fish in the air) on white mullet (Mugil curema), quite often during autumn and winter while preying frequently on southern anchovy (Lycengraulis grossidens) in summer and spring (P.A.C. Flores, pers.obs.). Various prey items of marine tucuxis including the white mullet and the southern anchovy are found in different numbers in some parts of Baía Norte, thus suggesting seasonality in occurrence (CEPSUL – IBAMA, 1998; UNIVALI, 2001, 2002). Therefore, seasonal variation in the marine tucuxi diet could be expected, though no data are available at this time as the scarce information comes from only four stomach contents (Emerim, 1994). Furthermore, the white mullet is larger and faster than the southern anchovy, which indeed form larger schools. If prey items are patchy and/or scarce and even faster or more difficult to catch, tucuxis might have to move longer distances. Tucuxis in Baía Norte spend more of their daily activity time in traveling or feeding/traveling during winter and autumn than expected and the activity/movement ratio is higher during these seasons as well (Bazzalo and Flores, unpublished data). These factors are likely to affect marine tucuxi feeding success and foraging time and detailed

![Figure 8. Home ranges of two ‘probable male’ marine tucuxis (‘Parceiro’ – top, and ‘Dude’ – bottom) in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP – right) methods.](image)

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studies on marine tucuxi feeding habits and prey item abundance, distribution and nutritional value would contribute to understanding of movement patterns of tucuxis in Baía Norte.

Boat traffic increases greatly during summer (Pereira, 2004), the season during which marine tucuxis demonstrated the lowest values for both distance moved (mean = 3.72km, SD = 4.7) and rate of movement (mean = 1.38km/h, SD = 1.32). Besides the regular fishing and tourism boats, summer brings countless other tourism, speed, sailing and inflatable boats as well as wave runners and jet skies. Whether such high levels of boat traffic create physical and acoustic barriers shrinking the area available for dolphins is unknown. Disturbance responses for tucuxis relative to boats in Baía Norte have been demonstrated during data collected from 1993 to 2003 (Pereria, 2004). From 665 boat-dolphins encounters recorded, 64.3% (n = 428) caused negative responses, defined as interruption and change in previous surface behavior due to the boat approach (Pereira, 2004). Furthermore, the vast majority of encounters occurred in summer and dolphins’ responses were affected by season, boat type and boat approach (Pereira, 2004). In Baía Norte, daily movement and activity cycles show that in summer, marine tucuxis tend to spend much more time in and nearby their core areas where probably physiographical and ecological factors favor protection and food gathering at the same time (Bazzalo and Flores, unpublished data).

Tucuxi movement patterns clearly follow the 3m-depth contour usually parallel to the coastline. Bottlenose dolphins in Golfo de San Jose, Argentina, likely use the 5m depth contour as a guidance lane (Würsig and Würsig, 1979) and it is likely that tucuxis in Baía Norte may use the 3m depth contour in the same way. All movements from the North and South sectors of the home range were undertaken in the same area between Anhatomirim Is. and mainland, thus enhancing the importance of this pathway (Fig. 10).

This study presents the first data on marine tucuxi home range and movement patterns. These findings must be viewed with caution, however, as ‘conclusions based on short-term data tend to be transitory and simplistic’ (Scott et al., 1990). The continuation and even refinement of our studies is then extremely important, not just because the subject is long living and has low reproductive rate (Ramos et al., 2000; Rosas and Monteiro-Filho, 2003; Santos et al., 2003) but also as the studied population is discrete and resident with high site fidelity to the area (Flores, 1999; 2003).

**Conservation implications**

The studied population of marine tucuxi was given specific protection in May 1992 through the creation of the Environmental Protection Area of Anhatomirim (Federal Decree # 528 of 20 May 1992). The limits of this open-use, protected area were defined with the very preliminary knowledge on distribution and movements available at that time from systematic observations using fixed observation points on land and few boat surveys (Flores, 1992) as well as opportunistic observations (Simões-Lopes, 1988). Later regulations in January 1998 applied boat traffic restrictions in a small sector of the marine tucuxi distribution (Directive 58-N of January 1998) taking into consideration the zones with higher usage by tucuxis from 1993 to 1996 (Flores, unpublished data).

The percentage of marine tucuxi’s overall home range within the EPAA could be considered moderate to high.

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**Figure 9.** Home ranges of one tucuxi (‘Shark Bite’ or #SB) in Baía Norte, southern Brazil, calculated by the kernel (left) and the minimum convex polygon (MCP – right) methods.
depending on the estimator used (54% or 5.9 km² by MCP and 74.71% or 11.32 km² using the kernel). Nevertheless, core areas at both the 25 and 50% UD levels are completely within the EPAA and comprise the ‘boat restricted zone’ created in 1998. Therefore, the boundaries of the EPAA are instrumental in fulfilling its main goal of helping to protect the marine tucuxi population. These data combined with those presented elsewhere on residency and site fidelity (Flores, 1999; 2003), distribution and occurrence patterns (Flores 2003) indicate that conservation of this population would be appropriately managed on a small spatial scale over a long term perspective albeit including further practices and regulations. Clearly, conservation efforts would not work properly if existing laws are not strictly respected. Among such important conservation actions we recommend that a buffer zone should be created southward of limits of the protected area. This zone would encompass the overall home range (considering both the MCP and the kernel methods). This will not be effective without the limitation and/or restriction of boat traffic and

Figure 10. Movement patterns of marine tucuxi (Sotalia fluviatilis) by seasons in Baía Norte, southern Brazil, during 2001 and 2002.
aquaculture farming in sections of this area within at least the tucuxi core areas both at the 50% and 25% UDs—where and when regulations are yet not available. Additionally, concomitant with the above, there is a need for constant, adequate enforcement of fishery and boat traffic regulations throughout the protected area as well as the proposed buffer zone.

Incidental mortality in fisheries and ocean pollution have long been considered important threats to cetaceans mainly in coastal habitats (e.g., Twiss and Reeves, 1999; Reeves et al., 2003). Mortality of marine tucuxi have been reported in the study area though no direct assessment has been conducted (Simões-Lopes and Ximenez, 1990; Flores 1992). Also, this impact is known elsewhere in coastal Brazil, being considered the main direct threat to the species in the marine environment (e.g., Siciliano, 1994; Da Silva and Best, 1996; Flores, 2002). More recently, pollutants such as PCBs and heavy metals have been found in low levels in the marine tucuxi (Monteiro-Neto et al., 2003; Yougui et al. 2003). The effects of these factors on marine tucuxis in Baía Norte also deserve attention and further studies. The southern area of Baía Norte has more urban development and sewage discharge from domestic, incipient industries and agricultural outfalls than in the dolphin’s home range. Organic substances and heavy metals are not a major problem in the bay yet (Silva et al., 1996; Cerutti and Barbosa, 1997) but high bacterial contamination was found in two locations in the western mainland coast (near 27°30’S) and the southernmost sector of the study area (Cerutti and Barbosa, 1997). Considerable levels of heavy metals including arsenic, lead, and selenium were found in the water and sediments at the very South sector of Baía Norte and in its mangroves (Queiróz et al., 1993; Silva et al., 1996). A decreasing gradient of contamination of these metals was found from the south to the north in the locations assessed (Silva et al., 1996). However no signs of such metals were present in mullets (Mugil spp.) studied in the southern sector of the bay and the mangrove located near the major urban development (Benatto, 1999). This may indicate either the efficiency of mangroves in retention of such pollutants (Queiróz et al., 1993) or a need of further and more detailed analysis on fishes as well as other animals (Benatto, 1999). Combining studies on these aspects with the continuation of the research on the tucuxi together with biopsy of individuals already underway will contribute even further to their conservation.

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HOME RANGES AND MOVEMENT PATTERNS OF SOTALIA FLUVIATILIS IN BAÍA NORTE, SOUTHERN BRAZIL


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