RUFFORD SMALL GRANT FINAL REPORT

SITE FIDELITY, ABUNDANCE AND HABITAT USE OF GUIANA DOLPHINS (*Sotalia guianensis*) IN A COSTAL AREA OF RIO GRANDE DO NORTE, NORTHEASTERN BRAZIL

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Introduction

The structure of biological populations can be defined as the spatial pattern and density of individuals of the same species in a given area (Ricklefs, 2003). Population biology studies applied to cetaceans are important for both the understanding of population ecology (e.g.: what determines population size) and to accesses the conservation status, moreover many cetaceans species are threaten to extinction or assigned with unknown knowledge about basic aspects of their ecology. However, the habitat of cetacean's populations poses several challenges for abundance estimation and often the definition of a population itself is not always clear. Usually it is hard to define where a population starts and the other finishes, especially for cetaceans that occupy great extensions of the ocean. Techniques used in population parameters estimation for terrestrial animals have been adapted to cetaceans (Hammond, 1986; 2001). Capture-recapture studies can be used to estimate cetaceans that posses natural marks using photo-identification recognition of the individuals (Wursig & Jeferson, 1990; Hammond et al., 1990) and with the advantage that "marked" animals do not need to be physically handle during the course of the investigation.

Another important aspect of cetacean population studies is to determine habitat usage and degree of movement within the habitat. As any animal group, coastal dolphins use its habitat in a heterogeneous manner and distribution of the animals are often patch along the coast with many studies indicating preferences for waters near rivers, estuaries, bays and inlets (Wursig, 1978; Scott et al., 1990; Ballance 1992; Karczmarski et al., 2000; Borobia et al., 1991). For coastal dolphin's populations, many studies reveals some degree of fidelity by animals and residence by at least part of population to particular areas, although with different intensity among individuals (Wells, 1991; Balance, 1992; Karczmarski et al. 1999; Parra et al. 2006; Rossi-Santos et al. 2007).

The Guiana dolphin, *Sotalia guianensis* (Van Bénéden, 1864), is a cetacean of the Family Delphinidea, it is relatively small, the average size is 1.70 m and maximum size is 2.20 m (Silva & Best, 1996; Flores & da Silva, 2009). Its coloration is dark grey in the dorsal region and light grey to pink in the ventral region. It has a distinct line that goes from the rostrum passing through the limit of the pectoral fins. Other characteristics are a triangular dorsal fin, small mellow and an extended and thin rostrum (Figure 1).

Figure 1: Guiana dolphins (*Sotalia guianensis*) in Pipa beach, Brazil. (Photo: Alexandre Paro)

Guiana dolphin is endemic to the coast of the western Atlantic Ocean, from the south of Brazil to Honduras (Borobia et al, 1991). The species has gone to a recently taxonomic revision (Monteiro-Filho et al. 2002, Cunha et al 2005, Caballero et al. 2007), separating the Guiana dolphin from the fluvial species, known as Tucuxi (*Sotalia fluviatilis*), that inhabits the Amazon and Orinoco Basin. Behavior and habitat usage studies have shown that Guiana dolphins present preferences for restricted shallow and coastal areas along its distribution (Wedekin et al., 2007; Azevedo et al. 2007; Filla & Monteiro-Filho, 2009). The predominant behavior observed in all areas is foraging (Daura-Jorge et al., 2005; Azevedo et al., 2007; Flach et al., 2008b).

The coastal habit of the species makes it vulnerable to many human activities that take place along the coastal areas, such as: port activities, over-exploration of fishing resources, by-catch in fishing nets, urbanization of coastal areas, pollution, habitat degradation and uncontrolled tourism.

Abundance estimates for this dolphin are scarce and concentrated in the south and south-east regions of Brazil, and very few information is available for other larger regions, such as the northeast and north of Brazil, and the Caribbean continental coast. The importance of studies of population parameters for the success of programs of conservation reinforces the necessity of this kind of studies for different populations along the distribution of the species. In fact, due to the scarcity of crucial information the species is considered “data deficient” by the IUCN (*International Union for*

Conservation of Nature) Red Book (IUCN, 2010). The IBAMA (Brazilian Federal Environmental Agency) Action Plan for Aquatic Mammals of Brazil (IBAMA, 2001) classifies the species as "insufficient known" and put it as priority the investigation of population abundance.

In the State of Rio Grande do Norte (RN), Northeast Brazil (Figue 2) the Guiana dolphin is commonly seen, manly in the southern coast. The animals are frequently found all year long in some areas of the region (Link, 2000; Sartório, 2005; Queiroz, 2006). However, most of these studies were mainly to describe the behavior of the species, and none has been conducted to investigate population abundance and habitat use.

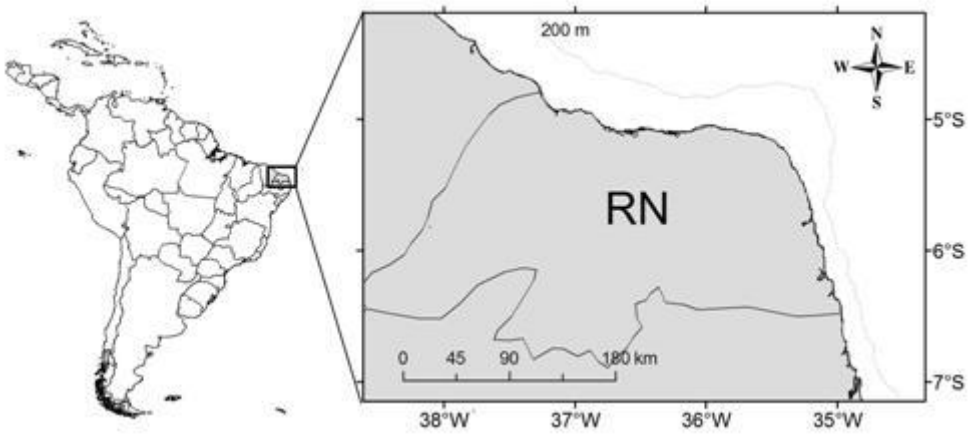


Figure 2: Map showing the State of Rio Grande do Norte (RN), Northeastern Brazil.

Objectives

The objectives of this is study were: 1) Estimate the population size of Guiana dolphins in the south coast of State of Rio Grande do Norte; 2) investigate the site fidelity and movement of individuals in the different areas; and 3) verify if there is spatial variation in grouping patterns and behavior.

Methods

Study Area

The study area encompasses four different independent locations identified as frequently used by Guiana dolphins along a 40 km stretch of coast in the south of the State of Rio Grande do Norte (Link, 2000; Sartório, 2005; Queiroz, 2006). These

locations were: Tabatinga (TAB) (6º03’ S; 35º06’W), Guarairas Lagoon (6 º11’S; 35º05’W), Pipa (06º14' S; 35º03'W); and Baia Formosa (6º22'S; 35º00'W) (Figure 3). Tabatinga, Pipa and Baia Formosa are shallow inlets that share similar characteristics, which include sandy beaches and cliffs that offer protection from the predominant southeast winds.

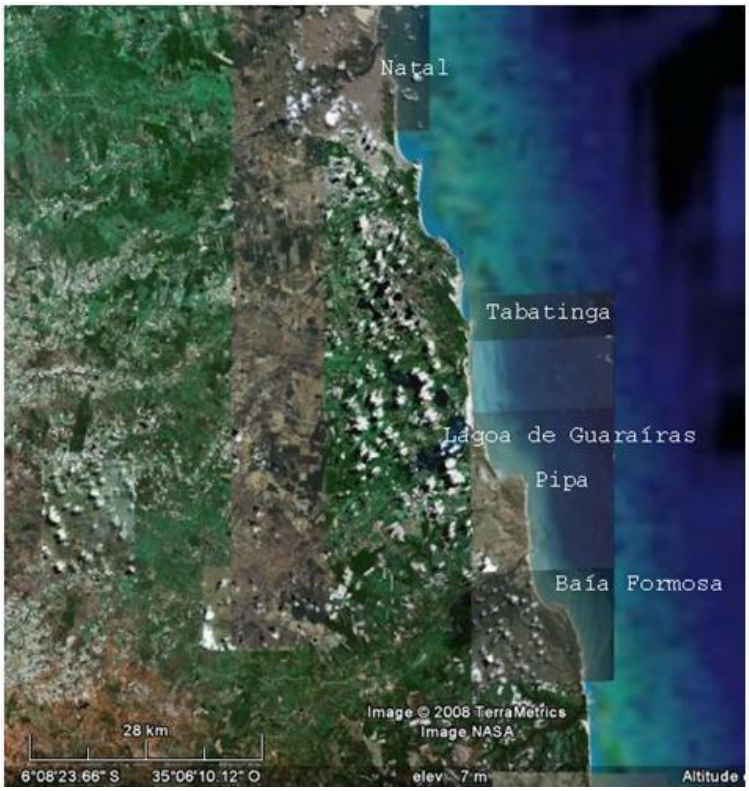


Figure 3: Study area showing the 4 localities investigated: Tabatinga (TAB), Guarairas Lagoon (LG), Pipa (PIP) and Baia Formosa (BF). Up north is Natal , capital of Rio Grande do Norte.

In Pipa there are two inlets used by the dolphins (Madeiro and Curral) (Figure 4) and they are part of the Tibau do Sul Wildlife Reserve (Figure 5), a municipal protected area created in 2006 with the main objective to protect the local marine fauna, including the dolphins. The Guarairas Lagoon is located approximately 5 km to the north of Pipa, its stretches around 7 km long and 3 km wide, and it is part of a larger lagoon complex connected to other lagoons and river streams. The lagoon is very shallow in its most inner areas, presenting sand banks and mangroves.

The areas surveyed in this study cover the inlets and adjacent waters in the case of the beaches. For the Lagoon the survey was conducted in the mouth of the Lagoon and up to 1 km inside, where navigability was possible. The total area covered for each

locality was: Tabatinga (TAB) = 3.3 km², Guarairas Lagoon (LG) = 3.0 km², Pipa (PIP) = 6.0 km² e Baia Formosa (BF) = 10 km².

A division of 3 sectors was established for each study area. It was done through division lines using visible spots as references (Figure 6). Broadly speaking, sector 1 corresponded to the inlets (sheltered areas); sector 2 was an intermediate area between the open sea and the sheltered areas and finally the sector 3 corresponded to the open sea. The open sea is the sector with greater influence of oceanic waters. The water is less turbid but with stronger winds, currents and waves. In the case of Guarairas Lagoon, sector 1 corresponded to the more interior waters; sector 2 was the inside waters close to the mouth, and the sector 3 corresponded to the waters around the mouth of the Lagoon (Figure 6d).

Figure 4: Aerial photograph of Pipa area. (CI = Curral Inlet, MI = Madeiro Inlet and GL = Guarairas Lagoon).

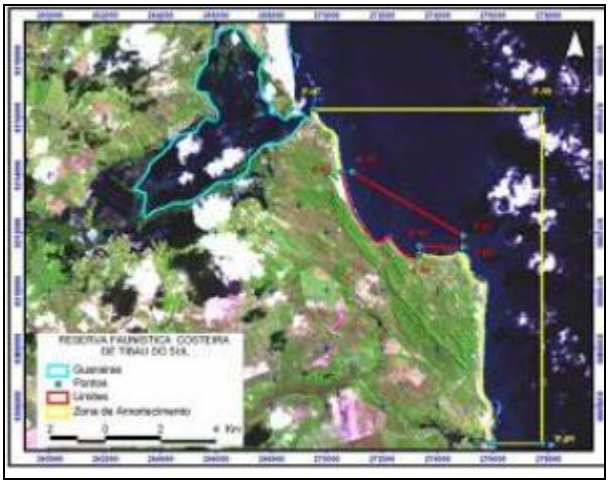


Figure 5: Limits of the Tibau do Sul Wildlife Reserve (in red). In blue is Guarairas Lagoon and in yellow the Reserve buffer zone.

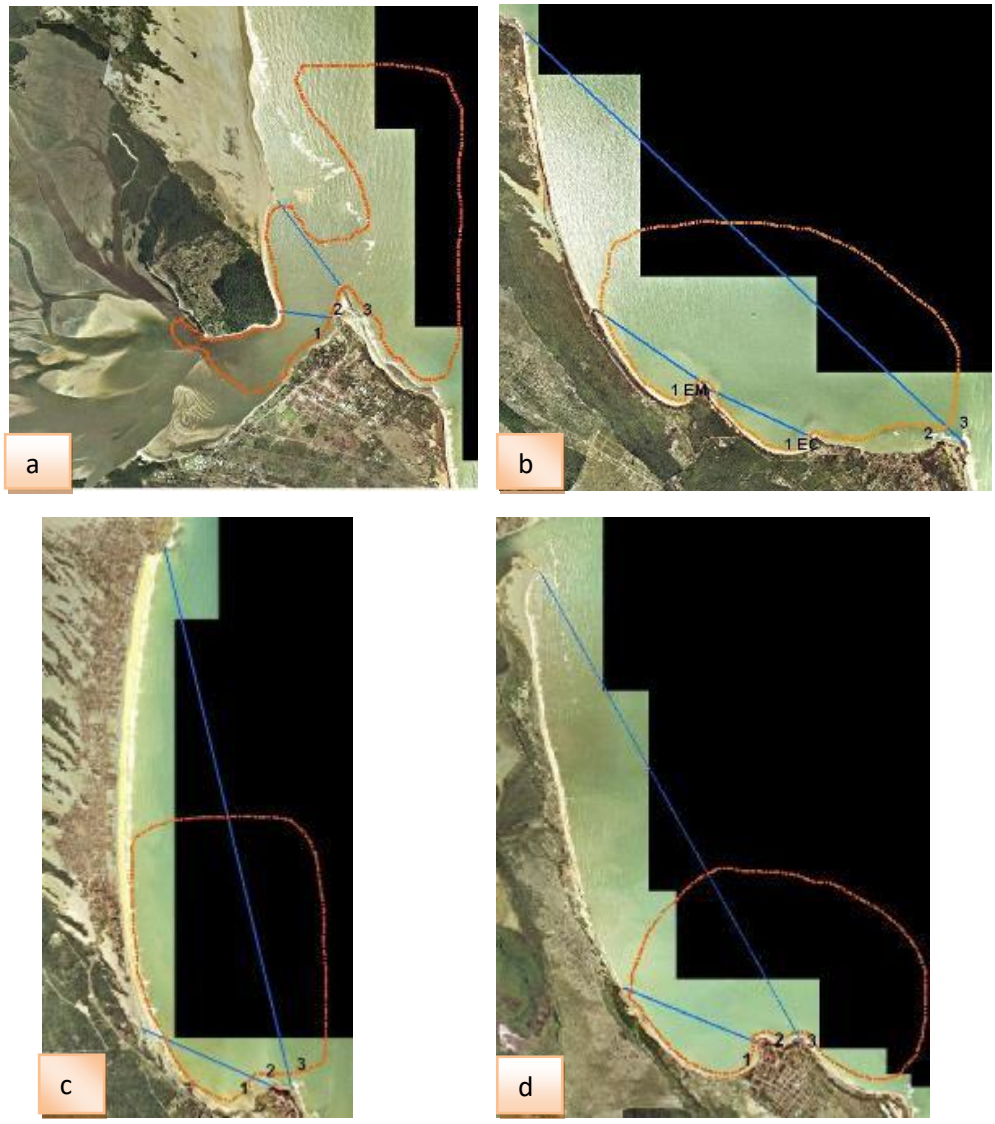


Figure 6: Maps of the study area. Sectors divisions are represented in the blue lines (Sector 1= 1, sector 2 = 2 and sector 3 = 3). Upper left (a) Guarairas Lagoon; Upper right (b) Pipa – EC = Curral inlet EM = Madeiro inlet; Lower left (c) Tabatinga; Lower right (d) Baia Formosa. Dot lines in orange represent the total area covered for each study location.

Data collection

The field work was conducted from March 2008 to March 2009. Periodic cruises were done to all study areas using a wooden boat of 10 m and a 50 HP diesel center motor. Each day corresponded to the sampling of one of the four areas, always with observation effort from 8:00 to 15:00 h, guaranteeing equal effort for all sampling occasions. The crew consisted of the sailor and at least two experienced researches. Before we started the surveys, field trips were conducted in February 2008 in order to establish the limits of the study area for each locality. We established our limits based

on theses field trips as well as in information from dialogues with local fisherman. The same boat and sailor were kept during the whole period of field work.

When a group of dolphins was detected, the research protocol consisted of approaching and following the group for a variable period (focal group follow - Altmann, 1974). We established a maximum length of 1 hour follow, both to prevent disturbance of the animals and also to make it possible to continue the survey in search for other groups. Photo-identification was attempted for all animals of the group by the natural marks in its dorsal fin (Würsig & Jefferson, 1990). The equipment consisted of SLR Nikon D80 digital camera with zoom lens autofocus Nikkor AF 70 – 300 mm. All photos were taken by the same researcher (AP). A second researcher was responsible for filling-up the field sheet (RT). We registered the following data for each group: date, locality and time. At every 5 minutes we also collected data regarding: geographic position (GPS Garmin E-trex), number of animals present (group size), age category of the individuals and behavioral state.

Age category was registered as below:

Adult: Individuals with total length of approximately 1.70 m or more.

Immature: Individuals with total length up to ¾ of the adults. It can include juveniles or calves. Calves are up to half the size of adults and usually are escorted by an adult.

Behavioral states were classified according to four categories (according to Tosi & Ferreira, 2009):

Foraging: Any activity that involves search, chasing, capture, manipulation and ingestion of prey. Group performing this behavior move erratically and movement is periodically interrupted by events of chasing and capture of prey;

Travelling: Groups swimming constantly in a defined direction, moving from one point to another;

Socialization: Groups swinging in the surface with frequent physical contact between two or more animals, which can include rubbing, chasing and elevation of parts

of the body. The movement is usually fast and includes aerial activities such as leaping, slaps and spy-hoping;

Foraging Mixed: When foraging was observed together with the other behaviors described.

Unknown: Behaviors that could not be identified.

Rest was never observed.

We recorded the group size considering all individuals in the visual range of the researchers, not necessarily swimming in the same direction or engaged in the same activity. This concept was used because a group can be very fluid with individuals splitting in sub-groups and joining together again, and acoustic contact among individuals is probably occurring at larger areas than the visual range.

Data Analysis

We built a catalogue of all photo-identified dolphins containing information about date and locality of each individual sighted. Animals that did not posses natural marks were named "unmarked" (UM) and animals with few and small marks "slight marked" (SM). Animals considered UM and SM were not included in the catalogue, only well marked animals were included. This is important because individuals must be easily recognized when photo-identified to avoid ambiguity (false negatives or positives can affect population estimates in different ways).

Population size estimation

The method used in this study for population size estimation is the Capture-Recapture (CR). A great diversity of methods has been developed to estimate population parameters trough Capture-Recapture (see Begon, 1979; Seber, 1982; Krebs, 1989, Amstrup et. al, 2005 for an appreciation of the methods). When a dolphin was photo-identified it was considered a "capture" and the subsequent sightings of the individual the "recaptures".

The population size was estimated through mark-recapture closed population models. It means that there is no birth, deaths, immigration and emigration. Closed

population models are simpler and given the relative short period of study for a slow breeder mammal, it is likely that population does not change through the course of the study.

The basic Lincoln-Petersen estimator is calculated through two samples where is assumed that the proportion of animals previous marked in a first sample and recaptured in a second sample equals the proportion of marked animals in the population. Using this simple idea and subsequent samples, various estimators of animal abundance can be derived (Otis et al., 1978). We used MARK software (White & Burnham, 1999) to build closed population models and maximum likelihood estimation of parameters of capture and abundance.

Closed capture- recapture models have assumptions that need to be followed to avoid distortions of the results. For cetaceans, there are two which are the most important (see Hammond, 1986), namely marks that are recognizable through time and equal probability of capture among individuals. Since only well marked individuals in good quality photos were included in the analysis, this avoids misidentifications and get around the first assumption. The second assumption is more problematic, since different source of heterogeneity on capture and recapture of individuals of animal populations can occur (Willians et al. 2002). To minimise that problem during the photo taken procedure no preference was given to any groups or individuals, in an effort to photo-identify as many dolphins as possible and reduced capture heterogeneity. Also dolphins were photo-identified regardless of presenting conspicuous natural marks or not, an important procedure for a realistic estimation of Theta (proportion of marked and unmarked individuals in the population). Another important assumption is that recapture probability is not affected by previous capture (behavioural effect). This is unlikely for "captures" through photo-identification since no animal handling is needed (although avoidance of boats is an uncontrolled variable).

All models were built in MARK using Huggins Close Capture, which conditioned abundance as a derived parameter out of the likelihood function (Huggins, 1989). Different models were built, testing capture constancy (Mo), variation through time (Mt), behavioural effect (Mb) and the combination (Mtb). In order to test these same models accounting for some heterogeneity of capture probability among individuals, we run the finite mixtures models in MARK, the "Closed Captures with

Heterogeneity" and "Full Closed Capture with Heterogeneity". These models include the parameter π (pi), which represents the probability of individuals belongs to different sets of mixtures, and it correct heterogeneity-induce bias in the estimation (Pledgers, 2000). Models in these data type are: Mh, Mth, Mbh and Mtbh. Models were then compared in MARK using the Akaike's information criterion corrected for small samples (AICc). Best fit models are those with lowest AICc, meaning the highest likelihood probability estimation for parameters but also a balance for more parsimonious models (models with less number of parameters) (Burnham & Anderson, 2002).

The population size estimation using natural marks of the individuals will give us the population size of the well-marked portion of the population. For estimating the total population size it is necessary to calculate the proportion of marked and unmarked individuals in the population or Theta (θ). This was done directly counting the number of photo-identified individuals and the number of unmarked or slight marked individuals for each sampling occasion in order to establish an average from all sampling occasions. The slight marked animals could be easily identified within a sampling occasion. For unmarked individuals, superficial marks had to be used, such as scratches, tooth marks, coloration, dorsal fin shape and even consistent companion of a photo-identified adult in the case of a young. Because these marks were used only within a day they could be considered reliable for identification purposes.

Abundance estimation from marked animals was divided by Theta value to obtain total population size and delta methods were used to compute confidence intervals.

Site fidelity

We defined as site fidelity the frequency in which photo-identified individuals were seen at a certain area. It was done an analysis of site fidelity for the four areas investigated; we calculate a site fidelity index as shown below:

$$FA_i = \frac{NA_i}{\sum Ni}$$

Where: FA*i* is the fidelity of the area A by the animal *i*; NA*i* is the number of sightings of the individual *i* in the area A, and $\sum Ni$ is the sum of the sightings of the individual *i* in all areas.

The site fidelity index was then classified in 5 arbitrary categories: Very High (1,0-0,8), High (0,79-0,6), Moderated (0,59-0,4), Low (0,39-0,2) and Very Low (0,19-0,1).

A comparison between areas was performed in order to investigate if photo-identified individuals were seen in different locations. Number of matching of identified individuals in different locations was divided by total numbers of identified individuals in each location as a measure of movement of dolphins between areas. It permits to elucidate if there is a movement of individuals between areas and, if it is the case, between which areas it is more frequent.

Distribution, Group Size and Behaviour

All data of geographic position of each dolphin group encounter was plotted in digitalized aerial photographs trough ESRI ArcGis version 9.3. Comparisons between the spatial usage and group pattern and behaviour were performed. The 3 sectors were used as the independent variables and group size, behaviour, presence of immature and period of the day as dependent variables. Analysis for each location separately and for all the beaches areas together (Tabatinga, Pipa and Baia Formosa) was performed. The Guarairas Lagoon was excluded of this analysis because it is a different environment when considering beach areas.

It was used the first record of each encounter for area usage and period of the day analysis. Group size, behaviour and the presence of immature was defined along the encounter. Because each encounter could extend up to 1 hour before we left the dolphins, and there was a minimal interval of at least 15 minutes between encounters, the events were considered as independents for the statistical analysis. Non - parametric statistics was used, since the data did not show normal distribution.

The comparisons and statistical tests performed are summarized below:

Variation of group size according to areas: Group size in each sector was compared using Kruskal Wallis (for the 3 sectors) or Mann-Whitney (for dyadic comparisons).

Variation of behaviour according to areas: The behaviour of the groups found in each sector was compared using qui-square tests and Adjusted Residual analyses.

Variation in the presence of immature according to areas: Groups were classified as with and without immature (calves and juveniles) and compared between different sectors using qui-square tests and Adjusted Residual analyses.

Variation in the area usage according to time of day: Encounters were classified as morning (8:00 – 11:59) and afternoon (12:00 – 15:00) and compared between the different sectors using qui-square tests.

Variation of group size according to behaviour: The behaviour of the group and its size was compared using Kruskal Wallis (comparison of the three areas together) or Mann-Whitney (for dyadic comparisons).

Results

The photo-identification data was collected through 44 field trips, with a total of 11 field trips for each area. In all field trips it was possible to verify the presence of dolphins, except from Guarairas Lagoon, which from a total of 11 field trips in 7 of them dolphins were present. Total effort in the field, effective effort (direct observation of the animals), and total number of photos obtained are summarized in the Table 1. From the total of photos obtained (13.661) around 24% (3.351) could be used for photo-identification. The percentages of usable photographs for photo-identification for each location were: Tabatinga (20%), Pipa (28%), Guarairas Lagoon (14%) e Baia Formosa (20%).

Table 1: Total hours of effort in the field, effective effort and number of photos taken during the data collection for photo-identification of *Sotalia guianensis* in each study location. (TAB = Tabatinga, PIP = Pipa, LG = Lagoa de Guarairas e BF = Baia Formosa).

Local	Total Effort	Effective Effort	No. Photos
TAB	77h	30h (39%)	3.745
PIP	77h	30h 15min (39%)	4.024
LG	77h	11h 45min (15%)	1.345
BF	77h	32h (41%)	4.547
Total	329h	113h 30min (34%)	13.661

Table 2 summarize the data obtained regarding the total number of encounters, total number of animals sighted, mean number of animals sighted among the sampling occasions and the total number of animals photo-identified. It is important to note that possible recounts were incorporated since same animals could be in different encounters.

Table 2: Total and average number for each sampling occasion of encounters and of animals sighted and total number of animals photo-identified for each study location during the period of photo-identification data collection. (TAB = Tabatinga, PIP = Pipa, LG = Lagoa de Guarairas e BF = Baia Formosa).

Local	Total No. Encounters	Average No. Encounters per day	Total No. Animals	Average No. Animals per day	No. Total Animals photo Id.
TAB	62	5.6 (2-12) SD: 2.97	352	32 (8-60) SD: 13.94	39
PIP	78	7,0 (4-10) SD: 2.07	441	40 (9 -71) SD: 20.51	57
LG	20	2,8 (1-4) SD:1.06	74	10 (2-25) SD: 10.04	16
BF	77	7 (3-9) SD: 1.27	559	51 (23-70) SD: 10.18	76
Total	260	5,6 (2-10) SD: 2.02	1533	33 (2-72) SD: 17.22	136

Population size estimative

To conduct a population estimate for all areas it was considered a capture occasion the combination of 4 field trips, one for each study areas. The interval between a field trip to one area and another varied between one to ten days. The total number of sampling occasions for all areas was 11 and a total of 136 animals were photo-identified.

The discovery curve (Figure 8) showed a steep increase up to the III capture occasion; follow by a gradual increase up to the VII capture occasion, and a tendency for stabilization afterwards. The stabilization of the discovery curve suggests that the animals that using the area were well sampled trough the study. Around 30% of the

individuals observed in the study were capture only once. It was observed a gradual decrease in the number of animals capture more than once and a more homogeneous distribution of animals captured four times or more which corresponds to another 30% of the animals (Figure 9).

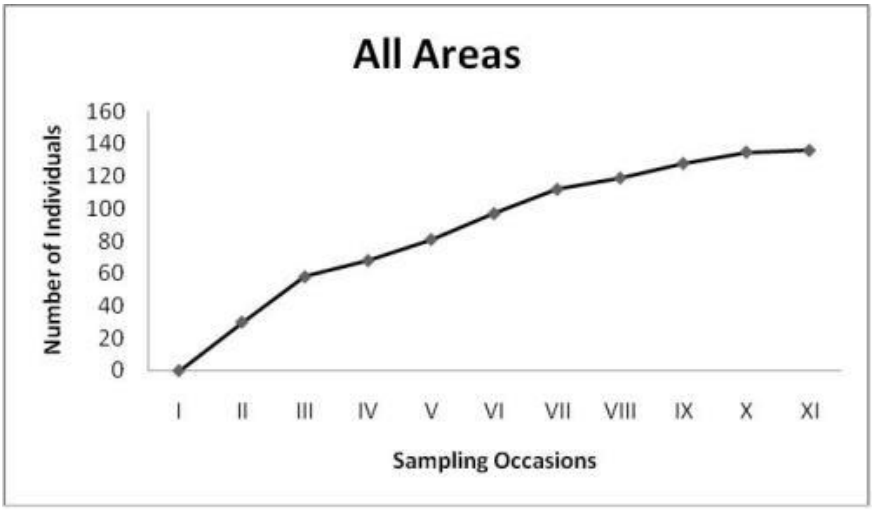


Figure 8: Discovery curve of individual dolphins of *Sotalia guianensis* for All Areas.

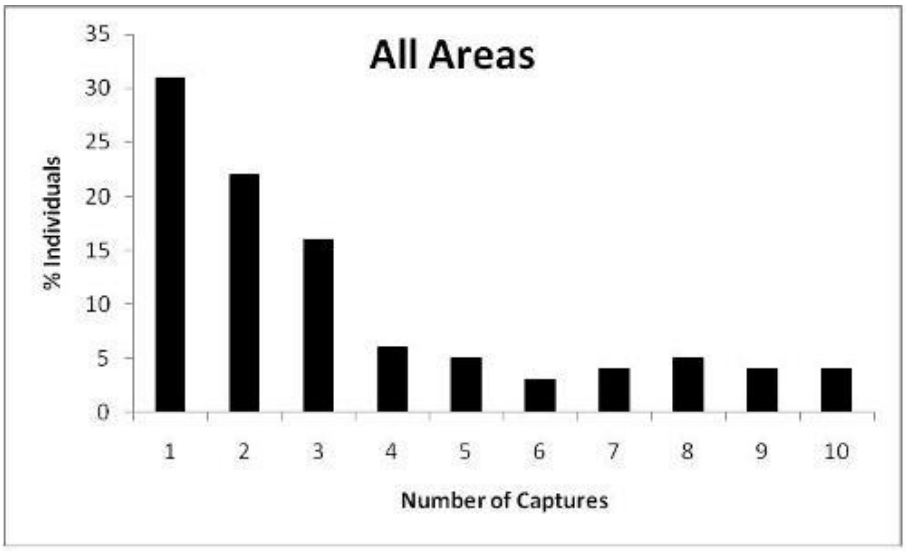


Figure 9: Capture frequency of individual dolphins of *Sotalia guianensis* for All Areas.

From all models built in MARK, only models including heterogeneity showed significant support (Table 3). These are the models "Huggins Full Closed with Heterogeneity". It was set 2 mixtures of capture probability that showed to be enough to account for the heterogeneity between individuals. Best fitted models also had

parameters that varied through sampling occasions (time effect). Models that also accounted for behaviour effect (Mtbh), did not show as much support trough AICc. Different recapture probabilities (behaviour effect) for both mixtures large increase the number of parameters and showed low fit. All support in fact pointed to a single model Mth, meaning a time effect and heterogeneity on capture probability.

Table 3: Results of AICc scores computed in MARK for the different set of models for population abundance of *Sotalia guianensis*.

Model	AICc	Delta AICc	AICc Weights	Parameters	Deviance
Mth	1618.62	0.00	0.996	23	1507.54
Mtbh	1630.20	11.58	0.003	43	1477.26
Mh	1636.00	17.38	0.000	3	1565.66
Mbh	1638.63	20.01	0.000	5	1564.26
Mtb	1791.98	173.36	0.000	21	1685.02
Mb	1814.78	196.16	0.000	2	1746.45
Mt	1825.20	206.58	0.000	11	1738.70
Mo	1831.31	212.68	0.000	1	1764.98

Assuming the model Mth, the number of well marked animals in all areas was estimated to be 153 (95% IC = 145 – 169); SE: 5.9 CV = 0.04. For the calculation of the Theta correction, the proportion of marked/unmarked animals in the population was calculated as the average for all areas, except by Guarairas Lagoon. This last area was used in an irregular manner and by less number of dolphins, and it could potentially bias the real proportion. Average Theta correction calculated for marked/unmarked animals in all areas was: 0.66 ± 0.08. Delta methods were used to compute confidence intervals. Therefore total population estimates for all areas:

Nt = **232** individuals (95% IC = 195 – 277; CV = 0.08).

Site Fidelity

We performed the calculation of the site fidelity index including in the analysis only those individuals that had at least two sightings during the course of the studies. Individuals that had only one sighting were excluded since these animals had the lowest site fidelity of the study area. From the total of 136 animals individually indentified 41 had only one sight and the remaining 95 individuals were investigated regarding site fidelity.

We compared the number of animals registered in the field with the number of individuals photo-identified (including slight marked and unmarked animals) during the analysis. In most of the encounters there was a match between numbers of animals counted in the field and numbers photo-identified. So, a reliable site fidelity index calculation could be made. The result of number of animals classified in each of the 5 categories of site fidelity established is presented in table 4.

Table 4: Absolute number and percentage of photo-identified individuals of *Sotalia guianensis* classified in each of the fidelity category in the respective areas and in all areas.

	Fidelity Degree	Very High	High	Moderate	Low	Very Low
Local	Tabatinga	4 (4%)	4 (4%)	14 (15%)	7 (7%)	66 (70%)
	Pipa	5 (5%)	11 (12%)	18 (19%)	7(7%)	54 (61%)
	Guarairas	0	3 (3%)	7 (7%)	7 (7%)	78 (83%)
	Baia Formosa	45 (47%)	2 (2%)	3 (3%)	1 (1%)	44 (47%)

In general, few individuals showed very high or high site fidelity, in TAB only 8% of the animals sighted at least twice, PIP had a larger number corresponding to 17%, and in Guarairas Lagoon animals showed the lowest site fidelity, with no animals classified as “very high”, and few classified as “high”. Contrasting with the other areas, in BF much larger number of animals showed “very high” or “high” site fidelity, representing almost half of the individuals sighted at least twice (47%). While most of

individuals were classified as with very low or low site fidelity, composing 48% – 85% of the animals depending on the location, "moderated" category had low percentages of individuals in BF (3%) but higher in TAB, PIP and LG (14%,18% and 7% respectively) (see table 3). The values of site fidelity observed for the population is related to the movement pattern of the individuals between areas.

Movement between areas

Table 5 shows how many individuals photo-identified in one particular area were also observed in any other different area during the study, indicating movement between areas from these individuals.

Table 5: Absolute number and percentage of the total of photo-identified individuals of *Sotalia guianensis* that moved between areas (Ind. MOV) for each location and for all areas.

Local	Total Ind. MOV
TAB (n=39)	27 (69%)
PIP (n=57)	42 (74%)
LG (n=16)	16 (100%)
BF (n=76)	11 (14%)
All Areas (n=136)	44 (32%)

High numbers of photo-identified dolphins from Pipa (74%) and Tabatinga (69%) were seen in at least one more area. Also, all individuals photo-identified in Guarairas Lagoon were seen in other areas. Baia Formosa is the only location where movement of individuals was low, reaching only 14% of all individuals identified in this location. Considering all locations as a whole, from the animals seen at least more than once, 44 (32%) were seen in different areas. Few dolphins were seen in more than 2 areas, only 5% of total of the individuals photo-identified in this study or 11% of animals that movement was detected.

The greater exchange of individuals was found between Pipa and Tabatinga, where 26 individuals were detected in both areas, corresponding to a total of 37% of the individuals of both locations sharing the area. In Guarairas Lagoon the majority of individuals were also seen in Pipa, a proportion of 24% animals of both locations sharing the area, and also a moderate number of individuals of Guarairas Lagoon sharing the area of Tabatinga (12%). In Baia Formosa, low number of individuals moved, mostly to Pipa, where only 8% of animals of both locations shared these areas. Number of animals seen in more than 2 areas was very low, only 7 individuals (5%) and mostly between Pipa, Tabatinga and Guarairas Lagoon. A diagram (Figure 7) shows the pattern of movement found between areas: a larger movement between Tabatinga, Pipa and Guarairas Lagoon and low movement rate for Baia Formosa to all other areas.

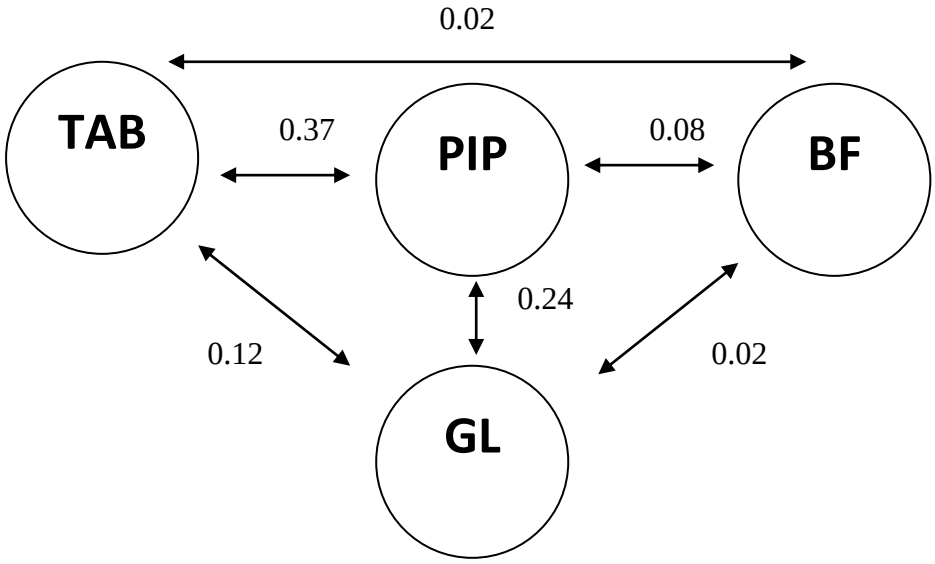


Figure 7: Diagram representing the percentage of photo-identified individuals of *Sotalia guianensis* that share the different locations of the study area. Numbers represent the proportion of dolphins common to each pair of location from the total of animals photo-identified in each locations considered. (TAB = Tabatinga, PIP = Pipa, GL = Guarairas Lagoon and BF = Baia Formosa).

The animals that were seen only once during the entire study, regardless in which areas it was sighted, reached 30% of the photo-identified animals. These animals are considered transients of the study. In fact, it was noticed that most of the transients of the whole study area is composed of groups of animals that were in a determined location or encounter in particular sampling occasions (4 of 11 occasions in Tabatinga and 3 of 11 in the case of Pipa). As expected in Baia Formosa transients were found in

more sampling occasions (6 of 11) because animals in that area presented low movement rate.

Habitat Usage

Distribution, Group size and Behaviour

The data base for distribution, group size and behaviour is larger than the data for photo-identification effort, and it is summarized in Table 6. All data was collected using the same methodology, and included the days with photo-identification effort.

Table 6: Total hours of effort in the field and effective effort during the data collection for distribution, group size and behaviour of *Sotalia guianensis* in each study location. (TAB = Tabatinga, PIP = Pipa, LG = Lagoa de Guarairas e BF = Baia Formosa).

Local	Total Effort	Effective Effort
TAB	147h	51h34min (35%)
PIP	147h	69h12min (47%)
LG	161h	16h45min (10%)
BF	140h	58h10min (41%)
Total	595h	196h11min (33%)

Table 7 summarize the data obtained regarding the total number of encounters, average number of encounters per sampling occasion, total number of animals sighted, and mean number of animals sighted among the sampling occasions considering each study location.

Table 7: Total and average number of encounters and animals sighted for each sampling occasion in each study location during the period of data collection for distribution, group size and behaviour of *Sotalia guianensis* (TAB = Tabatinga, PIP = Pipa, LG = Lagoa de Guarairas e BF = Baia Formosa).

Local	Total No. Encounters	Average No. Encounters	Total No. Animals	Average No. Animals
TAB	104	4,9 (2-12) SD 2,24	575	27,3 (8-60) SD 12,13
PIP	155	7,3 (4-11) SD 1,71	863	41 (9-72) SD 16,09
LG	31	2,0 (1-4) SD 1,09	115	7,6 (1-25) SD (7,86)
BF	137	6,8 (2-10) SE 2,0	951	47,8 (4-70) SE 13,7
Total	427	5,2 (1-12) SD 2,4	2504	30,9 (1-72) SD 17,7

Tabatinga

Figure 10 illustrates the distribution of sightings in Tabatinga. The plot of dots represents the encounters registered. Total area sampled was 3.3 Km² in Tabatinga.

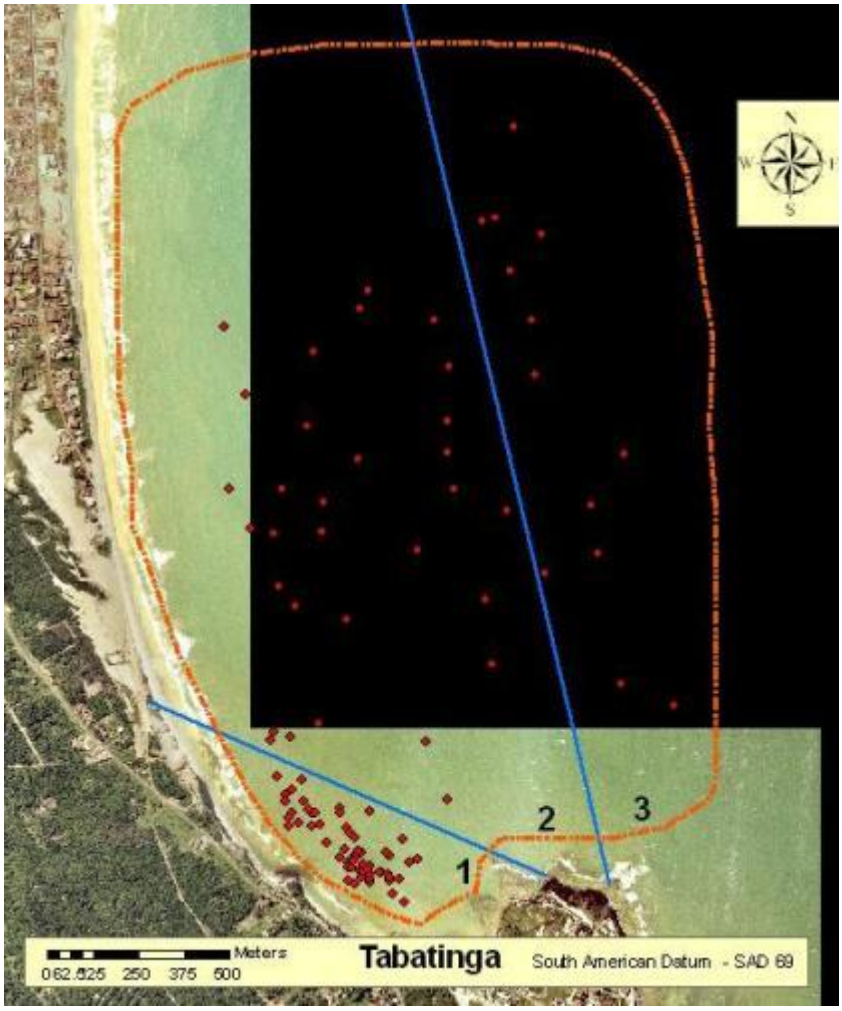


Figure 10: Map of Tabatinga. The dots correspond to the encounters of groups of *Sotalia guianensis*. Numbers indicates the respective sectors. Dot line corresponds to area covered.

The image shows that animals are concentrated in the inner sector (sector 1). From a total of 104 encounters, 64 (62%) were in this sector. Dolphins groups could also be observed outside the inlet, up north along the beach, in areas further out of the coast line. Sightings in sector 2 corresponded to 25% of the total while in sector 3 (further than 1 km of the shore) sightings were even lesser, corresponding to 13% of the total.

Figure 11 illustrates the plotting for the dolphin encounters in Pipa (n = 150). Total area sampled was 6 Km². In Pipa there are two inlets where animals concentrated, namely Curral (C) and Madeiro (M). Both inlets correspond to sector 1, Madeiro had 40% of total encounters while Curral had 20%. Total for both inlets is 60% of the encounters. Besides seen in inlets animals were also seen distributed along areas further from the coast. Dolphins in sector 2 mostly concentrated in areas in front of the inlets

from 0.5 to 1 km of the coast line. Encounters in sector 2 corresponded to 28% of the total. Sector 3, outside the embayment of the region, around 1.5 to 2 km from the coast had the smaller number of encounters, 12% of the total.

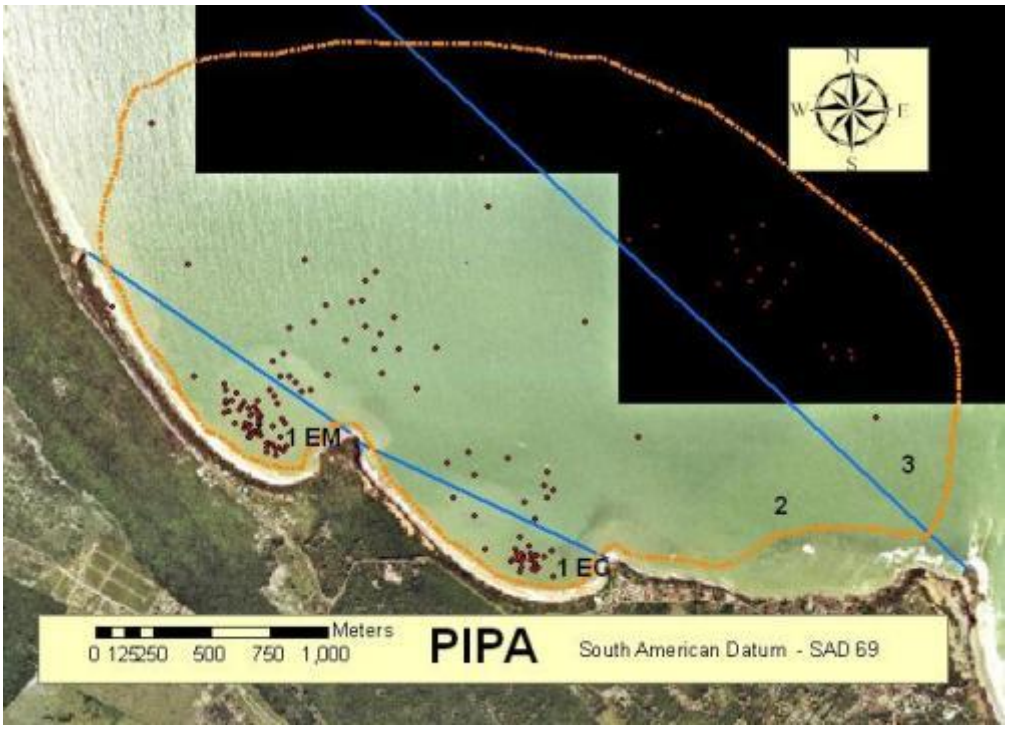


Figure 11: Map of Pipa. The dots correspond to the encounters of groups of *Sotalia guianensis*. Numbers indicates the respective sectors. Dot line corresponds to area covered.

In Guarairas Lagoon, 5 Km north from Pipa, it was observed frequent use of both the areas inner and outside the Lagoon as illustrated in Figure 12. However, area usage was more irregular: of 23 field trips to Guarairas Lagoon in only 15 (65%) of them dolphins were observed. Total area coverage in Guarairas Lagoon was 3,0 Km². The more inner areas of the Lagoon could not be surveyed due to the depth and presence of sand banks, and information from local fisherman suggested that animals do not enter in this areas. From the total of 31 encounters, 19% were in sector 1, the inner portion. In sector 2, near the mouth, occurred 39% and outside the Lagoon, in sector 3, occurred 42% of the encounters.

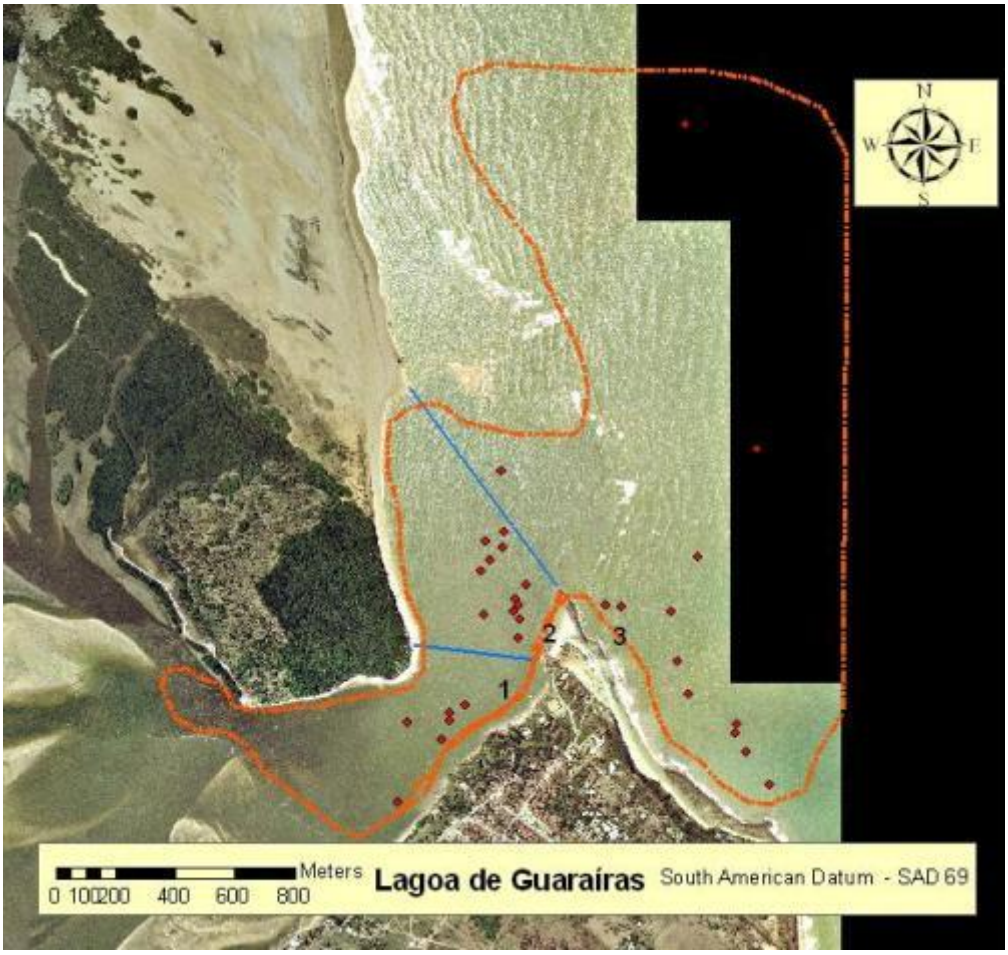


Figure 12: Map of Guarairas Lagoon. The dots correspond to the encounters of groups of *Sotalia guianensis*. Numbers indicates the respective sectors. Dot line corresponds to area covered.

In Baia Formosa the area covered was larger corresponding to 10 Km², and the pattern of distribution of the animals in the area was different than the other beach areas. (Figure 13): From the 137 encounters only 22% were in sector 1. Sector 2 concentrated 27% and sector 3 concentrated most of the sightings with 51% of the total. Most of the sightings in sector 2 were relatively distant from the coast (around 300 m), in spite the fact that sector 2 in Baia Formosa has a small stretch of coast line. Also, most of the sightings in sector 3 were in open areas, in front of the most southern beach in Baia Formosa.

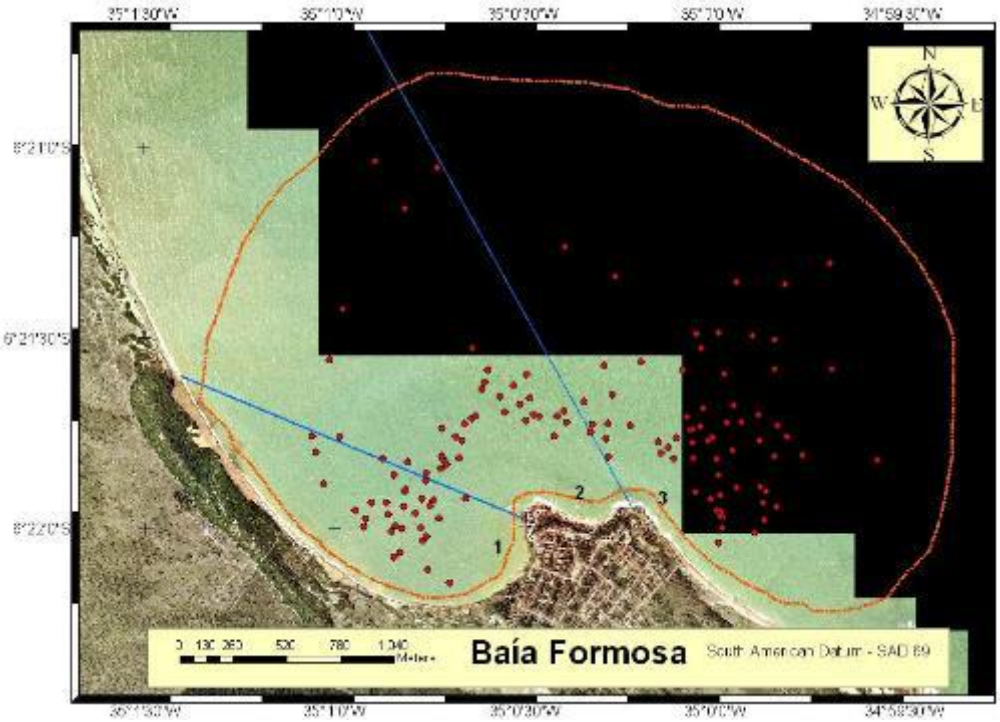


Figure 13: Map of Guarairas Lagoon. The dots correspond to the encounters of groups of *Sotalia guianensis*. Numbers indicates the respective sectors. Dot line corresponds to area covered.

Average group size was similar in the beaches areas but smaller in Guarairas Lagoon. Group size in each areas was: TAB 6.0 (1-19 SD: 3.1); PIP 5.5 (1-30 SD: 4.1), GL 3.7 (1-12 SD: 2.9) and BF 6.9 (1-25 SD: 4.8).

For tests including all areas together Guarairas Lagoon was excluded from the analysis since it showed particular differences between the beaches areas.

As a whole, differences between area usage in the different sectors of the beach areas were detected. Larger groups were found in the outer sector (sector 3) than in the others (Kruskal Wallis: H=13.845 N=391 GL=2 p=0.001) (Figure 14). This was more evident in Baia Formosa, but Pipa and Tabatinga showed progressively larger standard errors in sector 2 and 3 compared with sector 1. In Guarairas Lagoon when sectors 1 and 2 (inner sectors) are grouped together and compared with the sector 3 (outer sector), a significant difference in group size was found (Mann-Whitney: U = 60.5 Z(U) = -2.306 N=31 p=0.021). Larger groups were observed in sector 3, average group size inside the Lagoon was 2.38 (1-4 SD: 1.09) and outside was 5.53 (1-12 SD: 3.6).

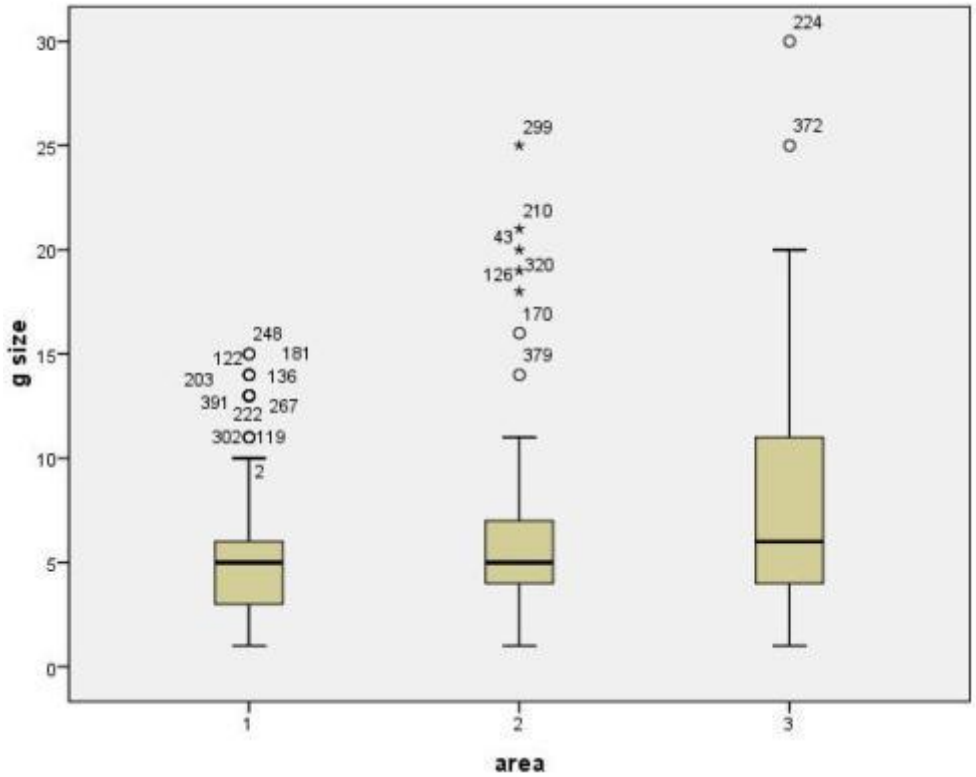


Figure 14: Box-pot of the relation of group size in the different sectors for all beach areas.

The predominant behaviour of the animals was foraging (49%), followed by travelling (26%), foraging mixed (20%) and socialization (6%) as showed in the histogram of the Figure 15. Type of mixed foraging differed among areas: while in Tabatinga it was most seen foraging/ socialization, in Baia Formosa foraging/travelling predominated, and in Pipa foraging /travelling and foraging /socialization was observed. Guarairas Lagoon had very low frequency of foraging mixed behaviour and only foraging/ socialization was observed. Analysis of behaviour frequency for each area separately showed that foraging mixed behaviour had low frequencies for all areas (< 10%) but in Baia Formosa where foraging mixed had higher frequency (17%). Foraging alone had the highest frequency in Guarairas Lagoon (72%), followed by Pipa (61%), Tabatinga (52%) and Baia Formosa (48%). Travelling was lower in Guarairas Lagoon and Pipa (22 and 26% respectively) and higher in Tabatinga and Baia Formosa (32 and 31% respectively). Finally socializing was higher in Pipa (9%), slight lower in Tabatinga (7%) and lower in Baia Formosa (4%). In Guarairas Lagoon no socialization was observed.

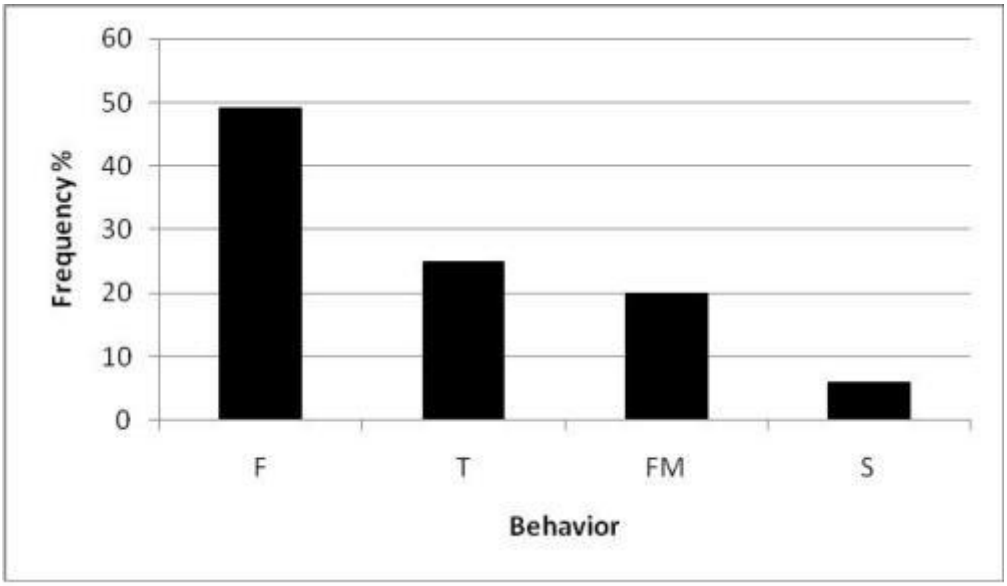
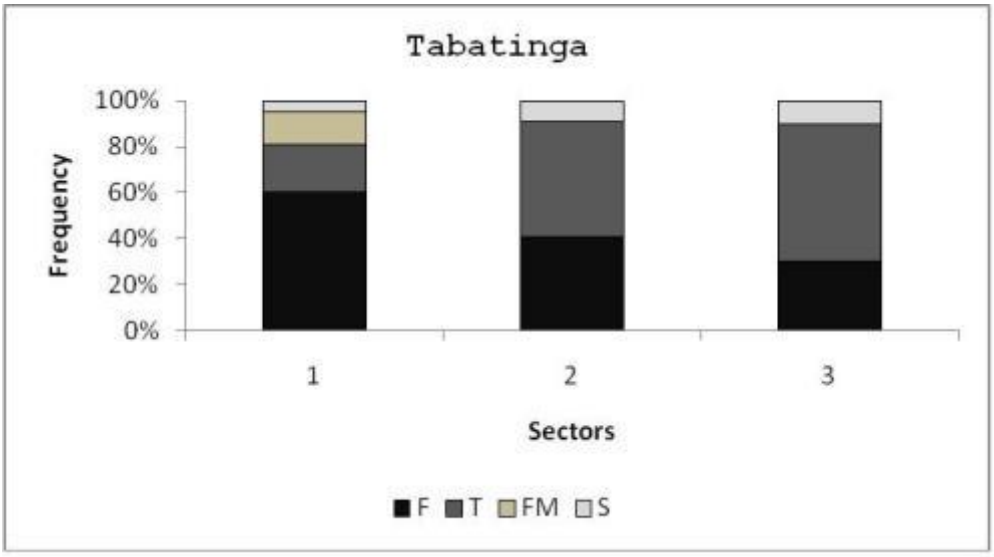
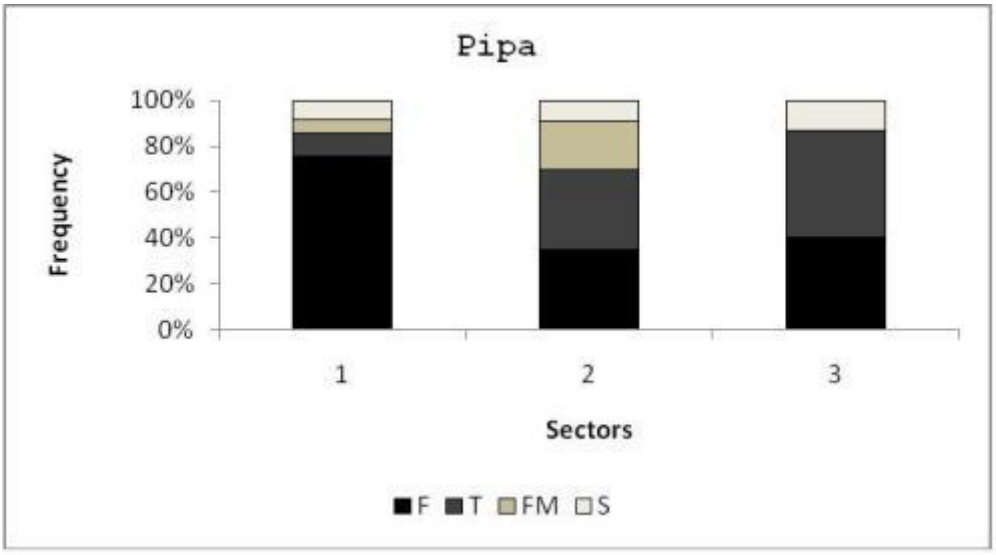
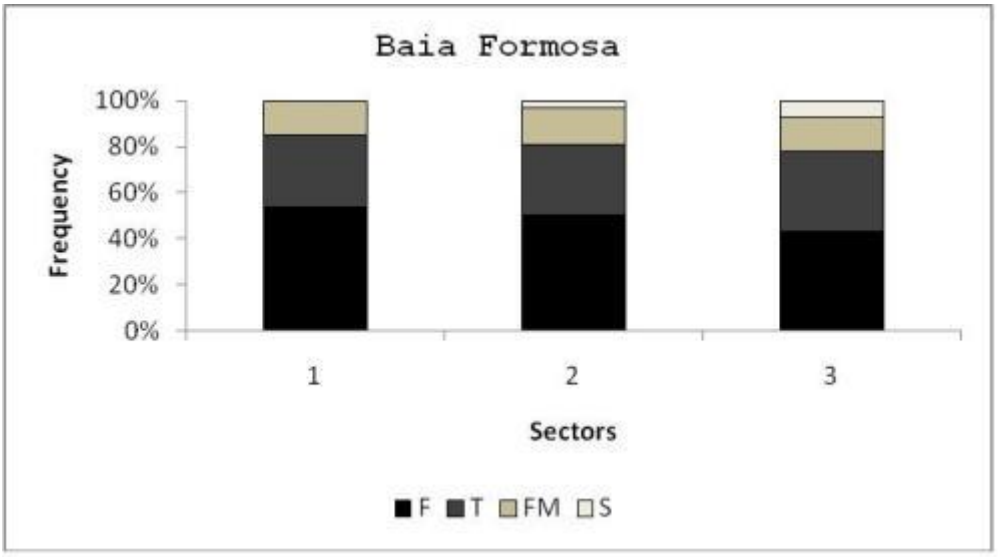


Figure 15: Frequency of the behaviours of *Sotalia guianensis* observed in all areas. (F = foraging, T = travelling, S = socialization and FM = foraging mixed).

Behaviour frequencies were compared between sectors and the histograms for each of the four areas is represented in Figure 16. Foraging animals were more observed in sector 1 (inlets) than in the other sectors, and the inversed occurring for travelling (χ^2=23.564, N=346, GL=6 p=0.001) for the beach areas, but this was more evident in Pipa. In Guarairas Lagoon foraging predominated in sectors 1 and 2, corresponding to the inner area of the Lagoon. Only in Baia Formosa foraging was not concentrated in the inner sector as any differences between use of sectors and behaviours were detected when data of Baia Formosa was analysed separately (χ^2=2.969, N=117, GL=6 p=0.813).


Tabatinga
100%
80%
60%
40%
20%
0%
Frequency
1
2
3
Sectors
F T FM S


Pipa
100%
80%
60%
40%
20%
0%
Frequency
1
2
3
Sectors
F T FM S


Baia Formosa
100%
80%
60%
40%
20%
0%
Frequency
1
2
3
Sectors
F T FM S

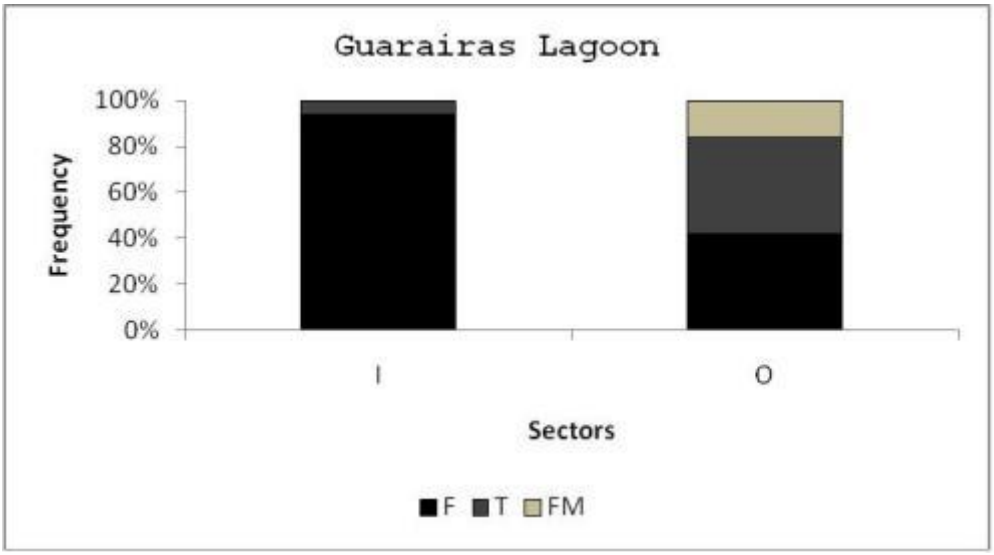


Figure 16: Histograms representing the frequency of behaviours of *Sotalia guianensis* in the different sectors in each location of the study area as labelled. F = foraging, T = Travelling, FM = foraging mixed and S = socializing. In Guarairas Lagoon sector I correspond to inner sectors (1 and 2) and sector O the outer sector (3).

Also group size differed according to behaviour of animals (Kruskal Wallis: H=26.761 N=349 GL=3 p=0. 001) (Figure 17). Mann-Whitney dyadic comparisons show significant differences pointing larger groups in socialization than foraging (Mann-Whitney: U =1329.000 Z(U) = -3.298 N=212 p=0.001) or travelling (Mann-Whitney: U =617.500 Z(U) = -3.483 N=119 p=0.001); and foraging mixed behaviour than foraging (Mann-Whitney: U =2500.500 Z(U) = -3.736 N=230 p=0.001) or travelling (Mann-Whitney: U =1161.000 Z(U) = - 3.917 N=137 p=0.001). Larger socializing groups were observed in Pipa and Tabatinga, but larger groups in foraging/travelling were found in Baia Formosa.

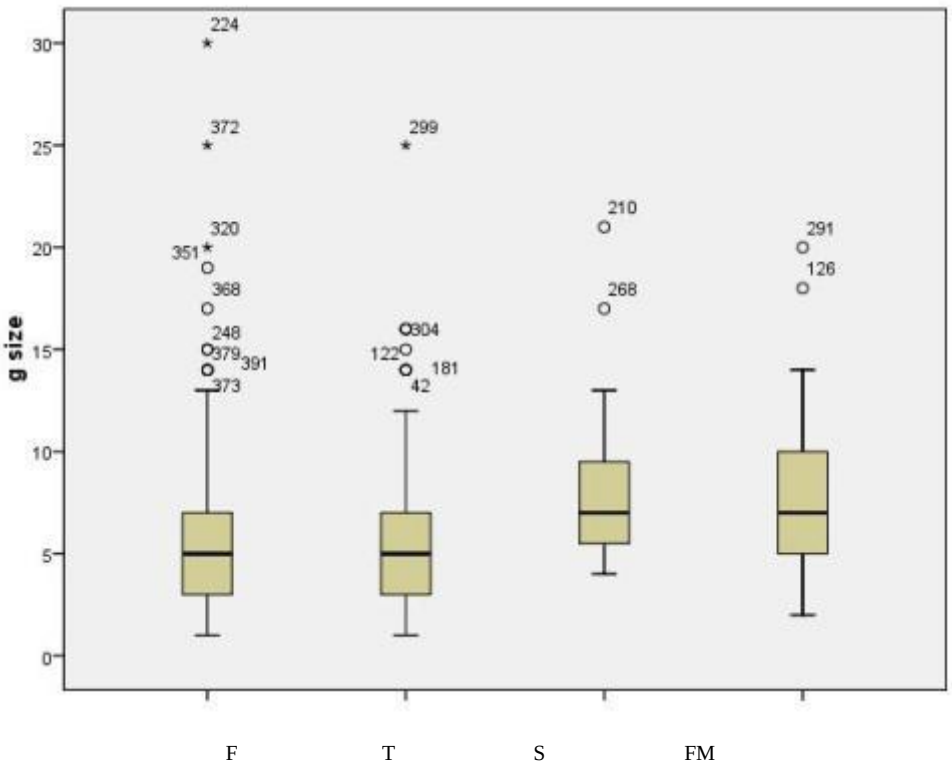


Figure 17: Box-plot of the relation group size and behaviour of *Sotalia guianensis* for All Areas (F=foraging, T=travelling, S= socialization and FM= foraging mixed).

Test for the all beach areas for usage of different sectors and the presence of immature was significant (χ^2=12.457, N=362, GL=2 p=0.002), with more frequency of immature in the inner sector (sector 1) and the inverse in the outer sector (sector 3), but Baia Formosa differed from this pattern. Data from Baia Formosa analysed separately had significant difference for the presence of immature in the outer sector (sector 3), where sightings concentrated (χ^2=7.116, N=124, GL=2 p=0.028). In the case of Guarairas Lagoon also significant difference between inner sectors (1 and 2) and outer sector was found regarding the presence of immature (χ^2=7.180, N=29, GL=1 p=0.007). Immature were mostly seen outside the Lagoon (sector 3) and no calves were observed in sector 1.

No differences were found regarding the presence of animals in the different sectors and the period of the day (χ^2=1.887, N=391, GL=2 p=0.389).

Discussion

Population size

In this study different patterns of residence and fidelity was observed and it seems to be the main source of heterogeneity in capture probabilities among individuals of the population. Since animals could be moving between the locations sampled and possibly outside the limits of the study area, it is clear that it is a violation of the closure assumption. Closure assumption can be violated by process of birth and mortality or immigration and emigration of the study area (geographic closure). Since the study was conducted in a period of one year the effects of birth and deaths are likely to be insignificant for a slow breeder animal that presents low mortality probability such as dolphins. The violation of the geographic closure assumption implicates that animals that present low site fidelity have a lower capture probability than animals with high site fidelity, but these animals are part of the superpopulation (Kendall, 1999) and the lower capture probability of some animals reflects the capture heterogeneity incorporated in the model selected. While Jolly-Seber open population models perform well for survival estimation, it is known to be less robust to capture heterogeneity regarding abundance estimation (Carothes, 1973; Pollok, 1982) and since the primary aiming of our population model is abundance estimation the closed population model used is more robust to the sources of variation of capture probabilities found in this population. The model selected trough AIC criteria pointed a time effect and heterogeneity of individuals in capture probability (Mth), and it is the model that makes intuitive sense: variation between sampling occasions (e.g. some sampling occasion in Guarairas Lagoon no animals were registered and number of captures varied between sampling occasions for the pooled data) and among individuals of the population (different residence levels) would be expected. The behavioral effect of capture is apparently no existent through photo-identification procedure but boat avoidance still need to be empiric accessed.

The study is the first attempt on estimating population abundance of Guiana dolphins in the area. In fact population abundance studies are still scarce, and most of the studies regarding the species have been conducted in the south - south-eastern regions of Brazil. Most of the studies points to relatively small to medium size populations: in North Bay, the south limit of the species, it is believed that the

population is around 60-80 animals (Flores, 2003, Daura-Jorge et al., 2005, Wedekin et al., 2007). Also in the south Brazil, the population of Babitonga Bay was estimated to be 248 (146 – 422) through line transects by Cremer (2007). In Paranagua Bay, upper south Brazil, a study using line transects primarily for density estimation, estimated population size as 409 (CV = 24%) and density of 11.56 ind/ Km² (Filla, 2004).

In southeast Brazil there are controversial studies. Studies in Cananeia Estuary by Geise & Cerqueira (1999), using strip transects, resulted in population estimate of 704 (337-1071) animals but a capture-recapture study by Acuña (2002) estimated a population of 249 (159-372). In Guanabara Bay a line transect study conducted by Geise (1991) concluded that Guiana dolphins are relatively abundant in the area, with an estimated population of 417 animals (no confidence intervals were provided). However, other studied conducted in the area by Pizzorno (1999) using capture-recapture concluded that it is a small population of only 67 (56-81) animals. Still in southeast Brazil, Sepetiba Bay is the only area at the present where a large population of Guiana dolphins was found. Flach et al. (2008a), using transect lines in the area, estimated a population of 1.269 (IC=739-2.196) animals. Finally, a long term population dynamics studied was performed in Caravelas, easterner coast of Brazil (Cantor et al. in press). Population size was relatively constant across the years (57 - 124 individuals) and temporary emigration of the studied area was detected for part of the population.

In Nicaragua, near the northern limit of distribution of the species, strip transects conducted in Caio Miskito indicate a population of 49 animals (no confidence intervals were provided), although the authors argued that population would be larger as just part of the area was covered (Edwards & Schnell, 2001).

In all areas where very small populations were detected (< 100), it may be attributed to the particularities of each location. In North Bay, it is believed that only a single aggregation of dolphins is found and that it functions as a single social unit. Also a bottlenose dolphin population is found in the same bay and an aggressive interaction was reported between species (Flores, 2003, Daura-Jorge et al. 2005, Wedekin et al. 2004). In Guanabara Bay the small population was attributed to the high urbanized and degraded conditions of the area (Pizzorno, 1999).

Apart from the small populations and from Sepetiba bay, where the largest population is found, the results of this study in northeast Brazil (232 dolphins; 95% IC = 195 – 277 animals) points to a population abundance similar to the areas of south -

southeast Brazil. It is interesting to remark that northeast Brazil has particular different characteristics of its coastal area: there are no closed and protected bays or many large estuaries as in south-southeast Brazil. Continental shelf in northeast Brazil is shorter and the coast is not as meandering as down south. Particularly in the south of the State of Rio Grande do Norte animals take advantage of the few small inlets formed by the cliffs of sedimentary rocks typical from some northeast areas, which are shallow and protected shore lines along the coast.

It is important to note that population abundance for Guiana dolphins is not only scarce but also differ in methodological approaches which may explain the controversial results for the same areas which can indicate bias in the estimations. As noted by Gormeley et al. (2005), population estimative using different techniques could not be measuring the same extension of the population. Capture recapture studies usually takes more sampling occasions and a longer period of time and can include animals that were just passing through or uses the area more irregularly. Transects studies are usually conducted in a short period of time and estimative reflects animals that were in the area during the sampling occasions. Ideally both techniques should produce similar results. More studies and enhance in methodological rigour is urgently necessary for more reliable comparisons to be made as well as a better population assessment of Guiana dolphin stocks.

The fact that dolphins can show different patterns of residence and fidelity to a given area can further complicate population size assessment and need to be accounted in capture-recapture population models. For instance, Zolman (2002) observed different residence patterns of bottlenose dolphins in South Carolina, USA; including seasonal residents and transients individuals, and a 3 year capture-recapture abundance showed strong seasonality in number of individuals in the area with high abundance in the summer and lower in the winter (Speakman et al., 2010). Cantor et al. (in press) investigated Guiana dolphins population trends during 8 years in the east coast of Brazil, the authors observed fluctuations in number of dolphins across the years and attributed it to different residence levels of individuals. Also, Bejder & Dawson (2001) in a study of hector dolphin abundance in a small bay of New Zealand observed individual less consistently sighted than others and attributed it to individuals of neighbourhood populations visiting the area or that could be individuals with larger home ranges.

Site fidelity

As observed in other populations of Guiana dolphins (Flores, 1999; Santos et al., 2001; Azevedo et al., 2004) at least part of the Rio Grande do Norte population showed site fidelity. Considering the photo-indentified individuals sighted at least twice, around 10% to 47% were classified as presenting very high to moderated site fidelity, depending on the location. It means that during the study period at least half of the sightings of these animals were in the same location. Previous studies of photo-identification have been conducted only in Pipa (Link, 2000; Sartório, 2005; Ananias, 2006). A preliminary comparison with these studies showed evidences of at least 4 individuals using Pipa beach for at least 7 to 10 years (Paro et al., 2007). These individuals were sighed in almost all sampling occasions between Pipa and Tabatinga in this study and can be considered residents of the area. Residency for Guiana dolphins was first showed by Flores (1999) in Baia Norte where a large number of individuals were resighted across years and some individuals were observed up to 4.8 years. In Cananeia estuary, Santos et al. (2001) also reported long term sightings of up to 4 years for some individuals and high resightings frequency across years. In Guanabara Bay, Azevedo et al. (2004) registered long term residency of up to 8 years with 55% of the individuals sighted in the first year resighted in the last year. Site fidelity for other species of dolphins is also documented in long term studies of coastal bottlenose dolphins (Wells, 1991) as well as other coastal dolphins species such as hector dolphins (Bräger et al. 2002).

However, about 53% - 90% of the animals presented low or very low site fidelity. Also, around 30% of photo-identified dolphins were not included in site fidelity analysis because they were sighted only once during the study and were considered transients of the area, and it is an indication that part of the population is possibly using a larger area. Similar results has been found for other Guiana dolphins populations, Rossi - Santos et al. (2007) investigated site fidelity of Guiana dolphins in Caravelas Estuary and documented high number of individuals with few resightings and movements up to 35 km, although residence of up to 3 years was observed and some individuals had high number of resightings. In Septiba Bay, Nery et al. (2008) investigated site fidelity and suggested that the area is not always used by the entire population as the majority of animals were seen just once, and only 36% of individuals were resighted. Although Sepetiba Bay has a large population, and the authors

commented that results could be a consequence of sampling effort as it could not cover the entire population. Long term use of the area was confirmed as 10% of individuals had interval between first and last sight of up to 5 years, and some animals reached 11 years. Studies with other dolphin species also showed similar patterns of site fidelity with variable degrees of site fidelity as many individuals are not permanent residents and it is suggested that different site fidelity among individuals can be related to the way animals explore key resources in their habitat (Bjder & Dawson, 2001; Zolman, 2002; Parra et al., 2006)

Guarairas Lagoon is the study location where dolphins presented the lowest site fidelity, no animals were classified in "very high" site fidelity and virtually all animals photo-identified were seen in other areas. However, the results in Guarairas Lagoon should be seen with caution because dolphins were not observed in all sampling occasions as in the other locations, and more data is needed to confirm if there are individuals in the population using Guarairas Lagoon on a regular basis. In Tabatinga, where the number of identified individuals is the lowest of the beaches areas (39 individuals), it was also the area that animals showed less site fidelity compared with the other beach areas (PIP and BF). Pipa and Baia Formosa are the locations where the population showed highest site fidelity, around 36% of photo-identified animals in Pipa and up to 47% in Baia Formosa.

The high number of dolphins considered with low and very low site fidelity in all locations is explained by the movement of animals. There is a great movement of dolphins between Pipa, Guarairas Lagoon and Tabatinga. Guarairas Lagoon is next to Pipa (5 km) where most of the Guarairas Lagoon dolphins resightings was observed. Tabatinga is further 20Km from Pipa, and these locations had the highest proportion of animals sharing the areas. In Baia Formosa the lowest proportion of individuals that shared any other area was observed.

These results suggest that there is not much exchange of animals between Baia Formosa and the other areas investigated for this population. Animals from the areas between Tabatinga, Guarairas Lagoon and Pipa seem to interact and share a larger portion of their range (which would comprise a coast extension of 20km) as compared with animals from Baia Formosa. The low movement of animals from one geographic area but not to the others may be attributed to the existence of sub-populations. It does not necessary mean that they are different reproductive units or populations (see Wells & Scott, 1990) but they can be considered different units to emphasise the social and

geographic relation of the individuals, and it is similar to the definition of social group used in ethology (Hinde, 1976).

Another evidence of low movement between Pipa nucleus (Pipa/Guarairas Lagoon/Tabatinga) and Baia Formosa comes from past photo-identification studies conducted in Pipa. From the individuals considered residents mentioned previously none of them were seen in Baia Formosa. From Pipa distances to Tabatinga or Baia Formosa are approximately the same and there is no geographic barrier preventing animals from movement. Pipa and Baia Formosa are both next to estuarine systems (Guarairas Lagoon in Pipa and Cunhau River in Baia Formosa) and we suggest that the pattern observed is due to behavioural responses of the dolphins that can be a response to patch resources (in that case the estuarine systems) facilitated by environmental cues (estuaries). It is also important to note that even though the movement rate between Baia Formosa and Pipa was low, there is still an exchange of individuals.

Because more than a half of the animals considered transients of the study area were sighted in Baia Formosa, it is possible that these animals are moving to areas southern from Baia Formosa. In Pipa, 75% of individuals were resighted at least once, indicating fewer transients. In Tabatinga numbers of transients were proportionally larger than Pipa, and animals could be moving up north. These results indicate more transiency in the border limits than in the centre of the study area and it suggests that there are movements outside these limits. It is noteworthy that most of the individuals considered transients were observed in groups composed by other transients. There is the possibility that these groups of dolphins are occasionally passing through the area. This kind of behaviour is observed in primates, as in chimpanzees groups patrolling their territory or in groups of male sub-adults baboons trying to immigrate (Smuts et al., 1987). It is not totally clear the social structure of the groups of Guiana dolphins, but as described by Santos & Rosso (2008) and Lunardi (2011), it is suggested that they form "fission-fusion" society (based on observations of unstable associations between photo-identified individuals, and on frequent changes of animals between groups).

It is still unclear the differences regarding movement and home range of individuals within populations of Guiana dolphins. Due to the amount of data necessary, home-range studies are scarce and based on few individuals. These studies suggest that Guiana dolphins has a small home range (average around 8 - 15 km^2). Home-range of individuals overlapped intensively in the case of Baia Norte (Flores & Bazzalo, 2004) but in other areas major differences between individuals was found and sex difference is

still inconclusive (Flores & Bazzalo, 2004; Hardt, 2005; Rossi-Santos et al., 2007; Oshima et al., 2010).

Habitat usage

Habitat selection by Guiana dolphins have been described in many locations along its distribution (e.g. Geise, 1991; Azevedo et al., 2007; Wedekin et al., 2007; Flach et al., 2008b). Corroborating what have been seen elsewhere, Guiana dolphins at the south coast of the State of Rio Grande do Norte was observed very close to the shoreline (within 3 km from the coast) usually in inlets.

Distribution, Behaviour and Group Size

Tabatinga and Pipa locations presented similar patterns of spatial use, with most sightings concentrated in the sheltered sector (around 60%) and gradually less in sectors 2 (around 25%) and 3 (around 15%). Distribution of sightings in Baia Formosa was different from the other beaches areas. Dolphins do not concentrated in the inlets in Baia Formosa, as half of the observations were in the outer sector (3) and the rest of the sightings were distributed more equally in sections 1 and 2.

Mean group size in Pipa and Tabatinga was similar and there were no differences in group size related to the usage of sectors, although larger standard error indicate larger variability in group size in the outer sectors (sectors 2 and 3). Average group size in Baia Formosa was slight larger than Pipa and Tabatinga. Also the outer sector of Baia Formosa had larger groups than the other sectors (mean 8 SD: 5.18).

Foraging behaviour predominated in all beach areas; followed by travelling, foraging mixed behaviours and socialization. Behaviour between sectors did not differ in Tabatinga and Baia Formosa, but did differ in Pipa sectors. In Pipa the frequency of foraging in sector 1 is higher than sector 2 and the inversed occurred for travelling. Notably, the sightings in sector 2 of Pipa concentrated in front of the inlets. Dolphins in sector 2 could be in movement of entering and exiting the inlets and it seems that this movement is related to the process of searching and driving schools of fish to the inlets as part of their foraging strategy. In Tabatinga the distribution of animals in sector 2 and

3 is diffused and indicates that, tough animals concentrated in the inlets using the same strategies, they also forage outside the sheltered area.

Overall dolphins in Pipa and Tabatinga seem to be in large groups in socialization behaviour and smaller groups when travelling or foraging. Other studies already pointed out that Guiana dolphin in Pipa forage in small groups and usually undertaking solitary strategies. This strategy includes trap fishes into the shore banks (Nascimento, 2006; Pansard, 2009). In Baia Formosa larger groups corresponded to animals involved in foraging mixed behaviours and most frequently in the outer sector. That behaviour seems to reveal a different foraging strategy than that used in the inlets and possibly some degree of cooperation is involved as animals are in larger groups and in more open and deeper waters. In fact, a behavioural study in Baia Formosa through land observation described a circular cooperative foraging strategy in Bacopari beach, which corresponds to sector 3 of this study (Campos et al. 2010). Also, similar small groups foraging strategies that used in the inlets of Pipa and Tabatinga was observed in section 1 of Baia Formosa, and was also described in the study of Campos et al. (2010).

Group size found for the population in Rio Grande do Norte was small (6 SE: ± 4.2) and similar to the most of other populations studied (Oliveira et al., 1995; Santos & Rosso, 2007, Fila & Monteiro-Filho, 2009; Azevedo et al., 2005, Araujo et al., 2007, Santos et al., 2010). Large aggregations of 20 to 60 guiana dolphins foraging had been observed in Cananeia Estuary (Santos & Rosso 2007); in North Bay animals are regularly seen in groups of 30 animals and small groups are rare (Daura-Jorge et al. 2005), and aggregations as large as hundreds of animals in the neighbourhood areas of Paraty and Sepetiba Bay are reported (Lodi & Hetzel, 1998; Dias et al., 2009). Presumably larger aggregations increase the foraging efficiency in areas of high prey abundance. According to the descriptions based on land observations of Campos et al. (2010), a circle cooperative foraging is displayed by dolphins in Baia Formosa. Large aggregations related to foraging were not seen in this study as average group size was small and groups larger than 20 individuals were very uncommon. Nevertheless, the larger groups detected in the outer sector of Baia Formosa were indeed engaged in foraging mixed behaviour of travelling/foraging. This behaviour is similar to what was described as “travelling/foraging” by Daura-Jorge et al. (2005) as sub-groups formations could be observed spread through the area moving in defined directions. It was not possible to detect cooperative foraging in circle formations in this study, although it must be considered that behavioural observations from land can have a

broader view of the behaviour of the animals as a group when compared with observations from a boat.

In Pipa foraging takes place mostly in small groups and larger groups were observed in socialization behaviour. Although not functionally clear, larger socializing groups can be a form of animals strengthen their social bonds, develop social skills in case of calves, and it is probably when copula takes place. As already pointed out the inlets of Tabatinga and Pipa, besides to be an important feeding area, are also nursery areas, as calves were frequently present and playing behaviour such as playing with objects (mostly algae and mangrove sticks), surfing, leaping and animals rubbing each other was observed. Although no resting behaviour was registered in this study, it does not mean that it does not occur, but it might be difficult to detect.

Immatures were registered throughout the year in all beach areas, and at Pipa and Tabatinga they were more frequently observed inside the inlets (sector 1). The preference of females and calves to calm and sheltered areas makes these inlets an important nursery ground as it is distant from the more exposed areas that poses treats such as predators and strong currents (Nascimento, 2006; Gondim, 2006). In Baia Formosa the presence of immature was more frequent in sector 3, where the sightings in Baia Formosa are concentrated. Since dolphins groups were larger in this sector, it can be less threatening for calves to be in the open waters, as larger groups offers more protection for the group as a whole.

Guarairas Lagoon is not used as intensively as the beaches areas investigated in this study. As already observed by Sartório (2005), the main activity when animals are inside the lagoon is foraging. Small groups of animals were observed for up to 4 hours inside the lagoon and leaving the area after many events of chasing and preying fish. Dolphins were sighted in areas up to 1 km inside the lagoon, corresponding to the deeper and stronger currents waters of the lagoon. Notably there was an increase in sightings in the sector 3 (outside the lagoon) up to the second semester of the year but a more regular use of the areas inside the lagoon. Groups outside the lagoon were larger and foraging behaviour was lower than inside the lagoon. Also social behaviour was observed only outside the lagoon and in the context of foraging mixed behaviour. While dolphins clearly make incursions inside the lagoon to feed, it remains to be investigated the ecological aspects that influences the abundance and distribution of prey and presence of dolphins in the lagoon area. Tidal state may play a role as in 74% of the

encounters registered in Guarairas Lagoon were in low or flooding tidal state, and this could be related to food resources, as fishes may follow the current, with dolphins taking advantage and spending their time foraging there. It might also explain the absence of socialization in the inner sector. Another notably characteristic of animals using the areas inside the lagoon is the absence of calves; Sartório (2005) also made the same observation. These observations indicate that feeding inside the lagoon is an activity performed by adults.

Daily behavioural pattern studies for Guiana dolphins pointed out that there is a peak of foraging behaviour in the morning (Daura-Jorge et al. 2005; Azevedo et al., 2005, Flach et al. 2008b). In Pipa it was also observed by Araújo et al. (2001), Nascimento (2006) and Guilherme - Silveira & Silva (2009). Although, Guilherme - Silveira & Silva (2009) reported no differences in the period of the day and the presence of the dolphins, and this study corroborates with these observations as no major differences was detected. In the same study Guilherme - Silveira & Silva (2009) also reported no differences in the number of individuals regarding the period of the day. These results reinforces the idea that dolphins are using the inlets of Pipa not just for foraging and other important activities are also taking place such as nursing and socialization.

Population abundance and site fidelity of Guiana dolphins reported in this study is in accordance to other studies regarding the species (Acuña, 2002, Azevedo et al. 2004; Cantor et al, in press). It is a relatively small and resident population (in the sense that individuals use regularly a determined geographic area) that it is occasionally visited by members of other geographic units or populations. Other species of coastal dolphins such as humpback dolphin, *Sousa chinensis* (Karczmarski et al., 1999) and Hector dolphin, *Cephalorhyncus hectori* (Bjeder & Dawson, 2001) are also reported to have a similar pattern.

It was also verified the preference of animals for inlets next to estuaries as usually observed for Guiana dolphins (Flores & da Silva, 2009). In the southern coast of the State of Rio Grande do Norte, Guiana dolphins had higher frequency and abundance in the beach areas when compared to the Guarairas Lagoon, next to Pipa study area. Located 6 Km north of Baia Formosa there is an estuarine area (River Cunhau), it has a much narrower entrance (500m) and there are no reports of animals sighted inside the river so far. In Nicaragua, Edward & Schnell (2001) also observed Guiana dolphins much more frequent in the adjacent coastal waters than inside the rivers and lagoons of

the region. Although in large estuarine systems as in Caravelas, Brazil, animals were sighted 14 Km inside the river (Rossi-Santos, 2006) and in Cananeia Estuary animals can make incursions to narrow channels in the region (Geise & Cerqueira, 1999), but still the frequency of animals reported is higher near to the mouth of estuaries.

High energetic demand is expected for animals such as dolphins, which are high mobile animals and top chain predators. Areas around estuarine systems can be considered as suitable habitats for coastal dolphins. They are areas of rich nutrient waters and dolphins makes extensive usage of these areas, mainly for foraging behaviour. In a sophisticated method Hastie et al. (2004) showed for bottlenose dolphins in Scotland that the higher probability of foraging dolphins were observed in areas of higher density and intensive usage. Ballance (1992) also pointed out the presence of bottlenose in Gulf of California near estuaries and the higher foraging frequency in these sites. For Guiana dolphins the same conclusions can be made as the sites where dolphins are found foraging behaviour predominate (Daura - Jorge et al. 2005; Cremer et al., 2004; Azevedo et al, 2005; this study).

Differences in habitat usage regarding the areas of Pipa and Tabatinga compared to Baia Formosa need more investigation to elucidate what can be causing these differences. Dolphins in Baia Formosa used more frequent open waters than in Pipa and Tabatinga, where animals are most frequent sighted in the inlets. There is a large number of fishing boats in the inlets of Baia Formosa as well as sewage discharge. At Pipa there are a total of 09 daily dolphin watch boats that can perform up to 36 tours that also expose dolphins to the presence of boats (Lunardi, 2011). In Tabatinga there is a much smaller fishing community and no recreational boats in the inlet is found. It remains unclear if there is any anthropogenic factor affecting distribution of dolphins in these areas. It is possible that the open waters of Baia Formosa are naturally richer in resources and it affects the distribution of animals in the area. As noted, average group size was larger in the outer sector of Baia Formosa, and it suggests that different foraging strategies in larger groups using open waters may takes place much more frequent in Baia Formosa than in the other areas. For instance, different foraging strategies for Guiana dolphins were described in North Bay (Rossi-Santos & Flores, 2009) and also in Baia Formosa (Campos et al. 2010).

Conservation

Sotalia guianensis presents a strictly coastal distribution in the Atlantic Ocean of South and Central America, with only one exception known in Abrolhos Bank, Brazil located around 35 n.m. from the coast (Borobia et al., 1991). Apart from that, all populations are found in coastal areas near rich nutrient estuarine systems. For most of the areas investigated, populations concentrate in these suitable habitats in relatively small numbers of hundreds and at least part of individuals are residents and possibly presenting small home range. These areas are clearly important for animals as they provide a feeding ground as well as an area safe of the harshness of open waters such as predators. Although animals can move between areas, suitable habitat areas are not continuous along the coast.

Habitat degradation can have severe consequences for the species and it is suggested that it is occurring in Guanabara Bay, a high degraded area surrounded by a metropolitan complex, where population size seems to have dropped from 417 animals in 1991 to 60 in 2009 (although part of this difference can be attributable to differences in methods of data collection and analyses) (Geise, 1991; Pizzorno, 1999; Azevedo et al., 2005; Sechi, 2009). In Santos Bay, another degraded area where one of the main harbours in Brazil is located, observations and numbers of Guiana dolphins is very reduced compared to other areas (Rollo Jr. - personal communication). Beside habitat degradation, accidental by-catch in fishing nets occurs along the distribution of the species, and it can occur in unsustainable levels in some areas (DiBeneditto, 2003; Meirelles et al., 2009). In the south of the State of Rio Grande do Norte, the population estimated can be considered relatively small as it is spread in two hundreds of individuals along suitable habitats in the region. The conservation of the species is a concern given the accelerated process of occupation of the coastal area, mainly from tourism development what implicates in an increase in number of boats in this region, use of resources and degradation and contamination of the coastal waters.

The strategy of protected areas can be a tool for conservation; in fact some of the areas are already in some level of conservation status by local authorities stretching for 5km of coast (Tosi & Ferreira, 2008; Lunardi, 2011). In Pipa beach the presence of dolphins involves important social-economic issues as dolphin watch tours is held in a daily basis. A dialogue with all parts involved is necessary for the conservation of

dolphins and consequently its ecosystem. The results of this study points to a need for a unified management of this 40 km of shore line investigated. That is the only way to assure the presence of the animals in the area as well as its natural behaviour pattern and genetic flow between the different geographic areas. Although this study can serve as a baseline for conservation, the sustainable use of these coastal areas still needs a deeper knowledge of the results presented here, including the ecological constraints regarding the area and the impact of anthropogenic activities such as urbanization, shrimp farms, fishing and dolphin watch activities. Controlled tourism can be an alternative for a low impact and a social fair economical development of the area.

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PHOTOS

In the left is “Lunara”, it was observed many times in the year of 2008 in Pipa, and in the beginning of 2009 more frequently in Tabatinga. “Lunara” was first identified in 1999 (Link, 2000). Right is “Deda”, it was observed many times always in one inlet from Pipa (Curral). “Deda” was first identified in 2002 (Ananias, 2006). By the frequency that these two animals were seen with calves they are thought to be resident females from Pipa. (Photos: Alexandre Paro)

In the left: a Guiana dolphin preying a mullet in Guarairas Lagoon. In the right: a tight group of dolphins from Baia Formosa. (Photos: Alexandre Paro)