OCCUPATION PATTERNS OF A HARBOR INLET BY THE ESTUARINE DOLPHIN, *SOTALIA GUIANENSIS* (P. J. VAN BÉNÉDEN, 1864) (CETACEA, DELPHINIDAE)

Marta J. Cremer[1;2]; Paulo César Simões-Lopes[3] & José Salatiel Rodrigues Pires[1]

[1]Laboratório de Análise e Planejamento Ambiental, Departamento de Hidrobiologia, Universidade Federal de São Carlos, São Carlos, Brazil. [2]Current Address: Universidade da Região de Joinville, Departamento de Ciências Biológicas, Laboratório de Nectologia. Address: Caixa Postal 110, Cep 89240-000, São Francisco do Sul, SC, Brazil. Phone: 55-474619072. Fax: 55-474619159. marta.cremer@univille.net. [3]Laboratório de Mamíferos Aquáticos, Departamento de Ecologia e Zoologia, Universidade Federal de Santa Catarina, Florianópolis, Brazil.

ABSTRACT
The occupation patterns of Sotalia guianensis in São Francisco do Sul harbor inlet, in Babitonga bay, southern Brazil, were studied between September/1996 and October/1997. We totaled 200 hours of naturalistic observations and 141.2 hours of gray dolphin systematic observations using binoculars 7 x 50. At each 3 minutes interval we registered data about number of individuals and behavior. The population used the harbor inlet intensively, mainly for fishing activities. Ebb tide was responsible for a higher occupation index, so as decrescent moon phase. Considering the months analyzed, the higher occupation index occurred in May, and in January we founded the lower occurrence. The mean group size was four individuals. Despite the importance of this area for this estuarine dolphins' population, the inlet was completely abandoned from 1999, when the harbor suffered enlargement repairs.

RESUMO
Os padrões de ocupação da enseada do porto de cargas de São Francisco do Sul, no interior da Baía da Babitonga, sul do Brasil, pela população de botos cinza *Sotalia guianensis* foi estudada entre setembro/1996 e outubro/1997. Totalizou-se 200 horas de observações naturalísticas e 141.2 horas de observação sistemática na área, utilizando-se binoculares 7 x 50. Foram registrados a cada intervalo de 3 minutos dados sobre o número de indivíduos presentes e comportamento. A população utilizou intensamente a enseada do porto, principalmente para atividades de pesca. A maré enchente foi responsável por maiores taxas de ocupação, assim como o período de lua minguante. Dentre os meses analisados, maio foi o mês com maior média nas taxas de ocupação, e janeiro o mês de menor ocorrência. O tamanho de grupo médio na área foi de quatro indivíduos. Apesar da importância da área para a população, a enseada foi completamente abandonada pelos botos a partir de 1999, quando iniciaram as obras de duplicação do cais.

Key words: *Sotalia guianensis;* occupation index; Babitonga bay; harbor use, behavior.

INTRODUCTION
Studies about cetacean habitat use confirmed the existence of core areas, or concentration areas, inside the home range area of many species. This characteristic has been corroborated in studies related to the estuarine dolphin *Sotalia guianensis* (Cremer, 2000; Bonin, 2001; Edwards & Schnell, 2001; Lodi, 2003; Flores & Bazzalo, 2004; Wedekin *et al.,* in press), so as also for other cetacean species with coastal habits, like the atlantic white-sided dolphin *Lagenorhynchus acutus* (Selzer & Payne, 1988) and the bottlenose dolphin *Tursiops truncatus* (e. g., Wursig & Wursig, 1979; Gubbins, 2002), e.g. In most cases, data indicated that these areas are strongly related to fishing activities, constituting key areas in the populations´ home range. This fact becomes more evident considering the resident populations. *S. guianensis* resident populations are being registered in the last years through use of photo identification techniques along the Brazilian coast, such as in Guanabara bay (RJ) (Pizzorno, 1999), Cananéia estuarine complex (SP) (Santos *et al*., 2001), Babitonga bay (SC) (Cremer, 2000; Hardt, 2005) and Baía Norte (SC) (Flores, 1999).

The knowledge about habitat use patterns and home range areas are important for improving conservation strategies, mainly for resident populations, subsiding monitoring work and impacts evaluation (Clemmons & Bucholz, 1997; Primack & Rodrigues, 2001).

Babitonga bay have an estuarine dolphin population *Sotalia guianensis* (P.J. van Bénéden, 1864) (*sensu* Monteiro-Filho *et al.,* 2002), that show strong evidence of residence, and is being studied for at least ten years (Cremer, 2000; Hardt, 2005). *S. guianensis* is a typical coastal specie, that occurs in bays and inlets along all its distribution area. It occurs in most of South America coast and part of Central America. Its distribution seems to be continuous, from Nicaragua (Carr & Bonde, 2000) to Florianópolis, SC, Brazil (Simões-Lopes, 1988). The present work analyzed data about habitat use patterns of this population in the São Francisco do Sul harbor inlet, in Babitonga bay. This area was considered a dolphin concentration point, although this place suffers a strong impact resulted from harbor activities.

METHODOLOGY

Study area

The São Francisco do Sul harbor is located inside Babitonga bay, south Brazilian region (48.6358º W; 26.2349º S) (Fig. 1). The bay comprehend an area of 160 km2, representing an important estuarine area in south Brazil. The harbor is located in the central portion of the bay, in its south margin, beside the historical city of São Francisco do Sul. Its was inaugurated in 1955 and is considered a "natural harbor", because of the presence of a deep entrance channel (with 11 meters of deep along its extension) and a natural opening channel with 1.8 km of width.

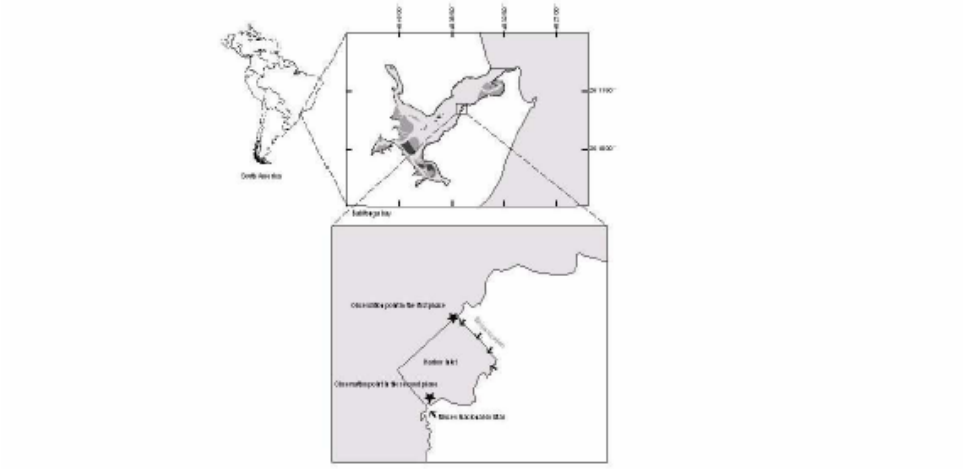

Fig. 1: São Francisco do Sul harbor inlet, located inside Babitonga bay, southern Brazil (48.6358º W; 26.2349º S).

The sampling area was defined visually, using as reference the harbor signal buoys and the anchorage of Museu do Mar (Fig. 1), corresponding to an area of around 0.24 km2. The mean depth in this area is between 8 and 11 meters, and the evolution basin is periodically dredged (two or three years interval) for the depth maintenance. This area forms an inlet that was known by the local people as "dolphins inlet", because of *S. guianensis* occurrence along all the year. This area had also intense boat traffic, including tourist boats, that did go there for dolphin watching.

Data collection
The observations were done in two phases, with the presence of one or two experienced observers. In the period between September 1996 and October 1997 two hundred observations hours were accomplished using naturalistic methods (Altmann, 1974). In this period the observers were positioned on the charge ships that were attracted in the harbor (Fig. 1). Because of logistic reasons for ships access, the observation point had to be changed. In this way, in the period between January and June 1998, we totalized 141.2 sampling hours from a point in the margin (Fig. 1). In this phase, there had been used the scan sampling method, which was adapted from Altmann (1974). Group behavior and number of individuals in the area were registered continuously during 45 minutes, with the information accumulated in each three minutes sampling periods, followed by a 15 minutes resting period. Only the behavioral states were registered because of the distance between the point sampling and the animals (maximum of 600 meters). The recording of events at this distance might produce sampling distortions, favoring more evident aerial behaviors, like jumps. The samplings were conducted from 7:00 am to 6:00 pm, but if the environmental conditions changed, with Beaufort more than 2, the samplings were interrupted.
The behavioral states considered in this work were adapted from many authors, and four categories were defined: fishing, traveling, resting and socializing (Norris & Dohl, 1980; Shane, 1990; Ballance, 1992; Daura-Jorge *et al.*, 2005).

Group was defined adapted from Shane (1990) that establishes it as "any aggregation of dolphins in an apparent association, frequently, but not always, engaged in the same activity". For the group composition we differentiated only adults and calves. So, all animals that remained near an adult most of time and that had at least 1/3 its size were considered calves.

An occupation index was calculated considering the mean number of individuals inside the inlet at each hour as an indicative of intensity use. Variations in this index were analyzed considering the months (Kruskal-Wallis), tide (ebbing or flowing) (Mann-Whitney U test), moon phases (Kruskal-Wallis) and the day periods (Kruskal-Wallis). In this case, three periods were defined: morning (7:00 am – 10:59 am); middle-day (11:00 am – 1:59 pm); and afternoon (2:00 pm – 6:00 pm). For behavior pattern analysis Kruskall-Wallis test was used.

RESULTS

Considering the systemized sampling period, we totaled 94.35 hours of direct observation of the inlet, distributed in 30 days, with an inlet medium occupation index of 3.95 (± 3.12) individuals/hour along all the period.

Inlet occupation
The occupation of the inlet by the dolphins showed difference between months (Fig. 2) [$H (5, N = 201) = 26.982$; $p = 0.0001 < 0.05$]. May was the month with highest occupation index (12.27 individuals/hour) and January was the month of lowest index (0.26 individuals/hour). Along the sampling period, at only one day (in April) the dolphins do not enter in the inlet.

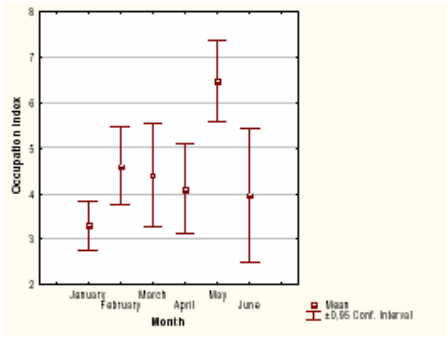

Fig. 2: *S. guianensis* occupation index variation in São Francisco do Sul harbor inlet along the months.

Inlet occupation index do not varied along the day periods [H (2, N = 201) = 0.547; p = 0.76 > 0.05] (Fig. 3).

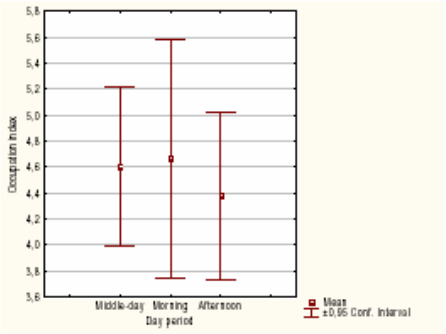

Fig. 3: *S. guianensis* occupation index variation in São Francisco do Sul harbor inlet along the day.

Tide influenced the inlet occupation (z = 2.642; p= 0.008 < 0.05) (Fig. 4). The observations indicated that the dolphins tended to enter the inlet in the beginning of the high tide, and the ebb is the period of highest occupation index. The number of groups in the inlet was gradually reduced with the beginning of the low tide, and in the end of the flood tide few groups remained in the inlet.

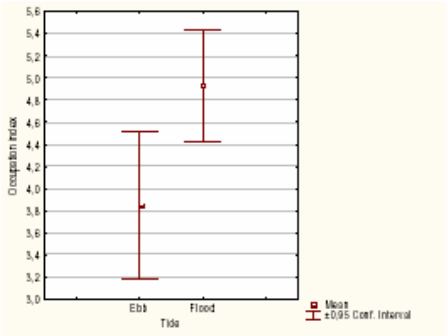

Fig. 4: *S. guianensis* occupation index variation in São Francisco do Sul harbor inlet along tide variation.

Moon phase also influence inlet use by the dolphins ($F_{1; 201} = 376.105$; $p = 0.000$) (Fig. 5). The results indicate a decrease in occupation index from crescent phase to the new phase of the moon.

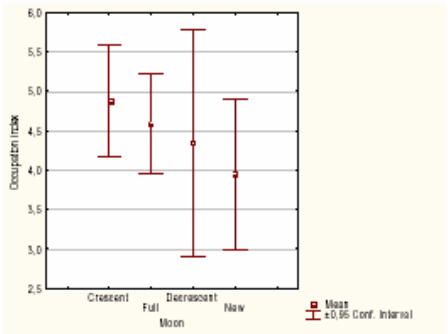

Fig. 5: *S. guianensis* occupation index variation in São Francisco do Sul harbor inlet along moon phases.

The main inlet entrance route of the dolphins was from the south and southwest direction, so as the leaving route. In many occasions the entrance was conducted in fast traveling, followed by an intense fishing activity, seeming that the dolphins had detected the prey distantly. In no one occasion the dolphins were saw arriving the inlet from north or northeast directions that correspond to the entrance channel. Inside the inlet the principal area used by the dolphins was the vicinity of the attracted charge ships where the dolphins fished actively, sometimes showing a characteristics´ fishing movement (for a detailed description of the behaviors see Cremer (2000)). The dolphins grouped the fish schools in the central portion of the inlet and conducted them in the direction of the ships, using them as a barrier for catch facilitation. In the ships vicinity it was common to see dolphins jumping with fishes in the mount (Fig. 6). In some occasions, the dolphins went out of the inlet temporally, probably grouping fishes in the channel and conducting them to the vicinity of the ships.

Fig. 6: *S. guianensis* jumping near a ship with a fish in the mount.

In general the dolphins get temporally away from the area when was ship movement, returning soon after. Although an intense fishing activity was observed in some occasions in the inlet thereupon a ship passage. Considering that the ships move the bottom sediment when passing, lasting the water turbid, we consider that probably the preys that were in the bottom became displaced and disoriented becoming easier to catch. The dolphins also fished intensively in the ship places thereupon they leave the harbor.
Although systemized observations were not conducted with rough sea, naturalistic observations indicated that the sea state maybe influenced the inlet occupation. In days with rough sea the winds created waves towards the ship direction, and dolphins' occurrence in the inlet was much reduced. According to some fishermen, fishes do not approach the ships in rough sea, and probably the absence of fishes is the factor that influenced the dolphins' occurrence.

Time budget
The predominant inlet behavior was fishing, followed by traveling [H (3, N = 24) = 19.448; p = 0.0002 < 0.05)] (Fig. 7).

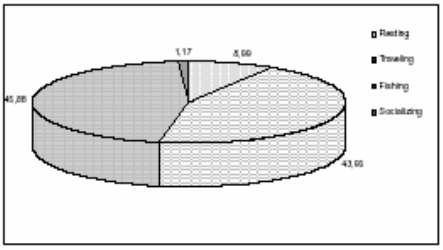

Fig. 7: Time budget for behavioral patterns sampled in São Francisco do Sul harbor inlet between January and June 1998.

Group size and composition
The mean group size of *S. guianensis* in the inlet was of four individuals (Table 1).
Table 1: *S. guianensis* group size and composition in São Francisco do Sul harbor inlet during January and June 1998.

Parameters	Adults	Calves	Group
Mean	3.68	0.43	4.11
SD	2.46	0.61	2.71
Mode	2	1	2
N° minimum	1	0	1
N° maximum	18	3	18

Although there were groups of 18 individuals, group division was very common when they approach the ships in inlet, forming smaller groups, in general with two individuals (= mode). In the same way, when the groups escaped from the inlet, there was a tendency to form larger groups.

DISCUSSION

The harbor inlet occupation by *S. guianensis* population showed to be very intense, considering the Babitonga bay size (= 160 km2) and good conservation status of a great part of the bay. The observations showed that the population used the harbor inlet with fishing purposes. This habitat use pattern seems that of other dolphin species, like *Cephalorhynchus hectori* (Bejder & Dawson, 2001), *Lagenorhynchus acutus* (Selzer & Payne, 1988) and *Tursiops truncatus* (Wursig & Wursig, 1979; Gubbins, 2002). The harbor inlet constitutes an artificial environment inside the bay and we believe that the population learned to use its structure for prey catch, supporting the intrinsic perturbations of the harbor activity. The vantage for obtaining food resources offered by this place apparently was more important than the pressure by the threats. One possibility is that the animals became habituated with the activities of the area along the more than 40 years of the establishment of the harbor in this region. Environmental parameters showed a significative influence on the inlet occupation by the dolphins, so as many other studies that analyze cetacean habitat use (Wells *et al.,* 1980; Shane *et al.,* 1986; Selzer & Payne, 1988; Acevedo-Gutiérrez & Parker, 2000). However, we believe that in this case the environmental parameters influence mainly the prey movement. Tide movement is an important variable in fish movement inside estuarine areas (Gibson, 1999). Moon phases are directly associated to tide level and movement, and so affect fish movement too. Fishes movement is also influenced by the seasons, with the occurrence of migration events. May, which corresponded to the month of highest inlet occupation, is the period of Mugilidae species migration along the south coast, inside estuarine areas. *Mugil* spp are part of *S. guianensis* diet in Babitonga bay population (Marcucci & Cremer, 2004). The harbor inlet, positioned in the bay entrance channel, can be an important area of concentration of this species. Thus, cetacean distribution and abundance are being associated to the oceanographic characteristics from a region connected directly to the food chain.

Although few records were done regarding socializing behaviors, during naturalistic observations conducted on ships board we observed court and sexual behaviors beside the ships in one occasion [for more details see Cremer (2000)]. Moreover, calves were constant in the area, in spite of ships movement and noise pollution, that possible reflects the population habituation. In fact, there were in general between two and three ships in the area that maybe do not represent a very strong impact.
Feeding was the most common behavior in the area, that reflects the specific purpose of the population for the inlet occupation. Feeding was also the most frequent behavior observed for *S. guianensis* population in Baía Norte, Brazil (Daura-Jorge *et al.*, 2005), and in Cispatá bay, in Colombian Caribbean coast (García & Trujillo, 2004). Analyzing the Babitonga bay at all, Cremer (2000) observed that traveling was the most frequent behavior pattern for the population, so as observed by Bonin (2001) in Guaraqueçaba bay, Brazil.

S. guianensis harbor inlet groups tend to be smaller that groups occurring in the Babitonga bay in general

(Cremer, 2000), probably because of the typical behavior showed in the area, that was fishing. *S. guianensis* groups varied between one to 30 individuals, and groups between two and six individuals were the most common (Simões-Lopes, 1988; Geise, 1991; Carr & Bonde, 2000; Bonin, 2001; Torres & Beasley, 2003; García & Trujillo, 2004; Daura-Jorge *et al.*, 2005).

Cetacean coastal species are more threatened by antropic impacts, considering the intense use of their habitats for development of human activities. In this sense, it is probable that the species that occur in bays and inlets show a more flexible behavior supporting disturbs resulting from human activities. Although *S. guianensis* is considered a shy specie that avoid motor boats (Silva & Best, 1994; Santos *et al.*, 2001), its long time occurrence in some environments that suffer a significative impact, so as Guanabara bay (RJ) (Geise, 1991), Babitonga bay (SC) (Cremer, 2000) and Baía Norte (SC) (Flores, 1999; Wedekin *et al.*, 2005), for example, indicate that the specie presents a considerable tolerance level to antropic perturbations. However, so as verified for other coastal cetacean species, impact intensity might lead to impacts in a medium and long time.

Impacts resulting from boats are reported in the literature and are mainly associated to tourism activities (dolphin-watching) (Lusseau, 2003). Foote *et al.* (2004) detected significant changes in orca communication associated to the increase of pollution caused by boats noise. Instead, this behavioral flexibility can also bring negative consequences to population survival. In the case of coastal dolphins, adaptation associated to remaining in highly impacted environments can result in high contamination indexes, related to discharge of effluent containing heavy metals and organochlorides. This kind of pollution can cause many kinds of tumours (Geraci *et al.,* 1987) and/or epidermal lesions associated with a disease (Wilson *et al.,* 2000). São Francisco do Sul harbor inlet present a high pollution level, both in water as in sediment, a consequence of the contaminants apport from the estuarine system, which was impacted by the industrial activities, but also arriving from the harbor activity, as oil and grease residues, anti-fowling paintings and granel charge (Tureck, 2003). The reduction of *Delphinapterus leucas* population in Canada was directly related to a high pollutant level, mainly organochlorides, identified in animals' tissue (Martineau *et al.*, 1988). Besides of chemical pollution, the noise pollution can be very dangerous. The maintenance of dolphin populations in areas with a high noise level can produce irreversible damage to the ear apparatus, reducing individuals hear acuity (Richardson *et al*., 1997). However, more studies are necessary to verify population dynamic in these areas in a medium and long time. In regions so as in Adriatic Sea, the low density of *Tursiops truncatus* and the disappearing of *Delphinus delphis* were associated to habitat quality reduction (Bearzi *et al.*, 2004).

The continuity of *S. guianensis* research in this area after the period of the present work showed a drastic change from 1999. In this year the harbor suffered enlargement repairs, using drags and pile-drivers, so as other heavy machines, promoting and intense perturbation in the area. From 1999 to recent observations (2006) the dolphins do not more enter the inlet, so as in the São Francisco do Sul city vicinity (behind the harbor), where they were frequently observed by the local people and tourists (Cremer *et al*., 2004). Considering the anterior inlet occupation index and the total abandonment of this area by the dolphins, we saw a clear example of the potential impact of human activities in cetacean habitat use, including the habitat leaving. Although *S. guianensis* can be considered a specie with high tolerance degree in relation to human activities, in this case the limits were aimed.

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