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Habitat use of the Guiana dolphin, *Sotalia guianensis* (Cetacea, Delphinidae), in the Caravelas River Estuary, Eastern Brazil

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Abstract: Habitat use patterns of the Guiana dolphin (*Sotalia guianensis*) were assessed in the Caravelas River Estuary, eastern Brazilian coast (17°54'S, 39°21'W). During 191 surveys (2002-2004), 187 groups were sighted. The Arcview 3.1 software was used to create a GIS environment that included the distribution of dolphin sightings, a 5x5km quadrats grid, and the bathymetry of the study area. Each quadrat was characterized according to environmental variables such as depth, contour index, distance from sand banks and distance from the coastline. The Caravelas River mouth was found as the core area of the dolphins. Guiana dolphins did not use the several classes of environmental variables homogeneously, occurring more frequently in shallow waters, closer to sand banks and closer to the coastline. Also more dolphins occurred in areas with flatter bottoms and in waters with salinity ranging from 35 to 38ppm, despite dolphins being sighted in waters 14km inside the river. Dolphins used a wide range of habitat types but the Caravelas River mouth seems to propitiate the most adequate conditions for foraging strategies or concentration of prey.

Resumen: El uso de habitat por el delfin de Guyana (*Sotalia guianensis*) fue evaluado en el Estuário do Rio Caravelas, costa brasileña (17°54'S, 39°21'W). Durante 191 salidas de campo (2002-2004), 241 grupos fueron avistados. El programa Arcview 3.1 fue utilizado para crear un ambiente SIG el cual incluyó la distribución de las observaciones de delfines, una red de cuadrantes de 5x5km y un modelo batimétrico del área de estudio. Cada cuadrante fue caracterizado de acuerdo con variables ambientales como profundidad, índice de contorno del fondo marino, distancia de bancos de arena, distancia de la linea de costa. La salida del rio Caravelas fue identificada como el sitio de mayor concentración de *S. guianensis*. En toda el área de estudio, los delfines no utilizaron las distintas clases de variables ambientales de manera homogénea. Se observó que la especie utilizó una gran variedad de ambientes, pero la salida del rio Caravelas parece propiciar mejores condiciones para estratégias de alimentacion ó concentración de presas.

Keywords: Habitat use, behavior, ecology, *Sotalia guianensis*, Abrolhos Bank, Brazil.

Introduction

Cetacean distribution has been related to a variety of environmental variables such as depth and ocean bottom relief (Hui, 1979; Baumgartner, 1997), water temperature and salinity (Selzer and Payne, 1988). Particularly, for the Guiana dolphin, *Sotalia guianensis* (P. J. van Bénéden, 1864), classified as 'Data Deficient' (IBAMA, 2001), some studies linked behavior and tidal state (Araújo *et al.*, 2001) behavior and environmental daily and seasonal cycles (Daura-Jorge *et al.*, 2005), and occurrence and distance from the coast (Edwards and Schnell, 2001). Despite these studies, the knowledge about how distinct environment features influence the Guiana dolphin spatial use is still scarce.

In the Abrolhos Bank, eastern coast of Brazil, the Guiana dolphins have been observed to use shallow waters, areas close to river mouths and close to the coast (Rossi-Santos *et al.*, 2006). One of these river mouths, located in the northern portion of the Abrolhos Bank, is the Caravelas River Estuary. A resident population of the Guiana dolphin is observed to use the Caravelas River Estuary and its coastal adjacent areas (Rossi-Santos *et al.*, 2007).

The present study aims to describe physical habitat use patterns for the Guiana dolphins in the Caravelas River Estuary and adjacent waters, eastern coast of Brazil.

Material and Methods

Study area

The Caravelas River Estuary (17°45'S, 39°15'W) (Figure 1) is surrounded by the second largest mangrove forest in the northeastern Brazilian coast (Herz, 1991). Freshwater is supplied by the input of five small rivers. Mud bottoms predominate in the sea floor of the study area. The estuarine-mangrove system communicates with the open coast through two channels. In the communication with the open sea, deep channels are surrounded by sand banks which are exposed in the low tide.

Field procedures

Boat surveys, with mean duration of 7hr, were conducted following routes designed to cover the study area homogeneously. Data such as geographic positions, group size and behavior were collected in blocks of five minutes when a group of dolphins was being followed. Environmental data such as tidal state, salinity, depth and surface water temperature were collected regularly every one-hour interval.

Data analysis

The habitat utilization of the Guiana dolphin was analyzed using a Geographic Information System (GIS)

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with the program ESRI Arcview GIS 3.1, including a quadrat grid (5x5km), the bathymetry of the study area and the distribution of dolphin sightings. The bathymetry was obtained through a digitized nautical chart of the study area and a TIN model of the sea bottom (Triangulated Irregular Network), generated using ESRI Spatial Analyst 1.0 and 3D Analyst extensions.

For the characterization of the physical habitat of each quadrat, the means of five measures were extracted for three variables (depth, distance from the sand banks and distance from the coast): one at the center and the other four at the vertexes of each quadrat. The contour index (*CI*, following Hui, 1979) was calculated using the minimum and the maximum measures of depth obtained for each quadrat. The *CI* was defined as:

$CI = 100*((M - m)/M)$, where M = maximum water depth and m = minimum water depth.

The Chi-square test (Zar, 1999) was used to determine whether the groups were homogeneously distributed in relation of the proportion of the different classes of each environmental variable (available habitat).

To calculate the expected distribution of each class of environmental variable, we applied the equation proposed by Hui (1979):

$Ei = Ot * Li/ Lt$,

where *Ei* is the expected number of animal sightings in the quadrats of each class, *Ot* = total number of sightings of Guiana dolphin groups; *Li* = total number quadrats of each class; *Lt* = total number of quadrats.

Overall salinity and surface water temperature data (without dolphin presence) were compared to the values collected during dolphin sightings.

Results

During a three-year period (2002-2004), 191 surveys were conducted (Figure 2), totaling 990hr of sampling effort and 128hr of direct observation of Guiana dolphin groups (12.9%). We observed 834 adult Guiana dolphins and 112 calves during 187 encounters with dolphin groups.

The majority of sightings were in the Caravelas River mouth, indicated as the core area for Guiana dolphin distribution in the study area (Figure 2). About 14 dolphin sightings (7.5% of the total sightings) were registered in the quadrats inside the estuary (2B, 2C and 3C), with a mean distance from the river mouth of 10.8km (min = 7.5, max = 14). These sightings occurred during the years 2002 (n = 10) and 2003 (n = 4), with no register for 2004. On the other hand, only 1.6% (n = 3) of the sightings were registered over distances larger than 5km from the coast.

Guiana dolphin distribution was significantly different from an expected uniform distribution in relation to the four physical habitat variables (Figure 3). Dolphins tended to use more shallow waters (total range used: 0-15m / preferred range: 0-6m; X^2 = 110.78, df = 4 $p < 0.005$; Figure 3a), closer to sand banks (total range used: 0-12km / preferred range: 0-6km; X^2 = 54.62; df = 3 $p < 0.005$; Figure 3b), closer to the coast line (total range used: 0-12km / preferred range: 0-5km; X^2 = 80.35; df = 2 $p < 0.005$; Figure 3c),

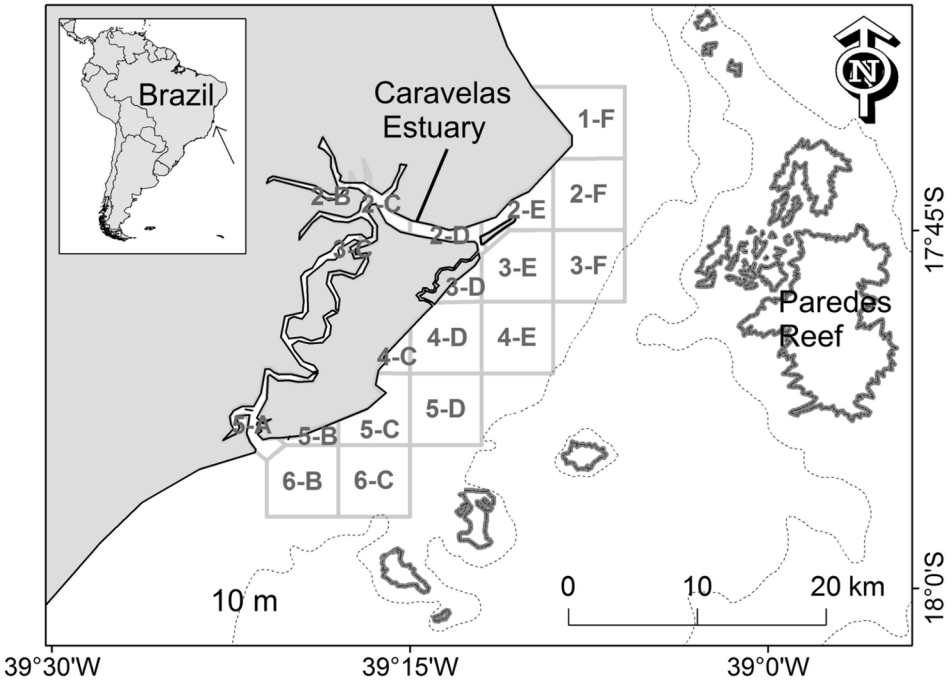

Figure 1. Study area map, located at Abrolhos Bank, eastern Brazilian coast. The 5x5km quadrat grid is shown in detail.

and flatter areas, where the contour index was lower (X^2 = 99.72; df = 3 p < 0.005; Figure 3d). Dolphins also used waters with salinity similar to open sea waters (Figure 4) and the same usual temperature found in the study area (Figure 5).

Overall, Guiana dolphin groups were observed more frequently when the tide was rising (Figure 6). This trend was more pronounced when the moon phase was full or new, when tidal currents and, consequently, its influence on the estuary are stronger.

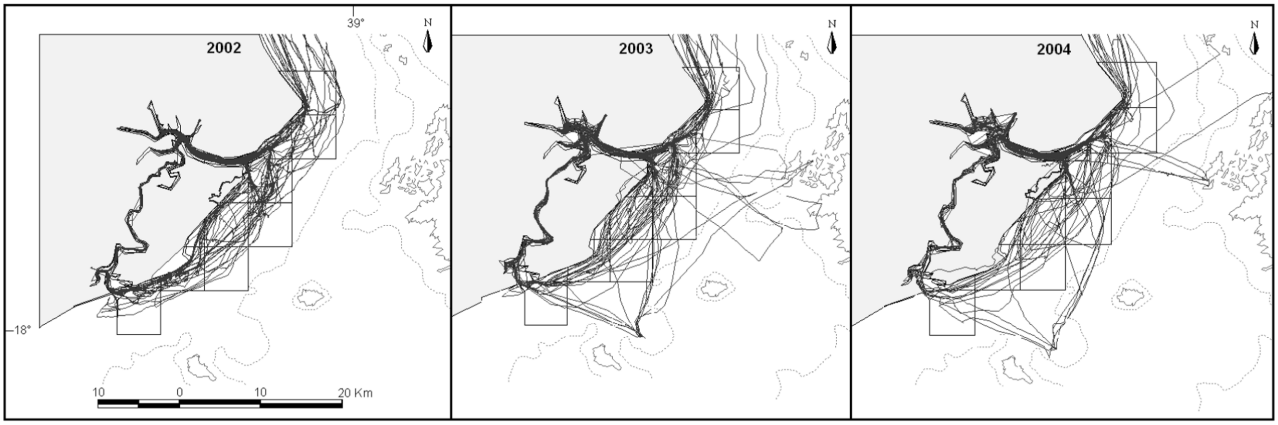

Figure 2. Sampling routes (gray lines) and sightings (black dots) in the Caravelas River Estuary, southern Bahia State, between 2002 and 2004.

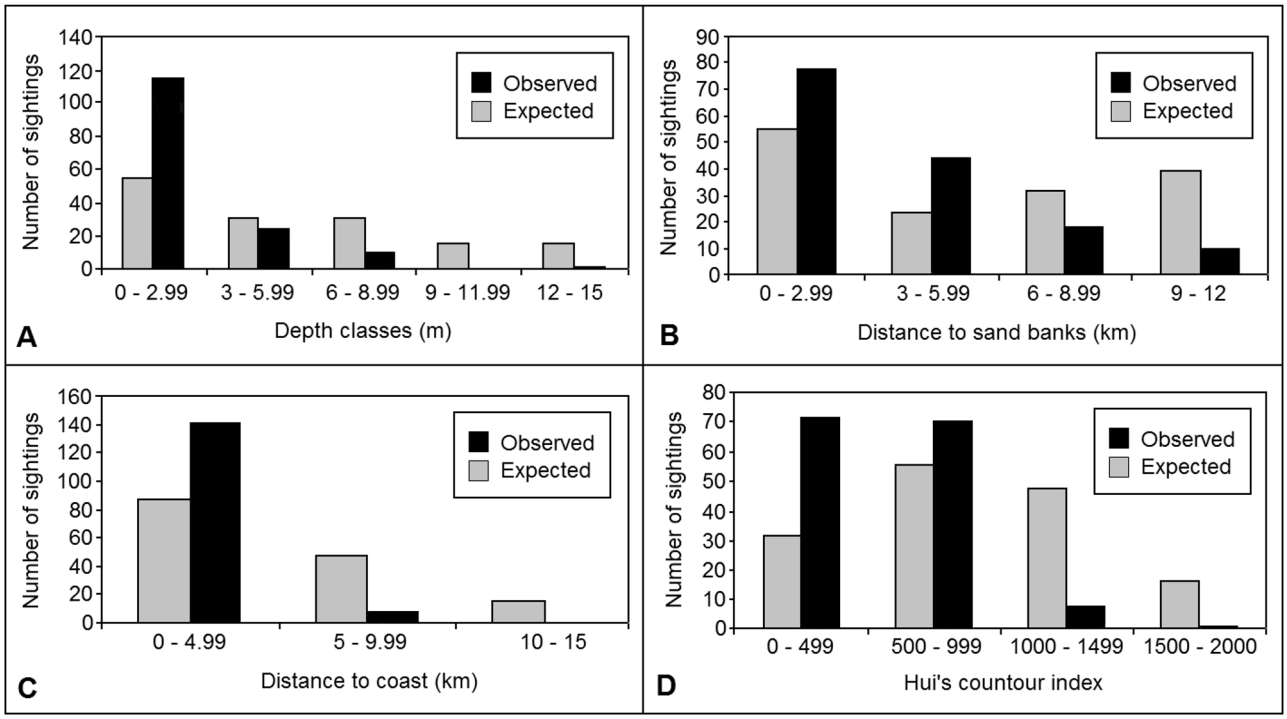

Figure 3. (a) Frequency distribution for habitat use of the Guiana dolphin, *S. guianensis*, based on depth classes (in m); (b) on classes of distances from sand banks (in m); (c) on classes of distance from the coast (in km); (d) on classes of bottom declivity (Hui contour index) in the Caravelas River Estuary, southern Bahia State, between 2002 and 2004.

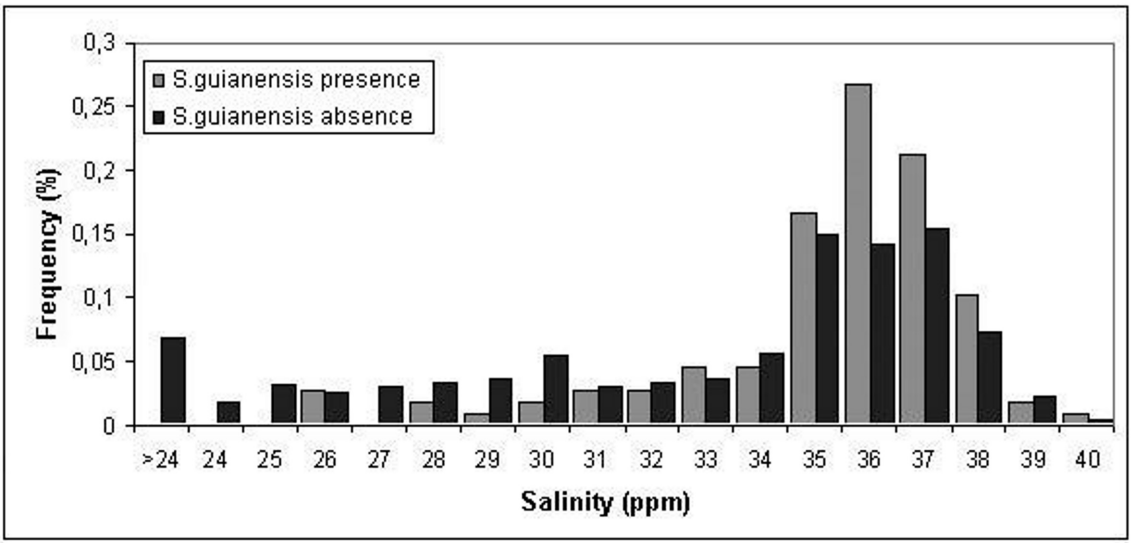

Figure 4. Salininity (ppm) frequencies during the presence and absence of the Guiana dolphin, *S. guianensis*, in the Caravelas River Estuary, southern Bahia State, between 2002 and 2004.

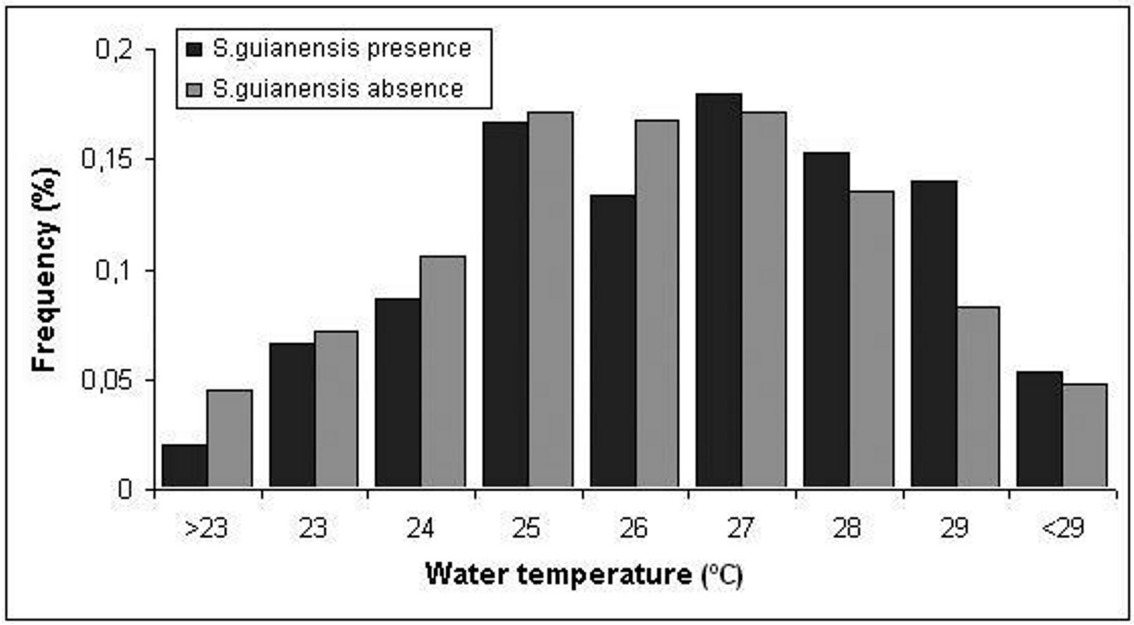

Figure 5. Water temperature (°C) frequencies during the presence and absence of the Guiana dolphin, *S. guianensis*, in the Caravelas River Estuary, southern Bahia State, between 2002 and 2004.

Discussion

Recent studies indicate that core areas of dolphin use are related to the foraging (Hastie *et al.*, 2004; Johnston *et al.*, 2005). Indeed, the Caravelas River mouth was used intensively by Guiana dolphin groups while foraging, and, for this reason, may be regarded as a critical habitat for the species in the region.

The sightings outside of the estuary, although less frequent than sightings inside the estuary, represent important information for the species occurrence outside bays and other protected areas where most studies on the species have been conducted. The results presented here report on a wide range of habitat utilization patterns, ranging from estuarine/riverine to open coastal waters. The species was also observed using waters near coral reefs and more than 70km far from the coast in the Abrolhos Bank (Borobia *et al.*, 1991; Rossi-Santos *et al.*, 2006), but our systematic effort did not included these habitats.

In the present study, we verified that Guiana dolphins occurred more in areas with flatter bottoms. This is different from what was observed in southern Brazil, where the species showed preference for steeper areas

(Cremer, 2000; Wedekin, 2007). It was suggested that steeper areas would propitiate more heterogeneous habitats, favoring the concentration of prey or foraging strategies (Cremer, 2000). Two explanations for this contrasting pattern are suggested. First, the scale of analysis in the present work was coarse in comparison with other studies and a preference for steeper bottoms may be revealed at finer-scales. Alternatively, the heterogeneity of the habitat may be promoted by other characteristics of the habitat in the Caravelas River Estuary besides bottom relief.

One of these characteristics may be the proximity to sand banks, which dolphins showed to prefer in the Caravelas River Estuary. These sand banks are concentrated in the vicinity of the river mouth, where shallow channels and passes are formed by the accumulation of sediment carried by the constant discharge of the Caravelas River.

Areas close to the coast and those with shallow bottoms were used more intensively by Guiana dolphins in the Caravelas River Estuary and surroundings, corroborating other studies that showed these habitat characteristics as important for the species (Cremer, 2000; Bonin, 2001, Edwards and Schnell, 2001; Lodi, 2003; Wedekin, 2007). Areas characterized by shallow bottoms and those close to the coast are widely considered critical habitats for the Guiana dolphin, despite the anomalous occurrence far from the coast (but still shallow), in the waters of the Abrolhos Bank, contiguous to our study area. This suggests that depth, and not distance from the coast, is the main limiting factor for the species. The anomaly in the Abrolhos Bank may be explained by the fact that the area is an enlargement of the continental shelf. Depth and distance from the coast are not necessarily correlated in the area as observed along other regions of the Brazilian coast.

Temperature did not affect the occurrence of Guiana dolphin in the study area. But the species apparently avoided waters with low salinity, indicating that the estuary is used mostly when the sea water intrudes in the system. This is corroborated by the analysis that identified the tide as an important environmental variable related to the Guiana dolphin occurrence in the study area, as preliminarily reported by Rossi-Santos *et al.* (2003). Other studies in the northeastern coast of Brazil have identified the tide as an important factor affecting the behavior of the Guiana dolphin (Araújo *et al.*, 2001; Hayes, 1999). Thus, Guiana dolphins may take advantage of the rising tide currents, either for saving energy while swimming, or for specific foraging strategies. Dolphins may take advantage of the movements of fish schools in and out of the estuarine system, or use habitats available only with the rise of the water column.

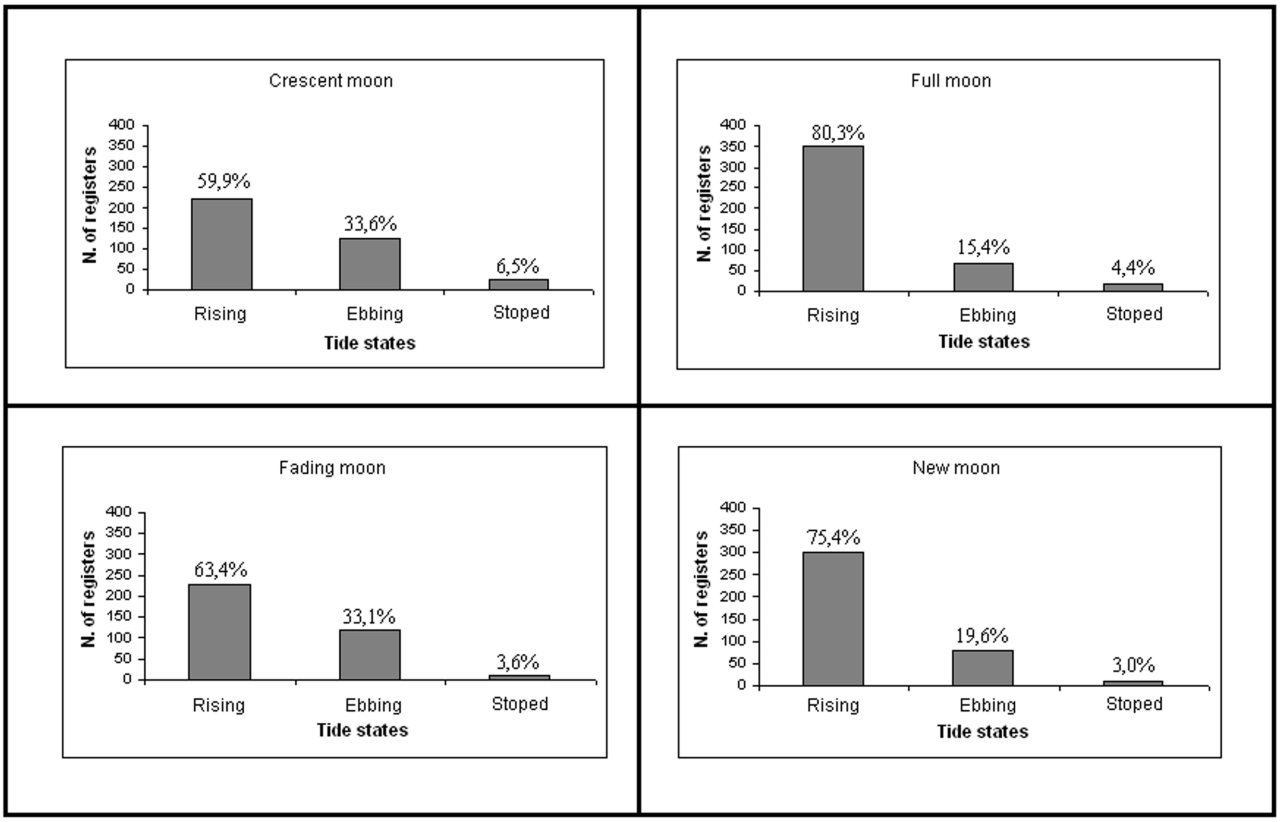

Figure 6. Occurrence frequency of *S. guianensis* during different tide states and moon phases in the Caravelas River Estuary, southern Bahia State, between 2002 and 2004.

Recent dredging activities and other habitat alterations in the Caravelas River Estuary raise concern about the possible effects of human activities over the population of Guiana dolphins. A decrease in the relative abundance of Guiana dolphins has been detected over the years of this study (Instituto Baleia Jubarte, unpublished data). The dependence of the dolphins on shallow habitats and sand banks is an important factor to consider in future licensing of human activities that cause habitat alteration to this estuary and other coastal habitats where the species occur.

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