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Research Article

Tourism growth altering spinner dolphins' area of occupation in Fernando de Noronha Archipelago, Brazil

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ABSTRACT. The objective of this study was to record the occupation of spinner dolphins at the northeastern end of the Fernando de Noronha Archipelago -a new occupation area. Data indicates that the area of the Inter Islands is the one in which the spinner dolphins present a longer permanence, defining a new pattern of occupation, with an annual tendency to stay for longer periods in the region. This change of permanence area may be related to the increase of tourism in Fernando de Noronha. The study points to the area of the Inter Islands as crucial for the conservation of spinner dolphin habits in the Fernando de Noronha Archipelago.

Keywords: *Stenella longirostris*, Cetacea, conservation, behavior, Fernando de Noronha Archipelago, Brazil.

INTRODUCTION

Like other species inhabiting certain areas -either looking for preys, a place to rest or for reproductive purposes- cetaceans can establish occupational patterns for short or long term periods. Cetaceans' occupational patterns have been linked to environmental features (Darling *et al.*, 1998; Karczmarski *et al.*, 2000; Bejder & Dawson, 2001; Azevedo *et al.*, 2007; Garaffo *et al.*, 2007; Bazalo *et al.*, 2008; Danilewicz *et al.*, 2009). Nevertheless, anthropogenic interactions can also influence their occupational patterns, especially where dolphin watching occurs (Bejder *et al.*, 2006).

Spinner dolphins (*Stenella longirostris*) can be found in tropical and subtropical waters of all oceans (Norris *et al.*, 1994). They show pelagic habits with a preference for deep waters, but also they frequently visit continental shores, islands, sandbanks, and atolls (Perrin & Gilpatrick, 1994). Spinner dolphins are usually seen in large groups, with more than 20 individuals, and a fluid composition, a population structure known as fusion-fission (Norris & Dohl, 1980; Silva-Jr., 1996).

The presence of spinner dolphins in Fernando de Noronha Archipelago has been reported since 1556

(Silva-Jr., 2010), in a location that was eventually baptized as Dolphin's Bay. There, the spinner dolphins were documented resting, mating, nursing and sheltering against predators (Silva-Jr. *et al.*, 2005, 2007). None of the previous studies report encounters with spinner dolphins in the northeastern extremity of the archipelago. However, since 2007 researchers and residents have reported sightings of spinner dolphins in these areas, specifically in the Santo Antônio Bay and the Inter Islands area, which are frequent routes for diving and sight-seeing boats. The anecdotal encounters and the heavy presence of boats led the Spinner Dolphin Project, a conservation and research institution based in the archipelago, to initiate an effort to systematically monitor this new location.

Tourism is the main economic activity in Fernando de Noronha (Cordeiro & Gomes, 2016), with the spinner dolphin as one of the most important touristic attractions. However, tourism has grown significantly in recent years, which has caused unforeseen consequences for the human population (Cordeiro & Gomes, 2016) and for the spinner dolphins (Tischer *et al.*, 2013).

This paper reports the usage patterns of spinner dolphins in the northeastern part of the Fernando de Noronha Archipelago. We discuss how the increase in

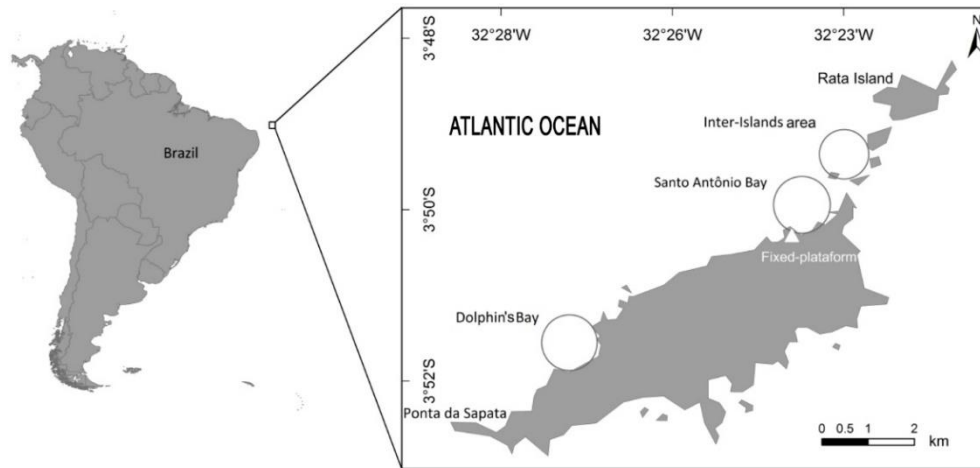


Figure 1. Location of the Fernando de Noronha Archipelago, study sites (Santo Antônio Bay and Inter Islands area) and location of the fixed platform from which observations were made.

dolphin watching activities might be related to this change, and management needs for the conservation of this species in this newly-recognized area.

MATERIALS AND METHODS

The Fernando de Noronha Archipelago (FNA), is located off the Brazilian coast ($3^{\circ}50'S$, $32^{\circ}24'W$), 345 km from Natal, Rio Grande do Norte. The archipelago has one main island -Fernando de Noronha Island- and 17 islets (Silva-Jr., 2010) with a total area of 26 km². The archipelago has two well-defined seasons: a dry season, from August to February; and a rainy season, from March to July (Linsker, 2003). It is also divided in two faces, according to its geographical, meteorological and oceanic features. The Inside Sea refers to the northern portion of FNA, facing the South American continent and protected from currents and oceanic winds; and the Outside Sea corresponds to the southern portion of the archipelago, facing the African continent, with strong winds and waves all year around (Linsker, 2003). The archipelago is also divided in two different categories of federal level protected areas: Fernando de Noronha Marine National Park (PARNAMAR-FN) (FUNATURA/IBAMA, 1990) and Fernando de Noronha, Rocas, São Pedro and São Paulo Islands Environmental Protection Area (APA-FN) (IBAMA, 2005).

The study sites, the Santo Antônio Bay and the Inter Island Area, also have different geographical and oceanic features. Santo Antônio Bay is an open water bay, where the Santo Antônio Port -the only port of the archipelago- is located. Its depths vary from zero (starting on the sandy beach) down to 20 m. The Inter Island area is slightly more turbulent than the port, and

it is in the open sea area, with depths up to 15 m. Another important difference is that the Inter Islands area is located inside the Marine National Park, while the Santo Antônio Bay lays inside the Environmental Protection Area -a less restrictive protected area category.

The two sites were monitored from a fixed point located at Nossa Senhora dos Remédios Fort, at 45 m above the sea surface (Linsker, 2003), with a broad view of both sites (Fig. 1). Observations were carried out between February 2009 and December 2012. Data were collected from the moment the dolphins entered the bays (researchers waited every day at sighting point at 05:50 h AM) until the moment the animals left the study areas (to assure the animals would not return, researchers held position for at least one hour after the last animal's departure (usually around 15:00 h PM).

Data were collected with 10×50 binocular and Rongda XBZ 30×260×160 zoom and mechanical counters. Data were registered in field sheets and transferred daily to an electronic data bank. Observations started when dolphins were at a maximum distance of 1500 m. The groups were monitored continuously until the animals left the study areas.

Data collected included the time of entrance and departure, number of individuals, permanence time in each bay as well as displacement direction and behavioral states for each focal group (Altmann, 1974). When two or more groups merged, they were registered as one new group - since the group composition became distinct. The group sizes were classified in four different categories: A: 1-50 individuals; B: 51-100 individuals; C: 101-200 individuals and D: >200 individuals. Behavioral state was classified in two categories: still or in displacement. A displacement

behavior was noted when the group passed from side to side of the bay, in direct and constant movement without change in direction, either to reach the next bay or to exit the area. A still behavior, on the other hand, was noted when there was no direct and constant movement of the group, with dolphins remaining for the longest time in the bay of the study area. Displacement directions had as main references two extremities of the archipelago, towards Rata Island -in the northeastern portion- and towards Ponta da Sapata-southeastern.

Data were analyzed with PASW Statistics 18 for non parametrical tests, since data had no normal distribution (Siegel & Castellan, 2006). For all analysis, significance level adopted was 5% ($\alpha = 0.05$).

RESULTS

During 809 days, 7,999 h of observations were carried out, from February 2009 to December 2012 (Table 1).

Table 1. Monitoring efforts and the presence of dolphins in Santo Antônio Bay and Inter Islands area in each of the sampled years.

Period	Year			
	2009	2010	2011	2012
Months	11	12	12	12
Days	174	178	266	191
Hours	1717	1791	2567	1924
Presence of dolphins (% of days)	90%	97%	90%	90%

Permanence time

Permanence time per day showed significant difference among the years (Kruskal Wallis test, $H = 33.854$; $df = 3$; $P < 0.001$). Mann-Whitney paired test, with Bonferroni adjustment, showed that the median permanence time in 2010 was greater than the values found for other years (Fig. 2).

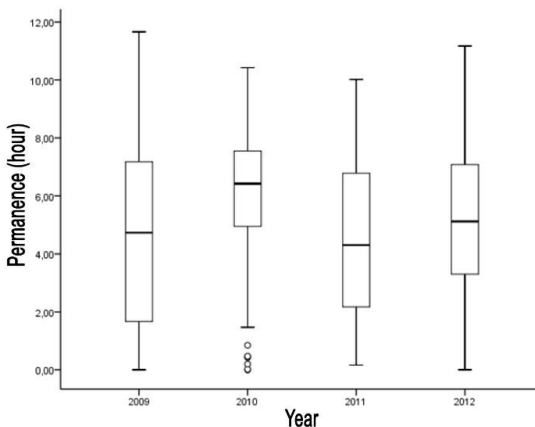


Figure 2. Median permanence time per day, for each sampled year.

The permanence time in the Inter Islands area was greater than the one observed for Santo Antônio Bay for all the sampled years (Fig. 3).

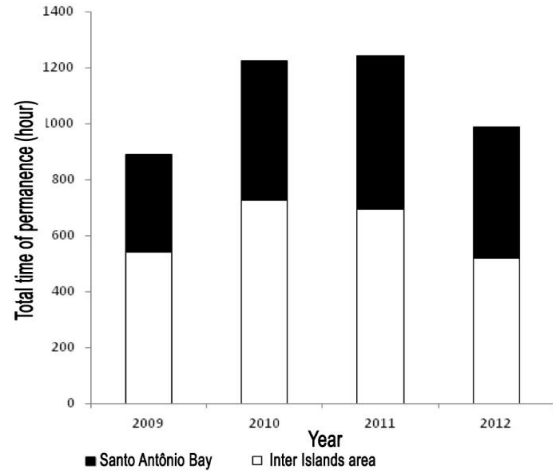


Figure 3. Spinner dolphins permanence time in both studied areas, during the sampled years. Mann-Whitney test, $P < 0.001$, for each year.

Seasonal permanence time

There was a statistically significant difference in the permanence time of dolphins during each season (Mann-Whitney test U, $U = 52,939.500$; $Z = -5.902$; $P < 0.001$). Seasonal difference was also noticed in the permanence time among 2009, 2011 and 2012 (Table 3).

Table 3. Permanence time ($h d^{-1}$) of dolphins during each season. Mann-Whitney values for permanence time, for dry and rainy seasons.

Year	Dry	Rainy	U	Z	P
2009	5.20	4.07	2801	-2.835	0.005
2010	6.16	5.42	2901.5	-1.708	0.088
2011	5.07	3.53	5019.5	-3.868	0.000
2012	5.26	4.25	2855.5	-2.395	0.017

Group sizes

A total of 2,066 groups were observed and group size categories were determined for 1,966 of those. The most common groups size category was D (>200 individuals), for all sampling years 2009, 2010, 2011 and 2012 (Table 4).

Table 4. Group sizes distribution, in absolute numbers and percentage, for each of the sampled years.

Group size	2009	%	2010	%	2011	%	2012	%
A	109	21	63	12	80	14	61	16
B	105	22	94	18	116	21	46	13
C	139	27	137	26	154	27	88	24
D	154	30	234	44	215	38	171	47
Total	507		528		565		366	

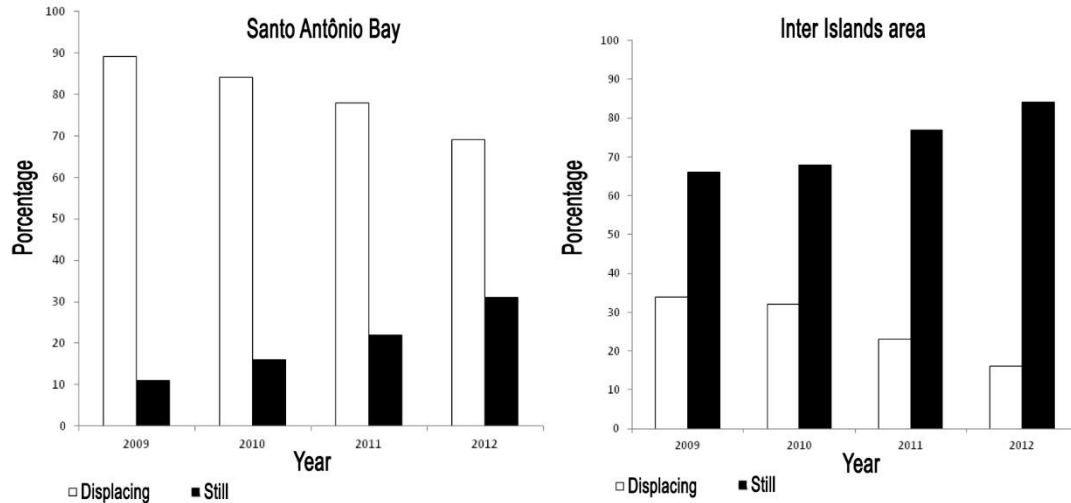


Figure 4. Behavioral states categories observed (%) in each studied area, for each of the sampled years.

Behavioral state

Most of the observed groups were in displacement in the Santo Antônio Bay. In the Inter Islands area, on the other hands, most groups were 'still' for all the sampled years (Fig. 4).

Displacement direction

We noted dolphins displacing from and towards two main directions, the northeastern portion of the archipelago and the southeastern portion of the archipelago (where the Dolphin's Bay is). Displacement towards Rata Islands (northeastern) was the most common for all sampled years (Table 5).

Table 5. Dominant displacement directions and their significance (Chi-square test) for each of the sampled years.

Year	Towards Rata Island (northeastern)	Towards Ponta da Sapata (southeastern)	<i>P</i>
2009	80%	20%	0.001
2010	85%	15%	0.001
2011	84%	16%	0.001
2012	86%	14%	0.001

DISCUSSION

Research on spinner dolphins in the Fernando de Noronha Archipelago started over 20 years ago, focusing mainly on the Dolphin's Bay (Silva-Jr., 1996). The first study with spinner dolphins in Santo Antônio Bay and Inter Islands area was in 2006, and involved use of microsatellite DNA markers to better understand the population dynamics of the spinner dolphins in Fernando de Noronha (Farro, 2006). Since then, few

studies have been conducted in the area, and none quantifying occupation patterns. In that sense, this is a pioneering study of dolphins' occupancy in the northeastern portion of Fernando de Noronha Archipelago.

In cetaceans, the occupation pattern refers to their daily occurrence and use of specific areas. In the Fernando de Noronha Archipelago, previous studies show daily variations in dolphin' occupation pattern. According to Silva & Silva-Jr. (2009) animals arrive at the Dolphin's Bay from the open ocean soon after the sunrise. Dolphins leave the bay in the afternoon back to open waters, where they will forage during night time (Silva & Silva-Jr. 2009). Norris & Dohl (1980) found a similar occupation pattern for spinner dolphins in Hawaii (USA) with nocturnal foraging and diurnal movement towards protected bays along the coast to rest. The same pattern was described for spinner dolphins in the Red Sea, Egypt (Sciara *et al.*, 2009).

Occupation patterns have been studied and documented for other delphinids, both oceanic and coastal species. The Guiana Dolphin (*Sotalia guianensis*), for example, can be daily observed at Pipa Beach (RN) inside another so-called Dolphin's Bay which is, unlike the one in Fernando de Noronha used for feeding, as well as mating and socializing behaviors (Araújo *et al.*, 2003).

Our results show greater permanence time in the studied area during the dry season, when compared to the rainy months. This data is in agreement with the previously pattern documented for spinner dolphins' occupation in Dolphin's Bay (Silva-Jr., 1996). This pattern may be related to the visibility conditions in the water in the bays. In the rainy months, the water becomes turbid, because of sediment carried into the bays by rainwater.

Regarding group sizes, the prevalence of groups >200 individuals (D category) for all the sampled years is also in agreement with studies carried out in the past by Silva-Jr. (1996), which showed an average number of 257 per day in the Dolphin's Bay. In Hawaii, a few animals are observed, with group's size varying from 1 up to 175 individuals (Östman-Lind *et al.*, 2004). The average size of groups in the Red Sea is also much smaller, with an average of 39 individuals observed per day (Sciara *et al.*, 2009). Larger groups in Fernando de Noronha do not necessarily mean the population is larger, since there is no estimate for the archipelago. This higher concentration is expected since Fernando de Noronha is the only archipelago in the south Atlantic Ocean with environmental, geographic and oceanographic conditions that allow spinner dolphins to rest in protected calm-waters bays. In Hawaii and the Red Sea, archipelagos with larger territorial extension, there are a greater number of bays for spinner dolphins to rest (Norris & Dohl, 1980; Norris *et al.*, 1994; Östman-Lind *et al.*, 2004; Karczmarski *et al.*, 2005; Sciara *et al.*, 2009).

The difference in permanence time between the Inter Islands area and the Santo Antônio Bay indicates that the Inter Islands area of greater importance for the spinner dolphins. In Hawaii dolphins linger for hours in different bays, throughout the days, displaying resting and mating behaviors as well as seeking for protection against predators (Norris & Dohl, 1980; Norris *et al.*, 1994; Östman-Lind *et al.*, 2004; Karczmarski *et al.*, 2005).

In the Fernando de Noronha Archipelago, spinner dolphins are now occupying more than one area or slowly changing their main area of occupation from the Dolphin's bay to the Inter Islands area. This change from one site to another has been previously reported for spinner dolphins in Hawaii (Östman-Lind *et al.*, 2004).

In the Santo Antônio Bay, 'displacement' was the most observed behavior for all sampled years. In the Inter Islands area, on the other hand, dolphins showed predominantly still behavior. This suggests that the Inter Island area is relevant for the conservation of spinner dolphins and their habits in the archipelago, and may play a significant role in the dolphins' life cycle, just as Dolphin's Bay, where the access of boats and people is prohibited. Luis-Jr. (2009) recommends against scuba diving with spinner dolphins in Fernando de Noronha Archipelago and advocates the closure of a diving point known as 'Sela Ginete Island'. The diving point is located in the Inter Islands area, where research to assess the interaction between divers and dolphins is needed. Our data indicate that the Santo Antônio Bay works as a passageway to the Inter Islands area, where they remain for longer periods.

The frequent displacement towards Rata Island, which was the predominant direction for all the sampled years, may indicate a change in occupation with the use of a complementary area. Many groups arriving in the Inter Islands area come from Dolphin's Bay, which remains as the most important area for the species in the archipelago.

Data presented here, for all sampled years, indicate that spinner dolphins are now regularly found in the Santo Antônio Bay and the Inter Islands area in the Fernando de Noronha Archipelago. Further studies to detail the presence and behaviors of dolphins in these areas are recommended, as they would provide the scientific support needed for the development of adequate conservation management strategies in both locations. Tyne *et al.* (2015) advocate the creation of new protected areas which are entirely free of human presence and able to ensure the conservation of spinner dolphins.

Spinner dolphin population has shown different behaviors than the ones described in previous studies. The occupancy of a new area, situated in the northeastern extremity of Fernando de Noronha Archipelago may indicate an attempt to find regions with fewer anthropogenic impacts, especially related to nautical tourism. Despite being near the port -a place with significant marine traffic, the Inter Islands area is closer to feeding grounds and has a greater oceanographic dynamics, which may diminish noise pollution. In order to dislocate from Dolphin's Bay towards the feeding grounds, spinner dolphins must cross the entire Inside Sea area, where the marine traffic is intense all day long. Leaving from Inter Islands region towards feeding grounds could represent a faster and less disturbed movement.

Studies regarding the groups flow from one region to another are also fundamental for a better understanding of spinner dolphins' population range in Fernando de Noronha Archipelago. Nevertheless, as highlighted before, the access of boats in the Inter Islands area should be immediately banned. As well described for Dolphin's Bay, the Inter Islands area hosts spinner dolphins groups which are constantly carrying out essential behaviors for their life cycle. The Inter Islands area, therefore, represent a crucial region for the conservation of the species in the archipelago.

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