



Influence of tide on composition of the bird fauna in Ilha Comprida, São Paulo, Brazil

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Abstract: Given the lack of information on the influence of tide on estuarine birds, this study analyzed the variation of abundance, diversity and richness, in response to the tidal cycle in an estuarine lagoon in the northern part of Ilha Comprida, south coast of São Paulo State. The method used for numerical scores was the fixed point. Correlation coefficients were determined between the number of individuals, richness diversity and shifting of the tide. There was a strong negative correlation between the number of species present ($r = -0.71$) and the total number of individuals ($r = -0.80$), when correlated vs. tidal range. As for diversity, there was a very weak negative correlation with tidal amplitude ($r = -0.43$). Some species depend more than others to tide movement in the lagoon of Ilha Comprida, and are mainly conditioned with the type of food, size of the bird, beak size and legs.

Keyword: correlation, richness, diversity, tide variation, Ilha Comprida

Resumo: **Influência da maré sobre a composição de aves estuarinas na Ilha Comprida, São Paulo, Brasil.** Dada a falta de informação sobre a influência da maré em aves estuarinas, este estudo analisou a variação do número de indivíduos, riqueza de espécie e diversidade de aves em resposta ao ciclo das marés na lagoa estuarina na parte norte da Ilha Comprida, litoral sul do Estado de São Paulo. O método utilizado para as contagens numéricas foi o do ponto fixo. Os coeficientes de correlação foram determinados entre o número de indivíduos, riqueza, diversidade e mudança da maré. Houve uma forte correlação negativa entre o número de espécies ($r = -0,71$) e o número total de indivíduos ($r = -0,80$), quando correlacionados com a amplitude das marés. . Quanto à diversidade, houve uma correlação negativa, muito fraca ($r = -0,43$). Algumas espécies dependem mais e outras menos da variação da maré na lagoa da Ilha Comprida, pois estão condicionadas principalmente com o tipo de alimento, tamanho da ave, tamanho bico e pernas.

Palavras-chave: correlação, riqueza, diversidade, variação mareal, Ilha Comprida

Introduction

Seasonal fluctuations in the abundance of shorebirds and seabirds are usually associated with temperature, rainfall, tidal fluctuations, and salinity (Branco *et al.* 2011), variations in prey populations, migration, in addition to intra- and interspecific interactions (Numao & Barbieri 2011).

After the breeding period, shorebirds tend to group in dense flocks in suitable sites to rest and protect themselves from predators (Danufsky &

Colwell 2003). In wintering areas, they usually exploit a habitat mosaic governed by the tidal cycle that limits access to feeding sites for long periods (Hale 1980). This environmental factor directly influences the abundance, spatial distribution and behavior of beach birds (Pitelka 1979, Myers *et al.* 1979, Burger 1984, Barbieri & Paes 2008).

These birds are sensitive to spatial variations in prey density and relative number of foraging sites (Burger *et al.* 1977, Myers *et al.* 1979). Several

studies have reported the selection of preferred foraging areas of beach birds (Pitelka 1979, Burger 1984, Zanin *et al.* 2009). Other authors examined the availability of food in relation to the daily rhythm of tides (Tiedemann & Nehls 1997, Delchiaro *et al.* 2013), because their amplitude also directly affects the foraging space (Ribeiro *et al.* 2004) and behavior of birds over the tidal cycle (Zanin *et al.* 2008, Lunardi 2010).

On the Brazilian coast, few studies have addressed the temporal effects of tides on beach birds. This study aimed to analyze the fluctuations in community variables (by means of abundance, diversity and richness) of estuarine birds, in response to the tidal cycle, in an estuarine lagoon in the northern of the Ilha Comprida, southern coast of the São Paulo State. In this context, we tested the hypothesis that the tidal range influences the abundance of birds in this lagoon, reflected in the number of individuals, richness and diversity.

Material and Methods

Study area: At the southernmost end of the state of São Paulo there is a scarp retreat of the Serra do Mar, which forms the basin of the Ribeira de Iguape River, whose mouth marks the northern boundary of the Estuarine-Lagunar Table of Cananéia-Iguape-Paranaguá, where Ilha Comprida is situated in the central region (Figure 1). This island has around 70 km long and 3 km wide, on average, and is intersected by small streams, becoming a major

attraction for birds and many other animals. The beach of Ilha Comprida consists of wide sandy strip parallel to the coast line, with fine sediments, homogeneous and of low slope (Suguio & Martins 1987), formed by the accumulation of sandy materials (Barbieri *et al.* 2013).

The Estuarine-Lagunar Table of Cananéia-Iguape-Ilha Comprida is one of the most important ecosystems of the southeastern coast for marine and estuarine birds (Zanin *et al.* 2009). The North Lagoon of the Ilha Comprida (24°40'29.71''S 47°25'56.94''W) has 7.73 ha length and is located at the northern end of the Comprida Island, near Icarapa Bar (Figure 2). It is inside a mosaic of Conservation Units, part of the Area of Relevant Ecological Interest of Guará (ARIE do Guará) (Figure 3).

Sampling methodology and data treatment: Beach birds were sampled, between the morning and afternoon, depending on the tide and the possibility of access to the site. We counted the number of birds from a fixed point, lasting 15 to 30 minutes, where the observer with binoculars recorded the number of birds per species (Bibby *et al.* 1992, Wiens 1997) in each observation. The same amount of time was used in the observations for both high tide and low tide

In this study, we analyzed data of 70 samples collected in the years 2005, 2008, 2009 and 2010 at North Lagoon of the Ilha Comprida.

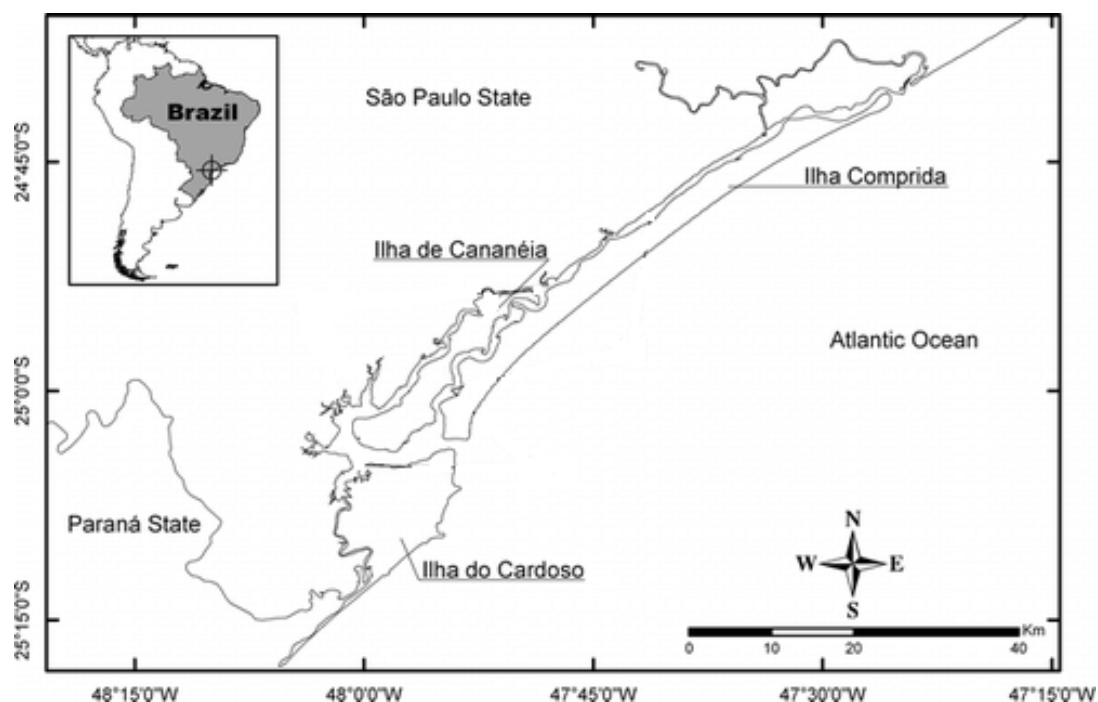


Figure 1: Estuarine-Lagunar of Cananéia-Iguape-Ilha Comprida.

The North Lagoon of the Ilha Comprida was previously selected because of the easy access, abundance of birds, tidal influence and lack of study on the site. The data were analyzed regarding normality distribution using Shapiro-Wilk's test. Pearson linear correlation coefficients were calculated between values of richness, diversity, number of individuals, families and species and

values of tidal range. Also the correlation between the families present the amplitude of tide was realized. Correlation was considered very weak (VW) when lower than 0.50; weak (W) between 0.50 and 0.65, strong (S) between 0.65 and 0.80 and very strong (VS) above 0.80 (Cabral 2006). The specific diversity was calculated using the diversity index of Shannon (Magurran, 1988).



Figure 2.- Aerial view of the Lagoa Norte of the Ilha Comprida, located in the Northern This Island. Source : “Ilha Comprida” 24° 40`45.46`` S 47° 26`12.13`` Google Earth. August 3, 2011. May 22, 2012



Figure 3.- Images of the North Lagoon of the Ilha Comprida A) Lagoon at high tide. B) Lagoon at low tide

Results

Considering the correlation between tidal fluctuations and the species richness and total number of birds, there was a strong negative relationship between these variables (Table I), indicating that the number of species and individuals reduce with rising tide. In respect to diversity and tidal range, there was a very weak negative correlation (Table I).

The species belonging to the family Ardeidae (*Egretta caerulea*, *E. thula* and *Ardea alba*) also showed VW correlation with tidal range (Table I), as well as *Rynchops niger* (Rynchopidae).

Discussion

Birds have the ability to respond to environmental dynamics and show adaptations to stochastic processes related to fluctuations of the system where they live (Dubowy 1996). Habitat selection and the foraging decision are often carried out to optimize temporal events, such as tidal fluctuations. They can also be more critical during periods of limited resources (Barbieri & Delchiaro 2009), particularly for migrant birds of the families Scolopacidae and Charadriidae using the North Lagoon of the Comprida Island as a stopping site.

The flood tidal cycle in mud banks and beaches causes changes in the availability of foraging areas, consequently in diversity and availability of prey (Branco, 2007, Zanin *et al.* 2008,

Ebert *et al.* 2014). Shorebirds continually adjust their activities, flying between the feeding areas (Burger *et al.* 1977, Branco *et al.* 2015), as evidenced by the inverse correlations between the different parameters tested with tidal range in this study.

Lags in tidal cycles, especially in estuarine lagunar systems, may require longer foraging time in the same habitat or moving between areas, besides the dependence on a particular type of prey. The distribution of birds in tidal areas is usually associated with beak size, body size and mode of feeding. Birds like *Ardea alba* can forage in areas at higher tide, than Charadriidae birds with short beak and legs (Zanin *et al.* 2008), which depend on vision to find food. Perhaps *Egretta caerulea*, which feeds on crab and even polychaetes in exposed mud banks, is more affected by the unavailability of exposed areas in the sand bank, than other Ardeidae (*Ardea alba* and *Egretta thula*) that mainly feed on fish (Zanin *et al.* 2008).

The tidal range in the North Lagoon of the Comprida Island reaches up to 1.80 m, and when low, the entire upper area becomes available for feeding and resting, as occurred in each sampling. Nevertheless, when the tide rises, it becomes unavailable, leading the birds to move to other areas. Our findings are consistent with Powell (1987), who demonstrated that foraging activity of some Ardeidae depends on the tidal cycle.

Table I. Correlation between the variables tested and the tidal range in the Lagoon on the Comprida Island, state of São Paulo. Correlation very weak (VW); weak (W), strong (S), very strong (VS).

Variables	R-value	Type of correlation	Number of samples
Richness/Tidal range	- 0,70	S	70
Number of individuals/Tidal range	- 0,81	VS	70
Diversity/Tidal range	- 0,43	VW	70
Scolopacidae/Tidal range	- 0,40	VW	70
Charadriidae/Tidal range	- 0,51	W	70
Ardeidae/Tidal range	- 0,49	VW	70
<i>Egretta caerulea</i> (Linnaeus, 1758) /Tidal range	- 0,25	VW	70
<i>Egretta thula</i> (Molina, 1782) /Tidal range	- 0,43	VW	70
<i>Ardea alba</i> (Linnaeus, 1758) /Tidal range	- 0,20	VW	70
<i>Rynchops niger</i> (Linnaeus, 1758) /Tidal range	- 0,44	VW	70
<i>Charadrius semipalmatus</i> (Bonaparte, 1825) /Tidal range	- 0,43	VW	70
<i>Tringa flavipes</i> (Gmelin, 1789) /Tidal range	- 0,38	VW	70

The pattern of habitat use by families Charadriidae, Scolopacidae and Ardeidae follows the observed in other populations of waterfowls influenced by local tidal cycle (Myers *et al.* 1979, Burger 1984, Ribeiro *et al.* 2004, Zanin *et al.* 2008, Branco *et al.* 2015, Ebert *et al.*, 2014). Despite the negative correlations, mostly very weak between number of individuals, richness, diversity and tidal range, these could be even more pronounced, if the migratory shorebirds like *Rynchops niger* did not use the areas available for feeding and mud area, as a site for resting and plumage maintenance. Some species depend more and others less of tide movement in the lagoon of the Ilha Comprida, and are mainly conditioned with the type of food, size of the bird, beak size and legs.

At last, we confirmed the hypothesis that the tidal range negatively influences the abundance of birds in this lagoon, affecting the number of individuals, richness and diversity.

Acknowledgements

The authors thank FAPESP (2012/ 50184-8) and CNPq (303920/2013-0) for financial support for this study.

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Received: October 2016

Accepted: April 2016

Published: July 2017