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# Seasonal variation of estuarine birds from Trapandé Bay, Cananéia, Brazil

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## ABSTRACT

Estuaries are important environments for birds as resting and foraging sites. Therefore, information about the abundance, distribution, and biology of bird populations are necessary for preservation of such ecosystems. In this work, we studied the dynamic population of birds at Baixio do Arrozal, Trapandé Bay, Cananéia Estuary on the southern coast of São Paulo state, Brazil. As an original hypothesis, we expected that the species abundances would display differences across months and seasons. Using the point count method, bird data were collected monthly between April and December 2013. For comparing the assemblages, a bar chart of the total abundance as a function of the monthly frequency was used along with boxplot graph of this index as a function of the seasons. We also investigated variations in the abundance of some specific bird populations. The results obtained for the total abundance indicated a seasonal pattern, peaking during the warmer months. The population analyses showed a greater abundance occurring in spring/summer, and a decrease of resident species populations in the winter. Migratory birds were recorded in the autumn and spring, following the migratory movements. This demonstrated that bird assemblages varied according to seasons due to the life cycle and the population sizes. Therefore, Baixio do Arrozal is an important environment for avifauna, which use the area throughout the year and need to be preserved.

**Descriptors:** Abundance, Assemblage, Avifauna, Estuary, Population.

## INTRODUCTION

Coastal ecosystems, especially estuaries, have high primary productivity, which together with the environmental complexity, contribute to the high abundance of invertebrates and their use as a nursery for some fish species. These features represent important resources for birds, and these environments are highly attractive for foraging and resting (Branco, 2007; Barbieri et al., 2013; Branco et al., 2015). Coastal ecosystems that are close to mangroves also contribute to the presence of species inhabiting the shores, who take advantage of the low tide to expand their foraging area (Branco, 2000; Branco et al., 2004). Several studies carried out along the Brazilian coast have showed that the bird assemblages associated with environments under marine influence are usually composed of a variety of species, including migratory, resident, and occasional or vagrant species (Branco, 2007; Barbieri and Paes, 2008; Manoel et al., 2011).

The southeast Brazilian coast is important for marine birds and shorebirds, since it is the wintering grounds for migrants from both hemispheres, providing optimum environmental conditions for foraging and resting (Neves et al., 2006; Cestari 2015; Tavares et al., 2015). It also serves as a breeding site for *Larus dominicanus, Sterna superciliaris, Sula leucogaster, Fregata magnificens*, and *Thalasseus acuflavidus*

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(Branco et al., 2004; Branco et al., 2009; Branco and Machado, 2011; Fracasso et al., 2011), among others.

The estuarine-lagoon complex of Cananéia-Iguape-Ilha Comprida is one of the main sites for marine birds and shorebirds in southeast Brazil for resting, wintering, and breeding. It is part of the Atlantic migratory route; thus, this region receives species of Charadriidae, Scolopacidae, Laridae, and Stercocariidae (Barbieri and Paes, 2008; Barbieri et al., 2010). Due to the large abundance of invertebrates and fishes (Tommasi, 1970; Barbieri, 2007), the estuary is a foraging site for resident species outside of breeding seasons (Barbieri, 2007, Barbieri, 2008; Barbieri, 2009) and a nesting site for *Eudocimus ruber* and several Ardeidae species (Noguchi, 2015; Paludo et al., 2018). However, in Trapandé Bay, which is the largest portion of the estuary, the dynamics of the bird population has not yet been studied.

Although Cananéia-Iguape-Ilha Comprida Estuary holds a great richness of species and favorable environmental conditions for resting and foraging (Heinemann et al., 1989; Barbieri and Paes, 2008; Brusius et al., 2021), other variables such as seasonal variations may influence the avifauna composition during the year. The seasons provide distinct conditions that set off different biological processes, resulting in birds moving to areas with favorable conditions for their survival (Branco et al., 2001; Branco et al., 2004).

A majority of information about the bird assemblage of Cananéia-Iguape-Ilha Comprida estuary has been obtained on the beaches; however, little is known about the composition and the dynamics of the populations in inner sites of this estuary. Although the Baixio do Arrozal is used by many bird species, little is known about the abundance patterns and seasonal variations of avifauna present there (Numao and Barbieri, 2011). This information is important to help understand the relevance of estuarine environments for fauna, because the seasonal and monthly differences may be connected to life cycles, niches, and behavior in most cases (Branco et al., 2001; Branco, 2007; Manoel et al., 2011). Therefore, the main goal of this study was to characterize the bird population dynamics at Baixio do Arrozal, assuming that there would be monthly and seasonal variations. Our hypothesis is that there is seasonal variation in bird abundances during the year.

## METHODS

Trapandé Bay is situated between Cananéia Island, Cardoso Island, and Ilha Comprida Island, facing Barra de Cananéia, which receives a larger volume of sea water than the other areas of the estuary. Baixio do Arrozal, located in the center of Trapandé Bay (Figure 1), is a well-preserved area, since it is accessible only by vessels. This shallow area is characterized by the flat surface that is exposed at low tide and the proximity to the mangrove vegetation composed of three species: *Rhizophora mangle*, *Laguncularia racemose*, and *Avicennia schaueriana*. It is also possible to find marshes with *Spartina* (Schaeffer-Novelli *et al*., 1990; Barbieri and Cavalheiro, 1999; Vieri et al., 2021), despite the predominance of red mangrove (Pereira *et al*., 2001b), which benefits the abundant invertebrate fauna (Tararan, 1994; Pereira et al., 2007).

The mean temperature in this region is around 21.2°C during the year; it can reach an average of 25.5°C in the warmest month and an average of 17.7°C in the coldest month (Bérgamo, 2000). The mean tidal range is 0.82 m (Schaeffer-Novelli et al., 1990; Barbieri and Cavalheiro, 1999). The mean annual rainfall is 2,200 mm with seasonal variations including rainy summers, especially between January and March, and dry winters, between June and August. Therefore, the amount of fresh water in the estuary is higher during the summer (Bérgamo, 2000).

Data were collected through a biweekly census of the birds between April 2013 and December 2016, totaling 72 samples. 11 censuses were performed in 2013, 21 in 2014, 16 in 2015, and 24 in 2016. The distance maintained between the counting points was 200 meters and these points were visited once a day in all seasons. We used the point count method to survey bird communities (Bibby et al., 1992) with binoculars to help the observations. The censuses occurred during the morning period and lasted 15 to 30 minutes, according to the possibility of local access and the status of the tide. All point counts have the same environmental characteristics. Unfavorable weather conditions, such as rain and strong wind, prohibited sampling. The total abundance at each sampling point was considered.

The data of the seasons were taken from the website of the Astronomy Department at the Universidade de Sao Paulo, where these data are provided by the

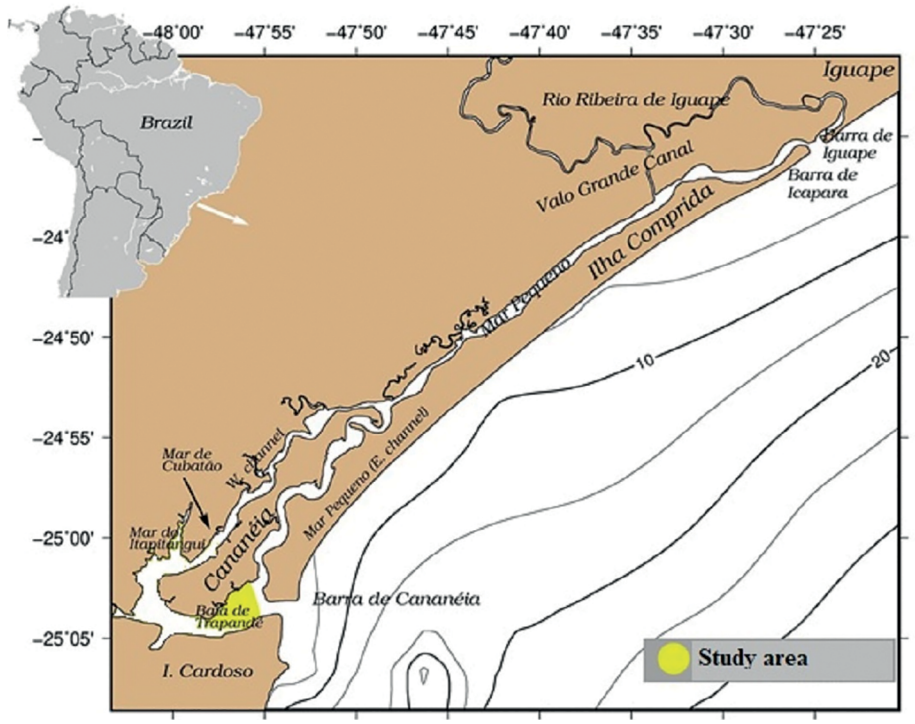


**Figure 1.** Map of the study area indicating the location of Trapandé Bay, where the Baixio do Arrozal (yellow study area) is situated within the Cananéia-Iguape-Ilha Comprida estuarine lagoon complex (Fontes et al., 2019).

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Birds' scientific names and their families were verified by the Annotated checklist of the birds of Brazil, by the Brazilian Ornithological Records Committee (Piacentini et al., 2015).

The abundance was calculated by the formula: *Abundance = (n/N)* x *100*, where "*n*" is the number of individuals of one species and "*N*" is the number of total individuals. The constancy was calculated by *C = p x 100 / P*, where "*p*" is the number of censuses that one species was recorded in and "*P*" the total number of censuses. Values obtained for constancy were used as a basis to classify the taxa as: dominant, when it was present in more than 50% of the visits; abundant, when it was present between 30% and 50%; not very abundant, when it was present between 30% and 10%; and rare, when the cases were less than or equal to 10% (Manoel *et al*., 2011; Barbieri *et al*., 2013). For comparing the assemblages, we created a bar chart of the total abundance as a function of the monthly frequency together with a boxplot graph of this index as a function of the seasons. We also investigated variations on the abundance of some specific bird populations.

### Statistical Analysis

The statistical software PAST, was used to perform descriptive statistics, normal probability graphs, and analysis results (boxplot model, where the centerline is the median), at 5% probability. For seasonality, the one-way analysis of variance was used, followed by Tukey's multiple comparison test, at a 5% probability. To verify the normality and homogeneity of the variances, the Shapiro-Wilk and Levene tests, respectively, were used. When data did not meet the homogeneity of the variances and normality of the residues, a Kruskal-Wallis nonparametric analysis was used, followed by the Tukey multiple comparison test.

## RESULTS

During the studied period, 32 species of birds belonging to 15 families were observed (Table 1). These species were classified as dominant, abundant, not very abundant, and rare, with most of them being migratory species who use the Baixio do Arrozal at certain periods of the year (Table 1). Only two species (*Calidris canutus rufa* and *Phoenicopterus chilensis*) with a Near Threatened (NT) Conservation IUCN

**Table 1.** List of species recorded at Baixio do Arrozal between April 2013 and December 2016, with their respective values of constancy (C%) and abundance and the classification according to the values obtained for constancy. Conservation IUCN status: Least Concern (LC) and Near Threatened (NT). Composition in terms of resident and migratory species: Resident (R), Northern migrant (NM), Southern migrant (SM) and Regional Migrant (RM).

| Family | Species | C (%) | Classification | Relative | Composition |
|---|---|---|---|---|---|
| Phalacrocoracidae | *Composition* | 80.50 | Dominant | 34.07 | R |
| Sternidae | *Thalasseus acuflavidus* (LC) | 100 | Dominant | 30.95 | R |
| Rynchopidae | *Rynchops niger* (LC) | 80.55 | Dominant | 14.89 | RM |
| Sternidae | *Thalasseus maximus* (LC) | 77.77 | Dominant | 5.12 | MS/MN |
| Ardeidae | *Egretta caerulea* (LC) | 77.77 | Dominant | 3.22 | R |
| Ardeidae | *Ardea alba* (LC) | 76.38 | Dominant | 2.11 | R |
| Laridae | *Larus dominicanus* (LC) | 88.88 | Dominant | 1.59 | R |
| Ardeidae | *Egretta thula* (LC) | 81.94 | Dominant | 1.76 | R |
| Threskiornithidae | *Eudocimus ruber* (LC) | 79.16 | Dominant | 1.25 | R |
| Fregatidae | *Fregata magnificens* (LC) | 52.77 | Dominant | 0.84 | R |
| Sulidae | *Sula leucogaster* (LC) | 51.38 | Dominant | 0.69 | R |
| Threskiornithidae | Platalea ajaja (LC) | 41.66 | Abundant | 0.38 | RM |
| Charadriidae | *Charadrius semipalmatus* (LC) | 40.27 | Abundant | 0.82 | NM |
| Ardeidae | *Ardea cocoi* (LC) | 37.50 | Abundant | 0.19 | R |
| Haematopodidae | *Haematopus palliatus* (LC) | 29.16 | Not very abundant | 0.08 | R |
| Scolopacidae | *Calidris fuscicollis* (LC) | 15.27 | Not very abundant | 0.07 | NM |
| Sternidae | *Sterna hirundinacea* (LC) | 15.27 | Not very abundant | 1.23 | RM |
| Sternidae | *Sterna hirundo* (LC) | 13.88 | Not very abundant | 0.34 | NM |
| Charadriidae | *Charadrius collaris* (LC) | 13.88 | Not very abundant | 0.06 | R |
| Ardeidae | *Bubulcus ibis* (LC) | 9.72 | Rare | 0.04 | R |
| Charadriidae | *Pluvialis dominica* (LC) | 6.94 | Rare | 0.02 | NM |
| Scolopacidae | *Calidris alba* (LC) | 6.94 | Rare | 0.02 | NM |
| Alcedinidae | *Megaceryle torquata* (LC) | 5.55 | Rare | 0.009 | R |
| Rallidae | *Aramides mangle* (LC) | 5.55 | Rare | 0.02 | R |
| Scolopacidae | *Calidris canutus rufa* (NT) | 5.55 | Rare | 0.03 | NM |
| Sternidae | *Sterna trudeaui* (LC) | 5.55 | Rare | 00.18 | RM |
| Scolopacidae | *Actitis macularius* (LC) | 4.16 | Rare | 0.01 | NM |
| Sternidae | Sternula superciliaris (LC) | 4.16 | Rare | 0.005 | RM |
| Phoenicopteridae | *Phoenicopterus chilensis* (NT) | 2.77 | Rare | 0.009 | SM |
| Falconidae | *Milvago chimachima* (LC) | 2.77 | Rare | 0.005 | R |
| Charadriidae | *Vanellus chilensis* (LC) | 1.38 | Rare | 0.002 | R |
| Stercorariidae | *Stercorarius pomarinus* (LC) | 1.38 | Rare | 0.003 | NM |

status were observed. The other species were classified as Least Concern (LC).

The highest abundance and variability of birds were recorded during the spring, whereas the lowest mean was registered in winter, a season with a tendency of a decreased number of birds observed (Figures 2A and 2B). Regarding the monthly variation, it was possible to observe an increase of the abundance between February and April for *Thalasseus acuflavidus*, *Rynchops niger*, *Nannopterum brasilianus*, and *Platalea ajaja* as well as between September and December. The months with the highest abundances were February 2015 (67.65), November 2016 (72.92), and December 2016 (76.03).

*Thalasseus acuflavidus*, *Rynchops niger* and *Nannopterum brasilianus* stood out among the most

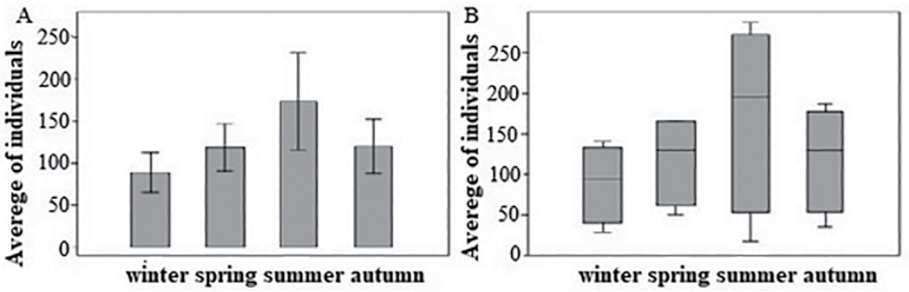


**Figure 2.** Seasonal fluctuations of the mean (A) and median (B) abundance of birds recorded between April 2013 and December 2016 at Baixio do Arrozal, Cananéia, SP, Brazil. (A) means ± standard deviation; (B) medians, minimum and maximum values, and quartiles.

abundant species due to the largest flocks and their presence in all months. The highest values of abundance of *T. acuflavidus* and *R. niger* were recorded between February and June (Figure 3A and 3B) and decreased in the winter and spring. In contrast, *N. brasilianus* had the highest abundance in spring (Figure 3C), between September and December, and decreased from summer to fall.

*Ardea alba* was more abundant in winter, even though it gradually increased up to its maximum number of individuals in September (N=80) (Figure 3D). During the other seasons, a population decrease occurred, with no significant differences; in the fall, there was the lowest variability. The medians in the box plot chart indicated a tendency to find flocks of 25 individuals throughout the year. *Larus dominicanus* was recorded throughout the entire year, with the highest abundance in the summer (Figure 3E), especially in January (mean of 33.04 and maximum of 88 individuals). Over the following seasons, there was a reduction in abundance. The lowest values for this species occurred in June and September, with means of 4.12 and 6 individuals, respectively, and a maximum number of individuals of 11.5 and 10, respectively. *Egretta thula* was abundant throughout the year and presented the lowest mean during spring; in the other seasons there were no significant differences (Figure 3F). Two peaks of abundance were recorded, the first between March and April and the second between July and August (Figure 3F). It was possible to find flocks of up to 12 individuals throughout the years, but with a reduced probability during the spring.

*Platalea ajaja* was recorded in all seasons, with a gradual increase from winter to summer (Figure 4a). The highest mean occurred in December and decreased gradually until April. The maximum number of individuals was recorded in June and July. In May and September, this species was absent (Figure 4A). It was possible to find between 1 and 4.16 individuals throughout the year. *Sula leucogaster* was recorded throughout the year and was more abundant between May and August, and between October and March (Figure 5d). The highest mean of individuals was registered in the fall, while the other seasons had no significant differences (Figure 4B). *Eudocimus ruber* was recorded during every month with an increase between October and December (Figure 4C). There were no significant differences in the summer and fall, but an increase in winter occurred until its abundance peaked in the spring (Figure 4C). There was a trend to find 10 to 15 individuals, except during the main abundance period, when it was possible to find flocks with about 20 individuals.

*Fregata magnificens* had the highest abundance in the spring, during the month of November (20.25) (Figure 4D). The population decreased in the summer and fall with no significant differences; the lowest abundance was recorded in July during the winter (Figure 4D). *Ardea cocoi* was recorded throughout all seasons, with the maximum number of individuals in August (around 13) (Figure 4E); however, the abundance peak occurred in October during spring (5.58). In summer there was a decrease, with the smallest means of abundance in January and February (0.125). *Haematopus palliatus* presented the highest abundance in the summer (Figure 4F), the highest averages of individuals were registered between January and April. During the fall and the winter there were lower means, because the species was absent in June and August. The smallest value of abundance was registered in the spring.

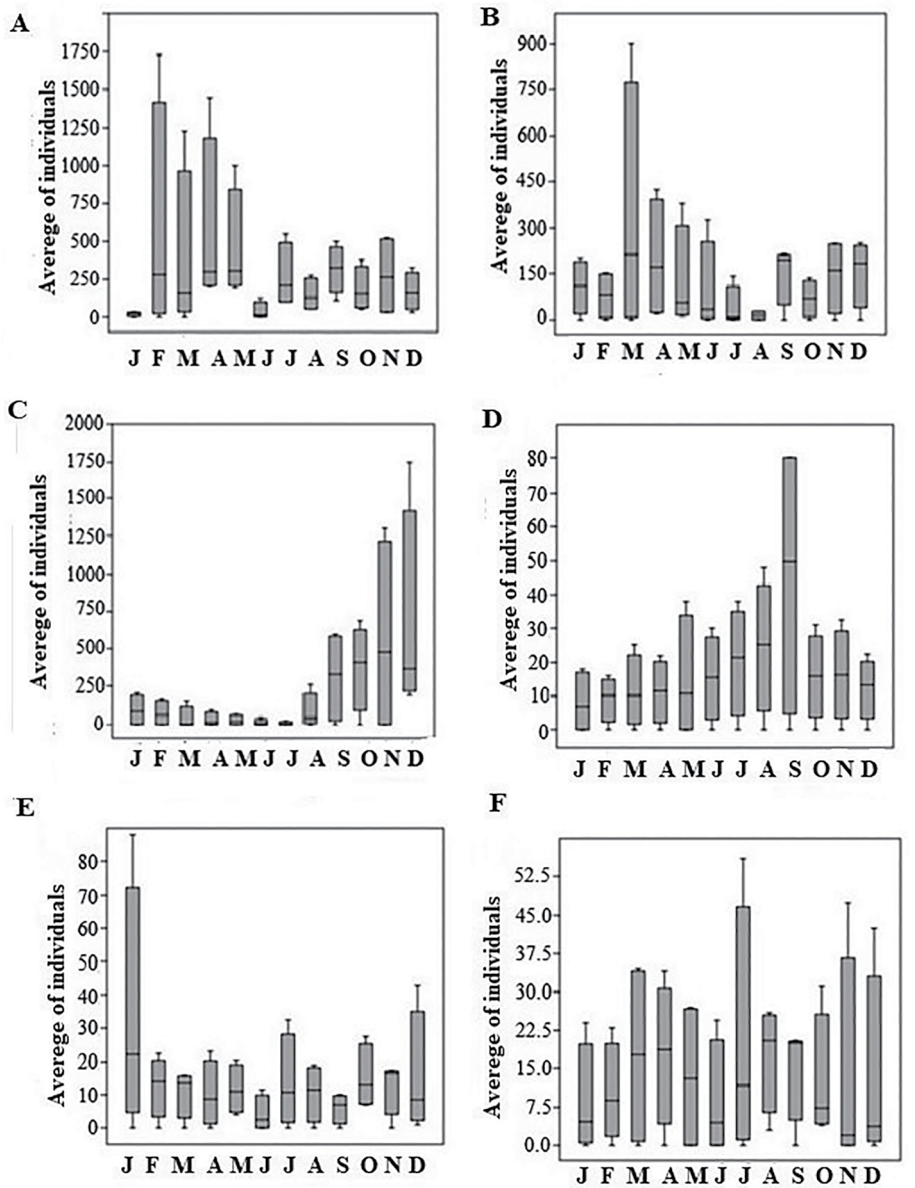


**Figure 3.** Seasonal and monthly variations of abundance of *Thalasseus acuflavidus* (A), *Rynchops niger* (B), *Nannopterum brasilianus* (C), *Ardea alba* (D), *Larus dominicanus* (E) and *Egretta thula* (F).

*Charadrius collaris* was registered beginning from the fall, in the month of March, and increasing in May up to the highest means in July and August, during winter (Figure 5A). There was a gradual decrease during the spring months until their absence in the summer. *Megaceryle torquata* was recorded only in February, April and August (Figure 5B), with the highest means during the summer. *Milvago chimachima* was recorded only in winter (August) and spring (October) (Figures 5 C). *Vanellus chilensis* was randomly recorded in winter with one individual in August (Figure 5 D). *Sternula superciliaris* was present only in April, August, and October (Figure 5E), during the fall, winter, and spring, respectively. No individual was recorded in the summer. *Stercorarius pomarinus* was observed only in the summer, in February (Figures 5F).

*Phoenicopterus chilensis* was randomly recorded with three individuals in the spring and summer, during December and January (Figures. 6A). *Pluvialis*

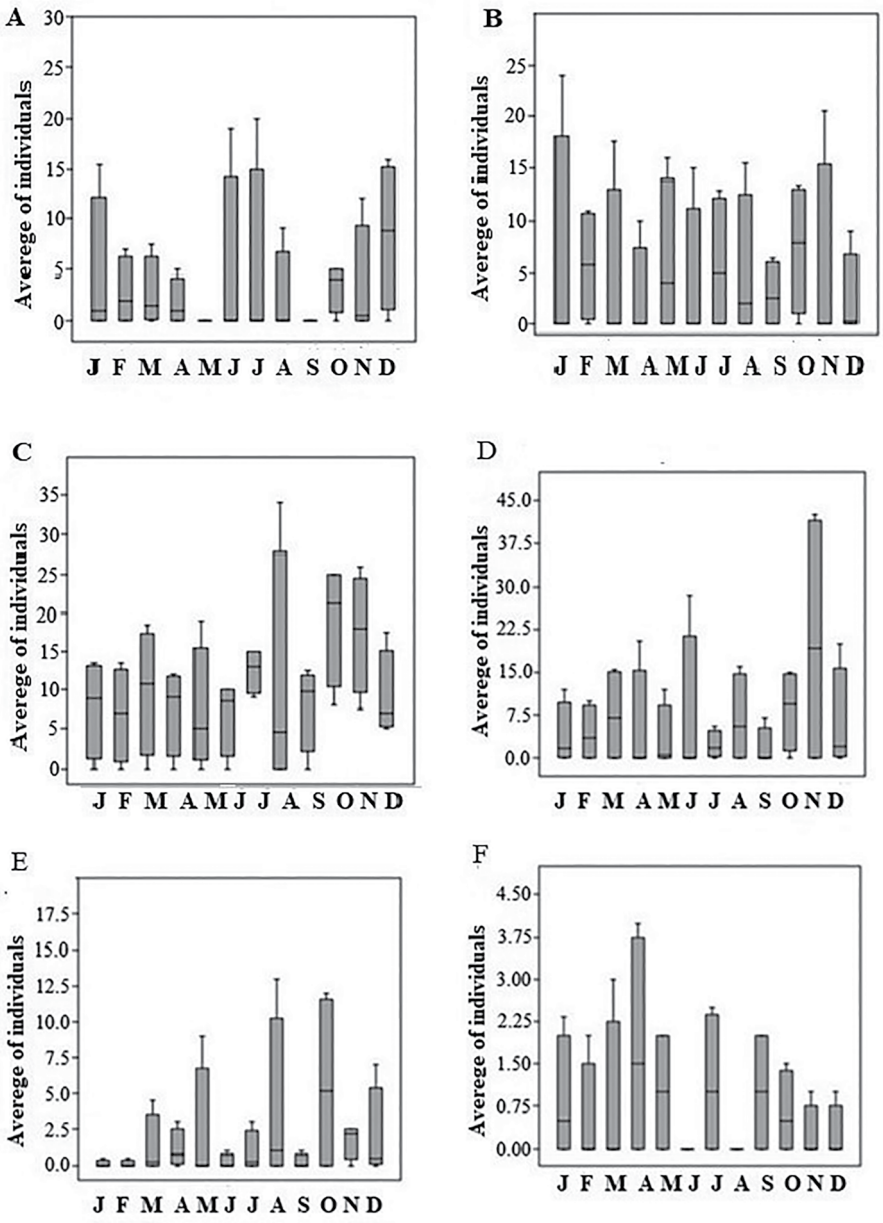


**Figure 4.** Seasonal and monthly variations of abundance of *Platalea ajaja* (A), *Sula leucogaster* (B), *Eudocimus ruber* (C), *Fregata magnificens* (D), *Ardea cocoi* (E) and *Haematopus palliatus* (F).

*dominica* had the highest average number of individuals in the spring, in October, which decreased from the summer until their absence in the winter. It was possible to observe only one individual of this species in December, January, and April as well (Figure 6B). *Aramides mangle* was recorded in the spring and summer (Figure 6C), in January, February, and October. October was the month with the highest mean (0.5) and the maximum number of individuals (2) (Figure 6C).

*Calidris alba* was recorded in the spring and summer (Figure 6D), in February, October, and November; the maximum of individuals (2.5) occurred in the latter month (Figure 6D). *Actitis macularius* was recorded only in spring and summer (Figure 6E), during October and January, when the maximum of individuals was registered (4) (Figure 6E). *Bubulcus ibis* was recorded occasionally in January, July, October, November and December (Figure 6F). It presented the highest abundance in spring and the highest

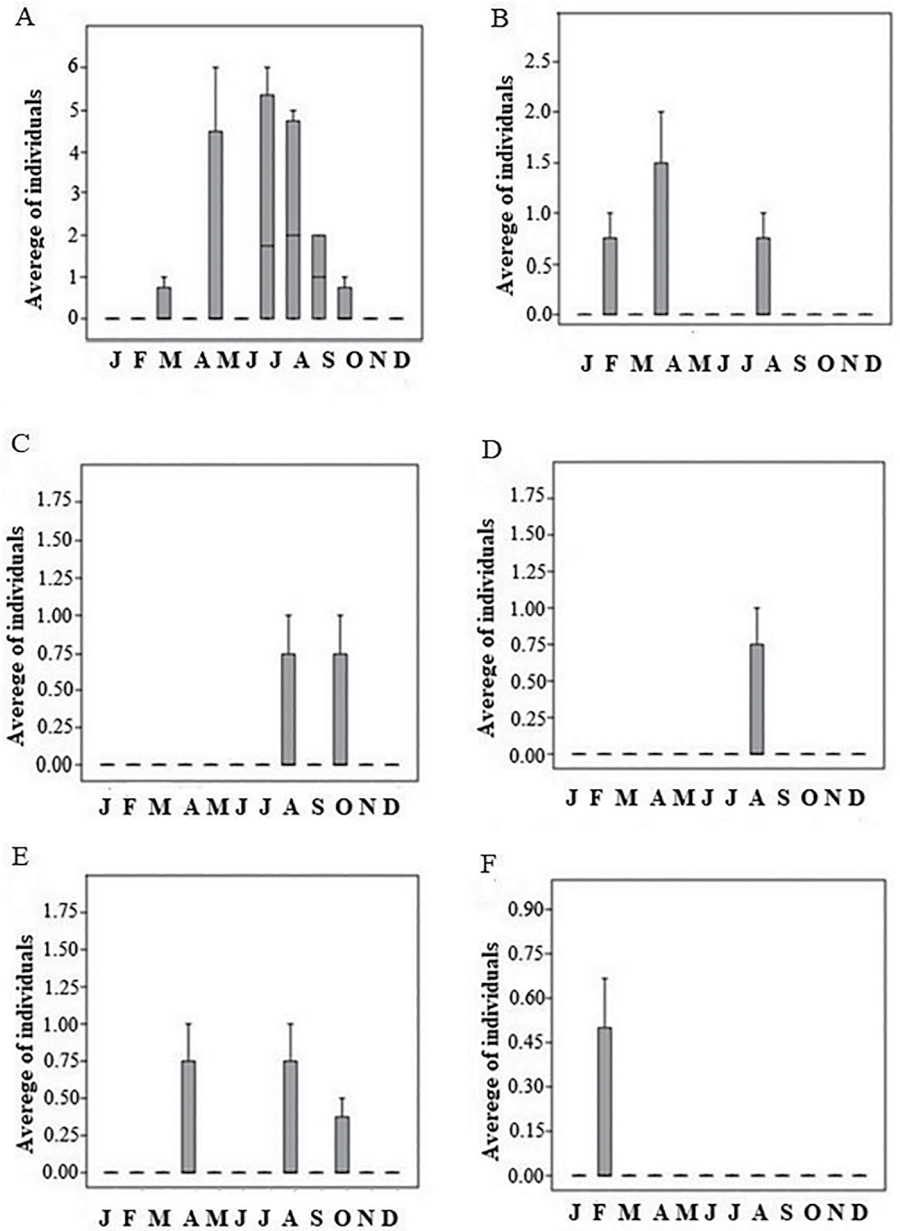


**Figure 5.** Seasonal and monthly variations of abundance of *Charadrius collaris* (A), *Megaceryle torquata* (B), *Milvago chimachima* (C), *Vanellus chilensis* (D), *Sternula superciliaris* (E) and *Stercorarius pomarinus* (F).

mean in October (1.125) as well the maximum individuals (Figure 6F). During fall this species was absent.

*Calidris canutus* was recorded in spring and in summer, during October when the maximum of individuals was registered (6.4); in December just one individual was observed (Figure 7A). *Calidris fuscicollis* presented the highest mean in the spring (Figure 7B), during October and December. It was possible to verify a decrease in the mean from January until the winter, when the species was absent. The medians suggested a possibility of finding at least one individual throughout the year, with the best chances occurring in December and January (Figure 7B). *Sterna trudeaui* was recorded only in three months: January, March, and July (Figure 7C). The highest abundance was registered in the summer, and the lowest in fall and winter (Figure 7C). *Charadrius semipalmatus* presented the highest mean of individuals during the fall

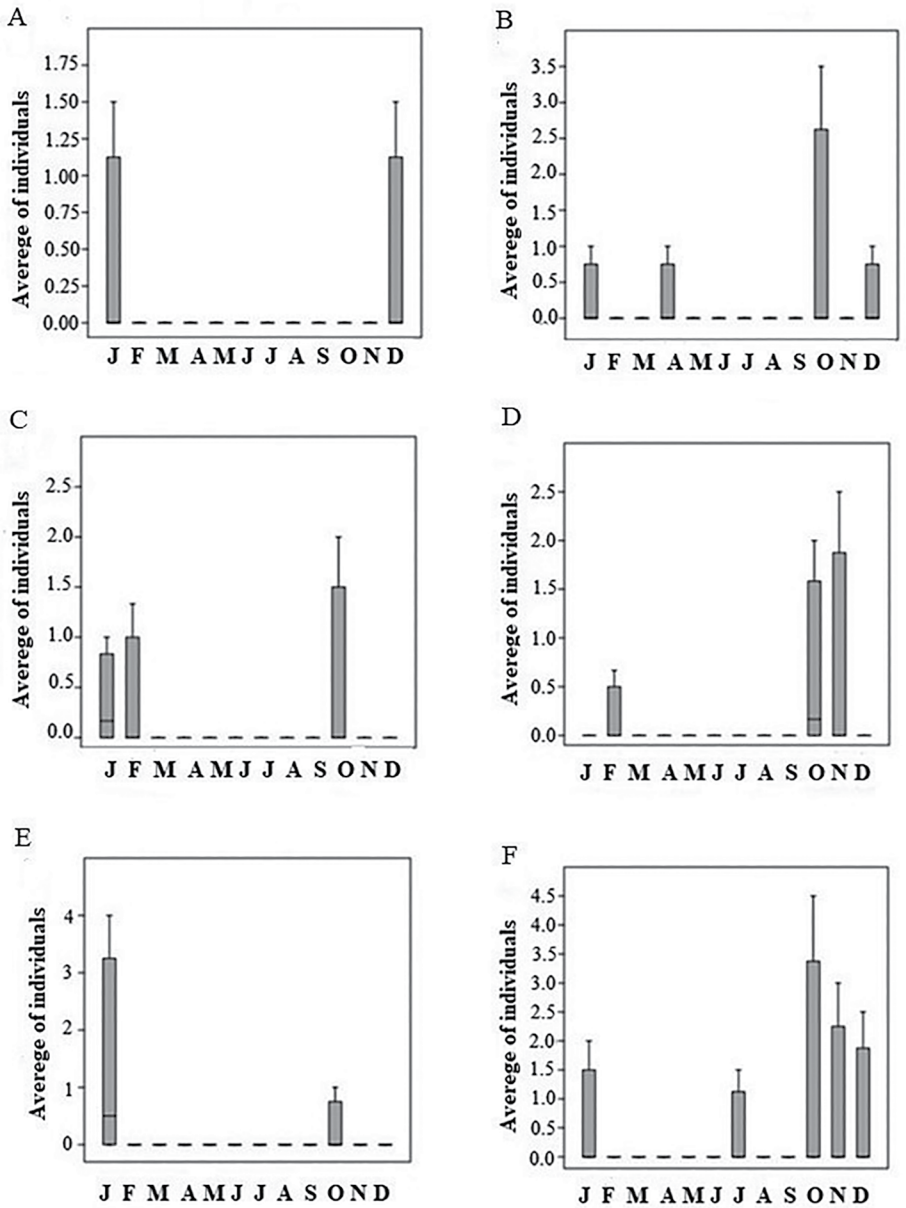


**Figure 6.** Seasonal and monthly variations of abundance of *Phoenicopterus chilensis* (A), *Pluvialis dominica* (B) and *Aramides mangle* (C), *Calidris alba* (D), *Actitis macularius* (E) and *Bubulcus ibis* (F).

(Figure 7D), in March, April, and May (13.62, 22, and 16, respectively); the latter of which had the maximum number of individuals (64) recorded (Figure 7D). Beginning from the winter, a decrease in abundance occurred, which remained low until the summer; the abundance reached the lowest means in June and December with no significant differences among the seasons. There was a tendency to find around 10 individuals throughout the year. *Sterna hirundo* was more abundant in summer with the highest means in February, March, and May (11.37, 6.2, and 5, respectively), as well the maximum number of individuals (45, 25, and 20, respectively) (Figure 7E). There was a decrease in abundance from the fall until the species' absence in the winter. A few individuals were only observed again in the spring, during October (Figure 7E). *Egretta caerulea* was recorded in all seasons, but with a higher abundance in the winter (Figure 7F); it

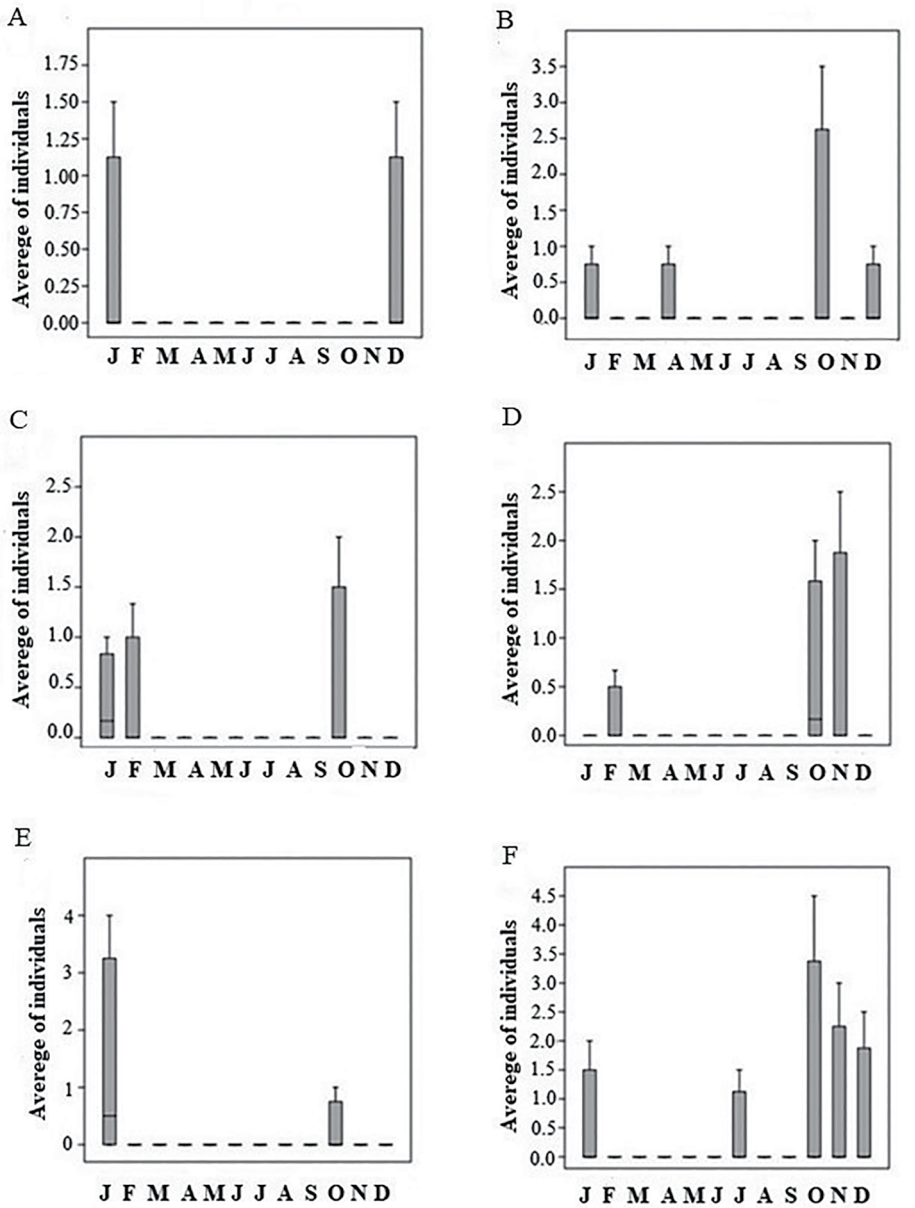


**Figure 7.** Seasonal and monthly variations of abundance of *Calidris canutus* (A), *Calidris fuscicollis* (B), *Sterna trudeaui* (C), *Charadrius semipalmatus* (D), *Sterna hirundo* (E) and *Egretta caerulea* (F).

was possible to notice an increase during the months of June and September (Figure 7F). There was a decrease from the spring to the summer, when the lowest mean was registered in January. During the fall, the population had an increase, similar to the spring. It was possible to find 20 to 40 individuals throughout the year.

*Thalasseus maximus* had a peak abundance during the fall (Figure 8A) from February to May, and the highest means were recorded in July. The abundance decreased from winter until the lowest value in the spring. The smallest flocks were observed in June, August, and November (Figure 8A). *Sterna herundinacea* was observed with its highest abundance in the summer (Figure 8B), during January and February. The smallest means were recorded in April and May, during the fall. In the winter months (July and August) there was a small increase in the number of individuals (Figure 8B). This species was absent in the spring.

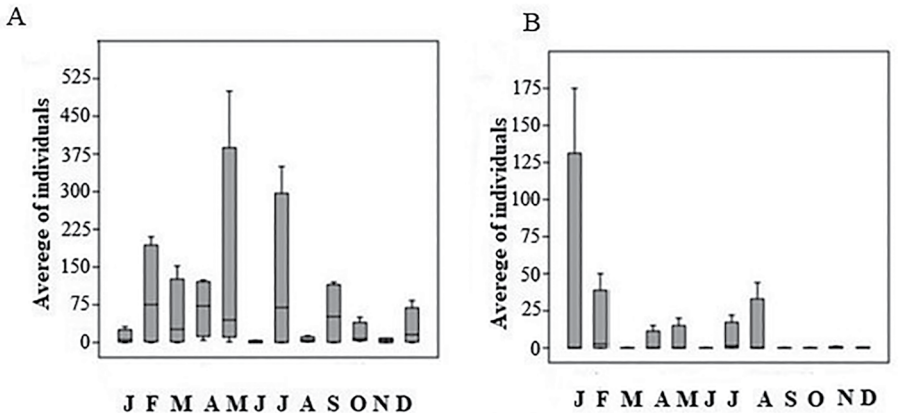


**Figure 8.** Seasonal and monthly variations of abundance of *Thalasseus maximus* (A) and *Sterna herundinacea* (B).

## DISCUSSION

The species *Thalasseus acuflavidus*, *Rynchops niger*, and *Nannopterum brasilianus* stood out for having demonstrated the largest flocks with similar values at times of greatest abundance. These species forage in estuarine waters and use areas like Baixio do Arrozal for resting and plumage maintenance during the non-breeding season (Naves, 1999; Barbieri, 2007; Branco *et al*., 2009). Baixio do Arrozal is a favorable place for the presence of these birds, because it is near foraging areas and there is little anthropogenic disturbance. The species from the Ardeidae and Threskiornithidae families share similar foraging habits, usually eating small invertebrates in muddy areas (Custer and Osborn, 1978; Frederick and Bildstein, 1992; Olmos *et al*., 2001; Moreno *et al*., 2005; Lorenz *et al*., 2009; Britto and Bugoni, 2015), just as was observed in this study. Even though *Egretta caerulea* has similar habits to the others from its family, the species was not grouped; it occurred more frequently and was a typical estuarine Ardeidae, feeding mostly on invertebrates, while the other species from this family fed on other sources (Zanin *et al*., 2008, Gianuca *et al*., 2012). *Sula leucogaster*, *Fregata magnificens*, and *Larus dominicanus* were also gathered into group II for being resident species with abundance similar to the other species from this group; although their behaviors are different since they are marine birds that accompany fishing boats (Branco, 2001; Branco and Ebert, 2002; Branco *et al*., 2005; Branco *et al*., 2007; Ebert *et al*., 2014). *Fregata magnificens* and *S. leucogaster* were observed overflying or feeding around the Baixio. The migratory species and the randomly observed resident species were similar due to their low constancy and low abundance. This data may indicate that the variations in composition and abundance of avifauna at Baixio do Arrozal can be influenced by seasonality, ecological niche, and life cycle of each species, in addition to heterospecific flocks that may give them an advantage for catching prey and protection from predators (Manoel *et al*., 2011a).

Concerning the total abundance recorded for Baixio do Arrozal, it was possible to observe a seasonal pattern throughout the years; the highest numbers of individuals registered during the warmest month might be related to the increase of available food, since the birds can make long trips looking for favorable places to rest and forage (Manoel *et al*., 2011; Barbieri and Pinna, 2007; Barbieri and Mendonça, 2008). Furthermore, the seasonal fluctuations may also be influenced by the breeding seasons of the species, as they migrate to the nesting areas and return with their recruits, increasing the population (Branco and Fracasso, 2005; Branco, 2007; Barbieri and Mendonça, 2008), possibly explaining variations observed in this study.

With regard to the resident species, *Nannopterum brasilianus* stood out for being the most abundant. In the Saco da Fazenda Estuary, SC, Branco (2002) and Branco *et al*. (2010) recorded a gradual decrease in this species from January to June, and an increase between October and December. A similar pattern was recorded in the present study, and this seasonal difference suggests a regional migration from the southern and southeastern coasts to the Paraná-Paraguay

basin in the coldest months during the breeding season (Manoel *et al*., 2011a). According to Branco (2001), the abundance of *Nannopterum brasilianus* is positively correlated with Atlantic seabob fishing, as it is a generalist and opportunistic species (Barquete *et al*., 2008; Conde-Tinco and Iannacone, 2013). This behavior is also probably related to the fishing activity in regions near Trapandé Bay during the season with the highest abundance of neotropic cormorants, which were observed resting and maintaining their plumage. Even though this species is quite common in Brazil and inhabits lagoons, rivers and estuaries, there is little information concerning its biology, migration, reproduction, or population dynamics.

*Rynchops niger* displayed a similar pattern to that observed by Barbieri (2007), whose study indicated the Baixio do Arrozal as an important place for the species during the non-breeding season because it uses the area to feed and rest. The decreased abundance in the Cananéia Estuary during the winter and the spring indicates that most of the population migrates to breeding areas, which are the Amazon region (Sick, 1997; Krannitz, 1989) and sandbanks near the Ibicuí River in Rio Grande do Sul State (Belton, 1984; Efe *et al*., 2001), with no records of this activity on the São Paulo State coast. It is likely that the individuals recorded during the breeding season were juveniles, which had not reached sexual maturity. Olmos and Silva and Silva (2001) also observed *R. niger* in Santos-Cubatão all year round, but with the peak of abundance in the autumn and winter, and they presumed it would be a population that probably nested in the Paraná-Paraguay basin. Although our data agree with the breeding season of this species, it is not possible to know the origin of the population recorded at Trapandé Bay.

In previous studies performed in the Cananéia-Iguape-Ilha Comprida Estuary, *Thalasseus acuflavidus*, and *Thalasseus maximus* were recorded with a high abundance at Baixio do Arrozal and have demonstrated a positive correlation with fishing (Numao and Barbieri, 2014). After foraging, these species use the Baixios for resting and plumage maintenance. Regarding *Sterna hirundinacea*, Barbieri and Mendonça (2008) recorded a low abundance at Ilha Comprida with marked peaks in the summer months, as was observed in the present study. The difference in number of individuals of *S. hirundinacea* was probably the reason the Cluster analysis did not group this species with other Sternidae species, even though the behaviors are similar. The seasonal variation of *T. acuflavidus*, *T. maximus*, and *S. hirundinacea* in particular times of year indicates that Baixio do Arrozal was used by these species during the non-breeding season. This is because both species normally breed in sympatry between April and September on coastal islands, decreasing their presence inshore (Branco, 2003; De Campos *et al*., 2007; Barbieri and Mendonça, 2008; Lenzi *et al*., 2010; Fracasso *et al*., 2011; Muscat *et al*., 2014; Romagna, 2016). It is likely that the individuals of both species recorded at the Baixio during the winter had not reached sexual maturity, as was reported in the works mentioned above. The fact that *S. hirundinacea* and *T. maximus* are under threat of extinction (ICMBIO, 2016) reinforces the need to conserve the areas used by them, such as the Cananéia-Iguape-Ilha Comprida Estuary.

*Larus dominicanus* was also considered a dominant species. It breeds during winter on coastal islands and feeds near the nesting sites (Sick, 1997, Branco *et al*., 2009), which indicates that the Cananéia-Iguape-Ilha Comprida Estuary is a feeding site during the non-breeding season. Moreover, the individuals recorded in this period were juveniles, as was also observed by Barbieri (2008). According to this author, *L. dominicanus* are more significantly abundant in the south of Ilha Comprida Island, near the Baixio do Arrozal. It is assumed that the presence of this species during all months is related to food availability and fishing, since *L. dominicanus* are also accustomed to feeding on fishing tailings (Branco, 2001) and use the Baixio do Arrozal as a resting site. Studies performed in Saco da Fazenda, in the city of Itajaí, SC, suggest that the *L. dominicanus* has the greatest feeding activity in the morning and evening (Branco, 2002), which can explain the high abundance of this species during the observations in the morning at the Baixio do Arrozal.

According to Branco *et al*. (2007) the abundance of *Fregata magnificens* is also correlated with fishing, because it is an opportunistic bird that feeds on fishing tailings (Sick, 1997). Barbieri (2010) registered the highest abundance of this bird and interaction with boats during the winter at Ilha Comprida Island when the smallest abundance occurred at the Baixio do Arrozal. This suggests that the seasonal variation

is related to the Atlantic seabob shrimp fisheries. During the spring, the highest number of individuals of *F. magnificens* was recorded and matched with the closed fishing season; thus, the foraging area may become wider in this period due to the decrease of fishing activity.

Although *Sula leucogaster* was considered dominant, the Baixio do Arrozal does not seem to be an important place for this species, because most of the individuals were observed flying over the area and used the water around to rest and feed. This was also observed by Cremer and Grose (2010) in Babitonga Bay, SC, where many individuals were observed landing on the water.

The species from Ardeidae family also presented considerable abundance, especially *A. alba*, *E. thula*, and *E. caerulea*, possibly because they reproduce in the Cananéia Estuary (Noguchi, 2015) and forage at the Baixio do Arrozal. *Ardea alba* and *E. caerulea* have a negative correlation with the tide (Zanin *et al*., 2009), and the highest abundance of these species in September may likely be related to the low tide, when the Baixio's exposed area is larger. *Bubulcus ibis* was the only species from this family classified as rare, because it is commonly found in pastures with cattle. Its presence at the Baixio do Arrozal could be explained by opportunistic behavior, since *B. ibis* has a large distribution and can reproduce in many environments as well as feed on different type of prey (Della Bella and Azevedo-Junior, 2004; Barbosa-Filho *et al*., 2010).

According to Hass *et al*. (1999) and Olmos *et al*. (2001), *Eudocimus ruber* starts breeding during the rainy seasons when there is more food available. It is possible that the variation in abundance of this species at Baixio do Arrozal could be related to the reproductive cycle of the individuals nesting in the region (Barbieri, 2009; Paludo *et al*., 2018), because the highest abundances were recorded during rainy periods. Our results indicate that the Baixio do Arrozal is used by this species every month, and this coincides with the results obtained by Barbieri (2009), who recorded a similar monthly variation and also indicated the Baixio do Arrozal as one of main foraging sites of this species in the Cananéia Estuary.

The results obtained for *Platalea ajaja* indicate the presence of this species foraging in Baixio do Arrozal throughout the year. According to Silva and Fallavena (1995), the young *P. ajaja* wander after they leave the nest, which could explain the abundance increasing in spring and summer months in the present study; it may be related to food availability in region. However, there is little information about the biology of this species (Silva *et al*., 1995; Sick, 1997).

*Aramides mangle*, *Vanellus chilensis* and *Milvago chimachima* are resident species and were considered rare. They live in other types of habitats, such as mangroves, pastures and open areas (Sick, 1997), but can be sporadically found in environments like Baixio do Arrozal.

Among the migratory birds, the species from Charadriidae and Scolopacidae families stood out. As expected, the record of these birds coincided with their migrations. During the spring, they reach South America to go to the wintering areas further south (Gonzales, 1996; Telino-Júnior *et al*., 2003; Barbieri *et al*., 2010; Scherer and Petry, 2012). They were possibly using the Baixio do Arrozal as a stopping point to feed and rest along the Atlantic migratory route; as was also recorded by Barbieri *et al*. (2013) on Ilha Comprida beach and by Tavares *et al*. (2015) in Rio de Janeiro.

The oscillating abundance of *Charadrius semipalmatus* throughout the year matched with its migration season. According to Barbieri and Mendonça (2000), the flocks arrive at Ilha Comprida in the spring and summer, when they are going to their wintering areas; in the autumn, they can be seen on the beach returning to their breeding areas. Similar patterns were observed at the Baixio do Arrozal and also by Lunardi *et al*. (2012) at Todos os Santos Bay. *C. semipalmatus* mates in austral winter (Sick, 1997), so it was presumed that the individuals recorded during this season were young and had not migrated; thus, it was the only migratory species recorded every month. This was also observed in the data obtained by Costa and Sander (2008) in Rio Grande do Sul and Almeida and Barbieri (2008) in Sergipe.

Bugoni and Vooren (2005) recorded the highest abundance of *S. hirundo* in Rio Grande do Sul between October and January with a rapid decrease in February, when the highest abundance on the Baixio do Arrozal occurred. This may indicate that this species used the Cananéia Estuary as a stopping point during their return to the Northern Hemisphere, because the return to the breeding areas starts between

March and April (Somenzari *et al*., 2018). In Brazil, there are two populations of *S. hirundo*, one reproducing in North America and another reproducing in the Azores, and they start their migration at different times (Neves *et al*., 2015; Nisbet and Mostello, 2015). However, it is not possible to know which population the individuals observed at the Baixio do Arrozal belong to.

## CONCLUSION

The data presented in this study suggests that birds use the Baixio do Arrozal throughout the year as a feeding and resting site, due to little human intervention. The bird populations varied from one season to another, because their movements to seek resources are also regulated by the seasonality; thus, the dynamics of bird assemblage at Baixio do Arrozal followed the life cycle of the recorded species. However, other abiotic factors must be considered for a better understanding of this faunal group in relation to the environment. The information presented in this article will be important for the management of the Cananéia Estuary, as well as for coastal ecosystems and resident and migratory bird habitats in general.

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## AUTHOR CONTRIBUTIONS

L.Y.R: analyzed and interpreted data and was a major contributor in writing the manuscript.

E.B.: performed the statistical analysis, was a contributor in writing the manuscript, and was the author who submitted the manuscript.

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