The birds at Ilha Comprida beach (São Paulo state, Brazil): a multivariate approach

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Abstract: Birds were censused weekly from January 1999 to January 2001 along Ilha Comprida beach, a barrier island off São Paulo, southeastern Brazil. To evaluate the similarity in the bird's species composition among the weekly surveys, species counts data were arranged on a data matrix with 144 weekly surveys, analyzed following a multivariate analysis protocol. We counted a total of 205,399 individuals and 52 species. Migratory birds were an important component of the avifauna (maximum N = 21,294 individuals and 14 species). The largest numbers of birds were observed during summer, when Nearctic migrants arrive. All 14 of the most common species were migrants, including *Calidris alba*, *Sterna maxima*, *Charadrius semipalmatus*, *Sterna hirundo*, *Thalasseus maximus*, *Pluvialis dominica* and *Calidris fuscicollis*. The most common residents were *Thalasseus s. eurrygnathus*, *Larus dominicanus*, *Coragyps atratus*, *Fregata magnificens* and *Sterna hirundinacea*. Recently, most of the peripheral area adjacent to the beach has been urbanized and rapid habitat change is progressing. In this paper, we establish a reference that will allow future comparisons to assess the impact of such urbanization on the composition of bird populations on Ilha Comprida.
Keywords: *seabirds, ecology, Ilha Comprida, migration, shorebirds, sandy beaches, multivariate analysis.*

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Resumo: As aves foram contadas semanalmente de janeiro 1999 a janeiro 2001 ao longo da praia de Ilha Comprida, sendo esta, uma ilha de barreira localizada ao sul do estado de São Paulo. Para se avaliar a similaridade da composição das aves, os dados das espécies foram arranjados numa matrix com 144 amostras semanais, estudados seguindo um protocolo de análise multivariada. Contou-se um total de 205.399 indivíduos de 52 espécies diferentes. As aves migratórias foram um componente importante da avifauna na ilha (máximo N = 21.294 indivíduos e 14 espécies). O maior número de aves foram observadas durante o verão, quando as migrantes nearticas chegaram. Dentre as 14 espécie migrantes identificadas as mais comuns foram: *Calidris alba*, *Thalasseus maximus*, *Charadrius semipalmatus*, *Sterna hirundo*, *Pluvialis dominica* and *Calidris fuscicollis*. Já as espécies residentes mais comuns foram: *Thalasseus s. eurrygnathus*, *Larus dominicanus*, *Coragyps atratus*, *Fregata magnificens* and *Sterna hirundinacea* Recentemente, a maior parte das áreas periféricas junto à praia estão sendo urbanizadas provocando mudanças rápidas do habitat. Neste trabalho, nós pretendemos estabelecer uma referência que permita futuras comparações, para se poder avaliar o impacto da urbanização na composição das populações das aves que são encontradas na praia da Comprida.
Palavras-chave: *aves marinhas, ecologia, Ilha Comprida, migração, aves de praia, praia arenosa, analise multivariada.*

Introduction

Of all migratory animals, the routes and movements of migratory birds are the best known. They are frequently conspicuous, migrate diurnally, and travel in large numbers (Orr 1996). In the New World, a large number of migratory species leave their breeding grounds in North America to spend the winter in South America (Sick 1997). These visitors are mostly waterbirds, birds of prey, and passerines. Although sand beaches occur along most of the Atlantic coast of tropical and subtropical America and many Neotropical birds are known to use this habitat (Sick 1997), most of the information concerning their avifauna comes from the northern Neotropics or southern North America (Olmos & Silva 2001, Vooren & Brusque 1999, Barbieri & Pinna 2007) There is little information on the avifaunas of localities along the tropical and subtropical coast of eastern Brazil. There are a few checklists and studies of birds using sandy beaches in Brazil, but most focus on specific groups like plovers and terns (Vooren & Chiaradia 1990).

According to McWhinter & Beaver (1977), the bird community of a specific region depends on factors such as environment, time of the year and region in relation to the geographic distribution of the species being studied. At a given time, the species community is composed of migrants, breeding birds, and residents that remain for the whole year. The avifauna of a specific region is formed by the total of species which leave and arrive and by the ones which are always present. When a habitat is developed for human habitation, some species will be displaced into other habitats in order to feed and reproduce (Barbieri et al. 2001). As a consequence, species of some regions can disappear or be excluded.

Bird population and communities clearly change through time, however, and these variations may represent real biological dynamics rather than sampling artifacts or noise (Wiens 1997, Barbieri 2007). A second, alternative view considers these variations to be evidence of a dynamic equilibrium. Resource levels change through time, and the variations in populations and communities reflect close tracking of these resources through short-term behavioral, distributional, or demographic adjustments (Cody 1981).

Studies on marine and coastal birds in the state of São Paulo are few, especially on the south coast. Although the Ilha Comprida beach covers roughly 70 km and is considered an environmental protection area subject to management, there are few studies on species composition, habitat use, or seasonal population changes. This region is becoming a prime tourist destination, so large numbers of people now compete for space with migratory birds during December, January and February (Barbieri 2008). It also supports an intense fishing in dustry, both artisanal and industrial, which affects seabird populations by providing discarded food. In this paper we describe the bird community and its seasonal variation along the sandy beaches of Ilha Comprida.

1. Study area

Ilha Comprida (47° 50' W and 24° 52' S) is a barrier island located on the southern coast of São Paulo State. It is part of the Ribeira de Iguape hydrographic basin, whose mouth marks the northern limit of the Iguape - Cananéia – Paranaguá estuarine complex. Ilha Comprida is a recent quaternary barrier island of marine origin (Suguiu & Martins 1987), and is about 70 km long with a mean width of 3 km (Figure 1).

The island's beautiful sandy beaches, interrupted only by small streams, make it a popular tourist destination. Like other barrier islands, it is easily disturbed by intensive human occupation. Progressing from east to west, its habitats include dune fields behind the beach, scrub (restingas), freshwater swamps squeezed between sand ridges, restinga forests and mangroves that line the estuarine complex between the island and the mainland. Lunar tides have an amplitude of about 1.5 m. The sea level is lowered by the prevailing northeasterly wind and raised by the southerly winds. The beach has a gentle slope (I/40 to I/60) and as a result the swash zone is wide, generally about 15 m. High densities of invertebrates (*Donax* sp., *Emerita* sp.) occur in this region (Barbieri & Pinna 2005).

Materials and Methods

We censused the total number of birds seen along Ilha Comprida beach each week between January 1999 and December 2001 (N = 144 samples). All the birds which used the area for feeding and/or resting, and also all such birds present on the beach and those flying or swimming inshore were counted. Not included were seabirds (albatrosses, petrels and the penguin *Spheniscus magellanicus*) which were frequently cast ashore dead or exhausted.

The censuses began in the morning (8:30 AM), and were between 2 hours 30 minutes and 4 hours in duration (N = 540 hours total). The Ilha Comprida beach was surveyed by car (medium speed = 40 km/h) along the stretch of 70 km of beach and 0.2 km wide as used by Vooren and Chiaradia (1990) in the Praia do Cassino, Rio Grande do Sul State (Brazil), also proposed by Bibby et al., (1992) to this kind of environment. The surveys were conducted from south to north (from Boqueirão Sul – Cananeia, to Canal de Icapara – Iguape (Figure 1). Observations were made with 7 x 50 mm and 20 x 60 mm binoculars.

To evaluate the similarity in the bird's species composition among the weekly surveys, species counts data were arranged on a data matrix with 144 weekly surveys and 39 principal species, and analyzed following a multivariate analysis protocol. Firstly the data matrix was analyzed using a Principal Coordinate Analysis (PCoord). Principal Coordinate Analysis is an ordination method of great interest to ecologists because the nature of ecological variables (i.e: species abundances) often makes it necessary to use other measures of resemblance than Euclidian distance preserved by ordinary Principal Component Analysis (PCA). (Legendre & Legendre 1998 pg 424). The data was previously transformed by natural logarithm +1, and the Bray-Curtis dissimilarity coefficient it was used as resemblance metrics. This coefficient has semimetric (non-Euclidean) properties but is generally acknowledged to be one of the best measure of ecological distance for species abundances (Faith et al. 1987, Legendre & Legendre 1998). The second pass of multivariate protocol it was use the axes of PCoord with non-negative and non-null eigenvalues (the Euclidian part of the Bray-Curtis resemblance), as new variables to build a new matrix (Bocard & Legendre 2002). This new matrix was classified by Minimum Variance algorithm (Ward Methods) using the squared Euclidean distance for generating hierarchical dendrograms, following suggestions of Milligan & Cooper, 1987 and Rossi-Wongtschowski & Paes, 1993. This procedure was carried out for Q-mode (weekly surveys; Figure 2) and R-mode (species; Figure 3) independently. The analysis was accomplished using the free software: FITOPAC1 (Shepherd, 1995).

The weekly abundance for each species group was ln- transformed and filtered using moving-average 4 (uses 4 values for way time continues) and plotted against the time sequence (Figure 3). To explore the relationships among the logarithm and filtered abundance of each species group it was used the Person correlation coefficient, and its statistical significance evaluated by Monte Carlo permutation test with 15,000 permutations for each comparisons (Crowley 1992, Paes & Blinder 1995).

Results

We counted 205,399 individuals of 52 species during three years of weekly surveys (Table 1). Some 20 species were found to use the

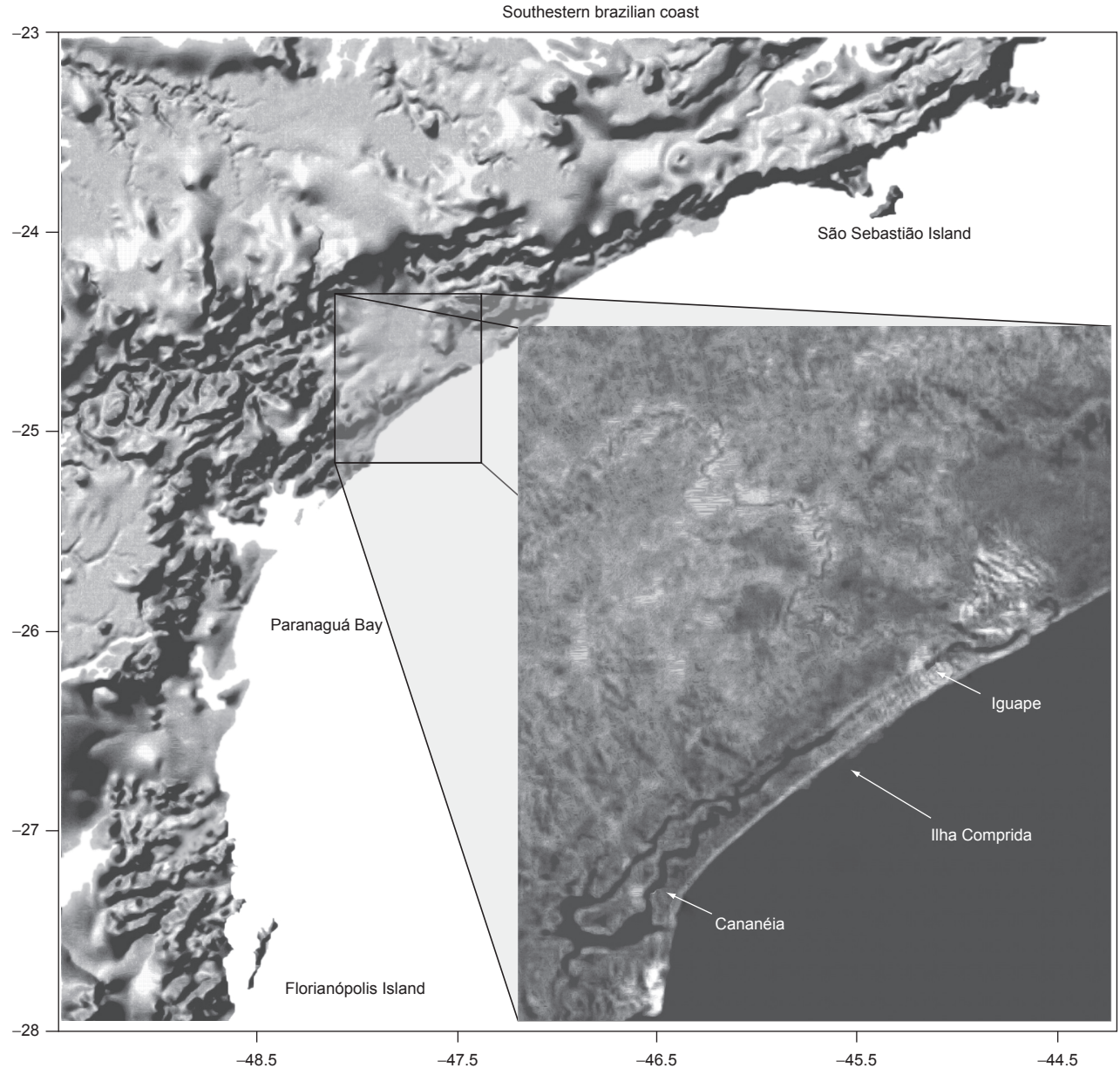

Figure 1. Southestern Brazilian coast with the indication of the Ilha Comprida.

Figura 1. Costa Sudeste do Brasil com a indicação da Ilha Comprida

area regularly (were recorded in more than 50% of the censuses a and were known to use the beach ecosystem in a daily or regular basis when present) (Figure 2). Some species nested in the nearby mangroves (*Egretta thula*, *Ardea alba*, *Ardea cocoi*, *Bubulcus ibi*, *Phalacrocorax brasilianus*), coastal islands (*Fregata magnificens*, *Sula leucogaster*, *Larus dominicanus*) and dunes (*Haematopus palliatus*, *Athene cunicularia*, *Charadrius collaris*).

The total weekly abundance for each species group was log-transformed and plotted against the time sequence (Figure 3). To explore the relationships among the abundances of the species we used a Pearson correlation coefficient and evaluated its statistical significance by Monte Carlo permutation tests with 10,000 permutations for each comparison (Crowley 1992, Paes & Blinder 1995).

Eight species of gulls and terns were recorded, four were the most abundant and variable and showed numerical differences in the three years: *Larus dominicanus*, *Thalasseus s. eurygnathus*, *T. maximus* and *Sterna hirundinacea*, all nesting in islands not far from Ilha Comprida or to the north. The other four *Sterna hirundo*, *Sterna trudeaui*, *Sterna superciliaris* and *Larus maculipennis* occurred in smaller numbers, but no nesting near Ilha Comprida. *Sterna hirundo*, a northern hemisphere migrant, showed marked seasonal variations along the years but was always rare. The others were migrants from the southern hemisphere.

The most numerous species in the family Charidriidae (Table 2) were *Charadrius collaris*, *Charadrius semipalmatus* and *Vanellus chilensis*, all of which were recorded every month. *Pluvialis dominica* and *Pluvialis squatarola* were more abundant in spring (October and November) We recorded ten species in the family Scolopacidae: *Actitis macularia*, *Arenaria interpres*, *Calidris alba*, *Calidris canutus*, *Calidris fuscicollis*, *Calidris melanotos*, *Numenius phaeopus*,

Table 1. Monthly occurrence frequency of birds record at Ilha Comprida beach between January 1999 and December 2001.

Tabela 1. Frequencia de ocorrência mensal das aves registradas na praia da Ilha Comprida entre janeiro de 1999 a dezembro de 2001.

Especie	J	F	M	A	M	J	J	A	S	O	N	D	FO
Actitis macularia	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,016
Ardea cocoi	0,0	0,01	0,0	0,0	0,01	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0014
Arenaria interpres	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,001
Bubulcus ibis	0,1	0,0	0,3	0,4	0,0	0,0	0,0	0,0	0,2	2,9	0,2	0,1	0,3
Rupornis magnirostris	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,01	0,01	0,0	0,0	0,0	0,0068
Calidris alba	1,0	0,0	0,1	0,1	0,8	0,0	0,0	0,1	3,5	2,2	1,6	1,9	0,89
Calidris canutus	0,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,4	0,8	0,1	0,016
Calidris fuscicollis	0,2	0,0	0,1	0,3	0,0	0,0	0,0	0,0	0,7	1,1	2,2	0,5	0,48
Calidris melanotos	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,0	0,03
Casmerodius albus	0,1	0,1	0,1	1,1	0,2	0,2	0,1	0,2	0,1	0,1	0,1	0,1	0,16
Catharacta skua	0,0	0,0	0,0	0,0	0,0	0,01	0,01	0,0	0,0	0,0	0,0	0,0	0,0034
Cathartes aura	1,3	0,7	2,3	3,7	2,2	1,3	0,6	1,7	1,5	1,6	1,1	1,3	1,47
Ceryle torquaryta	0,0	0,2	0,3	0,1	0,1	0,0	0,1	0,1	0,1	0,0	0,0	0,0	0,0089
Charadrius modestus	0,0	0,01	0,0	0,0	0,0	0,0	0,0	0,01	0,0	0,0	0,0	0,0	0,00097
Charadrius collaris	0,4	0,4	1,0	1,3	5,5	5,6	4,6	4,1	1,6	0,2	0,1	0,2	1,85
Charadrius semipalmatus	6,0	2,8	4,3	5,0	2,4	1,9	1,3	1,0	6,5	2,0	2,5	1,2	2,86
Chloroceryle americana	0,01	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00097
Colaptes campestris	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,01	0,0	0,014
Columba cayennensis	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0053
Coragyps atratus	5,8	3,2	14,2	14,3	12,4	9,6	6,8	8,8	9,4	7,1	8,0	6,9	8,11
Dendrocygna viduata	0,0	0,0	0,0	0,7	0,0	0,0	0,0	0,2	0,0	0,3	0,1	0,0	0,08
Egretta thula	1,5	1,8	4,4	5,0	4,6	3,2	3,0	2,9	2,6	1,9	1,0	1,3	2,46
Falco femeoralis	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,039
Egretta caerulea	0,0	0,01	0,0	0,0	0,01	0,0	0,0	0,0	0,01	0,0	0,0	0,0	0,0053
Fregata magnificens	4,9	1,8	9,9	8,1	4,0	5,8	11,9	9,9	5,9	7,3	3,8	2,6	5,65
Haematopus palliatus	0,1	0,1	0,0	0,1	0,1	0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,079
Himantopus himantopus	0,0	0,01	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0001
Larus dominicanus	52,0	32,7	24,5	11,9	6,0	12,2	6,6	4,2	7,8	12,7	24,9	45,9	22,32
Larus maculipennis	0,01	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,0	0,01	0,0	0,0	0,017
Leucopternis lacernulata	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,01	0,0	0,00097
Milvago chimachima	0,2	0,2	0,4	0,8	0,9	0,6	0,4	0,4	0,4	0,3	0,2	0,2	0,38
Milvago chimango	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,0	0,0	0,025
Numenius phaeopus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,0	0,0	0,02
Nycticorax nycticorax	0,0	0,0	0,0	0,0	0,01	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00004
Phalacrocorax brasilianus	3,2	1,3	1,9	1,0	0,1	0,0	0,0	0,0	0,1	0,4	0,4	1,2	0,8
Pluvialis dominica	0,3	0,1	0,4	0,1	0,0	0,0	0,0	0,0	0,4	0,9	0,8	0,5	0,3
Pluvialis squatarola	0,2	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,061
Polyborus carcara	0,2	0,2	0,5	0,9	1,1	0,3	0,6	0,5	0,4	0,4	0,2	0,2	0,39
Rynchops niger	2,5	2,6	2,6	4,5	6,0	2,3	7,8	2,6	2,2	3,2	1,6	1,9	3,08
Speotyto cunicularia	0,1	0,1	0,3	0,1	0,2	0,1	0,1	0,2	0,1	0,1	0,1	0,1	0,1
Thalasseus sandivicens eurygnathus	15,4	46,3	24,8	32,7	42,1	40,5	35,8	48,5	41,4	49,1	38,7	31,1	38,49
Sterna hirundinacea	1,3	0,4	1,4	0,3	0,9	2,2	1,6	0,7	4,4	2,7	8,8	0,0	2,19
Sterna hirundo	0,0	0,6	0,3	0,1	0,0	0,0	0,0	0,0	0,3	0,3	0,5	0,3	0,25
Thalasseus maximus	2,2	3,8	4,3	3,0	5,6	11,9	15,9	9,9	4,5	1,2	1,3	2,0	5,23
Sterna superciliaris	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,0072
Sterna trudeaui	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0034
Sula leuccogaster	0,0	0,0	0,1	1,3	0,4	0,1	0,2	0,1	0,2	0,1	0,1	0,0	0,16
Syrigma sibilatrix	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0024
Tringa flavipes	0,0	0,0	0,2	0,1	0,2	0,2	0,1	0,2	0,7	0,1	0,0	0,0	0,12
Tringa melanoleuca	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0014
Tringa solitaria	0,0	0,01	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00097
Vanellus chilensis	0,5	0,2	1,3	2,2	4,2	1,9	1,9	3,2	4,2	0,9	0,6	0,2	1,5

Table 2. Total number of the species more abundant counted in all the study. SG - specie group, EC - ecological category (MN - North migration, MS - South migration, M - Local migration, R - Resident). AVG - Abundance average, SD - Standard desviation of abundance, FO - Occurrence frequency), RA - ranking of the abundance in all the study. The group species symbols are the same symbol of the dendogram (Figure 4).

Tabela 2. Número total de espécies mais abundantes contadas durante o período estudado. SG - grupo de espécie, EC - categoria ecológica (MN - migrante do norte, MS - Migrante do Sul, M - migração local, R-residente). AVG - Média da abundância, SD - Desvio padrão da abundância, FO - Freqüência de ocorrência), RA - ranquim de abundancia em todo o estudo. Os símbolos dos grupos de espécies são os mesmos do dendograma (Figura 4).

RA	Species	SG	EC	Total	AVG	SD	FO (%)
1	*Thalasseus s. eurygnathus*	A	M	78994	1089.57	805.22	93.06
2	*Larus dominicanus*	A	R	45931	633.53	421.31	99.31
3	*Coragyps atratus*	A	R	16497	227.54	76.32	100.00
4	*Fregata magnificens*	A	R	11367	156.79	99.57	95.83
5	*Thalasseus maximus*	A	MN	10554	145.57	108.44	87.50
6	*Rynchops niger*	A	R	6340	87.45	81.48	45.14
7	*Charadrius semipalmatus*	A	MN	5888	81.21	62.05	73.61
8	*Egretta thula*	A	R	5080	70.07	20.08	99.31
9	*Sterna hirundinacea*	A	M	4508	62.18	189.58	44.44
10	*Charadrius collaris*	A	R	3774	52.06	32.54	87.50
11	*Vanellus chilensis*	A	R	3066	42.29	31.92	95.14
12	*Cathartes aura*	A	R	2953	41.01	14.27	96.53
19	*Bubulcus ibis*	C	M	618	8.52	22.67	16.67
27	*Dendrocygna viduata*	C	M	166	2.29	7.45	6.94
29	*Pluvialis squatarola*	C	MN	127	1.75	2.61	25.69
30	*Falco femeoralis*	C	R	81	1.13	4.86	14.58
31	*Calidris melanotos*	C	MN	63	0.87	2.17	9.03
32	*Milvago chimango*	C	R	52	0.72	1.71	10.42
33	*Numenius phaeopus*	C	MN	42	0.58	1.46	9.72
34	*Larus maculipennis*	C	MS	35	0.48	2.27	3.47
35	*Ardea cocoi*	C	R	30	0.41	0.71	14.58
36	*Colaptes campestris*	C	MN	29	0.40	2.25	2.08
37	*Actitis macularia*	C	MN	23	0.32	0.83	7.64
38	*Arenaria interpres*	C	MN	23	0.32	0.54	11.11
39	*Sterna superciliaris*	C	M	15	0.21	0.48	5.56
13	*Calidris alba*	B1	MN	1831	25.43	26.49	56.25
14	*Phalacrocorax brasilianus*	B1	R	1658	22.87	18.47	55.56
15	*Calidris fuscicollis*	B1	MN	990	13.66	25.58	37.50
18	*Pluvialis dominica*	B1	MN	634	8.74	7.27	56.94
20	*Sterna hirundo*	B1	MN	527	7.27	13.05	25.69
23	*Calidris canutus*	B1	MN	330	4.55	7.28	25.69
16	*Polyborus carcara*	B2	R	814	11.23	5.47	93.06
17	*Milvago chimachima*	B2	R	790	10.90	3.98	94.44
21	*Sula leuccogaster*	B2	R	347	4.79	9.52	40.28
22	*Casmerodius albus*	B2	R	338	4.66	7.19	57.64
24	*Tringa flavipes*	B2	MN	262	3.61	4.83	39.58
25	*Speotyto cunicularia*	B2	R	213	2.94	2.90	40.97
26	*Ceryle torquaryta*	B2	R	185	2.57	6.69	42.36
28	*Haematopus palliatus*	B2	R	164	2.26	1.61	45.83

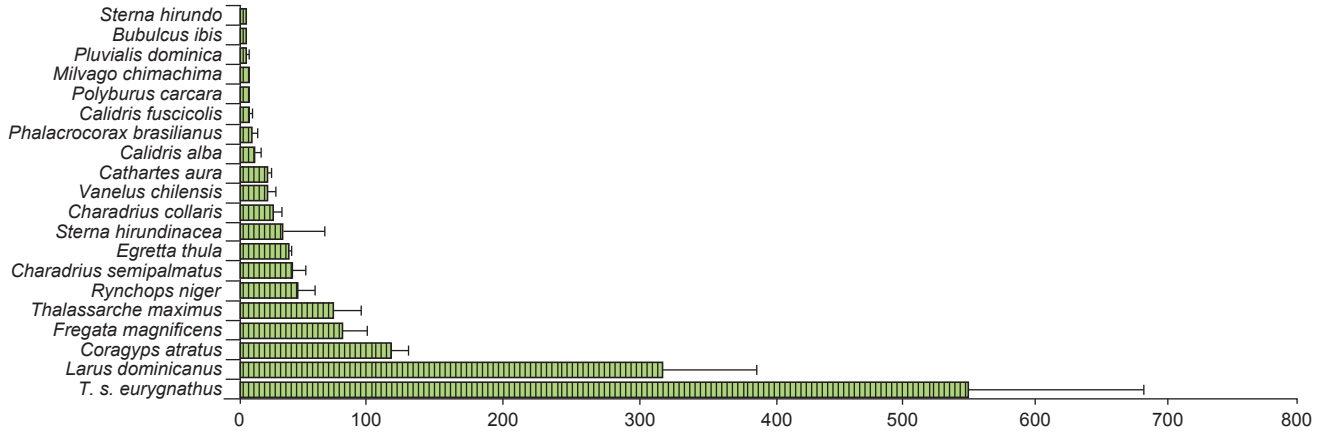

Figure 2. Average for first 20 species more abundant ranking (Weekly average and standard error). This twenty species were 98.77% of the all individuals counts during the period.

Figura 2. Médias das 20 espécies mais abundantes ranqueadas (média semanal e erro padrão). Estas vinte espécies representam 98,77% de todos os indivíduos contados durante o período.

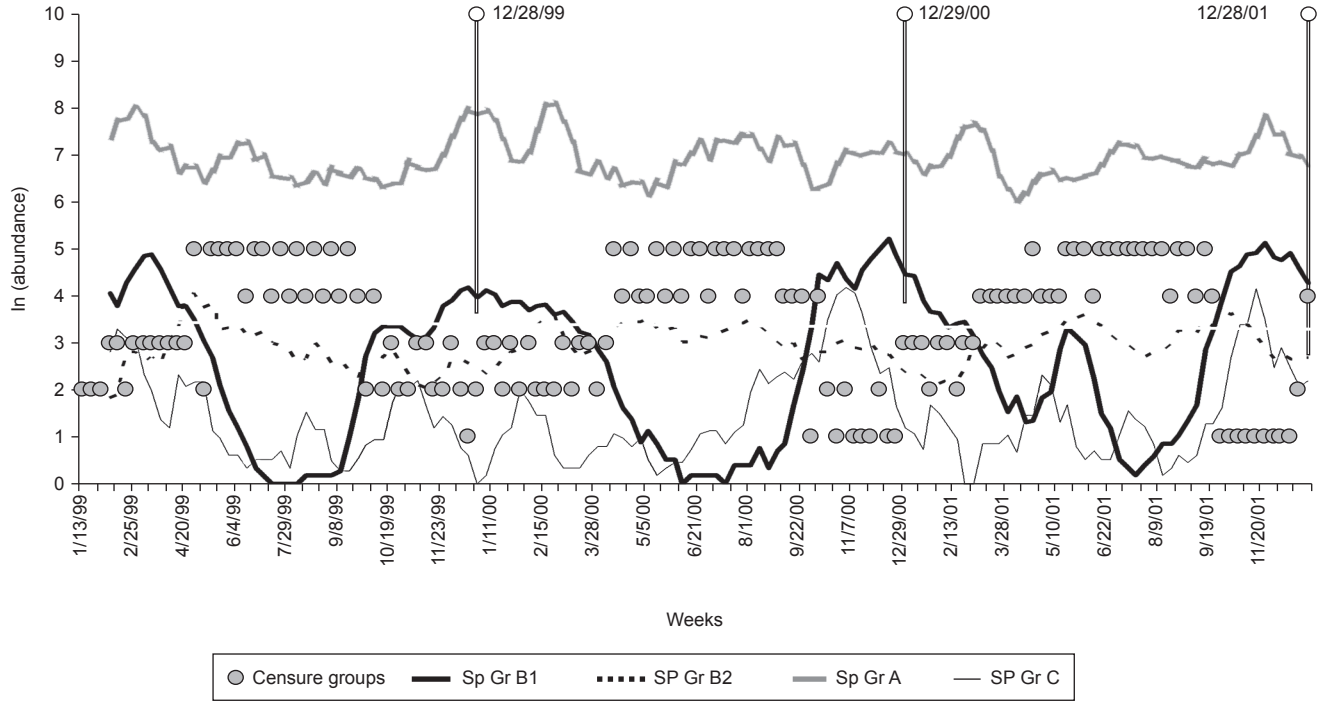

Figure 3. Temporal variation of average abundance (logaritmized) of each one of the groups of species (way r) identified in figure 4. The Points represent the weeks (samples) of each one of the five groups identified in the classification way Q. It is used to advantage scales it in axle Y to identify to the groups of 1 to 5.

Figura 3. Variação temporal da abundância média (logaritmizada) de cada um dos grupos de espécies (modo r) identificados na figura 4. Os pontos representam as semanas (amostras) de cada um dos cinco grupos identificados na classificação modo Q. Aproveita-se a escala no eixo Y para identificar os grupos de 1 a 5.

Trin flavipes, *Tringa melanoleuca*, and *Tringa solitaria*. All were recorded in larger numbers during the spring (September to November) when arriving from their breeding grounds (Table 1).

During June, July and August there were fewer birds, coinciding with the migration towards the Northern Hemisphere (Figure 3). Our surveys showed that most birds leave Ilha Comprida by the end of June, so most species occur infrequently during December, January and February (Table 1). Twenty-five individuals of *Charadrius semipalmatus* remained during winter (June, July and August), disappearing by mid- August. All were in immature plumage.

We recorded three species of Pelecaniformes: *Sula leucogaster*, *Phalacrocorax brasilianus* and *Fregata magnificens*. The population of the *Phalacrocorax brasilianus* increased during the summer (December, January and February) and decreased in winter (June,

July and August), but this species is recorded in large numbers in the mangroves of the Cananéia-Iguape-Ilha Comprida estuary throughout the year, suggesting local or regional movements.

The multivariate analysis protocol showed four groups of species (Figure 4). The species group A consisted of most abundant species present throughout the year: *Sterna eurygnatha*, *Larus dominicanus*, *Coragyps atratus*, *Fregata magnificens*, *Sterna maxima*, *Rynchops niger*, *Charadrius semipalmatus*, *Egretta thula*, *Sterna hirundinacea*, *Charadrius collaris*, *Vanellus chilensis* and *Cathartes aura*. Most of these species migrate along the Brazilian coast at least to some degrees. The latter, although nesting in North America, has a significant overwintering population of immature birds that moves along the Brazilian coast, mimicking the patterns of locally breeding species.

The species group C (Figure 4) was formed by species with few records: *Dendrocygna viduata*, *Falco femoralis*, *Larus maculipennis*, *Colaptes campestris*, *Actitis macularia*, *Sterna superciliaris*, *Bubulcus íbis*, *Pluvialis squatarola*, *Calidris melanotos*, *Milvago chimango*, *Numenius phaeopus*, *Ardea cocoi* and *Arenaria interpres*. Some are genuinely uncommon in southern São Paulo (*Calidris melanotos*, *Larus maculipennis*, *Milvago chimango*). *Actitis macularia*, *Pluvialis squatarola*, *Numenius phaeopus*, *Ardea cocoi* and *Arenaria interpres* are common in mangroves. *Milvago chimango*, *Falco femoralis*, *Bubulcus ibis*, are common in scrub and the beach is marginal habitat visited only sporadically.

The species group B1 was formed by species that left Ilha Comprida during the breeding season. Among them, *Calidris alba*, *Phalacrocorax brasilianus*, *Pluvialis dominica*, *Sterna hirundo*, and *Calidris canutus* remained for a shorter time on the island (between 3 and 4 months). With the exception of *Phalacrocorax brasilianus*, all of the species in group one are long-distance migrants that breed in the Northern Hemisphere and arrive on Ilha Comprida in September.

The species group B2 was formed by species that occur regularly during all the year with small seasonal variations of abundance when compared with the B1 group which use Ilha Comprida beach only for foraging: *Polyborus plancus*, *Milvago chimachima*, *Sula leucogaster*, *Ardea alba*, *Tringa flavipes*, *Speotyto cunicularia*, *Ceryle torquata* and *Haematopus palliatus*. The species in group B2 are all nonirruptive, short-distance migrants.

It was possible to observe 5 groups of the fauna in the summers winters and springs. The points in Figure 3 are accurately the weeks

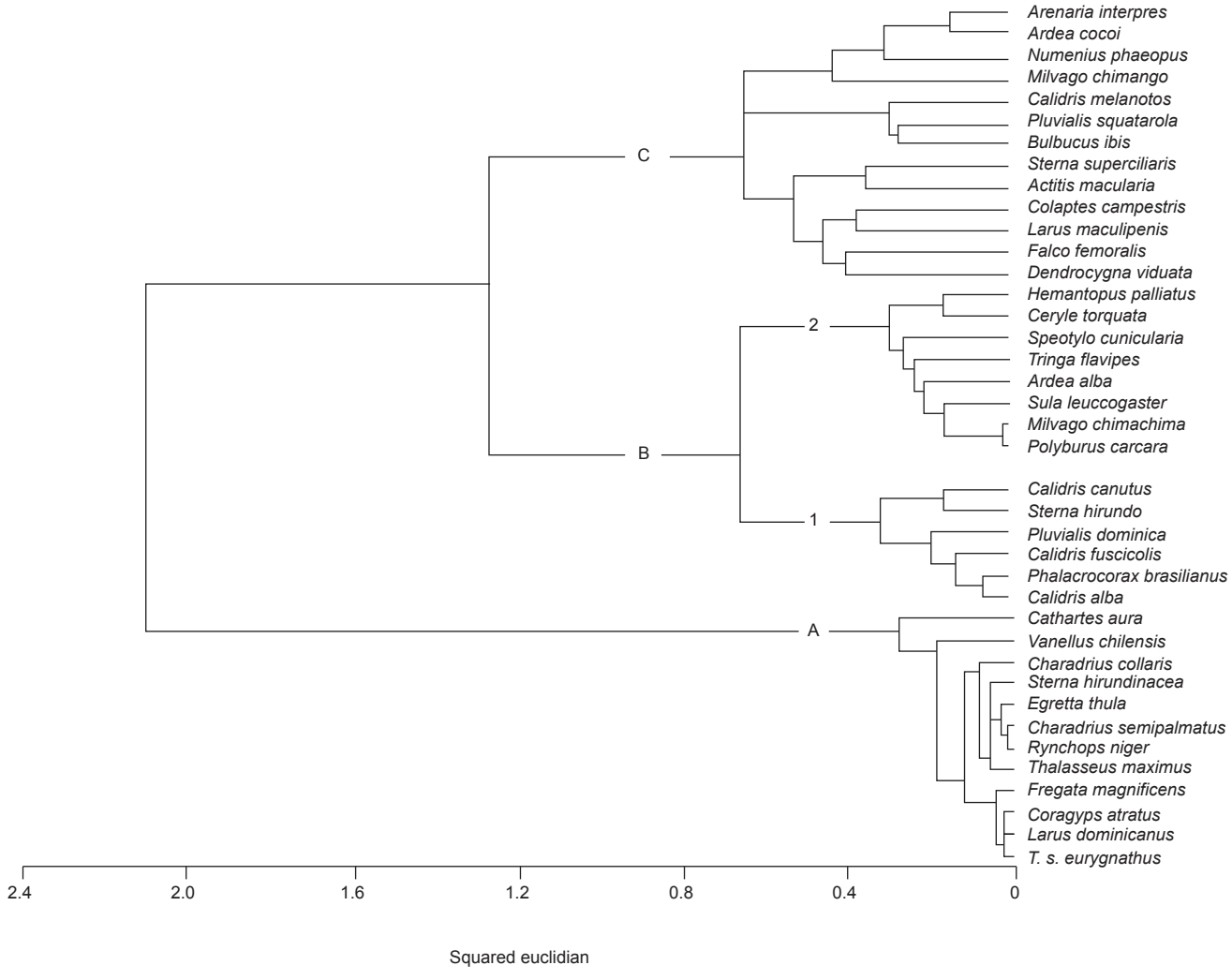

Figure 4. Dendrogram for 39 species record at Ilha Comprida beach.

Figura 4. Dendograma das 39 espécies registradas na praia da Ilha Comprida.

that belong to each one of the groups. That they can be seen in axle Y (of 1 the 5), axle Y also serves to show the abundance for group in logarithm scale.

The species of the B1 group have significant negative correlation with the B2 group, or either when a group increases the abundance the other decrease. However the B1 group have significant positive correlation with the group A and B (Table 3).

We found the censused bird community to be only moderately diverse and with low evenness (Table 2), a pattern retained throughout the study. Twenty species accounted for 98.8% of all bird records and many rare species were recorded only a few times or in groups of very few individuals.

Numerically, the most important species during the study period were *Sterna erygnatha*, *Larus dominicanus*, *Coragyps atratus*, *Fregata magnificens*, *Sterna maxima*, *Rynchops niger*, *Charadrius semipalmatus*, *Egretta thula*, *Sterna hirundinacea*, *Charadrius collaris*, *Vanellus chilensis*, *Calidris alba*, *Phalacrocorax brasilianus*, *Calidris fuscicolis*, *Caracara plancus*, *Mivalgo chimachima*, *Pluvialis dominica*, *Bubulcus ibis* and *Sterna hirundo* (Table 2).

Of the visitors and vagrants, about 20 species are represented by only 1-2 records (more than one bird observed together in some cases). Among these are several species considered to be rare in coastal São Paulo State, such as *Catharacta chilensis*, *Charadrius modestus* and *Calidris melanotus*.

Discussion

This study demonstrates that many species of Nearctic shorebirds and terns are absent or less abundant at Ilha Comprida beach during the boreal spring and summer (May, June, July and August). Maximum counts of all Nearctic shorebird migrants combined were roughly twice as high prior to September and October, when arriving from the breeding grounds, than afterwards, even when water levels remained low in early April. Data from specimen records and observations from other areas in Brazil indicate that most Nearctic shorebirds species are less abundant during northbound migration even in areas away from the coast (Barbieri et al. 2000). The data in this work can be disclosing that the species of the Group B1 and B2 are competitor, therefore soon after a reduction in the abundance of the B1 group occurs an increase of the species of the B2 group.

Most study of bird communities have been conducted over short periods and thus provide a "snapshot" view of patterns. In their reviews of experimental studies of competition, Schoener (1983), Connell & Souza (1983), Wiens (1997) and Hubbard & Dugan (2003) found relatively few studies (over all taxa) that were conducted long enough to assess whether or not there was temporal variation in the occurrence of competition. Without long-term data, it is not easy to determine if there are any general patterns to the variation that occurs in bird communities inhabiting different environments (Wiens 1997, Hubbard & Dugan 2003). Moreover, the extent of variability in any particular location may change seasonally and differ among species or guilds (CarrascaL et al. 1987).

Table 3. Correlation of the abundance of the groups of species.

Tabela 3. Correlação da abundância dos grupos de espécies.

	A	B1	B2	C
A	-	0.0066	0.2723	0.2174
B1	0.2013	-	0.0635	0.0000
B2	0.0499	–0.1281	-	0.5065
C	0.0663	0.3123	0.0001	-

For example, locally-breeding *Charadrius collaris* changed significantly in distribution and number of individuals during December, January and February, with fewer birds from September to April. This may be due to the arrival of North American migrants, such as *Charadrius semipalmatus* and *Pluvialis dominica*, which probably compete for food with *Charadius collaris* on the beach and cause it to move inland (Sick 1997). Vooren & Chiaradia (1990) report that *Charadrius collaris* bred in Lagoa do Peixe (RS) between November and January; they fed in a coastal lagoon during this period, but moved to the beach during the winter. Belton (1984) also observed more individuals of this species on the beach during June, July and August than in December January and February.

During winter (June, July and August), some individuals of *Charadrius semipalmatus*, *Pluvialis dominica* and *P. squatarola* can still be seen at Ilha Comprida beach. According to Sick (1997), these birds migrate to North Hemisphere to nest during the austral winter, so the individuals present at Ilha Comprida at that time are probably immature birds (Barbieri & Sato 2000, Olmos & Silva 2001).

There are some studies on waders found along the Brazilian coast (Vooren & Chiaradia 1990, Sick 1997), however, neither the number of individuals nor the preferred areas of occurrence are precisely quantified. Thus, little is known about the preferred resting and/or foraging areas of shorebirds along the Brazilian coast. Our results suggest that Ilha Comprida is a stopover site used by *Charadrius semipalmatus*, *Pluvialis dominica*, *P. squatarola*, *Calidris alba*, *C. canutus*, *C. fuscicolis* and *Sterna hirundo* for resting and foraging during their spring migration back to the Northern Hemisphere (April) and their fall migration to foraging areas in the Southern Hemisphere (September). Belton (1984), Vooren & Chiaradia (1990), Vooren & Brusque (1999), working in Rio Grande do Sul (Brazil) recorded large flocks of these species flying towards the Northern Hemisphere, passing through southern Brazil in April. Flocks of shorebirds begin to arrive on Ilha Comprida at the end of September, reaching a peak in December. From February onwards the abundance of shorebirds decreases, reaching the lowest numbers of individuals in April and May. Belton (1984) recorded that the northern migration of shorebirds returning to the breeding grounds occurred in April-May, consistent with the results of this study.

Our study shows that this zone is a passage and foraging area for *Calidris alba*, *C. canutus*, and *C. fuscicollis* during their migration to the southern areas of South America, such as the Lagoa do Peixe in Brazil and Tierra del Fuego in Argentina. Myers et al. (1990), evaluating the migration routes of the Sanderling (*Calidris alba*), writes that they fly through the Brazilian hinterland to reach Lagoa do Peixe at Rio Grande do Sul, Southern Brazil; however, they do not mention routes along the Brazilian coast. By contrast, Sick (1997) states that *C. alba* is the most abundant arctic sandpiper along Brazilian beaches, occurring along the whole Brazilian coast in small groups. It is even found at night in Copacabana beach, Rio de Janeiro and near Recife city (Pernambuco State) from the end of August to the middle of May, clearly showing a coastal route. Our results show that Ilha Comprida is a stopover area for birds moving along the coast. The recovery of a color band from a Sanderling in the Coroa do Avião (Pernambuco) demonstrates the strong fidelity of this species to its winter site (Neves et al. 2004).

The northbound routes of Nearctic migrants are not known for some species (Hayes & Fox 1991). It is likely that they either migrate northward along the Atlantic coast, or fly nonstop through central South America until they reach the Caribbean at the Atlantic coast or nearby inland areas (Antas 1990). Large concentrations of spring migrants have been reported along the Atlantic coastal of southern Brazil (Harrington et al. 1986, Vooren & Chiaradia 1990) and in

Ilha Comprida (Barbieri et al. 2000, 2003); however, further study is needed on the conservation status of these stopover areas.

The number of shorebirds occurring at Ilha Comprida beach is small in comparison to the numbers reported along coastal areas, like Lagoa do Peixe in Rio Grande do Sul State (Belton 1984, Vooren & Chiaradia 1990) and Coroa do Avião in Pernambuco (Sick 1997, Telino-Junior et al. 2003, Neves et al. 2004). Although large numbers of migrant shorebirds apparently move along the South American coast, they are widely dispersed; there are known "stopover areas" (Myers et al. 1990) in need of special protection (Barbieri et al. 2003).

Many species of migratory birds accumulate the energy necessary for migration at the beaches of the South Brazilian coast (Vooren & Chiaradia 1990). Stopovers on the migratory routes of shorebirds are important links between breeding and non-breeding areas (Myers et al. 1979), supplying the energy needed for continuous migratory flight. In addition, food obtained at stopovers increases energy savings that can be essential for reproductive success when migrants arrive on the breeding grounds (Barbieri & Mendonça 2005).

The expression "stopover" is still widely discussed by several authors. Melvim and Temple (1982) studied the migration of Canada geese (*Branta canadensis*) and defined two types of stopovers based on area fidelity and temporal factors. According to these authors, "traditional" stopovers are the areas used during successive years and for long term periods. "Non-traditional" stopovers are areas chosen opportunistically at the end of a daily flight. These are used during the entire year, but only for a short time period. However, Myers et al. (1990) defines several types of stopovers, based on the number of shorebirds occurring yearly in the area. Hands (1988) defines a foraging area as the place where migrants spend part of the year and accumulate fat; resting areas, by contrast, are locations where migrants accumulate little fat and remain inactive for long periods of time. These definitions are arbitrary, however, if there is an interaction between the two activities.

Numbers of *Thalasseus sandivicens eurygnathus* decreased during the autumn and winter of 1999. This was expected since this species breeds in the winter, nesting from May to July (Efe et al. 2000, 2004). In the autumn and winter of 2000 and 2001, however, numbers of *T. s. eurygnathus* increased. In the same period, the number of individuals at Espirito Santo decreased, suggesting that the events were related. It is possible that some individuals of *T. s. eurygnathus* observed in Ilha Comprida came from Santa Catarina, an island where this species breeds from May to December (Branco 2003).

Thalasseus maximus is considered to be a vulnerable species on the coast of Brazil because the breeding colonies have undergone extensive egg collecting by fishermen (Lista Oficial do IBAMA 2003). Some populations of *T. maximus* nest in the Northern hemisphere and migrate to the Caribbean and northern South America; another population nests in Chubut and Patagonia, Argentina (Yorio et al. 1994, Novelli 1997, Quintana and Yorio 1997, 1999), while another population nests in Africa. This species was recorded throughout the year at Ilha Comprida, where both locally nesting birds and birds coming from southern South America may occur. Neves (1994) has recorded nesting *T. maximus* in Laje de Santos (São Paulo state); however, this is probably not the source of the individuals on Ilha Comprida since the birds that we recorded were not in breeding plumage.

Sterna hirundo occurred only during the hottest months (November, December, January and February) in Ilha Comprida, as well at Praia do Cassino in Rio Grande do Sul (Vooren & Chiaradia 1990, Hays et al. 1997, 1999). Their absence during the winter is expected since *Sterna hirundo* breeds in the Northern Hemisphere. It makes one of the longest migrations of all of the birds found at Ilha Comprida, traveling from Canada to Brazil each year (Harrington et al. 1986, Novelli 1997). According to Sick (1997), these birds are regular visitors on the Brazilian coast. The presence of *S. hirundo* at Ilha Comprida beach suggests that they use the island as a stopover point while migrating to their wintering grounds in southern South America (Vooren & Chiaradia 1990).

Besides known long-range migrants (*Thalasseus maximus*, *Tringa flavipes*, *Charadrius semipalmatus*, *Calidris alba*, *C. fuscicollis*, *C. canutus*) many species show marked population changes because migrations. However the population, decrease during the austral winter but not a complete disappearance. Among these are *Numenius phaeopus*, *Pluvialis dominica*, *P. squatarola*, *Thalasseus maximus*, *Calidris canutus*, *Tringa flavipes* and *Charadrius semipalmatus*. During austral winter, some individuals this species can still be seen at Ilha Comprida beach. According to Sick (1997), these birds migrate to the Northern Hemisphere for reproduction during the winter, so their presence in Ilha Comprida in this season suggests that they are immature individuals who don't follow their routes, as already mentioned by Barbieri & Mendonça (2005), Belton (1984), and Vooren & Chiaradia (1990), regarding other migratory birds.

Individuals of many species move en masse from one habitat to another and back again repeatedly during their life. The timescale involved may be hours, days, months or years. In some cases, these movements have the effect of maintaining the organism in the same type of environment. This is the case in the movement of shorebird on a shoreline: they move with the advance and retreat of the tide. In other cases, diurnal migration may involve moving between two environments: the fundamental niches of these species can only be satisfied by alternating life in two distinct habitats within each day of their lives (Begon et al, 2006), for example *Bulbucus ibis*, *Milvago chimachima*, *Polyborus carcara*, *Falco femeoralis*, *Dendrocygna viduata* and *Vanelus chilensis*.

Barbieri & Mendonça (2005) report the *V. chilensis* presence at Ilha Comprida beach was constant during all seasons, with higher densities during spring. Other authors mention the species occurrence all year, as demonstrated by Schiefler & Soares (1995) in analysis on the birds of Navegantes and Laguna (Santa Catarina State) beaches, where the constancy of *V. chilensis* in all seasons in 1994 was mentioned. Nascimento & Lazarrabal (2000), in research with shorebirds in Barra de Cunhau' (Rio Grande do Norte state), also observed that this species was constant all year, presenting high densities at the beach during October and November (spring). During the years studied, some small flocks of *V. chilensis* were seen feeding at the beach, although some authors such as Schiefler & Soares (1995) assure that the seaside region is used only as a resting place.

We conclude that the abundance of birds at Ilha Comprida varied substantially during the study period of three years, especially on a local scale. Many factors may contribute to this variation, including changes in habitat, habitat selection, behavior, food resources, site fidelity, predation, the population of source areas, or weather conditions during winter, migration, or breeding. Ilha Comprida is one of the very few barrier islands in eastern Brazil with habitat suitable to shorebirds. As such, it is a stopover area of great regional and international importance for migratory North American shorebirds.

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