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Diversity and associations between coastal habitats and anurans in southernmost Brazil

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ABSTRACT

This study aimed to verify the relationship between habitat and the composition of anuran species in dune and restinga habitats in southernmost Brazil. The habitats were sampled between April 2009 and March 2010 using pitfalls with drift fence. We have captured 13,508 individuals of 12 anuran species. Species richness was lower in the dunes and dominance was higher in the resting. Apparently the less complex plant cover, water availability, and wide daily thermal variation in dunes act as an environmental filter for frogs. This hypothesis is reinforced by the fact that the most abundant species (*Physalaemus biligonigerus* and *Odonthoprynus maisuma*) bury themselves in the sand, minimizing these environmental stresses. Despite being in the Pampa biome, the studied community was more similar to those of coastal restinga environment of southeast Brazil than with other of the Pampa biome. The number of recorded species is similar to those observed in other open habitats in Brazil, showing the importance of adjacent ones to the shoreline for the maintenance of the diversity of anurans in southernmost Brazil.

Key words: Amphibia, coastal dunes, restinga, niche.

INTRODUCTION

Brazil is the country with the greatest diversity of anurans in the planet, with nearly 900 described species and an endemism rate of approximately 70%. However, the number of species varies widely among different regions of the country. For example, in the Atlantic Forest biome, approximately 515 anuran species have been reported, while in the Cerrado biome, less than a half, about 200, are listed (IUCN 2010). The southern region of Brazil houses a large variety of biomes and has even fewer (91) anurans species than the formerly cited biomes (Maneyro and Carreira 2006, Machado and Maltchik 2007, Canavero et al. 2008, Caldart et al. 2010). Nevertheless, this number represents 10.7% of the diversity in Brazil and 1.6% of the diversity worldwide.

The southernmost region of Brazil, especially the coastal area, exhibits a variety of habitats, such as dunes associated with coastal grasslands and restingas (Calliari and Klein 1993, Neves and Bauermann 2001, Dorneles and Waechter 2004). Although intrinsically associated, dunes and restingas represent two distinct habitats regarding

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the availability of microhabitats. The dune habitat is characterized by sparse plant cover, wide daily thermal variation, high drainage, and predominance of temporary water bodies (Calliari and Klein 1993). The restinga exhibits a denser plant cover, predominantly shrubs, providing more shaded areas and more stable microclimatic conditions (e. g., humidity, temperature, sunlight) (Neves and Bauermann 2001, Dorneles and Waechter 2004). These differences may reflect distinct patterns of species richness and habitat use (see Cardoso et al. 1989, Pombal Jr 1997, Prado et al. 2005).

This study aimed to verify the species richness, relative abundance, and habitat use by anuran species in coastal dunes and restingas in southernmost Brazil. These habitats represent important remnants of the native Brazilian coastal landscape with biotic (plant cover) and abiotic (thermal variation, sub-temperate climate, and marine influence) characteristics, making them valuable sites for studies on the community structure of neotropical anurans. In addition, these habitats have faced severe degradation, making studies in these areas very important (Guadagnin 1999, Rolon and Maltchik 2006).

MATERIALS AND METHODS

Samplings were concentrated in an area known as Balneário Cassino, located in the coordinates 32°12' - 32°15'S and 52°10' - 52°14'W (Figure 1), approximately at sea level. We sampled (1) dune and (2) restinga habitats (Figure 1). These habitats are characterized by sandy soil, strong marine influence and constant winds (Cordazzo and Seeliger 1987).

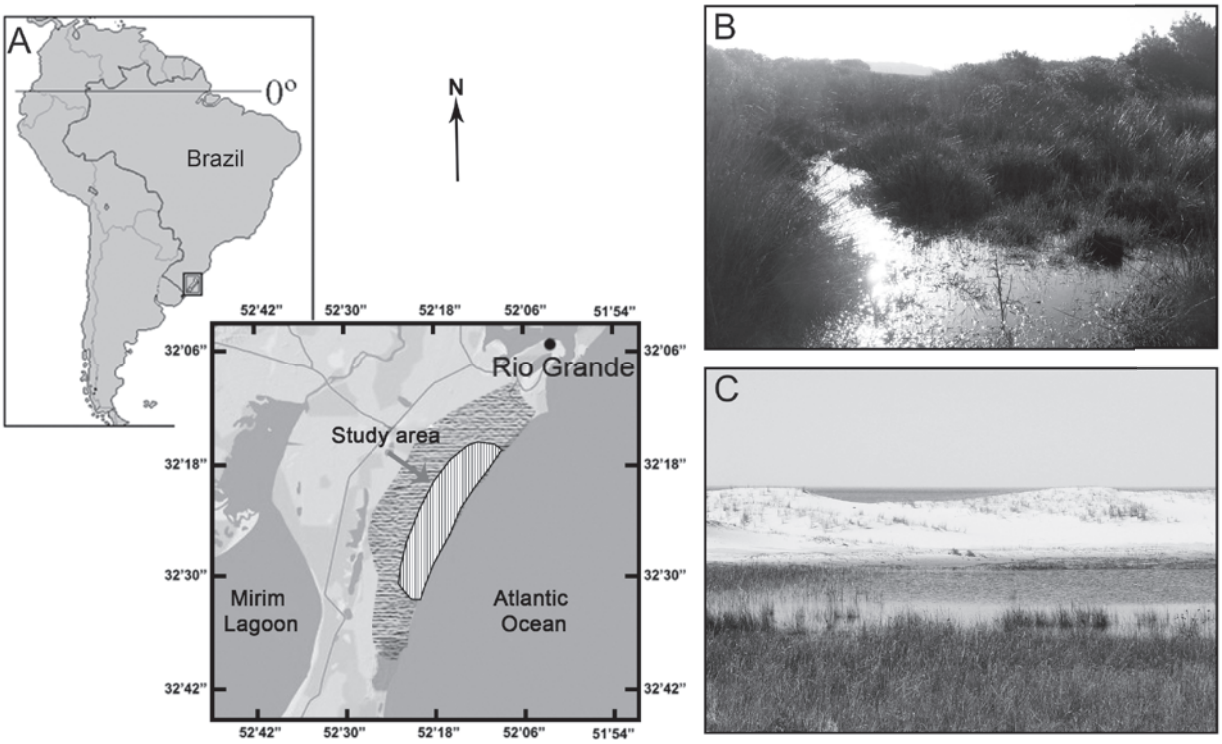

Figure 1 - Study area. **A)** samplings were conducted in the area indicated by the arrow, characterized by continuous coastal grasslands associated with dunes. **B)** resting habitat. **C)** dune habitat.

Samplings were carried out during five consecutive days, repeated every 15 days between April 2009 and March 2010. Animals were captured with pitfall traps with drift fences. For each area examined (dunes and restingas), three groups of pitfalls were set up approximately 600 m away from each other. Six groups of pitfall traps were set up (12 lines, 480 m of drift fence and 48 buckets).

To examine the efficiency of pitfall traps to describe the species of the area, a mean species accumulation curve was calculated with the program Estimates 8.2.0 (Colwell 2009), with 1,000 interations. To calculate the curves, each group (pair of lines of traps) was considered a sample. The data were grouped per field trip (five days of monitoring). Since we conducted 24 field trips, in which six groups of traps were monitored (three per habitat), we obtained 144 samples (72 for dune and 72 for restinga). All samplings were carried out simultaneously in the two habitats.

Five estimators of richness were tested regarding precision: Chao 1 and 2; Jacknife 1 and 2 and ACE. The former, Chao 1, was chosen for stabilizing quickly and constancy of the extrapolated value for 1,000 random iterations calculated with the program Estimates 8.2.0 (Colwell 2009). To examine the participation of each species in the assemblage composition, we also calculated dominance with the rarefaction method using the program Ecosim (Gotelli and Entsminger 2001), adjusted for 1,000 iterations.

The number of captures in both habitats was compared to the Mann-Withney test (Zar 1999), with each group of traps as a replicate. Species with any adaptation that could allow climbing and escaping from the traps (e.g., Hylids) (Enge 2001) were excluded, standardizing the efficiency of the method of capture.

Species composition was compared to those of other localities to identify associations between anurans and certain types of habitats. The characterization of the habitat of the compared assemblages was based on the information reported in each study and the classification of the biome was based on specific maps (e.g. IBGE 2004, IGN 2010). The following studies were selected: Brasileiro et al. (2005) - Cerrado, São Paulo, Brazil; Kacoliris et al. (2006) - Pampa, Argentine; Domenico (2008) - Atlantic Forest, São Paulo, Brazil; Maneyro (2008) - Pampa, Uruguay; Turci and Bernarde (2008) - Amazon Forest, Rôndonia, Brazil; Álvarez et al. (2009) - Oriental Chaco, Argentine; Loebmann and Haddad (2010) - Caatinga, Ceará, Brazil; Souza et al. (2010) - Pantanal, Mato Grosso do Sul, Brazil; Wachlevski and Rocha (2010) - Atlantic Forest, Santa Catarina, Brazil. In addition, we included three studies conducted in Rio Grande do Sul state(Brazil): Loebmann and Vieira (2005) - Pampa, Rio Grande do Sul, Colombo et al. (2008) - transition between the Atlantic Forest and Pampa biomes, Rio Grande do Sul and Quintela et al. (2009) - Pampa, Rio Grande do Sul. The similarity between assemblages was tested using presence and absence of species, considering only species with genus and species epithets, and excluding species of doubtful identification. This comparison was conducted with the cluster analysis using the program Statistica 8.0 (Statsoft 2007).

RESULTS

After a total of 120 days field work, 13,508 individuals of 12 species, belonging to six families, were recorded: Bufonidae (2 species), Cycloramphidae (1), Hylidae (3), Leiuperidae (3), Leptodactylidae (2), and Microhylidae (1) (Table I). The accumulation curve of species showed a tendency to stabilize indicating that the sampling effort reached a plateau for the sampling method used (Figure 2).

The richness in the dune habitat was represented by 10 species, while in the restinga, it was represented by 12 species. In the dune habitat, the estimated richness (Chao1 richness estimator) was 10 ± 0.79 species, lower than

the estimated for the restinga with 12 ± 1.15 species (Table II). The dominance observed in dune habitat was higher (46.68%) than that of the restinga (39.08%). The observed values of dominance observed were similar to the estimated ones. Estimated dominance of species composition was 46.73% for dunes and 39.18% for restinga (Table II).

TABLE I
Absolute number of individuals of anuran amphibians captured in dune and restinga habitats in the municipality of Rio Grande, coastal region of Rio Grande do Sul, southern Brazil. A% = percentage of the total number of individuals captured per habitat and T% = percentage of the total of individuals captured in the two habitats combined.

		Habitat					
Famíly	**Species**	**Dunes**		**Restinga**		**Total**	
		Captures	A%	Captures	A%	Captures	T%
Bufonidae	*Rhinella arenarum* (Hensel, 1867)	120	2.26	70	0.78	190	1.45
	Rhinella fernandazae (Duméril and Bibron, 1841)	17	0.3	19	0.23	36	0.25
Cycloramphidae	*Odontophrynus maisuma* Rosset, 2008	1,848	33.28	981	12.13	2,829	20.95
Hylidae	*Hypsiboas pulchellus* (Duméril and Bibron, 1841)	27	0.48	42	0.42	69	0.51
	Pseudis minuta Günther, 1858	60	1.07	64	0.8	124	0.91
	Scinax squalirostris (Lutz, 1925)	0	0	7	0.08	7	0.05
Leiuperidae	*Physalaemus biligonigerus* (Cope, 1861)	2,594	46.68	3,108	39.08	5,702	42.21
	Physalaemus gracilis (Boulenger, 1883)	138	2.44	1,154	14.21	1,292	9.56
	Pseudopaludicola falcipes (Hensel, 1867)	5	0.09	13	0.14	18	0.13
Leptodactylidae	*Leptodactylus gracilis* (Duméril and Bibron, 1840)	49	0.88	75	0.92	124	0.91
	Leptodactylus latrans (Steffen, 1815)	698	12.52	2,338	29.3	3,036	22.47
Microhylidae	*Elachistocleis bicolor* (Guérin-Méneville, 1838)	0	0	81	1.01	81	0.6
	Total Captures	5,556	100%	7,952	100%	13,508	100%

TABLE II
Observed species richness, estimated richness (Chao1), observed dominance and estimated dominance (obtained with the rarefaction method) of anuran amphibians in coastal dune and restinga habitats in the municipality of Rio Grande, coastal region of Rio Grande do Sul, southern Brazil.

Habitat	**Richness**		**Dominance**	
	observed	estimated	observed	estimated
Dunes	10	10 ± 0.79	0.46	0.46
Restinga	12	12 ± 1.15	0.39	0.39

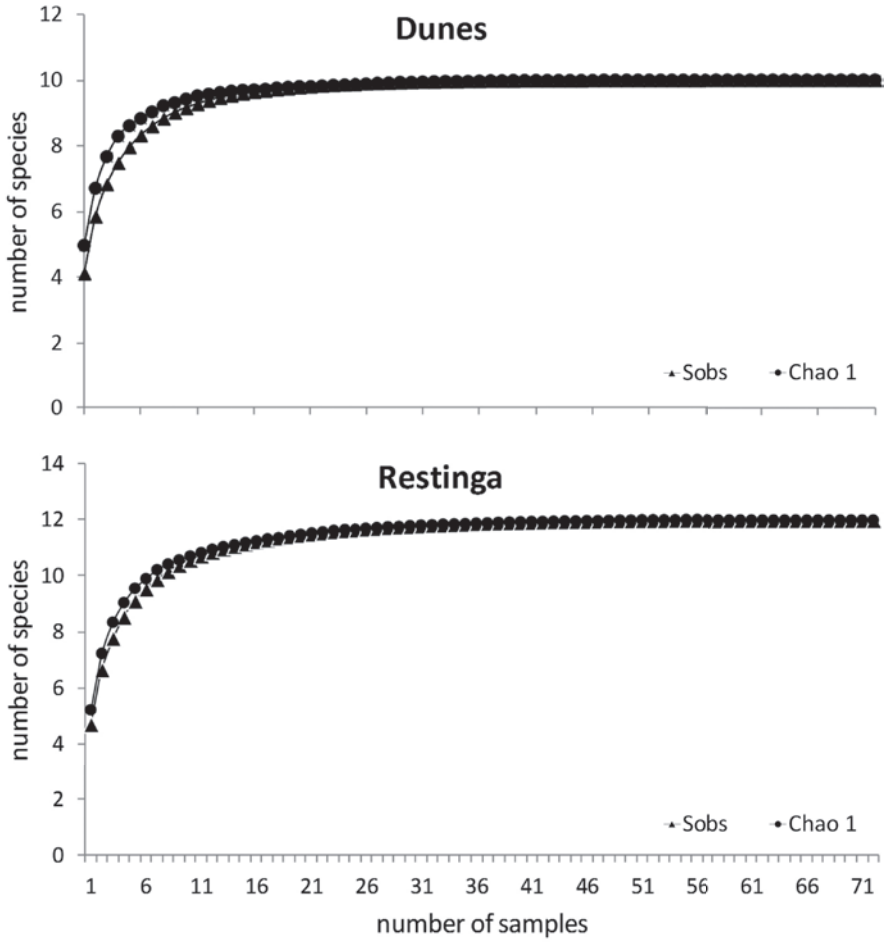

Figure 2 - Species accumulation curve of anurans captured between April 2009 and March 2010 in dune and restinga habitats in the municipality of Rio Grande, coastal region of Rio Grande do Sul, Brazil. The curves represent the total number of observed species (Sobs) and the number generated by the Chao1 richness estimator. Points represent the average of 1,000 curves generated with random order of samples. For details see Material and Methods.

In the two habitats, *Physalaemus biligonigerus* was the most abundant species with 2,594 captures in the coastal dune habitat and 3,109 in restinga, accounting for 42.21% of the total captures. Two species, *Scinax squalirostris* and *Elachistocleis bicolor* were captured exclusively in areas of restinga. The remaining species were found in both habitats. No significant variation in the capture rates between the two habitats was observed when all species were combined (U = 5,213.5; p = 0.981; n = 144). For this test, *Hypsiboas pulchellus*, *S. squalirostris*, and *Pseudopaludicola falcipes* were excluded as they potentially could escape from traps. The number of captures in the two habitats were significantly different for *P. gracilis* (U = 4,438.5; p = 0.001; n = 144) and *E. bicolor* (U = 4,860; p = 0.001; n = 144). The number of captures of *P. gracilis* was higher in restinga (n = 1,154) than in dunes (n = 138). The differences in the number of captures between habitats was not significant for *Rhinella arenarum* (U = 5,438.5; p = 0.315; n = 144), *Rhinella dorbignyi* (U = 5,151; p = 0.673; n = 144), *Odonthophrynus maisuma* (U = 5,571; p = 0,160; n = 144), Pseudis minuta

(U = 5,086.5; p = 0.510; n = 144), *Physalaemus biligonigerus* (U = 5,052; p = 0.502; n = 144), *Leptodactylus gracilis* (U = 4,981.5; p = 0.222; n = 144) and *Leptodactylus latrans* (U = 4,879; p = 0.167; n = 144).

The cluster analysis (Figure 3) revealed that the assemblage studied seems to be more similar to other assemblages of coastal habitats, especially areas relatively near the study areas. Similarity was higher to the assemblage described for the Lagoa do Peixe National Park and Marinheiros Island in the estuary of Laguna dos Patos, both located at a maximum distance of 200 km of our study area. Similarity was also higher to coastal restinga habitats of southeast Brazil than to other areas of the biome Pampa. The lowest similarity scores were observed for forests or in general, non-grasslands.

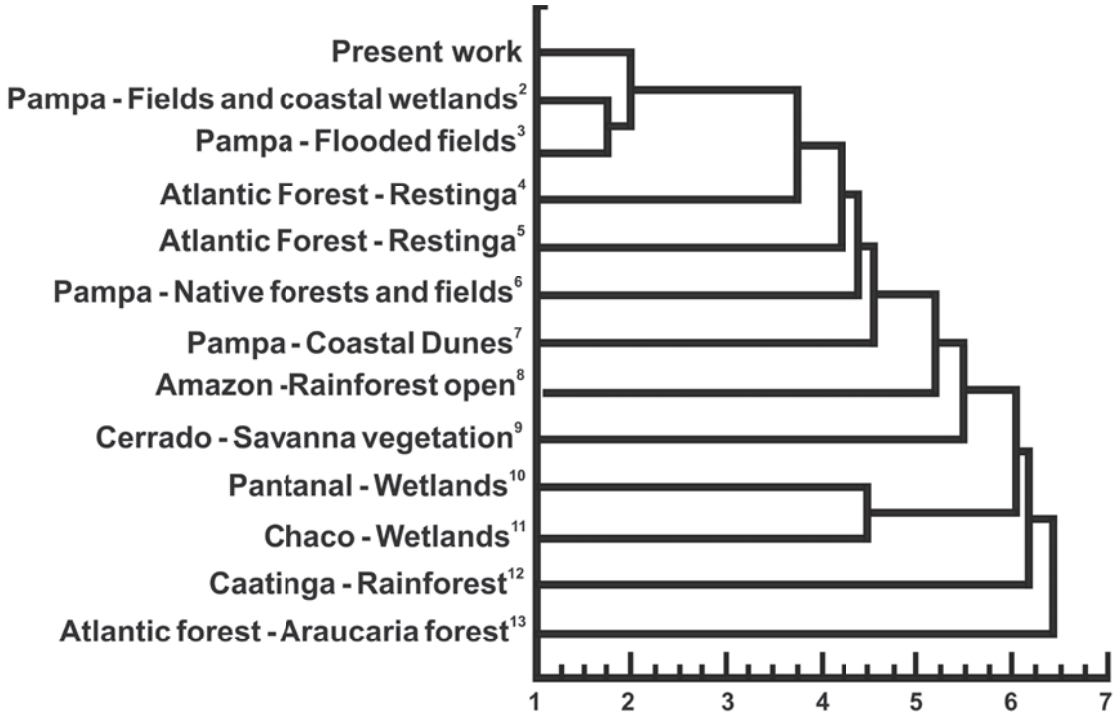

Figure 3 - Dendogram of the cluster analysis of the species composition of anuran amphibians (presence and absence of 157 spp.) from 13 assemblages. **2)** Loebmann and Vieira (2005); **3)** Quintela et al. (2009); **4)** Colombo et al. (2008); **5)** Wachlevski and Rocha (2010); **6)** Maneyro (2008); **7)** Kacoliris et al. (2006); **8)** Turci and Bernarde (2008); **9)** Brasileiro et al. (2005); **10)** Souza et al. (2010); **11)** Álvarez et al. (2009); **12)** Loebmann and Haddad (2010); **13)** Domenico (2008).

DISCUSSION

The lowest species richness and the higher dominance in species composition of the coastal dune habitat are probably correlated to characteristics such as water stress caused by the high permeability of soil, wide daily temperature variation of the substrate, constant and strong winds, and indirect influence of salt spray (Boyce 1954). This hypothesis is supported by the fact that the two most frequently captured species in the dune habitat were *P. biligonigerus* and *Odonthoprynus maisuma*, burying themselves in the sand and thus, minimizing these environmental stresses (Loebmann 2005, Achaval and Olmos 2003).

The restinga habitat exhibits higher diversity of microhabitas due to the more complex plant cover (e.g., presence of shrubs, woody plants) and consequently can house more species or have a more equitable distribution of species (Magurran 1988) than dunes. From the 12 species found in the restinga, ten were also observed in dunes. This suggests that species indentity (or species inventories) is not a good descriptor of environmental differences between coastal dune and restinga habitats. The variation in the abundance of each species may be a component more directly affected by differences between these two habitats.

Despite the dissimilarities in plant cover pattern, the different capture rates of species in the habitats might be associated with the availability of water bodies. The latter, even temporary ones, are more abundant in the restinga habitat. This hypothesis is supported by other observations, verifying that *E. bicolor* and *R. dorbignyi* were more frequently captured in marshes near the study area (M.C.L.M. Oliveira, personal observation).

The presence of two other species, *P. gracilis* and *P. biligonigerus*, also support the hypothesis that the availability of water bodies is a decisive factor for the "success" of a species in each habitat. The capture rate of *P. gracilis* was significantly higher in the restinga (n = 1,154) than in the dune habitat (n = 138). Despite being a common species in southern Brazil and part of Uruguay (Achaval and Olmos 2003), including in man-altered habitats (Rodrigues et al. 2008), the low availability of water bodies in the dunes might be a limiting faction to its presence. On the other hand, *P. biligonigerus*, which has physiological adaptations to prevent desiccation (D. Leidas et al., unpublished data), was relatively well represented in both habitats. Some species directly associated with the presence of water bodies were observed for the first time in the dune habitat in the region (Loebmann and Figueiredo 2004, Gayer et al. 1988): *P. minuta*, *P. falcipes*, *P. biligonigerus* and *L. gracilis*. It should be pointed out that this study was aimed at terrestrial organisms, thus excluding treefrogs, which make up a large portion of the regional diversity of anurans. However, some hylid frogs common in other habitats of the area, such a *Dendropsophus minutus*, *Dendropsophus sanborni* and *Scinax granulatus*, (Loebmann 2005) were not observed, even during field trips (although not systematic) at night to the dunes. This might be due to the ephemeral nature of the water bodies in these areas.

In addition to water availability, climatic factors could act as a complementary filter in the structure of the examined communities. This is in agreement with the higher similarity observed between the assemblage of amphibians of the present study and those reported by Loebmann and Vieira (2005) and Quintela et al. (2009) in geographically close regions. These regions have similar and peculiar climatic characteristics due to the transition between tropical and subtropical climates (Maluf 2000) and similar physical characteristics such as the presence of dunes and marine influence.

The species capable of overcoming these adversities could have less competition, explaining their high abundance, especially *P. biligonigerus* and *O. maisuma*. These species can be key elements in the local ecological dynamics because they can be consumed by a wide variety of predators, varying from a large diversity of birds, reptiles, and aquatic and terrestrial invertebrates (Toledo 2005, Toledo et al. 2007). Despite ecological restrictions imposed by physical aspects of the habitats examined, the number of captures, especially the number of anuran species found in our study (n = 12), is similar to other studies in areas of the Argentinian Pampa (Kacoliris et al. 2006) (n = 11), in Brazilian Pampa - Rio Grande do Sul (n = 14: Loebmann and Vieira 2005; n = 16: Quintela et al. 2009) and Brazilian Atlantic Forest - Santa Catarina (Wachlevski and Rocha 2010) (n =14) (Figura 3). The lower similarity of the assemblage of anuran amphibians of our study to the onde

described by Domenico (2008) in the Atlantic Forest in São Paulo might be mainly due to the wide phytogeographic differences between the two habitats. This result was expected, as more than half of the anuran amphibians are endemic (61.8%) (IUCN 2010), making the Atlantic Forest one of the main hotspots of biodiverisity of the world (Myers et al. 2000).

Our findings revealed the importance of coastal areas adjacent to the shoreline as habitat for a significant portion of the species of southernmost Brazil. In addition, the high number of individuals captured (between 200 and 300% higher than other studies with similar sampling effort; personal observation) shows the importance of the study area in the maintenance of the regional anurofauna. Despite that, coastal dunes and restingas do not receive the same conservation efforts compared to other tropical biomes. Unfortunately, the interface between these habitats and the shoreline is the area under most anthropogenic pressure (Orams 2003, Pereira da Silva 2004), which also occurs throughout the Brazilian coastline. This reinforces the need to establish conservation areas for these types of coastal habitats.

RESUMO

Este estudo teve como objetivo verificar a relação entre o hábitat e a composição de espécies de anuros em ambientes de duna e restinga no extremo sul do Brasil. Estes ambientes foram amostrados entre abril de 2009 e março de 2010 utilizando armadilhas de interceptação e queda, com barreira de contenção. Foram capturados 13.508 indivíduos de 12 espécies de anuros. A riqueza de espécies foi menor nas dunas e dominância foi maior na restinga. Aparentemente, a cobertura vegetal, com menor complexidade, a disponibilidade de água e a maior variação térmica diária nas dunas, atuam como um filtro ambiental para os anuros. Esta hipótese é reforçada pelo fato de que as espécies mais abundantes (*Physalaemus biligonigerus* e *Odonthoprynus maisuma*) se enterram na areia, minimizando esses estresses ambientais. Apesar de estar no bioma Pampa, a comunidade estudada foi mais semelhante às de hábitats costeiros de restinga do sudeste do Brasil do que às de áreas do bioma Pampa. O número de espécies registrado é semelhante ao observado em outros ambientes abertos no Brasil, mostrando a importância de hábitats adjacentes à linha costeira para a manutenção da diversidade de anfíbios anuros no extremo sul do país.

Palavras-chave: Amphibia, dunas costeiras, restinga, nicho.

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