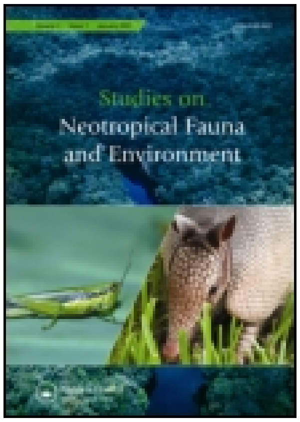

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Beetle (Insecta, Coleoptera) assemblage in a Southern Brazilian *restinga*: effects of anthropogenic disturbance and vegetation complexity

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Restinga is a term used to describe a mosaic of vegetation that occurs in predominantly coastal sandy plains, with physiognomies that range from creeping herbs to forests. In this paper we investigate how the beetle assemblage in a *restinga* habitat responded to anthropogenic disturbance and vegetation complexity. During four seasons in 2008 and 2009, we sampled beetles using pitfall traps at 10 stations along Pântano do Sul Beach, Santa Catarina Island, Brazil. We compared these beetle assemblages to parameters of anthropogenic disturbance and vegetation complexity at each sampling site. The species composition among the beetle assemblages was considerably different and showed high beta diversity. Disturbed vegetation sites had higher diversity and species richness than most of the undisturbed sites. Although correlations were generally weak, the species of Elateridae were positively correlated with disturbance. These results indicate that *restinga* vegetation heterogeneity and Coleoptera diversity are related and thus strengthen the importance of chance in beetle distribution across the beach. Despite the low level of endemism in *restingas*, species found in this habitat should be of greater concern for environmental policies involving Atlantic Forest preservation due to their high diversity.

Restinga é um termo usado para descrever uma vegetação em forma de mosaico que ocorre em planícies predominantemente arenosas, com fisionomias que variam de ervas rasteiras a florestas. Neste artigo nós investigamos se a comunidade de besouros apresenta resposta à antropização e à complexidade da vegetação em ambientes de restinga. Os besouros foram amostrados durante quatro estações usando armadilhas do tipo *pitfall* em dez pontos amostrais na Praia do Pântano do Sul, Ilha de Santa Catarina, Brasil. Também foram medidos parâmetros da antropização e da complexidade da vegetação, usando três transectos para a antropização e um transecto com dez quadrados para a vegetação, em cada ponto amostral. Foram calculadas medidas ecológicas para a comunidade de besouros e as comunidades encontradas em cada ponto amostral e estação do ano foram comparadas. Também correlacionamos os dados ecológicos dos besouros com as medidas ambientais. A similaridade encontrada para as comunidades de besouros foi baixa, e os pontos antropizados apresentaram maior diversidade e riqueza de espécies que a maioria dos pontos não-antropizados. As correlações foram, em geral, fracas, mas Elateridae apresentou correlação positiva com a antropização. A heterogeneidade das restingas e a diversidade de Coleoptera podem ter fortalecido a importância do acaso na distribuição dos besouros ao longo da praia. Apesar do baixo grau de endemismo da restinga, espécies encontradas nestes habitats deveriam receber maior atenção em políticas públicas para a conservação da Mata Atlântica, devido à sua alta diversidade e plasticidade.

Keywords: Atlantic Forest; Brazil; coastal ecosystems; diversity; ecological indicators

Introduction

Beetles can serve as reliable ecological indicators, as they present characteristics such as rapid response to environmental changes, short life-cycles, abundance and wide distribution in a broad range of habitats, ecological importance, and the possibility of easy, and low cost-effective sampling (Brown 1997; McGeoch 1998; Hodkinson & Jackson 2005; Pearce & Venier 2006; Barlow et al. 2007; Gardner, Barlow et al. 2008; Gardner, Hernández et al. 2008; Uehara-Prado et al. 2009). A useful definition of an indicator – in ecology and environmental management – would be "a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals" (Heink & Kowarik 2010). Because the Order Coleoptera is the most diverse known in the world, choosing a focal group (e.g. one or several families or guilds) would expand the chance to capture its individuals with appropriate techniques and thus improve sampling (Didham et al. 1996).

Anthropogenic disturbance can change environmental characteristics at different scales and degrees and under some circumstances increase structural

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†in memoriam

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complexity. Moreover, the "intermediate disturbance hypothesis" predicts local species richness may be maximal at an intermediate level of disturbance (Connell 1978). However, when too much disturbance occurs, complexity decreases and fragmentation begins – effects that may impact individual species differently. The "habitat heterogeneity hypothesis" assumes that structurally complex habitats can offer more niches and diverse ways of exploiting the environment and support higher diversity than simpler ones (MacArthur & MacArthur 1961; Tews et al. 2004; Pacini et al. 2009). In most terrestrial ecosystems the main factor determining heterogeneity and influencing species distribution is vegetation complexity, including plant architecture or structure (Lawton 1983; Brose 2003) and plant taxonomic diversity (Murdoch et al. 1972; Novotny et al. 2006).

One of the most threatened ecosystems of the world, the Brazilian Atlantic Forest is high in biodiversity and is considered a conservation hotspot (Myers et al. 2000; Ribeiro et al. 2009; Tabarelli et al. 2010). According to environmental conditions, the forest is interspersed with open vegetation, e.g. fields and *restingas*, which taken together create the Brazilian Atlantic Forest Complex (Rizzini 1979; Scarano 2002). *Restinga* is a term used to describe a group of ecosystems with distinct floristic and physiognomic plant communities. They occur on predominantly sandy plains that date mostly from the Holocene, on poorly developed soils of marine, fluvial, lacustrine or eolian origin (Falkenberg 1999). The plant communities on these soils form an edaphic and pioneer vegetation complex, covering *c.* 5000 km of Brazilian coastline; physiognomies range from creeping herbs on beaches, to forests on more sheltered locations (Araújo & Lacerda 1987).

In comparison to the neighboring Atlantic Forest *sensu stricto*, the *restingas* and their beetle faunas are poorly studied (Macedo & Grenha 2004; Lopes et al. 2005; Rocha et al. 2007; Vieira et al. 2008). In a comparison between forest *restinga*, shrubby *restinga*, burned *restinga* and pastures, the species assemblages of the families Histeridae (Lopes et al. 2005) and Scarabaeidae (Vieira et al. 2008) showed the greatest dissimilarity in the forest *restinga*, with lower abundance and higher diversity than in other sites. Also, the diversity pattern of dung beetles (Scarabaeinae, Scarabaeidae) in original forest *restinga* was different from reforested *restingas*, which had lower abundance and species richness (Malva I. M. Hernández, personal communication).

In this study we investigate if the beetle assemblage as a whole – as well as particularly abundant beetle families – responded to anthropogenic disturbance and vegetation complexity in *restinga* habitats. We also tested for seasonal patterns in the beetle community in order to investigate which species were evenly distributed year-round and which had a maximum abundance or occurrence restrained to a specific season of the year. We hypothesize that vegetation complexity affects beetle communities within *restingas*, and we predict that anthropogenic disturbance has the greatest impact in modifying beetle species composition.

Materials and methods

The study areas

The samplings were taken at Pântano do Sul Beach (between 27°46′59″ S, 48°30′35″ W and 27°47′11″ S, 48°31′36″ W), in a region with Atlantic Forest remnants in the southern portion of Santa Catarina Island, Florianópolis, Santa Catarina State, Brazil (Figure 1). The annual average temperature is approximately 20°C, with January being the hottest month (mean: 24°C) and July the coolest (mean: 16°C). The average rainfall of 1500 mm is distributed evenly throughout the year. Pântano do Sul Beach is 3550 m long, of which 2150 m is accompanied by dunes. The most disturbed areas of this location are the residential area, deforested more than a century ago, initially to provide space for manioc agriculture and later replaced by residences and local commerce (Figure 1C).

Beetle seasonal sampling

We sampled beetles over four seasons (winter: July 2008; spring: October 2008; summer: January 2009; autumn: April 2009) with pitfall traps. These traps were 300 ml plastic cups filled with 50 ml of a solution of water (*c.* 90%), 3% formaldehyde (*c.* 10%), and a few drops of detergent. The traps were buried in ground level near vegetation for one week. The extension of the dune was divided into 10 sampling stations (S1–S10) 200 m from each other. We used five traps per sampling station (Figure 2A), at least 2 m from each other, with a total of 200 traps (50 per season). Adult beetles captured in these traps were dried, pinned, sorted into morphospecies (called "species" from now on), and identified at "Laboratório de Entomologia Geral do Instituto Biológico de São Paulo" to the lowest taxonomic level possible. Voucher specimens were deposited at "Coleção Entomológica do Centro de Ciências Biológicas da Universidade Federal de Santa Catarina".

Environmental measurements

Environmental data were collected in autumn (March–April 2009). The disturbance level of each sampling station was estimated in three transects

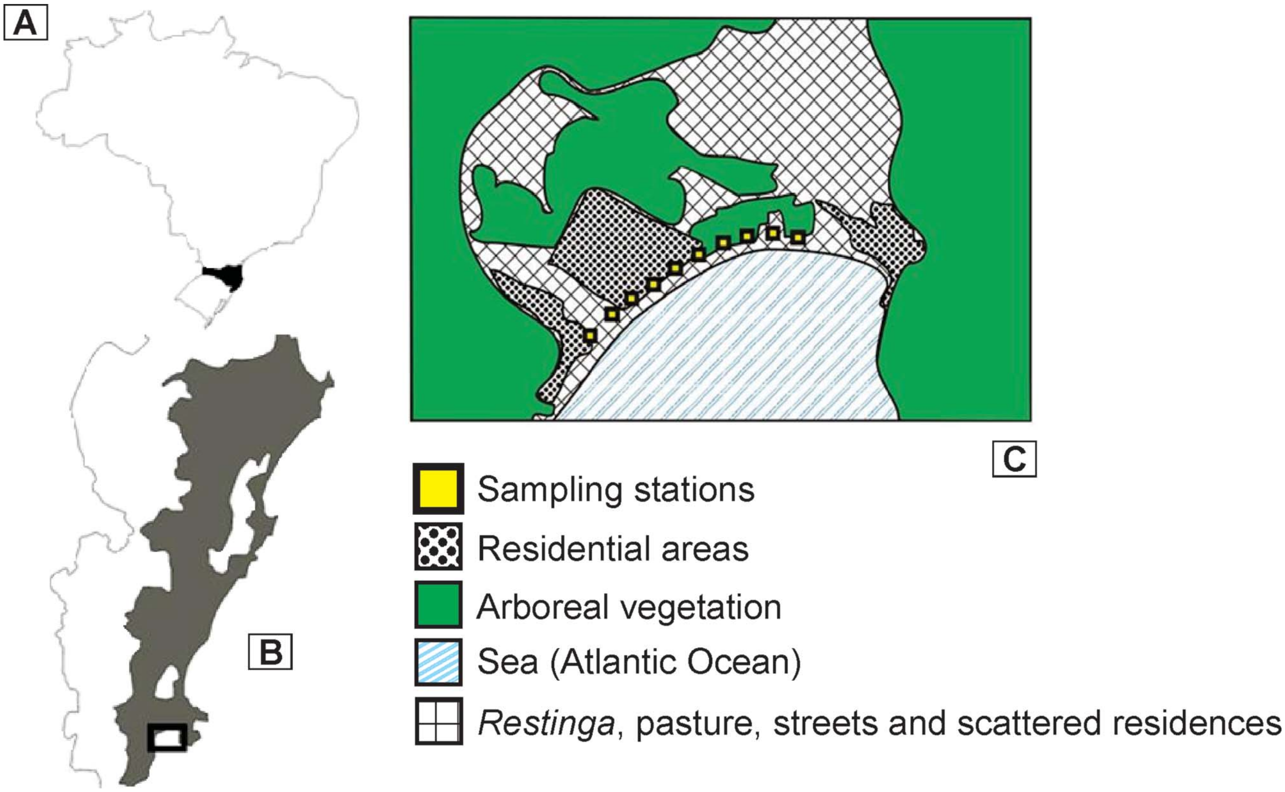

Figure 1. (Colour online) Location of the studied area. (A) Santa Catarina State in map of Brazil. (B) Santa Catarina Island, with a square over Pântano do Sul Beach. (C) Sketch of Pântano do Sul Beach.

100 m long (starting from the beginning of the dune's elevation and perpendicular in relation to the beach), 20 m from each other (Figure 2B). We registered the following impacts in a 10-m wide area: (1) rubble (construction refuse); (2) trash (any disposed material, except rubble); (3) buildings; and (4) streets. We divided the adjacent area of each transect into three sections: 0–30 m, 30–100 m, and more than 100 m (post-transect). In most cases, impact was classified according to the quantity of each impacting factor, with values between 0 (no impact) to 3 (high impact). Streets were considered to be high impact regardless of their size, while trash, rubble and buildings were attributed a value 1 for one to five items, 2 for six to ten items, and 3 for more than 10 items. In the 0–30 m area we also searched for trails and dune escarpment, both considered low impact (1) regardless of their extension.

The vegetation of each sampling station was analyzed by tracing a transect parallel to the beach, 20 m long and 30 m apart from the beginning of the dune's elevation (Figure 2C). Ten quadrats of 0.7 × 0.7 m were arranged 2 m from each other and 1 m from the transect, alternating sides. Plant species found in each plot were collected and identified, and the following measures were estimated: (1) the percentage coverage of each plant species; (2) the percentage of uncovered soil; (3) the percentage of leaf-litter above the soil, and (4) the maximum vegetation height. Percentages were expressed in classes (1: 0–5%; 2: 6–15%; 3: 16–25%; 4: 26–50%; 5: 51–75%; 6: 76–100%). All plant species found on the beach were collected, identified and deposited in the reference collection at "Laboratório de Ecologia Vegetal da Universidade Federal de Santa Catarina".

Data analysis

We first counted the number of specimens and species of beetles in each trap for analysis of variance, which was followed by the Tukey test. The next step was to calculate measurements of estimated richness (Jackknife 1 method), diversity (H′: Shannon–Wiener index), equitability (Pielou index), and similarity among stations and seasons (Bray–Curtis method). We also constructed species accumulation curves to analyze spatial and seasonal distribution.

In order to analyze the disturbance level, we calculated the mean value of the three transects for each sampling station. The Shannon–Wiener diversity index was calculated for vegetation using each species' coverage percentage data. The mean value of the

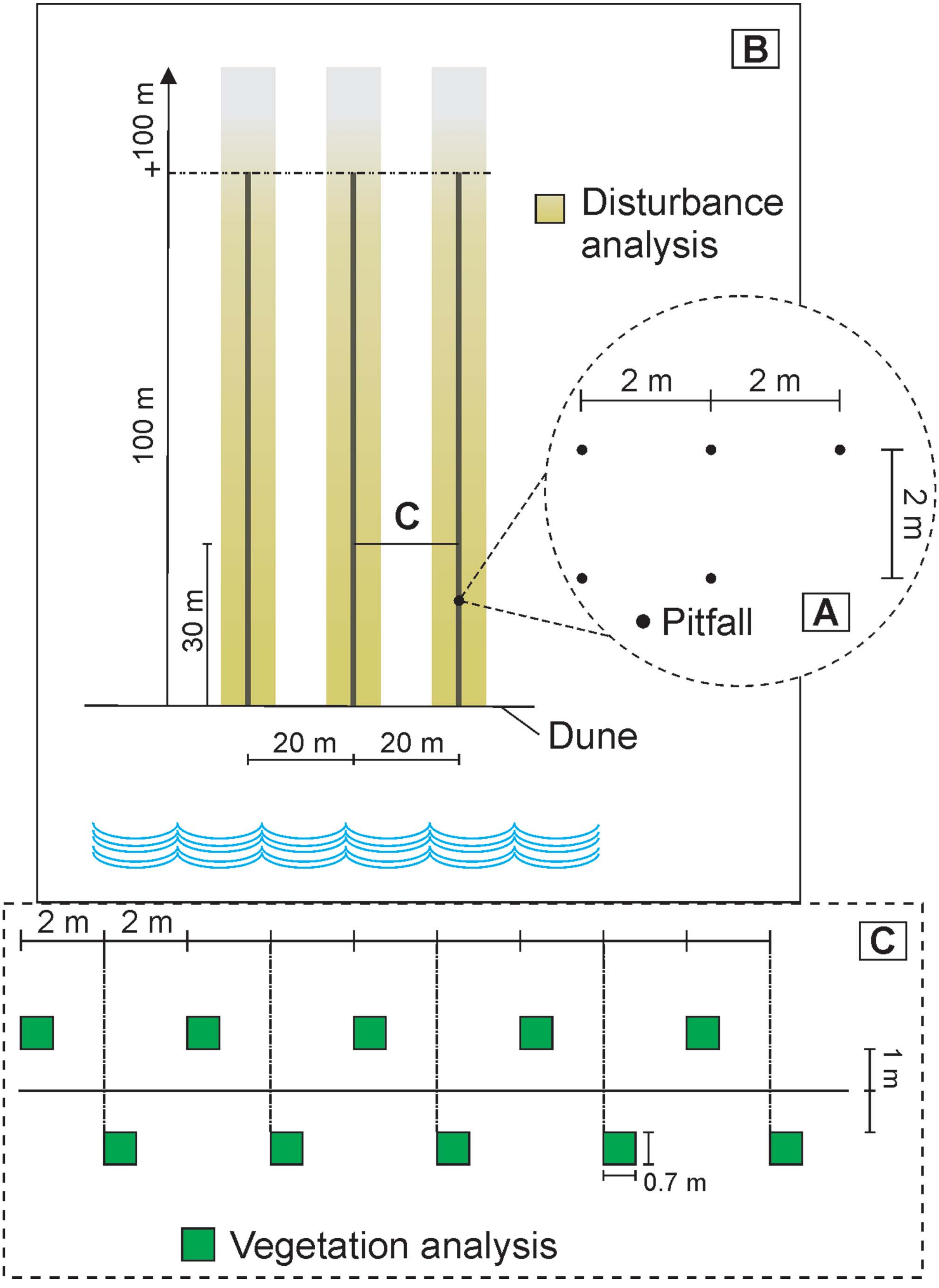

Figure 2. Study methodology at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, Brazil. (A) Beetle sampling. (B) Disturbance analysis. (C) Vegetation analysis.

vegetation parameters obtained from the 10 quadrats was calculated for each sampling station. We used principal component analysis (PCA) to analyze environmental data (disturbance and vegetation); the first and second PCA scores, along with other environmental measurements, were used in Spearman correlations with the beetles' ecological measurements.

Results

We collected 799 adult beetles belonging to 136 species and grouped into 22 families (Table 1). Of the total species, only six had 20 or more individuals, while 11 species had more than 10 individuals, 30 species were found in more than two traps (Appendix 1), 89 were found in a single trap ("uniques", Appendix 2), and 85 were recorded by one specimen only ("singleton"). These data resulted in an estimated beetle species richness of 225.

The Staphylinidae were best represented, with 306 individuals (38%), and the highest number of species (29 species; 21%). Individuals of Nitidulidae (N = 120) and Anthicidae (N = 72) were next in abundance. Curculionidae and Chrysomelidae showed high species richness (S = 22 and S = 11, respectively). Other remarkable families were Elateridae (N = 62; S = 8), Carabidae (N = 57; S = 9), and Tenebrionidae (N = 33; S = 7) (Table 1). The 10 most abundant species represented nearly 70% of beetles sampled. Overall, small size made beetle identification a demanding task. Body length of beetle species found in more than one trap were measured, and almost 70% of them were less than 5 mm long, and nearly 40% were less than 3 mm long, including the four most abundant species (Appendix 1).

Table 1. Abundance (N) and species richness (S) by family of beetles collected with pitfall traps in the *restinga* vegetations at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil, July 2008 through April 2009. The total includes four unidentified coleopterans.

Family	N	S
Staphylinidae	306	29
Nitidulidae	120	4
Anthicidae	72	2
Elateridae	62	8
Carabidae	57	9
Tenebrionidae	33	7
Scarabaeidae	27	8
Curculionidae	24	22
Chrysomelidae	23	11
Scydmaenidae	20	9
Corylophidae	9	1
Latridiidae	9	1
Ptiliidae	8	2
Coccinellidae	7	6
Mordellidae	5	3
Scirtidae	3	1
Histeridae	3	3
Hydrophilidae	2	2
Noteridae	2	1
Anobiidae	1	1
Bolboceratidae	1	1
Phalacridae	1	1
Total	799	136

Seasonal distribution

Highest richness was recorded in spring (October), followed by summer (January), autumn (April), and winter (July) (Figure 3). The sampled richness is likely lower than actual richness for all seasons as indicated by the species accumulation curves. Significantly more species were recorded in spring than in autumn and winter. Abundance was significantly different between seasons ($F = 7.59$; df = 3, 196; $p < 0.01$): spring was higher in abundance than summer and autumn; winter was also higher in abundance than autumn (Table 2). The estimated richness was 117 for spring, 81 for summer, 72 for autumn and 61 for winter.

The beetle species similarity among different vegetation communities found within each of the four seasons was low. Winter was the least similar to all others (25% similarity), and summer and autumn were more similar, with only 40%. Winter also showed less diversity ($H' = 1.74$) than other seasons (spring: $H' = 2.98$; summer: $H' = 3.44$; autumn: $H' = 3.47$) (Table 2). Only eight species were found throughout the entire year: Aleocharinae indet. 1 (Staphylinidae); cf. *Stelidota* sp. 1 (Nitidulidae); *Notoxus* sp. 1 (Anthicidae); *Bledius* sp. 1 (Staphylinidae); Elateridae indet. 1; *Tetragonoderus* (*Peronoscelis*) *variipennis* (Chaudoir, 1876) (Carabidae); cf. *Euconnus* sp. 1 (Scydmaenidae); and Alticini indet. 2 (Chrysomelidae).

Environmental characterization

The most disturbed sampling stations were S8, S10 and S7, while S4 was the least disturbed (Table 3). S1–3 and S10 (especially S2) presented the low vegetation characteristic of herbaceous *restinga*. S4, which had the highest diversity of plant species ($H' = 3.25$) and the tallest vegetation (in addition to epiphytes above the vegetation and soil completely covered with leaf litter), can be considered the most developed shrubby vegetation, due to its location in a sheltered slope protected from the wind. The other sampling stations presented shrubby *restinga*, and S9 had a great amount of leaf litter covering the soil. S7 had the highest number of plant species (S = 89), as well as the highest number of invasive exotic plant species (S = 19); it was also higher in diversity

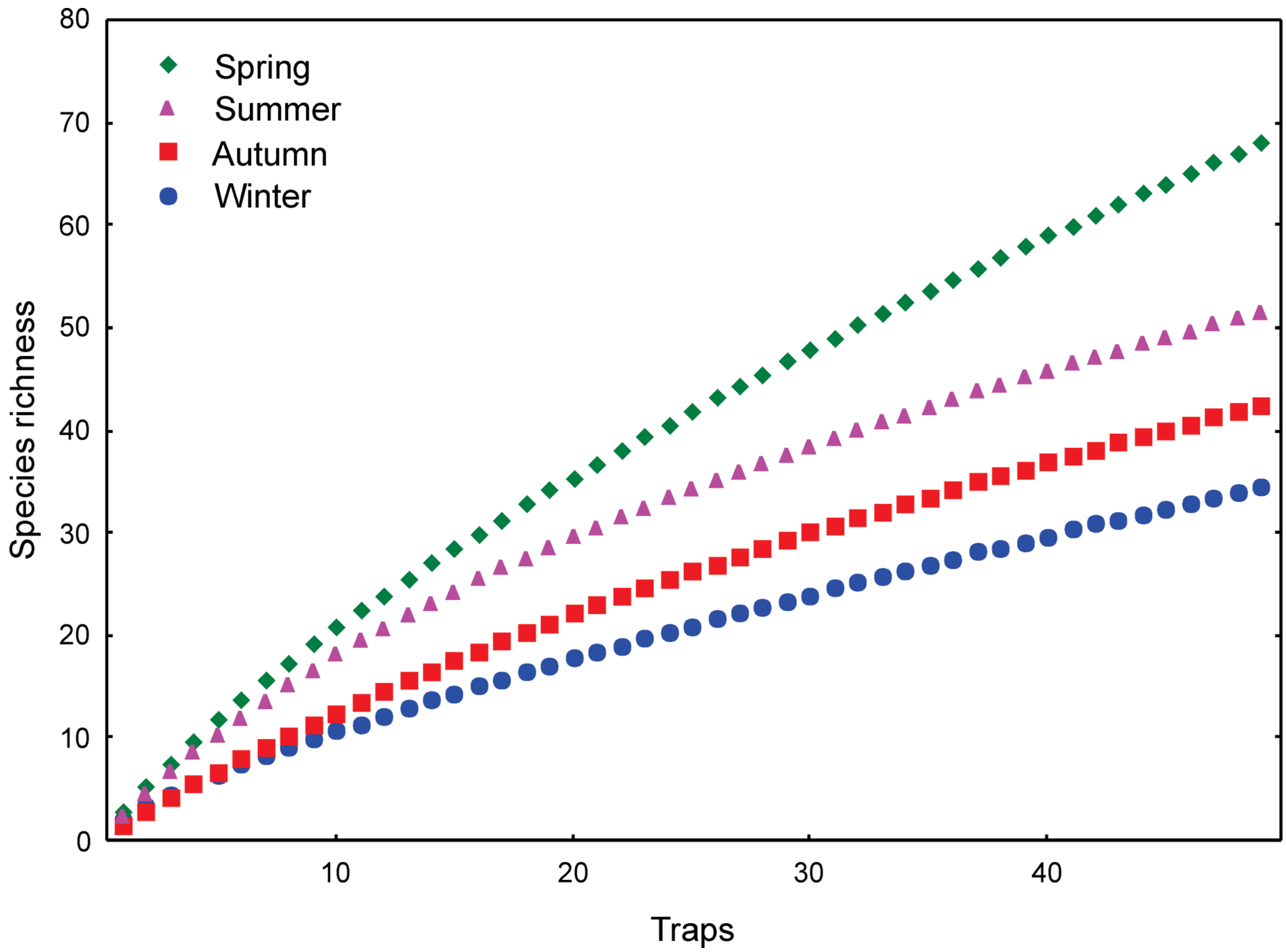

Figure 3. Species accumulation curves of beetles found in each season of the year at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil. Winter, July 2008; spring, October 2008; summer, January 2009; autumn, April 2009.

(H′ = 3.13) than all stations, excepting S4. S1 was also high in species richness (S = 83) and in invasive exotic species richness (S = 12). S8, however, had the highest proportion of invasive exotic plant species (26% of species found) (Table 3).

The PCA analysis showed high importance for buildings (0.43) and streets (0.43) on the main axis (PC1 explained 34% of variation); on the second axis (PC2, 32% of variation), the main variables were percentage of leaf litter (–0.41) and maximum vegetation height (–0.40). For this reason, we associated the first axis with anthropogenic disturbance and the second axis with vegetation complexity (Figure 4).

Spatial distribution

S4 presented higher abundance (N = 154) and species richness (S = 39) than all the others, followed by S8 (N = 119; S = 33) and S9 (N = 115; S = 29). S3 had the lowest abundance and species richness (N = 27; S = 11), with each species belonging to a different family. S2 (N = 39; S = 17) and S6 (N = 43; S = 15) were also low in abundance and species richness, with S6 having the lowest number of families represented. S7 had the highest diversity (H′ = 2.87), while S3 had the lowest (H′ = 1.80) (see Table 2).

The similarity between sampling stations was 20–45% (Figure 5). S4 was the most divergent, followed by S8 and S3. The other stations were approximately 30% similar. A group formed by S1, S2, S5, S6, and S9 presented at least 35% similarity. Representatives of only two families, Staphylinidae and Elateridae, were found in every sampling site, but no species was trapped in every site.

The sampling points had significantly different abundance (F = 3.06; df = 9, 190; $p < 0.01$) and species richness values (F = 5.69; df = 9, 190; $p < 0.01$). S4 was more abundant than S2, S3, and S6. S4 was also highest in species richness and differed from all other stations with the exception of S7–S9. S7–S9 only differed from S3.

Table 2. Ecological measurements of the beetle assemblage collected with pitfall traps at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil. Data from 10 sampling stations and four seasons: winter: July 2008; spring: October 2008; summer: January 2009; autumn: April 2009.

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total
Winter	N	3	8	15	52	16	15	8	16	59	36	228
	S	3	3	3	14	3	5	4	7	10	10	35
	J′	1.00	0.67	0.44	0.66	0.55	0.76	0.88	0.88	0.42	0.60	0.49
	H′	1.10	0.74	0.49	1.74	0.60	1.23	1.21	1.72	0.96	1.39	1.74
Spring	N	49	5	5	48	33	14	45	66	30	26	321
	S	10	5	5	17	9	7	12	13	9	11	69
	J′	0.58	1.00	1.00	0.77	0.79	0.84	0.76	0.50	0.80	0.78	0.70
	H′	1.34	1.61	1.61	2.19	1.74	1.64	1.90	1.28	1.77	1.88	2.98
Summer	N	11	16	6	32	15	9	20	29	17	8	163
	S	9	10	4	10	10	7	14	13	10	8	52
	J′	0.98	0.93	0.90	0.84	0.94	0.94	0.96	0.86	0.94	1.00	0.87
	H′	2.15	2.13	1.24	1.94	2.15	1.83	2.53	2.20	2.17	2.08	3.44
Autumn	N	7	10	1	22	2	5	12	8	9	11	87
	S	6	5	1	12	2	5	10	7	7	7	43
	J′	0.98	0.91	–	0.93	1.00	1.00	0.96	0.98	0.97	0.91	0.92
	H′	1.75	1.47	–	2.30	0.69	1.61	2.21	1.91	1.89	1.77	3.47
Total	N	70	39	27	154	66	43	85	119	115	81	799
	S	20	17	11	39	18	15	32	33	29	26	136
	J′	0.71	0.90	0.75	0.70	0.74	0.88	0.83	0.66	0.67	0.75	0.68
	H′	2.13	2.56	1.80	2.58	2.14	2.37	2.87	2.32	2.26	2.45	3.35

S1–10: sampling stations; N: abundance; S: species richness; J′: Pielou equitability index; H′: Shannon–Wiener diversity index.

Table 3. Environmental parameters from Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil. Anthropogenic disturbance was analyzed in three transects per sampling station, and vegetation complexity in 10 quadrats per station (mean values shown).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Anthropogenic disturbance										
Edifications	2.33	–	–	–	3.33	6.00	6.67	8.33	4.00	8.00
Streets	–	–	–	–	6.00	6.00	9.00	8.00	3.00	7.00
Rubble	2.67	1.33	1.67	–	–	–	–	0.33	0.67	1.00
Trash	2.67	2.67	2.00	1.33	2.33	1.00	1.00	1.67	2.00	2.33
Scarpment	–	–	0.67	0.67	0.67	0.67	1.00	0.33	1.00	0.33
Trails	0.67	0.33	0.67	1.00	1.00	0.67	–	–	–	–
Vegetation complexity										
Plant H′	2.55	2.90	3.03	3.25	2.63	2.06	3.13	2.05	2.63	2.16
Height (m)	0.56	0.36	0.73	1.45	1.13	1.07	1.04	1.18	0.99	0.70
Litter (%)	38	20	54	85	61	49	29	48	80	32
Soil (%)	23	49	25	–	23	15	26	6	–	27
S quadrat	8	9	10	12	8	6	10	6	8	5
S total	83	44	60	62	74	77	89	62	53	52
S exotic	12	1	2	2	5	8	19	16	4	11
S ruderal	8	8	6	5	6	7	9	9	7	6

S1–10: sampling stations; Plant H′: Shannon–Wiener diversity index for vegetation; Height: maximum vegetation height; Litter: percentage of leaf-litter covering the soil; Soil: percentage of uncovered soil; S quadrat: number of plant species by quadrat method; S total: number of plant species by scanning method; S exotic: number of invasive exotic plant species (included in 'S total'); S ruderal: number of ruderal plant species (included in 'S total').

Families Carabidae and Chrysomelidae could be correlated with one environmental variable each, while Elateridae correlated positively with several variables related to disturbance, including the PC1 score (anthropogenic disturbance) ($r(S) = 0.77$; $p < 0.05$) (Table 4).

Discussion

The *restinga* showed high alpha and beta diversity of beetle species – possibly some species exclusive to this kind of habitat – yet disturbance facilitated the occurrence of some species that originally did not occur in this habitat. This interpretation is supported by

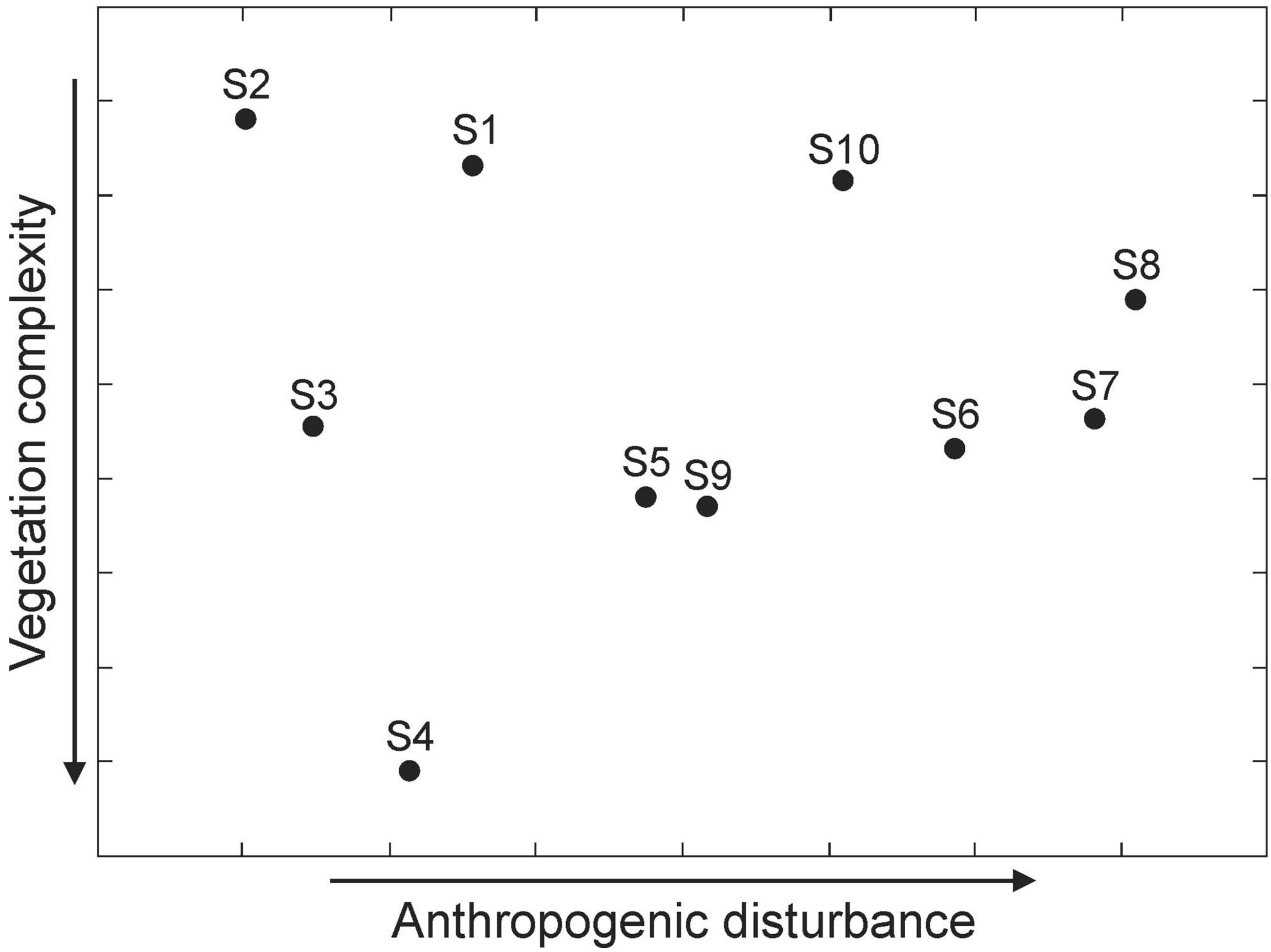

Figure 4. Principal component analysis (PCA) of environmental variables measured at 10 sampling stations at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil, in March and April 2009. S1–10, sampling stations.

the high species richness in the most disturbed sampling stations (near the larger residential area). It was higher than that of all other sites with the exception of site 4, a sheltered location with high vegetation complexity. Also, a known invasive exotic beetle species (*Lagria villosa* Fabricius, 1783, Tenebrionidae) was found as a singleton at a disturbed station. A positive shift in beetle diversity in disturbed sites has also been observed by other authors (Driscoll & Weir 2005; Ganho & Marinoni 2005; Marinoni & Ganho 2006). However, this pattern was not observed for *restinga* beetles in other studies (Lopes et al. 2005; Vieira et al. 2008; Malva I. M. Hernández, personal communication) and may actually be biased by the spatial scale in which disturbance has been measured (Hill & Hamer 2004). The high beetle diversity we found near residences in the area studied can be explained by exotic species introduction and the higher supply of detritus to nourish Elateridae species (Marinoni et al. 2003).

Although the studied area is located in a subtropical region, the seasonal patterns observed for the beetle community are similar to patterns described for the tropics in relation to the presence of beetle species active as adults in any season of the year (Wolda 1988). Additionally, in our study, spring had the highest number of species. The sampled Coleoptera showed high seasonality, related to increase in temperature and photoperiod. For dry environments, like *restingas*, it is also possible that abiotic factors could be more important for beetle species distribution than biotic factors (Wenninger & Inouye 2008). Also, anthropogenic disturbance in the studied area can also be more intense in summer (tourism) and winter (mullet fishing) (Castellani et al. 2007).

Restingas are composed of vegetation arranged in mosaics (Falkenberg 1999). Accordingly, the different areas may have distinct structure and diversity (Scarano 2002). Beetles, like other insects, are often highly associated with microhabitats (Barton et al.

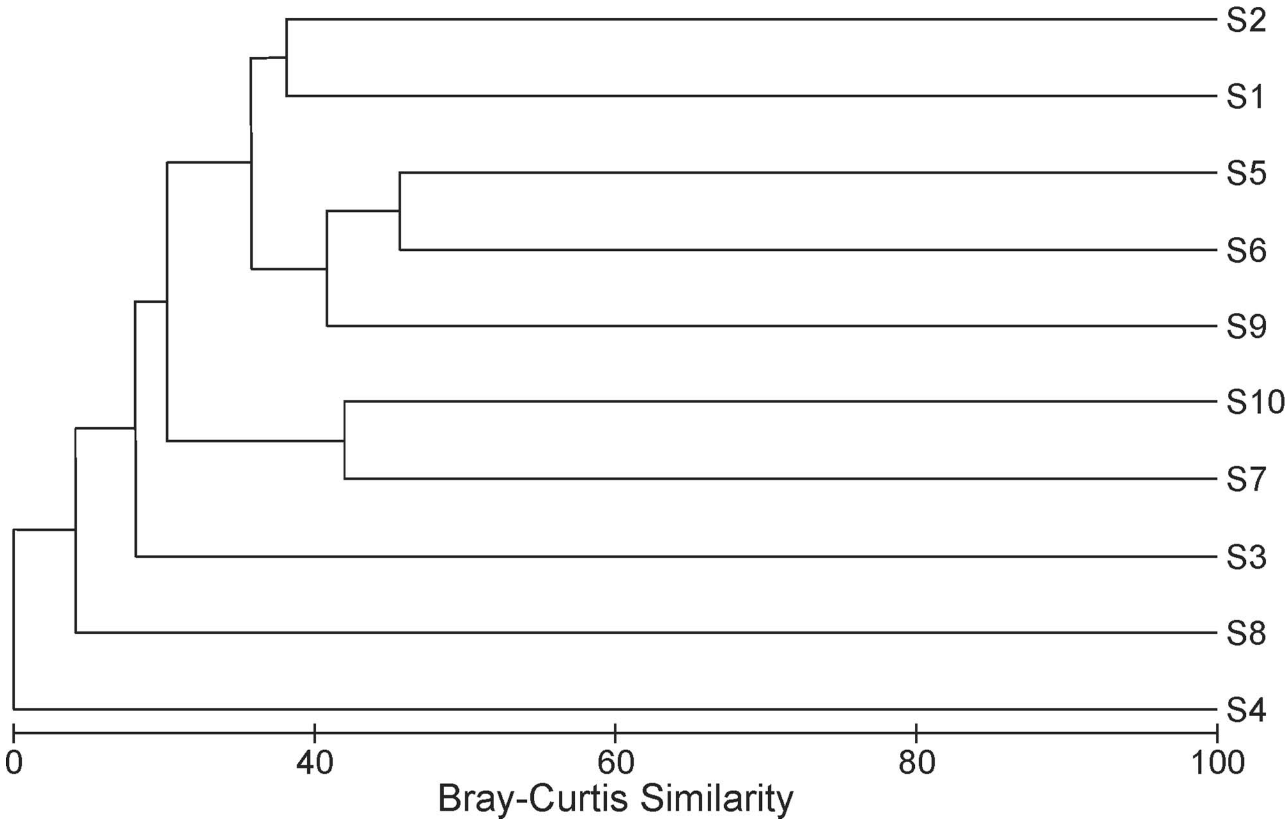

Figure 5. Similarity cluster of beetle sampled at 10 stations at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil. S1–10, sampling stations; vertical line represents 35%.

Table 4. Correlation between beetle families found at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil, and environmental factors. Families without significant correlation were omitted; values in bold are significant ($p < 0.05$).

		Elateridae N	Elateridae S	Carabidae N	Chrysomelidae N
Disturbance	PC1 score	**0.774**	0.535	0.332	−0.151
	Trails	**−0.729**	−0.614	**−0.713**	−0.198
	Edifications	**0.821**	**0.644**	0.330	0.006
	Streets	**0.754**	0.384	0.242	0.189
	S ruderal	**0.760**	0.576	0.575	−0.119
	S exotic	**0.875**	0.568	0.395	0.019
Vegetation	Soil (%)	0.245	−0.171	−0.189	**0.709**
	Litter (%)	**−0.671**	−0.239	−0.178	−0.447
	Plant H′	−0.486	**−0.732**	0.059	0.385

N: abundance; S: species richness; PC1 score: anthropogenic disturbance; S ruderal: number of ruderal plant species; S exotic: number of invasive exotic plant species; Soil: percentage of uncovered soil; Litter: percentage of leaf-litter covering the soil; Plant H′: Shannon–Wiener diversity index for vegetation.

2009) and sometimes with resources derived from particular plant genera (Lewinsohn et al. 2005; Novotny & Basset 2005; Scherer & Romanowski 2005). This specialization could help explain the great dissimilarity between sampling stations. Also, the results in S4, the more pristine shrub vegetation area, show the relevance of vegetation complexity on species settlement (Lassau et al. 2005).

Brazilian laws protect *restingas* as part of the Atlantic Forest and also as permanent preservation areas, yet few are protected as conservation units (Barbosa et al. 2004; Rocha et al. 2007). Therefore, they are being degraded along the entire Brazilian shore, chiefly by urbanization, but also by tourism, agricultural and livestock activities and exotic species introduction (Zamith & Scarano 2006). Despite the low endemism level of *restingas*, species found in these environments, most which originate in nearby forest (Rizzini 1979; Cerqueira et al. 1990; Falkenberg 1999; Graipel et al. 2001; Naka et al. 2002), show high plasticity to extreme and rapid changes (Scarano 2002). This is especially true of species occurring near the sea, probably due to the strong winds, high salinity, lack of water (or excess water in flooded areas), low nutrient supply, sand burial, and excessive heat and luminosity (Bresolin 1979; Castellani & Santos 2005, 2006; Maun 2009). These plastic species should be of greater concern in environmental policies involving Atlantic Forest preservation, as in addition to being endemic to the Atlantic Forest Complex, such species that are able to deal with environmental changes are of special interest in global warming times (Scarano 2009).

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Appendix 1. Morphospecies of beetles found in more than one pitfall trap at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil.

Morphospecies	N	Size (mm)
Staphylinidae		
Aleocharinae indet. 1	183	< 3
Bledius sp. 1	64	< 3
Staphylinidae indet. 2	3	< 3
Staphylinidae indet. 3	7	5–10
Staphylinidae indet. 6	2	> 10
Staphylinidae indet. 7	6	3–5
Staphylinidae indet. 12	2	< 3
Staphylinidae indet. 13	5	< 3
Staphylinidae indet. 19	10	< 3
Pselaphinae indet. 2	3	< 3
Pselaphinae indet. 4	2	< 3
Nitidulidae		
cf. *Stelidota* sp. 1	116	< 3
Nitidulinae indet. 1	2	3–5
Anthicidae		
Notoxus sp. 1	70	< 3
Tenebrionidae		
Epitragopsis semicastaneus	20	5–10
Allecula sp. 1	4	5–10
Scotobiini indet.1	4	> 10
cf. *Phaleria* sp. 1	2	5–10
Elateridae		
Elateridae indet. 1	20	3–5
Conoderus spinosus	17	> 10
Esthesopus sp. 1	5	5–10
Horistonotus sp. 2	15	3–5
Ischiodontus sp.1	2	5–10
Carabidae		
Tetragonoderus (*Peronoscelis*) *variipennis*	18	5–10
Lebiini indet. 1	16	3–5
Lebiini indet. 2	2	3–5
Selenophorus sp. 1	8	5–10
Megacephala brasiliensis	6	> 10
Cnemalobus cf. *striatus*	3	> 10
Clivinini indet. 1	2	5–10
Scydmaenidae		
cf. *Euconnus* sp. 1	11	< 3
Scydmaenidae indet. 4	2	< 3
Chrysomelidae		
Alticini indet. 2	10	< 3
cf. *Colaspis* sp. 1	3	3–5
Chrysomelidae indet. 1	2	3–5
Scarabaeidae		
Ataenius sp. 2	10	3–5
Ataenius sp. 1	8	3–5
Canthon conformis	3	5–10
Latridiidae		
Melanophthalma sp. 1	9	3–5
Corylophidae		
Corylophidae indet. 1	9	< 3
Ptiliidae		
Ptiliidae indet. 2	5	< 3
Ptiliidae sp. 1	3	< 3
Scirtidae		
cf. *Scirtes* sp. 1	3	< 3
Mordellidae		
Mordellistenini indet. 3	3	3–5

(*Continued*)

Appendix 1. (Continued).

Morphospecies	N	Size (mm)
Noteridae		
Noteridae indet. 1	2	< 3
Curculionidae		
Scolytinae indet. 7	2	< 3
Scolytinae indet. 12	2	< 3
Scydmaenidae		
Scydmaenidae indet. 4	2	<3

N: abundance

Appendix 2. Morphospecies of beetle found in only one trap ("uniques") at Pântano do Sul Beach, Santa Catarina Island, Santa Catarina State, southern Brazil.

Morphospecies	N
Coccinellidae	
Coccinellidae indet. 1	1
Coccinellidae indet. 2	1
Coccinellidae indet. 3	1
Coccinellidae indet. 4	2
Cryptolaemus montrouzieri	1
Eriopis connexa	1
Mordellidae	
Mordellistenini indet. 1	1
Mordellistenini indet. 2	1
Scarabaeidae	
Dichotomius sericeus	2
Ataenius sp. 3	1
Dichotomius ascanius	1
Dichotomius sp. 1	1
Dichotomius sp. 2	1
Anthicidae	
Lagrioida sp. 1	2
Anobiidae	
Petalium sp. 1	1
Staphylinidae	
Staphylinidae indet. 1	1
Staphylinidae indet. 4	1
Staphylinidae indet. 5	1
Staphylinidae indet. 8	1
Staphylinidae indet. 9	1
Staphylinidae indet. 10	1
Staphylinidae indet. 11	1
Staphylinidae indet. 14	1
Staphylinidae indet. 15	2
Staphylinidae indet. 16	1
Staphylinidae indet. 17	1
Staphylinidae indet. 18	1
Staphylinidae indet. 20	1
Staphylinidae indet. 21	1
Staphylinidae indet. 22	1
Pselaphinae indet. 1	1
Pselaphinae indet. 3	1
Scaphidiinae indet. 1	1
Scydmaenidae	
Scydmaenidae indet. 1	1
Scydmaenidae indet. 2	1
Scydmaenidae indet. 3	1
Scydmaenidae indet. 5	1
Scydmaenidae indet. 6	1
Scydmaenidae indet. 7	1
Scydmaenidae indet. 8	1

(*Continued*)

Appendix 2. (Continued).

Morphospecies	N
Phalacridae	
Phalacridae indet. 1	1
Chrysomelidae	
Alticini indet. 1	1
Alticini indet. 3	1
Alticini indet. 4	1
Alticini indet. 5	1
Alticini indet. 6	1
Bolboceratidae	
Bolbapium paralucidulum	1
Carabidae	
Carabidae indet. 1	1
Lebiini indet. 3	1
Nitidulidae	
Carpophilinae indet. 1	1
Colopterus sp. 1	1
Curculionidae	
Curculionidae indet. 1	1
Curculionidae indet. 2	1
Curculionidae indet. 3	1
Curculionidae indet. 4	1
Curculionidae indet. 5	1
Curculionidae indet. 6	1
Curculionidae indet. 7	1
Curculionidae indet. 8	1
Scolytinae indet. 1	1
Scolytinae indet. 2	1
Scolytinae indet. 3	1
Scolytinae indet. 4	1
Scolytinae indet. 5	1
Scolytinae indet. 6	1
Scolytinae indet. 8	1
Scolytinae indet. 9	1
Scolytinae indet. 10	1
Scolytinae indet. 11	1
Scolytinae indet. 13	1
Scolytinae indet. 14	1
Elateridae	
Elateridae indet. 2	1
Esthesopus sp. 2	1
Horistonotus sp. 1	1
Chrysomelidae	
Eumolpinae indet. 1	1
Megacerus reticulatus	1
Hispinae indet. 1	1
Tenebrionidae	
Falsomycterus sp. 1	1
Lagria villosa	1
Lagriinae indet. 1	1
Histeridae	
Histeridae indet. 1	1
Histeridae indet. 2	1
Histeridae indet. 3	1
Hydrophilidae	
Hydrophilidae indet. 1	1
Hydrophilidae indet. 2	1
Coleoptera indet. 1	1
Coleoptera indet. 2	1
Coleoptera indet. 3	1
Coleoptera indet. 4	1
Total species	89
Total specimens	93

N: abundance.