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Lichen community versus host tree bark texture in an urban environment in southern Brazil

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ABSTRACT – We investigated the changes in lichen community structure (vertical distribution and thallus size) in relation to host tree availability for lichen establishment in urban areas. Lichens were mapped on 300 phorophytes distributed in 30 sampling stations in order to verify differences in the vertical distribution of species and thallus size versus host tree characteristics. Significant differences were observed in vertical distribution, considering lichen richness and abundance. This study reported the influence of host trees, especially tree diameter and bark texture, on epiphytic lichen communities in an urban area.

Keywords: corticolous, specialist species, vertical distribution

RESUMO – **Estrutura da comunidade liquênica versus superfície da casca dos forófitos em ambiente urbano, no sul do Brasil**. Neste trabalho, investigamos as modificações na estrutura da comunidade liquênica (distribuição vertical e tamanho de talo liquênico) em relação à disponibilidade de forófitos para o estabelecimento dos liquens na área urbana. Os liquens foram mapeados em 300 forófitos distribuídos em 30 estações de amostragem, a fim de verificar as diferenças na distribuição vertical das espécies e no tamanho do talo dos liquens em relação às características dos forófitos. Diferenças significativas foram observadas quanto à distribuição vertical considerando a riqueza e abundância dos liquens. Este estudo demonstra a influencia dos forófitos, principalmente do diâmetro e da textura da casca sobre a comunidade de liquens epífitos em área urbana.

Palavras-chave: corticícolas, distribuição vertical, espécies especialistas

INTRODUCTION

Lichens are symbiotic organisms known as biological indicators, widely used to evaluate urban areas and forests, and are also pioneers in the colonization of different environments (Hawksworth & Rose 1976, McCarthy *et al*. 2009). However, even slight environmental changes could lead to substantial modifications in spatial distribution of lichen diversity (Wolseley *et al*. 2006, Pinho *et al*. 2012).

Environmental changes may cause many effects to lichen communities, as inhibition of growth and development of thallus, changes in the metabolic processes, and anatomical and morphophysiological changes (Glavich & Geiser 2008). Factors such as substrate features (Schmidt *et al*. 2001, Fritz 2009), macro and micro nutrient composition (Hawksworth 1975), bark pH (Brodo 1973, Van Herk 2001), and local luminosity and humidity (Martinez *et al*. 2006) also affect the distribution and establishment of the lichenized mycota. The vertical distribution of species in phorophytes is a determining aspect for lichens (Marcelli 1996) and a remarkable parameter to evaluate differences in the community structure (Cornelissen & Ter Steege 1989, Komposch & Hafellner 2000, Normann *et al*. 2010). Generalist species colonizing undifferentiated hosts tend to have a wide spatial distribution along the trunk, while specialist lichen species have a limited distribution range (Valencia & Ceballos 2002). Climate changes, atmospheric pollution, green areas fragmentation, and other environmental changes may also affect lichen communities, due to the physiological response of each individual. Such changes have been directly influencing lichens over the years, changing their habitats or the interaction of each specimen with other organisms (Insarov & Schroeter 2002, Aptroot & Van Herk 2007, Käffer *et al*. 2011).

In Brazil, few studies relate lichen community structure to host tree structure, and the existing ones are restricted to non-urban areas (Marcelli 1992, Cáceres *et al*. 2008, Fleig & Grüninger 2008, Käffer *et al*. 2009, 2010, Martins & Marcelli 2011). Studies carried out in urban areas correlate changes on lichen community structure with environmental pollution; however, habitat fragmentation, host tree structure, and the presence of different microclimates may also influence the establishment of some lichen species in large cities.

Therefore, our hypothesis is that the characteristics of the host trees, mainly those from more disturbed urban areas, influence the structure of lichen community, especially species vertical distribution and average size of the lichen thallus. Thus, the objective of this study is to characterize the structure of lichen communities in relation to host tree structure in different areas of the city of Porto Alegre. With this purpose, we analyzed lichen vertical distribution, presence of specialist species in the height levels and the average size of lichen thalli versus some host tree patterns, as diameter at breast height (DBH), bark pH and texture of bark.

MATERIALS AND METHODS

Study Area

The city of Porto Alegre encompasses an area of 496.8 km^2, of which 30% represents rural areas. It is located in the Central Depression region, at 30°01'S and 51°13'W, close to the Lake Guaiba, in the state of Rio Grande do Sul, Brazil. The region is characterized by a humid subtropical climate, with an annual average temperature of 19.4°C, average relative humidity of 76%, annual average rainfall of 1324 mm, and predominant southeastern winds (Ferraro & Hasenack 2000). The study also includes the Parque Estadual de Itapuã, in the city of Viamão (66º 43' W and 49º 64' S), in the metropolitan region of Porto Alegre, located 57 km far from this city. The study was undertaken between 2007 and 2008 summing up 30 sampling areas (Fig. 1).

Sampling and identification

The sampling areas were defined according to their distribution in the city of Porto Alegre, number of inhabitants in a given area and the anthropic pressure (Käffer *et al*. 2012). In every sampling station, for each host tree, the lichens were sampled from 50 cm to 150 cm

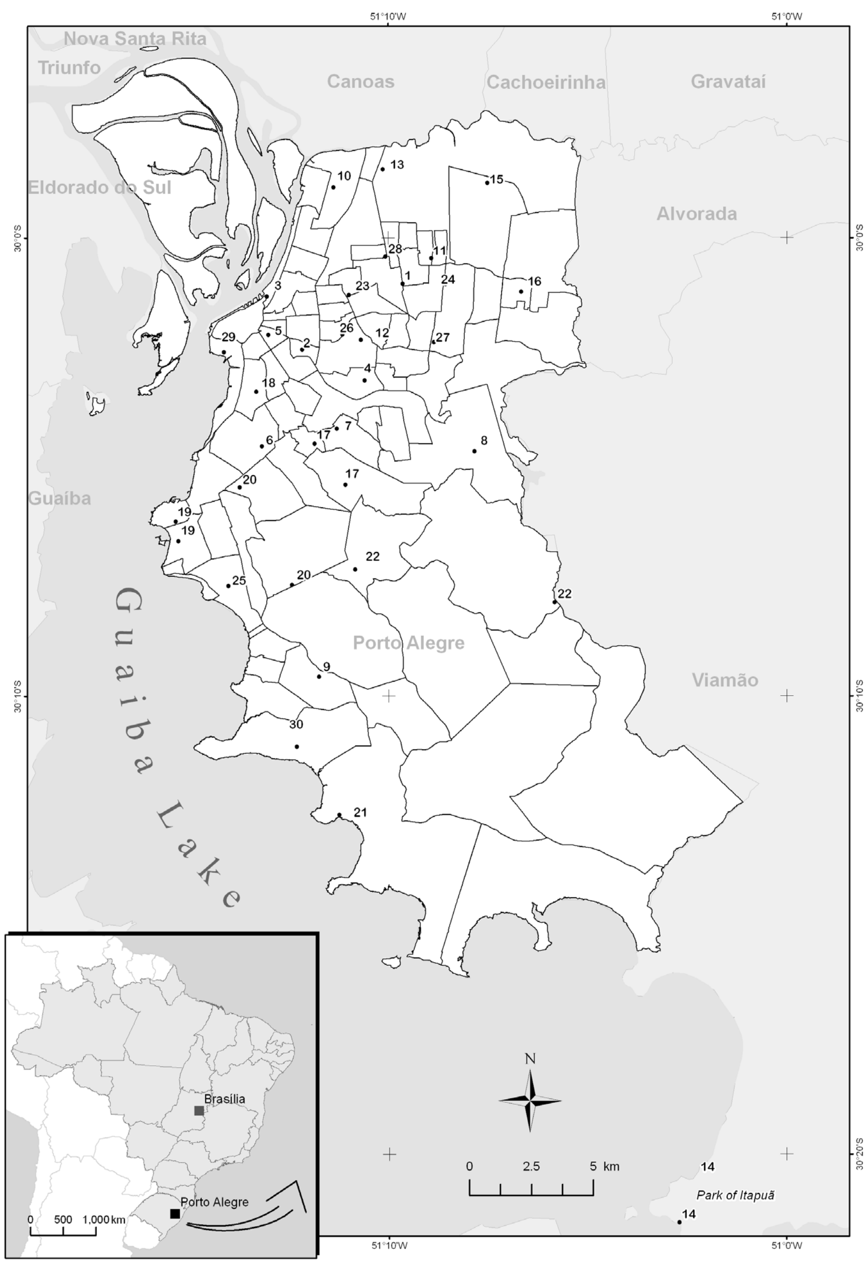

Fig. 1. Map of Porto Alegre, RS, Brazil and the location of the sampled stations.

above the ground by placing a rubber band (rubber band method) every 10 cm along the trunk (Marcelli 1992). Each rubber band was divided into 100 units of equal size, thus the number of rubber band units covered by lichens were used as a measurement of lichen cover (Käffer *et al*. 2011). All species that touched the rubber band were identified *in loco* or collected for posterior confirmation. The identification of specimens was carried out through usual identification techniques for lichens as well as with the help of specialists. The collected material was herborized and cataloged at the Herbarium Prof. Dr. Alarich Schultz (HAS) at the Museu de Ciências Naturais da Fundação Zoobotânica RS, Brazil.

Host trees characterization

At each station, 10 host trees with erect trunk, without ramifications below 150 cm, and diameter at breast height (DBH) over 20 cm were sampled, totalizing 300 phorophytes. These phorophytes were classified according to the bark texture and the bark surface pH. In table 1 are presented the average DBH of host trees and the variation of pH values bark surface. The pH of the bark surface in the host trees was verified through a portable digital pH-meter, model PH-1700 – Instrutherm (Käffer et al. 2009). The values of bark pH were classified into acidic (0 a 6.0), neutral (6.1-8.0) and alkaline (8.1 a 14).

Data analysis

In order to investigate possible differences in the vertical distribution of lichen species among the different sampled stations, two aspects were considered: (i) if lichen richness changed according to the height levels of the trunks; and (ii) whether there were height specialists or generalist species. To analyze if lichen richness changed among the 11 height levels of the trunk (from 50 cm to 150 cm high from the ground), abundance values of the species from each level in all host trees were used. Each height level in the trunk (10 cm) was defined as a height category to evaluate vertical distribution. Richness values were then compared with those from the other stations, considering height levels, diameter at breast height (DBH) and the interaction between these variables as independent variables in a General Linear Model (GLM). In order to test whether there were specialist or generalist species in the height levels, categories were created representing the difference between the maximum and the minimum height occupied by certain species in the sampled area of the trunk. We consider that height class specialists occur in only one amplitude category, whereas generalists occur in different categories (Käffer *et al*. 2009). Indicator species analysis was made to detect species that can be classified as specialist in the height levels. For that purpose, a Monte-Carlo test was performed on lichen species frequency and abundance data (McCune *et al*. 2002). Species with only one record in the sampled areas were excluded from the analysis.

Differences in the average thallus size of lichens at the sampled stations were assessed by summing the size of all thallus pieces from each host tree and dividing it by the total quantity of thalli. The estimated average size of lichen thalli were compared at each sampled station through one-way ANOVA.

In order to investigate possible influences of the host trees on lichen community establishment, we tested: i) bark texture (smooth and fissured), bark pH and DBH of trees versus average thallus size through simple linear regression; ii) and the influence of bark texture on lichen richness and abundance, through one-way ANOVA, using LSD (Least Significance Difference) as *a posteriori* test. All statistical analyses were carried out using the software R, Version 3.0.1 (R Development Core Team 2013).

RESULTS

Lichen vertical distribution in the host trees

A total of 131 species of lichenized fungi were recorded in the studied sampling stations. Significant differences were found in lichen species richness among the height levels in the host trees and among the sampled stations (Table 2). In 54% of the stations, the amount of species was homogeneously distributed at the different height levels. These sampled stations were distinguished for the absence of species below 110 cm, whereas at the other stations most species occurred from 130 cm to 150 cm from the ground.

The amount of height generalist and specialist species was also different at the different sampled stations. Altogether, 46% of the stations presented generalist species at different height levels. Out of the total number

Table 1. Host tree characteristics in the sampled stations in Porto Alegre, Brazil. The DBH correspond to average values, while the Bark pH refer to minimum and maximum values recorded.

Species	Number of individuals	Average DBH	Bark texture	Bark pH
Peltophorum dubium (Spreng.) Taub.	124	34.1	fissured	5.2 - 9.3
Brachychyton populneum (Schott & Endl.) R.Br.	47	33.7	smooth	4.8 - 8.3
Handroanthus heptaphylla (Vell.) Mattos	32	33.3	fissured	6.0 - 9.0
Hovenia dulcis Thunb.	30	33.5	fissured	5.6 - 9.4
Ligustrum japonicum Thunb.	24	42.4	fissured	4.8 - 9.2
Enterolobium contortisiliquum (Vell.) Morong.	23	33.8	smooth	6.1 - 8.5
Myrsine umbellata Mart.	19	34.3	fissured	5.3 - 9.0
Melia azedarach L.	1	34.2	fissured	7.2

of species recorded at different height levels, eight were considered specialists, according to the values of richness of each species in the sampled areas. The taxa with highest indication values (IV), considering statistically significant values, can be seen in table 3.

Average size of lichen thalli on the host trees

The average size of lichen thalli on the sampled trunks (F= 3.49; gl = 29.270; P< 0.001) demonstrated the occurrence of significant differences at the different sampled stations. Larger and more numerous thalli were reported in sampling stations located in residential areas and at the Parque Estadual de Itapuã, whereas smaller thalli were reported in sampling stations located in industrial and commercial areas.

Host tree characterization and analysis

In the regression analysis, we verified only the influence of the host tree DBH in relation to the average size of lichen thalli (Table 4). In the analysis of possible influences of the host trees on lichen establishment, significant differences were recorded between bark texture and lichen species richness (F=60.43; gl = 46.07; P<0.001) and between bark texture and lichen abundance (F=50.64; gl = 46.00; P<0.01).

DISCUSSION

Lichen community structure, especially the parameters of thallus average size and species vertical distribution were influenced by the host tree characteristics, mainly in those trees located in more disturbed areas, corroborating our initial hypothesis.

Differences in vertical distribution of urban lichen species were found regarding species richness in the height levels of the host trees, in the number of height specialist species and thallus average size. These results may be reflecting the availability of sites for lichen establishment, characteristics of the phorophytes and/or climate variations, especially at some sampling stations. *Canoparmelia* sp. 1, *Canoparmelia* sp. 2, *Graphis paraserpens* Lizano & Lucking, *Hypotrachyna livida* (Taylor) Hale, *Parmotrema eciliatum* (Nyl.) Hale, *Parmotrema subcaperatum* (Kremp.) Hale, *Physcia stellaris* (L.) Nyl., *Physcia undulata* Moberg and *Ramalina aspera* Rasänen were considered height specialists, occurring in only one height level, mainly from 100 to 150 cm. These differences in the urban lichen community structure occurred especially in central and industrial areas of the city, where smaller thalli were recorded and also a decrease on the number of lichen

Table 2. One-way ANOVA between lichen species richness and the trunk height levels. Variation sources represent height levels (fixation height of lichen on the trunk) and the sampling stations (total of 30 stations). Captions: df = degrees of freedom, SS = Sum-of-Squares, MS = Mean-Square, F = ratio, P = Probabilities.

Lichen Richness					
Source	df	SS	MS	F	P
Height levels	1	404.25	404.250	63.77	0.00
Sampling stations	29	2666.56	95.234	15.02	0.00
DBH	1	1.505	1.505	0.24	0.63
Sampling stations x Height levels	29	946.85	32.650	5.15	0.00
Error	270	1711.63	6.339		

Table 3. Height indicator lichen species analysis in the sampled stations. Caption: IV indicates indicator values (combined abundance/frequency scores) of the urban lichen community.

Species	Observed IV	Expected IV	Standard deviation (SD)	p value
Candelaria concolor (Dicks.) Stein	53.9	28.5	12.07	0.049
Parmotrema subsumptum (Nyl.) Hale	81.8	22.9	12.74	0.010
Parmotrema haitiense (Hale) Hale	66.7	21.3	12.43	0.019
Dirinaria confluens (Fr.) D. D. Awashti	36.3	28.0	4.44	0.037
Graphis dolichographa Nyl.	60.6	22.5	12.08	0.026
Heterodermia albicans (Pers.) Swinsc. & Krog	47.4	29.6	7.46	0.015
Ochrolechia africana Vain.	51.2	28.2	10.89	0.043
Physcia poncinsii Hue	49.8	29.5	10.94	0.051

Table 4. Linear regression between bark texture (smooth and fissured), bark pH and DBH of the host trees in relation to mean thallus size.

Mean thallus size	df	r^2	F
smooth bark	1	0.032	0.858
DBH	1	4.733	0.039
Surface bark pH	1	0.522	0.476
Residuals	28		

thallus. In these areas, lower percentages of richness and species coverage were also recorded and such places were classified as lichen-desert or lichen-poor areas. Moreover, the presence of air pollutants and nitrogen compounds were detected in some lichen thalli and also mutagenic activity was observed through biomarkers (Käffer *et al.* 2011, 2012). The greatest number of generalist height species found in this study may be related to the colonizing ability of some taxa. Furthermore, the highest frequency of taxa sampled between 110 and 150 cm from the ground was probably associated to microclimatic differences along the host tree trunks.

The impacts of the urban environment include changes in structure of the lichen community (Gries 1996, Fuga *et al*. 2008, Knapp *et al*. 2008, Martins *et al*. 2008). Variations in the vertical distribution of lichen species are frequently accredited to differences in luminosity and humidity conditions to which phorophytes are submitted (Sipman & Harris 1989, Fleig & Grüninger 2008, Ellis 2012), as well as to the inclination of their trunks in the environment (Cristofolini *et al*. 2008, Ellis 2012).

This study reported the influence of host trees on epiphytic lichen communities in an urban area and the result found is probably reflecting changes on bark texture and tree diameter. Host trees with smooth bark presented the lowest values of lichen abundance and species richness. The correlation between lichen vertical distribution, abundance and thalli size with substrate structure were also found in other studies (Glime 2007, Williams & Sillet 2007, Fritz 2009, Thor *et al*. 2010, Mezaka *et al*. 2012). Some lichen groups tend to dominate specific height levels, resulting in different composition of species on the trunks (Moe & Botnen 2000). The host tree level has been an important variable explaining lichen species composition and richness (Jüriado & Liira 2009). Species from families *Parmeliaceae* and *Cococcarpiaceae*, as well as the crustose species, were cited as being height generalists by Komposch & Hafellner (2002) and Normann *et al*. (2010). In the present study, besides these groups, species from *Graphidaceae* and *Physciaceae* also had wide occurrence in the different height levels analyzed. The diameter of the tree is correlated to space availability for lichen species development and it is known as a key factor for community structure (Belinchòn *et al*. 2007). According to Lie *et al*. (2009) it is possible that physical-chemical bark characteristics change with time and that an older tree can provide a different substrate than a younger tree. Besides, the tree trunks may be considered as ecological units for lichen community establishment.

The sampled areas with exclusively residential characteristics and the Parque Estadual de Itapuã were the ones with a greater quantity of trees and so with a differentiated microclimate when comparing to the other regions. Due to these characteristics, these areas presented the highest species richness, abundance and a homogeneous pattern of species distribution. The study of plant communities inserted in urban regions contributes for the generation and the maintenance of natural or semi-natural ecosystems in these centers (Primack & Rodrigues 2001). And, since lichens are environment colonizing organisms, and also play a significant role on nutrient cycling, they are important components of the ecosystem, both in forest and urban areas. So, the present study demonstrated the great variability of species in the urban environment, as well as the differences in lichen community structure regarding their vertical distribution along the trunk height levels and the different sampled areas.

CONCLUSION

In this study it was found that factors as the bark texture and DBH contributed to structural changes in the lichen community, which corroborates our initial hypothesis. Thus, host tree structure parameters are important attributes for the evaluation of lichen communities in urban environments.

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