LICHEN RICHNESS WITHIN ANTHROPOGENIC AND TRADITIONAL LANDSCAPES

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The study was focused on the assessment of lichen richness across anthropogenic and traditional landscapes in relation to different environmental factors. Significant results were obtained between lichen richness and environmental factors such as the interaction between wood extraction and the presence of pollution sources near investigated sites within anthropogenic landscape whilst within traditional landscape only altitude affected significantly lichen richness. Lichen richness was different only within anthropogenic landscape as regard sampling sites and substrata types. The differences between major spatial scales were obtained only for altitude, wood extraction and the presence of pollution sources near studied sites.

Keywords: lichen, species richness, habitat, Romania.

INTRODUCTION

Worldwide biodiversity include among other living organisms lichen species as important elements for different biosystems (Boch *et al*., 2013). Lichens are indicators of human impact on their habitats (Ardelean *et al*., 2015) due to their thallus particularities (Bartók, 1985; Bartók and Mócsy, 1990). Lichen species decrease within disturbed habitats (Kapusta *et al*., 2004; Boch *et al*., 2013; Ardelean *et al*., 2015) whilst in undistrubed habitats lichen species is well represented (Vicol, 2016; Chuquimarca *et al*., 2019). Land-use activities have a significant influence on biodiversity at different spatial scales by mitigate the species diversity (Chongbang *et al*., 2018; Chuquimarca *et al*., 2019). Furthermore, industry and traffic vehicle are the other sources of pollution with a negative impact on lichen species (Larsen *et al*., 2007).

The aim of this study consist in the assessment of lichen richness across different habitats from traditional and anthropogenic landscapes. The objectives of the study are based on the following statements: (a) Relationships between lichen richness and environmental variables within anthropogenic and traditional landscapes; (b) Differences between lichen richness identified in different habitats from

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traditional and anthropogenic landscapes; (c) Differences between the lichen richness identified on different substrata within habitats from traditional and anthropogenic landscapes; (d) Differences between lichen richness from traditional and anthropogenic habitats based on environmental variables. The following questions were addressed: (1) Have anthropogenic preassures a significant impact on lichen richness identified within different habitats and substrata from traditional and anthropogenic landscapes? (2) Have gradient of altitude a significant impact on lichen richness along habitats from traditional and anthropogenic landscapes?

MATERIAL AND METHODS

The data were collected between 2005–2019 with different habitats from anthropogenic and traditional landscapes. Within anthropogenic landscape were identified 63 lichen species whilst within traditional landcape were identified 61 lichen species (Table 1). The lichen species were identified within different habitats (forest, meadow, urban green space, and rural space) on different substrata (lignicolous, epiphytic, tericolous, saxicolous, man made substrata).

Table 1

Lichen species identified within anthropogenic and traditional landscapes

No crt.	Lichen species within anthropogenic landscape	Lichen species within traditional landscape
1	*Amandinea punctata* (Hoffm.) Coppins & Scheid	*Allantoparmelia alpicola* (Th. Fr.) Essl.
2	*Bacidia rosella* (Pers.) De Not.	*Bagliettoa baldensis* (A. Massal.) Vězda
3	*Biatora helvola* Körb. ex Hellb.	*Biatora vernalis* (L.) Fr.
4	*Buellia schaereri* De Not.	*Brodoa intestiniformis* (Vill.) Goward
5	*Caloplaca cirrochroa* (Ach.) Th. Fr.	*Bryoria subcana* (Nyl. ex Stizenb.) Brodo & D. Hawksw.
6	*Caloplaca luteoalba* (Turner) Th. Fr.	*Cetraria islandica* (L.) Ach.
7	*Candelaria concolor* (Dicks.) Stein	*Cladonia amaurocraea* (Flörke) Schaer.
8	*Candelariella reflexa* (Nyl.) Lettau	*Cladonia arbuscula* (Wallr.) Flot.
9	*Candelariella xanthostigma* (Pers. ex Ach.) Lettau	*Cladonia caespiticia* (Pers.) Flörke
10	*Cetraria islandica* (L.) Ach.	*Cladonia carneola* (Fr.) Fr.
11	*Cladonia arbuscula* (Wallr.) Flot.	*Cladonia cenotea* (Ach.) Schaer.
12	*Cladonia fimbriata* (L.) Fr.	*Cladonia coniocraea* (Flörke) Spreng.
13	*Cladonia furcata* (Huds.) Schrad.	*Cladonia crispata* (Ach.) Flot.
14	*Cladonia rangiferina* (L.) Weber ex F.H. Wigg.	*Cladonia digitata* (L.) Hoffm.
15	*Evernia divaricata* (L.) Ach.	*Cladonia fimbriata* (L.) Fr.
16	*Evernia mesomorpha* Nyl.	*Cladonia foliacea* (Huds.) Willd.
17	*Evernia prunastri* (L.) Ach.	*Cladonia glauca* Flörke
18	*Flavoparmelia caperata* (L.) Hale	*Cladonia portentosa* (Dufour) Coem.
19	*Fulgensia schistidii* (Anzi) Poelt	*Cladonia pyxidata* (L.) Hoffm.
20	*Graphis scripta* (L.) Ach.	*Cladonia rangiferina* (L.) Weber ex F.H. Wigg.
21	*Hypogymnia farinacea* Zopf	*Cladonia scabriuscula* (Delise) Nyl.
22	*Hypogymnia physodes* (L.) Nyl.	*Cladonia squamosa* (Scop.) Hoffm.

Table 1 (continued)

No crt.	Lichen species within anthropogenic landscape	Lichen species within traditional landscape
23	*Hypogymnia tubulosa* (Schaer.) Hav.	*Cladonia subulata* (L.) Weber ex F.H. Wigg.
24	*Lecanora subintricata* (Nyl.) Th. Fr.	*Cladonia uncialis* (L.) Weber ex F.H. Wigg.
25	*Lecidea auriculata* Th. Fr.	*Dermatocarpon moulinsii* (Mont.) Zahlbr.
26	*Leproloma membranaceum* (Dicks.) Vain.	*Dibaeis baeomyces (*L. f.) Rambold & Hertel
27	*Leptogium lichenoides* (L.) Zahlbr.	*Evernia divaricata* (L.) Ach.
28	*Melanelia exasperatula* (Nyl.) Essl.	*Evernia mesomorpha* Nyl.
29	*Melanelia glabra* (Schaer.) Essl.	*Flavoparmelia caperata* (L.) Hale
30	*Melanelia grabratula* (Lamy) Essl.	*Graphis scripta* (L.) Ach.
31	*Melanelia olivacea* (L.) Essl.	*Hypogymnia physodes* (Schaer.) Hav.
32	*Parmelia saxatilis* (L.) Ach.	*Icmadophila ericetorum* (L.) Zahlbr.
33	*Parmelia sulcata* Taylor	*Lepraria neglecta* Vain.
34	*Parmelina quercina* (Willd.) Hale	*Micarea misella* (Nyl.) Hedl.
35	*Parmelina tiliacea* (Hoffm.) Hale	*Parmelia saxatilis* (L.) Ach.
36	*Peltigera canina* (L.) Willd.	*Parmelia sulcata* Taylor
37	*Peltigera horizontalis* (Huds.) Baumg.	*Peltigera degenii* Gyeln.
38	*Peltigera polydactylon* (Neck.) Hoffm.	*Peltigera polydactylon* (Neck.) Hoffm.
39	*Phaeophyscia ciliata* (Hoffm.) Moberg	*Phaeophyscia orbicularis* (Neck.) Moberg
40	*Phaeophyscia nigricans* (Flörke) Moberg	*Physcia stellaris* (L.) Nyl.
41	*Phaeophyscia orbicularis* (Neck.) Moberg	*Physconia distorta* (With.) J.R. Laundon
42	*Phaeophyscia sciastra* (Ach.) Moberg	*Platismatia glauca* (L.) W.L. Culb. & C.F. Culb.
43	*Physcia adscendens* (Fr.) H. Olivier	*Pseudevernia furfuracea* (L.) Zopf
44	*Physcia aipolia* (Ehrh. ex Humb.) Fürnr.	*Punctelia borreri* (Sm.) Krog
45	*Physcia caesia* (Hoffm.) Hampe ex Fürnr.	*Ramalina farinacea* (L.) Ach.
46	*Physcia semipinnata* (J.F. Gmel.) Moberg	*Ramalina pollinaria* (Westr.) Ach.
47	*Physcia stellaris* (L.) Nyl.	*Ramalina polymorpha* (Lilj.) Ach.
48	*Physcia tenella* (Scop.) DC.	*Rhizocarpon geographicum* (L.) DC.
49	*Physconia detersa* (Nyl.) Poelt	*Rhizocarpon plicatile* (Leight.) A.L. Sm.
50	*Physconia distorta* (With.) J.R. Laundon	*Squamarina lentigera* (Weber) Poelt
51	*Physconia enteroxantha* (Nyl.) Poelt	*Stereocaulon alpinum* Laurer
52	*Platismatia glauca* (L.) W.L. Culb. & C.F. Culb.	*Tephromela aglaea* (Sommerf.) Hertel & Rambold
53	*Pleurosticta acetabulum* (Neck.) Elix & Lumbsch	*Tephromela atra* (Huds.) Hafellner
54	*Pseudevernia furfuracea* (L.) Zopf	*Thamnolia vermicularis* (Sw.) Schaer.
55	*Punctelia borreri* (Sm.) Krog	*Tomasellia arthonioides* (A. Massal.) A. Massal.
56	*Ramalina farinacea* (L.) Ach.	*Umbilicaria cylindrica* (L.) Delise
57	*Ramalina pollinaria* (Westr.) Ach.	*Usnea ceratina* Ach.
58	*Usnea articulata* (L.) Hoffm.	*Usnea hirta* (L.) Weber ex F.H. Wigg.
59	*Usnea hirta* (L.) Weber ex F.H. Wigg.	*Xanthoparmelia centrifuga* (L.) Hale
60	*Usnea subfloridana* Stirt.	*Xanthoparmelia conspersa* (Ehrh. ex Ach.) Hale
61	*Vulpicida pinastri* (Scop.) J. E. Mattsson	*Xanthoria parietina* (L.) Beltr.
62	*Xanthoria fallax* Arnold	na
63	*Xanthoria parietina* (L.) Beltr.	na
Total	**63**	**61**

Legend: na – not available data

STATISTICAL ANALYSIS

The total lichen richness was calculated as total lichen species per sit. As dependent variable was used lichen richness whilst independent variables were continuous variable (altitude) and categorical variables such as anthropogenic pressure (tourism, wood extraction, grazing, the presence of pollution sources near investigated habitats). Substrata type (lignicolous, epiphytic, tericolous, saxicolous, man made substrata) and habitat type (forest, meadow, urban green space, and rural space) were used in comparison tests to obtain the variation of lichen richness across these variables. The lichen richness was assessed in regression analysis as total lichen richness against independent continuous and categorical variables and lichen richness identified within different habitats and on different substrata against independent variables. To avoid collinearity as regards fitting a multiple Poisson regression continuous variable was centered. Variance Inflation Factor (VIF) was used to check multicollinearity of independent variables (Logan, 2010).

Poisson Generalized Linear Model (Poisson GLM) was used to model count data (lichen richness) against independent variables. Poisson regression was used to model continuous and categorical variables against lichen richness. The assumptions of GLM such as lack of fit, the linearity between each of the independent variables and the link function, the influence of observations, and the dispersion were checked (Logan, 2010). Full and reduced models were compared to provide the importance of the interaction effect (Logan, 2010).

Kruskal–Wallis test was used to identify significant differences between lichen richness and their habitats particularities by use stats package (vers. 3.5.1, R CORE TEAM 2018). Multi-response permutation procedure (MRPP) was used to compare lichen richness from anthropogenic versus traditional landscapes using mrpp function provided by vegan package (vers. 2.5-2, Oksanen *et al*., 2018).

Finally, model selection was performed using drop1 function within lme4 package (Zuur *et al*., 2009; vers. 1.1-17, Bates *et al*., 2015).

The nomenclature of lichen species is according to www.mycobank.org.

RESULTS

The total lichen richness within anthropogenic landscape was significantly determined by interactions between wood extraction and the presence of pollution sources near investigated sites (Table 2).

Table 2

The effect of environmental variables on total lichen richness within anthropogenic landscape

Variables	Wood extraction: pollution					
Total lichen richness	VIF	DF	Deviance	AIC	LRT	Pr(>Chi)
	4.17	1	92.64	247.81	10.96	0.00092

Legend: VIF – Variance Inflation Factor; DF – degree freedom; AIC – Akaike Information Criterion; LRT – Likelihood Ratio Test, : – interaction between two variables

The total lichen richness within traditional landscape was significantly determined only by altitude (Table 3).

Table 3

The effect of environmental variables on total lichen richness within traditional landscape

Variables	Altitude					
Total lichen richness	VIF	DF	Deviance	AIC	LRT	Pr(>Chi)
	1.50	1	141.18	198.09	108.12	2.2e-16

Legend: VIF – Variance Inflation Factor; DF – degree freedom; AIC – Akaike Information Criterion; LRT – Likelihood Ratio Test.

Significant relationships between lichen richness and particular habitats or substrata were not obtained. Kruskal–Wallis test indicated significant differences between total lichen richness within sampling sites and their substrata from anthropogenic landscape (Table 4; Table 5).

Table 4

Kruskal–Wallis comparisons between sampling sites and total lichen richness from anthropogenic landscape

Response variable	Environmental variables					
	Forest			Rural space		
Total lichen richness	Chi-squared	df	p-value	Chi-squared	df	p-value
	34.67	11	0.00028	11.48	2	0.00320

Legend: df – degree of freedom

Table 5

Kruskal-Wallis comparisons between substrata types and total lichen richness within anthropogenic landscape

	Lignicolous			Epiphytic		
	Chi-squared	df	p-value	Chi-squared	df	p-value
Total lichen richness	28.54	8	0.00038	19.38	7	0.00705

Legend: df – degree of freedom

As regard traditional habitats no significant differences were obtained using Kruskal–Wallis test. Multi-response permutation procedure showed significant differences between anthropogenic and traditional landscapes as regards lichen richness versus altitude (Table 6), wood extraction (Table 7), and the presence of pollution sources near sampling sites (Table 8).

Table 6

MRPP results as regard differences between anthropogenic and tradional landscapes based on altitude

Variables	Altitude	
Lichen richness	A	p-value
	0.564*	0.038

Table 7

MRPP results as regard differences between anthropogenic
and tradional landscapes based on wood extraction

Variables	Wood extraction	
Lichen richness	A	p-value
	0.075**	0.001

Table 8

MRPP results as regard differences between anthropogenic and tradional landscapes based on the presence of pollution sources near sampling sites

Variables	Presence of pollution sources near sampling sites	
Lichen richness	A	p-value
	0.056**	0.001

No other significant results were obtained using MRPP method.

DISCUSSIONS

Within this study the lichen richness increased as a function of altitude in traditional landscape. At higher altitudes climatical and environmental conditions, availability and particularities of substrata are important factors which significantly determine the lichen richness (Baniya et al., 2010; Marmor *et al*., 2012). The old habitats from traditional landscape are important for lichen species conservation (Boch *et al*., 2013).

Different habitats offer different substrata and therefore lichen richness vary depends on the quality of environmental conditions (Ihlen *et al*., 2001). Air pollution and habitat management practices are also responsible for differences in lichen richness across landscape types (Boch *et al*., 2013). The lichen richness is higher in forestry areas than in anthropogenic habitats due to environmental quality (Chongbang *et al*., 2018; Chuquimarca *et al*., 2019). Contrary, across industrial areas lichen richness is really lower as a consequence of change of environmental conditions (Larsen *et al*., 2007).

CONCLUSIONS

Forest management and pollution sources have influenced lichen richness in anthropogenic habitats. Traditional landscape includes habitats that support higher lichen richness especially at higher altitude therefore these habitats should be conserved. The main factors implied in differences in lichen richness are forest management, pollution sources, and altitude across landscape types whilst across small spatial scale the habitat and substrata types contributed to significant differences on lichen richness.

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REFERENCES

1. Ardelean I.V., Keller C., Scheidegger C., 2015, Effects of management on lichen species richness, ecological traits and community structure in the Rodnei Mountains National Park (Romania), *PLoS ONE*, **10**, e0145808.
2. Baniya C.B., Solhøy T., Gauslaa Y., Palmer M.W., 2010, The elevation gradient of lichen species richness in Nepal, *Lichenologist*, **42**, pp. 83–96.
3. Bartók K., 1985, Lichenii şi poluarea chimică. Impactul chimie-societate, Simpozion organizat la 3 Iunie 1983 de Academia R. S. R., Filiala Iaşi, pp. 69–72.
4. Bartók K., Mócsy I., 1990, Studies upon lichen radioactivity, *Rev Roumaine Biol*, *Sér Biol Vég*, **35**, pp. 61–65.
5. Bates D., Maechler M., Bolker B., Walker S., 2015, Fitting linear mixed effects models using lme4, *Journal of Statistical Software*, **67**, pp. 1–48.
6. Boch S., Prati D., Hessenmöller D., Schulze E.D., Fischer M., 2013, Richness of lichen species, especially of threatened ones, is promoted by management methods furthering stand continuity, *PLoS ONE*, **8**, e55461.
7. Chongbang T.B., Keller C., Nobis M., Scheidegger C., Baniya C.B., 2018, From natural forest to cultivated land: Lichen species diversity along land-use gradients in Kanchenjunga, Eastern Nepal, *eco.mont*, **10**, pp. 46–60.
8. Chuquimarca L., Gaona F.P., Iñiguez-Armijos C., Benítez A., 2019, Lichen Responses to disturbance: clues for biomonitoring land-use effects on riparian Andean ecosystems, Diversity, **11**, p. 73.
9. Ihlen P.G., Gjerde I., Sætersdal M., 2001, Structural indicators of richness and rarity of epiphytic lichens on Corylus avellana in two different forest types within a nature reserve in south-western Norway, *Lichenologist*, **33**, pp. 215–229.
10. Kapusta P., Szarek-Łukaszewska G., Kiszka J., 2004, Spatial analysis of lichen species richness in a disturbed ecosystem (Niepołomice Forest, S Poland), *Lichenologist*, **36**, pp. 249–260.
11. Larsen R.S., Bell J.N.B., James P.W., Chimonides P.J., Rumsey F.J., Tremper A., Purvis O.W., 2007, Lichen and bryophyte distribution on oak in London in relation to air pollution and bark acidity, *Environm Pollut*, **146**, pp. 332–340.
12. Logan M., 2010, *Biostatistical design and analysis using R. A practical guide*, Oxford, UK: Wiley-Blackwell, pp: 510–515.
13. Marmor L., Tõrra T., Saag L., Randlane T., 2012, Species richness of epiphytic lichens in coniferous forests: the effect of canopy openness, *Ann Bot Fenn*, **49**, pp. 352–358.
14. Oksanen J., Blanchet F.G., Friendly M., Kindt R., Legendre P., McGlinn D., Minchin P.R., O'Hara R.B., Simpson G.L., Solymos P., Stevens M.H.H., Szoecs E., Wagner H., 2018, vegan: Community Ecology Package. R package version 2.5-2. https://CRAN.R-project.org/package=vegan
15. R Core Team, 2018, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.
16. Vicol I., 2016, Ecological patterns of lichen species abundance in mixed forests of Eastern Romania, *Ann For Res*, **59**, pp. 237–248.
17. Zuur A., Ieno E.N., Walker N.J., Saveliev A.A., Smith G.M., 2009, Mixed effects models and extensions in ecology with R, Springer Science+Business media, New York, New York, USA.