LICHEN SPECIES DISTRIBUTION ACROSS NON-PROTECTED AND PROTECTED AREAS FROM ROMANIA

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Abstract: The aim of the study reveals the importance of lichen richness within non-protected and protected areas, especially lichen species included in National Red List. This study was performed within protected and non-protected areas from Romania situated at both high and low altitude. The studied group is represented by lichens with a great diversity of their species. The data were collected between 2020–2023 from different geomorphological units of Romania. In total 94 lichen species were found of which 34 within non-protected areas and 86 within protected areas. Statistical analysis indicated non-significant results as regard the differences betwen the total number of lichen species and the number of lichens included in National Red List among non-protected and protected areas. Also, non-significant results were obtained as regard the differences between data recorded among non-protected and protected areas. The main conclusion is represented by a high number of lichen species identified within protected areas compared to non-protected areas.

Keywords: lichens, National Red List, protected areas, Romania.

INTRODUCTION

Protected areas have a great importance in the context of lichens and their habitats conservation (Gheza *et al*., 2023). The attributes of forest habitats could enhance the lichen richness especially the red listed ones in the protected areas (Palmroos *et al*., 2023). An important aspect, especially in forested protected areas is tree species diversity which is a determining driver on lichen diversity pattern (Vicol, 2016).

In the current context, a great importance is attributed to climate which determines the pattern of lichen species especially in the highland protected areas (Martínez *et al*., 2006). Nowadays, climate change is actively implied in the loss of biodiversity therefore management measures with implication in conservation of the wild habitats of lichens should be implemented (Lendemer and Allen, 2014).

The aim of this study consists in the analysis of the effectiveness of legislative tools designed for Romanian protected areas which are a crucial support needed to enhance the importance of lichen species richness, especially the species

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included in National Red List within protected areas, compared to lichen species richness which include species mentioned in National Red List within non-protected areas.

MATERIALS AND METHODS

The study was performed within protected and non-protected areas in both highland and lowland areas from Romania. The field work was performed between 2020–2023 in mountain, hilly, and plain areas from Romania.

Legislative tools. In Romania the legislative framework for designation of studied PAs is supported by Law no. 5/2000, Decision no. 2151/2004, Order of the Ministry of Environment and Sustainable Development no. 1964/2007, and Order no. 2387/2011.

The dataset components. Within this study were analysed two datasets represented by variables relating to Protected Areas (PAs) and Non-Protected Areas (NPAs). The dataset of PAs comprise spatial variables such as geographical coordinates of lichen species, the total number of lichen species and the evidence of lichen species included in National Red List (Vicol and Mihăilescu, 2022). Also, the dataset of NPAs is represented by geographical coordinates of lichen species, the total number of lichen species and the evidence of lichen species included in National Red List (Vicol and Mihăilescu, 2022).

Statistical analysis. Spatial autocorrelation was used to identify the relationships among the geographical coordinates where lichen species were collected and the variables taken into account within this study as follow: the evidence of lichen species included in National Red List for NPAs and PAs. The generalized estimating equations (GEE) recommended for binary data were used to analyze spatial autocorrelation based geepack package (Yan, 2002; Yan and Fine, 2004; Halekoh *et al*., 2006) in R software (R Core Team, 2024). The GEE indicated non-significant correlations ($p > 0.05$) among geographical coordinates of lichen species and all variables considered in this study for NPAs and PAs.

The chi-squared test was used to compare the total number of lichen species and the number of lichen species included in National Red List between NPAs and PAs (Hammer *et al*., 2001).

One-way ANOSIM analysis was used to identify differences between the variables of NPAs and PAs. The significance of the analysis was calculated based on permutation of group elements with 9999 replicates. The dataset is represented by binary data and therefore Jaccard distance index was selected for this analysis. The post hoc test was used to indicate the variability of all pairwise of investigated groups based on NPAs and PAs (Hammer *et al*., 2001).

The lichen species nomenclature was updated according to http://www.indexfungorum.org/names/names.asp (08.02.2024).

RESULTS

In total 94 lichen species were identified in the studied areas of which 34 were included in NPAs and 86 were found in PAs as is presented below:

Lichen species identified within NPAs: *Bryoria fuscescens* (Gyeln.) Brodo & D. Hawksw., *Cetraria islandica* (L.) Ach., *Cetrelia cetrarioides* (Duby) W.L. Culb. & C.F. Culb., *Cladonia crispata* (Ach.) Flot., *Cladonia foliacea* (Huds.) Willd., *Cladonia furcata* (Huds.) Baumg., *Cladonia portentosa* (Dufour) Coem., *Cladonia ramulosa* (With.) J.R. Laundon, *Cladonia scabriuscula* (Delise) Nyl., *Evernia mesomorpha* Nyl., *Evernia prunastri* (L.) Ach., *Flavoparmelia caperata* (L.) Hale, *Hypogymnia physodes* (L.) Nyl., *Parmelia saxatilis* (L.) Ach., *Parmelia sulcata* Taylor, *Parmelina tiliacea* (Hoffm.) Hale, *Parmotrema tinctorum* (Despr. ex Nyl.) Hale, *Phaeophyscia orbicularis* (Neck.) Moberg, *Physcia adscendens* H. Olivier, *Physcia stellaris* (L.) Nyl., *Physciella nigricans* (Flörke) S.Y. Kondr., Lőkös & Hur, *Physconia distorta* (With.) J.R. Laundon, *Physconia enteroxantha* (Nyl.) Poelt, *Pleurosticta acetabulum* (Neck.) Elix & Lumbsch, *Pseudevernia furfuracea* (L.) Zopf, *Ramalina calicaris* (L.) Röhl., *Ramalina farinacea* (L.) Ach., *Ramalina fastigiata* (Pers.) Ach., *Ramalina fraxinea* (L.) Ach., *Ramalina obtusata* (Arnold) Bitter, *Ramalina pollinaria* (Westr.) Ach., *Usnea ceratina* Ach., *Usnea hirta* (L.) F.H. Wigg., *Xanthoria parietina* (L.) Th. Fr.

Lichen species identified within PAs: *Alectoria ochroleuca* (Schrank) A. Massal., *Anaptychia ciliaris* (L.) Flot., *Arctoparmelia centrifuga* (L.) Hale, *Bryoria fuscescens* (Gyeln.) Brodo & D. Hawksw., *Bryoria subcana* (Nyl. ex Stizenb.) Brodo & D. Hawksw., *Cerothallia luteoalba* (Turner) Arup, Frödén & Søchting, *Cetraria islandica* (L.) Ach., *Cladonia arbuscula* (Wallr.) Flot., *Cladonia coniocraea* (Flörke) Spreng., *Cladonia ecmocyna* Leight., *Cladonia fimbriata* (L.) Fr., *Cladonia foliacea* (Huds.) Willd., *Cladonia furcata* (Huds.) Baumg., *Cladonia mitis* Sandst., *Cladonia portentosa* (Dufour) Coem., *Cladonia pyxidata* (L.) Hoffm., *Cladonia rangiferina* (L.) Weber, *Cladonia squamosa* Hoffm., *Cladonia uncialis* (L.) F.H. Wigg., *Cornicularia normoerica* (Gunnerus) Du Rietz, *Evernia divaricata* (L.) Ach., *Evernia mesomorpha* Nyl., *Evernia prunastri* (L.) Ach., *Flavoparmelia caperata* (L.) Hale, *Graphis scripta* (L.) Ach., *Heterodermia speciosa* (Wulfen) Trevis., *Hypogymnia farinacea* Zopf, *Hypogymnia physodes* (L.) Nyl., *Hypogymnia tubulosa* (Schaer.) Hav., *Hypogymnia vittata* (Ach.) Parrique, *Lepra albescens* (Huds.) Hafellner, *Leptogium saturninum* (Dicks.) Nyl., *Lobaria pulmonaria* (L.) Hoffm., *Melanelixia glabratula* (Lamy ex Nyl.) Sandler & Arup, *Nephromopsis cucullata* (Bellardi) Divakar, A. Crespo & Lumbsch, *Nephromopsis nivalis* (L.) Divakar, A. Crespo & Lumbsch, *Parmelia saxatilis* (L.) Ach., *Parmelia sulcata* Taylor, *Parmelina tiliacea* (Hoffm.) Hale, *Parmeliopsis ambigua* (Hoffm.) Nyl., *Parmotrema tinctorum* (Despr. ex Nyl.) Hale, *Peltigera canina* (L.) Willd., *Peltigera degenii* Gyeln., *Peltigera horizontalis* (Huds.) Baumg., *Peltigera malacea* (Ach.) Funck, *Peltigera praetextata* (Flörke ex Sommerf.) Zopf, *Peltigera rufescens* (Weiss)

Humb., *Pertusaria bryontha* (Ach.) Nyl., *Pertusaria flavida* (DC.) J.R. Laundon, *Phaeophyscia orbicularis* (Neck.) Moberg, *Phlyctis agelaea* (Ach.) Flot., *Physcia adscendens* H. Olivier, *Physcia aipolia* (Ehrh. ex Humb.) Fürnr., *Physcia stellaris* (L.) Nyl., *Physconia distorta* (With.) J.R. Laundon, *Physconia enteroxantha* (Nyl.) Poelt, *Physconia detersa* (Nyl.) Poelt, *Platismatia glauca* (L.) W.L. Culb. & C.F. Culb., *Poeltonia grisea* (Lam.) S.Y. Kondr., Lőkös & Hur, *Porpidia cinereoatra* (Ach.) Hertel & Knoph, *Porpidia crustulata* (Ach.) Hertel & Knoph, *Pseudevernia furfuracea* (L.) Zopf, *Punctelia borreri* (Sm.) Krog, *Punctelia subrudecta* (Nyl.) Krog, *Ramalina calicaris* (L.) Röhl., *Ramalina dilacerata* (Hoffm.) Hoffm., *Ramalina farinacea* (L.) Ach., *Ramalina fastigiata* (Pers.) Ach., *Ramalina fraxinea* (L.) Ach., *Ramalina pollinaria* (Westr.) Ach., *Rhizocarpon geographicum* (L.) DC., *Rhizocarpon petraeum* (Wulfen) A. Massal., *Ricasolia virens* (With.) H.H. Blom & Tønsberg, *Schaereria fuscocinerea* (Nyl.) Clauzade & Cl. Roux, *Stereocaulon alpinum* Laurer, *Thamnolia vermicularis* (Sw.) Schaer., *Umbilicaria nylanderiana* (Zahlbr.) H. Magn., *Usnea flammea* Stirt., *Usnea florida* (L.) F.H. Wigg., *Usnea glabrata* (Ach.) Vain., *Usnea glabrescens* (Nyl. ex Vain.) Vain., *Usnea hirta* (L.) F.H. Wigg., *Varicellaria hemisphaerica* (Flörke) I. Schmitt & Lumbsch, *Vulpicida pinastri* (Scop.) J.-E. Mattsson & M.J. Lai, *Xanthoparmelia conspersa* (Ehrh. ex Ach.) Hale, *Xanthoria parietina* (L.) Th. Fr.

The total number of lichen species was non-significantly different among NPAs and PAs ($chi^2=52$; $p=0.99$). A non-significant result was recorded as regard the difference between the number of National Red Listed lichen species among NPAs and PAs ($chi^2=11$; $p=0.35$).

One-way ANOSIM analysis did not indicate significant differences among data recorded for NPAs and PAs.

A great importance was attributed to the total number of lichen species which was higher within PAs than within NPAs. As regard the lichen species included in National Red List, it was observed that within PAs were identified three lichen species such as *Cetraria islandica*, *Lobaria pulmonaria*, and *Stereocaulon alpinum* compared to NPAs where two lichen species were identified for instance: *C. islandica* and *Ramalina obtusata*.

DISCUSSION

The non-protected areas are important for lichen species, especially red listed lichens, due to their diversity of habitats (Gustafsson *et al*. 2004; Johanson and Gustafsson, 2011). Otherwise, the lichen species, especially red listed species, are well-represented both in the highland and lowland protected areas within forest and non-forest vegetation types (Kondratyuk and Navrotskaya, 1995). A high diversity of lichens is supported by large PAs represented by a greater diversity of geomorphology, habitats, and substrata (Gheza *et al*., 2023; Jairus *et al*., 2009).

An important driver of PAs is represented by the complexity of forest habitats which determine the pattern of lichen species (Vicol, 2016). Also, non-forested areas represented by meadows and shrubs are important drivers for lichen richness, therefore their management should be adequately implemented (Gheza *et al*., 2020).

The conservation of lichen species and their habitats are related to their ecology and population attributes (Scheidegger and Werth, 2009). Also, the natural attributes of PAs and NPAs should be subjected to conservation management because represent lifeboating for lichen species (Bjelland, 2023; Ekström *et al*., 2023; Vicol and Mihăilescu, 2022).

CONCLUSIONS

A special attention should be granted to both PAs and NPAs due to their complexity of habitats which represent a natural support for lichen species diversity. Within this study, both within PAs and NPAs were identified red listed lichen species, therefore all these areas should be subjected to adequate management as a support for their long-term conservation.

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