

Standard procedure for the identification of lichen refuges: a case study of the Krajeńskie Lakeland area in Poland

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Received: 13 August 2019 / Accepted: 8 November 2019

Abstract. This paper presents guidelines for distinguishing lichen refuges based on research carried out in the Krajeńskie Lakeland region from 2009 to 2014. The main goal of this publication was to establish a methodology to distinguish refuges from other habitats. The main points of this methodology include the precise determination of the research area, comprehensive development of its local lichenobiotic biodiversity, identification of the most valuable species (mainly rare and endangered) and selection of areas with the highest concentration of their stands.

Key words: epiphytic lichens, refuge, endangered species, local biodiversity.

1. Introduction

The term refugium (from Latin *refuge*: a place providing safety, protection, shelter) can be used to describe an area or a region where refugees find shelter from areas where their lives are at risk or even threatened with destruction. It follows that a refuge is a place where someone (or something) escapes to in order to find the possibility of safe survival, which is consistent with the definition of Kopalinski (2007). In many languages, the term derived from the Latin word *refuge* is referred to as a refugee; for example, refugee in English, refugiado in Spanish and réfugie in French. In the natural sciences, a refuge is defined according to Mirek et al. (2005) as a “natural or semi-natural site, distinguished by an exceptional botanical richness and/or constituting a habitat for a distinctive set of rare, endangered and/or endemic plant species and/or plant communities of high botanical value”.

Until now, the problem of refuges and their protection has been treated rather marginally in lichenological literature. This issue is presented as an important research topic in only a few publications (i.e. Cieśliński, 1999, 2000, 2006; Czyżewska et al., 2002; Kossowska, 2002; Kościelniak, 2005, 2009; Wójciak & Urban, 2012; Kapek, 2014; Gruszka, 2017). Usually, this issue is not subject to detailed analysis, and naming areas refuges is not supported by unambiguous and convincing justification. In many cases, a set of undoubtedly valuable species is given from the studied area; however, due to a lack of proper analysis and interpretation of results, there is a fear that, in some cases, assignment of the rank of refuge may be not justified.

Due to the decreasing number of valuable sites and dying and endangered species of lichens in particular, lichenologists are faced with an urgent need to develop methods to properly distinguish refuges and then postulate to cover these areas with legal protection. Thus, in this

publication, suggestions and proposals of procedures to help to establish lichen refuges are given, which the authors base on results of their long-term observations and studies on changes in the qualitative and quantitative biodiversity of lichens in selected regions. Also, the authors' experience has been used, especially in the organization of the legal protection of these organisms. This research was carried out mainly in Tuchola Forest and Krajeńskie Lakeland (Lipnicki, 1991, 1993, 2002a, 2006, 2010, 2012; Gruszka, 2009, 2010, 2011, 2012, 2017).

This publication provides an example of the distinction of lichen refuge in the area of Krajeńskie Lakeland, based on the results of an analysis made by Gruszka (2014). It is also extending the issues discussed in the earlier publication of Gruszka (2017) supplemented with the results of further studies on lichen refugia. The presented scheme of conduct should be treated as material for further discussion.

2. Steps to distinguish a refuge

The basic standard for distinguishing a refuge within a larger area is the occurrence of valuable, endangered and perishing species; however, it should be kept in mind that the distribution of valuable taxon sites, both on the national scale and in smaller areas (for example in the mesoregion, in the forest complex, etc.), is not a permanent feature. The richness of species is due to the analysed area, diversity of habitats and lichens available to substrates, microclimate, human pressure, including the nature of land use and its changes, and the degree of urbanization. These dependencies are reflected in regional lists of endangered species (i.a. Czarnota, 2003; Czyżewska, 2003a; Lipnicki, 2003; Szczepańska, 2008; Leśniański, 2010; Kościelniak, 2012); these differ not only in a set of taxa, but in the case of the same species, in a different threat status. The distinction of a lichen refuge can be a very important prerequisite for legal protection and/or indication of the way it is managed in its area. Although this task is not troublesome, it is often overlooked by lichenologists.

The determination of a lichen refuge should take place in the following stages:

- 1) indication of the analysed area boundaries;
- 2) creation of the list of lichen taxa, including the results of previous (historical) studies, if any;
- 3) selection of indicator species;
- 4) creation of a map of the positions all indicator species.

Each of these tasks is usually performed as standard practice during lichenological characterization of an area. An additional analysis of the obtained results will lead to separation of the refuges, which will allow for the

submission of the appropriate postulates to the property owners.

Determination of the reference area

In the initial stages of work, the boundaries of an area on which lichen refuges are expected to exist (e.g. mesoregion, forest complex, city, etc.) should be strictly defined. Failure to do so will not only reduce the value of the work done but may also be the basis for questioning the results.

Determination of indicator species

To compile a list of lichen taxa whose occurrence will allow for the identification of the refuges within the boundaries of the analysed area, a complete list of species should be created together with the frequency of their occurrence. Among them, select regionally rare, very rare or endangered taxa, including relics of forests (acc. to Cieśliński et al., 1996; Czyżewska & Cieśliński, 2003b). One should be aware that a list created this way will be unique and characteristic of a given region and cannot be the basis for analysing other areas. If accurate historical results are available, they should also be analysed. As a result, it will be possible to determine the trends and pace of change in lichenobiotic biodiversity; in particular, taxa will be indicated, which deserve special attention due to the drastic reduction in the number of posts.

Stand mapping

The indicative taxonomic levels should be marked on the maps of the studied area. Concentrations of points will indicate the location of those parts of the terrain in which there are favourable conditions for the survival of the most valuable lichen taxa; they will be refuges.

3. Case study of the Krajeńskie Lakeland

3.1. Determination of the research area

The mesoregion of the Krajeńskie Lakeland is in north-western Poland (Fig. 1). It occupies an area of approximately 4380 km² (Kondracki, 2001). It is located between the Gwda Valley, Brda Valley and Central Noteć Valley, surrounded by Charzykowska Plain and Tuchola Forest in the north. Krajeńskie Lakeland is located between 53° 05' and 53° 50' north latitude and between 16° 45' and 17° 50' east longitude (Umiński, 1991). Krajeńskie Lakeland is a typical agricultural land. Forests occupy small areas. A more detailed description of the research area is provided in the article by Gruszka (2017).

3.2. Material and methods

Field studies of the mesoregion were conducted in the years 2009-2014. These studies were conducted with the same methods as the previous ones, aimed to develop a complex characterization of the epiphytic lichenobiotic of the chosen area to determine procedures for identifying the lichen sites (Gruszka, 2017).

Historical data compiled by Tobolewski (1966, 1971, 1979, 1981, 1983, 1988), Tobolewski & Kupczyk (1977) and Fałtynowicz (1992), as well as unpublished results by Nafalska (1981), Lipnicki (1998, 2001, 2002b) and Winkowska-Grześkowiak (2000) were also analysed. The

nomenclature follows the Index Fungorum (date of exploration 01/07/2019).

4. Results

In total, 160 species of epiphytic lichens were identified in the Krajeńskie Lakeland as a result of the present research (Gruszka 2014). Of all identified species of lichens, 43 species were identified as indicators of refuges (Table 1); most of them are endangered in the country and they are rare (or very rare) on Krajeńskie Lakeland. Nine areas were marked as lichen refuges (Fig. 2).



Figure 1. Location of the Krajeńskie Lakeland in Poland

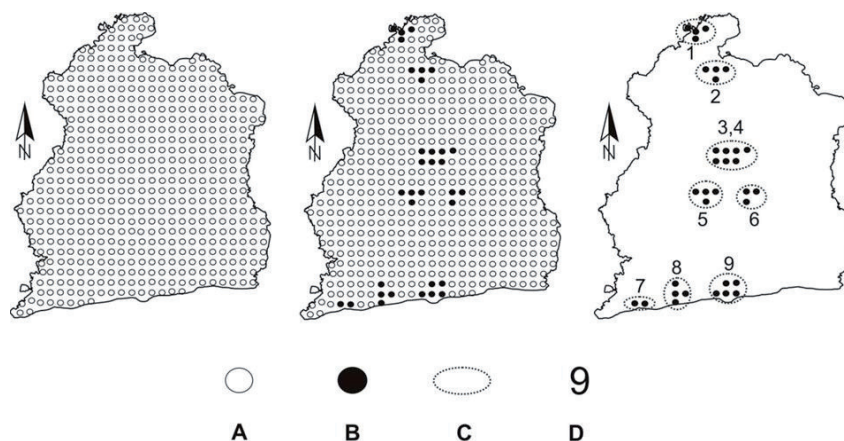


Figure 2. The scheme of refuge determination in Krajeńskie Lakeland. A – localities of lichen species, B – localities of selected indicator species, C – refuge areas; D – refuge names. Numbering in accordance with the numbering in Table 1

Table 1. Species that distinguish forest areas as refuges of lichens in the Krajeńskie Lakeland

Indicator species	Number of refuge								
	1	2	3	4	5	6	7	8	9
	“Osiedle Kormoranów” res.	“Sosny” res.	“Dęby Krajeńskie” res.	“Buczyna” res.	“Uroczyńska Złotowskie” Nature 2000 area;	“Torfowisko Messy” Landscape-Nature Protected Complex	“Struga Białosiwka” Nature 2000 area	“Zielona Góra” res.	“Borek” res.
<i>Acrocordia gemmata</i> (Ach.) A. Massal.									*
<i>Alyxoria varia</i> (Pers.) Ertz & Tehler	*	*				*	*	*	
<i>Arthonia atra</i> (Pers.) A. Schneid.				*			*		
<i>Arthonia spadicea</i> Leight.				*				*	
<i>Arthonia vinosa</i> Leight.		*							
<i>Arthothelium ruanum</i> (A. Massal.) Körb.				*					
<i>Bacidia arceutina</i> (Ach.) Arnold	*								*
<i>Bacidia circumspecta</i> (Norrl. & Nyl.) Malme									*
<i>Bacidia rosella</i> (Pers.) De Not.	*		*	*					
<i>Bacidia rubella</i> (Hoffm.) A. Massal.			*	*					
<i>Bacidina sulphurella</i> (Samp.) M. Hauck & V. Wirth			*					*	
<i>Biatora efflorescens</i> (Hedl.) Räsänen							*	*	
<i>Biatora globulosa</i> (Flörke) Fr.									*
<i>Bryoria implexa</i> (Hoffm.) Brodo & D. Hawksw.		*			*				
<i>Bryoria sophiae</i> (Motyka) Bystrek					*				
<i>Bryoria vrangiana</i> (Gyeln.) Brodo & D. Hawksw.						*	*		
<i>Calicium adpersum</i> Pers.			**	*	**	*	*	*	*
<i>Calicium salicinum</i> Pers.		*	*	*					*
<i>Calicium viride</i> Pers.			*		*				*
<i>Chaenotheca brachypoda</i> (Ach.) Tibell	*		*		*	*			
<i>Chaenotheca brunneola</i> (Ach.) Müll. Arg.			*						
<i>Chaenotheca furfuracea</i> (L.) Tibell	*				*	*	*		*

Table 1 continued

Indicator species	Number of refuge								
	1	2	3	4	5	6	7	8	9
	“Osiedle Kormoranów” res.	“Sosny” res.	“Dęby Krajeńskie” res.	“Buczyna” res.	“Uroczyńska Złotowskie” Nature 2000 area;	“Torfowisko Messy” Landscape-Nature Protected Complex	“Struga Białosiłwka” Nature 2000 area	“Zielona Góra” res.	“Borek” res.
<i>Chaenotheca trichialis</i> (Ach.) Hellb.						*			
<i>Chrysothrix candelaris</i> (L.) J.R. Laundon			**	*	***	*	*		*
<i>Chrysothrix flavovirens</i> Tønsberg		*							
<i>Fellhanera bouteillei</i> (Desm.) Vězda					*				
<i>Gyalecta flotovii</i> Körb.					*				
<i>Hypogymnia farinacea</i> Zopf					*				
<i>Lobaria pulmonaria</i> (L.) Hoffm.									*
<i>Micarea elachista</i> (Körb.) Coppins & R. Sant.			*		*				
<i>Micarea melaena</i> (Nyl.) Hedl.		*		*	*			*	
<i>Opegrapha vermicellifera</i> (J. Kunze) J.R. Laundon	*			**				*	
<i>Opegrapha vulgata</i> (Ach.) Ach.	*	*						*	
<i>Pertusaria flavida</i> (DC.) J.R. Laundon	*	*		*				*	
<i>Pertusaria leioplaca</i> DC.	**	*		**	*	*		**	
<i>Pertusaria pertusa</i> (L.) Tuck.	**	*			*			*	
<i>Pseudoschimatomma rufescens</i> (Pers.) Ertz & Tehler				*		*			
<i>Pyrenula nitida</i> (Weigel) Ach.	*	*			*		*	*	
<i>Pyrenula nitidella</i> (Flörke ex Schaer.) Müll. Arg.								*	
<i>Ramalina baltica</i> Lettau	*								
<i>Toniniopsis subincompta</i> (Nyl.) Kistenich, Timdal, Bendiksby & S. Ekman					*				
<i>Usnea fulvovirens</i> (Räsänen) Räsänen					*				
<i>Varicellaria hemisphaerica</i> (Flörke) I. Schmitt & Lumbsch	*		*	*	*			*	*

Descriptions: res – nature reserve; number of localities: * – 1≤5; ** 6≤10;*** ≥11

5. Discussion

Based on the authors' opinions presented in this paper, patterns of proceedings are based on:

- examination of the whole biota of lichens in a specific area;
- selection of index species (i.e. rare and/or the most endangered), including relics of primeval forests;
- prediction of areas with the highest concentration of positions of distinguished species.

This may look too simplistic, but it allows for the indication of lichen refuges (without resorting to other methods) and it is necessary when considering the importance of obtaining appropriate and non-negotiable results. The procedure itself does not require absolute support from statistical analysis, although this can also be helpful.

The analysis of relatively little historical data did not provide enough information about possible directions of lichenobiotic changes. Based on this, it was also not possible to indicate species which, due to the drastic reduction in the number of positions, would deserve attention. Available data indicate that the few positions are located mainly in the central and northern parts of the Krajeńskie Lakeland.

The eastern and southern regions were less researched, which was probably associated with a greater transformation of these areas and thus with their lower scientific attractiveness. Available historical data contained only a suggestion about lichenologically higher values in the vicinity of Kujania (Nafalska, 1981; Tobolewski, 1979) and the Buczyna Reserve (Lipnicki, 2002b). The studies conducted in 2009-2014 in both areas confirmed the significant lichenological values of these areas. In both areas, refuges were selected: Kujaniańskie Uroczysko and Buczyna Reserve. This confirms that historical research is valuable for determining refuges only when it has been carried out comprehensively and with due diligence; extracting conclusions based on fragmented data can produce misleading results.

For each species, there is a population threshold below which the population faces a danger of dying out (Wilson, 1999). Based on this axiom, documenting the fulfilment of the function of a refuge in a given area may and should be the basis for legal protection (e.g. reserve, ecological use, natural monument). When proposing forms of protection, ecological requirements of protected species should be considered (Fałtynowicz, 1997). The most important and the most effective method is in situ protection (Cieśliński & Czyżewska, 2002) based on multidirectional actions undertaken for the sake of permanent preservation of all elements of biodiversity associated with their natural occurrence and their natural

development processes. In practice, however, such actions are taken sporadically in relation to lichens. The authors realise that the presented theses and propositions do not exhaust the whole problem of lichen refuges. They count on their critical evaluation and verification by the lichenologists' community and they hope for a substantive discussion, because new conclusions may be formulated to complement the discussed topic.

6. Conclusions

1. A complete, even a rich list of currently occurring species cannot be the only or the basic criterion for recognizing the area as a refuge.
2. When creating a list of indicator species for the refuge, each area should be considered individually – this will allow protecting the region's most valuable species. Spatial and species variation of lichens are a result of the operation of numerous factors, related to, for example, the size of the area, level of the regional anthropopressure, microclimate and others.
3. With respect to refuge typing, complete historical data are particularly valuable, allowing for the tracking of the degree and direction of changes in the biota of lichens, selection of the most valuable species or the most endangered species and indication of the existence of areas with the best-preserved biota of lichens.
4. Since the problem of the refuge is not often discussed in the lichenological literature, it is advisable to continue researching this problem in other areas.
5. Research on lichen refuges, although only related to epiphytes, may be applied to other habitat groups.

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