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Freshwater lichens and habitat zonation of mountain streams

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ABSTRACT

Freshwater lichens of selected Carpathian streams were investigated to identify their diversity and distribution patterns. Lichens were investigated along six transects, each running across three different habitats (hydrological zones: submerged, splash and riparian), established in upper, middle and lower reaches of the streams and the data were a subject to statistical analyses. The studied mountain streams provided suitable habitats for a number of aquatic and semi-aquatic lichens and species richness in both streams was very similar. Overall, 52 species of lichens were identified from all sampling plots (γ diversity). Species number for a single plot (α diversity) ranged from 1 to 14 species and differences in species composition between the plots (β diversity) were high. Differences were mainly noted for typical terrestrial lichens occurring in riparian zones. The location along the stream reaches did not have a significant effect on species diversity and distribution. The hydrological zone appeared to be the most important predictor explaining the small-scale occurrence and diversity of lichens with species assembled into distinct, low-diversity communities in the transition from submerged to riparian habitats. The distinction among hydrological zones and their lichen biota were corroborated by nMDS analyses. The method of defined plots provides a way of recording baseline data for a particular river, which can be repeated (monitor) in the future.

1. Introduction

Lichens (lichenized fungi) are highly specialized fungi which live in stable and highly organized associations with algae and/or cyanobacteria, and other microbes. They are distinguished from other fungal-algal associations by the dominating role of the fungus, which provides the overall form and structure of the lichen, over the photobiont, the inhabitant surrounded by the fungal hyphae. About *ca.* 13,500 lichen species are currently accepted and it is estimated that the present world total is probably in the range 17,000–20,000 (Nash, 2008) or even more (Lücking et al., 2014). The vast majority of lichens are restricted to terrestrial environments and require alternate wetting and drying regimes for their existence. When fully hydrated for extended periods of time, their thalli disintegrate (Thüs et al., 2014). Some species, however, stand out as their distribution is clearly affiliated with or even restricted to aquatic and semi-aquatic habitats. These highly specialized lichens are widespread throughout the world, and often constitute major components of the biota in suitable habitats. There are approximately 700 species known from marine tidal zones and 250 from freshwater habitats (Thüs et al., 2014), but probably more can be expected, particularly in tropical areas that are still poorly explored.

In Europe, freshwater environments, especially mountain springs and streams, have recently received increased attention (Keller and Scheidegger, 1994; Keller, 2000; Krzewicka and Galas, 2006; Nascimbene and Nimis, 2006; Nascimbene et al., 2007; Thüs, 2002) as due to their water quality they potentially host a relatively high number of aquatic lichen species compare to urban areas. In total there are *ca.* 150 species of lichens observed in Europe which have a more or less strong affinity to freshwater habitats (Thüs and Schultz, 2009). However, water habitats at specific sites are rather poor in lichen species. For instance, Nascimbene et al. (2007) noticed only six species in perennially inundated habitats, and thirteen species in periodically inundated habitats of 36 springs examined in the Alps. In general, in European watercourses, species richness in the submerged zone rarely exceeds five to ten species at a given site (Gilbert, 1996; Gilbert and Giavarini, 1997; Hachułka, 2011; Keller, 2005; Krzewicka and Hachułka, 2008; Motiejūnaitė, 2003; Motyka, 1926) and 15–20 species at unpolluted sites in temporarily but regularly inundated and splash zones.

Freshwater lichens are in fact amphibious organisms, most of them being submerged during only a part of the year (Aptroot and Seaward, 2003). The majority of them occupy only the upper levels of water habitats and may be exposed to prolonged desic-

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cation during periods of drought. The distribution and diversity of their communities depend on several ecological and chemical factors such as the type and stability of the substrate, length of submergence, shading, water chemistry and pollution (Gilbert, 1996; Gilbert and Giavarini, 1997; Krzewicka and Galas, 2006; Nascimbene and Nimis, 2006; Nascimbene et al., 2009; Pentecost, 1977; Thüs, 2002). In his pioneering work Santesson (1939) recognized the zonation patterns of lichen assemblages, which seemed to be driven primarily by the length of inundation, and this view was broadly supported by other workers. Many later papers also focused on patterns and drivers of the zonation of lichen assemblages in watercourse beds or along lake margins (Coste, 2005; Gilbert, 1996; Gilbert and Giavarini, 1997, 2000; Hachułka, 2011; Motiejūnaitė, 2003; Keller and Scheidegger, 1994; Ried, 1960a,b; Rosentreter, 1984). The majority of these studies, however, provided at best only detailed floristic descriptions (with the exception of phytosociological treatment by Coste in 2005) and did not attempt statistical analyses of the patterns observed. Our work, following the work of Coste (2010), is one of the very few attempts to statistically analyze the influence of potentially meaningful ecological factors on the occurrence of freshwater lichens.

In this paper, we present an analysis of the diversity and distribution patterns of lichens from streams representative of the Bieszczady Mts in the Easter Carpathian Mts. The investigated streams are protected by the buffer zone of the transboundary mountain East Carpathian Biosphere Reserve extending from Poland through Ukraine and Slovakia. Because of the area's remoteness its original habitats are well preserved. We expected, therefore, that the investigated streams would host a rich diversity of aquatic and semi-aquatic lichens, and might provide a useful model site for understanding processes affecting variability of their communities in this region. We also hypothesized that diversity and distribution patterns of the investigated communities of freshwater are driven by hydrological zonation of habitats and location along the stream reaches.

In Europe, aquatic and semi-aquatic lichen conservation is usually entrusted to generalized habitat protection (Nascimbene and Nimis, 2007). However, to comprehend and monitor environmental changes in stream habitats, it is necessary to recognize and understand diversity patterns of their biota across environmental and geographical gradients (Wróbel, 1998). Such knowledge is also desirable if informed decisions concerning the management and conservation of stream habitats and their biota are to be made. This paper suggests a method of defined plots at individual sites as it allows comparison between sites, whether on the same river or different rivers. The method provides a semi-quantitative way of recording baseline data for a particular river, which can be repeated in the future. Such method is suitable for monitoring of environmental changes in stream habitats. The floristic information (pooled from all the sites) gained during the survey can also be compared with rivers in other parts of Europe.

2. Material and methods

2.1. Study area

The study area is located in the Bieszczady Mts, which form the western part of the Polish Eastern Carpathian Mts. The Bieszczady Mts are mid-sized mountains with the highest peaks exceeding 1400 m a.s.l., extending *ca.* 130 km in a northwest-southeast direction from south-east Poland through Ukraine and Slovakia. The mountain range is covered with vast beech forests. The original flora and fauna are well preserved because of the area's remoteness, with the most valuable part of the area being protected within a transboundary mountain East Carpathian Biosphere Reserve. Conservation projects in the reserve focus on the maintenance and protection of forests, mountain meadows, river corridors and aquatic habitats, and their biological diversity.

The field survey and sampling for this study were conducted along the valleys of the Roztoczka and Smerek streams (Fig. 1). These streams belong to two neighbouring stream catchments with sources located on opposite slopes of Mt. Okrąglik (1101 m a.s.l.). The Roztoczka is *ca.* 8 km long and originates from a source located on the north-western slopes at a height of *ca.* 990 m a.s.l. Its mouth, located at a height of 570 m a.s.l., discharges to the Solinka stream (a part of the drainage basin of the upper San river). The Smerek is *ca.* 8 km long and originates from a source located on the north-eastern slopes at a height of *ca.* 950 m a.s.l. Its mouth at the Wetlinka stream (a tributary of the Solinka stream) is located at a height of 610 m a.s.l. In the upper reaches, the channels of both streams are 1.1–2.5 m wide, characterized by a very steep gradient and a relatively smooth flow. In the lower sections, the stream channels are wider, ranging from 4 to 5 m in the middle to 8 m in the lower reaches; they are also characterized by a relatively steep gradient and a very turbulent flow. The width of the stream banks also varies considerably, ranging from 20 to 40 cm in the upper, 0.5–1.5 m in middle and 0.5–2.5 m in lower reaches. The channels of both streams are made of sandstones and shales of the Carpathian Flysch belonging to the Dukla and Silesian (Krosno) Units (Jankowski et al., 2004). The available rock belongs to the same geological units and comprises mainly small stones, and boulders reaching over 1 m diameter.

Both streams dissect the north-western and north-eastern slopes in the lower mountain zone, flow through the mixed beech-fir forest. Both streams are only partly shaded due to roads running along their banks, but no anthropogenic infrastructures and modification of the stream valleys are present in their upper reaches. The road along the Roztoczka stream leads to the small villages of Liszna and Roztoki Górne, whereas the road along the Smerek stream is completely closed to public transport and open only to forest workers. The traffic along the roads is, therefore, very limited and is not a source of any significant pollution.

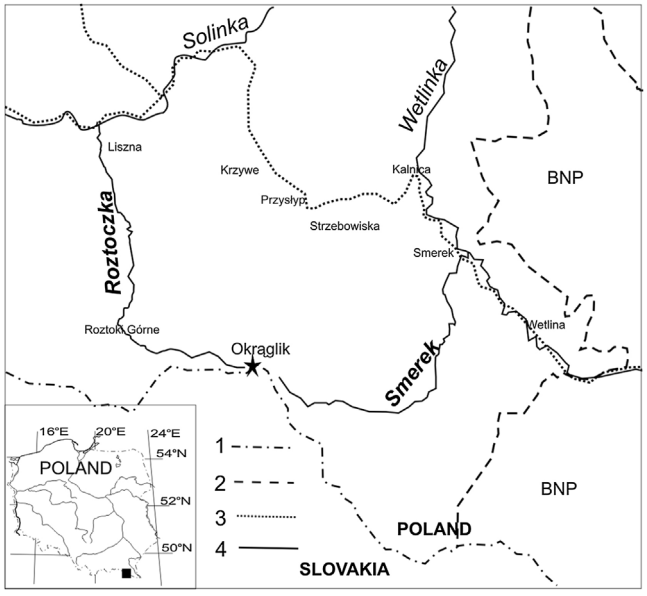

Fig. 1. The location of the Roztoczka and Smerek streams. Abbreviations: 1–national border; 2–border of the Bieszczady National Park; 3–road; 4–stream/river.