HUMAN TRACES IN THE BRYOPHYTE FLORA OF THE SUMMIT REGION OF KARKONOSZE MTS (POLISH SIDE)

EWA FUDALI

Department of Botany and Plant Ecology,
Wrocław University of Environmental and Life Sciences
Pl. Grunwaldzki 24a, 50-363 Wrocław, Poland
e-mail: efudali@ozi.ar.wroc.pl

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ABSTRACT

Based on results of the bryofloristic investigations carried out in 2006 along tourist roads and around mountain chalets the problem of bryophyte response to the tourist utilization of the summit region of Karkonosze Mts is discussed here. The hypothesis that introduction of cement as building material might have caused the income and spread of subneutral or basiphilous ruderal species in that naturally acidic region was formulated and tested.

In result 45 species were found, of which the majority do not occur in natural sites in the Karkonosze Mts. Among them 20 species are convinced to be highly hemerophilous. Most of the found species were eurytopic, only 14 prefered subneutral or basic substrata. Many of them produced sporogonia, what indicates high reproduction potential.

It seems that the phenomenon of synanthropisation is limited mainly to places in which cement (as mortar or concrete) has been used. The list of bryophytes found around all the anthropogenic sites and along the tourist roads in the summit region of Polish part of the massif with brief characteristics of their ecological preferences has been included.

KEY WORDS: bryophytes, synanthropisation, Karkonosze Mts, Sudetes.

INTRODUCTION

Recently, an increase of bryological investigations in the summit region of the Karkonosze Mts has been observed, both on the Polish and Czech side. The studies were carried out mainly in the post-glacial cirques (Kučera and Buryová 1999; Fudali 2001a, 2004; Fudali and Kučera 2002, 2003; Kučera et al. 2004a-c) and on slopes and the summit of Śnieżka Mt. (Fudali et al. 2003; Kučera et al. 2004c). These places were just in the 19th century thought as biodiversity centers and refugia of high-alpine vegetation (Nees von Essenbeck 1838, 1840; Milde 1861; Limpricht K.G. 1876; Limpricht W. 1930). Comparison of presently collected data with the historical ones showed that the bryoflora of subalpine zone of Karkonosze Mts is still reach and has kept its own specificity, although some species were not re-found (Kučera et al. 2004b-c; Fudali 2003).

As studies were focused on the biodiversity centers our knowledge concerning the bryoflora synanthropisation in that region is highly insufficient. There is no information about bryophyte response to long human presence and activity in the massif. We can suspect that human presence has influenced the species composition of bryophytes because this group of plants is known to be sensitive indicators of anthropogenic changes in the biosphere (Balcerkiewicz and Rusińska 1988). The aim of the investigations carried out in the summer of 2006th by author was to study that problem. The hypothesis that introduction of cement as building material have might caused the income and spread of subneutral or basiphilous ruderal species in that naturally acidic region was brought up. In the paper the obtained data are discussed.

OBJECTS AND METHODS OF INVESTIGATIONS

The range of Karkonosze Mts belongs to the old middle European mountains, the so-called Hercynians, and are situated in the areas of Poland and Czech Republic. The altitudinal span reaches in Poland 875 m (727 to 1602 m a.s.l.), but the elevation of the main massif seldom exceeds 1450 m a.s.l. The climate of Karkonosze Mts is severe, similar to that prevailed in the subarctic areas (Staffa 1985). The geology of the range is various, but the Polish part is dominated by very acid substrata. In the western part the geological substratum consists mainly of granitoids, while the eastern part is built of granite-gneiss and schists, with the exception of the Śnieżka Mt. and range of Czarny Grzbiet formed of mica schists (Staffa 1993).

The area of Karkonosze Mts has been influenced by man since the Middle Ages. At first it was exploited as a source of minerals and jewels. Some trade routes used by Czech

TABLE 1. Brief ecological characteristics of recorded bryophytes.

General pH requirements (follows Dierssen 2001)	Name of species		Localities													Number of records (= localities)
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	
c ac.-sn.	*Amblystegium serpens*	H	m,c; !	.	.	m; !	m	.	.	m	m; !	m	c,m	m; !	.	.	8
sn.-bas.	*Barbula convoluta*	H	d	.	d	.	.	.	.	.	d	.	.	.	.	.	3
c ac.-sn.	*Brachytheciastrum velutinum*		.	.	.	.	.	m; !	.	.	.	.	.	.	.	.	1
c ac.-sn.	*Brachythecium albicans*	H	m,c,d; !	c	c	.	m		c,s	.	m,s	s	.	.	.	c	8
(m ac.) sn.	*Brachythecium glareosum*		.	.	.	.	.	m; !	.	.	.	.	.	.		.	1
m ac.-sn.	*Brachythecium rivulare*		c (ditch)	.	.	.	c	.	.	.	.	.	.	.	.	.	2
(m ac.) sn.	*Brachythecium salebrosum*	H	.	c	.	.	.	.	c; !	.	m; !	.	.	.	.	c	4
sn.-bas.	*Bryoerythrophyllum recurvirostrum*	H	.	.	m; !	.	.	c; !	.	.	m; !	.	.	m; !	.	.	4
sn.	*Bryum argenteum*	H	m,c; !	.	c,b; !	m; !	c	m	c	m	m,s	m,s	s	c,d,b,m	b,c	m	14
sn.-bas.	*Bryum caespiticium*	H	c,d; !	.	r,s; !	r; !	.	.	s; !	.	s; !	.	.	.	.	.	5
m ac.-sn.	*Bryum pallens*		.	.	.	.	.	.	.	.	.	.	.	m; !	.	.	1
m ac.-sn.	*Bryum pallescens*		m,c; !	c; !	m; !	m; !	c,m; !	m,c; !	c; !	m; !	m; !	m; !	m; !	m; !	m; !	c,m; !	14
m ac.-sn.	*Ceratodon purpureus*	H	c,d; !	c; !	c,b; !	r; !	c,m; !	m,c; !	c,s; !	m; !	m; !	m,s; !	s,m	b,d,m; !	b,c,m; !	c,m; !	16
c ac.-sn.	*Dicranella subulata*		.	.	.	.	.	c	.	.	.	.	.	.	.	.	1
sn.	*Didymodon rigidulus*	H	.	.	.	.	.	.	c	.	.	m; !	.		.	.	2
m ac.-bas.	*Distichium capillaceum*		.	.	.	.	.	c,m; !	.	.	.	.	.	.	.	.	1
(m ac.) sn-bas.	*Drepanocladus polycarpos*													m			1
m ac.-bas.	*Dryptodon pulvinatus*	H	.	.	.	.	.	c; !	.	.	m; !	.	.	.	m; !	.	3
sn.-bas.	*Encalypta streptocarpa*		c	c	.	.	.	c,m; !	.	m	m;	m	.	m	.	c	8
m ac.-sn.	*Funaria hygrometrica*	H	m,c; !	.	m,s; !	.	.	c,m; !	c; !	.	m,s; !	.	m; !	.	.	.	6
(c ac.) bas.	*Homalothecium sericeum*	H	.	.	.	.	.	.	.	.	m; !	.	.	.	.	.	1
(c ac.) bas.	*Hygrohypnum luridum*		.	.	.	.	.	.	c	.	.	.	.	.	.	.	1
sn.	*Leptobryum pyriforme*	H	m	.	r; !	.	.	.	.	.	.	.	s	m	.	.	4
c ac.-sn.	*Lophocolea heterophylla*		.	c	.		.	.	.		.	.	.	.	.	c	2
c ac.-bas.	*Marchantia polymorpha ssp. ruderale*	H	.	.	.	.	.	.	.	.	.	.	.	.	.	c (ditch)	2
sn	*Orthotheciella varia*		.	.	.	.	.	.	.	.	.	.	.	m; !	.	c (ditch); !	2
m ac.-sn.	*Orthotrichum anomalum*	H	.	.	.	.	.	.	c; !	.	m; !	.	.	.	.	.	2
(c ac.) sn.	*Plagiomnium cuspidatum*	H	.	.	.	.	.	m	.	.	.	.	.	.	.	.	1
c ac. (sn.)	*Plagiothecium nemorale*		.	.		.	.	.	.	.	.	.	.	m	.	.	1
c-m ac. (bas.)	*Pohlia wahlenbergii*		.	.	.	.	.	.	.	m		b	.	b	.	.	3
h ac.-sn.	*Polytrichum piliferum*		.	.	.	.	.	.	.	.	.	.	.	b	.	.	1
c ac.-sn.	*Rhizomnium punctatum*		.		.	.	.	.	.	.	.	.	.	.	.	c (ditch)	3
sn.-bas.	*Rhynchostegium murale*	H	c; !	c; !	.	.	c	c,m	c	.	m; !	m	.	.	.	c,m; !	9
m ac.-sn.	*Rosulabryum laevifilum*		m,c; !	c; !	.	.	.	.	.	.	.	m; !	.	m; !	.	c; !	5
c ac.-sn.	*Sanionia uncinata*		.	.	.	.	.	m	.	m	.	.	.	m	.	.	3
m ac-bas.	*Schistidium apocarpum*	H	m,c; !	c; !	c,m; !	m; !	m,c; !	m,c; !	c; !	m; !	m; !	m; !	c,m; !	m; !	c; !	c,m; !	18
bas.	*Schistidium crassipilum*		.	.	.	.	.	.	.	.	m; !	.	.		.	.	1
bas.	*Schistidium robustum*		.	.	.	.	.	.	.	.	.	.	.	m; !	.	.	1

TABLE 1. Cont.

General pH requirements (follows Dierssen 2001)	Name of species		Localities I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Number of records (= localities)
c ac.-sn.	**Sciuro-hypnum populeum*	H	c; !	c	m; !	.	c,m; !	m	c	.	.	.	c	.	c	c	11
(c ac.)sn.-bas.	**Syntrichia ruralis s.l.*		.	.	.	.	.	.	.	.	m	.	.	m; !	.	.	2
m ac.-sn.	**Syntrichia norvegica*		.	.	.	.	.	.	.	.	.	.	.	m	.	.	1
bas.	**Tortella tortuosa*		.	.	.	.	.	.	.	.	.	.	.	.	.	c,m	1
sn.-bas.	**Tortula muralis*	H	m; !	.	m; !	m; !	m; !	m; !	.	.	m; !	m; !	m; !	m; !	.	.	9
sn.	*Tortula subulata*	H	.	.	.	.	.	.	.	.	.	.	m; !	.	.	.	1
m ac. (sn.)	*Trichostomum tenuirostre*		.	.	.	.	.	.	.	.	m	.	.	m	.	.	2
Total number of species in locality			16	10	12	7	10	17	13	8	20	12	10	21	6	15	.

Explanations: symbol of localities: I – Schronisko na Hali Szrenickiej chalet; II – paving road between Mt Szrenica and Schronisko na Hali Szrenickiej chalet; III – Schronisko na Szrenicy chalet; IV – chair-lift station on Mt Szrenica; V – Schronisko pod Łabskim Szczytem chalet; VI – TV station on the edge of Mały Śnieżny Kocioł cirque; VII – Schronisko Odrodzenie chalet; VIII – tourist point over the Kocioł Wielkiego Stawu cirque; IX – Schronisko Strzecha Akademicka chalet; X – Schronisko Samotnia chalet; XI – Schronisko Dom Śląski chalet; XII – revetments and walls on the top of Mt Śnieżka; XIII – paving road Droga Jubileuszowa; XIV – anti-erosive reinforcements, ditches and water-passages along roads; ecological requirements: bas. – basophilous; c ac. – considerably acidic; m ac. – moderately acidic; h ac. – highly acidic; sn – subneutral; type of substratum: b – between pavement; c – concrete; d – strongly trampled sites; m – mortar; r – ruins covered with soil; s – soil mixed with slag; others: ! – observed with sporogonia; * – also reported from the Czech part; H – species considered to be hemerophilous (see: Fudali 2005).

and Silesian merchants led across the mountain passes. In the 18th c. it was an important center of metallurgy and glass works what resulted in huge damage of natural forests, which were replaced by intensive shepherding. Since late the 1950s the highest part of the range, both on Polish and Czech side, has been protected in form of national parks (Staffa 1985).

There is an opinion that just the Karkonosze Mts were first among European mountains where mass-tourism was executed; in some parts too intensively. Presently, in the summit region of the range there are 21 buildings (10 in a Polish part) and a branched network of tourist routes. Some of them have artificial surfaces (asphalt, pavement, lime-gravel or slag), anti-erosive reinforcements and hydrotechnical infrastructure made of concrete. One of the distinctive features of all buildings are revetments and low walls built of granite bricks joined with mortar as well as sewage reservoirs made of concrete. All the buildings were built in the first decades of the 20th c.; some of them have been renewed recently.

The bryofloristic survey was carried out in the summer of 2006th in the summit region of Polish part of Karkonosze Mts. Bryophytes were collected from all man-made or man-influenced substrata occurring around mountain chalets and other buildings situated there and along tourist routes. These were: concrete, mortar, soil mixed with slag, slits in asphalt, intensively trampled soil. Nomenclature of mosses follows Ochyra et al. (2003), liverworts follows Grolle and Long (2000). Bryophyte general ecological requirements in relation to the substratum reaction were accepted as suggested by Dierssen (2001).

RESULTS AND DISCUSSION

In result 43 moss species and 2 liverworts were collected from anthropogenic sites in the study area (Table 1). Most of them was never noted on natural sites in the massif (Wilczyńska 1998; Fudali 2001b, 2004; Fudali and Kučera 2003; Fudali et al. 2003). Among them 20 species are considered to be highly hemerophilous, because they occur frequently and abundantly in urban areas (e.g. Fudali 2005). Most the taxa, 36, were collected from mortar; 26 occurred on concrete, 6 on soil mixed with slag, 4 in slits between pavement, 4 on intensively trampled soil and 3 on ruins covered with thin soil layer (Table 1). Ecologically, the majority of species are eurytopic in relation to the substratum reaction; they occur in a wide range of sites from considerably acidic to subneutral and basic (16 species) or from moderately acidic to subneutral and basic ones (15). Only 14 taxa show narrow preferences to subneutral and basic substrata. Among them one can find both ruderal species, typical for urban buildings (*Bryoerythrophyllum recurvirostrum*, *Bryum argenteum*, *B. caespiticium*, *Didymodon rigidulus*, *Leptobryum pyriforme*, *Rhynchostegium murale*, *Tortula muralis*, *T. subulata* and *Barbula convoluta*), and species associated mainly with natural calcareous sites (*Encalypta streptocarpa*, *Orthotheciella varia*, *Schistidium crassipilum*, *S. robustum* and *Tortella tortuosa*).

Analyses of species frequency and their spatial distribution along summit region of the massif revealed that 10 species showed a distinct relation to the anthropogenic sites in Karkonosze Mts (Table 1). These are: subneutral or ba-

sophilous – *Bryum argenteum* (14 study sites), *Rhynchostegium murale* (9), *Tortula muralis* (9) and *Encalypta streptocarpa* (8) as well as eurytopic – *Schistidium apocarpum* (18), *Ceratodon purpureus* (16), *Bryum pallescens* (14), *Sciuro-hypnum populeum* (11), *Brachythecium albicans* (8) and *Amblystegium serpens* (8). All the mentioned species occurred on substrata containing cement; additionally *Ceratodon purpureus*, *Bryum argenetum* and *Brachythecium albicans* were found on the ground. Its worthy to stress that the majority of recorded species produced sporogonia.

A number of species which occurred around particular buildings seems to depend on the substratum age – the oldest were the richest. Buildings renewed recently (Dom Śląski chalet, Szrenica chalet, Droga Jubileuszowa road) were poor in bryophyte species (Table 1). On paths around some chalets a moss species typical for urban trampled sites, *Barbula convoluta*, was stated. However the species has not spread along tourist routes.

It was observed that bryophyte response to the development of hiking in the study area is probably relevant to the type of route's surface not to trampling. Along paths, often covered with lime-gravel or slag, sporadically only one species, *Ceratodon purpureus*, was recorded. But the species occurred frequently and abundantly in slits in asphalt and between pavements. It was often associated with *Bryum argenetum*, *Polytrichum piliferum* and *Pohlia wahlenbergii*. In concrete ditches accompanying some routes, among prevailing xerophilous ruderals, some hygrophilous species were also found: *Brachythecium rivulare*, *Rhizomnium punctatum*, *Orthotheciella varia* and *Marchantia polymorpha ssp. ruderale*.

First tourist objects were set up in the summit region of the Karkonosze Mts in the second half of the 19th c. (Staffa 1985). But already in 1836 Nees von Eisenbeck noted on the summit of Śnieżka Mt. the presence of ruderal moss species *Bryum caespiticium*. In the same place Gustaw Limpricht observed in 1865 *Ceratodon purpureus* and *Leptobryum pyriforme*, and in 1876 Kern collected specimens of *Bryum argenteum* and *B. algovicum*. From the walls of the chapel situated then on the top of Śnieżka *Distichium capillaceum*, *D. inclinatum*, *Bryum cirrhatum* and *B. pallens* were also mentioned (Wilczyńska 1998; Kučera et al. 2004). The next notes concerning the occurrence of synanthropic bryophytes in subalpine zone of the Polish part of Karkonosze Mts appeared not before the end of 1950s. Lisowski (1956, 1961) reported the presence of *Funaria hygrometrica* around the Schronisko pod Łabskim Szczytem chalet and *Schistidium apocarpum* on the building of Schronisko Samotnia chalet. In the year 2003 *Ceratodon purpureus* on the tourist route sides near the base of Śnieżka Mt. as well as *Didymodon rigidulus* and *Encalypta streptocarpa* on concrete reinforcements along Droga Jubileuszowa road in the Śnieżka pass were noted (Fudali et al. 2003).

More information was collected from the Czech part of the range, but the investigations were limited to only some stations: surroundings of mountain chalets – Martinova bouda, Medvědi bouda (Kučera et al. 2004a), Labská bouda (Kučera et al. 2004b), Lučni bouda (Kučera and Buryová 1999) and the summit of Śnieżka Mt. (Kučera and Buryová 1999; Kučera et al. 2004c). Altogether the Czech bryologists reported 47 species from changed by man places, including 25 typical ruderals. The most of them were also found during the presented investigations.

CONCLUSION

The obtained data suggests that the phenomenon of bryoflora synanthropisation in the summit region of the Karkonosze Mts appeared only locally and is limited mainly to places in which cement (as mortar or concrete) has been used. It is manifested by the presence of many eurytopic hemerophilous ruderal species and some number of subneutral or basophilous epiliths, which do not occur naturally in the range. Most of the synanthropic species produced sporogonia, what indicates their high reproductive potential. However, the strongly acidic character of geological substratum seems to be a limiting factor for these bryophytes' spreading. The bryoflora synanthropisation rate in this region seems to be subjected to the intensity of cement utilization.

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