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The effects of hikers' paths on the distribution of liverworts in the Tatra Mountains (Western Carpathians)

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Abstract – The article concerns the reaction of liverworts to the origin of new synanthropic habitats in the Tatra Mountains (Western Carpathians). Tourist trails, their shoulders and scarps were investigated. Thirty-one liverwort species were recorded in the investigated synanthropic habitats, which make up *ca* 15% of the hepaticoflora of the Tatra Mts. *Cephalozia bicuspidata*, *Nardia scalaris*, *Solenostoma gracillimum*, *Scapania curta*, *S. umbrosa* and *Lophozia sudetica* display distinct hemerophilous features. Leading plant species are *Cephalozia bicuspidata* in typical synanthropic habitats (on tourist trails) and *Nardia scalaris* in semi-natural habitats (on trail scarps). Apophytes in the Tatra Mts. are mostly lowland-mountain species and they are widespread in the entire massif. Apophytization of liverworts in some aspects is similar to the phenomena described in the case of vascular plants. It concerns "walking down" of high mountains species to lower sites (*Marsupella brevissima*, *Lophozia sudetica*), "passing" of alpine scree-bed species to synanthropic habitats (*Anthelia juratzkana*, *Marsupella brevissima, Pleurocladula albescens*), and formation of plant communities with new floristic combinations (community with *Cephalozia bicuspidata*) or expansion of secondary forms of autogenic communities (e.g. *Calypogeietum trichomanis*, *Nardietum scalaris*). Some of them play an important role in stabilization of trail scarps, especially in the alpine belt (*Nardietum scalaris kiaerietosum starkei* subass. nova*)*.

Synanthropic liverworts / apophytization / the Tatra Mts. / Western Carpathians

INTRODUCTION

Transformations of plant cover in mountain and lowland territories are inseparably connected with the reduction or disappearance of areas of natural ecosystems and generation of new anthropogenic habitats. Plants may colonize the new habitats and persist, despite being permanently affected by various disturbance factors. The specificity of new habitats usually favours pioneer plants, mostly spore-producing species. Their apophytic capability is common, especially in the lowlands. Liverworts are a part of lowland synanthropic communities, *i.e.* field (*Riccia* sp. div.), field and carpet (*Fossombronia wondraczekii, Blasia pusilla*) or ruderal ones (*Marchantia polymorpha, Conocephalum conicum*). Compared to mosses, liverworts however seem to be a more hemerophobic, but less neophytic

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group. The Tatra Mountains, an area that has undergone disturbance for almost 200 years, is an excellent site for studying synanthropization of liverworts. The Tatra Mts. represent a centre of liverwort diversity in Poland. This paper focuses on the reaction of liverworts to the origin of new synanthropic habitats, mainly on tourist trails. The aim of the study was to indicate which species exhibit hemerophilous properties and to what degree, and to show this in the context of phenomena described for vascular plants. Considerations were carried out on floristic and phytocoenotic levels.

In the Tatra Mts. the apophytism of liverworts has rarely been documented and only as a part of phytosociological studies (e.g. Krajina, 1933; Balcerkiewicz, 1984; Górski, 2004). An extensive study of synanthropic vegetation on tourist trails in the Carpathians, including moss communities of the Tatra Mts., has been given by Górski (2007).

The Tatra Mts. are the highest mountain range in the Carpathians (with Gerlachovský štít elevated at 2655 m a.s.l.). This mountain chain is situated on the border between Poland and Slovakia, with the greater part belonging to the latter country. According to geobotanical classification, Tatra Mts. are divided to Western Tatra Mts. (Bystrá 2248 m a.s.l.), High Tatra Mts. (Gerlachovský štít, 2655 m a.s.l.), Bielskie Tatra Mts. (Havran, 2152 m a.s.l.), and the range of Siwy Wierch (Sivý vrch, 1806 m a.s.l.). The mountains are built of crystalline and sedimentary rocks. Major ranges of High Tatra Mts. are made of granitoids, whereas in Western Tatra they are made of metamorphic rocks (mostly gneiss) and granitoids, and in Bielskie Tatra Mts. and the range of Siwy Wierch – of sedimentary rocks (limestones and dolomites). The annual rainfall ranges from 1200 to 1600 mm, exceeding 1850 mm in highest areas.

MATERIAL AND METHODS

The list of the synanthropic Tatra liverworts was established upon the basis of geobotanical documentation made along tourist trails. Altogether, 70 floristic lists were made. They were made in the Polish part of the Western Tatra Mts. in the vicinity of Dolina Chochołowska Valley. The floristic lists comprised solely moss and liverworts phytocoenoses at official tourist trails in all vegetation belts. Liverwort habitats were divided into two groups:

– group A (see Fig. 1) – microhabitats *on the trail* (on the middle part or on the border), on compact soil, trampled out and periodically destroyed, depending on intensity of tourism,

– group B (Fig. 1) – microhabitats on slopes caused by the marking-out of tourist trails (seminatural habitats); the plants are not directly subjected to trampling.

Both epigeic and epilithic liverworts, growing on the exposed surfaces of larger stones species, are present in habitats A and B.

The list of synanthropic liverworts was supplemented with data from 500 phytosociological relevés made according to the Braun-Blanquet method (Dierschke, 1994) made at tourist trails in the Polish part of Tatra Mts. and published by Górski (2007).

The combined data did not include synanthropic habitats of limestone rock landscapes. Participation of species groups distinguished upon the affinity to altitude group and the presence of sexual organs (mono- and dioecious plants) was analyzed. The following measures of the participation of species groups were

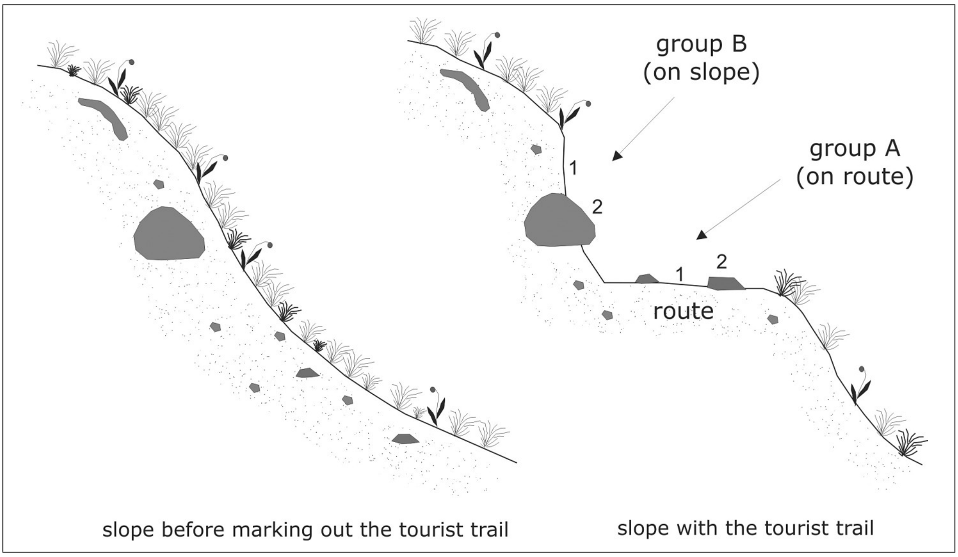

Fig. 1. Types of synanthropic habitats in the Tatra Mts: A – sites trampled out on trail, B – trail slopes, 1 – microhabitats of epigeic species. 2 – microhabitats of epilitic species.

used: a – number of species, b – percentage representation in the floristic list, c – percentage proportion of plant cover, d – collective participation of the group. The measures were calculated according to Pawłowski (1966). Floristic lists comprising liverworts with their quantitative relationships in plant patches were analyzed.

The synanthropic liverwort flora of the Tatra Mts. was related to the total liverwort flora of Tatra Mts. Due to the lack of a thorough study of the hepaticoflora of both the Polish and Slovakian parts of the Tatra Mts., all available data, starting with Szyszyłowicz (1885), were combined into a database comprising 5050 records. Based upon these data, especially the studies by Szweykowski (1957, 1960, 1996), the number of Tatra liverworts was determined to be 205. Frequencies of species were transformed into a four-stage scale (very frequent, frequent, rare, very rare). Affinity to altitude groups, based on the categorization of vascular plants given by Mirek (1989), is determined for all synanthropic liverworts. Selected biological characteristics of species were determined according to Damsholt (2002). Liverwort and plant community nomenclature was applied according to Szweykowski (2006), Hentschel *et al.* (2006, for *Chiloscyphus profundus*), Hentschel *et al.* (2007, for *Solenostoma gracillimum*, *S. sphaerocarpum*) and Marstaller (2006).

RESULTS

General characteristics of synanthropic liverworts

Nineteen liverwort species were recorded in trampled habitats along tourist trails in the Tatra Mts (group A), whereas 28 species were found on trail slopes (group B). Altogether, tourist trails, their shoulders and slopes were the site of permanent or occasional occurrence of 32 liverworts (Table 1), making up 16% of the known liverwort flora of the Tatra Mts. Typical hemerophiles of the Tatra Mts., growing frequently and profusely on trampled habitats, were: *Cephalozia bicuspidata*, *Nardia scalaris*, *Solenostoma gracillimum*, *Scapania curta*, *S. umbrosa* and *Lophozia sudetica*. They make up only 3% of the Tatra flora. Thus, liverworts as a systematic group are clearly hemerophobic.

Table 1. List of synanthropic liverworts of the Tatra Mts.

Liverworts tolerating direct trampling, growing on tourist trails (group A)	*Liverworts occurring on the slopes of tourist trails (group B)*
1. common on tourist trails (over 51% of records)	
●● *Cephalozia bicuspidata*	●● *Nardia scalaris*
● *Nardia scalaris*	● *Cephalozia bicuspidata*
2. frequent on tourist trails (21-50% of records)	
●● *Solenostoma gracillimum*	◦ *Lophozia sudetica*
◦ *Scapania umbrosa*	● *Solenostoma gracillimum*
● *Lophozia sudetica*	● *Lophozia floerkei*
◦ *Scapania curta*	● *Lophozia wenzelli*
	● *Solenostoma sphaerocarpum*
3. rare on tourist trails (below 20% of records)	
● *Lophozia floerkei*	◦ *Diplophyllum obtusifolium*
● *Pellia neesiana*	◦ *Lophozia ventricosa*
● *Scapania parvifolia*	◦ *Scapania curta*
● *Scapania undulata*	● *Scapania parvifolia*
◦ *Lophozia lycopodioides*	● *Calypogeia azurea*
◦ *Diplophyllum obtusifolium*	● *Scapania umbrosa*
◦ *Chiloscyphus profundus*	● *Pellia neesiana*
◦ *Lophozia ventricosa*	● *Calypogeia neesiana*
● *Marsupella brevissima*	◦ *Chiloscyphus profundus*
● *Marsupella funckii*	● *Pellia epiphylla*
◦ *Marsupella sphacelata*	◦ *Lophozia lycopodioides*
● *Marchantia polymorpha*	◦ *Bazzania tricrenata*
◦ *Marchantia alpestris*	◦ *Calypogeia muelleriana*
	● *Chiloscyphus polyanthos*
	◦ *Lophozia opacifolia*
	● *Marchantia polymorpha*
	◦ *Marsupella funckii*
	◦ *Anthelia juratzkana*
	◦ *Pleurocladula albescens*
	◦ *Lepidozia reptans*
	◦ *Gymnomitrion coninnatum*

Explanations:
●● species occurs with high coverage (modal quantity 4, 5)
● species occurs with significant coverage (modal quantity 2a, 2b, 3)
◦ species occurs with low coverage (modal quantity r, +, 1)
order of species in groups 1, 2 and 3 according to descending frequency

Altitude range of synanthropic liverworts

The largest group of synanthropic liverworts is that of lowland-mountain species (Table 2). They form the basis of liverwort cover in synanthropic habitats (90% participation). Upper and lower montane and multizonal mountain species have similar participation; however, the latter predominate in the plant cover. Major structure-building species of that group are *Cephalozia bicuspidata* and *Nardia scalaris*.

Mountain species, despite the fact that they make up 41% of the synanthropic flora, occur with low quantitative participation. Statistically, every fourth liverwort recorded on a tourist trail or its shoulder belonged to that group. Among alpine and multizonal highmountain species it is worth noting that three are scree-bed plants, *i.e. Anthelia juratzkana*, *Marsupella brevissima* and *Pleurocladula albescens*. Migration of species that normally grow in places of long-lasting snow cover to synanthropic habitats has been described for some vascular plants and mosses i.e. *Luzula alpino-pilosa*, *Gnaphalium supinum* or *Kiaeria starkei* (Balcerkiewicz, 1984; Górski, 2004, 2007).

Predominance of lowland-montane species over mountain ones in the synanthropic flora of the Tatra Mts. could be connected with the fact that the montane belts were earlier, and much more intensively, affected by disturbance than the regions above the upper montane belt. Disturbance of the montane belts has continued for as long a period as it has in the nearby lowlands. Moreover, synanthropic liverworts of these areas are lowland-montane species, with hemerophilous tendencies are distinct in lowlands.

Changes in vertical range of species

"Walking down" of high-mountain species, frequently noticed in the case of vascular plants, was also observed among liverworts. An example is *Lophozia sudetica*, whose altitudinal optimum in the Tatra Mts. ranges between 1,700 and 2,200 m a.s.l. (Fig. 2). This species was recorded on tourist trails in montane forests many times; the lowest occurrence being at 1,090 m a.s.l. *L. sudetica* reproduces effectively by gemmae and occupies open habitats, mainly trail slopes, which have originated inside compact forest complexes. Another example is the scree-bed and high-mountain species, *Marsupella brevissima*. This was previously recorded at altitudes above 1,600 m a.s.l., with an optimum between 1,800 and

Table 2. Participation of altitude groups of liverwort species in synanthropic habitats.

Participation measure / *Category of species*	*a*	*b*	*c*	*d*
Lowland-mountain species (total):	19	59	**90**	**76**
lowland-montane	10	31	5	15
lowland-multizonal mountain	9	28	**85**	61
Mountain species (total):	13	41	10	24
alpine and multizonal-highmountain	10	31	8	19
subalpine	3	10	2	5

Participation measures: a – number of species, b – percentage representation in the floristic list, c – percentage proportion of plant cover, d – collective participation of the group.

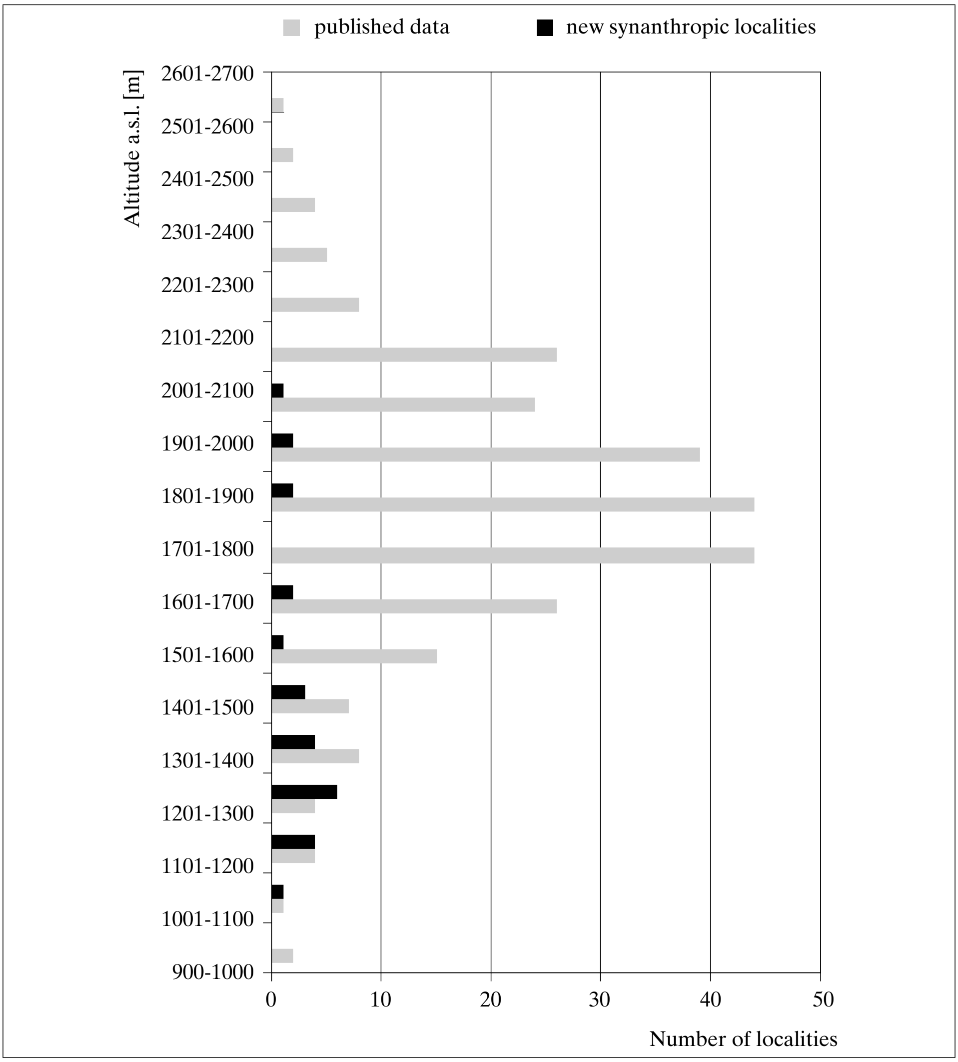

Fig. 2. Vertical distribution of localities of *Lophozia sudetica* in the Tatra Mts. (based on literature data and personal studies).

2,000 m a.s.l. (Fig. 3). During this study, the species was found at 1,385 m a.s.l., in the upper part of the upper montane belt. The presence of *M. brevissima* here is determined mainly by compaction of the soil (a characteristic feature of scree-beds) in places where tourists stop to rest and sit on *Nardus stricta* grassland.

Synanthropic liverworts and their distribution in the Tatra Mts.

From a consideration of the published localities of liverworts in the Tatra Mts., eleven species can be regarded as being common. Interestingly, as many as eight of them are apophytic liverworts (Table 3). Analyses of the flora of any region always show a higher number of very rare species compared to the

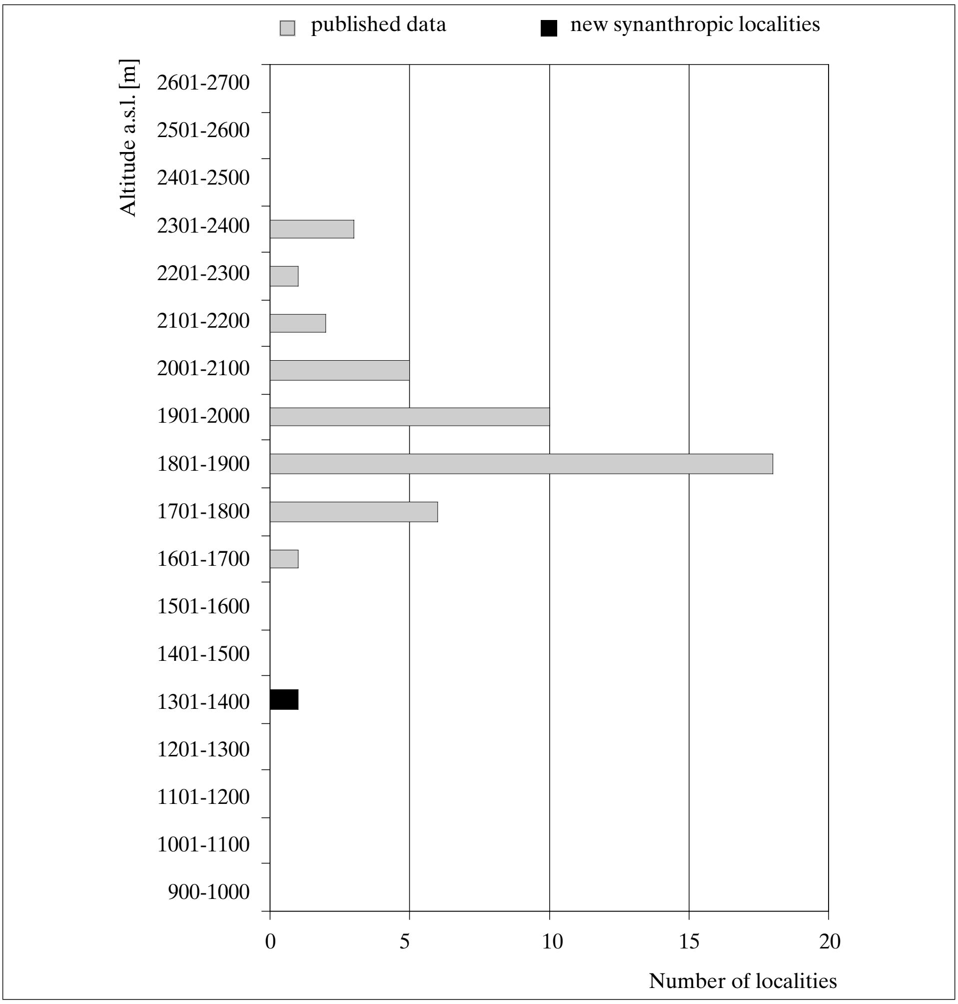

Fig. 3. Vertical distribution of localities of *Marsupella brevissima* in the Tatra Mts. (based on literature data and personal studies).

common ones. In the case of the synanthropic liverwort flora, this proportion is different. Almost 25% of synanthropic species are common liverworts in the Tatra Mts., but they make up only 5% of the Tatra flora. Very rare species, comprising 70% of the Tatra flora, make up only 40% of the synanthropic flora. It is worth noting that this group contains plants that are much more widespread in the Tatra Mts., than indicated in the literature (e.g. *Solenostoma gracillimum*, *Marsupella sphacelata, Lophozia opacifolia*, *Scapania umbrosa*).

Mono- and dioecious species in the synanthropic flora of the Tatra Mts.

Synanthropic liverworts are mostly dioecious (Table 4), a condition which also predominates among liverworts in general (Wyatt, 1982; Crandal-Stotler & Stotler, 2000; Bisang & Hedenäs, 2005). The lowest percentage of

Table 3. Distribution of synanthropic liverworts in the entire area of the Tatra Mts.

Status	*Synanthropic liverworts*		*Tatra liverworts*	
	No. of species	*% of synanthropic flora*	*No. of species*	*% of Tatra flora*
Common	**8**	**26**	11	**5**
Examples: *Anthelia juratzkana, Cephalozia bicuspidata, Gymnomitrion concinnatum, Lophozia floerkei, L. sudetica, Nardia scalaris, Solenostoma sphaerocarpum*				
Frequent	4	**13**	13	**6**
Examples: *Bazzania tricrenata, Lophozia ventricosa, Pleurocladula albescens, Scapania undulata*				
Rare	7	**23**	37	**18**
Examples: *Calypogeia neesiana, Chiloscyphus polyanthos, Ch. profundus, Marsupella brevissima, M. funckii, Lophozia wenzelli, Lepidozia reptans*				
Very rare	12	**39**	144	**70**
Examples: *Diplophyllum obtusifolium, Solenostoma gracillimum, Lophozia opacifolia, Marsupella sphacelata, Pellia epiphylla, Scapania parvifolia, S. umbrosa*				

Table 4. Participation of the mono- and dioecious groups of liverwort species in the synanthropic flora of the Tatra Mts.

Group	*Type of habitat*	*A trails*	*B slopes*	*Trails and slopes (together)*
Dioecious liverworts	a	13	18	20
	b	76	62	62
	c	40	70	61
	d	71	67	68
Monoecious liverworts	a	4	11	12
	b	24	38	38
	c	60	30	39
	d	29	33	32

Participation measures: a – number of species, b – percentage representation in the floristic list, c – percentage proportion of plant cover, d – collective participation of the group.
Type of habitat: A – synanthropic-carpet (on trail), B – synanthropic-seminatural (on trail slopes).

monoecious species was noticed on tourist trails; however, these plants are a major element of the plant cover of bryophyte communities (60% cover participation). On trail slopes, dioecious species predominate in cover in the floristic list and in the cover of spore plants. The variable quantitative participation of mono- and dioecious plants results mainly from relations between monoecious *Cephalozia bicuspidata*, which predominates on trails, and dioecious *Nardia scalaris*, which grows profusely on slopes. In all synanthropic habitats, a higher percentage of dioecious species and predominance in the cover of moss communities were characteristic.

Table 5. Occurrence of reproductive organs in liverwort species in synanthropic habitats.

Type of habitat		*A*			*B*	
No. of floristic lists analyzed		*27*			*42*	
	with gemmae	*with archegonia*	*sterile*	*with gemmae*	*with archegonia*	*sterile*
Monoecious liverworts						
Cephalozia bicuspidata	39	52	9	19	49	32
Diplophyllum obtusifolium	100	.	.	7	86	7
Calypogeia azurea	.	.	.	20	.	80
Dioecious liverworts						
Nardia scalaris	*	19	81	*	25	75
Solenostoma gracillimum	*	90	10	*	92	8
Lophozia sudetica	75	.	25	88	6	6
Lophozia ventricosa	100	.	.	71	29	.
Scapania curta	71	.	29	100	.	.
Scapania umbrosa	40	10	50	40	60	.

Abbreviations: A – synanthropic-carpet (on trail), B – synanthropic-seminatural (trail slopes), . – not observed, * – does not produce.

Reproductive organs in liverworts of synanthropic habitats

The slopes of tourist trails have more stable habitat conditions than the trails; liverwort species reproduce more often when growing on the slope. For example, *Lophozia vetricosa*, *L. sudetica* and *Diplophyllum obtusifolium* reproduce on trails almost exclusively by gemmae, whereas on slopes they also develop archegonia and perianths (Table 5). The most hemerophilous species (i.e. *Cephalozia bicuspidata*, *Nardia scalaris*, *Solenostoma gracillimum*) develop sex organs with equal frequency. It is worth noting that *C. bicuspidata* in extreme habitats (group A) develops sex organs more often than gemmae (which are twice more frequent than in B habitats), with a very low percentage of sterile individuals. This emphasizes the high adaptative capability of this plant.

Liverworts in synanthropic vegetation of mountain areas

Groups of communities with domination of liverworts

Based upon their floristic composition synanthropic liverwort communities in theTatra Mts. can be classified among the following phyto-sociological units:

Cl. *Cladonio digitatae-Lepidozietea reptantis* Jež. & Vondr. 1962

O. *Diplophylletalia albicantis* Phil. 1956

All. *Dicranellion heteromallae* Philippi 1963
Community with ***Cephalozia bicuspidata*** (floristic composition see Górski, 2007: tab. 1)
Suball. *Calypogeienion muellerianae* Marst. 1984
Calypogeietum trichomanis Neum. 1971
– *typicum* (see Górski l.c.: tab. 2)
Suball. *Pogonatenion urnigeri* (v. Krus. 1945) Phil. 1956
Dicranello heteromallae-Oligotrichetum hercinici Schum. *et al.* 1980 (syn. *Pogonato-Oligotrichetum* Balcerk. 1984)
– *typicum* (see Górski l.c.: tab. 6)
– *jungermannietosum gracillimae* Schum. *et al.* 1980 (syn. *Jungermannietum gracillimae* Neum. 1971 p. p., Tab. 6, rel. 1-4)
Nardietum scalaris Phil. 1956
– *typicum* (Tab. 6, rel. 6)
– *solenostometosum crenulati* Phil. 1956 (Tab. 6, rel. 5)
– ***kiaerietosum starkei* subass. nova** hoc loco (Tab. 6, rel. 7-10; typus: Table 6, rel. 8)
All. *Pellion epiphyllae* Marst. 1984
Pellietum epiphyllae Ricek 1970 (see Górski l.c.: tab. 3)

With regard to the dynamics of the ground moulded mainly by tourism, moss plant arrangements with domination of liverworts can be classified into two groups:

– communities in partially stabilized and stabilizing habitats, in which anthropogenically-generated erosion has already taken place: *Nardietum scalaris*, *Calypogeietum trichomanis, Dicranello-Oligotrichetum hercinici, Pellietum epiphyllae*

– communities on trampled ground, with sporadic anthropogenic erosion: community with *Cephalozia bicuspidata.*

Distinctive communities of major types of synanthropic habitats

The distinctive community on the shoulders of tourist trails (habitats A) is centered on phytocoenoses with *Cephalozia bicuspidata*. They occur in spruce and spruce-fir forests. They grow in trail microhabitats that protect them against mechanical destruction, i.e. hollows between spruce roots or stones. The predominating species is *C. bicuspidata* and usually *Dicranella heteromalla* is present sparingly. Vascular plants, mostly *Picea excelsa* seedlings, contribute slight coverage only. Average cover of the bryophyte layer in the patches is 75%.

Trail slopes are a major site of phytocoenoses based on *Nardietum scalaris*. This community slows down erosion and usually replaces the pioneer *Dicranello-Oligotrichetum hercinici* phytocoenosis. *Nardietum scalaris* is a multizonal mountain community. The forms from higher locations, growing on steep slopes of north exposition, are characterized by small contributions from scree-bed species of the class *Salicetea herbaceae*.

Outside the Tatra Mts., the community with *Cephalozia bicuspidata* has been recorded on Mt Babia Góra (Górski, 2007). It can also be found on the shoulders of forest roads in acidophilous deciduous forests in lowlands (unpublished observations).

New communities in the Tatra Mts.

A frequent, but previously unrecorded community in the Tatra Mts. is the *Dicranello heteromallae-Oligotrichetum hercinici jungermannietosum*

Table 6. Anthropogenic phytocoenoses of *Dicranello hateromallae-Oligotrichetum hercinici jungermannietosum gracillimae* (rel. 1-4) *Nardietum scalaris* (*solenostometosum crenulati* - 5, *typicum* - 6 and *kiaerietosum starkei* - 7-10) from the Tatra Mts.

Succesive number of relevé	1	2	3	4	5	6	7	8	9	10	Constancy	Cover coefficient
Number of relevé in the field	3	49	48	60	47	15	54	22	89	91		
Type of habitat	A	H	A	A	H	H	H	H	H	H		
Altitude a.s.l. [m]	1130	1200	1190	1095	1180	1360	1820	1815	1750	1640		
Moss layer cover [%]	80	80	90	70	95	90	85	95	60	40		
Herb layer cover [%]	5	3	0	5	5	zn	zn	zn	zn	zn		
Stone cover [%]	20	5	10	10	15	3		5	40	15		
Exposure	E	NE	W	NE	N	N	N	NE	NW	N		
Inclination [°]	5	44	34	24	38	34-50	20-90	60-96	80-90	70		
Date	25	27	27	27	27	25	23	25	31	31		
	09	09	09	09	09	09	08	09	07	07		
	06	06	06	06	06	06	02	06	03	03		
Area of relevé [m^2]	1,5	0,4	0,2	1	2	0,3	1	1	1	0,25		
Number of species	8	14	8	15	16	13	8	10	10	7		
Ch. All. ***Dicranellion heteromallae***												
Solenostoma gracillimum	4.5	4.5	4.5	4.4	2a.1	.	.	.	.	.	III	2600
Nardia scalaris	.	.	2a.2	2a.2	4.4	4.5	3.4	5.5	4.3	3.5	IV	3700
Oligotrichum hercynicum	.	2a.2	r	2b.2	.	+	+	2a.2	2a.2	+	IV	516
Cephalozia bicuspidata	1.1	+	1.1	1.1	2b.1	3.3	1.1	.	.	.	IV	780
Dicranella heteromalla	+.2	r	1.1	+	.	2b.1	.	.	.	.	III	261
Pogonatum urnigerum	1.1	2b.2	r	.	.	.	.	.	r	.	II	252
Scapania curta	.	.	.	r	1.1	+	.	.	.	.	II	56
Diplophyllum obtusifolium	.	.	.	.	1.1	.	.	.	.	.	I	50
Solenostoma sphaerocarpum	.	.	.	.	.	.	2a.2	.	.	+	I	105

Sporadic species: *Agrostis capillaris* 4(r); *Anthoxanthum alpinum* 10(r); *Lophozia lycopodioides* 6(r); *Calypogeia* sp. 2(r); *Deschampsia caespitosa* 4(+); *Dicranum scoparium* 2(r); *Epilobium angustifolium* 2(r); *Gnaphalium supinum* 4(+); *Hupezia selago* 9(r); *Nardus stricta* 6(r); *Pleurozium schreberi* 2(r); *Poa laxa* 9(r); *Pohlia* sp. 3(r); *Polytrichum alpnium* 9(r); *Potentilla erecta* 4(r).

Table 6. Anthropogenic phytocoenoses of *Dicranello hateromallae-Oligotrichetum hercinici jungermannietosum gracillimae* (rel. 1-4) *Nardietum scalaris* (*solenostometosum crenulati* - 5, *typicum* - 6 and *kiaerietosum starkei* - 7-10) from the Tatra Mts. *(suite)*

Ch. Cl. ***Salicetea herbaceae***											
Kiaeria starkei	.	.	.	.	.	.	1.2	3.4	+	.	II 430
Luzula alpino-pilosa	.	.	.	.	.	.	+	1.1	+	.	II 60
Kiaeria falcata	.	.	.	.	.	.	.	.	.	1.2	I 50
Others											
Polytrichastrum formosum	1.1	.	.	+	r	2a.1	.	.	.	.	II 156
Luzula nemorosa	1.1	.	.	.	1.1	.	.	.	.	.	I 100
Scapania umbrosa	.	.	.	.	1.1	.	.	.	.	.	I 50
Rumex acetosella	.	.	.	r	+	.	.	.	.	.	I 6
Picea excelsa juv.	.	.	.	.	+	r	.	.	.	.	I 6
Lophozia ventricosa	.	r	.	.	.	+	.	.	.	.	I 6
Deschampsia flexuosa	.	r	.	.	+	.	.	.	+	r	II 12
Lophozia sudetica	.	.	.	.	.	.	2b.2	r	+.2	+	II 211
Agrostis rupestris	.	.	.	.	.	.	+	r	.	.	I 6
Lophozia floerkei	.	.	.	.	.	.	.	1.2	.	.	I 50
Lophozia wenzelli	.	.	.	.	.	.	.	+	.	.	I 5

Sporadic species: *Agrostis capillaris* 4(r); *Anthoxanthum alpinum* 10(r); *Lophozia lycopodioides* 6(r); *Calypogeia* sp. 2(r); *Deschampsia caespitosa* 4(+); *Dicranum scoparium* 2(r); *Epilobium angustifolium* 2(r); *Gnaphalium supinum* 4(+); *Hupezia selago* 9(r); *Nardus stricta* 6(r); *Pleurozium schreberi* 2(r); *Poa laxa* 9(r); *Pohlia* sp. 3(r); *Polytrichum alpnium* 9(r); *Potentilla erecta* 4(r).

gracillimae (syn. *Jungermannietum gracillimae* Neum. 1971 p. p., Table 6). It can be found on fine-grained or clayey soils on the trampled shoulders of tourist trails. In plant succession it follows patches *Dicranello-Oligotrichetum typicum*. Examples in lower sites are characterized by the inclusion of forest and forest-clearing species (*Polytrichastrum formosum*, *Luzula nemorosa*). Other new communities are high-mountain forms of *Nardietum scalaris*. They are distinguished by scree-bed species, mostly mosses, i.e. *Kiaeria starkei* and *Kiaeria falcata*. Forms of this community develop on the slopes of tourist trails (always on the ascending side) orientated along contour lines of northern exposition. They can be found in both the Western and the High Tatra Mts. In this paper they are included within a separate subassociation, the *Nardietum scalaris kiaerietosum starkei* subass. nova.

The role of liverworts in stabilization of tourist trail slopes in the alpine belt

At high mountain sites the scarps of tourist trails traversing the slope are almost vertical and they are subjected to intensive slope processes initiated by tourism. Plant succession in these places is usually initiated by *Oligotrichum hercynicum* (phytocoenoses *Dicranello-Oligotrichetum*). Further stabilization of these habitats is favoured by the appearance and expansion of *Nardia scalaris*, *Solenostoma sphaerocarpum*, *S. gracillimum* and *Lophozia sudetica*. In sites of high inclination, the scarps usually turn to slopes in arches, creating mossy "slings", whose upper part (like a "roof") consists of untattered grassland. Snow can persist longer in the hollows, creating conditions in which scree-bed plants appear, *i.e. Kiaeria starkei*, *Anthelia juratzkana*, *Pleurocladula albescens* or *Luzula alpino-pilosa*. Stabilization of the scarp by liverworts eliminates slope processes and further leads to arrival of single vascular plants. Erosion returns only when moss turf is torn by tourist.

It seems that arrangements with domination of liverworts are fairly permanent. No forms of these communities were found that could indicate development of alpine grasslands. It is mostly connected with a lack of well-developed soil, because the scarp's slope is made of sand-gravel formations that have not been subjected to processes of soil formation.

FINAL REMARKS

Synanthropization of bryoflora in the Tatra Mts. has not been studied separately so far. There are no such data concerning mosses, either. Anthropogenic changes of hepaticoflora in Tatra Mts. can be regarded to synanthropization of the flora of vascular plant (Piękoś-Mirkowa & Mirek, 1982; Mirek, 1996). Liverworts, as a group, are more hemerophobic that vascular plants; lower percentage of liverworts (16%) compared to vascular plants (24%) is recorded in synanthropic habitats. A characteristic feature of the syn-anthropization of liverworts is the fact that synanthropic liverworts are usually common plants that occur in both the lowlands and mountains, including at high altitudes. Synanthropization of this group concerns mainly eurytypic liverworts. In the case of vascular plants, the highest percentage of synanthropic species occasionally found in secondary habitats is observed (Piękoś-Mirkowa & Mirek, 1982). Another observation is the complete lack of species of foreign origin in the liverwort flora of the Tatra Mts. All components of the synanthropic liverwort flora are species with natural habitats in the Tatra Mts.

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