Mosses of the Kocioł Małego Stawu glacial cirque (Karkonosze Mts) and their supposed response to the tourism impact in the 20th century

Mchy Kotła Małego Stawu (Karkonosze) i ich reakcja na oddziaływanie turystyki w XX wieku

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ABSTRACT: As a result of a bryological exploration carried out in 2009 within the Kocioł Małego Stawu glacial cirque a number of 90 moss species was recorded. Together with fragmentary notes collected in 1999, 2003 and 2007 the contemporary moss flora concerns 105 species (the list of mosses with a brief description of habitats is provided). 88% of them (92 species) were noted on no more than 25% of the plots (with 32 found exclusively once) and only 13 species were noted more frequently. The latter are widespread within the whole range of altitude and exposition as well as in the majority of plant communities what makes bryophyte vegetation in the glacial cirque rather monotonous in appearance. Species recorded showed visible substrata specialization: 80 taxa (76% – including 32 sporadic species) occurred only on one type of substratum. Rocks and boulders appeared to be the richest in the number of species – 34 species (with 28 occurring exclusively on this substratum) and coniferous litter and rotten leaves of grasses and ferns – 24 species (17 exclusive). Three plant communities were the richest in species: high subalpine grasslands of *Crepido-Calamagrostietum villosae* community – 48, spruce forest of *Piceetum hercynicum* community – 41 and dwarf-pine thickets *Pinetum mugo sudeticum* community – 40. The number of species noted in other plant communities was less than 30. The richest in species phytocoenoses occupied the most area within the glacial cirque and they showed rather high floristic similarity.

The comparison of bryo-floristic data from two periods: 1869–1998 and 1999–2009, showed essential changes in species richness and composition – the list of mosses increased by 69 taxa but 50% of the previously reported flora was not refound. The most of species reported for the first time at the beginning of the 21th

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century were noted in the Karkonosze Mts just in the 19th century on the natural sites. Synanthropization process manifesting in appearance of hemerophilous species, not occurring naturally in the Karkonosze Mts, is limited to the surroundings of the Schronisko Samotnia chalet and strictly associated with mortar or concrete usage. Ruderal species were not observed in other parts of the glacial cirque. It suggests that tourist usage of the area has not influenced on floristic composition of the Kocioł Małego Stawu glacial cirque's moss layer.

KEY WORDS: mosses of the Mały Staw glacial cirque, bryoflora of Karkonosze, mountain mosses, changes of bryoflora, tourism impact upon the bryoflora

Introduction

The Kocioł Małego Stawu glacial cirque is the most accessible for tourists object among other glacial cirques situated in the Polish side of Karkonosze Mts. In the bottom of the cirque, on the shore of mountain lake Mały Staw which filled a southern part of it a wooden tourist chalet called "Samotnia" was built in the 19th century and nowadays it is still working. Tourists reach it on foot along the eastern wall where tourist route, made of boulders, is conducted but there is also a motor road leading to the chalet used for stocking it with provisions. The tourist route, still made of boulders, run further along the whole cirque's bottom. The cirque is also intensively used in winter by skiers. Undoubtedly easy access to the cirque was a reason of numerous bryo-floristic records reported in the past from there. In the 19th century a number of 66 moss species was reported (Milde 1869; Limpricht 1876, 1880–1904; Wilczyńska 1996). The list was enlarged in the second half of the 20th century of 17 new species (Lisowski 1956; Bednarek-Ochyra 1995; Kwiatkowski 1999a,b). The next notes are dated on the year 2003 (Fudali et all. 2003) and they added the 23 species not reported earlier from the cirque. Unfortunately the last research were fragmentary and their results do not allow to characterize contemporary bryo-floristic relations within the glacial cirque as well as do not allow to solve the question whether intensive tourist activity and its service are a real threat for bryophyte diversity in there? Only around the Schronisko Samotnia chalet situated on the shore of Mały Staw lake Fudali (2007) recorded 11 hemerophilous mosses species.

To answer these question the author carried out field studies in the summer of 2009. Ecological-floristic notes obtained were analysed in aspect of the hemerophilous species presence and their frequency and spreading within the glacial cirque and they were compared with historical data reported from the Kocioł Małego Stawu glacial cirque in the 19th century. Comparison led to estimate changes in floristic richness and species composition during the 20th

century and their supposed relations to tourism impact. The paper presents a brief characterization of mosses nowadays noted within the Kocioł Małego Stawu glacial cirque in the aspects of their substrata demands, phytocoenotical preferences, frequency and spatial distribution as well as discussion of the problem arisen. The list of moss species noted from there in 19th and 20th centuries is also provided.

1. Study area

The Kocioł Małego Stawu glacial cirque is situated in the eastern part of the Karkonosze massif, next to the Kocioł Wielkiego Stawu glacial cirque and in the vicinity of the Kocioł Łomniczki glacial cirque (Fig. 1a,b). From the west it cut in the slope of Smogornia Mt and through the southern wall reaches Śnieżka Mt upland (Równia pod Śnieżką) on the altitude of 1430 m a.s.l. This is the longest glacial cirque – is almost 1 km long and 400–700 m wide. In the southern part of the bottom a mountain lake Mały Staw is situated and the altitude of water surface is 1138 m a.s.l. (Staffa 1996). The cirque's walls differ in the appearance: western is rocky, with numerous gullies and tracts with trickling water and rocky pillars, others as well as the bottom are covered with huge erratic blocks and rubbles. On the eastern wall there are rocky outcrops while along the southern wall – two springs conducting water from the subalpine bogs situated above the Mały Staw lake. Water from this lake is off-taken by the Łomnica river which come through the whole bottom. Frequent avalanche action hindered the dwarf-pine thickets development on the western and southern walls which are dominated by the mosaic of subalpine grasslands (*Crepido-Calamagrostietum villosae* community and *Carici rigidae-Nardetum* community), open blueberry aggregations (probably depauperated form of *Empetro-Vaccinietum* community) and fern *Athyrium distentifolium* aggregations (*Athyrietum alpestris* community). Around the Mały Staw lake subalpine bogs with bio-groups of *Salix lapponicum* thickets have developed. The eastern wall and bottom are overgrown with spruce forest *Piceetum hercynicum* community mixed with patches of dwarf-pine thickets *Pinetum mugo sudeticum,* aggregations of blueberry *Vaccinium myrtillus* or fern *Athyrium distentifolium.* In wet places spring phytocoenoses of the *Cardamino-Montion* alliance and herbaceous community *Adenostyletum alliariae* developed. On the eastern shore of the lake a mountain chalet, built in the 19th century is situated and along the eastern wall and the bottom tourist route, built of boulders, is conducted. The second tourist route lead along the upper edges of the southern and western walls.

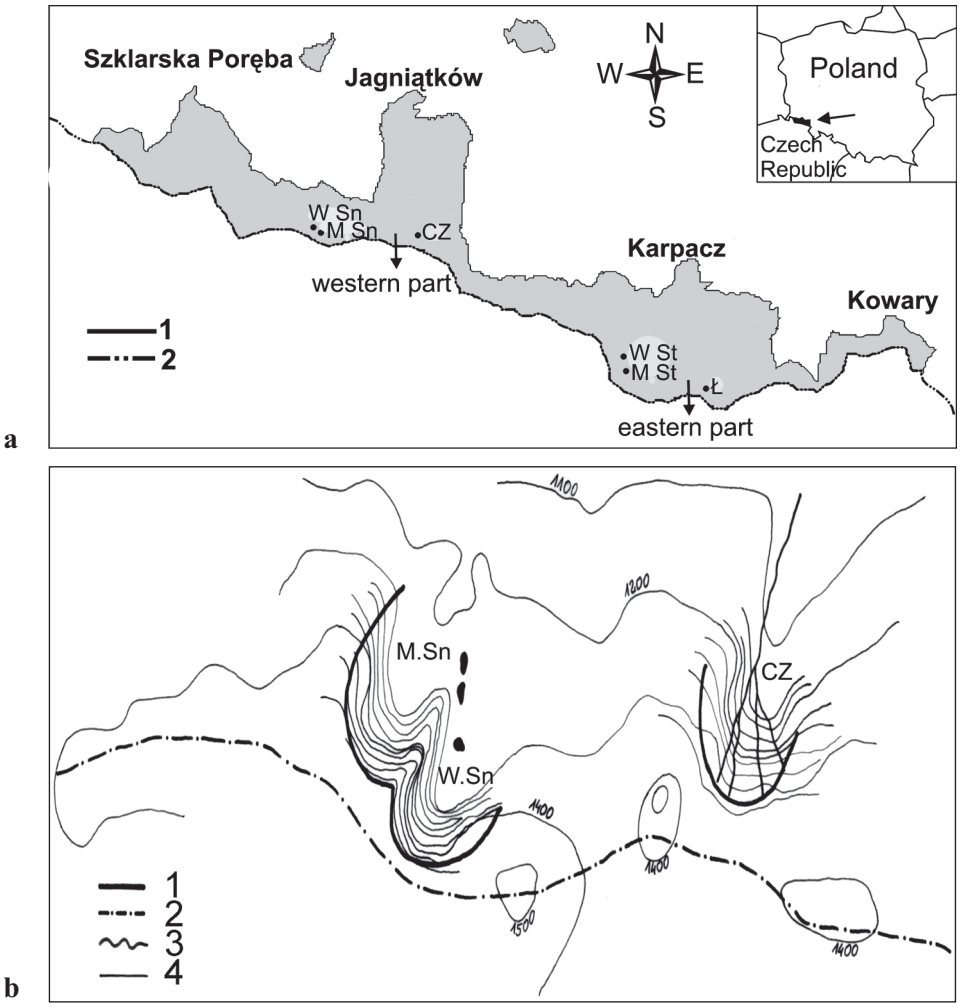

Fig. 1. Glacial cirques location in the Karkonosze Mts range (1a) and detailed map of the Kocioł Małego Stawu glacial cirque situation (1b)

Explanations: CZ – Czarny Kocioł, Ł – Kocioł Łomniczki, MSn – Mały Śnieżny Kocioł, MSt – Kocioł Małego Stawu, WSn – Wielki Śnieżny Kocioł, WSt – Kocioł Wielkiego Stawu.

2. Material and methods

Field works were conducted in July and August 2009 on 64 plots (each of 2×3 m) established in all types of habitats and plant communities on each wall and bottom of the glacial cirque (western wall – 20 plots, southern – 21, east-

ern – 11, the bottom – 12). Research were carried out only in places available for exploration without using of mountaineering equipment so rocky pillars on the western wall were not explored.

In every plot bryophytes were noted from each type of substratum (rocks or erratic boulders, mineral initial soil, humus layer on rocks and boulders, coniferous litter or rotten leafs of grasses and ferns, decayed wood, bark of living trees, peat, deer's dung) and some samples were picked up for identification. The altitude was measured using altimeter Suunto. Nomenclature of mosses follows Ochyra et all. (2003), plant communities were recognized according to Matuszkiewicz and Matuszkiewicz (1974). Herbarium material was deposited in KRAM.

Changes in the moss flora of the studied object in the years 1869–2009 were assessed on the basis of presence – absence data. The list of historical data was compiled basing on all available papers published containing data from the Kocioł Małego Stawu glacial cirque (Limpricht 1876, 1880–1904; Milde 1869). In Herbarium of Lower Silesia (WRSL) have preserved only 12 specimens of mosses collected in the Mały Staw glacial cirque in the 19th century and in the first half of the 20th century (Wilczyńska 1996). A part of K.G. Limpricht's collection containing specimens collected in Karkonosze Mts is deposited in the herbarium BP (Hungary) but their revision was not possible within the frame of this research. Additionally, some historical data were obtained from taxonomical work by Bednarek-Ochyra (1995) who revised specimens of the genus *Racomitrium* collected in Poland, also these from the Kocioł Małego Stawu glacial cirque.

3. Results and discussion

3.1. Contemporary bryo-floristic relations

3.1.1. Species richness, diversity and frequency of occurrence

In result of studies carried out in 2009 a number of 90 moss taxa was recognized. Including the bryo-floristic records from the Mały Staw glacial cirque reported in 2003 (Fudali et all. 2003) and in 2007 (Fudali 2007) the total number of moss species noted contemporary amounts 105 (Tab. 1). They represent 61 genera. Five species: *Brachydontium trichodes, Dicranodontium uncinatum, Sphagnum lindbergii, Tayloria serrata* and *Tetrodontium repandum* are considered to be threatened in Poland (Żarnowiec et all. 2004) and 23 are protected by law (Tab. 1).

Analysis of the plots number in which mosses were recorded shows that the most of them occurred sparsely – 88% (92 species) were noted on no more than 25% of the plots. 32 of them were found only once and 38 – very rarely (no more than 10% of plots). Quite frequently (26–50% of plots) occurred 12

Tab. 1. Ecological character of the mosses distribution within the Kocioł Małego Stawu glacial cirque observed in years 2003–2009

name of species	records number				exposition	altitude [m a.s.l.]	occurrence in phytocoenoses type		substrata type
	in 2003	in 2007	in 2009	total			number of records in the particular phytocoenoses type	number of phyto-coeno-ses	
1	2	3	4	5	6	7	8	9	10
COMMON SPECIES									
Polytrichastrum alpinum	2	.	34	**36**	E,S,W,B	1145–1430	Pic-13; Pm-6; Vac-6; G-6; H-2; At-1; Dec-1; Bg-1	8	r-h, h
QUITE FREQUENT SPECIES									
Sciuro-hypnum reflexum	1	.	31	**32**	E,S,W,B	1135–1385	Pm-6; Pic-5; Vac-5; At-5; G-5; Dec-3; H-2; MC-1	8	r-h, ep, h
Rhytidiadelphus subpinnatus	2	.	29	**31**	E,S,W,B	1135–1380	G-9; Pic-8; Vac-4; Pm-4; Dec-3; B-1; At-1; H-1	8	h
Plagiothecium curvifolium	.	.	27	**27**	E,S,W,B	1145–1430	Pic-13; Vac-5; Pm-4; Dec-2; G-2; At-1	6	h,
***Dicranum scoparium*	1	.	24	**25**	E,S,W,B	1145–1445	Pic-13; Pm-7; Vac-5	3	r, h, d, ep
***Pleurozium schreberi*	2	.	21	**23**	E,S,W,B	1145–1430	Vac-10; Pic-6; Pm-4; G-3	4	h
**Sphagnum girgensohnii*	1	.	22	**23**	E,S,W,B	1155–1385	Pic-7; Bg-5; Pm-4; Dec-3; G-2; H-1; Vac-1	7	b, r-h
Bucklandiella sudetica	1	.	18	**19**	E,S,W,B	1145–1380	Vac-7; G-6; Pm-2; N-3; Pic-1	5	r
Codriophorus fascicularis	1	.	18	**19**	E,S,W	1165–1380	G-5; Pm-4; At-4; Vac-4; Pic-1; N-1	6	r
***Hylocomium splendens*	1	.	17	**18**	E,S,W,B	1140–1430	Vac-8; Pic-7; Pm-2; G-1	4	h
Pohlia nutans	2	.	16	**18**	E,S,W,B	1145–1385	Vac-6; Pic-5; Pm-3; N-2; G-1; Bg-1	6	d, h, s-h
***Polytrichum commune*	1	.	17	**18**	E,S,W,B	1135–1385	Bg-8; Pic-4; Pm-2; MC-2; Dec-1; H-1	6	h, b
Kiaeria starkei	.	.	17	**17**	E,S,W,B	1140–1430	Pic-4; Pm-4; Vac-4; G-3; At-2	5	r-h, ep-1
RARE SPECIES									
Dicranodontium denudatum	.	.	16	**16**	E,S,W,B	1145–1250	Pic-8; Pm-2; Vac-2; At-2; G-1; Dec-1	6	r, d, h
Sciuro-hypnum starkei	2	.	14	**16**	E,S,W,B	1135–1365	G-6; Pic-3; At-3; Pm-2; Vac-2	5	h
**Sphagnum russowii*	1	.	15	**16**	E,S,W,B	1145–1380	Bg-5; Pic-3; G-3; Pm-2; Dec-1; Vac-1; Nw-1	7	b, r-h
Rhizomnium magnifolium	2	.	12	**14**	E,S,W,B	1140–1385	Pic-3; Dec-2; G-2; MC-2; Nw-2; Bg-1; H-1; At-1	8	h
***Sphagnum squarrosum*	1	.	13	**14**	E,S,W,B	1135–1430	Bg-4; MC-4; G-3; H-2; At-1	5	b, s-h
Straminergon stramineum	2	.	12	**14**	E,S,W,B	1155–1385	Bg-8; Pm-2; Pic-1; Vac-1; H-1; MC-1	6	b, on plants
Oligotrichum hercynicum	.	.	12	**12**	E,S,W,B	1135–1430	N-8; G-3; Pic-1	3	s
**Sphagnum denticulatum*	3	.	9	**12**	E,S,W,B	1135–1210	Bg-3; MC-3; Nw-3; G-2; Dec-1	5	b, r-h

1	2	3	4	5	6	7	8	9	10
**Andreaea rupestris*	2	.	9	**11**	E,S,W,B	1145–1380	N-8; G-2; Vac-1	3	r
Codriophorus acicularis	2	.	9	**11**	E,S,W,B	1135–1220	Nw-11	1	r
Polytrichum piliferum	1	.	10	**11**	E,S,W,B	1165–1430	Gn-6; Vac-4; N-1	3	s, r
***Buckiella undulata*	1	.	9	**10**	E,W,B	1140–1230	Pic-9; Pm-1	2	h
Herzogiella striatella	1	.	9	**10**	E,W,B	1140–1205	At-3; Pic-2; Vac-2, G-2; Dec-1	5	h
Plagiothecium cavifolium	.	.	10	**10**	E,S,W,B	1145–1220	G-4; Vac-2; Pic-1; Pm-1; Dec-1; At-1	6	h
Hylocomiastrum umbratum	1	.	8	**9**	E,S,W,B	1185–1335	Pic-3; Pm-3; Vac-1; G-1; N-1	5	h
Orthodicranum montanum	.	.	9	**9**	E,W,B	1145–1230	Pic-5; Pm-3; Dec-1	3	ep, h, r-h
Polytrichum juniperinum	.	.	9	**9**	E,S,W	1180–1430	G-4; Vac-3; Pm-1; Bg-1	4	r, b
**Philonotis seriata*	2	.	6	**8**	E,S,W,B	1135–1430	MC-4; Vac-1; G-1	3	s-w
Plagiomnium medium	2	.	6	**8**	E,W,B	1145–1220	G-4; Pic-1; Pm-1; Vac-1; Dec-1	5	h
Sanionia uncinata	1	.	7	**8**	E,S,W,B	1165–1230	Pm-5; Dec-2; N-1	3	r, ep
***Sphagnum fallax*	1	.	7	**8**	E,S,W,B	1165–1375	Bg-6; Dec-2	2	b
Warnstorfia exannulata	2	.	6	**8**	E,S,W,B	1135–1210	MC-2; W-4; G-1; Bg-1	4	r-w
VERY RARE SPECIES									
Cynodontium polycarpon	.	.	7	**7**	E,S,W,B	1140–1220	Pic-2; At-2; Vac-1; G-1; Dec-1	5	r
Dicranella heteromalla	1	.	5	**6**	E,S,W,B	1135–1225	Pic-3; G-3	2	h, s
Mnium hornum	.	.	6	**6**	E,W,B	1165–1230	Pic-6	1	h
Paraleucobryum longifolium	1	.	5	**6**	E,S,W,B	1145–1220	Pm-3; Nw-2; Pic-2; G-1	4	r, ep
Plagiothecium laetum	1	.	5	**6**	S,W,B	1140–1205	At-2; Vac-1; Pm-1; H-1; G-1	5	ep
Brachythecium salebrosum	.	.	5	**5**	E,S,W,B	1165–1250	G-2; Pic-1; Pm-1; At-1	4	d-3, r-2
Diobelonella palustris	1	.	4	**5**	E,S	1170–1190	MC-4; W-1	2	s-w
Dicranum fuscescens	1	.	4	**5**	E,S,W,B	1145–1220	Pic-3; Pm-1; Dec-1	3	r
Dicranum majus	.	.	5	**5**	E,W,B	1145–1335	Pic-2; Pm-3	2	r-h, d
Plagiothecium denticulatum	.	.	5	**5**	E,S,W,B	1145–1210	Pic-2; H-1; G-1; MC-1	4	d, nh
Pogonatum urnigerum	.	.	5	**5**	S,W	1165–1430	Pm-3; At-1; G-1	3	r-h
Cirriphyllum piliferum	1	.	3	**4**	S,W,B	1150–1195	G-4	1	s
Ditrichum heteromallum	.	.	4	**4**	E,S,B	1210–1365	G-2; Gn-2	2	s
Herzogiella seligeri	.	.	4	**4**	E,B	1145–1230	Pic-3; Pm-1	2	ep
Hygrohypnum ochraceum	1	.	3	**4**	S,B	1135–1205	Nw-4	1	r
Hymenoloma crispulum	.	.	4	**4**	E,W	1195–1220	Pm-2; G-1; At-1	3	r
Hypnum callichroum	1	.	3	**4**	E,S,W	1180–1250	G-3; H-1	2	r
Plagiothecium succulentum	.	.	4	**4**	E,S,B	1185–1205	G-2; Dec-1; Pm-1	3	h
Rhizomnium punctatum	.	.	4	**4**	E,S,W	1170–1210	MC-3; H-1	2	r
Rhodobryum roseum	.	.	4	**4**	S,W	1185–1385	H-2; Dec-1; G-1	3	h
**Sphagnum riparium*	3	.	1	**4**	S	1183–1380	G-3; Pm-1	2	b

1	2	3	4	5	6	7	8	9	10
Ceratodon purpureus	1	1	1	**3**	B	1185–1190	G-1; Antr.-2	1+A	s, mortar, slag
Dicranella cerviculata	.	.	3	**3**	E,S,W	1210–1365	Pic-1; G-1; MC-1	3	s
Kiaeria blyttii	1	.	2	**3**	S,W	1190–1225	N-1; Nw-1; Pm-1	3	r
Pseudoleskea incurvata	.	.	3	**3**	E,S	1185–1190	Pic-1; G-1; Dec-1	3	r
Pseudotaxiphyllum elegans	.	.	3	**3**	W,B	1140–1190	Pic-3	1	s
**Sphagnum capillifolium*	3	.	0	**3**	S	1190–1200	Bg-3	1	b
**Sphagnum compactum*	1	.	2	**3**	S,W	1215–1375	Bg-2; Nw-1	2	b
Tetraphis pellucida	.	.	3	**3**	E,S,B	1145–1230	Pic-2; Vac-1	2	d, h
Brachythecium albicans	.	1	1	**2**	E,B	1180–1335	G.Antr.-1; Pm-1	2	s, ep
Bryum argenteum	.	2	.	**2**	B	1180	Antr.-2	A	mortar, s
Bryum pseudotriquetrum	.	.	2	**2**	E,W	1210	MC-2	1	s
Codriophorus aquaticus	.	.	2	**2**	S,W	1195–1230	Nw-1; G-1	2	r
Fontinalis antipyretica	1	.	1	**2**	S	1170–1185	Nw-2	1	r
Hygrohypnum smithii	.	.	2	**2**	S,W	1170–1210	Nw-2	1	r
Mnium spinosum	.	.	2	**2**	W,B	1135–1190	H-1; G-1	2	r
Orthogrimmia donniana	.	.	2	**2**	E,W	1230–1380	N-1; G-1	2	r
**Sphagnum magellanicum*	.	.	2	**2**	S,B	1135–1375	Bg-2	1	b
SPORADIC SPECIES									
Amblystegium serpens	.	1	.	**1**	B	1180	Antr.-1	A	s with slag
***Aulacomnium palustre*	.	.	1	**1**	S	1375	Bg-1	1	b
Blindia acuta	1	.	0	**1**	S	1185	N-1	1	r
**Brachydontium trichodes*	1	.	0	**1**	S	1205	N-1	1	r
Brachytheciastrum velutinum	.	.	1	**1**	B	1185	Pm-1	1	ep
Brachythecium rivulare	1	.	0	**1**	S	1190	Nw-1	1	r
Bryum pallescens	.	1	.	**1**	B	1180	Antr.-1	A	mortar
Cynodontium strumiferum	.	.	1	**1**	W	1195	Pm-1	1	r
Dicranodontium uncinatum	.	.	1	**1**	S	1205	Vac-1	1	r-h
Dicranum flexicaule	.	.	1	**1**	B	1145	Pic-1	1	r
Didymodon rigidulus	.	1	.	**1**	B	1180	Antr.-1	A	mortar
Encalypta streptocarpa	.	1	.	**1**	B	1180	Antr.-1	A	mortar
Heterocladium heteropterum	.	.	1	**1**	W	1220	N-1	1	r
Oncophorus virens	.	.	1	**1**	W	1195	Pm-1	1	r
Plagiomnium affine	.	.	1	**1**	W	1180	Dec-1	1	h
Plagiothecium nemorale	.	.	1	**1**	W	1185	Dec-1	1	h

1	2	3	4	5	6	7	8	9	10
Pohlia cfr. *obtusifolia*	1	.	0	**1**	S	1200	G-1	1	r-h
Pohlia wahlenbergii	.	1	.	**1**	B	1180	N-1	1	s
Polytrichastrum formosum	.	.	1	**1**	B	1140	Pic-1	1	s
Racomitrium lanuginosum	.	.	1	**1**	W	1200	N-1	1	r
Rhynchostegium murale	.	1	.	**1**	B	1180	Antr.-1	A	mortar
Rhythidiadelphus loreus	.	.	1	**1**	E	1210	Pic-1	1	h
***Rhytidiadelpus squarrosus*	.	.	1	**1**	B	1185	G-1	1	h
Rosulabryum moravicum	.	1	.	**1**	B	1180	Antr.-1	A	mortar
Schistidum apocarpum	.	1	.	**1**	B	1180	Antr.-1	A	mortar
**Sphagnum cuspidatum*	.	.	1	**1**	S	1190	MC-1	1	w
**Sphagnum inundatum*	.	.	1	**1**	E	1210	MC-1	1	w
**Sphagnum lindbergii*	.	.	1	**1**	S	1375	Bg-1	1	b
**Tayloria serrata*	.	.	1	**1**	B	1185	Pm-1	1	dungy
Tetrodontium repandum	1	.	0	**1**	S	1195	N-1	1	r
Tortula muralis	.	1	.	**1**	B	1180	Antr.-1	A	mortar
Warnstorfia sarmentosa	.	.	1	**1**	S	1190	Nw-1	1	r-w

Explanations. Exposition of plots: B – bottom of the glacial cirque, E – eastern wall, S – southern wall, W – western wall. Type of vegetation: A – anthropogenic sites, At – fern community *Athyrietum alpestris*, Bg – plots of swamps within subalpine grasslands, Dec – shrubs of *Salix lapponicum*, G – high subalpine grasslands of *Crepido-Calamagrostietum villosae* community, Gn – short subalpine grasslands of *Carici rigidae-Nardetum* community, H – tall herbs of *Adenostyletum alliariae* community, MC – spring community of the *Cardaminae-Montion alliance*, N – dry naked boulders or rocks with cryptogamous communities, Nw – naked boulders or rocks with cryptogamous communities in water, Pic – spruce forest of *Piceetum hercynicum*, Pm – *Pinetum mugo sudeticum*, Vac – blueberry aggregations, probably depauperated form of *Empetro-Vaccinietum.* Substrata type: b – peat, d – decaying wood, ep – bark of trees and thickets, h – coniferous litter, rotten fragments of grass and fern leaves, r – rocks or boulders, r-h – layer of decomposed humus on the rocks or boulders, r-w – stones in water, s – bare mineral soil, s-h – layer of decomposed humus on soil, * – strictly protected species, ** – partially protected species.

species and only one species *Polytrichastrum alpinum* occurred frequently (51–75% of plots; Tab. 1). So bryophyte vegetation of the Kocioł Małego Stawu glacial cirque is generally rich in species but is dominated by the 13 mosses occurred more frequently than others what makes an impression of its floristic monotony.

3.1.2. Altitudinal and spatial distribution

Analysis of the altitudinal distribution of mosses (excluding sporadic species, noted only once) shows that the all of frequent and quite frequent species are widespread within the whole range of altitude while among the rare and very rare species dominate species occurring between 1135 and 1250 (31 taxa). Four species were noted only in higher altitudes (above 1210 m a.s.l.): *Dicranella cerviculata, Ditrichum heteromallum, Orthogrimmia donniana* and *Sphagnum compactum* while 7 did not exceed the altitude of 1200 m a.s.l. (*Ceratodon purpureus, Cirriphyllum piliferum, Diobelonella palustris, Mnium spinosum, Fontinalis antipyretica, Pseudoleskea incurvata* and *Pseudotaxiphyllum elegans*). Nineteen taxa are widespread in the whole altitudinal span.

Regarding species occurrence on the particular walls and the bottom one can notice than most of them are widely spread within the whole glacial cirque. Excluding sporadic species, among the rest only 5 showed limited occurrence to one of the walls or bottom, 35 were recorded in all the parts and 15 in three of the parts. The most rich in species were the southern wall (68 species with 13 exclusively noted in there) and the bottom – 68 (16 exclusive). On the eastern wall a number of 58 species was recorded (with 2 exclusive) and on the western – 65 (6 exclusive).

3.1.3. Substrata preferences

Species recorded showed a visible substrata specialization: 80 taxa (76% – including 34 sporadic species) occurred only on one type of substratum, 20 species (19%) – on two types, 4 species – on 3 types and one species *Dicranum scoparium* – on 4 types.

Two substratum types appeared to be the richest in species: rocks and boulders – 34 species (with 26 occurring exclusively on this substratum) and coniferous litter and rotten leaves of grasses and ferns – 24 species (17 exclusive) while dungy – the poorest, with 1 exclusive species (Fig. 2). Quite rich were: peat (14 species; 7 exclusive), mineral soil (15), concrete and mortar (9, 8 exclusive), bark of trees (10, 3), humus layer on boulders (11, 3).

3.1.4. Distribution in relation to the diversity of vegetation cover

Considering the total numbers of species noted in various plant communities a clear differences in species richness are visible (Fig. 3). Three plant

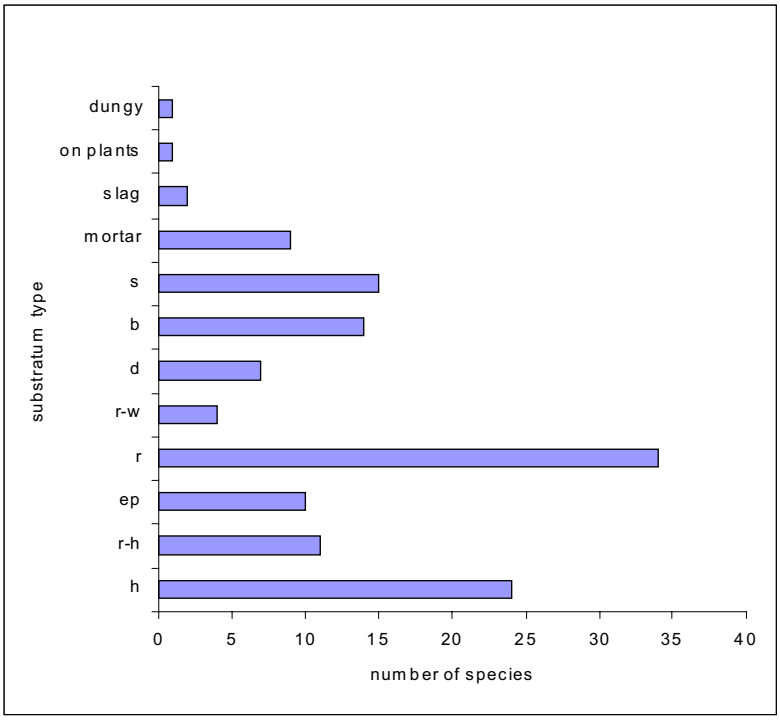

Fig. 2. Number of species occupying different types of substrata. Symbols as in Table 1

communities were the richest in species: high subalpine grasslands – 48, spruce forest – 41 and dwarf-pine thickets – 40. In blue-berry aggregations 28 species were noted and in thickets of *Salix lapponicum* – 23. Number of species noted in other plant communities was less than 20. The richest in species phytocoenoses occupied the most area within the glacial cirque and they showed rather high floristic similarity. Excluding sporadic species only 11 taxa occurred exclusively in one plant community, while the most species were observed in two (17 species), three (15) or five (9) types of plant community (Fig. 4). However some of species showed a certain preference to occur in one of the plant communities colonised. In a case of: *Buckiella undulata, Dicranodontium denudatum, Dicranum scoparium, Herzogiella seligeri, Mnium hornum, Plagiothecium curvifolium, Polytrichastrum alpinum* and *Pseudotaxiphyllum elegans* the most records were noted in *Piceetum hercynicum* community. Such species as: *Cirriphyllum piliferum, Plagiomnium medium, Plagiothecium cavifolium* and *Sciuro-hypnum starkei* occurred mainly in grasslands of *Crepido-Calamagrostietum villosae* community while *Diobelonella palustris*

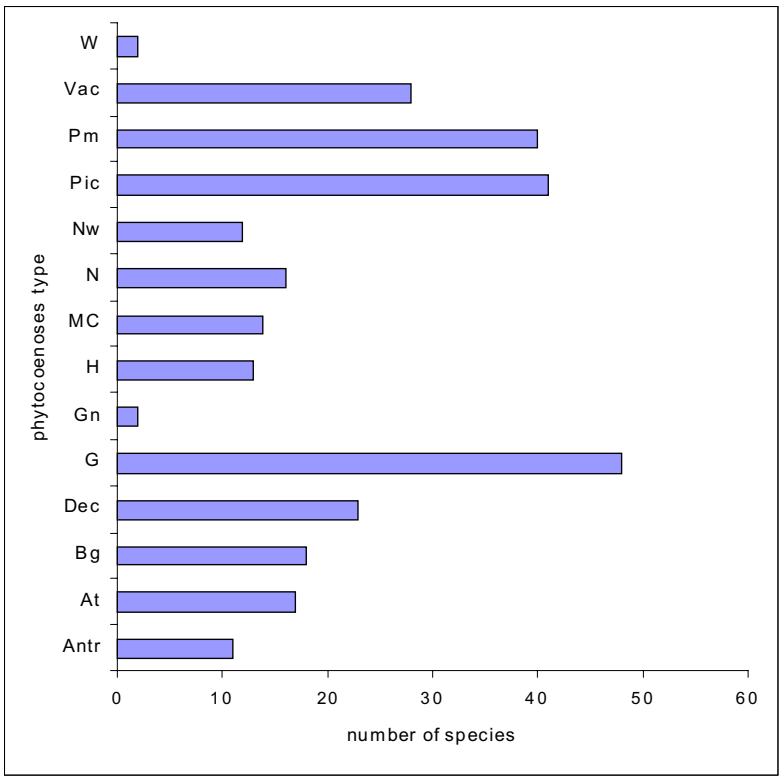

Fig. 3. Number of species recorded in different plant communities. Symbols as in Table 1

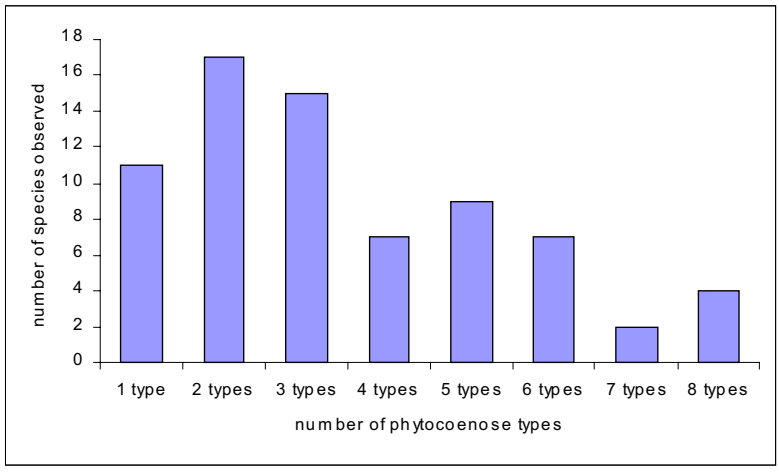

Fig. 4. Number of species found in one or more numbers of plant communities

and *Philonotis serriata* – in spring communities of the *Cardamino-Montion* alliance and *Pleurozium schreberi* – in aggregation of blue-berry *Vaccinium myrtillus* (Tab. 1).

3.2. Changes in floristic richness and species composition during the 20th century

3.2.1. Quantitative estimation

Historical papers published in the 19th century and some herbarium specimens dated before the year 1900 concern 66 moss species (Milde 1869; Limpricht 1876, 1880–1904; Bednarek-Ochyra 1995; Wilczyńska 1996; Tab. 2). Bryological reports dated from the period 1901–1998 are very scanty and they brought only 12 records which enlarged the list of the mosses of 6 new species (Lisowski 1956, 1961; Bednarek-Ochyra 1995; Wilczyńska 1996) what makes together 72.

Present-day research (Kwiatkowski 1999a,b; Fudali et all. 2003; Fudali 2007 and data presented in the paper) has documented occurrence of 105 moss species in the beginning of the 21th century (Tab. 2). This increase of species richness undoubtedly has resulted from methodological approach to research carried out by the author, which were detailed and including of anthropogenic sites within the glacial cirque (surroundings of the mountain chalet, mortar, tourist routes and rest places on the lake shore).

The comparison of bryo-floristic lists from both periods shows that among 141 moss species reported altogether from the Kocioł Małego Stawu glacial cirque only 36 species (26%) occurred both in 19th and 21th. 69 species were noted for the first time in the beginning of the 21th century while 36 species were not refound. They make 50% of the previously reported flora of mosses. Unfortunately, historical works do not provide any information of the species' occurrence frequency in the glacial cirques so we don't know whether the species not refound presently were abundant in the 19th century or scattered just then? The author's research showed that nowadays most of the moss species occur very rarely or sporadically, often only in one or a few places (Tab. 1).

Most of the species reported for the first time in the period 1999–2009 occurred in natural sites which are not accessible for routine tourists and they were just reported from the Karkonosze in the 19th century. Regarding the species relation to human impact only 11 are strictly hemerophilous. They occurred exclusively around the Schronisko Samotnia chalet: on concrete, on soil mixed with slag, between pavements or on open trampled soil on the Mały Staw lake shore and were not observed along any tourist routes.

3.2.2. Characterization of the species not refound

As historical works do not provide any information of the species' habitats in the Kocioł Małego Stawu glacial cirque an analysis of the not refound species' ecological demands was based on their general ecological characteriza-

Tab. 2. Comparison of historical and present-day records

name of species	author and date of the records (or paper)		
	1869–1900	1901–1998	1999–2009
1	2	3	4
SPECIES NOT REFOUND IN THE XXI CENTURY			
Amphidium lapponicum	M-1869		0
Amphidium mougeottii	M-1869		0
Andreaea rothii	M-1869; LG-1876		0
Bartramia ityphylla	M-1869		0
Bryum elegans	M-1869; LG-1876		0
Bryum pallens	Kern 1882 (W-1996)		0
Bryum weigellii	M-1869		0
Buclandiella macounii subsp. *alpinum*		B-O(1953)	0
Buclandiella microcarpa	B-O(1891)		0
Ctenidium molluscum	LG-1876		0
Dichelyma falcatum	M-1869; LG-1876		0
Dichodontium pellucidum	LG-1876		0
Dicranella subulata	M-1869		0
Diphyscium foliosum	M-1869		0
Dryptodon patens	M-1869; LG-1876	LS-1956	0
Grimmia funalis	M-1869		0
Hygrohypnum luridum	M-1869		0
Hylocomiastrum pyrenaicum	M-1869		0
Isothecium alopecuroides	LG-1876; M-1869		0
Kiaeria falcata	M-1869		0
Lescurea mutabilis	M-1869		0
Mnium spinulosum	M-1869		0
Palustriella decipiens	M-1869		0
Philonotis fontana		LS-1956	0
Platyhypnidium riparioides	M-1869		0
Pohlia cruda	M-1869		0
Pohlia drummondii	M-1869; LG-1876		0
Pseudobryum cinclidioides		LS-1961	0
Rhabdoweisia fugax	M-1869		0
Rhytidium rugosum	M-1869		0
Sciuro-hypnum plumosum	M-1869		0
Sphagnum teres	M-1869		0
Splachnum sphaericum	M-1869		0
Tortella tortuosa	M-1869		0
Ulota drummondii	LG-1895		0
Warnstorfia fluitans	Kern 1882 (W-1996)		0
SPECIES REPORTED FOR THE FIRST TIME IN 1999–2009			
Amblystegium serpens			F-2007
Andreaea rupestris			F-2003; F-2009
Aulacomnium palustre			F-2009
Brachydontium trichodes			F-2003
Brachytheciastrum velutinum			F-2009
Brachythecium albicans			F-2007; F-2009

1	2	3	4
Brachythecium rivulare			F-2003
Brachythecium salebrosum			F-2009
Bryum argenteum			F-2007
Bryum pallescens			F-2007
Bryum pseudotriquetrum			F-2009
Buckiella undulata			F-2003; F-2009
Ceratodon purpureus			F-2003; F-2007; F-2009
Dicranella cerviculata			F-2009
Dicranella heteromalla			F-2003; F-2009
Dicranodontium uncinatum			F-2009
Dicranum flexicaule			F-2009
Dicranum scoparium			F-2003; F-2009
Didymodon rigidulus			F-2007
Ditrichum heteromallum			F-2009
Encalypta streptocarpa			F-2007
Herzogiella seligeri			F-2009
Heterocladium heteropterum			F-2009
Hylocomiastrum umbratum			F-2003; F-2009
Hylocomium splendens			F-2003; F-2009
Hymenoloma crispulum			F-2009
Kiaeria blyttii			F-2003; F-2009
Mnium hornum			F-2009
Mnium spinosum			F-2009
Oligotrichum hercynicum			F-2009
Oncophorus virens			F-2009
Orthogrimmia donniana			F-2009
Paraleucobryum longifolium			F-2003; F-2009
Philonotis seriata			F-2003; F-2009
Plagiomnium affine			F-2009
Plagiothecium curvifolium			F-2009
Plagiothecium laetum			F-2003; F-2009
Plagiothecium nemorale			F-2009
Plagiothecium succulentum			F-2009
Pleurozium schreberi			F-2003; F-2009
Pohlia nutans			PK-1999; F-2003; F-2009
Pohlia wahlenbergii			PK-1999; F-2007
Polytrichastrum formosum			F-2009
Polytrichum commune			PK-1999; F-2003; F-2009
Polytrichum juniperinum			PK-1999; F-2009
Polytrichum piliferum			PK-1999; F-2003; F-2009
Pseudotaxiphyllum elegans			F-2009
Rhizomnium magnifolium			F-2003; F-2009
Rhizomnium punctatum			PK-1999; F-2009
Rhodobryum roseum			F-2009

1	2	3	4
Rhynchostegium murale			F-2007
Rhythidiadelphus loreus			F-2009
Rhytidiadelphus subpinnatus			F-2003; F-2009
Rosulabryum moravicum			F-2007
Sanionia uncinata			F-2003; F-2009
Schistidium apocarpum			F-2007
Sciuro-hypnum starkei			F-2003; F-2009
Sphagnum capillifolium			F-2003
Sphagnum cuspidatum			F-2009
Sphagnum denticulatum			F-2003; F-2009
Sphagnum fallax			F-2003; F-2009
Sphagnum girgensohnii			PK-1999; F-2003; F-2009
Sphagnum inundatum			F-2009
Sphagnum magellanicum			F-2009
Sphagnum riparium			F-2003; F-2009
Sphagnum russowii			F-2003; F-2009
Sphagnum squarrosum			PK-1999; F-2003; F-2009
Tetraphis pellucida			F-2009
Tortula muralis			F-2007
SPECIES PERSISTENT IN THE GLACIAL CIRQUE DURING THE WHOLE PERIOD ANALYSED			
Blindia acuta	M-1869		F-2003
Bucklandiella sudetica	B-O(1864, 1867)	LS-1956	F-2003; F-2009
Cirriphyllum piliferum		LS-1961	F-2003; F-2009
Codriophorus acicularis	B-O(1841)	B-O(1927, 1932)	F-2003; F-2009
Codriophorus aquaticus		B-O(1950)	F-2009
Codriophorus fascicularis	M-1869, B-O(1873, 1886)		F-2003; F-2009
Cynodontium polycarpon	LG-1876		F-2009
Cynodontium strumiferum	LG-1876		F-2009
Dicranodontium denudatum	M-1869		F-2009
Dicranum fuscescens	M-1869		F-2003; F-2009
Dicranum majus	M-1869		F-2009
Diobelonella palustris	M-1869		PK-1999; F-2003; F-2009
Fontinalis antipyretica	M-1869		F-2003; F-2009
Herzogiella striatella	M-1869		F-2003; F-2009
Hygrohypnum ochraceum	LG-1876; M-1869	LS-1956	F-2003; F-2009
Hygrohypnum smithii	LG-1876		F-2009
Hypnum callichroum	M-1869		F-2003; F-2009
Kiaeria starkei	M-1869		F-2009
Orthodicranum montanum	M-1869		F-2009
Plagiomnium medium	M-1869		F-2003; F-2009
Plagiothecium cavifolium	M-1869		F-2009
Plagiothecium denticulatum	M-1869	LS-1961	F-2009
Pogonatum urnigerum	Scamoni 1878 (W-1996)		F-2009

1	2	3	4
Pohlia cfr. *obtusifolia*		LW-1930	F-2003
Polytrichastrum alpinum	M-1869		F-2003; F-2009
Pseudoleskea incurvata	M-1869		F-2009
Racomitrium lanuginosum	M-1869, B-O(1865)		F-2009
Rhytidiadelphus squarrosus	M-1869		F-2003
Sciuro-hypnum reflexum	M-1869		F-2003; F-2009
Sphagnum compactum	M-1869		F-2003; F-2009
Sphagnum lindbergii	M-1869		F-2009
Straminergon stramineum	M-1869		F-2003; F-2009
Tayloria serrata	M-1869; LG-1876		F-2009
Tetrodontium repandum	M-1869		F-2003
Warnstorfia exannulata	Scamoni 1883 (W-1996)		F-2003; F-2009
Warnstorfia sarmentosa	M-1869	Kern 1917 (W-1996); LS-1956	PK-1999; F-2009

Explanation of symbols and abbreviations: B-O(1891) – specimen dated on the year given and revised by Bednarek-Ochyra (1995), M – Milde, LG – Gustaw Limpricht, LS – Stanisław Lisowski, LW – Wolfgang Limpricht, Kern 1882 (W-1996) – herbarium specimen collected by Kern in 1882 and checked by Wilczyńska (1996), cfr. – identification not certain, F – Ewa Fudali, PK – Paweł Kwiatkowski.

tion done by Dierssen (2001). It revealed that 19 taxa (53% of the species not refound) showed wide ecological amplitude to the substratum reaction (from acid to subneutral or basic) and 11 (31%) were acidophilous (Fig. 5a). Considering their substrata preferences the most were epiliths – 20 with 15 obligatory epilithic species. Among others: number of aquatic mosses amounts 5, epigeits on initial bare soil – 4, epiphytes – 3 (Fig. 5b). Only two species: aquatic *Sciuro-hypnum plumosum* and epiphytic-epilith *Lescurea mutabilis* are considered to be sensitive to environment contamination. This brief analysis shows that environmental changes generated by pedestrian tourism such as trampling and eutrophication of sites would not be a reason of these species disappearance.

4. Conclusions

1. Contemporary observed species richness of the bryophyte layer within the Kocioł Małego Stawu glacial cirque is rather rich (105 species of mosses) but the most of species occur in one or a few places. Only 13 species were noted more frequently. They are widespread within the whole range of altitude and exposition as well as in the majority of plant communities what makes bryophyte vegetation rather monotonous in appearance. The most of species do not exceed the altitude of 1250 m a.s.l.

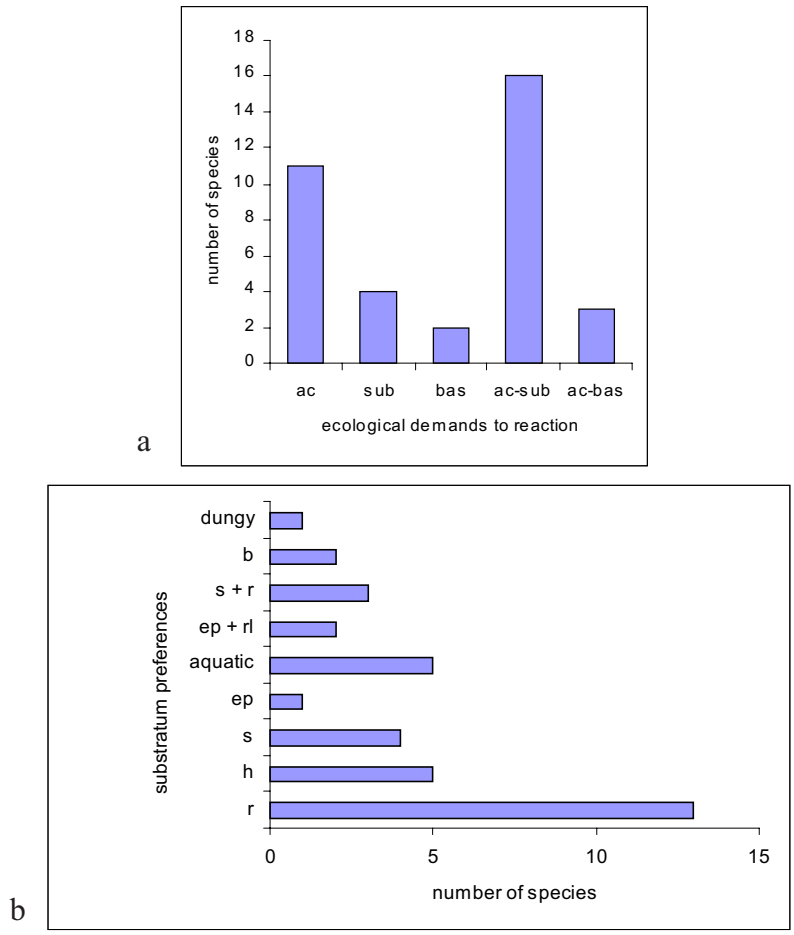

Fig. 5. Ecological character of the species not refound in 1999–2009: a – reaction demands, b – substrata preferences

Explanations. Reaction: ac – acidophytic species, sub – subneutral species, bas – basiphytic species, ac-sub – species of wide ecological amplitude from acid to subneutral conditions, ac-bas – species of very wide ecological amplitude from acid to base conditions; substrata as in Table 1.

2. The comparison of bryo-floristic data from two periods: 1869–1998 and 1999–2009 shows essential changes in species richness and composition – the list of mosses enlarged of 69 taxa and 50% of the previously reported flora of mosses was not refound. The latter differ in their ecological demands what makes difficult to point out the species disappearance reasons. The most of species noted for the first time in the period 1999–2009 were just reported from the Karkonosze Mts in the 19th century from the natural sites. The only

exception are 11 species occurring on mortar, on soil mixed with slag and between pavements around the Schronisko Samotnia chalet or on open trampled soil of the rest place on the Mały Staw lake shore.

3. Field studies and data comparison do not provide evident proves that tourist usage of the Kocioł Małego Stawu glacial cirque lead to floristic changes of moss layer. Synanthropization process manifesting in appearance of hemerophilous species not occurring naturally in Karkonosze Mts is limited to the surroundings of the Schronisko Samotnia chalet and strictly associated with mortar or concrete usage. Ruderal species were not observed in other parts of the glacial cirque.

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Streszczenie

W wyniku badań terenowych przeprowadzonych w 2009 w obrębie Kotła Małego Stawu stwierdzono występowanie 90 gatunków mchów. Uwzględniając wcześniejsze fragmentaryczne notowania z lat 1999, 2003 i 2007 łączna liczba gatunków mchów zarejestrowanych współcześnie wynosi 105 (w pracy przedstawiono wykaz gatunków wraz z krótkim opisem siedlisk). 88% (92 gatunki) wystąpiło rzadko (na mniej niż 25% stanowisk, których było 64), w tym 32 stwierdzono tylko raz. Warstwa mszysta jest zdominowana przez 13 gatunków występujących dość często, które są rozprzestrzenione na wszystkich ścianach i występują w większości zbiorowisk roślinnych porastających ściany i dno kotła, co nadaje warstwie mszystej wrażenie monotonii. Stwierdzone mchy wykazują wyraźną specjalizację co do typu zajmowanego podłoża: 80 (76%, włączając gatunki odnotowane tylko raz) wystąpiło na jednym tylko typie substratu. Najbogatsze okazały się skały i głazy (34 gatunki, w tym 28 występujące wyłącznie na tym podłożu) oraz butwiejące igliwie i szczątki liści traw oraz paproci (24, w tym 17 wyłącznych). W trzech zbiorowiskach roślinnych odnotowano największe bogactwo gatunków: w subalpejskich traworoślach *Crepido-Calamagrostietum villosae* – 48, w górnoreglowym borze świerkowym *Piceetum hercynicum* – 41 i zaroślach kosodrzewiny *Pinetum mugo sudeticum* – 40. W pozostałych typach zbiorowisk roślinnych notowano mniej niż 30 gatunków mchów. Fitocenozy najbogatsze brio-florystycznie zajmują większą część powierzchni w obrębie Kotła i wykazują duże podobieństwo składu gatunkowego.

Porównanie danych brio-florystycznych z dwóch okresów: 1869–1998 i 1999–2009 wykazało znaczące zmiany ilościowe i jakościowe w składzie gatunkowym – współcześnie odnotowano znacznie więcej gatunków, o 69, ale nie odnaleziono 50% podanych wcześniej. Większość gatunków stwierdzonych współcześnie po raz pierwszy była już w XIX w. notowana w innych miejscach Karkonoszy, na siedliskach naturalnych. Procesy synantropizacji objawiające się występowaniem mchów hemerofilnych, nie występujących naturalnie w Karkonoszach, są ograniczone do najbliższego otoczenia schroniska Samotnia i wyraźnie związane z zastosowaniem cementu lub zaprawy cementowej. W innych miejscach kotła nie odnotowano występowania mchów ruderalnych. Wydaje się więc uzasadnionym stwierdzenie, że intensywny ruch turystyczny w obrębie Kotła Małego Stawu nie spowodował widocznych zmian w składzie gatunkowym warstwy mszystej.