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Moss species diversity in the glacial cirques of the Polish Karkonosze Mts. and its changes during the 20th century

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Abstract: Bryo-floristic data from the 19th century and the first decade of the 21th century were compiled and compared to find trends in moss flora transformations during the analysed period. The total number of moss species reported from the glacial cirques in the Polish part of the Karkonosze Mts. amounted to 229 (230 taxa) and the comparison showed 49% of species replaced; 68 taxa were not refound and 45 were reported for the first time. But it seems highly probable that a great number of "newcomers" occurred only in the past and were omitted or overlooked by the 19th century researchers. 23 species among those persistent during the 20th century were found presently in no more than half of the previous localities, so they seem to demand care as probably threatened. Full list of taxa recorded from the individual objects in the studied period, including results of herbarium specimen revision, is provided.

Key words: bryophytes, moss flora changes, mountain mosses, glacial cirques

1. Introduction

In Poland, in the last decade, interest in research of bryophytes occurring in mountain ecosystems and their dynamics visibly increased (e.g. Szweykowski & Buczkowska 2000; Fudali & Kučera 2003; Zubel 2004; Stebel 2006; Wojtuń 2006; Dunajski & Fudali 2007; Fudali 2007, 2008, 2010a, 2010b; Górski 2007, 2008; Cykowska 2008; Ochyra & Stebel 2008; Żarnowiec & Staniaszek-Kik 2009; Staniaszek-Kik 2010). They proved that mountain regions have theirs own habitat specificity which resulted in different bryophyte species diversity and different floristic exemplification of changes caused both through natural processes and human impact. To better understand trends in the contemporary mountain moss flora transformations, data from various mountain ranges are needed.

In the past, the range of the Karkonosze Mts. was well bryologically explored as summarized by Limpricht (1876, 1890, 1895) and Milde (1869). Most of historical data, from the presently Polish side of this mountain range, were collected from the glacial cirques and the slopes as well as the summit of the Śnieżka Mt. (Wilczyńska 1996). In the first half of the 20th century, Limpricht (1930) published a complete study of mountain plants, including bryophytes, found in three cirques situated in the western part of the range. In the quoted publication, he inserted mainly data reported by J. Milde and K. G. Limpricht with some later notes not published. Between years 1930-1999, bryo-floristic survey of the Karkonosze Mts. was rather fragmentary (Koła & Wilczyńska 1985) but since the year 2000, some research projects concerning bryophytes have been realized in the Karkonosze Mts. and they brought quite numerous contemporary data (Fudali & Kučera 2003; Fudali 2004, 2007, 2010a, 2010b, 2011a; Fudali *et al.* 2003; Wojtuń 2006; Dunajski & Fudali 2007; Żarnowiec & Staniaszek-Kik 2009; Staniaszek-Kik 2010).

The paper presents a general analysis of changes in the species diversity of mosses occurring in six glacial cirques of the Karkonosze Mts. situated on the Polish side, in years 1869-2009. A full list of species reported from individual objects in the studied period is provided and the threat status of species discussed. Ecological and bryo-chorological aspects of moss flora changes were discussed in a separate paper (Fudali 2011b, 2012) to point probable reasons of the changes observed.

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Table 1. Brief characteristics of the glacial cirques studied

Name of the glacial cirque	Mały Śnieżny Kocioł	Wielki Śnieżny Kocioł	Czarny Kocioł	Kocioł Małego Stawu	Kocioł Wielkiego Stawu	Kocioł Łomniczki
Altitudinal span [m a.s.l.]	1175-1420	1240-1480	1095-1325	1145-1425	1225-1430	1150-1430
Geological composition	granitoids, basalt outcrop on western wall	granitoids	granitoids	granite-gneiss, schists	granite-gneiss, schists	granite-gneiss, schists
Dominating geomorhologic forms and presence of superficial water	rocky walls, rubble, erratic blocks; spring along the S wall	rocky walls, rubble, erratic blocks	erratic blocks, rubble, rocky outcrops (S wall); stream along the S wall and bottom	rubble, erratic blocks, rocky W wall, rocky outcrops in E wall; numerous springs along the S and W walls, in the bottom: mountain lake and river	rubble, rocky outcrops, the whole bottom filed with the mountain lake	rubble, erratic blocks, rocky S wall, spring along the SW wall and the bottom, numerous tracts with trickling water along the all walls
Main vegetation types on the walls	M, G, CN, F, V; *excl.* W wall: Xerophytic grassland on basalt outcrop, HM	M, G, CN, F	G, CN, F, M; *excl*. E, W walls: P; *excl.* S wall: MC, V	G, CN, F, V, M; *excl.* E, W walls: P, MC	M, CN, F, V; *excl.* S wall: HM, *excl.* W , N walls: Bg, D	M, CN, G, V, F; *excl.* E wall: P; *excl.* W wall: D; *excl.* S wall: HM, HT, Bg, MC
Main vegetation types in the bottom	M	G, F, M	MA, G, Bg, MC, HM	M, D, F, P, Bg, HM	aquatic vegetation	M, F, NC, G, V, P, D, Bg, HM, MC
Tourist infrastructure	road build of boulders in the bottom	lack	lack	road build of boulders across the western wall and along the bottom; motor road in the bottom; wooden mountain chalet with stony wall (mortar) in the bottom	ground path along the edge of southern wall; ruins of old mountain chalet	road build of boulders (enforced with concrete) across the southern wall and along the bottom; mountain chalet situated nearby the southern edge

Explanations: type of vegetation (plant communities were recognized according to Matuszkiewicz W. & Matuszkiewicz A. 1974), Bg – plots of subalpine swamps within subalpine grasslands, CN – short subalpine grasslands of *Carici rigidae-Nardetum* community, D – deciduous shrubs of *Pado-Sorbetum*, F – fern community *Athyrietum alpestris*, G – high subalpine grasslands of *Crepido-Calamagrostietum villosae* community, HM – tall herbs of *Adenostyletum aliariae* community, HT – tall herbs of *Aconitetum plicatae,* M – *Pinetum mughii sudeticum*, MA – tall grasslands *Molinio-Agrostietum* (according to Kwiatkowski (2004), MC – spring community of *Cardaminae-Montion* alliance, P – spruce forest of *Piceetum hercynicum*, V – blueberry aggregations, probably the depauperated form of *Empetro-Vaccinietum*

Post-glacial cirques in the Karkonosze Mts. resulted from erosion activity of local mountain glacier which occurred in Pleistocene (Staffa 1993). Altogether, there are 9 objects situated in the summit region of the range: six in the Polish (northern) part and three in the Czech (southern) part. The ones on the Polish side differ in altitudinal span, geological structure, geomorphologic forms and hydrological conditions making their vegetation different (Table 1). The specific local climate conditions in some cirques favour a long-term snow cover, which makes them similar to arctic or alpine objects. However, they lack perennial snow and permafrost.

2. Materials and methods

Changes in the moss flora of the glacial cirques were defined on the basis of presence-absence criterion by comparing historical bryophyte notes dated up to the year 1945 with the list of mosses reported from there in years 1999-2009 (Kwiatkowski 1999a, 1999b, 2004; Fudali & Kučera 2003; Fudali *et al.* 2003; Fudali 2004, 2007, 2010a, 2010b, 2011a; Wojtuń 2006). Additionally, a few notes reported in years 1956-1986 were included (Lisowski 1956, 1961; Koła 1986).

The historical data were compiled from all available historical papers published (Limpricht 1867, 1876,

1890, 1895; Milde 1861, 1867, 1869; Limpricht 1930) and suplemented with the results of historical specimen revision done both by the author (136 specimens of mosses picked in the glacial cirques in the 19th and in the first half of the 20th centuries from the collections of the Herbarium of the Wrocław University [WRSL] and the Herbarium of the Hungarian Natural History Museum [BP]) and by others. The latter were published in numerous bryo-chorological and taxonomical papers (49 specimens: Ochyra *et al.* 1985, 1990a, 1990b, 1990c, 1990d, 1990e, 1990f, 1992a, 1992b, 1992c, 1992d, 1992e; Szmajda *et al*. 1991a, 1991b; Bednarek-Ochyra *et al.* 1990a, 1990b, 1990c, 1990d, 1990e, 1994; Bednarek-Ochyra 1995; Blom 1996; Kučera & Fudali 2004; Wojtuń 2006). The list of historical specimens examined by the author is provided in the Appendix 1.

For the analysis of the bryoflora changes, analyses of the objects studied were taken as a whole, it means that information analysed was the fact of species occurrence at least in one of the glacial studied cirques. In that way, species not re-found in the 21th century, noted both in the 19th and 21st centuries as well as those reported for the first time from the glacial cirques at the beginning of the 21th century were listed.

The author's field studies were carried out along the glacial cirque walls, in band transects from the bottom up to upper edges including a narrow strip of ground (40 cm of width) lying above as well as in the bottoms and were delimited by the situation of walls and moraines closing the cirques from the north. The exception was the southern wall of the glacial Great Pond Cirque (Kocioł Wielkiego Stawu) whose lower parts appeared to be too dangerous for exploration.

The collection of moss specimens gathered during the author's field research was deposited in the Herbarium of the W. Szafer Institute of Botany of Polish Academy of Sciences [KRAM-B]. The nomenclature of mosses follows Ochyra *et al.* (2003) with the exception of *Rosulabryum moravicum* (Podp.) Ochyra & Stebel (= *R. laevifilum* (Syed) Ochyra). The threat status of bryophytes follows Żarnowiec *et al.* (2004) and the law protected species were pointed out according to Regulation...

3. Results

3.1. Species richness and share of protected and threatened species

Altogether 229 moss species (230 taxa including two subspecies of *Bucklandiella macounii*) were reported from the studied glacial cirques. Historical data mentioned above concern the 180 moss species (181 taxa including two subspecies of *Bucklandiella macounii*) occurring in the studied glacial cirques until 1945 (Appendix 2). Four species (*Ceratodon purpureus, Dicranum scoparium, Pleurozium schreberi* and *Polytrichum piliferum*) were not reported exactly from the glacial cirques but described as common around two of them (Limpricht 1867). As contemporary these species found as common within the glacial cirques studied it is very probable that they were also present in the past and neglected by researchers. Therefore, they were incorporated into the group of species reported up to the year 1945 which finally was estimated at 184 species (185 taxa). The identity of four species reported in the past (*Bryum schleicheri* var. *latifolium*, *Hygrohypnum molle*, *Plagiothecium ruthei* and *Schistidium apocarpum*) seems to be questionable as the revision of available historical specimens showed their misidentification (see Appendix 1).

At the beginning of the 21th century, the occurrence of 162 moss species was documented including 10 species collected only from anthropogenic sites, such as concrete and mortar and soil mixed with slag around the Samotnia mountain chalet (Fudali 2007). In total estimation, moss flora of the glacial cirques contained 32 species classified as threatened in Poland (including 7 defined as endangered) and 54 species protected by law (including 13 taxa partly protected).

3.2. Comparison of historical and contemporary data

The comparison of bryo-floristic lists from both periods revealed that species composition of the moss flora occurring in the glacial cirques changed considerably: from among 230 moss taxa reported altogether from the studied glacial cirques (including doubtful species quoted above), only 117 (51%) occurred both in the 19th and the 21th centuries. 45 taxa (20%) were noted for the first time at the beginning of the 21th century, while 68 taxa (29%) were not refound. Species reported both in the past and at present, called "persistent", exhibited various changes in their distribution: some of them were at present found mainly in the same objects as in the past, some of them were recorded, at the present time, additionally in other cirques and some were not refound in the cirques in which they were observed in the 19th century but were found in others (Appendix 2).

The lists obtained have rather approximate character as the data used were not entirely comparable because of the various methods of research in the past and nowadays. Additionally, some descriptions of the localities of historical moss specimens were vague or undecipherable.

3.3. Spatial distribution of mosses in the past and at present

Majority of species noted in the past were reported from only one or two objects (116 taxa – 63%) and six

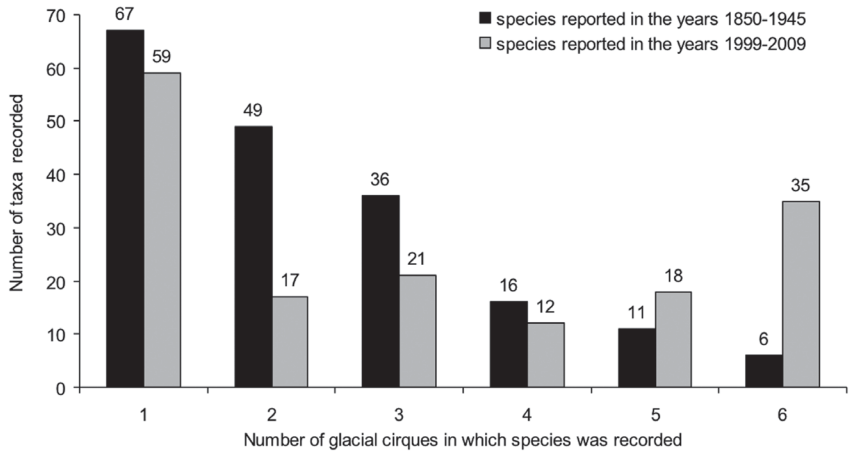

Fig. 1. Number of taxa recorded in the various numbers of glacial cirques

taxa (3%) were reported from all six cirques, while presently a bigger number of species (35 – 22%) were noted in all objects and a smaller number of species were limited in their occurrence to one or two glacial cirques (76 species – 47%) (Fig. 1).

Regarding the glacial cirques separately, quantitative relations between old and contemporary data look differently and percentage incidence of persistent taxa is smaller than in general estimation (Table 2).

3.4. Species (taxa) not refound in years 1999-2009

Majority of the taxa not re-found in years 2000-2009 were noted in the past only in one of the objects (Fig. 1) but seven of them, namely: *Hypnum pallescens*, *Kiaeria falcata*, *Lescurea mutabilis*, *Leskella nervosa, Orthotrichum speciosum*, *O. stramineum* and *Ulota crispa* were widely distributed. It is striking that all of them, with the exception of *Kiaeria falcata*, were epiphytic species.

The analysis of substratum preferences of species not refound showed a dominance of mono-substrate mosses (83%); among them, the most numerous were: epilithic species (17 – 38% of the taxa noted in the past on rocks or boulders; including 6 species on boulders in streams), humicolous species (12 – 48% of the species noted on raw humus covering rocks or soil in the past) and epiphytes (8 – 100% of species occurred exclusively on tree trunks in the past). That group contained 19 of the threatened species (including 6 endangered) and 15 species protected by law (Appendix 2).

3.5. Species noted in the glacial cirques for the first time in years 1999-2009

Among the species reported for the first time from the studied glacial cirques, 25 were noted in only one object; among them 6 hemerophilous taxa colonizing mortar and concrete, and six were currently widely distributed ones (occurred in 6 or 5 objects studied) but differed in the number of localities (Appendix 2). Only 7 (*Andraeaea nivalis, Aulacomnium androgynum, Sciuro-hypnum populeum, Dicranoweisia cirrata, Rhizomnium magni-*

Table 2. Comparison of moss taxa richness and species composition exchange among particular glacial cirques (excluding the Kocioł Wielkiego Stawu – explored presently only in parts)

Number of species:	Symbols of the glacial cirques studied				
	MSn	WSn	CZ	MSt	L
Recorded up to 1945	110	89	36	80	75
Reported in years 1999-2009	101	69	58	104	96
Found in the glacial cirque in total	147	113	74	146	136
Persistent during the 20th century/ percentage incidence	64/44%	45/41%	20/27%	38/26%	35/26%
Not found in the years 1999-2009/percentage incidence	46/31%	44/39%	16/22%	42/29%	40/29%
Reported for the first time in the years 1999-2009/percentage incidence	37/25%	24/20%	38/51%	66/45%	61/45%
Threatened in Poland	18	13	5	11	13
Protected by law	25	21	16	31	32

Explanations: MSn – Mały Śnieżny Kocioł, WSn – Wielki Śnieżny Kocioł, CZ – Czarny Kocioł, MSt – Kocioł Małego Stawu, L – Kocioł Łomniczki

folium, Plagiothecium platyphyllum and *P. succulentum*) were not reported from the Karkonosze Mts. in the past (Wilczyńska 1996). 11 species were protected by law (including 3 partly protected); two of them were classified as threatened in Poland.

3.6. Species (taxa) persistent during the 20th century

This group was not homogeneous as it contained five various combinations of the species currently occurring in relation to the historical distribution (Appendix 2). The most numerous (46) appeared to be the taxa which were found currently both in the glacial cirques in which they were noted in the past and in some new objects; among others: *Andreaea rupestris*, *Dicranella heteromalla*, *Dicranum scoparium*, *Dicranodontium denudatum*, *Hylocomium splendens*, *Oligotrichum hercynicum*, *Pleurozium schreberi*, *Pogonatum urnigerum*, *Pohlia nutans*, *Polytrichum commune*, *P. piliferum*, *Sanionia uncinata*, *Sciuro-hypnum starkei* and *Sphagnum girgensohnii*. Quite numerous (23) were taxa which showed visible decline in their distribution (they were reported only from some of the objects in which they were noted in the past), such as: *Blindia acuta*, *Dicranella subulata*, *Hylocomiastrum pyrenaicum*, *Hypnum callichroum*, *Philonotis fontata*, *Rhytidium rugosum*, *Sphagnum teres*, *Tortella tortuosa.* 19 taxa kept strictly their historical sites: those widely distributed as *Buclandiella sudetica*, *Codriophorus acicularis*, *C. fascicularis*, *Hygrohypnum ochraceum*, *Pseudoleskea incurvata* and *Warnstorfia sarmentosa* as well as those limited in their occurrence to only one glacial cirque, as *Brachytehcium geheebii*, *Fissidens osmundoides*, *Fontinalis antipyretica*, *Hypnum lindbergii*, *Polytrichastrum sexangulare*, *Sphagnum centrale*, *S. papillosum.* The rest of taxa changed their distribution either partly (were found in some of the historical localities and in some new, e.g. *Bartramia ityphylla*, *Brachytheciastrum velutinum*, *Codriophorus aquaticus, Rhytidiadelphus triquetrus*) or completely (were not re-found in historical localities but noted in other glacial cirques, e.g. *Arctoa fulvella*, *Dicranodontium uncinatum*, *Tetraphis pellucida*. Among species persistent during the whole period studied, 28 were protected by law (including 9 partly protected); 11 of them were classified as threatene in Poland.

4. Discussion

In general estimation a moss flora of the glacial cirques studied seemed to be quite rich – in total, 230 taxa (circa 33% of Polish mosses). It showed high bryo-chorological and ecological diversity (Fudali 2011b, 2012). However, only 162 species in total were reported in years 1999-2009 and the species number in individual objects fluctuated from 58 to 104. The number of moss species noted presently from glacial cirques situated on southern (Czech) side was visibly bigger than in the glacial cirques studied: Ùpská jáma cirque – 166, Malá Kotelní jáma cirque – 104, Velká Kotelní jáma cirque – 164 (Kučera *et al.* 2004a, 2004b), but one should remember that they were much larger and more geologically differentiated than the glacial cirques situated on northern (Polish) side. 68 taxa noted in the past in the studied cirques were not refound. Among them, 18 taxa were also not confirmed presently from the glacial cirques situated on the Czech side (Kučera *et al.* 2004a, 2004b) – Appendix 2. Comparison of contemporary notes from Polish and Czech glacial cirques revealed also that 6 species defined by Czech bryologists as extinct on their side of the Karkonosze Mts. (Kučera *et al.* 2004a, 2004b) were collected on Polish side but always in single sites (*Arctoa fulvella*, *Hygrohypnum smithii*, *Hylocomiastrum pyrenaicum*, *Pohlia obtusifolia*, *Ptychodium plicatum*, *Rhytidium rugosum*), while 8 species of those not refound in Poland were currently reported from the Czech side (A*mphidium lapponicum*, *Anomodon rugelii*, *Campylophyllum halleri*, *Kiaeria falcata*, *Lescurea mutabilis*, *Pseudobryum cinclidioides*, *Saelania glaucescens, Tetraplodon mnioides*). 78% of the taxa not refound in the 21th were reported from only one or two glacial cirques suggesting that these taxa were not widespread just in the past. 19 of them are considered to be threatened in Poland (Żarnowiec *et al.* 2004).

It is striking that almost all epiphytic species recorded in the 19th century vanished (i.e. species of *Ulota*, *Pylaisia polyantha, Orthotrichum speciosum, O. stramineum, Isothecium alopecuroides, Hypnum pallescens*). According to Fudali (2012), this indicates the influence of air pollution (high emission of sulfur dioxide and acid rains) observed in the region in the second part of the 20th century. Similar trends in moss flora changes (and similar species exemplification) were found by Stebel (2006) in the mountains of the Beskidy Zachodnie (Carpathians). Such species presently not refound as: *Hookeria lucens, Ctenidium moluscum, Ptilium crista-castrensis, Diphyscium foliosum, Buxbaumia viridis* are forest species and, in the past, were probably picked in fragments of spruce forests overgrowing lower parts of some of the glacial cirques. The species were quite numerously documented in the historical herbarium specimens from various sites in the Karkonosze Mts. (Wilczyńska 1996); however, currently, they were not found in the upper forest belt of the Karkonosze Mts. (Dunajski & Fudali 2007). Żarnowiec *et al.* (2004) defined *Hookeria lucens* and *Buxbaumia viridis* to be endangered in Poland.

In the moss collection of WRSL, there were 13 bags of the *Dichelyma falcatum* specimens gathered in years 1857-1933. They were all picked from one locality

(waterfalls flowing into the Mały Staw lake). The species were not refound nowadays in spite of very careful investigation giving rise to suspition that the population might have been overcollected in the past. It would not be the first such case in the Karkonosze Mts. During the first half of the XXth century, the population of vascular plants of *Saxifraga nivalis* was almost completely damaged by collectors (Fabiszewski 1985). But *Dichelyma falcatum* was still reported in 1956 from the Karkonosze Mts. by Lisowski (1956).

Among taxa reported in both studied periods, there was a group of 46 species which seemed to spread out as they were reported presently from the bigger number of the glacial cirques than in the past (see Appendix 2). A trend for a contemporary expansion of such bryophytes as: *Oligotrichum hercynicum, Orthodicranum montanum, Pogonatum urnigerum* and *Plagiothecium curvifolium* was also reported by Stebel (2006) from the Beskidy Zachodnie range and by Janovicová *el. al* (1999) and Górski (2008) from the Tatra Mts. In the latter case, just in 1980s, Balcerkiewicz (1984) observed a descent of *Oligotrichum hercynicum* in lower altitudes along tourist paths and interpreted it as a result of trampling and damage of vegetation cover. However, in the glacial cirques of Karkonosze Mts., the species was found mainly along erosion furrows caused by avalanches frequent there. Tourist traffic is limited to roads built from boulders, sometimes reinforced with concrete so trampling does not affect moss cover directly. In the past, *Orthodicranum montanum* was recorded only in two glacial cirques, while currently it was reported from the all objects. According to Greven (1992) and Söderström (1992), the species spread due to acidification. In recent years, an increase in the number of localities of this acidophitic epiphyte was observed in the Beskidy Zachodnie Mountains (Stebel 2006) and in the Cracow-Częstochowa Upland (Fojcik 2011).

45 species were reported for the first time from the glacial cirques studied in result of surveys carried out since 1999. Only 7 of them were new for the Karkonosze Mts., the rest occurred in this mountain range in the past (Wilczyńska 1996). This questions whether they were present in the glacial cirques in the 19th century and were omitted by researchers or, perhaps, they began to spread in the 20th century. 21 of the species reported for the first time now were found in single localities, e.g. *Andreaea nivalis*, *Ditrichum zonatum*, *Sciuro-hypnum populeum*, *Sphagnum fuscum*, *S. palustre*. It is highly probable that some of them occurred in the past and might have been overlooked as investigation methods of the 19th century researchers were not as detailed as at present. Two of the *Sphagnum* species, *S. fallax* and *S. russowii*, reported currently for the first time from the eastern glacial cirques (Fudali 2010a, 2010c, 2011a) were described as frequent in the subalpine bogs of the Karkonosze Mts. only in the second half of the 20th century (Wilczyńska 1996).

There are no doubts for the "newcomer" status in the case of 9 species found on concrete or mortar used for reinforcement of tourist paths constructed in the second half of the 20th century. Such species as *Bryum argenteum* and *Ceratodon purpureus* were also reported from the alpine zone of the Slovák Tatra Mts., but they spread along tourist paths (Janovicová *et al.* 1999). 8 of those species not reported from the glacial cirques before 1999 (i.e. *Mnium hornum*, *Brachythecium rutabulum*, *Bryum pseudotriquetrum*, *Plagiomnium affine*, *Polytrichastrum formosum*, *Cirriphyllum piliferum*, *Herzogiella seligeri* and *Thuidium tamariscinum*) were noted in the 19th century in the Karkonosze Mts. only below the altitude of 1000 m a.s.l. (Wilczyńska 1996). At present, they were found higher, at least at the altitude of 1110 m a.s.l., but always in single sites. Seven of the quoted species occurred abundantly in deciduous and mixed forests. In recent years, the phenomenon of plant species shift upwards in the elevation was reported from Norwegian mountains (Klanderud & Birks 2003) and the Alps (Theurillat & Guison 2001) and interpreted as a response to climate warming. Unfortunately, the research concerned only vascular plants. During seven years of research (2001-2008) carried out in Europe's major mountain ranges, Pauli *et al*. (2012) observed an increase in vascular plant species richness in boreal-temperate mountains of Europe due to a shift in species ranges to higher altitudes. Regarding these reports, it can be assumed that moss species mentioned above could have changed their altitudinal distribution during the 20th century. The more so, since the meteorological data analysed by Głowicki (2009) proved that the average annual air temperature on the Śnieżka Mt. rose by about 1ºC in the period from 1959-2008, while the average monthly temperature for January – by 2.5ºC. However, the accuracy of historical research is questionable. These species, common in lower altitudes, could be neglected by the former researchers. Also from Czech glacial cirques, many species were reported currently for the first time and their share in the contemporary bryoflora (including liverworts) ranged from 30% to 40% (Kučera *et al.* 2004a, 2004b). 30 of the species were the same as listed by the author (Appendix 2). Kučera *et al.* (2004a, 2004b) also found historical survey as "not complete".

The discussion presented above showed that the real list of "newcomers" in the glacial cirques could be much shorter than it appeared from the comparison of the historical and contemporary data. Also the list of taxa reported in the past should be considered as approximate, although the historical data were published by such prominent bryologists as J. Milde and K. G. Limpricht. During the 20th century, the taxonomical approach to

some taxa changed (Ochyra *et al.* 2003) and a revision of all old specimens collected in the studied objects and recognized as critical taxa would be necessary to make a historical list adequate. But many historical specimens were damaged during the Second World War and they could not be revised. This remark refers especially to numerous species of the *Schistidum apocarpum* complex described in 1996 by Blom (1996). Only six specimens named as *Grimmia apocarpa* (=*Schistidum apocarpum*) collected from the glacial cirques studied in the past were preserved. Their revision revealed that they belong to three various species (see Appendix 1) and none was *Schistidum apocarpum* sensu Blom (1996). Thus, the possibility that the presented list of moss taxa occurring in the glacial cirques in the past was not complete cannot be rejected. Additionally, some descriptions of the localities of historical moss specimens were vague or undecipherable.

As the contemporary flora of the Karkonosze Mts. has not been elaborated so far, it seems there is not a background to define the local threat status of species found presently in the glacial cirques. With respect to the opinion of Hallinbäck *et al.* (1998) that "a visible decline in the number of sites" was a relevant criterion for bryophytes threat estimation we can point to 23 species which were found presently in no more than half of the historical localities. These species seem to demand care and monitoring in the Karkonosze Mts. as they appear to be threatened. Similarly to 68 species not refound currently within the glacial cirques. One of the latter, *Dicranum elongatum*, was refound on the Śnieżka Mt. slopes in 2003 (Fudali *et al.* 2003).

5. Conclusions

- The total moss flora recorded in the glacial cirques, some of the best investigated in the past sites in the Karkonosze Mts., is quite rich – it contains 229 species (230 taxa) constituting 33% of Polish moss species. However, 190 of them (83%) occurred in no more than two objects. 32 species belonged to the group classified as threatened in Poland (including 7 defined as endangered) and 54 species were protected by law (including 13 taxa partly protected).
- The comparison of the bryo-floristic data from the 19th century and the first decade of the 21th century showed a 49% exchange of species; 68 taxa were not re-found and 45 were reported for the first time. But it is highly probable that a great number of "newcomers" occurred also in the past and were omitted by the 19th century researchers so the real species turnover could have been much smaller. In the case of such small plants as mosses, there is always a possibility that small turf would be overlooked.
- 23 taxa showed visible decline in the number of localities. They demand care and monitoring in the Karkonosze Mts. as probably threatened.

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Appendix 1. Historical specimens examined by the author

Amphidium lapponicum: [WRSL]: MSn. 25.07.1885, 25.07.1886 *leg.* GL (as *Amphoridium l.*); *Amphidium mougeotii*: [WRSL]: WSt. 10.07.1866 *leg.* Schultze (as *Amphoridium m.*); *Andreaea rupestre*: [WRSL]: WSn. 1.10.1866 *leg.* GL; (as *A. petrophila*); *Bartramia ityphylla*: [WRSL]: MSn. 4.08.1865 *leg.* Schultze; *Blindia acuta*: [WRSL]: MSn. 22.07.1865 *leg.* GL; *Bryum pallens*: [WRSL]: MSt. 25.07.1882 *leg.* Kern; *Cirriphyllum crasinervium*: [WRSL]: MSn. 1.10.1917 *leg.* Kern (as *Eurhynchium c.*); *Ctenidium molluscum*: [WRSL]: MSt. 31.07.1865 *leg.* Schultze (as *Hypnum m.*); *Dicranodontium uncinatum*: [WRSL]: WSn. 07.1868 *leg.* GL (as *D. circinatum*): MSn. 07.1869 *leg.* GL (as *Dicranum circinatum*), 07.1869 *leg.* Her. (as *Dicranum circinatum*); *Dichelyma falcatum*: MSt. 08.1857 *leg.* Miechlitz, 31.07.1865 *leg.* Schultze, 07.1865 *leg.* Fritze & Stein, 23.07.1866 *leg.* GL, 09.1866 *leg.* Fritze, 13.07.1867 *leg.* Fiek, 28.07.1873 *leg.* Schultze, 11.07.1876 *leg.* Schultze, 25.08.1884 *leg.* Schultze, 18.06.1905 *leg.* Lingelsheim, 24.08.1909 *leg.* Baumgart, 4.06.1933 *leg.* WL; *Dichodontium flavescens*: [WRSL]: L. 28.06.1865 *leg.* GL (tested by R. Ochyra 1990); *Diobelonella palustris*: [WRSL]: MSn. 2.08.1869 *leg.* GL (as *Dicranella squarrosa*); *Dicranum elongatum*: [WRSL]: SN. 1.10.1866 *leg.* GL, 5.08.1869 *leg.* Her.; *Dryptodon funalis*: [WRSL]: MSn. 2.10.1866 *leg.* GL (as *Grimmia f.*); *Fissidens osmundoides*: [WRSL]: MSn. 1.10.1917 *leg.* Kern; *Fontinalis antipyretica*: [WRSL]: MSt 11.07.1876 *leg.* Schultze, 25.07.1882 *leg.* Kern: L. 08.1867 *leg.* Schultze; *Herzogiella striatella*: [WRSL]: MSn. 2.10.1866 *leg*. GL (as *Plagiothecium mühlenbeckii*): MSt. 9.09.1878 *leg.* Schultze (as *Plagiothecium mühlenbeckii*): CZ. 8.10. 1913 *leg.* Kern (as *Plagiothecium mühlenbeckii*); *Heterocladium heteropterum*: [WRSL]: SN. 1.08.1869 *leg.* GL; *Hylocomiastrum pyrenaicum*: [WRSL]: MSn. 22.07.1865 *leg.* GL (as *Hylocomium oakesii*), 4.08.1865 *leg.* Schultze (as *Hylocomium oakesii*), 20.07.1886 *leg.* Kern (as *Hylocomium* oakesii): WSn. 1.10.1866 *leg.* GL (as *Hylocomium oakesii*), 31.07.1915 *leg.* Baumgart (as *Hylocomium p*): L. 16.07.1866 *leg.* GL (as *Hylocomium oakesii*); *Hylocomiastrum umbratum*: [WRSL]: L. 2.08.1865 *leg.* GL (as *Hylocomium u.*), 24.08.1884 *leg.* Schultze (as *Hylocomium u.*); *Hygrohypnum smithii*: [WRSL]: MSt. 07.1865 *leg.* Fritze (as *Limnobium arcticum*);11.07.1876 *leg.* Kern (as *Hypnum arcticum*), 29.07.1868 *leg.* Schultze (as *Hypnum arcticum*), 29.07.1882 *leg.* Kern (as *Hypnum arcticum*), 6.08.1868 *leg.* Her. (as *Hypnum arctivum*); *Hypnum lindbergii*: [WRSL]: MSn. 24.07.1865 *leg.* GL (as *Hypnum arcuatum*); 1.10.1866 *leg*. GL (as *Hypnum arcuatum*); 26.07.1886 *leg*. Kern (as *Hypnum arcuatum*); *Hypnum calichroum*: [WRSL]: WSn. 20.09.1865 *leg.* GL, 1.08.1867 *leg.* GL, 19.07.1906 *leg.* Kern: L. 8.07.1865 *leg.* Engler, 07.1866 *leg.* GL: SN. 20.10.1865 *leg.* GL.: MSt. 07.1867 *leg.* Schultze, 16.07.1886 *leg.* Schultze, 26.07.1886 *leg.* Kern: MSn. *leg.* Milde (without date); *Hygrohypnum duriusculum*: [WRSL]: MSt. 20.07.1876 *leg.* GL (as *Hypnum dilatatum*), 11.07.1876 *leg.* Kern (as *Hypnum dilatatum*), 28.07., 31.07.1865 *leg*. GL (as *Hypnum molle*), 08.1876 *leg*. Schultze (as *Hypnum molle*), 11.07.1876 *leg*. Schultze (as *Hypnum molle*); *Hygrohypnum ochraceum*: [WRSL]: MSn. 22.071865 *leg.* GL (as *Hypnum o.*), 20.07.1886 *leg.* Schultze (as *Hypnum o.*): MSt. 07.1867 *leg.* Schultze (as *Hypnum o.*), 28.07.1873 *leg.* Schultze (as *Hypnum o.*), 20.07.1876 *leg.* GL (as *Hypnum palustre*); 2.10.1917 *leg.* Kern (as *Hypnum o.*): L. 6.07.1917 *leg.* Schultze (as *Hypnum o.*), 30.09.1919 *leg.* Kern (as *Hypnum o.*); *Hypnum pallescens*: [WRSL]: WSn. 1865 *leg.* G.L: L. (without date) *leg.* Milde; *Isopterygiopsis pulchella*: [WRSL]: L. 1.10.1919 leg. Kern (as *Plagiothecium pulchellum*); *Isothecium alopecuroides*: [WRSL]: L. 07.1867 *leg.* Schultze (as *I. myurum*); *Kiaeria blyttii*: SN. 2.08.1869 *leg.* GL *(*as *Dicranum b.*) [BP no 32.116]; *Kiaeria starkei*: [WRSL]: SN. 1.08.1879 *leg.* Schulze (as *Dicranum starkii*); *Lescurea saxicola*: [WRSL]: MSn. 22.07.1865 *leg*. GL (as *L. striata* var. *saxicola)*; 2.10.1866 *leg*. GL (as *L. striata* var. *saxicola)*; 1.10.1866 *leg.* Zimmermann (as *L. striata* var. *saxicola)*; *Mnium spinosum*: [WRSL]: L. 07.1866 *leg.* GL; 07. 1867 *leg.* Schultze; *Philonotis fontana*: [WRSL]: MSt. 31.07.1865 *leg.* Schultze: L. 2.08.1865 *leg.* Schultze; *Philonotis seriata*: [WRSL]: WSn. 19.07.1906 *leg.* Kern: L. 24.08.1884 leg. Schultze (as *P. fontana* var. falcata), 20.09.1919 *leg.* Kern; *Plagiothecium curvifolium*: [WRSL]: MSn. 1.10.1917 *leg.* Kern; *Plagiothecium denticulatum*: [WRSL]: WSn. 19.07.1906 *leg.* Kern, 19.07.1906 *leg.* Kern (as *P. sylvaticum*); *Pseudotaxiphyllum elegans*: [WRSL]: CZ. 8.10.1913 *leg.* Kern (as *Plagiothecium e.*); *Plagiothecium cavifolium*: [WRSL]: CZ. 8.10.1913 *leg*. Kern (as *P. rutheanum*); *Plagiothecium nemorale*: [WRSL]: CZ. 8.10.1913 *leg.* Kern (as *P. sylvaticum*); *Pseudoleskea incurvata*: [WRSL]: MSn. 1.10.1917 *leg.* Kern (as *P. atrovirens*): MSt. 4.09.1888 *leg.* Schultze (as *P. atrovirens*); *Platyhypnidium riparioides*: [WRSL]: MSn. 25.07.1865 leg. GL (as *Rhynchostegium rusciforme*), 28.07.1865 *leg.* GL (as *Brachythecium rusciforme*); *Pohlia ludwigii*: [WRSL]: WSn. 2.09.1928, 14.10.1928 *leg.* WL (as *Bryum schleicheri* var. *latifolium*); *Pteryginandrum filiforme*: [WRSL]: MSt. 07.1867 *leg.* Schultze; *Ptychodium plicatum*: [WRSL]: MSn. 22.07.1865 *leg*. GL, 4.08.1865 *leg.* Schultze; 1.10.1866 *leg*. GL; *Rhizomnium pseudopunctatum*: [WRSL]: L. 27.08.1884 *leg*. Schultze (as *Mnium subglobosum* – tested by R. Ochyra 2012); *Rhytidiadelphus loreus*: [WRSL]: SN. 25.07.1865 *leg.* GL (as *Hylocomium l.*); *Rhytidiadelphus subpinnatus*: SN? 2.10.1866 *leg*. GL (as *Hylocomium triquetrum* var. *subpinnatum*) [BP 57.646]; *Rhytidium rugosum*: [WRSL]: MSn. 31.07.1873 *leg.* Zimmermann (as *Hypnum r.*); *Straminergon stramineum*: [WRSL]: MSt. (without date) *leg.* Schultze (as *Hypnum s.*); *Sanionia uncinata*: [WRSL]: MSn. 4.08.1865 *leg.* Schultze (as *Hypnum uncinatum*), 10.1927 *leg.* WL (as *Hypnum calichroum*): L. 07.1867 *leg.* Schultze (as *Hypnum uncinatum*); *Sciuro-hypnum reflexum*: [WRSL]: MSn. 08.1865 *leg.* Schultze (as *Brachythecium r.*); 26.07.1886 *leg.* Kern (as *Brachythecium r.*); 1.10.1917 *leg.* Kern (as *Brachythecium r.*); 12.04.1928 *leg.* WL (as *Brachythecium r.*); *Sciuro-hypnum starkei*: [WRSL]: CZ. 8.10.1913 *leg*. Kern (as *P. rutheanum*); *Sphagnum girgensohnii*: [WRSL]: MSt. 20.07.1887 *leg*. GL; *Splachnum sphaericum*: [WRSL]: MSt. 27.08.1884 *leg.* Schultze; *Schistidum flexipile*: [WRSL]: MSn. 2.10.1866 *leg.* GL (as *Grimmia apocarpa* var. *rufula*), [BP: 2.10.1866 *leg.* GL: 37993, 5799], (tested by R. Ochyra 2012); *Schistidum agassizii*: [WRSL]: MSt. 28.07.1873 *leg.* Schulze (as *Grimmia apocarpa* – tested by R. Ochyra 2012); *Tortula euryphylla*: [WRSL]: MSn. (without date) *leg.* Schoepke (as *Desmatodon latifolius*); *Ulota bruchii*: [WRSL]: L. (without date) *leg*. Milde (mixed with *Hypnum pallescens*); *Warnstorfia exannulata*: [WRSL]: MSt. 10.07.1883 *leg.* Schulze (as *Hypnum exannulatum*), 25.08.1884 *leg.* Schulze (as *Hypnum exannulatum*), 16.07.1886 *leg.* Schulze (as *Hypnum exannulatum*), 16.07.1886 *leg.* Schulze (as *Hypnum fluitans* var. *aduncum*), 2.09.1888 *leg.* Schultze (as *Hypnum fluitans* var. *exannulatus*): L. 18.07.1886 *leg.* Schultze (as *Hypnum fluitans f. amphibium*); *Warnstorfia sarmentosa*: [WRSL]: MSn. 24.07.1869 *leg.* GL (as *Hypnum sarmentosum*): MSt. 4.09.1888 *leg.* Schultze (as *Hypnum sarmentosum*), 2.10.1917 *leg.* Kern (as *Hypnum sarmentosum*): WSt. 16.07.1886 *leg.* Schultze (as *Hypnum sarmentosum*);

Abbreviations of the glacial cirques names: CZ – Czarny Kocioł (germ. Agnetendorfen grube), MSn – Mały Śnieżny Kocioł (germ. Kleine Schneegrube), MSt – Kocioł Małego Stawu (germ. Kleine Teich grube), WSt – Kocioł Wielkiego Stawu (germ. Grosse Teich grube), WSn – Wielki Śnieżny Kocioł (germ. Grosse Schneegrube), L – Kocioł Łomniczki (germ. Melzergrund), SN – MSn and/or WSn (germ. Schneegruben; description of the site not precised); abbreviations of the collectors names: GL – Karl Gustaw Limpricht, Her – germ. „vom Herausgeber" (name of a collector unknown), WL – Wolfgang Limpricht; *leg.* – collected and determined by…. ; [BP] – Herbarium of the Hungarian Natural History Museum, [WRSL] – Herbarium of the Natural Museum of the Wrocław University.

Appendix 2. Historical and contemporary moss floristic notes from the individual glacial cirques ordered according to the present-absent nowadays criteria

	Name of species	MSn		WSn		CZ		MSt		WSt		L	
		1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009
	Species reported in 1850-1945 not re-found in 1999-2009												
1	**Amphidium lapponicum* TR	▲	1956	.	.	.	.	■	0	.	.	.	.
2	**Anomodon rugelii* P, TV	■	0	.	.	.	.	.	.	.	.	.	.
3	*Bartramia halleriana*	■	0	.	.	.	.	▲	0	.	.	.	.
4	*Bartramia pomiformis*	.	.	.	.	.	.	■	0	.	.	.	.
5	*Rosulabryum elegans*	■	0	.	.	.	.	■	0	.	.	.	.
6	*!Bryum muehlenbeckii*	■	0	.	.	.	.	.	.	.	.	.	.
7	*!Bryum pallens*	.	.	.	.	.	.	▲	0	.	.	■	0
8	*Bryum turbinatum*	.	.	■	0	.	.	.	.	.	.	.	.
9	*Bryum weigeli* P, TV	.	.	.	.	.	.	■	0	.	.	.	.
10	*Buxbaumia viridis* P, TE	.	.	.	.	.	.			.	.	■	0
11	*Calliergon trifarium*	.	.	.	.	.	.	.	.	■	0	.	.
12	*Campylium stellatum*	■	0	.	.	.	.	.	.	.	.	.	.
13	**Campylophyllum halleri*	.	.	.	.	.	.	.	.	.	.	■	0
14	*Campylopus flexuosus* P, TI	.	.	.	.	.	.	.	.	.	.	■	0
15	*Cirriphyllum crassinervium*	▲	0	.	.	.	.	.	.	.	.	.	.
16	*Ctenidium molluscum*	.	1953	.	.	.	.	▲	0	.	.	■	0
17	*Dichelyma falcatum* P, TE	.	.	.	.	.	.	▲	0	.	.	.	.
18	*Dichodontium flavescens* TI	.	.	.	.	.	.	.	.	.	.	▲?	0
19	*Dicranum elongatum* TR	▲	0	▲	0	.	.	.	.	.	.	.	.
20	*!Diphyscium foliosum*	.	.	.	.	.	.	■	0	.	.	▲	0
21	*Ditrichum pusillum*	.	.	.	.	.	.	.	.	.	.	■	0
22	*Dryptodon patens*	.	.	▲	0	.	.	■	0	■	1956	.	.
23	*Encalypta ciliata*	■	0	.	.	.	.	.	.	.	.	.	.
24	*Encalypta microstoma* TI	▲	0	.	.	.	.	.	.	.	.	.	.
25	*Fissidens dubius*	■	0	.	.	.	.			.	.	.	.
26	*Gymnostomum aeruginosum*	■	0	■	0	.	.	.	.	.	.	.	.
27	*!Heterocladium dimorphum*	■	0	.	.	.	.	.	.	.	.	.	.
28	*!Hookeria lucens* P, TE	.	.	.	.	.	.	.	.	.	.	■	0
29	*Hygrohypnum duriusculum*	.	.	.	.	■	0	▲	0	.	.	.	.
30	*!Hygrohypnum luridum*	.	.	.	.	.	.	■	0	.	.	.	.
31	*Hypnum pallescens*	■	0	▲	0	■	0	.	.	.	.	■	0
32	*Isopterygiopsis pulchella*	.	.	.	.	.	.	.	.	.	.	▲	0
33	*Isothecium alopecuroides*	.	.	.	.	.	.	■	0	.	.	▲	0
34	**Kiaeria falcata*	■	0	■	0	.	.	■	0	■	0	■	0
35	**Lescuraea mutabilis*	■	0	■	0	.	.	■	0	■	0	■	0
36	*!Lescuraea saxicola*	▲	1956			.	.			.	.	.	.
37	*!Leskella nervosa*	■	0	■	0	■	0	.	.	.	.	■	0
38	*Mnium spinulosum*	■	0	.	.	.	.	■	0	.	.	■	0
39	*Orthothecium intricatum*	■	0	.	.	.	.	.	.	.	.	.	.
40	*Orthotrichum pallens*	■	0	■	0	■	0	.	.	.	.	.	.
41	*!Orthotrichum rupestre* P	.	.	.	.	.	.	.	.	.	.	■	0
42	*!Orthotrichum speciosum*	■	0	■	0	■	0	.	.	.	.	■	0
43	*!Orthotrichum stramineum* TV	■	0	■	0	■	0	.	.	.	.	■	0
44	*Palustriella decipiens*	.	.	.	.	.	.	■	0	.	.	■	0
45	*Serpoleskea subtilis*	.	.	.	.	.	.	.	.	.	.	■	0
46	*Pohlia elongata*	■	0	.	.	.	.			■	0	.	.
47	**Pseudobryum cinclidioides* P, TE	.	.	.	.	■	0	.	1961	.	.	.	.
48	**Pteryginandrum filiforme*	.	.	.	.	.	.	▲	0	.	.	.	.
49	*!Ptilium crista-castrensis* P*	.	.	.	.	.	.			.	.	■	0
50	*Pylaisia polyantha*	.	.	.	.	.	.	.	.	.	.	■	0
51	*Rhizomnium pseudopunctatum*	■	0	■	0							▲	0
52	**Saelania glaucescens*	■	0	.	.	.	.	.	.	.	.	.	.
53	*Schistidium agassizi*	.	.	.	.	.	.	▲	0	.	.	.	.
54	*Schistidium confertum*	■	0	.	.	.	.	.	.	.	.	.	.
55	*Schistidium flexipile* TI	▲	0	.	.	.	.	.	.	.	.	.	.
56	*Schistidium papillosum*	▲?	0	▲?	0	.	.	.	.	.	.	.	.
57	**Schistidium rivulare*	.	.	.	.	.	.	■	0	.	.	.	.
58	*Splachnum ampullaceum* P	.	.	.	.	.	.	▲	0	.	.	.	.
59	*Tetraplodon angustatus*	■	0	■	0	.	.	.	.	.	.	.	.
60	**Tetraplodon mnioides* TR	■	0	■	0	.	.	.	.	.	.	.	.
61	*Tomentyhypnum nitens* P, TV	.	.	.	.	.	.	.	.	■	0	.	.
62	*!Ulota bruchii* P, TV	■	0	■	0	.	.	.	.	.	.	▲	0
63	*!Ulota coarctata* P, TE	■	0	■	0	.	.	.	.	.	.	■	0
64	*!Ulota crispa* P, TV	■	0	■	0	■	0	.	.	.	.	■	0
65	*Ulota drummondii* P, TE	■	0	■	0	.	.	■	0	.	.	.	.
	Doubtful species (available historical specimens misidentified)												
66	*!Bryum schleicheri* var. *latifolium*	.	.	▲	0	.	.	.	.	.	.	.	.
67	*!Hygrohypnum molle*	.	.	.	.	.	.	▲	0	.	.	■	0
68	*Plagiothecium ruthei*	.	.	.	.	▲	0	.	.	.	.	.	.

	Name of species	MSn		WSn		CZ		MSt		WSt		L	
		1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009
	Species recorded in the both periods studied												
	Contemporary localities the same as historical												
1	*Brachyhecium geheebii* P, TV	■	1	.	.	.	.	.	.	.	.	.	.
2	*Bucklandiella sudetica*	▲	30	▲	30	■	30	▲	19	▲	13	▲	18
3	*Codriophorus acicularis*	■	5	■	10	■	2	▲	10	▲	1	■	8
4	*Codriophorus fascicularis*	■	20	▲	10	▲	20	▲	18	▲	6	▲	19
5	*Fissidens osmundoides* P, TR	▲	1	.	.	.	.	.	.	.	.	.	.
6	*Fontinalis antipyretica*	.	.	.	.	.	.	▲	2	.	.	▲	0
7	*Hygrohypnum ochraceum*	▲	3	■	2	■	2	▲	4	.	.	▲	3
8	**!!***Hygrohypnum smithii*	.	.	.	.	.	.	▲	2	.	.	.	.
9	*Hypnum lindbergii*	▲	3	.	.	.	.	.	.	.	.	.	.
10	*Kiaeria starkei*	▲	25	▲	10	■	3	■	16	■	4	■	16
11	*Polytrichastrum alpinum*	■	30	■	30	■	20	■	35	■	14	■	31
12	*Polytrichastrum sexangulare*	■	1	.	.	.	.	.	.	.	.	.	.
13	*Pseudoleskea incurvata*	▲	10	■	10	.	.	▲	3	.	.	■	1
14	*Sphagnum centrale* P	.	.	.	.	.	.	.	.	▲	1	.	.
15	*Sphagnum papillosum* P, TI	.	.	.	.	.	.	.	.	▲	1	.	.
16	*Sphagnum warnstorfii* P	.	.	.	.	.	.	.	.	▲	1	.	.
17	*Tetrodontium repandum* TI	.	.	.	.	.	.	■	1	.	.	.	.
18	*Tortula euryphylla*	▲	2	.	.	.	.	.	.	.	.	.	.
19	*Warnstorfia sarmentosa*	▲	1	■	2	.	.	▲	1	▲	1	■	2
	Re-found in every historical locality and noted in some new sites												
20	*Andreaea rupestris* P	■	20	▲	20	.	10	.	10	.	6	.	9
	**Buclandiella macounii* ssp.												
21	*macounii* TI	▲	5	.	.	.	.	.	.	.	.	.	1
22	*Cynodontium polycarpon*	■	10		2	.	10	■	8	.	2	■	4
23	*Dicranella cerviculata*	■	4	■	5	.	6	.	3	.	4	.	10
24	*Dicranella heteromalla*	.	10	■	10	.	6	.	11	.	1	.	.
25	*Dicranodontium denudatum*	■	10	■	10	.	20	■	14	■	2	■	19
26	*Dicranum flexicaule*	■	20	■	20	■	10	.	1	.	1	.	4
27	*Dicranum fuscescens*	.	.	.	.	.	.	■	5	.	5	.	10
28	*Dicranum majus*	.	3	.	1	.	.	■	5	.	.	.	7
29	*Dicranum scoparium* P*	■	50	■	40	.	40	.	25	.	15	.	31
30	*Diobelonella palustris*	▲	1			.	4	■	5	■	1	■	6
31	*Hylocomiastrum umbratum*	.	1	.	.	.	.	.	7	.	2	▲	11
32	*Hymenoloma crispulum*	■	10	■	10	.	10	.	4	.	1	■	4
33	*Kiaeria blyttii*	▲	30	▲	20	.	10	.	3	.	3	.	1
34	*Mnium spinosum*	.	4	.	1	.	.	.	2	.	.	▲	3
35	*Niphotrichum canescens*	■	4	.	1	.	.	.	.	.	.	.	.
36	*Oligotrichum hercynicum*	■	20	■	20	■	20	.	12	.	5	■	12
37	*Orthodicranum montanum*	.	2	.	4	.	1	■	9	■	6	.	14
38	*Orthogrimmia donniana*	.	2	■	5	.	.	.	2	.	.	.	1
39	*Paraleucobrym longifolium*	.	5	■	10	.	1	.	10	.	3	■	8
40	*Philonotis seriata* P	■	5	▲	2	.	5	.	12	.	1	▲	15
41	*Plagiomnium medium*	.	2	.	1	.	2	■	6	.	4	■	11
42	*Plagiothecium cavifolium*	.	10	.	5	▲	8	■	8	.	3	■	12
43	*Plagiothecium curvifolium*	▲	2	.	5	.	10	.	25	.	7	.	24
44	*Plagiothecium denticulatum*	.	20	▲	10	.	20	■	5	.	4	■	11
45	*Pleurozium scheberi* P*	■	40	■	30	.	10	.	22	.	11	.	25
46	*Pogonatum urnigerum*	.	20	.	20	.	.	■	3	.	6	.	11
47	*Pohlia ludwigii*	■	10	▲	3	.	.	.	.	.	.	.	.
48	*Pohlia nutans*	■	10	■	20	.	10	■	17	■	10	.	20
49	*Pohlia wahlenbergii* var. *glacialis*	■	3	.	3	.	5	.	.	.	2	■	3
50	*Polytrichum commune* P*	■	10	■	10	■	30	.	19	.	10	.	16
51	*Polytrichum juniperinum*	■	30	■	30	■	10	.	9	.	4	.	8
52	*Polytrichum piliferum*	■	40	■	40	.	4	.	11	.	3	.	8
53	*Pseudotaxiphyllum elegans*	.	6	.	2	▲	6	.	3	.	.	■	10
54	*Rhizomnium punctatum*	■	10	■	3	■	3	.	4	.	2	.	6
55	*Rhodobryum roseum*	.	3	▲	1	.	.	.	3	.	1	.	.
56	*Rhytidiadelphus loreus*	▲	4	▲	5	.	1	.	1	.	.	.	5
57	*Rhytidiadelphus squarrosus* P*	■	3	■	2	.	6	■	1	■	1	.	.
58	°*Rhytidiadelphus subpinnatus*	▲	5	▲	10	.	6	.	30	.	11	.	25
59	*Sanionia uncinata*	▲	20	■	10	.	3	.	8	.	9	▲	18
60	*Sciuro-hypnum reflexum*	▲	30	■	20	.	10	■	26	■	8	■	25
61	*Sciuro-hypnum starkei*	.	5	■	10	▲	4	.	14	.	5	■	15
62	*Sphagnum denticulatum* P	.	.	.	.	.	6	.	10	▲	2	.	4
63	*Sphagnum girgensohnii* P	■	20	■	20	■	20	▲	23	.	8	■	26
64	*Sphagnum magellanicum* P	.	.	.	.	.	.	.	2	▲	1	.	1
65	*Straminergon stramineum*	.	10	.	10	.	4	▲	12	■	1	■	5
	Found only in some of the historical localities												
66	*Andreaea rothii* ssp. *falcata* TR	.	.	■	2	.	.	■	0	.	.	.	.

	Name of species	MSn		WSn		CZ		MSt		WSt		L	
		1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009
67	*Blindia acuta*	▲	1	■	1	.	.	■	1	■	0	■	0
68	*Bucklandiella macounii* ssp. *alpinum*	▲	3	▲	1	.	.	.	1953	.	.	.	1970
69	*Cynodontium strumiferum*	.	.	.	.	.	.	■	2	.	.	■	0
70	*Dicranella subulata*	■	1	.	.	■	0	■	0	.	.	■	0
71	*Dryptodon funalis*	▲	2	■	3	.	.	■	0	.	.	.	.
72	*Dryptodon incurvus*	■	0	■	4	.	.	.	.	.	.	.	.
73	*Herzogiella striatella*	▲	1	■	2	▲	0	▲	8	■	0	▲	8
74	!!*Hylocomiastrum pyrenaicum*	▲	2	▲	0	.	.	▲	0	.	.	▲	0
75	*Hypnum callichroum*	▲	1	▲	0	■	0	▲	4	.	.	▲	1
76	*Philonotis fontana*	■	0	■	0	■	1	.	1956	.	.	▲	0
77	*Pohlia cruda*	■	1	.	.	.	.	■	0	.	.	.	.
78	!!*Pohlia obtusifolia*	.	.	.	.	.	.	■	1-cfr.	.	.	■	0
79	!!*Ptychodium plicatum*	▲	2	■	0	.	.	.	.	.	.	.	.
80	*Rhabdoweisia fugax*	■	2	■	0	.	.	■	0	.	.	.	.
81	!!*Rhytidium rugosum*	▲	1	.	.	.	.	■	0	■	0	.	.
82	*Sphagnum compactum* P	.	.	.	.	.	.	■	3	■	0	■	2
83	*Sphagnum subsecundum* P	.	.	.	.	.	.	■	0	■	1	.	.
84	*Sphagnum teres* P	■	0	■	0	■	0	■	0	▲	1	.	.
85	*Splachnum sphaericum* P, TE	■	0	■	0	.	.	▲	0	.	.	.	1
86	*Tayloria serrata* P, TI	▲	0	■	0	■	0	▲	1	.	.	.	.
87	*Tortella tortuosa*	■	2	■	0	.	.	■	0	.	.	.	.
88	*Warnstorfia exannulata*	■	1	■	0	.	.	▲	7	.	.	▲	0
	Re-found only in some of the historical localities but reported from new sites												
89	*Amphidium mougeotii*	■	2	.	1	.	.	■	0	▲	0	.	.
90	*Bartramia ityphylla*	▲	3	▲	0	.	2	■	0	.	2	.	.
91	*Brachytheciastrum velutinum*	.	.	■	0	.	.	.	2	.	1	■	1
92	*Buckiella undulata* P*	■	1	■	0	.	.	.	8	■	2	.	9
93	*Ceratodon purpureus*	■	0	■	1	.	1		A+1	.	A+1	.	A
94	*Codriophorus aquaticus*	▲	5	▲	5	.	1	■	5	■	0	.	4
95	*Heterocladium heteropterum*	▲	4	▲	0	■	0	.	1	.	.	■	2
96	*Hylocomium splendens* P*	■	20	■	10	■	0	.	18	.	7	.	19
97	*Plagiothecium nemorale*	.	.	■	0	▲	2	.	2	.	4	■	4
98	*Pohlia drummondi*	■	5	.	4	.	.	■	0	.	.	■	0
99	*Racomitrium lanuginosum*	▲	2	▲	4	■	1	▲	1	■	0	.	6
100	*Rhytidiadelphus triquetrus* P*	■	1	■	0	.	.	.	.	.	.	.	2
101	*Sphagnum capillifolium* P	■	2	■	0	■	2	.	3	.	.	.	.
102	*Sphagnum cuspidatum* P	.	.	.	.	.	.	■	1	■	0	.	1
103	*Sphagnum lindbergii* P, TV	■	0	■	0	.	.	■	1	.	1	■	2
104	*Sphagnum squarrosum* P*	■	4	■	0	■	5	.	14	1961	3	.	11
	Found only in the new cirques and not re-found in the historical localities												
105	!!*Arctoa fulvella*	.	1	■	0	.	.	.	.	.	.	.	.
106	*Aulacomnium palustre* P*	.	.	.	.	.	.	.	1	■	0	.	.
107	*Brachydontium trichodes* P, TR	.	.	■	0	.	.	.	1	.	.	■	0
108	*Rosulabryum capillare*	.	2	.	.	.	.	■	0	.	.	.	.
109	*Bucklandiella affinis*	.	.	■	0	.	.			▲	0	.	1
110	*Bucklandiella microcarpa*	▲	0	■	0	.	.	.	1981	.	.	.	1
111	*Dichodontium pellucidum*	.	1	.	.	.	.	■	0	.	.	■	0
112	*Dicranodontium uncinatum* TR	▲	0	▲	0	.	6	.	2	.	.	.	4
113	*Dryptodon hartmanii*	.	.	.	.	.	.	.	.	■	0	.	1
114	*Platyhypnidium riparioides*	▲	0	.	.	.	.	■	0	.	.	.	2
115	*Sciuro-hypnum plumosum*	.	4	.	.	.	.	■	0	■	0	■	0
116	*Tetraphis pellucida*	.	.	.	1	.	3	.	3	■	0	.	9
117	*Warnstorfia fluitans*	.	1	.	.	.	.	■	0	.	.	.	.
	Species reported in 1999-2009 for the first time												
1	°*Amblystegium serpens*	.	.	.	.	.	.	.	A	.	.	.	.
2	*Andreaea nivalis* P, TI	.	1	.	.	.	.	.	.	.	.	.	.
3	*Aulacomnium androgynum*	.	.	.	.	.	1	.	.	.	.	.	.
4	°*Brachythecium albicans*	.	.	.	.	.	.	.	1	.	2	.	1
5	*Brachythecium rivulare*	.	2	.	1	.	.	.	1	.	1	.	1
6	*Brachythecium rutabulum*	.	.	.	.	.	.	.	.	.	.	.	1
7	°*Brachythecium salebrosum*	.	5	.	1	.	1	.	6	.	5	.	4
8	°*Bryum argenteum*	.	1	.	.	.	.	.	A	.	.	.	.
9	°*Bryum pallescens*	.	.	.	.	.	.	.	A	.	A	.	A
10	*Bryum pseudotriquetrum*	.	2	.	1	.	.	.	2	.	1	.	2
11	*Buclandiella heterosticha*	.	.	.	.	.	.	.	.	.	.	.	3
12	°*Cirriphyllum piliferum*	.	2	.	.	.	.	1961	5	.	.	.	3
13	*Dicranoweisia cirrata*	.	.	.	.	.	.	.	.	.	.	.	1
14	*Didymodon rigidulus*	.	.	.	.	.	.	.	A	.	.	.	.
15	°*Ditrichum heteromallum*	.	.	.	1	.	.	.	4	.	.	.	4
16	°*Ditrichum zonatum*	.	1	.	.	.	.	.	.	.	.	.	.

	Name of species	MSn		WSn		CZ		MSt		WSt		L	
		1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009	1850-1945	1999-2009
17	*Dryptodon muehlenbeckii*	.	1	.	.	.	.			.	.	.	.
18	°*Encalypta streptocarpa*	.	.	.	.	.	.	.	A	.	.	.	.
19	°*Herzogiella seligeri*	.	.	.	.	.	.	.	4	.	2	.	.
20	°*Hypnum cupressiforme*	.	.	.	.	.	.	.	.	.	.	.	1
21	*Mnium hornum*	.	.	.	.	.	.	.	5	.	1	.	3
22	*Oncophorus virens*	.	.	.	.	.	.	.	1	.	.	.	.
23	°*Plagiomnium affine*	.	2	.	2			.	1	.	.	.	.
24	°*Plagiothecium laetum*	.	4	.	1	.	1	.	6	.	.	.	4
25	°*Plagiothecium platyphyllum*	.	1	.	.	.	.	.	.	.	1	.	1
26	°*Plagiothecium succulentum*	.	5	.	2	.	1	.	4	.	.	.	5
27	°*Polytrichastrum formosum*	.	1	.	5	.	2	.	1	.	.	.	3
28	°*Polytrichastrum longisetum*	.	2	.	.	.	3	.	.	.	.	.	.
29	*Polytrichum strictum* P*	.	1	.	.	.	.	.	.	.	2	.	4
30	*Rhizomnium magnifolium*	.	1	.	.	.	.	.	13	.	3	.	11
31	°*Rhynchostegium murale*	.	.	.	.	.	.	.	A	.	.	.	.
32	°*Rosulabryum laevifilum*	.	.	.	.	.	.	.	A	.	.	.	.
33	°*Sciuro-hypnum populeum*	.	.	.	.	.	.	.	.	.	.	.	1
34	*Sphagnum angustifolium* P	.	.	.	.	.	.	.	.	.	1	.	.
35	*Sphagnum fallax* P*	.	.	.	.	.	6	.	8	.	1	.	3
36	*Sphagnum flexuosum* P	.	.	.	.	.	.	.	.	.	1	.	.
37	°*Sphagnum fuscum* P, TV	.	.	.	.	.	.	.	.	.	1	.	.
38	*Sphagnum inundatum* P	.	.	.	.	.	.	.	1	.	1	.	1
39	°*Sphagnum palustre* P	.	.	.	.	.	.	.	.	.	1	.	2
40	°*Sphagnum riparium* P	.	.	.	.	.	.	.	2	.	1	.	1
41	°*Sphagnum russowii* P	.	.	.	.	.	.	.	16	.	8	.	17
42	°*Thuidium tamariscinum* P*	.	.	.	.	.	.	.	.	.	.	.	2
43	°*Tortula muralis*	.	.	.	.	.	.	.	A	.	.	.	.
44	°*Trichostomum tenuirostre*	.	4	.	1	.	.	.	.	.	.	.	.
	Species of questionable status (available historical specimens misidentified but contemporary found on anthropogenic sites)												
45	*Schistidium apocarpum*	■	0	.	.	.	.	.	A	.	.	.	.

Explanations: name of objects, MSn – Mały Śnieżny Kocioł, WSn – Wielki Śnieżny Kocioł, CZ – Czarny Kocioł, MSt – Kocioł Małego Stawu, WSt – Kocioł Wielkiego Stawu, L – Kocioł Łomniczki; ■ – taxa reported in the years given in the table heading, ▲ – species collected in the years given in the table heading and documented in the herbarium specimens revised, ▲? – specimen site description partly undecipherable so not certain, 0, 1, 2... – number of contemporary notes, A – anthropogenic site (mortar, concrete, slag), 1956, 1961 – the year of the species reports not included in the analysis of moss flora changes, cfr. – identification not certain; law protection status, P – species protected strictly by law, P* – species protected partly by law; threat categories in Poland, E– endangered, I – indeterminate, R – rare, V – vulnerable; * – species refound in glacial cirques situated on the Czech side of Karkonosze Mts, ! – species not refound, including glacial cirques situated on the Czech side of Karkonosze Mts, !! – species defined as probably extinct on the Czech side of Karkonosze Mts, ° – species reported for the first time in the beginning of the 21th century in the glacial cirques on the Czech side of Karkonosze Mts.