Roczniki Akademii Rolniczej w Poznaniu CCCXCI

Botanika – Steciana

16, 2012, 81-92

www.up.poznan.pl/steciana

ISSN 1896-1908

ECOLOGICAL ASSESSMENT OF THE CHANGES IN THE MOSS FLORA OF THE GLACIAL CIRQUES IN THE POLISH KARKONOSZE MTS DURING XX CENTURY

Ewa Fudali

E. Fudali, Department of Botany and Plant Ecology, Wrocław University of Environmental and Life Sciences, pl. Grunwaldzki 24 A, 50-363 Wrocław, Poland, e-mail: ewa.fudali@gmail.com

(Received: January 16, 2012. Accepted: May 14, 2012)

ABSTRACT. Ecological characters of moss species noted in glacial cirques situated in the Polish part of the Karkonosze Mts in two periods: on the turn of the 19th century and first decade of the 21st century, were compared to find whether moss flora changed during the 20th century in a way which indicates environmental transformations in last 50 years. Analysis showed that the moss flora has changed considerably, both in floristic and ecological aspects. Regarding the latter the most spectacular changes refer to species' habitat reaction demands (most of basophytes and subneutrophytes vanished and new acidophytic species appeared) and to substrata preferences (almost all former obligatory epiphytes disappeared and some acidophytic epiphytes spread, as well as the number of poly-substrata species increased markedly). These results correspond to sozological data documenting high deposition of sulphur dioxide and acid rains in the Karkonosze Mts in 1970-1980. Responses of mosses to significantly higher nitrogen deposition in the second half of the 20th, as well as to warming were not evident.

KEY WORDS: mountain mosses changes, acidification effect, warming effect, epiphytes, Karkonosze Mts, Sudetes

INTRODUCTION

During the 20th century the natural environment of the Karkonosze Mts, protected as a National Park since 1969, changed visibly. This mountain range has suffered huge ecological disasters in 1970-1980 due to long-distance atmospheric pollution from power stations located nearby and resulted in acidification and nitrification of habitats (Kmieć et al. 1994, Dunajski 2007). What more, meteorological data analysed by Głowicki (2009) have proved that an average annual air temperature on the Śnieżka Mt rose by about 1°C in the period of 1959-2008 while an average monthly temperature for January by 2.5°C. Additionally, this mountain range has been visited intensively by tourists since the first decades of the 20th century (Staffa 1993, Symonides 2007). Mosses are thought to be plants which react rapidly to environmental changes, both concerning chemical composition and climatic fluctuations, by disappearance or change in their geographical distribution (Rao 1982, Winner 1988, Agneta and Burton 1990, Frahm and Klaus 2001, Gignac 2001). Bryological surveys in the Karkonosze Mts were done nearly continuously since the end of the 18th century what was summarized by Limpricht (1867, 1876, 1890, 1895) and Milde (1861, 1867, 1869). The most data were collected then from the glacial cirques and the slopes and summit of the Śnieżka Mt, the highest top in the range (Wilczyńska 1996). Later bryo-floristic exploration was rather fragmentary (Wilczyńska 1996, Fudali 2001) therefore mosses response to the environmental changes during the 20th century in the summit region of the Karkonosze Mts has been weakly recognised (Fabiszewski and Wojtuń 2001, Fudali 2003, 2007, 2010 b, c).

The author has raised a following question: has moss flora of the Karkonosze Mts glacial cirques changed during the 20th century in such a way which confirms environmental changes in last 50 years? Looking for the answer the bryo-floristical data known from the Karkonosze Mts glacial cirques situated in the Polish part of the range on the turn of the 19th century and the first decade of the 21st (collected by the author in the field) were compared to select the groups of species not found at present, those which survived the period studied and reported for the first time in the years 1999-2009. The lists obtained were analysed regarding various aspects: percentage incidence of bry-chorological groups (Fudali 2011 b) and the general ecological demands of the species. The paper presents results of the latter analyzes.

MATERIALS AND METHODS

Changes in the moss flora of the glacial cirques have been assessed comparing bryophyte data compiled from all available historical papers published (Limpricht 1867, 1876, 1890, 1895, Milde 1861, 1867, 1869) with

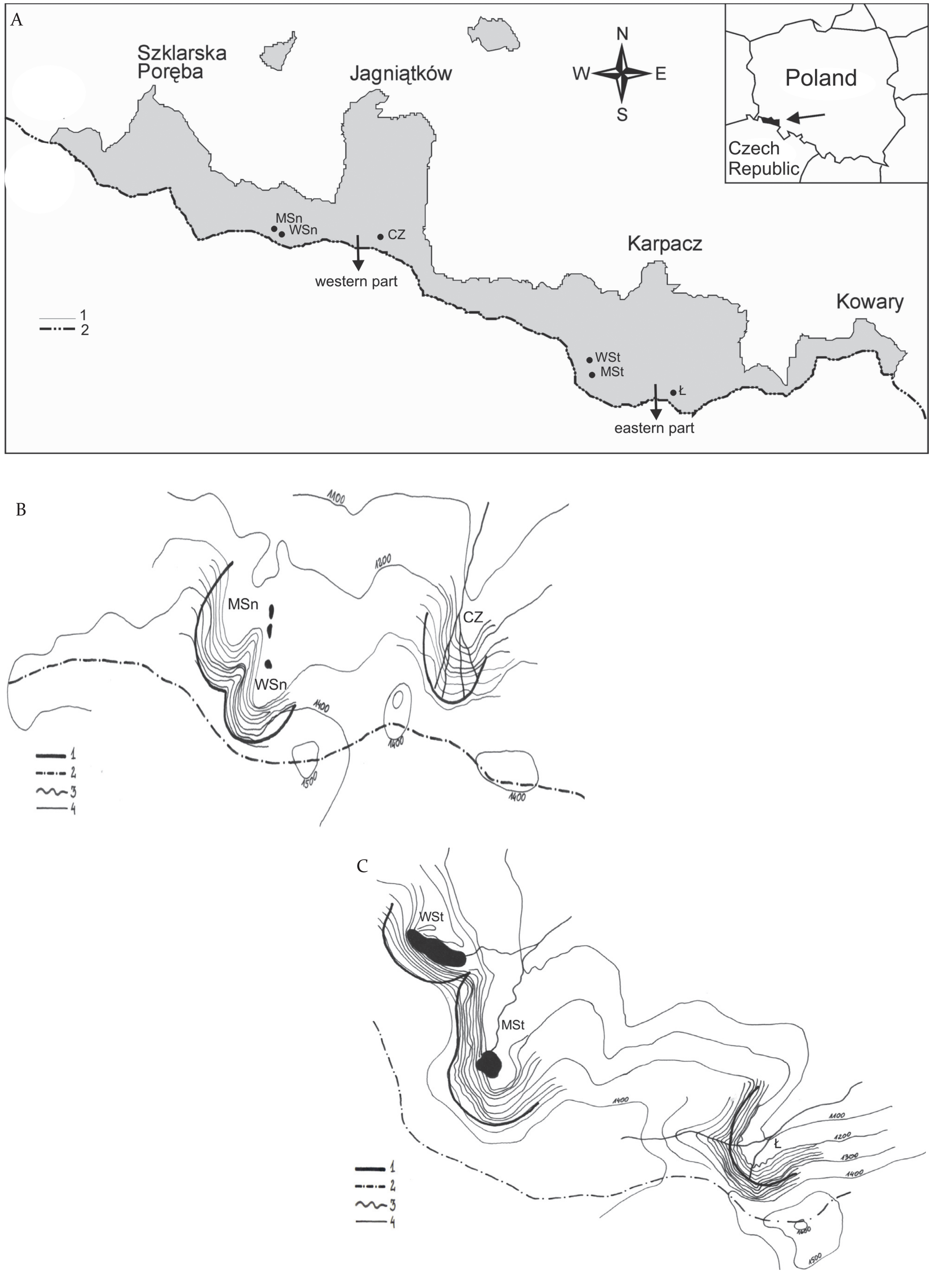

Fig. 1. General view of the studied glacial cirques location in the Karkonosze Mts range (1A) and detailed maps of their situation in the western part (1B) and eastern part (1C) of the range

Explanations: CZ – Czarny Kocioł, Ł – Kocioł Łomniczki, MSn – Mały Śnieżny Kocioł, MSt – Kocioł Małego Stawu, WSn – Wielki Śnieżny Kocioł, WSt – Kocioł Wielkiego Stawu; Fig. 1A: 1 – borders of Karkonosze National Park, 2 – state borders; Fig. 1B and 1C: 1 – upper edges of glacial cirques, 2 – state border, 3 – streams and rivers, 4 – hypsometric lines.

a list resulting from the author's field studies carried out in the years 2000-2009 (Fudali 2004, 2007, 2010 a, c, 2011 a, Fudali et al. 2003, Fudali and Kučera 2003) on a basis of presence-absence criterion. In that comparison all studied objects were taken as a whole.

Additionally, the list of historical published data was completed by the results of herbarium specimens revision done both by the author (136 specimens of mosses picked up in the glacial cirques in the 19th century and in the first half of the 20th from the collections of the Herbarium of the Wrocław University [WRSL] and the Herbarium of the Hungarian Natural History Museum [BP]: Fudali 2012 – in press) and by others. The latter were published in numerous bryo-chorological and taxonomical papers (49 specimens: Ochyra et al. 1985, 1990 a-f, 1992 a-d, Szmajda et al. 1991 a, b, Bednarek-Ochyra et al. 1990 a-e, 1994, Bednarek-Ochyra 1995, Blom 1996, Kučera and Fudali 2004, Wojtuń 2006). Some data concerning contemporary stations of *Sphagnum* sp. were included from Wojtuń (2006). Collection of moss specimens gathered during field research by the author was deposited in the Herbarium of the W. Szafer Institute of Botany of Polish Academy of Sciences [KRAM-B].

General ecological demands of all analysed species in relation to temperature, light, substrate types, reaction and humidity were defined following Dierssen's (2001) characterisation of the European bryophytes ecological amplitudes. Application of the species's descriptive ecological characterisation which refers to full spectrum of life conditions of the species in Europe and not exclusively to their ecological amplitudes in the Karkonosze Mts makes this analysis approximate. In relation to species found contemporarily, their substratum preferences were specified on a base of observation in the field. Nomenclature of mosses follows Ochyra et al. (2003) with exception of *Rosulabryum moravicum* (Podp.) Ochyra & Stebel (= *R. laevifilum* (Syed) Ochyra).

CHARACTERISTICS OF OBJECTS STUDIED

The range of the Karkonosze Mts, situated on the boundary of Poland and the Czech Republic, is the highest range in the Sudetes which belong to the old middle European mountains, the so-called Hercynians. Their geology is various but granitoids prevail (Staffa 1993). The altitudinal span reaches from 727 to 1602 m a.s.l. in the Polish area but the elevation of the main massif seldom exceeds 1450 m a.s.l.

Post-glacial cirques in the Karkonosze Mts resulted from erosion activity of local mountain glacier which occurred in Pleistocene. In the northern, Polish part there are six objects situated in the summit zone (Fig. 1 A) which form two separated groups: western (3 objects; Fig. 1 B) and eastern (three objects; Fig. 1 C) differing in altitudinal span, geological structure, geomorphological forms, hydrological conditions and vegetation. They differ also in an intensity of tourist impact (Table 1). According to the anemo-orographic theory formulated by Jeník (1997) the glacial cirques of the Karkonosze Mts differ from the plane of summit region in climatic conditions. By this author the specific topography, georelief and uneven distribution of snowpack due to wind action make them similar to arctic or alpine objects in spite of rather low altitudes. However, they lack perennial snow and permafrost.

RESULTS AND DISCUSSION

1. General remarks of changes in the species richness and composition

Historical data mentioned above concern the 183 moss species (184 taxa including two subspecies of *Bucklandiella macounii*) occurring in the studied glacial cirques until 1945. The identity of four species (*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 (Fudali 2012 – in press). Therefore, they were excluded from the further ecological analyses of the historical data.

At the beginning of the 21st century the occurrence of 161 moss species was documented including 10 species collected only from anthropogenic sites, as concrete and mortar and soil mixed with slag around the Samotnia mountain chalet (Fudali 2007). So, the species richness showed a slight decrease.

The comparison of bryo-floristic lists from both periods revealed that species composition of moss flora occurring in the glacial cirques has changed considerably: among 228 moss taxa reported altogether from the glacial cirques studied (including doubtful species quoted above) only 113 occurred both in the 19th and the 21st centuries. 48 species were noted for the first time in the beginning of the 21st century while 67 taxa were not refound (see: Appendix). Some of the persistent species were presently found mainly in the same objects as in the past, some of them were noted nowadays additionally in other cirques and some were not refound in the cirques, in which they were observed in the 19th century but recorded in others (Appendix).

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

Especially the list of species reported for the first time from the glacial cirques studied brings some doubts. Only seven of them are new for the Karkonosze Mts, the rest occurred in this mountain range just in the past (Wilczyńska 1996). This fact leads to a question whether they were present in the glacial cirques in the 19th century and omitted by the researchers or spread in the 20th century? Four of them (*Ceratodon purpureus*, *Dicranum scoparium*, *Pleurozium schreberi*, *Polytrichum piliferum*) were found around two glacial cirques and described as common (Limpricht 1867). It is very probable that they were also present within these cirques and therefore they have been incorporated to the group of persistent species, what makes their ultimate number of taxa equal 117 (51.3% – Fig. 2).

According to Wilczyńska (1996) the eight species of "newcomers" (*Mnium hornum*, *Brachythecium rutabulum*, *Bryum pseudotriquetrum*, *Plagiomnium*

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, at 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 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 at 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 built of boulders across the western wall and along the bottom; motor road at the bottom; wooden mountain chalet with stony wall (mortar) at the bottom	ground path along the edge of southern wall; ruins of old mountain chalet	road built of boulders (enforced with concrete) across the southern wall and along the bottom; mountain chalet situated nearby the southern edge

Explanation of symbols: type of vegetation (plant communities recognized according to MATUSZKIEWICZ and MATUSZKIEWICZ (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 alliariae* community, HT – tall herbs of *Aconitetum plicatae*, M – *Pinetum mughii sudeticum*, MA – tall grasslands *Molinio-Agrostietum*, MC – spring community of *Cardamino-Montion* alliance, P – spruce forest of *Piceetum hercynicum*, V – blueberry aggregations, probably depauperated form of *Empetro-Vaccinietum*.

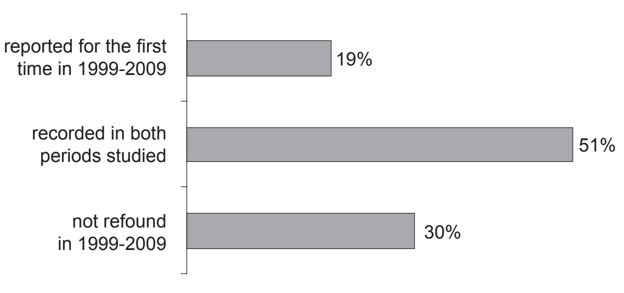

FIG. 2. Percentage estimation of changes in the moss flora species composition during the 20th century

affine, *Polytrichastrum formosum*, *Cirriphyllum piliferum*, *Herzogiella seligeri* and *Thuidium tamariscinum*) were reported in the 19th century only below 1000 m a.s.l. while presently they have been found higher, at least 1110 m a.s.l., but always on singular sites. So they could have been absent in the glacial cirques studied in the past.

The group of newcomers contains also eight species of the genus *Sphagnum*, three species of *Polytrichum* and four species of *Plagiothecium*. Some of these species occurred probably earlier in the glacial cirques and they were overlooked as the methods of the 19th century researchers were less detailed. Two of the peat moss species reported for the first time, *Sphagnum fallax* and S. *russowii*, which occurred quite abundantly in the eastern glacial cirques (Fudali 2010 a, c, 2011 a) were described as frequent in the subalpine bogs of the Karkonosze Mts by Tołpa (1949).

The historical data were published by such prominent bryologists as J. Milde and K.G. Limpricht but during the 20th century a taxonomical approach to many taxa changed (Ochyra et al. 2003) and revision of all old specimens collected in the studied objects and recognised as critical taxa would be necessary to make a historical list complete. This remark refers especially to the numerous species of *Schistidum apocarpum* complex described in 1996 by Blom (in: Ochyra et al. 2003). Unfortunately, only a part of the specimens have been preserved. Thus one cannot reject such a possibility that a presented list of moss species occurring in the glacial cirques in the past is not entirely adequate and a list of real newcomers in there would be much shorter and the percentage of species exchange smaller. But as many of historical specimens were damaged during the WWII and they could not be revised, there is no scientific ground to make changes in the lists described in spite of the doubts discussed above.

2. Quantitative changes within ecological groups of mosses

Substratum reaction demands

Comparison of number of species representing particular ecological groups in historical and present-day moss flora (Table 2) shows similar share of stenobionts (60; 57%) but visible shift in percentage incidence of obligatory acidophytes which definitely increased (from 40% to 48%), as well as obligatory subneutrophytes which decreased (from 13% to 6%), so did obligatory basophytes (from 4% to 1%). Also among species of wide amplitude of site's reaction the highest increase showed those which could tolerate highly acidophytic conditions (from 16% to 21%). During the 20th century disappeared 71% of subneutrophytes and basophytes noted in the 19th century, as well as 47% species of wider amplitude of site's reaction from moderate acidophytic to subneutral or basic.

Table 2. Comparison of taxa number in both periods studied in relation to the ecological groups defined according to species ecological demands

Ecological groups	Noted up to 1945 in total	Not re-found in 1999-2009	Noted in the both periods studied	Noted for the first time in 1999-2009	Noted in 1999-2009 in total
	179*	62*	117	44	161
	Number of taxa				
1	2	3	4	5	6
General substratum reaction demands					
STENOBIONTS:					
Acidophytes [ac.]:	71	13	58	20	78
highly and considerably acidic [h, c ac.]	25	5	20	5	25
moderately acidic [m ac.]	13	3	10	2	12
highly to moderately acidic [h-m ac.]	33	5	28	13	41
Subneutrophytes [sub.]	24	17	7	2	9
Basophytes [bas.]	7	5	2	0	2
[sub. – bas.]	6	5	1	2	3
In total stenobionts	108	40	68	24	92
EURYBIONTS:					
[h, c ac. – sub.]	26	2	24	8	32
[m ac. – sub.]	38	19	19	8	27
[c-m ac. – sub.]	2	0	2	0	2
[m ac. – bas.]	5	1	4	2	6
[c ac. – bas.]	0	0	0	2	2
In total eurybionts	71	23	49	20	69

Table 2 – cont.

1	2	3	4	5	6
Approximate requirements in relation to temperature					
STENOBIONTS:					
Cryophytes [cryo.]:	45	16	29	2	31
highly and considerably cryophytic [h, c cryo.]	14	7	7	0	7
moderately cryophytic [m cryo.]	23	7	16	1	17
highly to moderately cryophytic [h, c-m cryo.]	8	2	6	1	7
Mesothermophytes [mesother.]	27	12	15	9	24
Thermophytes [thermo.]	4	1	3	0	3
moderately termophytic [m thermo.]	3	1	2	0	2
considerably termophytic [c thermo.]	1	0	1	0	1
In total stenobionts	76	29	47	11	58
EURYBIONTS:					
[h-c cryo. – c thermo.]	9	0	9	1	10
[h-c cryo. – m thermo.]	3	0	3	1	4
[m cryo. – c thermo]	7	4	3	5	8
[m cryo. – m thermo.]	6	1	5	3	8
[c cryo. – mesother.]	9	3	6	1	7
[m cryo. – mesother.]	28	9	19	5	24
[mesother. – m thermo.]	11	6	5	2	7
[mesother. – c thermo.]	2	1	1	2	3
In total eurybionts:	75	24	51	20	71
indifferent to temperatures	1	1	0	2	2
undetermined temperature requirements	27	8	19	11	30
General light requirements					
STENOBIONTS:					
Heliophytes [phot.]:	73	28	45	12	57
highly and considerably photophytic [h c phot.]	55	21	34	11	45
moderately photophytic [m phot.]	4	1	3	1	4
highly to moderately photophytic [h, c-m phot.]	14	6	8	0	8
Sciophytes [scio.]:	28	13	15	7	22
highly and considerably sciophytic [h, c scio.]	11	4	4	2	6
moderately sciophytic [m scio.]	13	9	4	2	6
highly to moderately sciophytic [h, c-m scio.]	4	0	7	3	10
In total stenobionts	101	41	60	19	79
EURYBIONTS:					
[c scio – c, h phot.]	6	1	5	0	5
[h, c scio – m phot.]	21	7	14	4	18
[m scio – c, h phot.]	29	6	23	13	36
[m scio – m phot.]	21	7	14	8	22
In total eurybionts:	77	21	56	25	81
undetermined light requirements	1	0	1	0	1

Table 2 – cont.

1	2	3	4	5	6
General moisture requirements					
STENOBIONTS:					
Aquatic	21	7	14	2	16
Hygrophytes [hygro.]:	49	17	32	15	47
highly and considerably wet sites [h, c hygro.]	20	9	11	5	16
moderately wet sites [m hygro.]	17	7	10	6	16
highly to moderately wet sites [h – m hygro.]	12	1	11	4	15
Mesophytes [meso.]	70	26	44	18	62
Xerophytes [xer.]:	10	4	6	2	8
considerably dry sites [c xer.]	3	2	1	1	2
moderately dry sites [m xer.]	4	2	2	1	3
Moderately to highly dry sites [m – h xer.]	3	0	3	0	3
In total stenobionts	150	54	96	37	133
EURYBIONTS:					
[c hygro. – meso.]	6	1	5	0	5
[meso. – c xer.]	7	1	6	5	11
[m hygro. – m xer.]	12	5	7	1	8
[h hygro. – m xer.]	4	1	3	1	4
In total eurybionts	29	8	21	7	28
Substratum preferences					
Only one type of substratum	132	53	79	28	107
Bi-substrata species	36	6	30	8	38
Poly-substrata species	11	3	8	8	16
Type of substratum:					
rocks and boulders: exclusively (facultatively)	51 (34)	22 (6)	29 (26)	5 (14)	34 (40)
raw humus covering rocks or soil	26 (13)	12 (9)	14 (7)	0 (11)	14 (16)
bark of living trees	8 (14)	8 (7)	0	1 (5)	1 (12)
rotten wood	3 (23)	2 (7)	1 (26)	3 (17)	4 (38)
peat	14 (4)	2	12 (3)	9	21 (3)
gravel	7	0	7	0	7
mineral initial soil	17 (14)	4 (2)	13 (15)	4 (17)	17 (27)
animal dungs and bones	5	3	2	0	2
concrete or mortar	1	0	1	6 (1)	7 (1)

Explanations: * – without four species of doubtful identity (see: Appendix).

Most of the species noted for the first time represented acidophytes (46%) or eurybionts which can survive in sites of reaction from highly or moderate acid to subneutral (36%).

In the group of persistent species, noted nowadays in a bigger number of glacial cirques than in the past, 27% are considerably acidophilous, 46% highly to moderate acidophilous and 27% eurybionts. Among nine persistent species related to basophytic or subneutral habitat's reaction five (55%) were refound in a smaller number of glacial cirques than in the past and only four (45%) kept their historical stations.

These results correspond with sozological data documenting high deposition of sulphur dioxide and acid rains in the Karkonosze Mts in 1970 -1980 (Kmieć et al. 1994). Acid rains cause changes in the substratum reaction (pH) (Park 1987).

Temperature requirements

As already mentioned ecological requirements concerning temperature used in this paper should be regarded as approximate (Dierssen 2001). The comparison of species number representing particular ecological "thermal" groups (Table 2) shows a clear decrease of the cryophytes number and share (from 25% to 19%). 16 species (36%) of cryophytes noted in the 19th century disappeared during the 20th century, among them half of the highly or considerably cryophytic species and 30% of moderate cryophytes, which might be related with slight increase of average January temperature in the second half of the 20th century reported from the summits of Karkonosze Mts (Głowicki 2009). However 29 species (64%) of cryophytes reported in the 19th century have survived. Analysis of substratum reaction requirements of the not refound cryophytes shows that four of them were subneutrophytes and six preferred moderately acid to subneutral sites. So their disappearance might be attributed as well to the results of acidification. Also dynamic changes observed within a group of mesothermophytes (58% of species exchange) suggest influence of other than warming environmental factors.

Light requirements

The comparison of species number representing particular ecological groups (Table 2) shows a slight decrease in the number and share of photo-stenobionts (from 56% to 49%) and increase of eurybionts tolerating conditions from moderate shadow to open light [m scio – h, c, m photo] (from 28% to 36%). These changes probably have a natural character resulting from a very slow ecological succession disturbed by avalanches (snowy, muddy or stony) action, often occurring in the glacial cirques.

Moisture requirements

Both historical and present-day moss flora has shown high specialization in its moisture demands and high similarity in percentage incidence of the moisture ecological groups (Table 2). Among species tolerating periodical change of water supply a slight tendency to increase in a number of species tolerating more dry sites appeared. Among seven not refound aquatic species one was basophyte and others were moderate acidophytes or eurybionts. So, there is no clear evidence that acid rains were the reason for their disappearance.

Substrata preferences

In the studied glacial cirques mosses were reported from nine substratum types (Table 2). During the 20th century the number and share of species growing on one type of substratum decreased (from 74% to 66%), especially of epilithic, humicolous and coprophytic species. Disappeared also all obligatory epiphytes. There are more poly-substratum species in the present-day moss flora. A decrease of the specialized species is generally considered as indicator of the human impact intensification (Fojcik 2011, Kornaś and Medwecka--Kornaś 2003, Pullin 2004).

Among 51 epilithic species noted in the past disappeared 20% of acidophytes, 53% of basophytic or/and subneutral species and 48% of mosses tolerating broader reaction amplitude while species noted for the first time were either acidophytes or eurybionts. None new basophytic or subneutral species was reported what seems to be mosses response to habitat's acidification, similarly as disappearance of epiphytes.

It is striking that also on the Czech side almost all epiphytes reported in the 19th century were not refound in the 21st century (Kučera and Buryová 1999, Kučera et al. 2004 a, b). Epiphytes are known to be the most sensible to sulphur dioxide effect among the mosses and they vanish from polluted areas (Rao 1982, Winner 1988). In 1970-1980 Karkonosze Mts suffered huge atmospheric pollutions (Kmieć et al. 1994) so epiphytes could disappear as a result of sulphur dioxide or acid rain influence.

It is also highly probable that acidification due to the acid rains caused spreading of some acidophilous epiphytic mosses as *Orthodicranum montanum* or *Dicranoweisia cirrata* in the glacial cirques. In the past *Orthodicranum montanum* was recorded only in two objects while nowadays it bas been reported from all the glacial cirques (Fudali 2011 b). *Dicranoweisia cirrata* was not reported from Karkonosze Mts before 2008 (Fudali 2001, 2010 a). According to Greven (1992) and Söderström (1992) these species have being spread due to acidification. In the last years an increase of the number of these acidophilous epiphytes stations was observed in Beskidy Zachodnie mountains (Stebel 2006) and in the Cracow-Częstochowa Upland (Fojcik 2011).

Decrease of coprophytic and humicolous species, which distribution is limited by substratum availability, could have natural character.

In the 21st century the number of species recorded on peat increased visibly, especially in genus *Sphagnum*, probably as result of more detailed method of field research and of changes in taxonomical approach to this group of mosses (Ochyra et al. 2003, Wojtuń 2006). Also a number of species colonizing concrete and mortar, used for tourist roads' reinforcement, increased (Table 2) but they occurred sporadically or very rarely.

Relation to habitats' nitrification

Response of mosses to significantly higher nitrogen deposition in the second half of 20th century (Kmieć et al. 1994) seems to be not clear. There were only two taxa considered to be anitrophytes (Dierssen 2001) among species not refound but within the group of species reported nowadays there were 19 taxa classified by Dierssen (2001) as nitrophytic. 11 of them were noted for the first time in the glacial cirques but most of them were found sporadically or very rarely (see: Appendix).

CONCLUSIONS

1. Basing on the comparison done it seems that moss flora in the glacial cirques of Karkonosze Mts has changed considerably during the 20th century, both in

floristic and ecological aspects. Regarding the latter the most spectacular changes refer to species' habitat reaction demands (most of basophytes and subneutrophytes vanished and new acidophytic species appeared; some acidophytes, persistent during the 20th century, widespread) and to substrata preferences (almost all former obligatory epiphytes disappeared but some acidophytic epiphytes spread and a number of poly-substrata species increased markedly). These results correspond to sozological data documenting high deposition of sulphur dioxide and acid rains in the Karkonosze Mts in 1970-1980. Responses of mosses to significantly higher nitrogen deposition in the second half of the 20th century, as well as to warming in January were not evident.

2. Historical data drawn from literature should be given for bryo-floristic comparisons with care as they could be incomplete.

REFERENCES

Agneta M., Burton S. (1990): Terrestrial and aquatic bryophytes as monitors of environmental contaminants in urban and industrial habitats. Bot. J. Linn. Soc. 104: 267-280.

Bednarek-Ochyra H. (1995): Rodzaj Racomitrium (Musci, Grimmiaceae) w Polsce: taksonomia, ekologia i fitogeografia. Fragm. Florist. Geobot. Pol. 2.

Bednarek-Ochyra H., Ochyra R., Szmajda P. (1990 a): M. 269. Racomitrium affine (Schleich. ex Weber & Mohr) Lindb. In: Atlas of the geographical distribution of spore plants in Poland, Ser. V. Mosses (Musci), 6. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 21-23.

Bednarek-Ochyra H., Ochyra R., Szmajda P. (1990 b): M. 270. *Racomitrium microcarpon* (Hedw.) Brid. In: Atlas of the geographical distribution of spore plants in Poland, Ser. V. Mosses (Musci), 6. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 25-30.

Bednarek-Ochyra H., Ochyra R., Szmajda P. (1990 c): M. 665. *Racomitrium sudeticum* (Funck) Bruch & Schimp. In: Atlas of the geographical distribution of spore plants in Poland, Ser. V. Mosses (Musci), 6. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 41-46.

Bednarek-Ochyra H., Ochyra R., Szmajda P. (1990 d): M. 666a. *Racomitrium macounii* subsp. *macounii* Kindb. In: Atlas of the geographical distribution of spore plants in Poland, Ser. V. Mosses (Musci), 6. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 47-48.

Bednarek-Ochyra H., Ochyra R., Szmajda P. (1990 e): M. 666b. *Racomitrium macounii* subsp. *alpinum* (Lawton) Frisvoll. In: Atlas of the geographical distribution of spore plants in Poland, Ser. V. Mosses (Musci), 6. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 49-50.

Bednarek-Ochyra H., Ochyra R., Szmajda P. (1994): M. 632. *Rhytidiadelphus loreus* (Hedw.) Warnst. In: Atlas of the geographical distribution of spore plants in Poland, Ser. V. Mosses (Musci), 9. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 47-48.

Blom (1996): A revision of the Schistidium apocarpum complex in Norway and Sweden. Bryophytorum Bibl. 49.

Dierssen K. (2001): Distribution, ecological amplitude and phytosociological characterization of European bryophytes. Bryophytorum Bibl. 56.

Dunajski A. (2007): Status dynamiczny zbiorowisk leśnych Karkonoszy przed i po wielkoobszarowym zamieraniu drzewostanów świerkowych. Stud. Nat. 54, 2: 67-80.

Fabiszewski J., Wojtuń B. (2001): Contemporary floristic changes in the Karkonosze Mts. Acta Soc. Bot. Pol. 70, 3: 237-245.

Fojcik B. (2011): Mchy Wyżyny Krakowsko-Częstochowskiej w obliczu antropogenicznych przemian szaty roślinnej. Pr. Nauk. Uniw. Śl. Katow. 2800.

Frahm J.P., Klaus D. (2001): Bryophytes as indicators of recent climate fluctuations in Central Europe. Lindbergia 26: 74-104.

Fudali E. (2001): Element alpejski i subalpejski we florze mchów polodowcowych kotłów polskiej części Karkonoszy. Ann. Siles. 31: 89-98.

Fudali E. (2003): Zmiany we florze mchów Śnieżnych Kotłów w latach 1930-2002. Ann. Siles. 32: 19-32.

Fudali E. (2004): Mchy Czarnego Kotła. Ann. Siles. 33: 43-50.

Fudali E. (2007): Human traces in the bryophyte flora of the summit region of Karkonosze Mts (polish side). Acta Soc. Bot. Pol. 76, 4: 345-349.

Fudali E. (2010 a): Mosses of Kocioł Łomniczki glacial cirque (Karkonosze Mts) in relation to ecological and phytocoenotical diversity of habitats. Rocz. AR Pozn. 389, Bot. Stec. 14: 11-17.

Fudali E. (2010 b): Mosses of the Kocioł Mały Staw glacial cirque (Karkosze Mts) and their supposed response to tourism impact in the 20th century. Acta Bot. Siles. 5: 111-130.

Fudali E. (2010 c): Zmiany we florze mchów Kotła Łomniczki (Karkonosze) w latach 1869-2008. Przyr. Sudetów 13: 17-26.

Fudali E. (2011 a): Bryo-chorological analysis of the changes in the moss flora of Karkonosze glacial cirques during XX century. Rocz. AR Pozn. 390, Bot. Stec. 15: 105-121.

Fudali E. (2011 b): Materiały do flory mchów Kotła Wielkiego Stawu w Karkonoszach. Przyr. Sudetów 14: 7-16.

Fudali E. (2012): Moss species diversity in the glacial cirques of Polish Karkonosze Mts and its changes during XX century. Biodiv. Res. Cons. (in press).

Fudali E., Kučera J. (2003): Bryogeographical elements of moss flora in glacial cirques "Śnieżne Kotły" (Karkonosze Mts) and their threat. Acta Soc. Bot. Pol. 72, 1: 79-85.

Fudali E., Stebel A., Rusińska A., Klama H., Żarnowiec J., Pisarek W., Duda-Klimaszewski S., Staniaszek M., Wierzcholska S. (2003): Materiały do brioflory wschodnich Karkonoszy. Ann. Siles. 32: 33-41.

Gignac L.D. (2001): Bryophytes as indicators of climate change. Bryologist 104, 3: 410-420.

Głowicki B. (2009): Extreme meteorological phenomena in the Karkonosze Mts in a period of 1959-2008. In: Book of abstracts of the 7th International Conference “Geoecological problems of the Karkonosze Mts”, Szklarska Poręba 21-23.09.2009. Eds R. Knapik, J. Andrle. Karkonoski Park Narodowy, Szklarska Poręba: 54-55.

Greven H.C. (1992): Changes in the Dutch bryophyte flora and air pollution. Dissert. Botan. 194. J. Cramer, Berlin.

Jeník J. (1997): Anemo-orographic systems in the Hercynian Mts and their effects on biodiversity. Acta Univ. Wratisl. 1950, Pr. Inst. Geogr. Ser. C Meteorol. Klimatol. 4: 9-21.

Kmieć G., Kacperczyk K., Zwoździak J., Zwoździak A. (1994): Ocena stężenia i rodzaju zanieczyszczeń w opadach atmosferycznych w rejonie Karkonoszy. In: Karkonoskie badania ekologiczne. Ed. Z. Fisher. II Konferencja Dziekanów Leśny, 17-19 stycznia 1994. Oficyna Wydawnicza IE PAN, Dziekanów Leśny.

Kornaś J., Medwecka-Kornaś A. (2003): Geografia roślin. Wyd. Naukowe PWN, Warszawa.

Kučera J., Buryová B. (1999): Bryofloristic survey of the summit region of the Eastern Giant Mts (Czech Republic). Opera Corcontica 36: 105-132.

Kučera J., Fudali E. (2004): *Encalypta microstoma* Bals.-Criv. & De Not. In: New national and regional bryophyte records, 8. Ed. T.L. Blockeel. J. Bryol. 25: 217-218.

Kučera J., Zmrhalová M., Buryová B., Košnar J., Plašek V., Váňa J. (2004 a): Bryoflora of the glacial cirques of the Western Krkonoše Mts. Čas. Slez. Muz. Opava (A), 53: 1-47.

Kučera J., Zmrhalová M., Buryová B., Plašek V., Váňa J. (2004 b): Bryoflora of the Úpská jáma cirque and adjacent localities of the Eastern Krkonoše Mts. Čas. Slez. Muz. Opava (A), 53: 143-173.

Limpricht K.G. (1867): Beitrag zur Bryologischen Kenntnis der grossen Schneegrube und der Kesselkoppe im Riesengebirge. Jahresber. Schles. Ges. Vaterl. Cult. 44: 139-146.

Limpricht K.G. (1876): Laubmoose. In: Kryptogamen-Flora von Schlesien. Ed. F. Cohn. J.U. Kern’s Verlag, Breslau.

Limpricht K.G. (1890): Die Laubmoose Deutschlands, Oesterreichs und der Schweiz. In: Dr L. Rabenhort’s Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz, 2 Aufl. 4(1): Bryinae (Stegocarpae [Acrocarpae, Pleurocarpae excl. Hynpnaceae]). E. Kummer, Leipzig.

Limpricht K.G. (1895): Die Laubmoose Deutschlands, Oesterreichs und der Schweiz. In: Dr L. Rabenhort’s Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz, 2 Aufl. 4(2): Sphagnaceae, Andreaceae, Archidiaceae, Bryinae (Cleistocarpae, Stegocarpae [Acrocarpae]. E. Kummer, Leipzig.

Matuszkiewicz W., Matuszkiewicz A. (1974): Mapa zbiorowisk roślinnych Karkonoskiego Parku Narodowego. Ochr. Przyr. 40: 45-112.

Milde J. (1861): Uebersicht über die schlesische Laubmoss-Flora. Bot. Zeitung 19.

Milde J. (1867): Botanische Mitteilungen aus dem Jahre 1866. Jahresber. Schles. Ges. Vaterl. Cult. 44: 108-139.

Milde J. (1869): Bryologia Silesiaca. Laubmoss-flora von Nord u. Mittel-Deutschland. A. Felix, Leipzig.

Ochyra R., Rusińska A., Szmajda P. (1985): M. 360. *Rhodobryum roseum* (Hedw.) Limpr. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 2. Eds Z. Tobolewski, T. Wojterski. PWN, Warszawa-Poznań: 15-20.

Ochyra R., Bednarek-Ochyra H., Szmajda P. (1990 a): M. 264. *Dryptodon patens* (Hedw.) Brid. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 5. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 11-13.

Ochyra R., Bednarek-Ochyra H., Szmajda P. (1990 b): M. 265. *Racomitrium aciculare* (Hedw.) Brid. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 5. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 15-18.

Ochyra R., Bednarek-Ochyra H., Szmajda P. (1990 c): M. 265. *Racomitrium aquaticum* (Brid. ex Schrad.) Brid. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 5. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 19-22.

Ochyra R., Bednarek-Ochyra H., Szmajda P. (1990 d): M. 267. *Racomitrium fasciculare* (Hedw.) Brid. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 5. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 23-27.

Ochyra R., Bednarek-Ochyra H., Szmajda P. (1990 e): M. 271. *Racomitrium lanuginosum* (Hedw.) Brid. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 5. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 29-33.

Ochyra R., Bednarek-Ochyra H., Szmajda P. (1990 f): M. 640. *Diphyscium foliosum* (Hedw.) Mohr. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 5. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 47-52.

Ochyra R., Szmajda P., Bednarek-Ochyra H. (1992 a): M. 393. *Bartramia ityphylla* Brid. In: Atlas of the geographical distribution of mosses in Poland 8. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 25-34.

Ochyra R., Szmajda P., Bednarek-Ochyra H. (1992 b): M. 395. *Bartramia halleriana* Hedw. In: Atlas of the geographical distribution of mosses in Poland 8. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 35-39.

Ochyra R., Szmajda P., Bednarek-Ochyra H. (1992 c): M. 600. *Herzogiella stratella* (Brid.) Iwats. In: Atlas of the geographical distribution of mosses in Poland 8. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 51-53.

Ochyra R., Szmajda P., Bednarek-Ochyra H. (1992 d): M. 635. *Hylocomiastrum pyrenaicum* (Spruce) Fleisch. In: Atlas of the geographical distribution of mosses in Poland 8. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 61-65.

Ochyra R., Żarnowiec J., Bednarek-Ochyra H. (2003): Census catalogue of Polish mosses. Polish Academy of Sciences, Institute of Botany, Kraków.

Park C.C. (1987): Acid rains. Rhetoric and reality. Menthnen, London-New York.

Pullin A.S. (2004): Biologiczne podstawy ochrony przyrody. Wyd. Nauk. PWN, Warszawa.

Rao D.N. (1982): Responses of bryophytes to air pollution. In: Bryophyte ecology. Ed. A.J.E. Smith. Chapmann & Hall, London-New York: 442-471.

Söderström L. (1992): Invasions and range expansions and contractions of bryophytes. In: Bryophytes and lichens in a changing environment. Ed. J.W. Bates, A.M. Farmer. Oxford University Press, Oxford: 131-158.

Staffa M. (1993): Słownik geografii turystycznej Sudetów, 3. Karkonosze. Wyd. PTTK „Kraj", Warszawa--Kraków.

Stebel A. (2006): The mosses of the Beskidy Zachodnie as a paradigm of biological and environmental changes in the flora of the Polish Western Carpathians. Medical University of Silesia in Katowice, Habilitation thesis 17.

Symonides E. (2007): Ochrona przyrody. Wyd. Uniwersytetu Warszawskiego, Warszawa.

Szmajda P., Bednarek-Ochyra H., Ochyra R. (1991 a): *Splachnum ampullaceum* Hedw. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 7. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 27-42.

Szmajda P., Bednarek-Ochyra H., Ochyra R. (1991 b): *Tayloria serrata* (Hedw.) Bruch & Schimp. In: Atlas of the geographical distribution of spore plants in Poland. Ser. V. Mosses (Musci), 7. Eds R. Ochyra, P. Szmajda. W. Szafer Institute of Botany of Polish Academy of Sciences, Adam Mickiewicz University, Kraków-Poznań: 7-11.

Tołpa S. (1949): Torfowiska Karkonoszy i Gór Izerskich. Rocz. Nauk Roln. 52: 1-69.

Wilczyńska W. (1996): Flora mchów Karkonoszy. Part 1 (dane historyczne do 1965 r.). Acta Univ. Wratisl. 1886, Pr. Bot. 70: 111-139.

Winner W.E. (1988): Responses of bryophytes to air pollution. In: Lichens, bryophytes and air quality. Bibl. Lichenol. 30: 141-173.

Wojtuń B. (2006): Peat mosses (*Sphagnaceae)* in mires of the Sudetes Mountains (SW Poland): a floristic and ecological study. Wyd. Akademii Rolniczej, Wrocław.

APPENDIX

Lists of moss species not refound in the years 1999--2009, reported for the first time in years 1999-2009 and reported in the both periods compared.

Explanations: (AN) – anitrophytic species, (EP) – epiphytic mosses, (EP-EL) – species occurring both on bark of living trees and rocks, (N) – nitrophytic species, (conc.) – collected from concrete; in bold – species not reported before 1999 from Polish side of the Karkonosze Mts.

Moss species not refound in 1999-2009

Amphidium lapponicum, *Anomodon rugelii* (EP), *Bartramia halleriana*, *Bryum muehlenbeckii*, *B. pallens*, *B. turbinatum*, *B. weigeli*, *Bucklandiella macounii* ssp. *macounii*, *Buxbaumia viridis*, *Calliergon trifarium*, *Campylium stellatum*, *Campylophyllum halleri*, *Campylopus flexuosus*, *Cirriphyllum crassinervium*, *Ctenidium molluscum*, *Dichelyma falcatum*, *Dichodontium flavescens*, *Dicranum elongatum*, *Diphyscium foliosum*, *Dryptodon patens*, *Ditrichum pusillum*, *Encalypta ciliata*, *E. microstoma*, *Fissidens dubius*, *Gymnostomum aeruginosum*, *Heterocladium dimorphum*, *Hookeria lucens*, *Hygrohypnum duriusculum*, *H. luridum*, *Hypnum pallescens* (EP), *Isopterygiopsis pulchella*, *Isothecium alopecuroides* (EP), *Kiaeria falcata*, *Leskeella nervosa* (EP), *Lescuraea mutabilis* (EP), *L. saxicola*, *Mnium spinulosum*, *Orthothecium intricatum*, *Orthotrichum pallens* (P, N), *O. rupestre*, *O. speciosum* (EP), *O. stramineum* (EP, N), *Palustriella decipiens*, *Pohlia elongata*, *Pseudobryum cinclidioides*, *Pteryginandrum filiforme* (EP-EL), *Ptilium crista-castrensis*, *Pylaisia polyantha* (EP), *Rhizomnium pseudopunctatum*, *Rosulabryum elegans*, *Saelania glaucescens*, *Schistidium agassizi*, *S. confertum*, *S. flexipile*, *S. rivulare*, *Serpoleskea subtilis* (EP, AN), *Splachnum ampullaceum*, *Tetraplodon angustatus*, *T. mnioides*, *Tomentyhypnum nitens*, *Ulota bruchii* (EP), *U. coarctata* (EP), *U. crispa* (EP), *U. drummondii* (EP).

– DOUBTFUL SPECIES (the specimens revised were misidentified): *Bryum schleicheri* var. *latifolium* (= *Pohlia ludwigii*), *Hygrohypnum molle* (= *H. duriusculum*), *Plagiothecium ruthei* (= *P. cavifolium* mixed with *Sciuro-hypnum starkei*), *Schistidium apocarpum* (specimen described as *Grimmia apocarpa* = *Schistidium agassizi*; described as *Grimmia apocarpa* (Linné) var. *rufula* = *Schistidium flexipile*).

Moss species reported in 1999-2009 from the cirques for the first time

Andreaea nivalis, *Amblystegium serpens* (N), ***Aulacomnium androgynum*** (N), *Brachythecium albicans* (AN), *B. rivulare* (N), *B. rutabulum* (N), *B. salebrosum*, *Bryum argenteum* (N), *B. pallescens* (N), *B. pseudotriquetrum*, *Bucklandiella heterosticha*, *Cirriphyllum piliferum*,

Dicranoweisia cirrata (EP, N), *Didymodon rigidulus* (conc.) *Ditrichum heteromallum*, *D. zonatum*, *Encalypta streptocarpa* (conc.), *Dryptodon muehlenbeckii*, *Herzogiella seligeri*, *Hypnum cupressiforme*, *Mnium hornum*, *Oncophorus virens*, *Trichostomum tenuirostre*, *Plagiomnium affine*, *Plagiothecium laetum* (N), ***Plagiothecium platyphyllum***, ***Plagiothecium succulentum***, *Polytrichastrum formosum*, *P. longisetum* (N), *Polytrichum strictum*, ***Rhizomnium magnifolium***, *Rhynchostegium murale* (conc.), *Rosulabryum moravicum* (conc.), *Schistidium apocarpum* (conc.), ***Sciuro-hypnum populeum*** (EP, N), *Sphagnum angustifolium*, *S. fallax* (N), *S. flexuosum*, *S. fuscum*, *S. inundatum*, *S. palustre*, *S. riparium*, *S. russowii*, *Thuidium tamariscinum*, *Tortula muralis* (conc.).

– species not reported in 19th century from the cirques but noted around them as common (and incorporated to the group of species reported in the both periods studied): *Ceratodon purpureus* (N), *Dicranum scoparium*, *Pleurozium scheberi*, *Polytrichum piliferum*.

Moss species reported both in the 19th and 21st centuries

– presently found mainly in the same objects as in the past: *Amphidium mougeotii*, *Andreaea rothii* ssp. *falcata*, *Bartramia ityphylla*, *Blindia acuta*, *Brachythecium geheebii*, *Bucklandiella macounii* ssp. *alpinum*, *B. sudetica*, *Codriophorus acicularis*, *C. aquaticus*, *C. fascicularis*, *Cynodontium strumiferum*, *Dicranella subulata*, *Dicranodontium denudatum*, *Fissidens osmundoides*, *Fontinalis antipyretica*, *Dryptodon funalis*, *D. incurvus*, *Herzogiella striatella*, *Heterocladium heteropterum*, *Hygrohypnum ochraceum*, *H. smithii*, *Hylocomiastrum pyrenaicum*, *Hypnum callichroum*, *H. lindbergii*, *Kiaeria starkei*, *Niphotrichum canescens*, *Oligotrichum hercynicum*, *Philonotis fontana*, *Pohlia cruda*, *P. drummondi*, *P. ludwigii*, *P. obtusifolia*, *Polytrichastrum alpinum*, *P. sexangulare*, *Pseudoleskea incurvata*, *Ptychodium plicatum*, *Racomitrium lanuginosum*, *Rhabdoweisia fugax*, *Rhytidiadelphus squarrosus* (N), *R. triquetrus* (N), *Rhytidium rugosum*, *Sciuro-hupnum reflexum* (N), *Sphagnum capillifolium*, *S. centrale*, *S. compactum*, *S. denticulatum*, *S. lindbergii*, *S. magellanicum*, *S. papillosum*, *S. squarrosum* (N), *S. subsecundum*, *S. teres*, *S. warnstorfii*, *Splachnum sphaericum*, *Tayloria serrata* (N), *Tetrodontium repandum*, *Tortella tortuosa* (AN), *Tortula euryphylla* (N), *Warnstorfia exannulata*, *W. sarmentosa*;

– presently noted also in new cirques: *Andreaea rupestris*, *Brachytheciastrum velutinum* (EP), *Buckiella undulata*, *Cynodontium polycarpon*, *Dicranella cerviculata*, *D. heteromalla*, *Dicranum flexicaule*, *D. fuscescens*, *D. majus*, *Diobelonella palustris*, *Orthogrimmia donniana*, *Hylocomiastrum umbratum*, *Hylocomium splendens* (AN), *Hymenoloma crispulum*, *Kiaeria blyttii*, *Mnium spinosum*, *Orthodicranum montanum* (EP), *Paraleucobrym longifolium*, *Philonotis seriata*, *Plagiomnium medium*, *Plagiothecium cavifolium*, *P. curvifolium*, *P. denticulatum*, *P. nemorale*, *Pogonatum urnigerum*, *Pohlia nutans*, *P. wahlenbergii* var. *glacialis*, *Polytrichum commune*, *P. juniperinum*, *Pseudotaxiphyllum elegans*, *Rhizomnium punctatum*, *Rhodobryum roseum* (AN), *Rhytidiadelphus loreus*, *R. subpinnatus*, *Sanionia uncinata*, *Sciuro-hypnum starkei* (N), *Sphagnum cuspidatum*, *S. girgensohnii* (N), *Straminergon stramineum;*

– presently not refound in the cirques in which were observed in the 19th century but recorded in others: *Arctoa fulvella*, *Aulacomnium palustre*, *Brachydontium trichodes*, *Bucklandiella affinis*, *B. microcarpa*, *Dichodontium pellucidum*, *Dicranodontium uncinatum*, *Dryptodon hartmanii*, *Platyhypnidium riparioides*, *Rosulabryum capillare*, *Sciuro-hypnum plumosum*, *Tetraphis pellucida*, *Warnstorfia fluitans*.

For citation: Fudali E. (2012): Ecological assessment of the changes in the moss flora of the glacial cirques in the Polish Karkonosze Mts during XX century. Rocz. AR Pozn. 391, Bot. Stec. 16: 81-92.