Polish Botanical Journal 51(1): 1–24, 2006

THE LICHEN BIOTA OF THE POLISH CARPATHIANS – GENERAL CHARACTERISTIC

URSZULA BIELCZYK

Abstract. Current knowledge of the Polish Carpathian lichens is reviewed and the lichenological characteristics of the area are analysed on the basis of ecological requirements of selected species. The following aspects are discussed: i) altitudinal elements: mountain species – montane species, subalpine species, high mountain species; multizonal mountain species; non-mountain species, ii) edaphic elements, iii) geographical elements. Maps of selected lichen species representing various distribution patterns are presented. Different aspects of the anthropogenic changes, endangerment and conservation of lichens in the area are also discussed.

Key words: lichens, lichen conservation, biodiversity, Carpathians, Poland

Urszula Bielczyk, Laboratory of Lichenology, W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, PL-31-512 Kraków, Poland; e-mail: bielczyk@ib-pan.krakow.pl

CONTENTS

INTRODUCTION

The Carpathians, a mountainous region of special natural importance, have been an object of many studies within the framework of different scientific disciplines, including lichenology. The lichens are an important part of the biodiversity of the Carpathians, being inseparable, specific elements of mountain landscapes. The species richness of the lichen biota is related to habitat diversity, which in turn is connected with the variable features of surface and climate of the mountains. This richness and diversity is also due to the specific biology of lichens, enabling them to adapt to extreme conditions prevailing at high altitudes.

Lichenological studies of the Carpathians have been undertaken for more than 100 years, the results of which are contained in many published sources covering a wide spatial and thematic range (physiography, taxonomy, phytosociology, ecology). An increasing number of publications concerning changes in the lichen biota caused by anthropogenic impacts on the environment are appearing and many studies are being aimed at lichen conservation, including the compilation of local red lists of threatened lichens. The Carpathians are among the best known areas in Poland in terms of the lichen biota, the respec-

tive bibliography comprising about 300 items (see Bielczyk 2003a).

The first stage of the work summarizing our knowledge of the Carpathian lichens was the compilation of a list of the Polish Carpathian lichen species based on a critical analysis of data derived from a literature review and a revision of the most important herbarium collections, and original data collected during field studies (Bielczyk 2003a). The present paper is the next stage of work, synthesizing our current knowledge of the Carpathian lichens. Its aim is to present the lichenological characteristics of the area based on an analysis of selected lichen species requiring particular ecological requirements associated with particular elements of the natural environment (geological structure, surface features, climate, hydrology, soils) and vascular plant cover. Different aspects of the distribution, endangerment and conservation of lichens in that area are also discussed. The comparative analysis of data is based on the contemporary lichen checklists of the Western Carpathians situated in Poland, Slovakia, Hungary, Czech Republic and Austria (Bielczyk *et al*. 2004), Tatra Mts (Lisická 2005) and the Eastern Carpathians in Poland, Slovakia, Ukraine and Romania (Kondratyuk *et al*. 2003) and on the most recent lichen checklist of Poland (Fałtynowicz 2003).

The present paper is based on a detailed investigation of publications and herbarium material, the data from which was collected by the author during work on the checklist and *Atlas of the geographical distribution of lichens in Poland*, supplemented by the author's own studies, as yet unpublished, carried out in the Western Carpathians and the Eastern Carpathians in Ukraine. Distribution maps for the species in the Carpathians were made using the ATPOL grid square system (see Cieśliński & Fałtynowicz 1993).

General characteristics of the study area

Situation

The Carpathians are the second largest (to the Alps) mountain system of Central Europe. The Carpathian arch, about 1300 km long, stretches from the Danube River gorge at the Austrian-Slovakian border near Bratislava to the so-called 'Iron Gate' at the Romanian-Serbian borderland (Fig. 1A). Three main parts have been distinguished within the Carpathians, namely Western Carpathians, Eastern Carpathians and Southern Carpathians (Fig. 1B), various parts of which are situated in the territories of Poland, Slovakia, Czech Republic, Ukraine, Hungary and Romania, with a small peripheral fragment belonging to Austria. Within Poland the Carpathians cover 19,600 km^2, which is 9.3% of the total area of the mountains and about 7% of the total area of the country; here they are composed of the northern part of the Western Carpathians and a small fragment of the Eastern Carpathians (Groch *et al*. 2000).

Geology and surface features

The Carpathians were folded and uplifted in the Cretaceous and Tertiary periods. They are divided into two large geological units, differing in structure, arrangement of particular ranges and relief. The Outer Western and Eastern Carpathians are built mainly of sandstone and shale (flysch), developed as folds, flakes and nappes. The Central Carpathians are built mostly of granites, gneiss and crystalline shale, with limestone, dolomite and magma intrusions.

The present relief of the Carpathians is the result of many factors which have shaped this area since the Miocene, more particularly the role of rivers and glaciers. According to Kondracki (2001), the Polish Carpathians comprise the following geomorphological units (subprovinces): Outer Western and Eastern Carpathians (Beskidy Mts and Pogórze Karpackie foothills) and Central Western Carpathians (Tatra Mts and Pieniny Mts). Thirty mesoregions are distinguished (Fig. 2) representing four types of environment: uplands, low mountains, medium height mountains and high mountains. The Outer Western Carpathians are medium height mountains: Beskidy Zachodnie (with the highest peak of Babia Góra Mt. – 1725 m a.s.l.) and Beskidy Środkowe (Lackowa Mt. – 997 m a.s.l.) or hilly, undulating foreland (400 to 500 m a.s.l.) and mountain basins (250 to

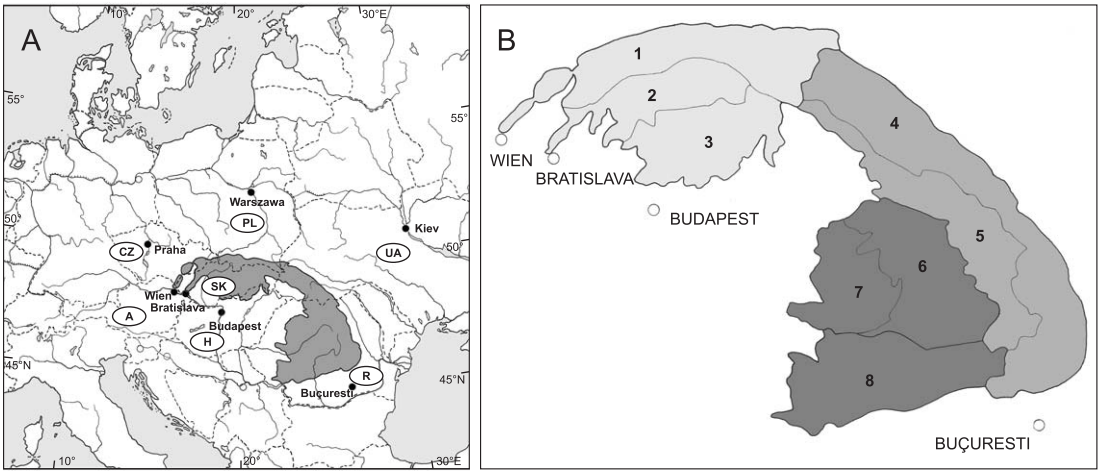


Fig. 1. Location of the Carpathian Mountains within Europe (A), and their geographical divisions (after Kondracki 1998). 1 – Outer Western Carpathians, 2 – Central Western Carpathians, 3 – Inner Western Carpathians, 4 – Outer Eastern Carpathians, 5 – Inner Eastern Carpathians, 6 **–** Transylvan Upland, 7 – Bihor Mts, 8 – Southern Carpathians.

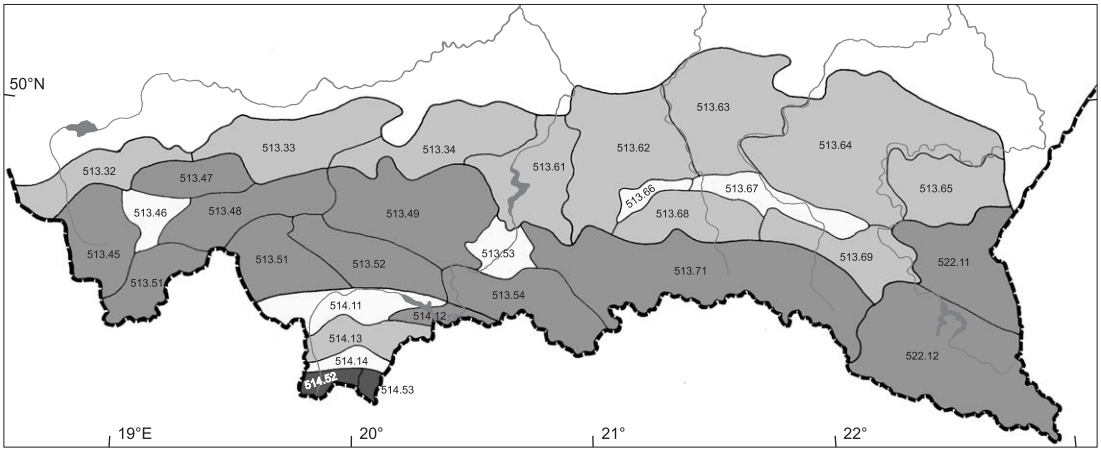


Fig. 2. Physico-geographical regions of the Polish Carpathians (after Kondracki 2001). 513 – Outer Western Carpathians: 513.3 – Pogórze Zachodniobeskidzkie foothills: 513.32 – Pogórze Śląskie foothills, 513.33 – Pogórze Wielickie foothills, 513.34 – Pogórze Wiśnickie foothills; 513.4/5 – Beskidy Zachodnie Mts: 513.45 – Beskid Śląski Mts, 513.46 – Kotlina Żywiecka basin, 513.47 – Beskid Mały Mts, 513.48 – Beskid Makowski Mts, 513.49 – Beskid Wyspowy Mts, 513.51 – Beskid Żywiecki Mts, 513.52 – Gorce Mts, 513.53 – Kotlina Sądecka basin, 513.54 – Beskid Sądecki Mts; 513.6 – Pogórze Środkowobeskidzkie foothills: 513.61 – Pogórze Rożnowskie foothills, 513.62 – Pogórze Ciężkowickie foothills, 513.63 – Pogórze Strzyżowskie foothills, 513.64 – Pogórze Dynowskie foothills, 513.65 – Pogórze Przemyskie foothills, 513.66 – Obniżenie Gorlickie depression, 513.67 – Kotlina Jasielsko-Krośnieńska basin, 513.68 – Pogórze Jasielskie foothills, 513.69 – Pogórze Bukowskie foothills; 513.7 – Beskidy Środkowe Mts: 513.71 – Beskid Niski Mts. 514 – Central Western Carpathians: 514.1 – Obniżenie Orawsko-Podhalańskie depression: 514.11 – Kotlina Orawsko-Nowotarska basin, 514.12 – Pieniny Mts, 514.13 – Pogórze Spisko-Gubałowskie foothills, 513.14 – Rów Podtatrzański depression; 514.5 – Tatra Mts: 514.52 – Western Tatra Mts, 514.53 – Hight Tatra Mts. 522 Central Eastern Carpathians: 522.1 – Beskidy Lesiste Mts: 522.11 – Góry Sanocko-Turczańskie Mts, 522.12 – Bieszczady Zachodnie Mts.

400 m a.s.l.). The Central Western Carpathians are characterized by diverse tectonics and patchy relief. The highest mountain group, the Tatra Mts (Rysy Mt. – 2499 m a.s.l.), exhibits the features of an alpine landscape. The Pieniny Mts, much lower than the Tatra Mts (Wysokie Skałki Mt. – 1052 m

a.s.l.) are a unique geological structure, its relief completely different from that of the Beskidy ranges. The north-easternmost Outer Eastern Carpathians – Beskidy Lesiste Mts (Góry Sanocko-Turczańskie Mts and Bieszczady Zachodnie Mts) have the character of medium-height mountains (Tarnica Mt. – 1346 m a.s.l.).

FLORA AND VEGETATION

About 1700 vascular plant species occur in the Polish part of the Carpathians, which constitutes about 75% of the native flora (Mirek & Piękoś-Mirkowa 1992a). The Carpathians are the most important centre for endemism in Poland in that they harbour 45 endemic vascular plant species (Mirek & Piękoś-Mirkowa 1992b). Worthy of notice is a large number of mountain species (e.g. 39% in the Tatra Mts, 22.5% on Babia Góra Mt., 20.5% in the Bieszczady Zachodnie Mts, 17.5% in the Gorce Mts). Many species are important for determining the physiographic division of the area, such species reaching the limits of their occurrence in the Carpathians and their distributions delimiting the border between the Western and Eastern Carpathians (Zemanek 1992; Towpasz & Zemanek 1995).

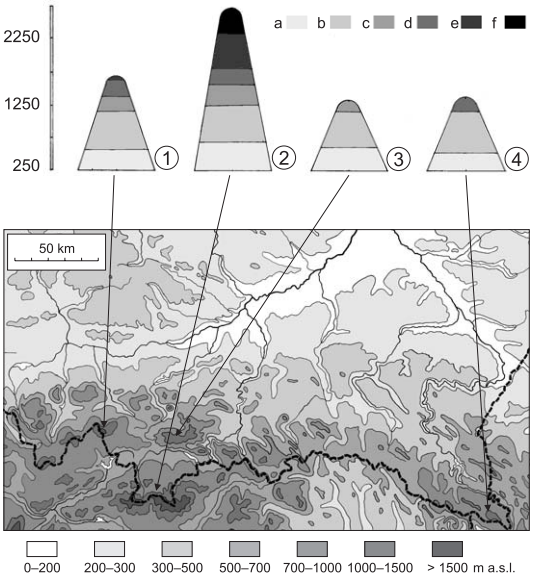


Fig. 3. Altitudinal vegetation belts in Polish Carpathian ranges (after Mirek & Piękoś-Mirkowa 1992b, modifield). 1 – Babia Góra Mt., 2 – Tatra Mts, 3 – Gorce Mts, 4 – Bieszczady Mts; a–f – vegetation belts (a – submontane, b – lower montane, c – upper montane, d – subalpine, e – alpine, f – subnival).

Six climatic and vegetation belts have been distinguished in the Carpathians, but their development is different in particular mesoregions (Fig. 3). The belt of foothills ranges to an altitude of about 450–550 m; its natural vegetation has been destroyed almost completely. Deciduous forests (mainly oak-hornbeam and mixed forests) were once a dominating plant community, but are now represented only by few small patches. The lower montane forest belt reaches 1180 m a.s.l. in the Beskidy Mts and 1250 m a.s.l. in the Tatra Mts. Natural forests of that belt are mainly beech forests, and in places also fir-spruce or spruce forests. The upper montane forest belt extends up to 1390 m (Babia Góra Mt. in the Beskidy Zachodnie Mts) and up to 1500 m a.s.l. in the Tatra Mts. The Carpathian spruce forest is the dominant plant community in the belt. The dwarf mountain pine belt reaches 1650 m (Beskid Żywiecki Mts) and 1800 m a.s.l. (Tatra Mts). In the Beskidy Lesiste Mts (Eastern Carpathians) the dwarf mountain pine does not occur. The higher elevations (at 1100–1300 m a.s.l.), above the upper limit of the beech forests are occupied by *Alnus viridis* (Chaix) DC. The alpine belt, which occurs on Babia Góra Mt. and in the Tatra Mts where it reaches about 2300 m a.s.l., is characterized by an abundance of lichen species of different habitat preferences. Their occurrence is connected with springs, streams, tarns, low alpine shrubs, alpine meadows, snow-beds, walls and rocks crevices. The subnival belt occurs only in the High Tatra Mts, where due to severe climatic conditions in their highest parts only a few vascular plants occur; this belt is dominated by lichens and bryophytes, which form distinctive associations on rocks.

Many protected areas established in the Carpathians are evidence of the unique values of their natural environment. Currently, in the Polish Carpathians, there are six national parks, numerous nature reserves, three international biosphere reserves and 14 landscape parks, harbouring many rare lichen species and their habitats.

Present knowledge of the Carpathian lichens

In 2003, the lichen flora of the Polish Carpathians comprised 1346 taxa, including 8 subspecies and 8 variants, belonging to 293 genera, and composed of 1248 taxa of lichens, 61 lichenicolous fungi and 18 'allied' non-lichenized fungi (Bielczyk 2003a), the most numerously represented taxa found in the genera *Caloplaca*, *Cladonia*, *Lecidea*, *Lecanora* and *Rhizocarpon*.

The Carpathian lichen species constitutes more than 76% of the Polish lichen biota (see Fałtynowicz 2003). Therefore, in view of the fact that the Carpathians represents a mere 7% of the territory of the country, it is a very rich biota. The total number of the Polish Carpathian lichen species is also high as compared with other Carpathian ranges in the neighbouring countries. In terms of the whole Western Carpathians, more lichen species occur in Slovakia (Fig. 4), but this is undoubtedly connected with the fact that the area of mountains in this territory is almost twice the size.

The number of lichen species differs in particular physical-geographical units of the Polish Carpathians, being dependent on the area of the investigated units, their morphological differentiation, habitat types occurring there and the extent of habitat transformation. The number of species

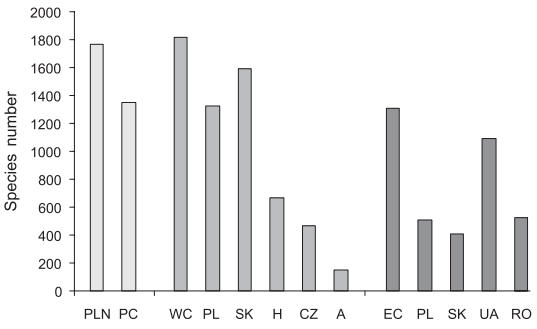


Fig. 4. Numbers of lichen species in the Polish Carpathians (PC) relative to Poland (PLN) and another parts of the Carpathians in Slovakia (SK), Hungary (H), Czech Republic (CZ), Austria (A), Ukraine (UA), Romania (RO). WC – Western Carpathians (after Bielczyk *et al*. 2004), EC – Eastern Carpathians (after Kondratyuk *et al*. 2003).

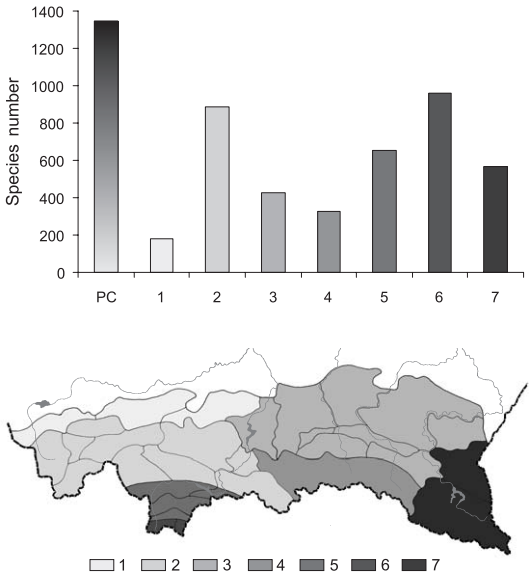


Fig. 5. Number of lichen species in particular macroregions of the Polish Carpathians (PC). 1 – Pogórze Zachodniobeskidzkie foothills, 2 – Beskidy Zachodnie Mts, 3 – Pogórze Środkowobeskidzkie foothills, 4 – Beskidy Środkowe Mts, 5 – Obniżenie Orawsko-Podhalańskie depression, 6 – Tatra Mts, 7 – Beskidy Lesiste Mts.

in particular macroregions is shown in Fig. 5. The Tatra Mts are the main centre for lichens, with 963 species belonging to 250 genera, constituting more than 54% of the lichen biota of Poland. The species richness of the Tatra lichen biota distinguishes that area from other parts of the Carpathians and the whole of Poland. Also noteworthy is the high number of lichen taxa in the Beskidy Zachodnie Mts, the 891 species only being surpassed in the Tatra Mts; this is followed by the Obniżenie Orawsko-Podhalańskie depression, the limestone Pieniny Mts supporting 653 species.

There is a difference in the number of species between the Polish Western Carpathians (1327 species, i.e. 73% of the total number of lichen species for the whole of the Western Carpathians) and the Polish Eastern Carpathians (569 species, i.e. 51% of the total number of lichens for the whole of the Eastern Carpathians). One should, however, note that the Polish Eastern Carpathians (Beskidy Lesiste Mts) constitute only a small fragment of the whole Eastern Carpathians and a mere 13% of the area of the Polish Carpathians.

The numbers of species found in the particular mountain ranges reflect, to some extent, the uneven state of knowledge of the Carpathians (Fig. 6). Beside regions for which satisfactory current information is available, e.g. Gorce Mts, Beskid Sądecki Mts, Góry Sanocko-Turczańskie Mts (Olech 1972, 1973; Kiszka & Piórecki 1991, 1992; Śliwa 1998, 2000; Czarnota 2000; Kościelniak 2004; Czarnota *et al*. 2005), there are regions for which data are completely lacking or are old and out-of-date, particularly in the light of rapid changes in the environment occurring under the influence of human activity. Such areas as the Beskidy Środkowe Mts (Beskid Niski Mts), Pogórze Zachodniobeskidzkie foothills and a large part of the Pogórze Środkowobeskidzkie foothills require a comprehensive and up-to-date study; even the Tatra Mts have not been investigated thoroughly enough, particularly their highest parts (cf. Olech 2004).

Continuous lichenological studies have recently intensified in the Carpathians, particularly in places difficult to access and on certain microhabitats that have so far been neglected; furthermore, the progress in taxonomic studies and the use of modern methods for lichen identification has resulted in the discovery of new species and new localities of the very rare lichens (Fig. 7), especially lichenicolous fungi which have hitherto lacked detailed study. Since the publication of the Carpathian lichen list (Bielczyk 2003a), 78 new species, including 2 non-lichenized saprobiontes and 6 lichenicolous fungi, have been discovered in the Polish Tatra Mts (see Bielczyk 2003b, 2006b), and due to intense studies in the Eastern

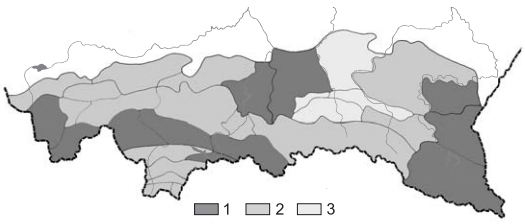


Fig. 6. Current stage of lichenological research in the Polish Carpathians. 1 – characterized in monographs, 2 – published data available, 3 – unpublished data present or no survey conducted.

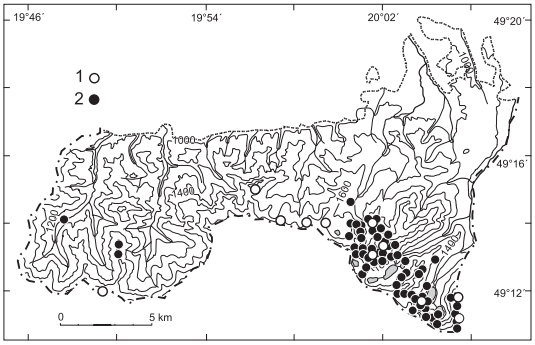


Fig. 7. Localities of *Umbilicaria crustulosa* (Ach.) Frey in the Tatra Mts. 1 – reported before 1990, 2 – recently discovered (according to Krzewicka 2004, updated).

Carpathians, the number of known lichen species has increased by 33 since 2003 (Kościelniak & Kiszka 2003, 2005).

Altitudinal elements

Altitudinally, Carpathian lichens comprise two groups, either mountain or non-mountain, the classification of species within each being based on Nowak (1972), Nimis (1993), Wirth (1995) and Lisická (2005).

Mountain species

These are species which occur exclusively in mountains or whose centers of occurrence are in mountains. Taking into account the occurrence of lichens in particular vegetation belts, one may distinguish the four groups characterized below.

Montane species

To this group belong species which occur mostly in one or both mountain forest belts. These are primarily epiphytic species, and some lignicolous ones. They form distinctive lichen communities within different microhabitats generated by the vascular plant associations (Bielczyk 1986). The dominant forest lichens are epiphytes of spruce. Forest lichens may be divided into the lower and upper montane belt species. The number of forest lichen species in different ranges of the Car-

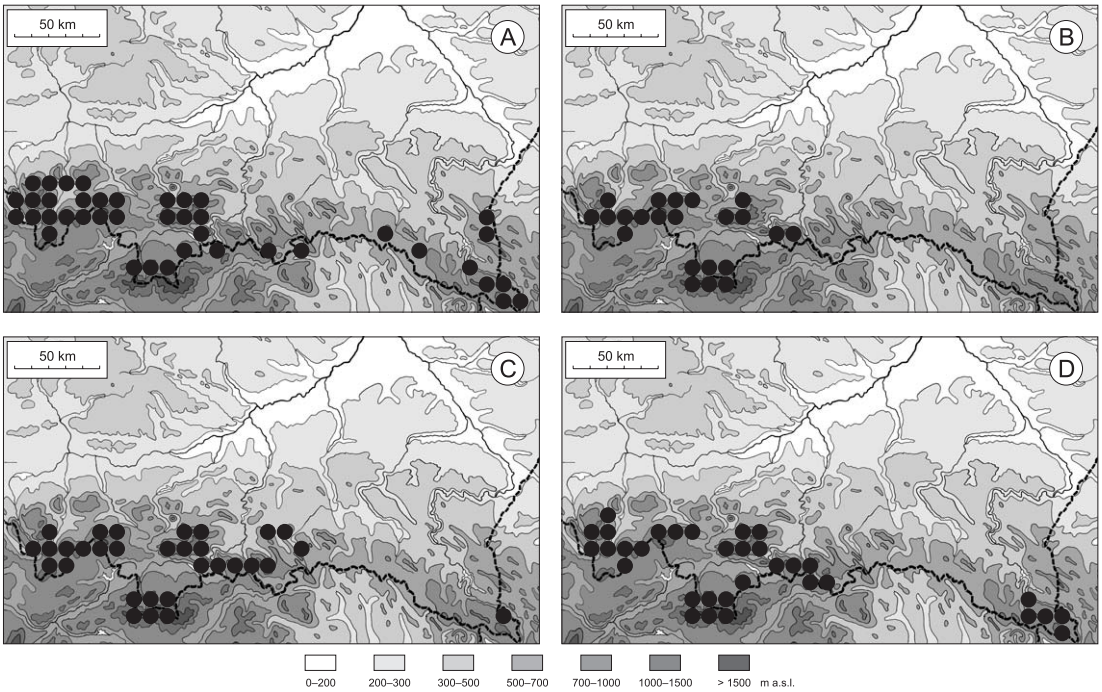


Fig. 8. Distribution of selected montane species in the Polish Carpathians. A – *Thelotrema lepadinum* (Ach.) Ach. (according to Tobolewski 1981, updated), B – *Mycoblastus sanguinarius* (L.) Norman (according to Tobolewski 1979, updated), C – *Lecanactis abietina* (Ach.) Körb. (according to Tobolewski 1979, updated), D – *Bryoria bicolor* (Ehrh.) Brodo & D. Hawksw. (according to Tobolewski 1979, updated).

pathians is connected with the size of the occupied area and depends largely on the conservation status and degree of naturalness of the existing forest associations, and on the altitude (see Cieśliński & Czyżewska 1991).

Thelotrema lepadinum (Ach.) Ach., a representative species of the lower montane belt (Fig. 8A), is very rare today, occurring in pure and humid air and in those patches of the Carpathian beech wood *Dentario glandulosae-Fagetum* which have retained the character of primeval forest. It is known throughout the Polish Carpathians, being reported from the Tatra Mts and all ranges of the Beskidy Zachodnie Mts (Beskid Śląski, Beskid Żywiecki, Beskid Mały, Beskid Wyspowy, Beskid Sądecki, Gorce), through the Beskid Niski Mts to the Eastern Carpathians (Góry Sanocko-Turczańskie Mts and Bieszczady Zachodnie Mts). It is concentrated mostly in the upper part of the lower montane belt, i.e. at 1150–1250 m a.s.l. which is the upper limit of its range in the Carpathians. This type of distribution is shown also by other lower montane belt species, such as *Menegazzia terebrata* (Hoffm.) A. Massal., *Lecanora albella* (Pers.) Ach., *Gyalecta truncigena* (Ach.) Hepp, *Pertusaria pertusa* (Weigel) Tuck. and *Caloplaca herbidella* (Hue) H. Magn.

The upper montane belt species are mostly epiphytes of spruce growing within the natural spruce forests. These forests occupy considerable areas in the upper part of the lower montane belt and almost all habitats in the upper montane belt of the Carpathians. The upper limit of the occurrence of spruce forests is also the upper forest limit. A typical upper montane belt epiphyte is *Mycoblastus sanguinarius* (L.) Norman which in the Polish Carpathians grows exclusively on the bark of spruce in the Tatra Mts and Beskidy Zachodnie in the best preserved fragments of the coniferous forests (*Plagiothecio-*

Piceetum and *Polysticho-Piceetum*) (Fig. 8B). Most localities have been found in the Tatra Mts where these forests occupy the largest area in the Carpathians, covering more than 4,000 hectares. It is worth noticing that this species occurs with the same frequency in both the limestone part of the Western Tatra Mts and the granitic High Tatra Mts. Its other centre of occurrence in the Polish Carpathians is the upper montane coniferous forest in the massif of Babia Góra. The remaining localities have been noted in the natural upper montane forests in the Gorce, Beskid Żywiecki (Pilsko, Romanka, Polica), and Beskid Śląski (Barania Góra) mountains. Single localities have been reported from the Beskid Sądecki Mts and one locality from the Beskid Wyspowy Mts. This species grows at an altitude of 1150–1550 m a.s.l. A similar distribution is shown by other upper montane belt species, e.g. *Mycoblastus affinis* (Schaer.) T. Schauer, *Bryoria nadvornikiana* (Gyeln.) Brodo & D. Hawksw., *Alectoria sarmentosa* (Ach.) Ach., and *Parmeliopsis hyperopta* (Ach.) Arnold.

A slightly different pattern of distribution is presented by such lichen species as *Lecanactis abietina* (Ach.) Körb. (Fig. 8C). This lichen, which grows on spruce and fir, occurs in the upper montane belt as well as in the mixed forest *Abieti-Piceetum* of the lower montane belt. It is known from all the Carpathian ranges, except for the Pieniny Mts. It has been reported from the Western Tatra and High Tatra, Beskidy Zachodnie (Beskid Śląski, Beskid Żywiecki, Gorce, Beskid Sądecki, Kotlina Sądecka) and the Pogórze Spisko-Gubałowskie foothills. It was found also in the Eastern Carpathians (Bieszczady Zachodnie Mts). Its pattern of distribution is also shown by, for example, *Arthonia leucopellaea* (Ach.) Almq., *Loxospora cismonica* (Beltr.) Hafellner, *Hypogymnia farinacea* Zopf and *Cybebe gracilenta* (Ach.) Tibell. In the Western Carpathians these species grow in the upper montane forest belt and the upper part of the lower montane belt. In the Bieszczady Zachodnie Mts, where the upper montane belt is lacking, the upper montane belt lichens occur in the lower montane belt on tree species other than spruce, such as birch, or occupy other types of substratum, such as turf and humus (Kiszka 2003).

A group of forest species with a wider range is represented by *Bryoria bicolor* (Ehrh.) Brodo & D. Hawksw. (Fig. 8D). This species grows mostly on spruce, but also on fir and beech, and additionally on mosses and humus on siliceous rock and on soil. It occurs mostly in the upper montane belt and upper parts of the lower montane belt, but some localities have been found in the dwarf mountain pine (subalpine) belt and alpine belt (in the Tatra Mts from 1115 m to 2114 m a.s.l.). It is found in the large forest complexes of the Carpathians, i.e. in the Tatra Mts, Beskidy Zachodnie Mts (Beskid Śląski, Beskid Żywiecki, Beskid Sądecki, Gorce) and Bieszczady Zachodnie Mts. It has also been reported from the Pogórze Spisko-Gubałowskie foothills. This type of distribution is also shown by *Hypogymnia vittata* (Ach.) Parrique and *Calicium viride* Pers.

Subalpine species

The lichen biota of the dwarf mountain pine belt is very species-rich, but it is difficult to indicate species associated exclusively with that belt. They are partly montane species that reach here the limits of their occurrence and partly alpine species occurring predominantly in that altitudinal belt. The dominant plant community is *Pinetum mughi carpaticum*, and the dwarf mountain pine is overgrown by several epiphytic species, whose occurrence is characterized by high frequency and constancy; however, these species grow also in the lower vegetation belts (Bielczyk 1986). The only specific epiphyte of the dwarf mountain pine belt is *Lecanora sarcopidoides* (A. Massal) A. L. Sm. [*L. pumilionis* (Rehm.) Arnold], which has been found in all the mountain ranges of the Carpathians where the subalpine belt occurs, at altitudes of 1300–1800 m a.s.l. (Fig. 9). In Poland it is known from the three places: the Tatra Mts, Babia Góra Mt. and Pilsko Mt., and also from the small patches of dwarf mountain pine on Polica Mt. There are also a few saxicolous species, *Rhizocarpon hochstetteri* (Körb.) Vain., *Protothelenella corrosa* (Körb.) H. Mayrhofer & Poelt, *Ionaspis*

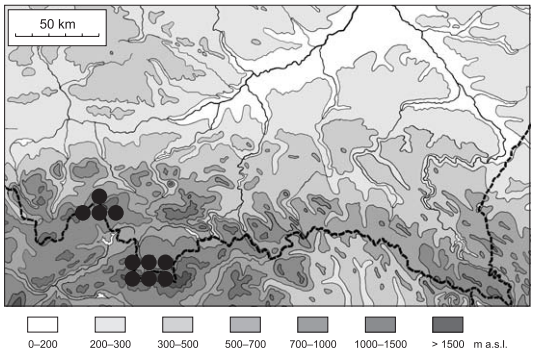


Fig. 9. Distribution of subalpine species *Lecanora sarcopidoides* (A. Massal.) A. L. Sm. in the Polish Carpathians.

odora (Ach.) Stein and *Umbilicaria torrefacta* (Lightf.) Schrad., which occur exclusively in the subalpine belt. Many lichen species have the optimum conditions for their occurrence in the dwarf mountain pine belt (Nowak 1972).

High mountain species

The high mountain species are the most interesting group of mountain lichens. The center of their occurrence is in non-forest belts, i.e. in the alpine and subnival belts, with a mosaic of habitats of different types. In the Polish part of the Carpathians only the lichen biota of Babia Góra Mt. and the Tatra Mts are characterized by the presence of numerous alpine species, where, with mosses and liverworts, they form the dominant elements of the vegetation. Here, many of these lichen species have their only localities in Poland (e.g., Flakus & Bielczyk 2006).

Alectoria ochroleuca (Hoffm.) A. Massal., an example of the alpine species, grows on soil and rarely on acid rock within the alpine grasslands which are the dominant plant formation of the alpine belt. In the Western Carpathians it is known from the Western Tatra Mts, High Tatra Mts and Babia Góra Mt. (Fig. 10A). In the Tatra Mts it grows in the subalpine, alpine and subnival belts, at an altitude of 1520–2450 m a.s.l. However, its localities concentrate in the alpine belt where it probably finds the optimum conditions for its development. The species is also known from the Eastern Carpathians where it has been found in the belt of grasslands in the Bieszczady Zachodnie Mts at an altitude of 1340 m a.s.l. A similar type of distribution is also shown by the saxicolous *Tremolecia atrata* (Ach.) Hertel and *Acarospora badiofusca* (Nyl.) Th. Fr., the terricolous *Lecidoma demissum* (Rutstr.) Gotth. Schneid. & Hertel and calciphilous epibryophytic *Caloplaca tiroliensis* Zahlbr.

Flavocetraria nivalis (L.) Kärnefelt is an alpine lichen species which in the Polish Carpathians grows only in the Tatra Mts and on Babia Góra Mt. (Fig. 10B). It occurs in the alpine and subalpine belts, often accompanied by *Alectoria ochroleuca* (Hoffm.) A. Massal. A similar type of distribution is shown by, for example, *Melanelia hepatizon* (Ach.) Thell, *Schaereria fuscocinerea* (Nyl.) Clauzade & Cl. Roux, *Sphaerophorus fragilis* (L.) Pers., *Ophioparma ventosa* (L.) Norman and *Brodoa intestiniformis* (Vill.) Goward. The presence of these species on Babia Góra Mt. confirms unequivocally the alpine character of the

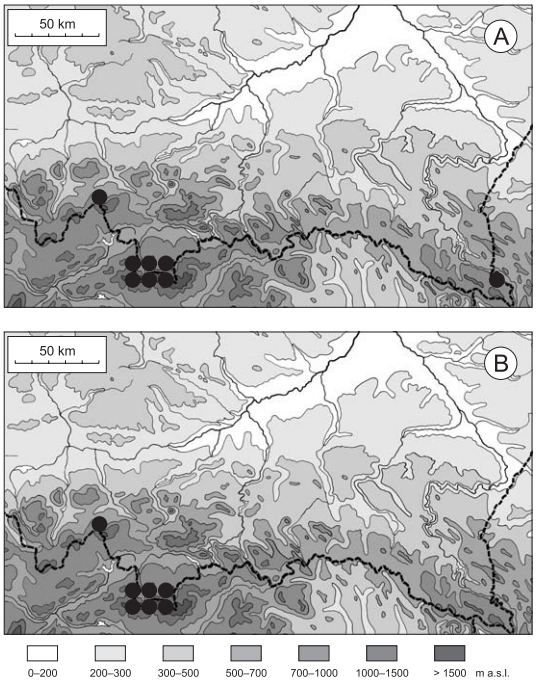


Fig. 10. Distribution of selected hight mountain species in the Polish Carpathians. A – *Alectoria ochroleuca* (Hoffm.) A. Massal., B – *Flavocetraria nivalis* (L.) Kärnefelt (according to Tobolewski 1976, updated).

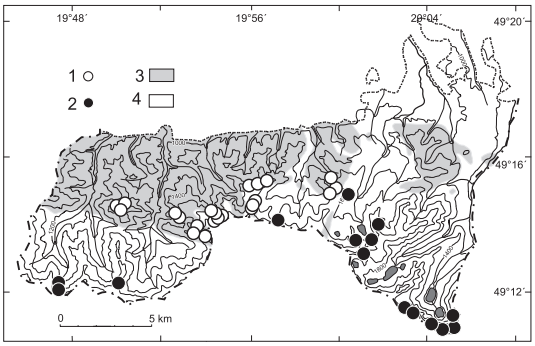


Fig. 11. Distribution pattern of alpine species in the Polish Tatra Mts. 1 – calciphilous *Ochrolechia upsaliensis* (L.) A. Massal., 2 – acidophilous *Ramalina carpatica* Körb.; 3 – calcareous substrate, 4 – non-calcareous substrate.

massif, and also indicates the geobotanical connections between the Tatra Mts and Babia Góra Mt., as well as its specific character when compared with other Beskid ranges.

The distribution of many alpine lichen species is highly dependent on the chemical properties of the substratum. *Ochrolechia upsaliensis* (L.) A. Massal., an example of a calciphilous lichen (Fig. 11), occurs only in the limestone areas of Western Tatra Mts, as do *Biatorella hemisphaerica* Anzi, *Caloplaca aurea* (Schaer.) Zahlbr., *Myxobilimbia accedens* (Arnold) Hafellner, *Protoparmeliopsis admontensis* (Zahlbr.) Hafellner, *Rinodina roscida* (Sommerf.) Arnold and *Rinodina turfacea* (Wahlenb.) Körb. An example of

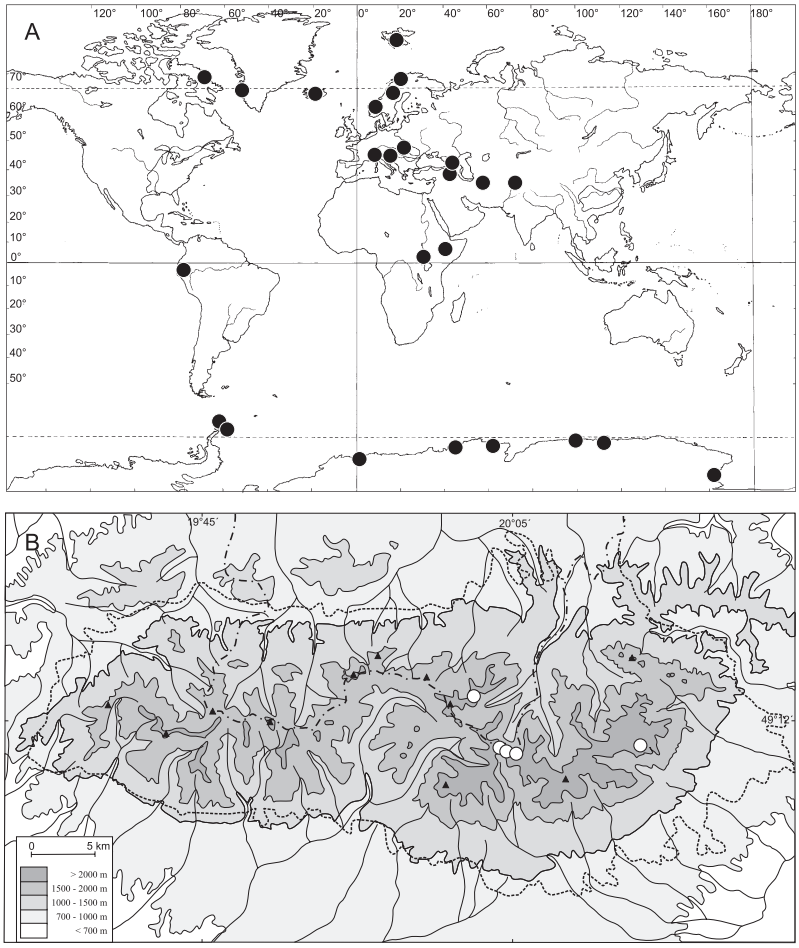


Fig. 12. *Umbilicaria aprina* Nyl. A – world distribution, and B – localities in the Tatra Mts.

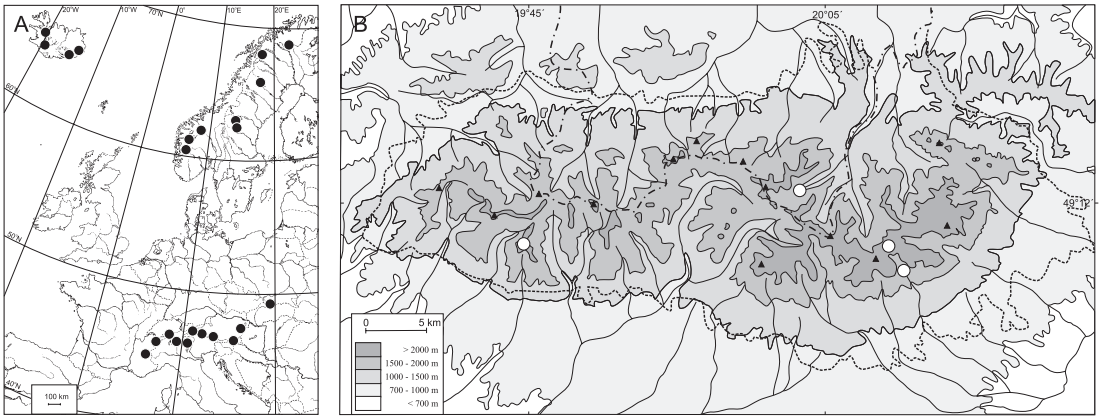


Fig. 13. *Bryodina rhypariza* (Nyl.) Hafellner & Türk. A – European distribution (after Poelt 1983), and B – localities in the Tatra Mts (original).

an alpine acidophilous lichen is *Ramalina carpatica* Körb. (Fig. 11), which occurs only on granite in the High Tatra Mts and on crystalline rock in the Western Tatra Mts. A similar distribution is shown, for example, by *Calvitimela armeniaca* (DC.) Hafellner, *Orphniospora moriopsis* (A. Massal.) D. Hawksw., *Pleopsidium flavum* (Bellardi) Körb., *Allantoparmelia alpicola* (Th. Fr.) Essl. and *Psorinia conglomerata* (Ach.) Gotth. Schneid.

In the subnival belt, which occurs only in the Tatra Mts and extends from about 2300 m a.s.l. to the highest mountain peaks, lichens are mainly found on rocks, forming distinctive saxicolous communities. Most species growing in the subnival belt also occur in the alpine belt. On the basis of current knowledge it is difficult to indicate typical species of the subnival belt. However, there are many taxa, e.g. *Umbilicaria aprina* Nyl. (Fig. 12), *Bryodina rhypariza* (Nyl.) Hafellner & Türk (Fig. 13) and *Umbilicaria lyngei* Schol., *Gyalecta sudetica* Vězda, *Bacidina delicata* (Larbal. *ex* Leight.) V. Wirth & Vězda or *Staurothele bacilligera* (Arnold) Arnold (Fig. 14), reported only from this belt, but they are very rare and it is likely that they will be found in lower mountain situations in the course of further investigations. In the Slovakian part of the Tatra Mts many such rare species, e.g. *Buellia papillata* (Sommerf.) Tuck., *Brodoa atrofusca* (Schaer.) Goward, *Rhexophiale rhexoblephara* (Nyl.) Hellb., *Placynthium dolichoterum* (Nyl.) Trevis., *Schadonia fecunda* (Th. Fr.) Vězda & Poelt, *Solorina octospora* Arnold, are reported at lower elevations (Fig. 15).

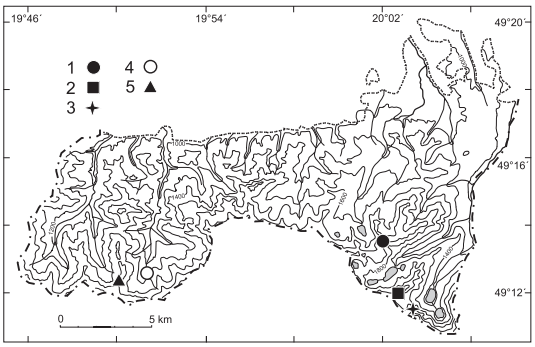


Fig. 14. Localities of selected rare alpine species in the Polish Tatra Mts. 1 – *Umbilicaria lyngei* Schol., 2 – *Gyalecta sudetica* Vězda, 3 – *Staurothele bacilligera* (Arnold) Arnold, 4 – *Bacidina delicata* (Larbal. *ex* Leight.) V. Wirth & Vězda.

Multizonal mountain species

Multizonal mountain species, occurring with similar frequency in all altitudinal belts, are mostly saxicolous, while terricolous and lignicolous species are scarce and epiphytic species are unknown.

Porpidia macrocarpa (DC.) Hertel & A. J. Schwab, a saxicolous species occurring on acidic substrata which is a representative of this group,

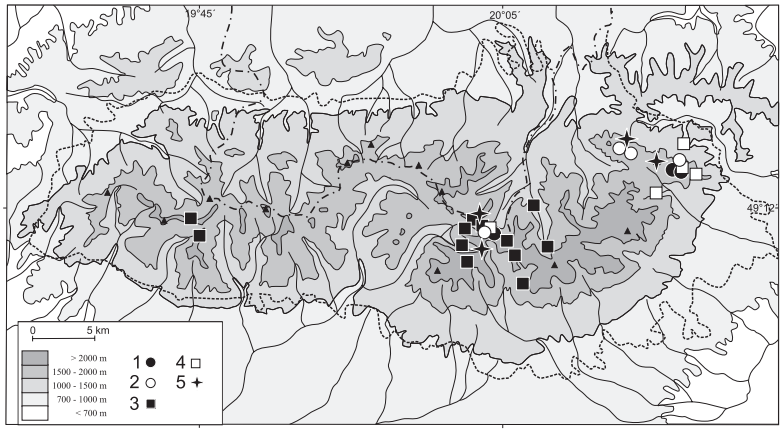


Fig. 15. Localities of selected rare alpine species in the Tatra Mts. 1 – *Buellia papillata* (Sommerf.) Tuck., 2 – *Brodoa atrofusca* (Schaer.) Goward, 3 – *Rhexophiale rhexoblephara* (Nyl.) Hellb., 4 – *Placynthium dolichoterum* (Nyl.) Trevis., 5 – *Schadonia fecunda* (Th. Fr.) Vězda & Poelt, 6 – *Solorina octospora* Arnold.

occurs from the lowest situations in the foothill belt up to the subnival belt. In the Polish Tatras it has been reported up to 2115 m a.s.l. and in the Slovakian Tatras reaches 2633 m a.s.l. (Lisická 2005). It is known from all regions of the Polish Carpathians where it grows in the foothill belt of the Beskidy Zachodnie Mts, Tatra Mts, Obniżenie Orawsko-Podhalańskie depression, Beskidy Środkowe and Beskidy Lesiste Mts (Fig. 16A). A similar distribution is shown by *Protoparmelia badia* (Hoffm.) Hafellner, *Lecanora intricata* (Ach.) Ach., *Rhizocarpon geographicum* (L.) DC., *Porpidia speirea* (Ach.) Kremp., *Umbilicaria deusta* (L.) Baumg., *Lecidella carpathica* Körb. and *Stereocaulon nanodes* Tuck.

Another representative of the group of multizonal mountain lichens, *Miriquidica leucophaea* (Flörke *ex* Rabenh.) Hertel & Rambold, is, however, a rare species in the Carpathians (Fig. 16B). It is known from the Beskidy Zachodnie Mts, Pieniny Mts, and Bieszczady Zachodnie Mts, where it occurs from the foothills to the alpine belt (1660 m a.s.l. on Babia Góra Mt.). Examples of other species, growing at scattered localities within the various montane belts of the Carpathians are *Buellia leptocline* (Flot.) A. Massal., *Lecidella asema* (Nyl.) Knoph & Hertel, *Verrucaria latebrosa* Körb., *Catillaria chalybeia* (Borrer) A. Massal. and *Placidium lachneum* (Ach.) de Lesd.

NON-MOUNTAIN SPECIES

Species common throughout Europe, in both lowlands and mountains, belong to this group. In the Carpathians they are the most frequent lichens, represented mainly by ubiquitous species. They occur in all the Carpathian ranges, from the lowest situations to the highest peaks of the Tatra Mts. Even detrimental human activity in the environment has not reduced their frequency since they have established themselves in secondary habitats. Epiphytic species such as *Hypogymnia physodes* (L.) Nyl., *Pseudevernia furfuracea* (L.) Zopf, *Phlyctis argena* (Spreng.) Flot. and *Hypocenomyce scalaris* (Ach.) M. Choisy belong to this group, as well as saxicolous *Acarospora fuscata* (Schrad.) Th. Fr., *Candelariella vitellina* (Hoffm.) Müll. Arg., *Protoparmeliopsis muralis* (Schreb.) M. Choisy, *Lecanora polytropa* (Ehrh. *ex* Hoffm.) Rabenh. and *Porpidia crustulata* (Ach.) Hertel & Knoph, and terricolous *Cetraria islandica* (L.) Ach., *Cladonia coniocraea* (Flörke) Spreng., *C. digitata* (L.) Hoffm., *C. pyxidata* (L.) Hoffm. and *C. squamosa* Hoffm.

In addition to these ubiquitous species, there is also a large group of typical lowland species whose distribution is connected with the lowest situations in the Carpathians, such as *Melanelia disjuncta* (Erichsen) Essl., *Polysporina lapponica*

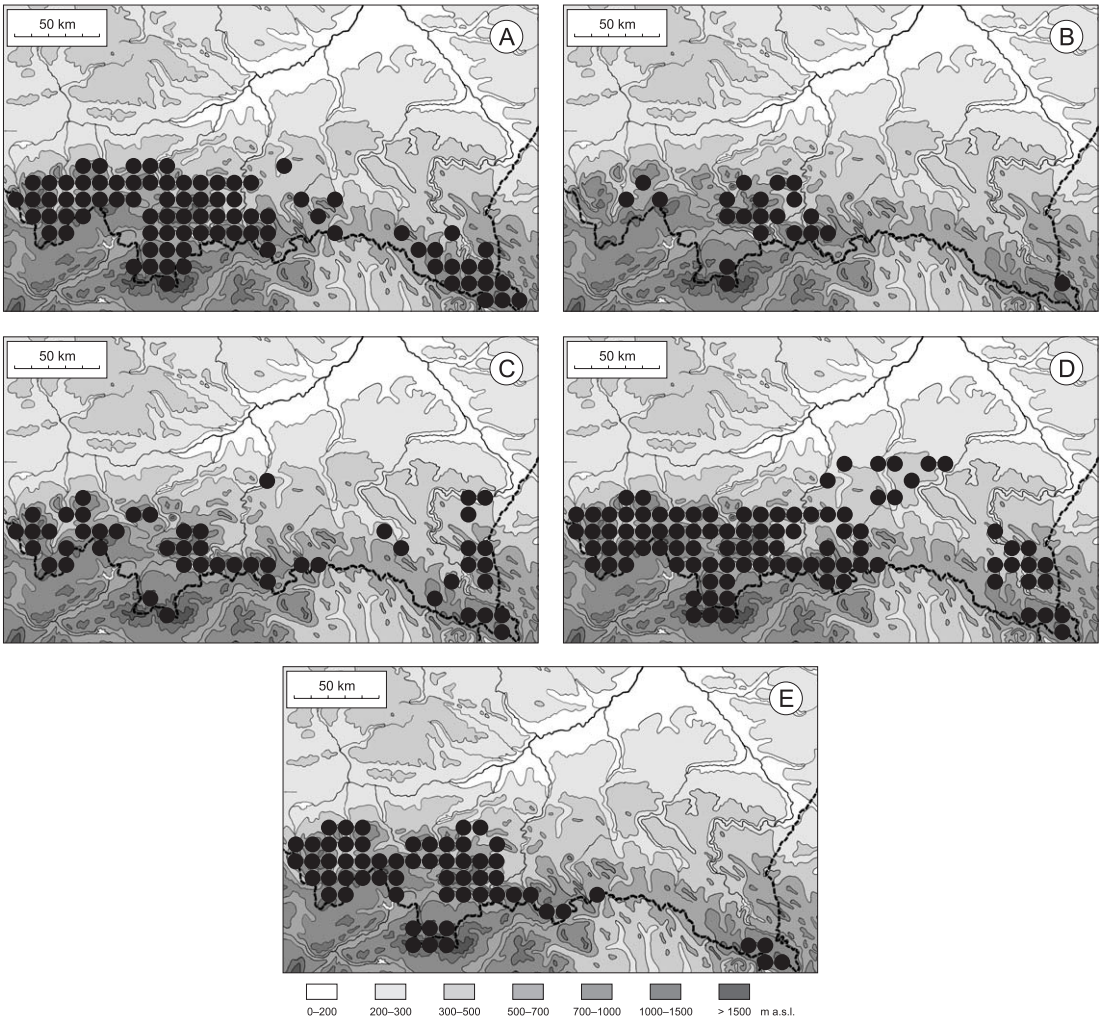


Fig. 16. Distribution of selected multizonal mountain species in the Polish Carpathians. A – *Porpidia macrocarpa* (DC.) Hertel & A. J. Schwab., B – *Miriquidica leucophaea* (Flörke *ex* Rabenh.) Hertel & Rambold., C – *Lecanora intumescens* (Rebent.) Rabenh. (according to Tobolewski 1988, updated), D – *Parmeliopsis ambigua* (Wulfen) Nyl. (according to Tobolewski 1981, updated), E – *Tephromela atra* (Huds.) Hafellner (according to Tobolewski 1988, updated).

(Ach. *ex* Schaer.) Degel., *Xanthoparmelia conspersa* (Ehrh. *ex* Ach.) Hale, *Psilolechia lucida* (Ach.) M. Choisy, *Rinodina colobina* (Ach.) Th. Fr. and *Bacidia rosella* (Pers.) De Not.

After the primaeval forests of the foothill belt and the lower part of the lower montane belt had been cut down, many non-mountain forest epiphytes extended their occurrence to the mountain forests. The distribution of these species is very similar to that of the mountain forest species, such as *Lecanora intumescens* (Rebent.) Rabenh. (Fig. 16C), which grows mainly on the bark of old beeches, and more rarely sycamores, in *Dentario glandulosae-Fagetum*. It is concentrated in the upper part of the lower montane belt, reaching an altitude of 1250 m a.s.l., and is common throughout the Carpathians in Poland. It has been reported from the Tatra Mts and all ranges of the Beskidy Zachodnie Mts (Beskid Śląski, Beskid Żywiecki, Beskid Mały, Beskid

Wyspowy, Beskid Sądecki, Gorce), as well as the Beskid Niski Mts through to the Eastern Carpathians (Góry Sanocko-Turczańskie Mts and Bieszczady Zachodnie Mts). It also occurs in the lower mountain ranges (Pieniny Mts, Pogórze Spisko-Gubałowskie foothils) and in the foothill belt (Pogórze Rożnowsko-Ciężkowickie, Pogórze Przemyskie). In the Carpathians this pattern of distribution is also shown by the non-mountain species *Graphis scripta* (L.) Ach., *Pertusaria pertusa* (Weigel) Tuck., *Pyrenula nitida* (Weigel) Ach., *Flavoparmelia caperata* (L.) Hale, *Melanohalea exasperatula* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawskw. & Lumbsch. and *Cetrelia olivetorum* (Nyl.) W. L. Culb. & C. F. Culb. The distribution of these species in the Carpathians is associated with the occurrence of large deciduous or mixed forests. This type of distribution is similar to that of lower montane belt species, e.g. *Thelotrema lepadinum* (Ach.) Ach.

Parmeliopsis ambigua (Wulfen) Nyl. is an example of a lowland species which occurs throughout the Carpathians, from the lowest situations to the subalpine belt (Fig. 16D). This epiphyte grows on different tree species. It is a frequent species, even in the upper montane belt and the subalpine belt, as are *Platismatia glauca* (L.) W. L. Culb. & C. F. Culb., *Chaenotheca chrysocephala* (Turner *ex* Ach.) Th. Fr. and *Cladonia digitata* (L.) Hoffm. *Vulpicida pinastri* (Scop.) J.-E. Mattsson & M. J. Lai exhibits the same distribution, however, it is a rare species in the Carpathians as are *Cetraria sepincola* (Ehrh.) Ach., *Tuckermannopsis chlorophylla* (Willd.) Hale, *Calicium abietinum* Pers. and *Ochrolechia androgyna* (Hoffm.) Arnold.

The distribution of lowland saxicolous species is very often similar to the distribution of multizonal mountain epilithic species, as charcterised by, for example, *Tephromela atra* (Huds.) Hafellner (Fig. 16E) and *Lecanora rupicola* (L.) Zahlbr.

Edaphic elements

Most lichens use nutrients occurring on the surface of substratum on which they grow. Therefore, the chemical character of the substratum has a very important influence on the development and species composition of the lichens in particular areas. Affinity of certain species to habitats of specific properties is noted in all ecological groups of lichens. It is, however, easiest to observe in saxicolous species, due to their dependence on the pH of the substratum. Calciphilous species grow exclusively on substrata rich in calcium carbonate, while acidophilous species occur on rock that is poor or lacking this compound. The Carpathians well illustrate this phenomenon, where, in a small area, one may observe lichens characteristic of both types of habitat, such as in the mountain group of Czerwone Wierchy in the Western Tatra Mts.

Calciphilous lichens are mostly saxicolous species, but they also grow on soil and rock waste, rich in $CaCO_3$. Many calciphilous lichens are connected indirectly with carbonate substrata, growing, for instance, on decaying bryophytes and remnants of calciphilous vascular plants. They occur in different biotopes and at different altitudes in Poland (Bielczyk 2006a). In the Carpathians, calciphilous lichens, such as *Petractis clausa* (Hoffm.) Kremp. (Fig. 17A), *Lecanora reuteri* Schaer., *Fulgensia bracteata* (Hoffm.) Räsänen, *F. schistidii* (Anzi) Poelt and *Fuscopannaria praetermissa* (Nyl.) P. M. Jørg., are concentrated in the Pieniny Mts and in the limestone part of the Western Tatra Mts. Another type of distribution is shown by calciphilous lichens growing on mylonite within the granite rock in the High Tatra Mts. Such habitats are very rich in lichen species (Flakus, in preparation), including many calciphilous arctic-alpine species such as *Solorina bispora* Nyl. (see Fig. 18A) and *Gyalecta foveolaris* (Ach.) Schaer., *Thelopsis melathelia* Nyl., *Caloplaca sinapisperma* (Lam. & DC.) Maheu & Gillet, *Catapyrenium daedaleum* (Kremp.) Stein and *Protopannaria pezizoides* (Weber) P. M. Jørg. & S. Ekman.

Certain calciphilous species, distributed throughout the Carpathians, occur not only in the limestone Western Tatra Mts and Pieniny Mts but also in all ranges of the Beskidy Zachodnie Mts, Beskidy Środkowe Mts and Beskidy Lesiste Mts, and in the foothills. Their distribution is

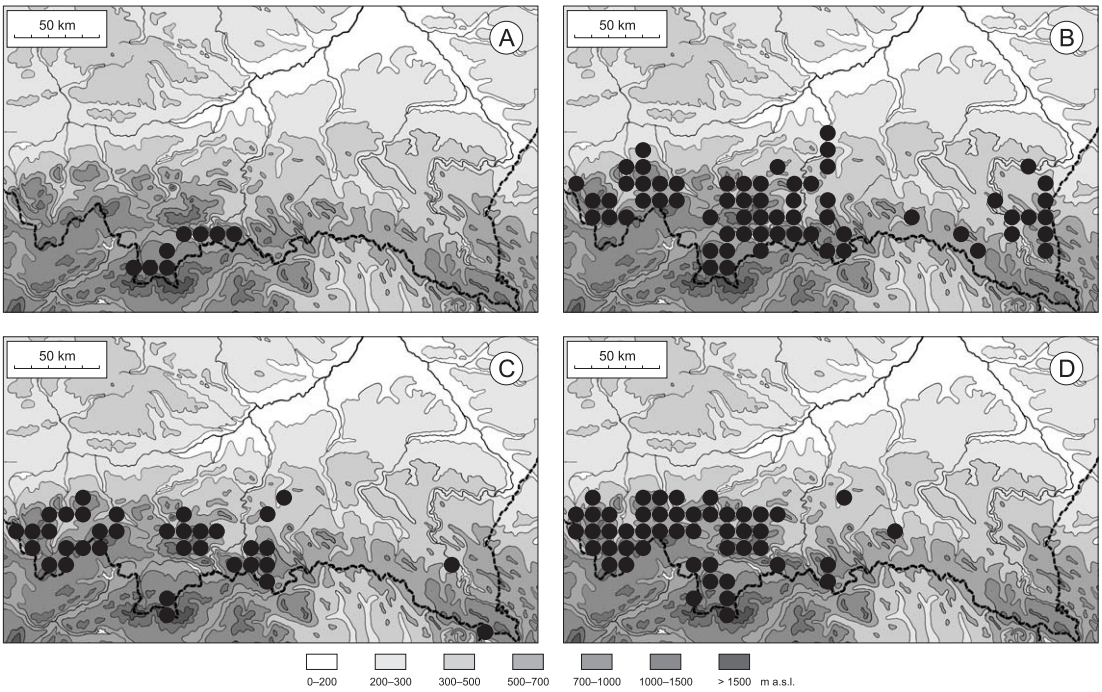


Fig. 17. Distribution of selected species in the Polish Carpathians. A – *Petractis clausa* (Hoffm.) Kremp. (according to Bielczyk 1993b, updated), B – *Placynthium nigrum* (Huds.) Gray (according to Leśniański 2004, updated), C – *Opegrapha gyrocarpa* Flot. (according to Czarnota 2004, updated), D – *Bryophagus gloeocapsa* Nitschke *ex* Arnold (according to Bielczyk 1993a, updated).

connected with the presence of flysch formations which contain a considerable admixture of calcium carbonate. Some of these species, e.g. *Placynthium nigrum* (Huds.) Gray (Fig. 17B), also occupy man-made habitats, usually in lower mountain situations. A similar distribution pattern is also typical of other calciphilous species, e.g. *Gyalecta jenensis* (Batsch) Zahlbr., *Acarospora glaucocarpa* (Ach.) Körb., *Catillaria lenticularis* (Ach.) Th. Fr., *Sarcogyne regularis* Körb. and *Protoblastenia rupestris* (Scop.) J. Steiner.

Acidophilous species have appropriate substrata throughout the Carpathians, from the lowest situations to the peaks of the Tatra Mts. They occur on sandstone in the Beskidy Mts and in their foothills, and on siliceous rock in the Tatra Mts; many acidophilous species are terricolous. Saxicolous examples of this type of the distribution are *Opegrapha gyrocarpa* Flot. (Fig. 17C) and *Orphniospora moriopsis* (A. Massal.) D. Hawksw. (Fig. 18B) and for terricolous species, *Bryophagus gloeocapsa* Nitschke *ex* Arnold (Fig. 17D).

In addition to these two distinct groups strongly dependent on pH of the substratum, there are also many 'substrate independent' lichens, growing on both acidic and basic substrata. These are often ubiquitous species, widely distributed in the Carpathians, e.g. *Xanthoria elegans* (Link.) Th. Fr., *Candelariella vitellina* (Hoffm.) Müll. Arg., *Protoparmeliopsis muralis* (Schreb.) M. Choisy, *Physcia caesia* (Hoffm.) Fürnr. and *Verrucaria muralis* Ach. An example of the high mountain species, not connected with a particular chemical character of its substratum is *Thamnolia vermicularis* (Sw.) Schaer. (Fig. 18C), which has the same frequency of occurrence on both limestone and crystalline rock in the Tatra Mts.

Among those species strongly dependent on edaphic and climatic conditions are aquatic lichens (Aptroot & Seaward 2003). Such lichens occur in

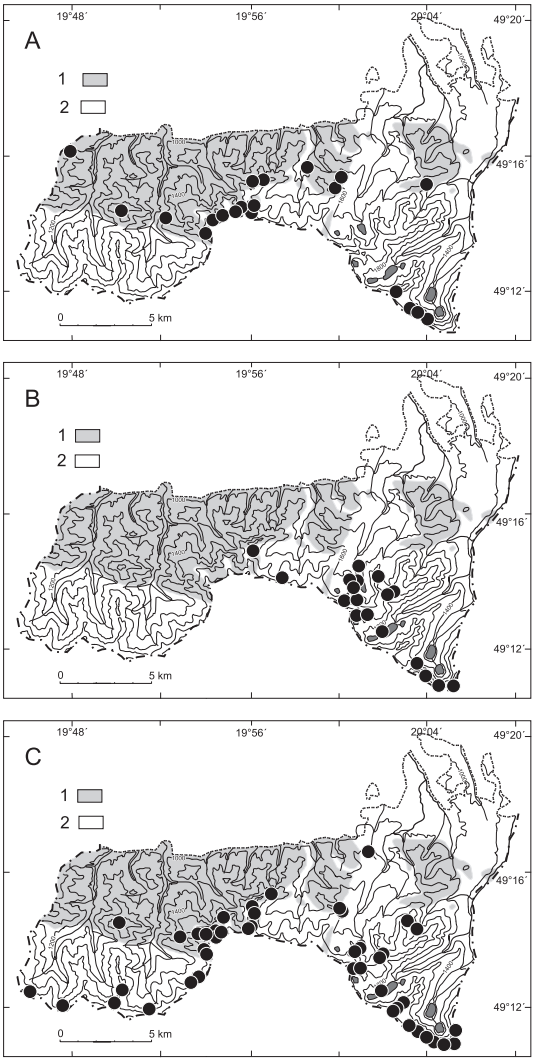


Fig. 18. Distribution of selected species in the Polish Tatra Mts. A – *Solorina bispora* Nyl., B – *Orphniospora moriopsis* (A. Massal.) D. Hawksw., C – *Thamnolia vermicularis* (Sw.) Schaer. 1 – calcareous substrate, 2 – non-calcareous substrate.

places permanently or periodically inundated or sprinkled with water that is rich in oxygen, i.e. on boulders in streams or on the banks of ponds, on rock near waterfalls etc. The distribution of aquatic lichens is also dependent on the chemical composition of substratum (Gilbert 1996; Gilbert & Giavarini 1997). Examples of calciphilous aquatic species are *Eiglera flavida* (Hepp) Hafellner, *Thelidium decipiens* (Nyl.) Kremp., *T. miniatum* (A. Massal. *ex* Körb.) Arnold and *Verrucaria elaeomelaena* (A. Massal.) Arnold; those on acidic substrata include *Ionaspis lacustris* (With.) Lutzoni, *Verrucaria aquatilis* Mudd, *V. hydrela* Ach., *V. funckii* (Spreng.) Zahlbr., *Aspicilia laevata* (Ach.) Arnold, *Bacidina inundata* (Fr.) Vězda and *Pseudosagedia chlorotica* (Ach.) Hafellner & Kalb., *Verrucaria hydrela* Ach.

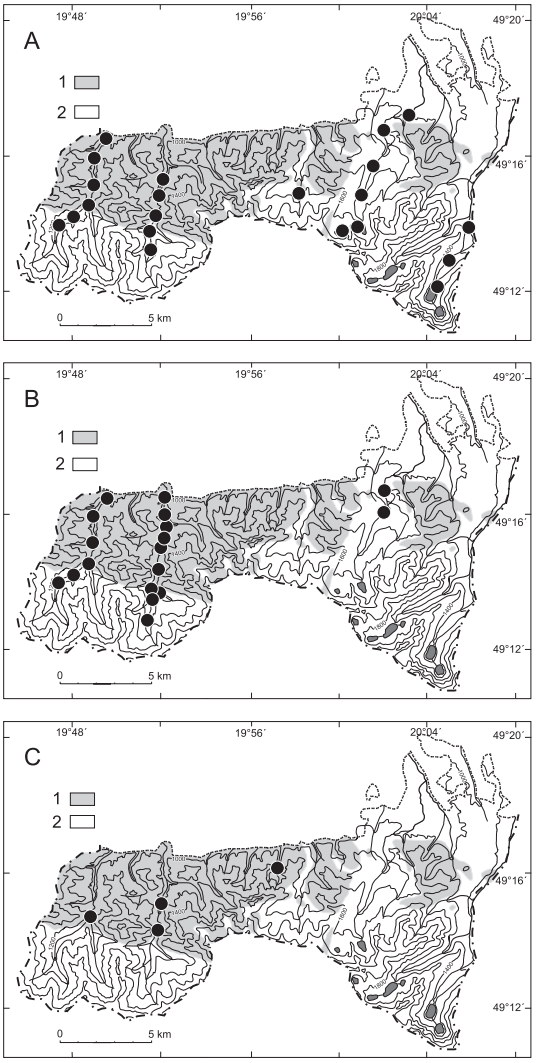


Fig. 19. Localities of selected aquatic species in the Polish Tatra Mts. A – *Verrucaria hydrela* Ach., B – *Verrucaria aquatilis* Mudd., C – *Verrucaria elaeomelanea* (A. Massal.) Arnold. 1 – calcareous substrate, 2 – non-calcareous substrate.

(Fig. 19A) and *V. aquatilis* Mudd (Fig. 19B) are examples of acidiphilous aquatic lichens in the Tatra Mts, where they occur at many localities along streams in both the High Tatra and Western Tatra Mts. Calciphilous aquatic lichens, such as *Verrucaria elaeomelaena* (A. Massal.) Arnold (Fig. 19C) due to the limited occurrence of their habitat, have only single scattered localities in the Western Tatra Mts (Krzewicka & Galas 2006). There is also a group of aquatic lichens, including *Verrucaria aethiobola* Wahlenb., *V. praetermissa* (Trevis.) Anzi, *V. rheitrophila* Zschacke, *Staurothele fissa* (Taylor) Zwackh, *S. fuscocuprea* (Nyl.) Zschacke, *Thelidium minutulum* Körb. and *Dermatocarpon luridum* (With.) J. R. Laundon, that develop on both acidic and basic substrata.

Geographical elements

Since knowledge of the world distribution of lichens, their origin and history is still fragmentary, a detailed lichenogeographical analysis of the Carpathians is very difficult. It is, however, possible to study the ranges of some more interesting groups of species occurring there as undertaken for other areas in Europe (Wirth 1995).

The Carpathians are dominated by Holarctic lichens whose general distribution is connected with the temperate and cool zones of the northern hemisphere. The group of high-mountain lichens is dominated by arctic-alpine species, also known from the arctic areas and higher mountain elevations in Europe, Asia and North America. These species usually occur at the highest mountain situations, mainly in the Tatra Mts, the only range of the alpine character in the whole Carpathian arch. To these species belong: *Nephroma arcticum* (L.) Torss., *Bryodina rhypariza* (Nyl.) Hafellner & Türk, *Allocetraria madreporiformis* (Ach.) Kärnefelt & Thell, *Rinodina roscida* (Sommerf.) Arnold, *R. turfacea* (Wahlenb.) Körb., *Lecanora leptaclina* Sommerf., and many others. In the Polish Carpathians the ranges of species representing this geographical element comprise also the highest peaks of Beskidy Zachodnie Mts, and particularly the massif of Babia Góra. Arctic-alpine species are also known from the Pieniny Mts; however, their localities in these mountains are considered as relic ones because of their situation at low altitudes (Tobolewski 1982). To these species belong: *Catapyrenium daedaleum* (Kremp.) Stein, *Myxobilimbia lobulata* (Sommerf.) Hafellner, *Rhizocarpon umbilicatum* (Ramond) Flagey, *Caloplaca sinapisperma* (Lam. & DC.) Maheu & Gillet and *Fulgensia schistidii* (Anzi) Poelt. In the Bieszczady Zachodnie Mts, the arctic-alpine element is also represented by few species, e.g. *Caloplaca ammiospila* (Wahlenb.) H. Olivier, *C. tiroliensis* Zahlbr., *Megaspora verrucosa* (Ach.) Hafellner & V. Wirth, *Rinodina mniaraea* (Ach.) Körb. and *Micarea lignaria* (Ach.) Hedl. Only in the much higher ranges of the Eastern Carpathians, e.g. in the Gorgany Mts and Czarnohora Mts in Ukraine, is the list of arctic-alpine species similar to that of the Tatra Mts. This list comprises such species as *Cladonia amaurocraea* (Flörke) Schaer., *Flavocetraria cucullata* (Bellardi) Kärnefelt, *F. nivalis* (L.) Kärnefelt, *Cornicularia normoerica* (Gunnerus) Du Rietz, *Sphaerophorus fragilis* (L.) Pers., *Cladonia macrophylla* (Schaer.) Stenh., *C. cyanipes* (Sommerf.) Nyl., *Thamnolia vermicularis* (Sw.) Schaer., *Massalongia carnosa* (Dicks.) Körb., *Umbilicaria crustulosa* (Ach.) Frey and *Solorina bispora* Nyl.

The boreal-mountain element is represented in the Carpathians by many montane lichen species. They have more or less continuous ranges in the whole Holarctica (e.g., Ahti 1977). They probably came to the Carpathians together with forest plant communities. This type of distribution is represented by, for example, *Mycoblastus sanguinarius* (L.) Norman, *Parmeliopsis hyperopta* (Ach.) Arnold, *Bryoria nadvornikiana* (Gyeln.) Brodo & D. Hawksw., *Hypogymnia vittata* (Ach.) Parrique, *Schismatomma pericleum* (Ach.) Branth & Rostr., *Chaenotheca chrysocephala* (Turner *ex* Ach.) Th. Fr., *Cladonia stellaris* (Opiz) Pouzar & Vězda and *Vulpicida pinastri* (Scop.) J.-E. Mattsson & M. J. Lai.

Of particular note are the subatlantic species which are characterized by their poor resistance to desiccation, occurring in areas of high air humidity, and therefore also in mountains. In Poland their distribution ranges from the western

part of the country, influenced by the atlantic climate, through the whole Carpathians far to the east. They are mainly epiphytic species, many of them rare and threatened with extinction, such as *Normandina pulchella* (Borrer) Nyl., *Thelotrema lepadinum* (Ach.) Ach., *Parmeliella triptophylla* (Ach.) Müll. Arg., *Leptogium saturninum* (Dicks.) Nyl., *Loxospora cismonica* (Beltr.) Hafellner, *Parmotrema chinense* (Osbeck) Hale & Ahti, *Hypotrachyna revoluta* (Flörke) Hale, *Heterodermia speciosa* (Wulfen) Trevis., *Flavoparmelia caperata* (L.) Hale, *Cliostomum griffithii* (Sm.) Coppins, *Ochrolechia subviridis* (Høeg) Erichsen and *Opegrapha viridis* (Pers. *ex* Ach.) Behlen & Deserger. Some of these species are currently in good condition only in the Eastern Carpathians where, as epiphytes of beech, alder and fir, they occur in old humid beech forests of a primaeval nature and in alder forests along streams. Two oceanic species, *Pannaria conoplea* (Ach.) Bory and *Bactrospora dryina* (Ach.) A. Massal., occur exclusively in the Eastern Carpathians.

Southern lichens of Central European-Mediterranean or Central European-sub-Mediterranean ranges occur in the Tatra Mts and Pieniny Mts, in areas of limestone and dolomite, from low situations to the alpine belt. These species are common in Southern Europe, while in Central Europe their localities are becoming increasingly rare (Clauzade & Roux 1985; Nimis 1993); only few species have localities to the north in Scandinavia. They grow mostly on rocky walls and ledges and in rocky crevices, in well-insolated and warm places sheltered from western and northern winds, usually south-facing. Some of these species occur only at higher altitudes in the Tatra Mts, e.g. *Squamarina lamarckii* (DC.) Poelt, *Protoparmeliopsis admontensis* (Zahlbr.) Hafellner and *Caloplaca aurea* (Schaer.) Zahlbr. For most of them, the optimum conditions of occurrence are at lower mountain elevations, between 700 and 900 m a.s.l. Only in the Tatra Mts does their occurrence extend to 1700 m a.s.l., with single localities situated even higher. This geographical element is represented by *Toninia tristis* (Th. Fr.) Th. Fr., *Lecanora reuteri* Schaer., *Psora vallesiaca* (Schaer.) Timdal and *Squamarina lentigera* (Weber) Poelt. In the Polish Carpathians some of these species occur only in the Pieniny Mts, e.g. *Psora testacea* Hoffm., *Toninia toniniana* (A. Massal.) Zahlbr. and *Lecania turicensis* (Hepp) Müll. Arg.; others, beyond the Tatra Mts and Pieniny Mts, occur also at single locations in the Beskidy Mts, such as *Synalissa symphorea* (Ach.) Nyl., *Peccania coralloides* (A. Massal.) A. Massal., *Placocarpus schaereri* (Fr.) Breuss and *Lecanora pruinosa* Chaub. Of other lichens common in Southern Europe, a large group of xerothermic species occur in the Carpathians, including *Placidium lachneum* (Ach.) de Lesd., *Endocarpon pusillum* Hedw., *Anema decipiens* (A. Massal.) Forssell, *Thyrea confusa* Henssen, *Placynthium subradiatum* (Nyl.) Arnold, *P. filiforme* (Garov.) M. Choisy, *Mycobilimbia lurida* (Ach.) Hafellner & Türk, *Toninia candida* (Weber) Th. Fr., *Cladonia symphycarpa* (Flörke) Fr., *Acarospora cervina* A. Massal., *Caloplaca coronata* (Kremp. *ex* Körb.) J. Steiner, *C. cirrochroa* (Ach.) Th. Fr., *Dirina stenhammari* (Fr. *ex* Stenh.) Poelt & Follmann, *Fulgensia fulgens* (Sw.) Elenkin and *F. schistidii* (Anzi) Poelt. The northern limit of their local ranges comprises the Gorce Mts, Beskid Sądecki Mts and southern part of Beskid Wyspowy Mts. These species probably migrated from the Pieniny Mts to the Beskid ranges along the Dunajec River valley. A large group of xerothermic lichens composed of species such as *Diploschistes muscorum* (Scop.) R. Sant., *Bacidia bagliettoana* (A. Massal. & De Not.) Jatta, *Staurothele hymenogonia* (Nyl.) Th. Fr. and *Synalissa symphorea* (Ach.) Nyl., scattered throughout the Carpathians, occur in areas offering the farourable edaphic and climatic conditions.

Changes in the lichen biota

The above-mentioned typical distribution patterns of different ecological and geographical groups of lichen in the Carpathians are often disturbed by both natural and anthropogenic factors. Natural factors include steep slopes of mountain peaks and stream valleys which allow the species of higher mountain elevations to move down. The progressive destruction of spruce stands in the upper montane forest belt, natural death of single old trees

which are often the only refuges of many species, and the destructive activity of periodically swollen streams are also examples of such natural factors. Furthermore, destructive natural floods, fires or windstorms change the natural environment over large areas, typified by the 1977 flood in the Tatra Mts and Podhale foreland and the windstorm and fire in the Slovakian Tatra Mts in 2004.

Anthropogenic factors which affect the lichen biota in the Carpathians, as well as in the whole of Poland and other European countries, are chemical pollution of air, water and soil, inappropriate forest management, changes in water resources, exploitation of rock, intensive agriculture, extension of overbuilt areas, construction of roads, and mass tourism. These factors may operate directly, destroying phytocoenoses with lichens, or indirectly, causing irreversible changes in the abiotic characteristics of the environment, as, for example, by the construction of a dam reservoir on the Dunajec rives near Czorsztyn and Sromowce Wyżnie villages, resulting in the decline of 51 lichen species in the Pieniny Mts. The same construction has become a serious threat to other lichen species (Kiszka 1997) since it is not known whether those species occurring in the protection zone of the reservoir will overcome the stress and adapt to new microclimatic conditions.

Significant anthropogenic impacts on the Carpathian forest communities have been observed, particularly in the forests of the foothill and lower montane belts. The natural forests of the foothills have for the most part been completely destroyed and within the lower montane belt, the tree layer has been thinned in the beech forests and the artificially introduced spruce has been colonized by common lichen species typical of coniferous forests. Simultaneously, the dense and strongly sheltered spruce or beech monocultures of lower mountain elevations are almost completely lacking in lichens.

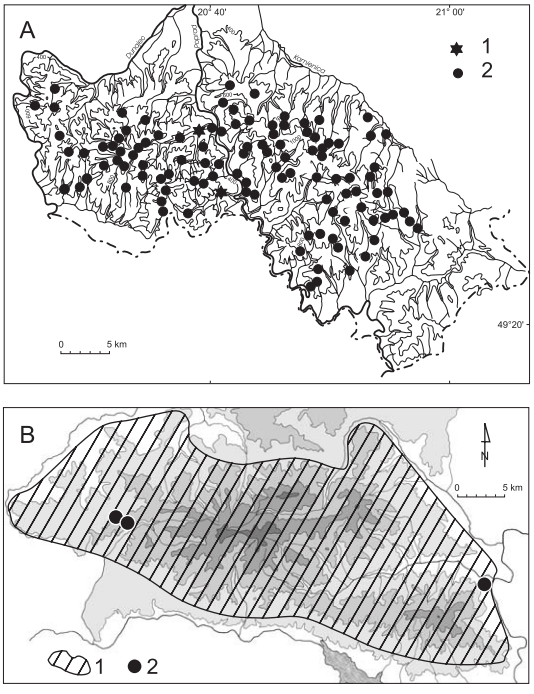
The effect of anthropogenic factors is not always destructive, as demonstrated by studies carried out in the Góry Sanocko-Turczańskie Mts, where as many as 60% of the known species, particularly epiphytes, are associated with, or adapted to, man-made habitats (Kościelniak 2004). Many rare and important forest species have survived, even increased their ranges, on fruit trees in abandoned orchards, including species considered as relics of primaeval forests and indicators of the naturalness of forests in lowland Poland (Czyżewska & Cieśliński 2003).

The current state of the lichen biota of the Carpathians is the result of two parallel processes: recession of certain lichen species and expansion of the others, as a response to changes in the natural environment. The results of studies carried out over the past 30 years show the extinction of certain lichen species, disappearance of localities and shrinkage of the ranges of many others (Śliwa 1998). These phenomena are concerned primarily with epiphytic and lignicolous lichens, and to a lesser extent with saxicolous and terricolous species. The most endangered species are stenotopic, and therefore of interest ecologically and geographically. Of the total number of the Polish Carpathian lichens, 47 species are considered extinct and most of these are epiphytic and lignicolous, among which species *Usnea* and *Bryoria* prevail.

Extinction of certain species in the Carpathians is accompanied by the expansion of others that is often due to the creation of new artificial substrata and phytocoenoses. The changes in the chemical properties of existing substrata, often correlated with environmental pollution, may result in the recession of certain species or enable the expansion of others. Lichens extending their ranges in the Carpathians are mostly acidophilous and nitrophilous epiphytes and calciphilous epiliths. The two commonest ubiquitous epiphytic species, *Lecanora conizaeoides* Nyl. *ex* Crombie (Fig. 20) and *Scoliciosporum chlorococcum* (Graewe *ex* Stenh.) Vězda spread significantly in the area of Polish Carpathians at the end of the 20th century. Species currently expanding their ranges are *Hypocenomyce caradocensis* (Leight. *ex* Nyl.) P. James & Gotth. Schneid. and *Chaenotheca ferruginea* (Turner & Borrer) Mig., more frequently observed on spruce, and *Pseudosagedia aenea* (Wallr.) Hafellner & Kalb and *Dimerella pineti* (Schrad. *ex* Ach.) Vězda, more frequently on beeches and sycamores. Another

lichen extending its range is *Fellhanera subtilis* (Vězda) Diederich & Sérus., a species growing on twigs of *Vaccinium*. The expansion of calciphilous lichens is also associated with the deposition of calcareous dust around cement works as well as with the creation of artificial calcareous habitats such as concrete constructions. The additional habitats suitable for colonization of calciphilous species are those created by natural factors such as the slopes of proglacial stream and river valleys and surfaces generated by erosion processes or by human activities such as brickworks, gravel pits, quarries, mine spoils and embankments.

The results of human activity are particularly marked in the epiphytic associations *Calicietum viridis*, *Ptatismatio glaucae-Ochrolechietum androgynae*, *Thelotremetum lepadini* and *Nephrometum levigatae*, their qualitative and quantitative impoverishment due to low tolerance to changes in ecological conditions. On the other hand, the associations of toxi-tolerant lichens, such as *Chaenothecetum ferrugineae*, *Lecanoretum conizaeoidis*, *Hypocenomycetum scalaris* and *Hypocenomycetum caradocensis*, show dynamic development, forming large patches on tree trunks (Bielczyk 1986, 2002, 2004).



Ryc. 20. Distribution of *Lecanora conizaeoides* Nyl. *ex* Crombie in some Carpathian ranges. A – Beskid Sądecki Mts: 1 – 1960/1970, 2 – 1980/90 (according to Śliwa 1998, updated); B – Gorce Mts: 1 – 1959/69, 2 – 1994/1997 (according to Czarnota 2000; Czarnota *et al*. 2005, updated).

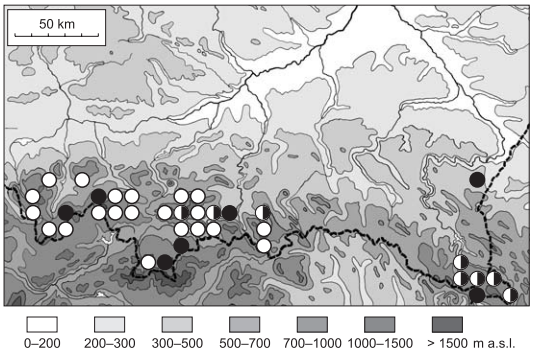


Fig. 21. Known localities of *Lobaria pulmonaria* (L.) Hoffm. in the Polish Carpathians. 1 – before 1980, 2 – after 1980, 3 – discovered before 1980 and confirmed after 1980.

As a result of the uneven level of anthropogenic transformation of the environment in the Carpathians, its impact on the lichen biota is also different in particular ranges. Generally, in the lowest situations most influenced by human activity, lichen biota are mostly affected in terms of both quality and quantity, especially on the westernmost Polish Carpathian ranges, while the Eastern Carpathians and the neighbouring Pogórze Przemyskie foothills and Beskid Niski Mts remain uninfluenced in terms of species diversity and condition of epiphytic lichens and their communities. The conservation state of the Carpathian forests is well-illustrated by the current distribution of *Lobaria pulmonaria* (L.) Hoffm., a lichen considered to be one of the best bioindicator of a stable environment (Fig. 21).

Conservation of lichens

Lichens are important when considering the conservation of biological diversity in the Carpathians. An indicator of the lichenological value of the Polish Carpathians is not only the number of species occurring there but also the presence of lichens of special conservation interest, namely

rare and threatened species. The Carpathians harbour almost 80% of the species included in the red list of endangered lichens of Poland (Cieśliński *et al*. 2003). Particular categories of threat are represented as follows: critically endangered (CR) – 151 species, endangered (EN) – 181, vulnerable (VU) – 146, near threatened (NT) – 66, lesser concern (LC) – 20, and data deficient (DD) – 84. Many of these species are frequent inhabitants of the Carpathians, showing no symptoms of lowered vitality and locally seem less threat than in other parts of the country. The Carpathians are also of lichenological importance in terms of the number of legally protected species found there, with 212 species under strict protection and 9 species under partial protection in Poland. Some of these species occur in the Carpathians in good condition, showing no features of degeneration, and often form large populations (e.g., Kiszka & Kościelniak 2001, 2004). The presence of relics of the former primeval forest increase a lichenological value of the Carpathians, since they support well-developed associations, dominated by large foliose lichens, mostly epiphytes, as well as interesting lignicolous species. Thanks to the highly natural character of many forest communities and large accumulation of dead wood (including large tree trunks), the Carpathians are one of the most important refuges for many rare and threatened lichen species in Poland, added to which they contribute high mountain elements, and particularly arctic-alpine ones, concentrated in the Tatra Mts and in the highest parts of the Beskidy Mts. Sub-Mediterranean species and their associations, occurring mainly in the Pieniny Mts and in the limestone part of the Western Tatra Mts are also worthy of notice.

Lichen conservation should be considered in terms of conserving hot spots of species diversity and abundance and of sites with unique biota and of entire biocoenoses containing such taxa (Scheidegger *et al*. 1995; Scheidegger & Clerc 2002). Conservation of species that are rare, threatened, legally protected, occurring at the limits of their ranges etc. may in fact be related to the conservation of their habitat. Many lichen species have found suitable conditions for their survival until now in those protected areas of the Carpathians which enable conservation of the whole ecosystems and phytocoenoes, including species with their habitats. As already mentioned, there are currently six national parks, some tens of nature reserves and seven landscape parks in the Polish Carpathians. Part of the Polish Carpathians has been designated for the conservation of biological diversity on a supranational scale. There are also three UNESCO-MAB biosphere reserves (Babia Góra Biosphere Reserve, Tatra Biosphere Reserve and the Biosphere Reserve of the Eastern Carpathians), as well as 11 Important Plant Areas (IPA) and 16 Natura 2000 sites. The Carpathians are in the European network of important areas for conservation of species diversity of all groups of flora and phytocoenoses in Europe, and their national parks contain many lichen species (Fig. 22), particularly in the nature reserves (e.g., Krzewicka

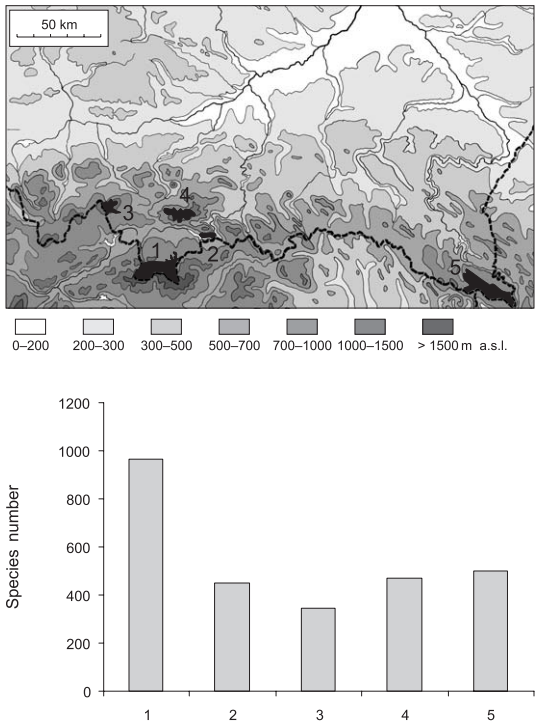


Fig. 22. Number of lichen species in five national parks in the Polish Carpathians. 1 – Tatra National Park, 2 – Pieniny National Park, 3 – Babia Góra National Park, 4 – Gorce National Park, 5 – Bieszczady National Park.

& Śliwa 2000; Czarnota 2002; Bielczyk & Betleja 2003; Kiszka 2005; Kościelniak 2005; Kościelniak & Kiszka 2005).

ACKNOWLEDGEMENTS. I am greatly indebted to Mark R. D. Seaward (Bradford) for very valuable comments on the manuscript and for kindly checking the English, and to Zbigniew Mirek (Kraków) for valuable help in carrying out the research and constructive remarks on the manuscript. Special thanks are also due to Adam Flakus, Marian Wysocki and Jacek Wieser (Kraków), for technical assistance with figures, and to Lucyna Śliwa and Beata Krzewicka (Kraków) for their kind support and cooperation. This work was supported by the Ministry of Science and Information Society Technologies in Poland (MNiI) for the years 2005–2007, grant no. 2 P04G 015 28.

REFERENCES

AHTI T. 1977. Lichens of the Boreal Coniferous Zone. In: M. R. D. SEAWARD (ed.), *Lichen Ecology*, pp. 145–181. Academic Press, London, New York, San Francisco.

APTROOT A. & SEAWARD M. R. D. 2003. Freshwater lichens. *Fungal Diversity Research Series* **10**: 101–110.

BIELCZYK U. 1986. Epiphytic lichen-dominated communities in the Western Beskidy Mountains, Western Carpathians. *Fragm. Florist. Geobot*. **30**(1): 3–89 & Tabs 1–24 (in Polish with English summary).

BIELCZYK U. 1993a. *Bryophagus gloeocapsa* Nitsche *ex* Arnold. In: S. CIEŚLIŃSKI & W. FAŁTYNOWICZ (eds), *Atlas of the geographical distribution of lichens in Poland.* **1**: 9–15. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

BIELCZYK U. 1993b. *Petractis clausa* (Hoffm.) Krempelh. In: S. CIEŚLIŃSKI & W. FAŁTYNOWICZ (eds), *Atlas of the geographical distribution of lichens in Poland.* **1**: 47–50. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

BIELCZYK U. 2002. Epiphytic lichen-dominated communities on spruce bark in the upper montane of the Tatra Mts. In: W. BOROWIEC, A. KOTARBA, A. KOWNACKI, Z. KRZAN & Z. MIREK (eds), *Changes of the Nature Environment of the Tatra Mountains*, pp. 187–190. Tatrzański Park Narodowy, Polskie Towarzystwo Przyjaciół o Ziemi, Oddział Kraków, Kraków – Zakopane (in Polish with English summary).

BIELCZYK U. (ed.) 2003a. The lichens and allied fungi of the Polish Carpathians – an annotated checklist. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

BIELCZYK U. 2003b. The lichens and allied fungi of the Polish Western Carpathians. In: U. BIELCZYK (ed.), *The lichens and allied fungi of the Polish Carpathians – an annotated checklist*, pp. 23–232. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

BIELCZYK U. 2004. Lichen species diversity of the Babiogórski National Park. In: B. W. WOŁOSZYN, A. JAWORSKI & J. SZWAGRZYK (eds), *The Nature of the Babiogórski National Park*, pp. 285–314. Komitet Ochrony Przyrody PAN, Babiogórski Park Narodowy, Kraków (in Polish with English summary).

BIELCZYK U. 2006a. Distribution of calciphilous lichens in Poland. In: A. LACKOVIČOVÁ, A. GUTTOVÁ, E. LISICKÁ & P. LIZOŇ (eds), *Central European Lichens – diversity and threat*, Mycotaxon Ltd, Ithaca (in press).

BIELCZYK U. 2006b. Lichens of the Tatra Mountains: The state of knowledge and prospective studies. In: W. BOROWIEC, A. KOTARBA, A. KOWNACKI, Z. KRZAN & Z. MIREK (eds), *Changes of the Nature Environment of the Tatra Mountains*. Tatrzański Park Narodowy, Polskie Towarzystwo Przyjaciół o Ziemi, Oddział Kraków, Kraków – Zakopane (in Polish with English summary) (in press).

BIELCZYK U. & BETLEJA L. 2003. The lichens of the 'Bór na Czerwonem' raised peat-bog in the Orawa-Nowy Targ Basin (southern Poland). *Polish Bot. J.* **48**(1): 69–75.

BIELCZYK U., LACKOVIČOVÁ A., FARKAS E. E., LŐKÖS L., LIŠKA J., BREUSS O. & KONDRATYUK S. YA. 2004. Checklist of lichens of the Western Carpathians. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

CIEŚLIŃSKI S. & CZYŻEWSKA K. 1991. Threatened lichens in Poland and their conservation. *Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich* **106**: 133–149.

CIEŚLIŃSKI S. & FAŁTYNOWICZ W. 1993. Note from Editors. In: S. CIEŚLIŃSKI & W. FAŁTYNOWICZ (eds), *Atlas of the geographical distribution of lichens in Poland.* **1**: 7–8. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

CIEŚLIŃSKI S., CZYŻEWSKA K. & FABISZEWSKI J. 2003. Red List of extinct and threatened lichens in Poland. In: K. CZYŻEWSKA (ed.), *The threat to lichens in Poland. Monogr. Bot*. **91**: 13–49 (in Polish with English abstract).

CLAUZADE G. & ROUX C. 1985. Likenoj de Okcidenta Europo. Ilustrita determinlibro. *Bull. Soc. Bot. Cetre-Ouest. Numero Spécial* **7**: 1–893.

CZARNOTA P. 2000. The lichens of the Gorce National Park. Part I. List and distribution of the lichen species. *Parki Narodowe i Rezerwaty Przyrody* **19**(1): 3–73 (in Polish with English summary).

CZARNOTA P. 2002. Lichens of the 'Żebracze' nature reserve in Beskid Sądecki Mts (Carpathians, Western Beskidy, S Poland). *Parki Narodowe i Rezerwaty Przyrody* **21**(4): 385–410 (in Polish with English abstract).

CZARNOTA P. 2004. *Opegrapha gyrocarpa* Flot. In: U. BIELCZYK, S. CIEŚLIŃSKI & W. FAŁTYNOWICZ (eds), *Atlas*

of the geographical distribution of lichens in Poland. **4**: 59–63. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Czarnota P., Glanc K. & Nowak J. 2005. Materials to the biota of lichens housed in the Herbarium Instituti Botanici of the Polish Academy of Sciences in Kraków. *Fragm. Florist. Geobot. Polonica* **12**(2): 327–370 (in Polish with English summary).

Czyżewska K. & Cieśliński S. 2003. Lichens – indicators of lowland old-growth forests in Poland. In: K. Czyżewska (ed.), *The threat to lichens in Poland. Monogr. Bot*. **91**: 223–239 (in Polish with English abstract).

Fałtynowicz W. 2003. The lichens, lichenicolous and allied fungi of Poland – an annotated checklist. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Flakus A. & Bielczyk U. 2006. New and interesting records of lichens from the Tatra Mountains. In: A. Lackovičová, A. Guttová, E. Lisická & P. Lizoň (eds), *Central European Lichens – diversity and threat.* Mycotaxon Ltd, Ithaca (in press).

Gilbert O. L. 1996. The lichen vegetation of chalk and limestone streams in Britain. *Lichenologist* **28**(2): 145–159.

Gilbert O. L. & Giavarini V. J. 1997. The lichen vegetation of acid watercourses in England. *Lichenologist* **29**(4): 347–367.

Groch J., Kurek W. & Warszyńska J. 2000. Tourist regions in the Polish Carpathians. Universitas, Kraków.

Kiszka J. 1997. Lichens on the bottom and surroundings of the water retention reservoirs in the Dunajec River Valley in the Pieniny Mts (Western Carpathians). *Fragm. Florist. Geobot. Ser. Polonica* **4**: 253–323 (in Polish with English summary).

Kiszka J. 2003. The specificity of altitudinal occurrence of lichens in the Bieszczady National Park. *Roczniki Bieszczadzkie* **11**: 87–93.

Kiszka J. 2005. Lichens of the Biała Woda nature reserve in the Małe Pieniny Mts (Western Carpathians). *Polish Botanical Studies* **19**: 177–188.

Kiszka J. & Kościelniak R. 2001. Preservation of *Lobaria pulmonaria* and the *Lobarion* alliance in the Polish part of the International Biosphere Reserve 'Eastern Carpathians'. *Roczniki Bieszczadzkie* **9**: 33–52 (in Polish with English summary).

Kiszka J. & Kościelniak R. 2004. Species from the Red List of extinct and threatened in Poland and their viability in the Polish Eastern Carpathians. *Roczniki Bieszczadzkie* **12**: 15–31 (in Polish with English summary).

Kiszka J. & Piórecki J. 1991. Lichens of the Przemyśl Foothill. Uniwa, Warszawa (in Polish with English summary).

Kiszka J. & Piórecki J. 1992. The lichens of the Słonne Mts in the Polish Eastern Carpathians. Zakład Fizjografii i Arboretum w Bolestraszycach, Bolestraszyce (in Polish with English summary).

Kondracki J. 1989. Karpaty. Ed. 2. Wydawnictwo Szkolne i Pedagogiczne, Warszawa.

Kondracki J. 2001. Geografia regionalna Polski. Ed. 2. Wydawnictwo Naukowe PWN, Warszawa.

Kondratyuk S. Y., Popova L. P., Lackovičová A. & Pišút I. 2003. A catalogue of Eastern Carpathian Lichens. M. H. Kholodny Institute of Botany, National Academy of Sciences of Ukraine & Institute of Botany Slovak Academy of Sciences, Kiv – Bratislava.

Kościelniak R. 2004. The lichens of the Bieszczady Niskie Mts. *Fragm. Florist. Geobot. Ser. Polonica, Suppl.* **5**: 3–164 (in Polish with English summary).

Kościelniak R. 2005. Lichen refuge in the Smorż stream valley near Ustrzyki Dolne. *Roczniki Bieszczadzkie* **13**: 249–260 (in Polish with English summary).

Kościelniak R. & Kiszka J. 2003. The lichens and allied fungi of the Polish Eastern Carpathians. In: U. Bielczyk (ed.), *The lichens and allied fungi of the Polish Carpathians – an annotated checklist*, pp. 233–294. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Kościelniak R. & Kiszka J. 2005. A supplement to the lichen checklist of the Eastern Carpathians. *Roczniki Bieszczadzkie* **13**: 235–244.

Krzewicka B. 2004. The lichen genera *Lasallia* and *Umbilicaria* in the Polish Tatra Mts. *Polish Botanical Studies* **17**: 1–88.

Krzewicka B. & Galas J. 2006. Ecological notes on *Verrucaria aquatilis* and *V. hydrela* in the Polish Tatry Mountains. In: A. Lackovičová, A. Guttová, E. Lisická & P. Lizoň (eds), *Central European Lichens – diversity and threat*. Mycotaxon Ltd, Ithaca (in press).

Krzewicka B. & Śliwa L. 2000. Lichens of the Prządki nature reserve near Krosno (Pogórze Dynowskie Foothills, Carpathians). *Ochr. Przyr*. **57**: 51–58 (in Polish with English summary).

Leśniański G. 2004. *Placynthium nigrum* (Hads.) Gray. In: U. Bielczyk, S. Cieśliński & W. Fałtynowicz (eds), *Atlas of the geographical distribution of lichens in Poland.* **4**: 69–79. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Lisická E. 2005. The lichens of the Tatry Mountains. VEDA, Slovak Academy of Sciences, Bratislava.

Mirek Z. & Piękoś-Mirkowa H. 1992a. Contemporary threat to the vascular flora of the Polish Carpathians (S. Poland). *Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich* **107**: 151–162.

Mirek Z. & Piękoś-Mirkowa H. 1992b. Plant cover of the Western Carpathians (S. Poland). *Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich* **107**: 116–150.

Nimis P. L. 1993. The lichens of Italy. An annotated catalogue.

Monografie **12**: 1–897. Museo Regionale di Scienze Naturali, Torino.

NOWAK J. 1972. Problems of the distribution of lichens in the Polish Western Beskids. (Silesia-Babia Góra subdistrict). *Fragm. Florist. Geobot*. **18**(1): 45–143 (in Polish with English summary).

OLECH M. 1972. Lichens of the Radziejowa Range (Polish Western Carpathians). *Fragm. Florist. Geobot*. **18**(3–4): 359–398 (in Polish with English summary).

OLECH M. 1973. Lichens of the Beskid Sądecki Mts (Western Carpathians). *Zesz. Nauk. Univ. Jagiellon., Prace Bot.* **1**: 87–192 (in Polish with English summary).

OLECH M. 2004. Lichens of the Tatra National Park. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

POELT J. 1983. *Bryonora*, eine neue Gattung der Lecanoraceae. *Nova Hedwigia* **38**: 73–111.

SCHEIDEGGER C. & CLERC P. 2002. Rote Liste der gefährdeten Arten der Schweiz: Baum- und erdbewohnende Flechten. Hrsg. Bundesamt für Umwelt, Wald und Landschaft BUWAL, Bern, und Eidgenössische Forschungsanstalt WSL, Birmensdorf, und Conservatoire et Jardin botaniques de la Ville de Genève CJBG. BUWAL-Reihe Vollzug Umwelt.

SCHEIDEGGER C., WOLSELEY P. A. & THOR G. (eds). 1995. Conservation Biology of Lichenised Fungi. *Mitteilungen der Eidgenössischen Forschungsanstalt für Wald, Schnee und Landschaft* **70**(1): 1–173.

ŚLIWA L. 1998. Anthropogenic changes in the lichen flora of the Beskid Sądecki Mts (Southern Poland). *Zesz. Nauk. Univ. Jagiellon., Prace Bot.* **31**: 7–158 (in Polish with English summary).

ŚLIWA L. 2000. The use of lichens for estimation of environmental changes in the Beskid Sądecki Mts. (Southern Poland). *Ochr. Przyr*. **57**: 41–49 (in Polish with English summary).

TOBOLEWSKI Z. & KUPCZYK B. 1976. Lichens (Lichenes). In: J. SZWEYKOWSKI & T. WOJTERSKI (eds), *Atlas of geographical distribution of spore plants in Poland*, *Ser. III* **3**: 1–35 + 10 maps. Państwowe Wydawnictwo Naukowe, Warszawa – Poznań.

TOBOLEWSKI Z. 1979. Lichens (Lichenes). In: J. SZWEYKOWSKI & T. WOJTERSKI (eds), *Atlas of geographical distribution of spore plants in Poland*, *Ser. III* **5**: 1–30 + 10 maps. Państwowe Wydawnictwo Naukowe, Warszawa – Poznań.

TOBOLEWSKI Z. 1981. Lichens (Lichenes). In: J. SZWEYKOWSKI & T. WOJTERSKI (eds), *Atlas of geographical distribution of spore plants in Poland*, *Ser. III* **7**: 1–37 + 10 maps. Państwowe Wydawnictwo Naukowe, Warszawa – Poznań.

TOBOLEWSKI Z. 1982. Porosty. In: K. ZARZYCKI (ed.), *Przyroda Pienin w obliczu zmian*. *Studia Naturae* **30**: 173–188.

TOBOLEWSKI Z. 1988. Lichens (Lichenes). In: J. SZWEYKOWSKI & T. WOJTERSKI (eds), *Atlas of geographical distribution of spore plants in Poland*, *Ser. III* **9**: 1–47 + 10 maps. Państwowe Wydawnictwo Naukowe, Warszawa – Poznań.

TOWPASZ K. & ZEMANEK B. 1995. Flora and vegetation. In: J. WARSZYŃSKA (ed.), *The Polish Carpathians – nature, man and his activities*, pp. 77–93. Uniwersytet Jagielloński, Kraków (in Polish with English summary).

WIRTH V. 1995. Die Flechten Baden-Württembergs. Teil 1, 2. E. Ulmer, Stuttgart.

ZEMANEK B. 1992. The phytogeographical character of the north-western part of the Eastern Carpathians (S.E. Poland). In: K. ZARZYCKI, W. LANDOLT & J. J. WÓJCICKI (eds), *Contributions to the knowledge of flora and vegetation of Poland. Veröff. Geobot. Inst. ETH, Stiftung Rübel, Zürich* **107**: 265–280.

Received 3 February 2006