We would like to dedicate this book to the memory
of
Professor Zygmunt Tobolewski
(1927-1988),
on the 60th anniversary of the release of his first scientific publication regarding the lichens in the area of Łagowo in Lubusz Land

Książkę tę poświęcamy pamięci
Profesora Zygmunta Tobolewskiego
(1927-1988)
w 60. rocznicę ukazania się Jego pierwszej publikacji naukowej dotyczącej porostów okolic Łagowa na Ziemi Lubuskiej

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Lichen protection
- Lichen protected species

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Druk

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PREFACE

Lichens, i.e. lichenified fungi, are the fixed components of almost all known ecosystems. Despite the diversity of their morphological and ecological forms as well as their capability of colonising extreme habitants, they remain generally little-known. Unnoticed, they live next to us and usually, also unnoticed, they disappear or die out as a result of the changes, which directly or indirectly are caused by anthropopression. This problem has already been noticed and discussed by lichenologists for years. Postulates on the need to protect this group of organisms have also appeared. However, very rarely have they found any understanding among the persons and institutions directly responsible for the management of natural resources. In order to educate about the scale of the danger to these organisms, national and local Red Lists of endangered lichens have been created. The data included in them have been, to a great extent, the basis for the setting forth of the subsequent protective postulates.

So far only in several countries have lichens been granted the status of legally protected organisms - on the basis of provisions in legal statutes. Poland has significant achievements within this sphere. The number and extent of the legally protected species lists have been defined, approved and released to the public from many years. The formation of facilities, wherein the main objects of legal protection are lichens and the main task is the preservation of the populations of endangered species and species under extinction, is unprecedented. This follows the understanding of the biocenotic role of these organisms, the awareness of the fact that there are no unnecessary and redundant organisms growing in nature. Proper functioning of the ecosystems depends on the presence of all, directly or indirectly connected, elements. Such elements also include lichens. On the other hand, on the basis of the peculiar "feedback", in the well preserved and little distorted ecosystems there are proper conditions for the existence of various populations forming permanent communities. This is the main reason why the best preserved and the most abundant populations of the endangered lichens grow in the natural wilderness forests. Certainly, the presence of these lichens, similarly as of other organisms, is concurrently the guarantee of sustainability of these forests. The same phenomenon may be described in relation to the epilithic lichens, growing on natural rocks.

A great number of lichenologists conduct research in the national and landscape parks as well as nature reserves. The lichens constitute the natural component only of the superficial legally protected places. This direction of research enables familiarisation in detail with the dynamics and conditions of vegetation of the most complex lichens in the damaged environments to a lesser extent than anywhere else. Many papers included in this book are devoted to this issue. Proper interpretation of the results of these studies constitutes the basis for covering with protection not only the subsequent parts of forests or peat lands, but also, for instance, buffer and road strips in the strongly economically transformed areas where lichens are also present. This will be the protection of places - the peculiar refugium - from which the most sensitive and endangered lichens "will be able to return" to the forest ecosystems when the hazards to their vegetation currently present there have been eliminated. Such phenomena of "returns" of the lichens are already a fact and they also constitute the subject of several papers included in this book. Some of the authors - mainly in understanding with the representatives of the forest administration – provide information on their activities intended to protect the places in which they have proved the presence of protected and endangered lichens by means of their research.

The book also presents the results of the activities intended to protect lichens outside the borders of Poland. It presents the list of legally protected lichens in Hungary and endangered lichens in the selected protected places in Russia. Moreover, it also depicts the effects of activities of the Polish lichenologists in the Antarctic. Due to their initiative, practical protection of valuable (not exclusively for the purpose of lichens) places was implemented.

A separate and very interesting issue covered by this book is also the condition of the lichens protected and endangered on a national scale which grow in the strongly transformed places, e.g. in the cities or in their suburbs as well as in the post-industrial areas.

Contemporary research methods, including the molecular and chemical ones, enable, inter alia, the conduct of taxonomic revisions and study genetic connections of the protected and endangered taxons. It is a particularly valuable and important research trend of contemporary lichenology. Its results may contribute to the establishment of more effective protective activity, securing the existence of these organisms.

This book is fully devoted to the issues connected with the protection of lichens as well as species of protected and endangered lichens, and it will be presented at the XXVI Polish Lichenologists Convention that will take place on 11-14 September 2012 in the "Bory Lubuskie" Forest Promotion Complex within the framework of the conference to be held under the banner of "Protection of lichens - protected lichens".

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Gorzów Wielkopolski, May 2012.
Ludwik Lipnicki

PRZEDMOWA

Porosty, czyli grzyby zlichenizowane, są stałymi składnikami prawie wszystkich znanych ekosystemów. Mimo różnorodności form morfologicznych i ekologicznych oraz zdolności do kolonizowania skrajnych siedlisk, w obiegowej opinii pozostają organizmami mało znanymi. Niezauważane żyją obok nas i przeważnie też niezauważalnie zanikają lub wymierają przeważnie pod wpływem zmian, jakie bezpośrednio lub pośrednio powodowane są antropopresją. Problem ten już od wielu lat był zauważany i dyskutowany w gronie lichenologów. Od dawna też pojawiały się postulaty o potrzebie ochrony tej grupy organizmów. Jednak bardzo rzadko znajdowały one zrozumienie u osób i instytucji odpowiedzialnych bezpośrednio za gospodarowanie zasobami przyrody. Dla uświadomienia skali zagrożenia tych organizmów tworzone są krajowe i lokalne Czerwone Listy porostów zagrożonych. Zawarte w nich dane w znacznej mierze były podstawą do wysuwania kolejnych postulatów ochronnych.

Dotychczas tylko w nielicznych krajach porosty zyskały status organizmów prawnie chronionych – w oparciu o zapisy w rządowych aktach prawnych. Polska ma w tym zakresie znaczące osiągnięcia. Już od wielu lat są tworzone, zatwierdzane i podawane do publicznej wiadomości kolejne, coraz obszerniejsze listy gatunków prawnie chronionych. Bezprecedensowe jest powoływanie obiektów, w których głównym przedmiotem prawnej ochrony są porosty, a celem – zachowanie populacji gatunków ginących i zagrożonych. Wynika to ze zrozumienia biocenotycznej roli tych organizmów; coraz większa jest świadomość, że w przyrodzie nie ma organizmów niepotrzebnych, zbędnych. Prawidłowe funkcjonowanie ekosystemów zależne jest od obecności wszystkich, pośrednio lub bezpośrednio powiązanych ze sobą elementów. Są wśród nich także porosty. Z kolei, na zasadzie swoistego „sprzężenia zwrotnego", w dobrze zachowanych i mało odkształconych ekosystemach istnieją właściwe warunki do egzystencji różnorodnych populacji tworzących trwałe zbiorowiska. To przede wszystkim z tego powodu najlepiej zachowane i najbogatsze populacje zagrożonych porostów rosną w lasach o puszczańskim charakterze. Zapewne obecność tych porostów, podobnie jak i innych występujących tam organizmów, jest jednocześnie gwarantem trwałości tych lasów. O podobnym zjawisku można też mówić w odniesieniu do porostów epilitycznych, żyjących na naturalnych skałach.

Liczna grupa lichenologów prowadzi badania w parkach narodowych i krajobrazowych oraz w rezerwatach przyrody. Lichenobiota stanowi naturalny składnik tych wielkopowierzchniowych obiektów prawnie chronionych. Ten kierunek badań umożliwia dokładne poznanie dynamiki i warunków wegetacji najbardziej zagrożonych porostów w środowiskach odkształconych w mniejszym stopniu niż gdzie indziej. Wiele prac zamieszczonych w tej książce poświęconych jest temu zagadnieniu. Właściwe zinterpretowanie wyników tych badań jest podstawą do obejmowania ochroną nie tylko kolejnych fragmentów lasów lub torfowisk, ale też np. zadrzewień śródpolnych i przydrożnych w obszarach silnie przekształconych gospodarczo, w których porosty również występują. Będzie to ochrona miejsc – swoistych refugiów – skąd najbardziej wrażliwe i zagrożone porosty „będą mogły powrócić" do ekosystemów leśnych, gdy już ustaną panujące tam obecnie zagrożenia ich wegetacji. Takie zjawiska „powrotów" porostów są już faktem i stanowią również temat kilku prac zamieszczonych w tej książce. Niektórzy autorzy – przeważnie w porozumieniu z przedstawicielami administracji leśnej – informują o swoich działaniach zmierzających do obejmowania ochroną obiektów, w których swoimi badaniami wykazali obecność chronionych i zagrożonych porostów.

W książce prezentowane są także wyniki działań w kierunku ochrony porostów poza granicami Polski. Prezentowana jest lista prawnie chronionych porostów na Węgrzech oraz zagrożonych porostów w wybranych obiektach chronionych Rosji. Przedstawione są także efekty działalności polskich lichenologów w Antarktyce. Z ich inicjatywy została wdrożona w życie praktyczna ochrona cennych (w tym też i ze względu na porosty) obszarów.

Osobnym, bardzo interesującym zagadnieniem poruszanym także w tej książce jest stan chronionych i zagrożonych w skali kraju porostów żyjących w miejscach silnie zmienionych, np. w miastach i na ich obrzeżach oraz na terenach poprzemysłowych.

Współczesne metody badawcze, w tym molekularne i chemiczne, umożliwiają między innymi przeprowadzenie rewizji taksonomicznych oraz powiązań genetycznych taksonów chronionych i zagrożonych. Jest to szczególnie cenny i ważny nurt badawczy współczesnej lichenologii. Jego wyniki mogą przyczynić się do wypracowania skuteczniejszych działań ochronnych i zabezpieczających byt porostów.

Niniejsza książka, która w całości poświęcona jest zagadnieniom związanym z ochroną porostów, a także wybranym gatunkom porostów chronionych i zagrożonych, będzie prezentowana także podczas XXVI Zjazdu Lichenologow Polskich, który odbędzie się w dniach 11-14 września 2012 roku na terenie Leśnego Kompleksu Promocyjnego „Bory Lubuskie" w ramach konferencji pod hasłem „Ochrona porostów – porosty chronione".

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Ludwik Lipnicki

WHY CONSERVE LICHENS?

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Abstract. There is an increasing need to pay attention to the conservation of rare and endangered lichens in view of the destruction of many habitats on a local, regional, national or global scale. Since most lichens are sensitive to various kinds of environmental pollution, lichen protection should aim mainly at the conservation of their habitats and regulation of pollution. It is essential that information on the vital ecological functions of lichens and their economic importance is provided for a general audience. Hitherto, conservation efforts have been directed mainly towards the visually more striking macrolichens, with basic activities including the collection of distribution and ecological data into regional and national databases, on the basis of which Red Lists comprised of condensed information of threatened, endangered, etc. species can be drawn up. From such lists, it appears that some ecological groups are more vulnerable than others, such as lichens on large logs in virgin and old-growth forests, and lichens of peat bogs, marshland, boggy forests, sand dunes, moorlands, heathlands and old permanent pastures on soils poor in nutrients, and lichens in forests subjected to acidification and/or nitrogen accumulation from air pollution. There is a wealth of evidence to show the decline, and indeed disappearance, of lichens due to the above factors, but the effects of over-zealous collecting for economic and cultural, and indeed scientific, purposes have been less critically investigated by means of environmental monitoring.

Key words: conservation, red lists, environmental sensors, lichen-rich ecosystems, lichen sensitivity, environmental impact assessment

INTRODUCTION

There is a wealth of evidence to show that lichens are greatly affected by environmental disturbance, of both natural and human origin. In consequence, habitats and ecosystems are destroyed not only at a local and regional level, but also on a global scale. The deterioration of lichen floras, reduction in biodiversity and the loss of specific lichen taxa due to natural disasters are beyond our control, but such losses are exacerbated by human mismanagement, particularly as a result of deforestation, agricultural practices and a wide variety of atmospheric pollutants, the latter contributing significantly to global warming, the effects of which are currently being detected by shifts in the ecology and distribution of many lichens. It is therefore increasing urgent to conserve rare and endemic lichen species, but in order to address this, it is necessary to have a detailed understanding of the status of the targeted species, a difficult task where ecological and distributional data are incomplete.

It is debatable as to whether habitats or species should be of primary concern: on the one hand, lichen conservation should aim at conserving habitats and regulating pollution and, on the other, red lists of threatened species need to compiled, as is in the case of many European countries; however, it should be noted that some lists are constructed to cater for political/national interests rather than being based on natural geographical/ecological principles (cf. SÉRUSIAUX 1989). Ideally, both approaches are clearly necessary. A review of the principles and priorities of lichen conservation is provided by SEAWARD (1982) and more detailed accounts of practices employed in the measurement of biodiversity and the maintenance of lichen habitats are given in SCHEIDEGGER et al. (1995). Undoubtedly, the maintenance of threatened species and lichen biodiversity in general depends on good management practices. In assessing lichen loss, one should not overlook human needs, such as the collection of lichens for medicinal use (RICHARDSON 1988), but there is also over-zealous collecting of material for economic (e.g. curries) and cultural (e.g. wreaths, decorations, models) purposes (RICHARDSON 1991) and, often more alarmingly, of rarities for reference collections (herbaria and exsiccatae).

Undoubtedly, human beings are currently the paramount agents of lichen destruction, by causing disturbance of ecosystems worldwide, through deforestation, agricultural practices, urbanization, pollution of air, water and soil, and exploitation of natural resources. It has often proved difficult to make a convincing case to justify the conservation of lichens when weighed against other pressing needs (SEAWARD 1982), but numerous measures are currently being explored and practised worldwide to counteract this (SCHEIDEGGER et al. 1995). However, lichens form such an important component of the complex web of life that their disappearance affects the balance of nature to a surprising degree. This is particularly the case in tundra zones, high altitudes, cold deserts, dune systems, semi-arid lands and deserts, and even urban areas, where they provide vital links in food chains and are important in community development and succession on rocks and soils. Some, but not enough, attention has been paid to global deforestation and the on-going decline of associated lichen vegetation, more particularly foliose and pendulous forms, but terricolous fruticose species still dominate huge regions of arctic and subarctic landscapes where their future is often uncertain due to commercial exploitation of oil, minerals, timber and, indeed, lichens themselves, as well as long-range air pollution and global warming.

THE ROLE OF LICHENS IN SHAPING OUR WORLD

Lichens undoubtedly play an important role in the shaping of the physical and biological environment of our planet and in maintaining its equilibrium. As well as their role as biological weathering agents in the development of soils, lichens often contribute substantial biomass to ecosystems and support a high biodiversity of fauna, creating complex food-webs and adding significantly to energy-flow and mineral cycling. Therefore, the disappearance of lichens, due to many aspects of human interference in the natural world, would lead inexorably to environmental impoverishment.

Lichens represent one of the most successful forms of symbiosis, exploiting all manner of natural, usually stable, micro- and macro- environments worldwide, in many cases adapting to extreme conditions. However, although they display a remarkable resilience, they are highly susceptible to disturbance, particularly that generated by a very wide range of human activities. Although many communities where lichens play a significant or indeed dominant role have been studied in some detail, many remote and currently inaccessible parts (polar, arid and tropical regions) of the world undoubtedly harbour undiscovered lichenological riches, as exemplified by tropical rainforests.

Lichen species and assemblages are faithful to particular habitats and as such make ideal environmental indicators. Lichen communities, often species rich and supporting complex biotic interactions, produce spatial and temporal patterns ecologically delimited by one or more factors. The distributions of rocky shore lichens delimit littoral and supralittoral zones and those of freshwater lichens delimit upper terrestrial, fluvial, fluvial mesic and submerged zones zones. Changes in such zonations have monitoring value in terms of determining natural and man-made hydrological disturbances, including global warming, as well as water quality (Davis et al. 2000).

Lichens are not only of pedogenic significance, degrading substantial quantities of the substratum even over relatively short periods of time, but also have the capacity to accumulate elements, such as N, P and S, thereby increasing the latters' potential bioavailability to successive life-forms. Organic material derived from lichen decomposition, together with detached particles of the substratum and atmospherically-derived dusts trapped by thalli, all contribute to the development of soils. The impact of lichen weathering of rocks on a global scale has been, and continues to be, important in terms of climatic consequences and the habitability of our planet: their disappearance from particular ecosystems would be critical over major areas. It has been noted that if today's weathering were to take place under completely abiotic conditions, dramatic increases in global temperature would result (Schwartzman & Volk 1989).

The wide range of lichen communities delimited through phytosociological analyses and other means have determined not only the diversity, frequency, cover value and biomass of the different species, but also the relative importance of the lichens relative to the other components of the community or ecosystem; lichen-rich systems are self-evident, but in many cases where the lichens contribute a relatively low biomass, they may nonetheless assume greater lichenological importance in terms of, for example, invertebrate associations (e.g. Wessels & Wessels 1991) and nutrient turnover / mineral cycling. In any study of ecological dynamics, it is necessary to determine the key components in order to reveal the relative importance of lichens for a particular ecosystem. Boreal coniferous forests, cold deserts, dune systems, hot arid and semi-arid lands, maritime rocks, high altitudes and tropical rain forests contain examples of ecosystems where lichens often contribute a significant proportion of the biomass and/or biodiversity. It is estimated that 8-10% of terrestrial ecosystems are dominated by lichens (cf. LARSON 1987); furthermore, lichens are often abundant in particular strata of other ecosystems, such terricolous mats in boreal forests or arboreal epiphytes in temperate rain forests.

North American forest systems show a wide variation in lichen biomass, and consequently mineral capital, which seldom accounted for more than 10% of the annual above-ground turnover of a particular element (PIKE 1978). BOUCHER and NASH (1990) showed that the epiphyte *Ramalina menziesii* plays an important role in the annual turnover of biomass and macronutrients, calculating that the former to be 706 kg ha^{-1} (94% of the total epiphytic lichens by weight), and that it not only contributed 26.4% of the biomass but also 9.4% of the total litter biomass when compared with the blue oak on which it grew. Canopies supporting such pendulous epiphytes considerably increase their surface area, nutrient input being further enhanced by the scavenging nature of lichens which accumulate aerosols (including particulate trapping) and ions at exchange sites. The surface area of air dried samples of *R. menziesii* collected from a blue oak stand in California has also been tentatively determined as between 0.15 and 1.0 million m^2 ha^{-1} (SEAWARD 1996), the latter figure being 100 times the surface area of the ground on which the trees stand. Clearly, loss of such an extensive surface area, with a very high atmospheric scavenging capability, as a result of air pollution (even at moderate levels) and by the felling of the trees themselves is bound to have significant repercussions, ecologically and physiologically (e.g. KNOPS et al. 1996).

Quantitative data on numbers and weight of the various faunal groups per unit area of lichen thallus, thalli or community, on which to base ecological energetic studies, have been derived mainly from microhabitat studies, but more attention is now being focussed on environments where lichens form a major component of the flora, such as littoral zones, Arctic and Antarctic ecosystems, and certain types of woodland. The effects of environmental pollutants need more detailed investigation, since air pollution adversely affects lichens, and hence their primary consumers and in turn their predators. A significant uptake of heavy metals, pesticides and radioelements by invertebrate grazers via lichens should be expected. Studies of ecosystem dynamics to determine residence times of toxins and rate of detoxification, and decomposition are but a few of the many aspects of lichen – invertebrate associations in need of further study. Despite the presence of anti-herbivore secondary substances in numerous lichens (RUNDEL 1978), the biodiversity and abundance of invertebrates which feed on, shelter in, and are camouflaged by lichens are enormous. Calculations of their biomass and further study of their role in mineral cycling and energy-flow will reveal how highly significant invertebrates are in many ecosystems.

Many bird species use lichens as nesting material, some showing a definite preference for certain types of lichen not only for nest construction and but also its camouflage. The disappearance of epiphytic lichens, mainly due to deforestation and air pollution, will deplete this source of nest-building material, and the consequent loss of the associated lichenophagous insect fauna upon which bird populations depend.

A large number of mammal species are known to feed on lichens, although their importance in the animal's diet varies considerably (Richardson & Young 1977). Deer, elk, ibex, gazelle, musk ox, mountain goat, polar bear, lemming, vole, tree mouse, marmot, squirrel, monkeys and some domestic animals may include lichens in their diets, perhaps fortuitously, but more likely as a means of supplementing their normal diet or as winter feed. By far the most important mammalian lichen feeders are reindeer and caribou, their winter diet containing more than 50% of lichens. Remote imagery has been effectively employed to map changes in lichen habitats in order to understand population dynamics and define wildlife management in respect of the Canadian caribou (Théau & Duguay 2003; Théau et al. 2005), a demographic explosion of the herd causing severe local degradation of the vegetation cover, particularly the lichen mats (Théau & Duguay 2004).

Clearly, detailed inventories from a wide range of woodlands and forests are necessary in order to gauge the associated lichen assemblages in terms of the inherent characteristics of particular tree assemblages, community structure, their age, ecological continuity, and past and present management, as well as determining the spatial (vertical and horizontal) contribution of the different epiphytic species to the arboreal lichen flora. A fundamental challenge for modern forest management is how to extract needed resources, such as timber, without adversely affecting biodiversity and other factors important to long-term ecosystem sustainability. As a precursor to such management, it is necessary to combine design- and model-assisted approaches to interpret systematically collected inventory data on the distribution and ecology of lichens, particularly of rare and vulnerable species (Edwards et al. 2004).

Therefore, for present and future management of woodlands and forests, habitat models to forecast the frequency of occurrence of epiphytic lichen species in a forested landscape under different plans have been developed (McCune et al. 2003) and detailed ecological studies have been undertaken on the effects (detrimental or otherwise) of a variety of forestry practices on the diversity and biomass of epiphytic lichens, such as selective felling (Rolstad et al. 2001), green-tree retention (Sillett & Goslin 1999) and clear-cutting of major areas (Esseen et al. 1997). One such study on the effects of a fragmented logging pattern on the epiphytic lichens of a boreal spruce forest showed that diasporas were less successful in establishing themselves in logged areas, and since colonization was species-specific, it was recommended that the development of management guidelines should be based on wide scientific knowledge about the species life-history characteristics (Hilmo et al. 2005). In the case of conserving *Nephroma occulatum*, a rare nitrogen-fixing macrolichen endemic to the Pacific northwest, management needed to focus on populations and habitat requirements rather than on individuals (Rosso et al. 2000). However, perhaps too much attention has been paid to macrolichens, since recent habitat studies in Scottish woodlands have shown that the effect of decreasing woodland extent on epiphytic richness is generally more severe for microlichens (comprising a greater number of rare and specialist species) than the more generalist macrolichens (Ellis & Coppins 2007).

It would appear that some ecological groups are more vulnerable than others, such as lichens on large logs in virgin and old-growth forests (endangered by intensive forestry), lichens of peat bogs, marshland and boggy forests (endangered by reclamation and drainage), lichens of sand dunes (endangered by recreation, removal of sand and afforestation), lichens of moorlands, heathlands and old, permanent pastures on soils poor in nutrients (endangered by fertilizer application, afforestation or lack of appropriate management) and lichens in forests subjected to acidification and/or nitrogen accumulation from air pollution.

ROLE OF ENVIRONMENTAL MONITORING IN LICHEN CONSERVATION

Lichens are natural sensors of our changing environment: the sensitivity of particular lichen species and assemblages to a very broad spectrum of environmental conditions, both natural and unnatural, is widely appreciated. Lichens are therefore used increasingly in evaluating threatened habitats, in environmental impact assessments, and in monitoring environmental perturbations, particularly those resulting from a disturbingly large and growing number of chemical pollutants.

There are areas of the globe where the results of lichen denudation are now being detected by means of remote sensing. Such losses may well have climatic repercussions and exert a measurable influence on global warming, as, for example, in the case of the disappearance of epilithic lichens over a very large area of the Canadian shield as a direct consequence of atmospheric pollution formerly emanating from the smelting operations at Sudbury (Seaward 1996), which has fortunately subsided due to pollution abatement measures, allowing the barren rock surfaces to be re-colonized by lichens, thereby restoring their light-absorbing ability (Rollin et al. 1994).

Similar situations prevail in areas dominated by terricolous lichens where human disturbance has significantly reduced lichen cover. This is particularly apparent in mountainous regions where skiing, once the pastime of a select few, is now enjoyed by thousands, resulting in the wholesale erosion of lichen dominated vegetational cover; in some cases the entire ecosystem has been buried beneath alien imported materials such as bitumen. Sensitive lichen-dominated ecosystems in hot and cold deserts have been similarly destroyed through human activities. It has been shown, for example, that the microphytic crusts of lichens, mosses and cyanobacteria in semi-arid regions of eastern Australia contribute up to 27% of the ground cover and decrease reflectance (O'Neill 1994) and that some gypsiferous soils in the intermountain area of the western United States can support soil crust communities with a high species diversity and a 60-100% ground cover of lichens (St. Clair et al. 1993). Over a long period of time, lichen crust communities change the physico-chemical properties of soil, enhancing their stability and fertility (Belnap & Lange 2005a); their retention and indeed restoration are necessary when human interference affects the natural equilibrium through increasing desertification (Bowker et al. 2005), and land mismanagement (Evans et al. 2001), by, for example, the introduction of domestic animals (Warren & Eldridge 2001; Ponzetti & McCune 2001), including the impact of off-road vehicles. The latter effects are equally profound in the case of mat-lichen ecosystems of boreal forests, tundra and sand-dunes.

Changes in reflectance and in ecophysiological responses, such as chlorophyll levels, gaseous exchange, and water absorbance, brought about by anthropogenic disturbances to lichen dominated communities are being detected in remotely sensed images (Petzold & Goward 1988; O'Neill 1994; Karnieli et al. 2001). As a consequence, the environmental significance of variations in these activities is increasingly being recognized. Field studies have established the importance of lichens to environmental modification. In arctic and alpine areas, lichens possess specialized physiological mechanisms enabling them to photosynthesize and take up water at low temperatures. Lichens may also be effective ice nucleating agents and can therefore initiate freezing of super-cooled water at relatively warm temperatures. Such phenomena may be used to interpret data derived from remote sensing (Nordberg & Allard 2002). In the case of global warming, temperature differences in remote areas such as the polar regions could be reflected by the presence or absence of lichen cover.

As well as playing a major role in shaping the natural world, both physically and biologically, lichens are natural sensors of our ever-changing environment. Environmental interpretation by means of lichens, based on the presence and/or absence of particular species and/or the nature and composition of assemblages indicative of one or more identifiable factors. It is, for example, possible to use the composition of the lichen flora to evaluate habitat and ecosystem stability, often in terms of ecological continuity over time, as in the determination of the age and past management of deciduous woodlands and coniferous forests (Rose 1976).

Information gained from our knowledge of how lichens respond to long-term perturbations and short-term upheavals in nature can be applied to the interpretation and monitoring of environmental changes and disasters brought about through a wide range of human activities. The reaction of lichens to sudden natural events such as fire, volcanic eruptions and earthquakes on the one hand and to the long-term effects of glaciers, snow and water on the other can be effectively employed to determine those human impacts which destabilize soil, rock and water systems. Thus, lichens can often be used as an early warning system for other biota which without remedial action would subsequently suffer stress or indeed extinction through forest and agricultural mismanagement, desertification, urbanization, industrialization and a whole host of other problems arising from world overpopulation.

Baseline information on lichen assemblages and ecosystems which are ecologically or geographically zoned on the basis of particular natural phenomena have proved invaluable in assessing widespread increases in various pollutants and climatic changes resulting from global warming; for example, distinctive lichen zonations at freshwater and marine water-lines can be affected by acidification, eutrophication (and indeed hypertrophication) and other polluting agencies, as well as climatic disturbances. From detailed field studies and remote sensing, it should be possible to monitor changes in lichen zonations resulting from displaced snow-lines, episodic snow-kill, avalanches, seismic landslides and other unstable debris flows, retreating glaciers due to climatic shifts, and flooding (Benedict 1991; Bull et al. 1994; Insarov & Schroeter 2002; Sonesson et al. 1994; Wolken et al. 2005; Wolken 2006).

Long-term field investigations involving stringent ecological and phytogeographical criteria through a comprehensive on-going programme of detailed mapping can provide the basis for large-scale monitoring of quantitative and qualitative changes in environmental regimes, ranging from air pollution to climatic disturbances/global warming (e.g. van Herk et al. 2002; Belnap & Lange 2005b). Intensive lichen monitoring is a necessary component of any programme aimed at effective long-term observation of environmental disturbances, both natural and man-made. The proper use of lichens as indicators and samplers of ambient conditions is a valuable resource for the environmentalist for appraisals and impact studies, particularly where on-site instrumentation would be expensive to install and maintain (Seaward 2004). Unfortunately, most of the methodologies require a fairly detailed understanding of the taxonomy of lichens and the development of protocols for consistency in measurement and interpretation by future researchers; similarly, techniques based on bioassays necessitate depletion of the resource material, rigorous protocols for its collection, preparation and analysis, and sophisticated analytical equipment.

POSTSCRIPT

So, why conserve lichens? It is hoped that the above review has demonstrated the importance of lichens to our planet and *a priori* some reasons for conserving them. Clearly these apparently insignificant organisms not only dominate a significant proportion of the land masses, but also play a key ecological role in its well-being. The far-sighted British lichenologist William Lauder Lindsay (1829-1880) fully appreciated this over 150 years centuries ago (Lindsay 1856) in the following manner:

"*We may now be said to be entering on a new era in lichenology; it is now being studied in a more philosophic spirit, and with all the aids which modern discoveries in science … can furnish. Facts are being earnestly and patiently sought after; generalization and theory avoided until a sufficiency of data be accumulated ... labourers are increasing and volunteers are coming forward who esteem it an honour to join this forlorn hope of cryptogamic botany, who are eager for the work solely on account of its difficulty ... But the labours of the student* ***must equally begin and terminate on the spot where the lichens grow ... there he must watch patiently and note accurately*** *… the stages of origin, growth, and decay of species under all the influences, terrestrial and aerial, by which these are so liable to be affected.*"

It is hoped that in the current century, when "curiosity appears to be under threat from the internet" that detailed monitoring, adopting strict protocols, will be adopted on site for establishing baseline information and on-going detailed investigations to establish those factors responsible for the decline or disappearance of lichens, and that suitable management practices can be put into place the halt further losses.

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PROTECTION OF LICHEN SPECIES IN POLAND – GOVERNMENTAL LEGAL ACTS

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Abstract. The work features information on the most important proposals concerning the species protection of lichens, which were raised by Polish naturalists. It presents the successive governmental legal acts, which included provisions concerning lichens and lists of species under strict partial and zone protections.

Key words: legal acts, protected lichens, Poland

INTRODUCTION

The first proposals for the protection of spore plants, including lichens, appeared in Poland immediately after the end of World War I (Kulesza 1922). Similarly to other proposals from the interwar period (including Motyka 1934) as well as from the first 20 years of the post-war period (including Szweykowski & Tobolewski 1959), they did not focus on the species protection of lichens. The first formal and legally binding provision on the species protection of this group of organisms appeared in the year 1957 (Dziennik Ustaw *[Official Gazette]* of 1957, No. 15, Items 77 and 78). In this period the awareness of the threats to lichens also increased. At the same time, the effectiveness of the protective provisions was verified. Even such radical demands as the protection of all species of lichens were put forward (Gawłowska 1964, 1977). The ever increasing knowledge of the distribution of lichens in Poland and the observed changes in this regard made it possible to develop the first "Red List of lichens threatened in Poland" (Cieśliński et al. 1986), which presented 28.9% of the threatened biota of Poland. Following this publication, its authors presented a proposal to extent the legal protection of lichens in Poland (Czyżewska & Cieśliński 1991). They proposed that the existing list of protected species be verified, including the change of the existing category of partial species protection into a strict category. They also presented the list of epiphytic, epilithic, epigeic and epixylic lichens, which should be placed under strict species protection.

The authority of the proposal's creators, the eminent Polish lichenologists, caused the subsequent governmental list (Dz. U. *[Official Gazette]* 1995 No. 41 Item 214) to include almost all of the lichen species that had been indicated.

The subsequent official lists of lichen species under legal protection were - to a large extent - the effect of the knowledge presented in the successive issues of the "Red List of lichens threatened in Poland" (Cieśliński et al. 1992 – it presented 37.6% of the threatened biota, 2003 – it presented 55.4% of the threatened biota). The list published in the year 2006 is the reiteration, in the English language version, of the list from the year 2003 (Cieśliński et al. 2003, 2006).

THE LIST OF LICHENS PROPOSED BY CZYŻEWSKA AND CIEŚLIŃSKI (1991) TO BE PLACED UNDER STRICT SPECIES PROTECTION

The list incorporated the following lichens with their Polish and Latin names. The below-cited list maintained the Polish and Latin nomenclature used by the authors; English names were added according to Brodo et al. (2001):

Żyłecznik (Witch'shair) *Alectoria* genus, all species,

Włostka (Horsehairlichens, tree-hairlichens) *Bryoria* genus, all species,

Brodaczka (Beardlichens, oldman'sbeardlichens) *Usnea*, all currently living species,

Granicznik (Lungworts, lunglichens) *Lobaria*, all species,

Mąkla (Oakmosslichens) *Evernia*, all species,

Odnożyca (Ramalina) *Ramalina*, all species,

Pustułka (Tubelichens, bonelichens) *Hypogymnia*, all species, except of *H. physodes*,

Tarczownica (Shieldlichens) *Parmelia*, all species, except of *P. sulcata* i *P. glabratula*,

Tarczownica dziurkowana (Treeflute) *Menegazia terebrata*,

Tarczownica płucnicowa (Sea-stormlichen) *Cetrelia olivetorum*,

Płucnica modra (Varied rag lichen, ragbag) *Platismatia glauca*,

Płucnica (Iceland lichens, Icelandmoos, haeth lichens), *Cetraria*, all species,

Pawężnica (Pelt lichens, dog-lichens) *Peltigera*, all species, except of *P. rufescens* and *P. spuria*,

Błyskotka (Sulphurlichens) *Fulgensia*, all species,

Chróścik pasterski (Easter lichen) *Stereocaulon paschale*, ch. inkrustowany *S. incrustatum*, ch. orzęsiony (Woolly foam lichen, eyed foam lichen) *S. tomentosum*,

Czasznik modrozielony (Candylichen, spraypaint) *Icmadophila ericetorum*,

Chrobotek gronkowy (Woodensoldiers) *Cladonia botrytes*, ch. cielisty (Crownedpixie-cup) *C. carneola*, ch. siny *C. cyanipes*, ch. delikatny (Fence-railcladonia) *C. parasitica*.

THE MOST IMPORTANT LEGAL ACTS OF THE POLISH GOVERNMENT CONCERNING PROTECTION OF LICHEN SPECIES

The Ordinance of the Minister of Forestry and Timber Industry of 1957

The Nature Protection Act of 1949 stated in Article 15 that the species protection of plants and animals would be introduced (Dz. U. *[Official Gazette]* 1949 No. 25, Item 180). The secondary legislation to this Act was the Ordinance of the Minister of Forestry and Timber Industry on the introduction of species protection of plants, published in the year 1957 (Dz. U. *[Official Gazette]* 1957 No. 15, Item 77 and 78). In this document, in paragraph 5, under the group of medicinal and industrial wild species under partial protection, along with 1 species of fern and 126 species of vascular plants, also the following species are mentioned: *Cetraria islandica*, *Lobaria pulmonaria* and all the species from the *Usnea* genus. Epiphytic lichens might only be collected from the trees that had been felled in the course of ordinary forest management. In the subsequent paragraph, the legislator indicates that the mentioned plants may be exploited only by authorized persons, in the specified areas and in the amounts agreed with the preservation authorities.

The Ordinance of the Minister of Forestry and Timber Industry of 1983

In the subsequent Ordinance of the Minister of Forestry and Timber Industry (Dz. U. *[Official Gazette]* 1983 No. 27, Item 134) the provision from the year 1957 is reiterated, concerning the partially protected lichens list. Also the recommendations concerning the manner, places and rights to collection remain unchanged.

The Ordinance of the Minister of Environmental Protection, Natural Resources and Forestry on the species protection of plants (Dz. U. *[Official Gazette]* 1995 No. 41 Item 214)

This Ordinance was issued on the basis of the Nature Protection Act of 1991 (Dz. U. *[Official Gazette]* 1992 No. 114, Item 254).

Strict protection encompassed:

Usnaeceae – all species,
Stictaceae – all species,
Peltigeraceae – all species, except of *Peltigera rufescens* and *P. spuria*,
Parmeliaceae sensu lato – all species, except of *Hypogymnia physodes*, *Parmelia sulcata* and *Cetraria islandica*,
Anaptychia – all species,
Fulgensia – all species,
Icmadophila ericetorum,
Stereocaulon – all species,
Cladina – all species,

Partial protection encompasses *Cetraria islandica*.

The Ordinance of the Minister of the Environment dated 11th of September 2001 on the list of wild plant species strictly and partly protected by law and on the bans relevant to these species and exceptions thereto (Dz. U. *[Official Gazette]* 2001 No. 106, Item 1176)

This Ordinance reiterates the list of lichen species under strict protection on the basis of the ordinance from the year 1995. Only the regulation concerning *Peltigeraceae* was changed. Its new wording was: „*Peltigeraceae* – all species", and this meant that also *Peltigera rufescens* and *P. spuria* were placed under protection.

The Ordinance of the Minister of the Environment from the 9th of July 2004 on the protection of wild fungi species (Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765) dated 28th of July 2004

The Ordinance is the secondary legislation to Article 50 of the Act of the 16th of April 2004 on Protection of Nature (Dz. U. *[Official Gazette]* 2004 No. 92, Item 880) and is currently binding.

From among the bans mentioned in paragraph 6, the most important ones for the lichens under strict protection include: the ban on plucking, destroying and damaging, the ban on destroying the habitats and refugiums, the ban on the use of chemical agents, the destruction of forest bedding and soil in the refugiums, the exploitation, collection and offering for sale […] the living, dead, processed and conserved species, as well as their parts and derivative products (here a reference to decorative items from certain lichens may be made). The lichens under partial protection may not be: plucked, exploited, collected, destroyed and damaged; with reference to their localities and refugiums, it is forbidden to: destroy them, use chemical agents, destroy the forest bedding and the soil in the refugiums.

The provisions in Paragraph 8 concerning the manners of protection are essential for the practical protection of lichens. They must be treated as orders and recommendations of the field administration. The most essential of them include: the protection of the refugiums and localities against external threats, ensuring the presence and protection of the ground on which the protected species develop, including trees in appropriate age and of suitable type, decaying wood, stones and boulders. Moreover, this paragraph contains further stipulations concerning the nature of the recommendations on the monitoring of the localities, refugiums and populations, the *ex situ* protection and the subsequent restoration to the proper environment, the transfer of threatened lichens to new localities and – which is significant with reference to forest lichens – the promotion of forest works methods, which ensure the maintenance of refugiums and localities of the protected species.

In Appendix No. 1, in the list of wild fungi **under strict protection**, there are approximately 200 species of lichens. These include:

Cladoniaceae: *Cladonia stellaris*, *C. stygia*, *Pycnothelia papillaria*,
Stereocaulaceae: *Stereocaulon* spp. – all species,
Icmadophilaceae: *Icmadophila ericetorum*,

Lobariaceae: *Lobaria* spp. – all species, *Sticta* spp. – all species, *Lobarina scrobiculata*,

Umbilicariaceae: *Umbilicaria* spp.– all species, *Lasallia pustulata*,

Physciaceae: *Anaptychia* spp. – all species, *Heterodermia speciosa*,

Ramalinaceae: *Ramalina calicaris*, *R. thrausta*, *Ramalina* – other species,

Peltigeraceae: *Solorina* spp. – all species, *Peltigera* spp. – all species,

Nephromataceae: Nephroma spp. – all species,

Thelotremaceae: *Thelotrema lepadinum*,

Parmeliaceae: *Punctelia* spp. – all species; *Neofuscelia delisei*; *Allantoparmelia alpicola*; *Pseudephebe* spp. – all species; *Parmotrema* spp.– all species; *Allocetraria madreporiformis*; *Pseudevernia furfuracea*; *Cetrelia* spp. – all species; *Flavocetraria cucullata*; *Tuckernaria laureri*; *Parmeliopsis hyperopta*; *Parmeliopsis ambigua*; *Cetraria sepincola*;*Cetraria chlorophylla*; *Cetrariella delisei*; *Platismatia glauca*; *Imshaugia aleurites*; *Melanelia* spp.– all species; *Hypotrachyna revoluta*; *Hypogymnia* spp. – all species, with the exception of *Hypogymnia physodes*; *Parmelina* spp. – all species; *Arctoparmelia* spp. – all species; *Parmelia* – all species, with the exception of *Parmelia sulcata*; *Menegazzia terebrata*; *Pleurosticta acetabulum*; *Flavopunctelia flaventior*; *Vulpicida pinastri*; *Xanthoparmelia* spp. – all species, with the exception of *Xanthoparmelia conspersa*; *Flavoparmelia caperata*; *Usnea* spp. – all species; *Evernia mesomorpha*; *Evernia divaricata*; *Cornicularia normoerica*; *Bryoria* spp. – all species; *Alectoria sarmentosa,*

Chrysotrichaceae: Chrysotrix candelaris,

Teloschistaceae: Fulgensia spp. – all species, *Caloplaca marina.*

In Appendix No. 2, in the list of wild fungi under partial protection, there are 10 species of lichens. These include:

Cladoniaceae: Cladonia arbuscula (incl. *Cladonia mitis*), *C. portentosa, C. rangiferina, C. ciliata,*

Parmeliaceae: Evernia prunastri, Cetraria muricata, C. islandica, C. ericetorum, C. aculeata.

In Appendix No. 3, the list of wild fungi under partial protection, which may be exploited, includes *Cetraria islandica*.

Appendix No. 4 presents species for which the establishment of protection zones for their refugiums or localities is required. These include:

Lobaria pulmonaria – within the radius of up to 100 m from the boundaries of the locality;

Usnea subfloridana, Usnea hirta and *Usnea filipendula* – within the radius of up to 50 m from the boundaries of the localities.

THE COUNCIL DIRECTIVE NO. 92/43/EEC DATED THE 21 MAY 1992 ON THE CONSERVATION OF NATURAL HABITATS AND OF WILD FAUNA AND FLORA (DZ. U. [*OFFICIAL GAZETTE*] L 206 Z 22.7.1992)

In Appendix No. 5 to the Directive concerning the species of animals and plants which are of interest to the community, and the derivation of which from the wild and subsequent exploitation may be subject to activities in the framework of management, the group of "Lichenes" contains the following stipulation: "CLADONIACEAE – *Cladonia* L. subgenus *Cladina* (Nyl.) Vain." Its contents indicate that the Polish law concerning species protection of lichens (cf. Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765) is more restrictive than the one recommended by the European Union in the Directive Nature 2000. In Poland, all the species of *Cladonia* from the sub-genus of *Cladina* are under species protection – 2 are under strict protection, and the remaining ones under partial protection. It is also forbidden to exploit them.

PROPOSAL OF A NEW VERSION OF PROTECTED SPECIES LIST

The period of almost 8 years, in which the provisions of the Ordinance of the Minister of the Environment dated 2004 were in force, was sufficient to verify these provisions in practice. The experience obtained by lichenologists and other naturalists, as well as the changes occurring in the lichenobiotic composition of Poland, enable them to put forward proposals concerning the potential modifications of the list of protected lichen species. The following are the most significant:

- The provisions of Appendix No. 1 (lichens under strict protection), the provisions of Appendix No. 2 (lichens under partial protection) and Appendix No. 3 (lichens under partial protection which may be exploited) require no change.
  Note. The *Lobaria laetevirens* (Lightf.) reported to exist in the Puszcza Białowieska Forest Zahlbr. in reality belongs to *L. amplissima* (Scop.) Forssell (Kukwa et al. 2008).
- A change is proposed in Appendix No. 4, which presents the species for which the establishment of protection zones for their refugiums or localities is required. This proposal is slightly different from the minister's unofficial proposal.
  a) Resign from the establishment of protection zones for the localities and refugiums of *Usnea filipendula*, *U. hirta* and *U. subfloridana*.
  Justification: Still 20-30 years ago in the Western Poland, only a few localities of the *Usnea* were known (cf. Fałtynowicz 1992). As a rule, single thalli were found. Over the last decade, the appearance of relatively numerous populations of *U. filipendula*, *U. hirta* and *U. subfloridana* have been observed, particularly in the wood stands of *arix decidua* (cf. inter alia Lipnicki 1994, 2007 as well as some chapters in this monograph, e.g. Janczar & Liśkiewicz 2012, Lipnicki et al. 2012). This phenomenon is probably related to the improvement of aero sanitary conditions in the forest complexes situated by the western border of Poland.
  Note. It must be noted that, as a result of the molecular studies, it was shown that *Usnea subfloridana* Stirt. and *U. florida* (L.) Weber ex F.H. Wigg. constitute one polymorphic species, with *U. florida* being differentiated by, inter alia, the presence of fruiting bodies and lack of vegetative propagules (Articus et al. 2002).

b) Establish the zones for the protection of plants and refugiums for the following lichen species:

Lobaria spp. all species – within the radius of up to 100 m from the boundaries of the locality;

Sticta spp. all species – within the radius of up to 100 m from the boundaries of the locality;

Lobarina scrobiculata – within the radius of up to 100 m from the boundaries of the locality;

Ramalina calicaris – within the radius of up to 50 m from the boundaries of the locality;

Ramalina thrausta – within the radius of up to 50 m from the boundaries of the locality;

Nephroma spp. all species – within the radius of up to 100 m from the boundaries of the locality;

Parmotrema spp. all species – within the radius of up to 100 m from the boundaries of the locality;

Usnea spp. – all species (with the exception of *Usnea filipendula*, *U. hirta* and *U. subfloridana*) – within the radius of up to 50 m from the boundaries of the locality;.

Justification: All of the mentioned species are rare or very rare, currently found only in few localities in the territory of Poland (Fałtynowicz 2003). They are very vulnerable to changes in the conditions of the place where they occur.

The list of lichen species (published in 2004), which require the establishment of protection zones around their localities, as well as the draft of the new list, provoked many discussions, particularly among lichenologists and foresters. They particularly referred to the protection zones around the localities of *Lobaria pulmonaria.* This lichen is the relict of the forest, the indicator of the low-lying old growth forests (Czyżewska & Cieśliński 2003) and fulfils a very important role of an umbrella species for numerous, rare and threatened ones, including the "relict" epiphytic lichens. In the opinion of many explorers, *Lobaria pulmonaria* is one of the lichens with increasing number of localities, particularly in the north-east part of Poland (inter alia Ryś 2005; Bohdan 2010; Fałtynowicz 2010). It also occurs in the Gdańsk Pomerania and in the Bieszczady Mountains. The status of a species under strict protection should be sufficient to the effective preservation of the localities, without the necessity to establish protection zones. However, in order for it to be so, it is necessary to literally observe all of the provisions concerning the bans in the Ordinance of the Minister of the Environment from the 9 July 2004. (Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765). In practice, these regulations tend to be bypassed. This argument constitutes a limitation of the possibilities to perform management works in the forests. The same argument is proposed by the opponents of protection zones, particularly in the forests, where a larger number of *Lobaria pulmonaria* localities were inventoried. In accordance

with Section 2 Article 51 of the Ordinance of the Minister of the Environment from the 9th of July 2004: "With reference to wild plants and fungi under species protection, exceptions to the bans may be introduced […] which concern:
1) the performance of activities related with the rational management […] of the forests […], if the works technology makes it impossible to comply with the bans". The procedure of obtaining the permit for the destruction of localities of *Lobaria pulmonaria* is based on, similarly to the need to destroy the localities of other protected organisms (e.g. during the implementation of investments such as roads, pipe systems), on the provisions of the Administrative Procedure Code (Dz. U. [*Official Gazette*] of 2000, Item 1071).

CONCLUSIONS

Official provisions concerning the protection of lichens appeared in the legal regulations binding in Poland as early as in the year 1957 (Dz. U. *[Official Gazette]* 1957 No. 15, Item 77 and 78). It was the secondary legislation to the provisions of the Nature Protection Act of 1949 (Dz. U. *[Official Gazette]* 1949 No. 25, Item 180) and it contained the list of lichen species under partial protection. The minister's ordinances, which contained ever broader lists (in relation to the earlier ones) of lichen species under legal protection, appeared in the years: 1995 (Dz. U. *[Official Gazette]* 1995 No. 41 Item 214) – it introduced, besides the partial protection, also the strict protection, 2001 (Dz. U. *[Official Gazette]* 2001 No. 106, Item 1176) and in 2004 (Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765) – it furthermore introduced the obligation to establish protection zones around localities of the indicated species of lichens. Currently a new version of the list of protected lichens is being developed. In relation to the existing one, the likelihood is that the change will encompass the list of those species under strict protection whose localities will require the demarcation of protection zones.

Thanks to the legal protection of a relatively large group of lichens, the threat of dying of many lichens was reduced to some extent. In Poland, the formation of lists containing legally protected lichens is - to a considerable extent - based on the demands of lichenologists and on the evaluations of the threats to this group of organisms, which are conducted by the lichenologists.

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LEGALLY PROTECTED SPECIES OF LICHEN-FORMING FUNGI IN HUNGARY

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Abstract. To date eight lichen species (*Cetraria aculeata*, *Cladonia arbuscula*, *C. magyarica*, *C. mitis*, *C. rangiferina*, *Usnea florida*, *Xanthoparmelia pseudohungarica* and *X. subdiffluens*) have become protected by law in Hungary 23/2005(VIII.31) KvVM[1*]); 18/2008(VI.19) KvVM] due to our research activity and expertise. The short history of the protection process, a revised distribution map of *Usnea florida* and preliminary results on chemical revision of *Cladonia* (subgen. *Cladina*) and *Xanthoparmelia* species are presented.

Key words: lichens, protected species, *Cetraria*, *Cladonia*, *Usnea*, *Xanthoparmelia*, Hungary

INTRODUCTION

Nature conservational considerations and efforts in Hungary, which started more than 100 years ago, were summarised by Kaán (1931). At that time mainly natural sites and old trees were the objects of nature protection. Starting from 1934 with the Bátorliget mire nature reserves more and more areas received legal protection due to predominantly zoological values.

Protection of species gained more significance in the 1970s. Several checklists and proposals were prepared exclusively for vascular plants and the first comprehensive law for nature conservation [1/1982. (III. 15.) OKTH[2*]] was issued in 1982, including 320 vascular plants and 19 peat moss species, as well as numerous invertebrate and all vertebrate species (cf. Farkas 1999). The Hungarian Red Data Book was published in 1989 considering 730 vascular plants, 120 bryophytes, 110 vertebrates and 290 invertebrates (Rakonczay 1989). Based on this red list further vascular plants were added to the first list of protected species in several steps, and now ca. 40% of the Hungarian vascular plant species are legally protected. A considerable number of bryophytes (ca. 12% of the bryophyte species in Hungary) became protected by law [13/2001. (V. 9.) KöM[3*]] in 2001.

1 * KvVM = Környezetvédelmi és Vízügyi Minisztérium, Ministry of Environment and Water
2 * OKTH = Országos Környezet- és Természetvédelmi Hivatal, *National* Environment and Nature Conservancy Office
3 * KöM = Környezetvédelmi Minisztérium, Ministry of Environment

Red listing and conservational efforts for other cryptogamic organisms appeared only much later (red list of lichens – Lőkös, Tóth 1997; red list of macrofungi – Rimóczi et al. 1999; Siller, Vasas 1993, 1995a, 1995b). No species of fungi including lichens became legally protected in Hungary until 2005 though the first proposals date back to 1999. Legal protection of fungi is also represented by much lower values (ca. 1% of all macrofungi, ca. 1% of all lichen species in Hungary).

A SHORT HISTORY OF PROTECTION PROCESS OF LICHENS IN HUNGARY

Efforts for legal protection of lichens in Hungary from 1999 to 2004 were summarised in a former presentation during the 16th Symposium of Mycologists and Lichenologists of the Baltic States, Latvia (Farkas, Lőkös 2005) and additional information was presented later during the 18th Symposium of the Baltic Mycologists and Lichenologists, and Nordic Lichen Society Meeting, Lithuania (Farkas et al. 2011).

During our previous bioindication studies (1980–1990s) we also realised that the area of natural habitats for lichens was declining and lichen species tolerating anthropogenic effects became dominant and abundant practically all over the country. Our general knowledge on Hungarian distribution of lichens increased considerably so that we could decide on the red listed status for a large number of species. A first draft version of the Hungarian red list of lichens was compiled by Lőkös and Tóth (1997). The authors intended to apply IUCN categories for lichens (IUCN 1994), however, the distribution of several species was not (and still is not) known sufficiently, therefore continuous revision is necessary.

Nevertheless, the list was useful for preparing the first list of lichen species proposed for legal protection (Farkas et al. 1999). This consisted of 29 strictly protected species and 79 protected species, which number proved to be too large, especially as it was included in the list of fungi (over 500 species!) proposed for protection.

The second proposal was requested a few years later (Farkas, Lőkös 2003). It contained fewer species (10 strictly protected and 13 protected) of all growth forms.

As a result of a detailed discussion with nature conservancy experts, only the more conspicuous fruticose and foliose species were maintained in the list of the third proposal (Farkas, Lőkös 2004). Finally five species: *Cetraria aculeata*, *Cladonia magyarica*, *Usnea florida*, *Xanthoparmelia pseudohungarica* and *X. subdiffluens* became protected by law [23/2005(VIII.31) KvVM] in August 2005.

In the same time *Cladonia* subg. *Cladina* species were listed in the appendix of the Annex Vb of European Commission Habitat Directive (2003) concerning three species in the Hungarian lichen flora (*Cladonia arbuscula*, *C. mitis* and

C. rangiferina). Their collection in large amount was not allowed in European countries for this reason from 2003. Later these species were also selected for protection in connection with Natura 2000 project. Therefore, they were included in an additional law for conserving further rare and endangered organisms in Hungary [18/2008(VI.19) KvVM] in 2008.

MATERIALS AND METHODS

In order to prepare proposals for protecting lichen species all herbarium material from Hungarian herbaria[4*] BP, VBI, EGR, SZE, SZEU, SZO were studied.

The species became protected in 2005 were previously presented in a paper in Hungarian language (Farkas, Lőkös 2007). The characterisation of species was based on Pišút (1961), Ahti (1966), Kärnefelt (1986), Hale (1990), and also Purvis et al. (1992). Since these literature sources are available in English or German, here we only add some remarks, mostly on the distribution in Hungary. Names used on herbarium labels are listed after the Latin scientific and Hungarian names given as published in the relevant law.

The distribution map was prepared by a GIS application (Quantum GIS 1.7.4-Wrocław), combined with the Central European grid mapping system of 5×6 km (Niklfeld 1971).

THE SPECIES

Cetraria aculeata (Schreber) Fr. (Parmeliaceae, Lecanorales) – Tüskés vértecs, tüskebangy

≡ *Coelocaulon aculeatum* (Schreb.) Link; ≡ *Cornicularia aculeata* (Schreb.) Ach.

= *Cornicularia steppae* auct. hung.

= *Cornicularia tenuissima* (L.) Vain.

Main literature sources: Kärnefelt (1986), Verseghy (1994).

It grows in lowland sandy grasslands and in montane rocky grasslands in open habitats among grasses. In Hungary it is very rare, still a few localities were discovered recently. Originally it was known in Central Hungary from sand dunes (near Sződ) at a hilly area surrounded by Vác–Göd–Vácrátót, and from the Bakony and Velence Mts. Its recent occurrence was possible to establish at these or nearby sites. Occurrences in the Bakony Mts are at a distance from the original habitat and also further localities are recognised more to the west in Vasi-Hegyhát.

It is in danger of extinction because of the burning of the grasslands and by motocross activity. The distribution of the species reaches its eastern boundary in Hungary.

4 * Abbreviations mainly according to Index Herbariorum on-line.

Cladonia arbuscula (Wallr.) Flot. (Cladoniaceae, Lecanorales) – Fácska-tölcsérzuzmó

Main literature sources: Ahti (1961); Ruoss (1990); Wirth (1995); Nimis, Martellos (2004); Smith et al. (2009).

It occurs sporadically throughout the Hungarian Middle Mountain Range with ca. 40–50 localities. It grows usually on acidic soil in shaded forests, forest margins or clearings, on acidic sandy soil, as well as on open rock surfaces or in acidic rocky grasslands together with other *Cladonia* species or bryophytes. The ongoing taxonomic revision on the herbarium specimens by HPTLC analysis revealed its identity as *Cladonia arbuscula* subsp. *squarrosa* (Wallr.) Ruoss.

Cladonia magyarica Vainio (Cladoniaceae, Lecanorales) – Magyar tölcsérzuzmó

Main literature sources: Pišút (1961); Ahti (1966); Farkas, Lőkös (1994).

It was described from Hungary. It grows exclusively in the Carpathian Basin, but more frequently in lowland areas. It was generally regarded as endemic for the Pannonian floristical region, however, the possibility of a wider distribution range was also discussed by Litterski and Ahti (2004).

Cladonia mitis Sandst. (Cladoniaceae, Lecanorales) – Puha tölcsérzuzmó

Main literature sources: Ahti (1961); Ruoss (1990); Wirth (1995); Nimis, Martellos (2004); Smith et al. (2009).

It is known at ca. 20–30 scattered localities from the Hungarian Middle Mountain Range. It grows usually in similar habitats as *Cladonia arbuscula* subsp. *squarrosa* and *C. rangiferina*, in open, acidic places. As a result of the ongoing taxonomic revision by HPTLC and considering the recent taxonomic works the subspecies status as *Cladonia arbuscula* subsp. *mitis* (Sandst.) Ruoss is preferred.

Cladonia rangiferina (L.) Weber ex F. H. Wigg. (Cladoniaceae, Lecanorales) – Rénszarvas-tölcsérzuzmó

Main literature sources: Ahti (1961); Ruoss (1990); Wirth (1995); Nimis, Martellos (2004); Smith et al. (2009).

It is also a rare lichen species with ca. 60–70 localities mainly in the Hungarian Middle Mountain Range. Very often it grows in the same habitat among other *Cladonia* and bryophyte species on acidic forest soil, acidic rocky grasslands most frequently in humid, shaded places.

Usnea florida (L.) Weber ex F. H. Wigg. (Parmeliaceae, Lecanorales) – Virágos szakállzuzmó

Main literature sources: Purvis et al. (1992); Randlane et al. (2009); Smith et al. (2009).

It was considered as an extremely rare species in Hungary, mostly known from the Bükk Mts. Though the Hungarian distribution map of *Usnea florida* has been published in Farkas and Lőkös (2007), it was necessary to compile a new one, since previously not considered specimens were found recently in the herbarium

BP, which originate from the central and western part of Hungary. Also a recent collection of *Usnea florida* (Molnár et al. 2005) confirms the presence of this species in the current lichen flora of Hungary (Fig. 1).

Fig. 1. Revised distribution map of *Usnea florida* in Hungary

Xanthoparmelia pseudohungarica (Gyelnik) Hale (Parmeliaceae, Lecanorales) – Magyar bodrány

≡ *Parmelia pseudohungarica* Gyelnik

= *Parmelia pulvinaris* Gyelnik ≡ *X. pulvinaris* (Gyelnik) Ahti & D. Hawksw.

Main literature source: Hale (1990).

In a recent nomenclatural revision on European parmelioid lichen species (Hawksworth et al. 2008) *Xanthoparmelia pulvinaris* was found to be the correct name for this taxon (cf. Molnár et al. 2012). It was described from Hungary; however, it has a scattered distribution also in Bohemia, Slovakia and former Yugoslavia. Currently it is included in a chemical investigation for revising usnic acid containing *Xanthoparmelia* species in Hungary.

Xanthoparmelia subdiffluens Hale (Parmeliaceae, Lecanorales) – Területékeny bodrány

≡ *Parmelia subdiffluens* (Zahlbr.) Timkó

Main literature source: Hale (1990).

It was described from Hungary; however, it has a scattered distribution also in Mediterranean habitats of other countries (France, Spain). Its less convoluted form grows in Ukraine. As it is much more rare than *X. pseudohungarica*, it was an important achievement when its present occurrence became confirmed at its locus classicus in 2010 (Farkas et al. 2012). Currently the species is also included in a chemical investigation for revising usnic acid containing *Xanthoparmelia* species in Hungary.

DISCUSSION

It seems so that recently more attention is paid to the protection of lichen species. Further species are under consideration for protection in Hungary. *Lobaria pulmonaria* might be a possible candidate. Though some years ago it was thought to be extinct, the species was discovered at a new locality in the Bükk Mts in 2008, still it is considered to be critically endangered (Farkas, Lőkös 1998, 2009).

As another possible candidate *Cetraria islandica* has been considered in former proposals, but it was not possible to be accepted for protection because of certain trade union contracts on its import from foreign countries (e.g. for cosmetic or medicinal purposes).

Cladonia magyarica and the two *Xanthoparmelia* species described from Hungary have the most characteristic populations in the country. Compared to the low number of protected lichen species, the importance for preserving biodiversity via species conservation is much higher, since the limited knowledge on lichens in general stops most collection by the people. The most important aspect is that lichens were not collected in pioneer habitats, which lichens could potentially colonise. Hopefully the better understanding of the importance of biodiversity may lead in future to more lichen species gaining protection.

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SUMMARY

Due to our efforts eight lichen species became protected by law in 2005 and 2008 in Hungary. Law "23/2005(VIII.31) KvVM" protects 5 species: *Cetraria aculeata*, *Cladonia magyarica*, *Usnea florida*, *Xanthoparmelia pseudohungarica* and *X. subdiffluens*. Law "18/2008(VI.19) KvVM" protects further 3 species of genus *Cladonia* (subgen. *Cladina*): *C. arbuscula*, *C. mitis* and *C. rangiferina* earlier listed in Annex Vb of European Commission Habitat Directive (2003) as species important for their populations. Their collection in large amounts was not allowed for this reason from 2003 and finally they became legally protected in 2008. Taxonomic revisions of Hungarian populations of most of these species have been carried out recently. Preliminary results based on morphological and chemical (HPTLC) investigations are included in the present account.

PRACTICAL PROTECTION OF LICHENS IN POLAND – EXPERIENCE FROM THE YEARS 1992–2012

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Abstract. The work presents a brief historical outline of the views on the need and forms of lichen localities protection in Poland. Particular attention should be paid to the modern views presented in 1934 by Motyka as well as to the proposals of Szweykowski and Tobolewski from 1959. The first facilities for the protection of lichens were established primarily in the early 1990's in the Bory Tucholskie Forest. It was the "Bór Chrobotkowy" (Sub-continental lichen Scots pine forest) nature reserve and trees – nature monuments. The most effective is the protection of those localities, where abundant populations of protected and threatened lichens occur.

Key words: lichenological reserve, lichenological nature monuments, the Bory Tucholskie Forest, North Poland

INTRODUCTION

Practical fulfilment of the lichen protection in Poland definitely began later than the protection of plants and animals. The first facilities in the form of a reserve and nature monuments were established in the early 1990's. However, it was much earlier when naturalists were equally disturbed by the awareness of threats to lichens and disappearance of lichen localities as they were in the case of threats to plants or animals. It was as early as in the interwar period that Motyka (1934) indicated the main threats to lichens and proposed the forms of protection for their localities.

The work briefly presents the views of selected Polish lichenologists concerning the issue of threats and the manners of lichen protection. The first, and so far the only, reserve was presented, where the main object of protection are the ground lichens as well as the – also first – lichenological nature monuments. The effectiveness of those protection procedures has been analysed. Experience in this regard supports, to a considerable extent, the theses of the strategy for the protection of lichens presented by Scheideggera and Werth (2009). They may, by way of great simplification, be summarized in the statement that the basis method for the protection of lichens should be the maintenance of localities and the links between them, as well as placing populations containing numerous specimens under protection.

THE SHAPING OF VIEWS ON THE PROTECTION OF LICHENS IN POLAND

The need for securing and documenting the entire variety of nature in our country has been expressed by many Polish naturalists. The first proposals appeared directly after Poland regained its independence following the end of World War II. In order to achieve this goal, the establishment of nature reserves supplemented by a network of nature monuments was proposed (inter alia Szafer 1920, 1932). The issue of nature protection as a new branch of knowledge was further expanded by Wodziczko (1932). This author developed an innovative classification and introduced an appropriate nomenclature.

The need to protect spore plants, including lichens, was first described by Kulesza (1922). However, it was only Motyka (1934) who made an in-depth analysis of the threats to lichens and the need to protect them. He drew attention to the reduction of localities of large-thallus lichens of the following genera: *Lobaria*, *Sticta*, *Nephroma*, *Usnea* and *Alectoria*; and he also described the threats to *Mycoblastus sanquinarius* and *Usnea longissima*. He indicated the threat to lichens that results from the changes occurring in their habitats. Among the most important threats, he mentioned the changes of moisture conditions, logging of old forests, changes in the species composition of the mountain forests, as well as SO_2 air pollution. He analysed the requirements of and the threats to lichens settling on various soils typical for these organisms. He crowned his in-depth and multi-faceted deliberations on the threats to lichens by conclusions concerning the protection of these organisms. He claimed that in order to protect lichens, the protection must encompass entire plant communities that ensure persistency of the species composition of all organisms. He believed that the optimal action would be to place sections of forests, which are least changed and degraded, sub alpine forests in particular, under reserve protection. He also pointed to the need to protect other facilities with abundant species composition of lichens – such as alleys, old cemeteries and riparian tree covers. Those innovative views and appeals of one of the most eminent Polish lichenologists were among the first to be presented and not only the Polish lichenological literature. They anticipated by many decades the possibilities of their practical application.

From among the numerous works published by Polish lichenologists in the 1950's, particular attention should be paid to the work of Szweykowski and Tobolewski (1959). It contains proposals for the establishment of reserves for the protection of spore plants on the areas, where:

- these organisms are the main component of the vegetation cover;
- there are relict species, or even groups of these organisms;
- there are localities, where the species was described for the first time (*locus classicus*);
- there are boundaries on which the species or communities of spore plants occur;

– the spore plants produce regular reproductive structures, despite the fact that they are sterile in the remaining areas.

The authors indicated and provided a detailed description of the chosen areas that demonstrated the above-mentioned features. Those areas should be placed under protection on the basis of the species composition of bryophytes and lichens. In the same year, the work of Fabiszewski (1959) was published, providing justification for the need to protect lichens.

Protection in the form of a reserve, as the basic one for the maintenance of persistency in rare lichen species, was also the argument presented by such authors as: Czubiński (1965) and Michalik (1978). Toborowicz (1975) signalled the threats to the population of *Cetraria islandica* – a lichen used for the purposes of the pharmaceutical industry.

In their publications, contemporary Polish lichenologists frequently expressed their conviction about the effectiveness of reserve protection for the preservation of numerous lichens, including rare and threatened lichens (inter alia Fałtynowicz 1997, 2005; Grabarczyk & Lipnicki 2005; Cieśliński 2009). In recent years many lichenologists have undertaken studies of species composition and the population strength of lichens in protected facilities, for instance in national parks (cf. Czarnota 2002; Łubek 2004; Lipnicki 2012). It is particularly in the magazine entitled "Parki Narodowe i Rezerwaty Przyrody" (National Parks and Nature Reserves) that numerous articles on lichens in nature reserves have been published over the last two decades.

In the last quarter century many works have been written, including comparative works, whose authors point to the diminishing number of localities, and even to the extinction of lichen species. Their contents and the unpublished results of field observations conducted by the ever increasing group of Polish lichenologists provided the basis for the formulation of the subsequent versions of the "Red list of lichens in Poland" (Cieśliński et al. 1986, 1992, 2003). Thorough lichenological inventory and observations of changes in the qualitative and quantitative composition of lichens (inter alia Lipnicki 1990, 1993a; Cieśliński & Czyżewska 1992; Bystrek & Wójciak 1995; Czyżewska 1995; Kiszka 1997; Fałtynowicz 1998) paved the way for the compilation of regional lists of threatened lichens, under the supervision of Czyżewska (2003). The example of 10 local red lists indicated that the threat to the biota in the country in unevenly distributed, namely: it ranges from 34% in the Puszcza Bialowieska Forest to 73% in the Opole Silesia and Upper Silesia (whereas it has been estimated at 55.4% for the entire country), which corresponds to the non-uniform anthropogenic diversity of the natural environment of the country (Czyżewska & Cieśliński 2003). The documentation of the local changes of lichens in 10 different regions of Poland indicated that the causes of species extinction, disappearance of localities and shrinking of the range of native components of the lichens biota on the national scale may be generalised as (1) indirect activities – changes of the environmental conditions, (2) the destruction of phytocoenoses without further habitat changes or causing permanent abiotic changes of the habitats, (3) direct activities – physical eradication of species (Czyżewska 2003).

PRACTICAL FULFILLMENT OF THE PROPOSALS CONCERNING THE ESTABLISHMENT OF PROTECTIVE FACILITIES FOR LICHEN LOCALITIES

The observations of lichens conducted for many years in the chosen sections of the Bory Tucholskie Forest made it possible to determine the directions of changes in the species composition and quantity of the most precious species of lichens. On the basis of those studies, the preservation and forest services received indications as to the forms and manners of protecting the lichen localities (e.g. Lipnicki 1988, 1990, 1991a, b). The most important of them included the following protection proposals:

→ as a nature reserve – section of a well-developed community of *Cladonio-Pinetum* with abundant species composition of ground lichens.

→ as a nature monument – alleys of roadside trees between Jarcewo and Powałki; their bark has a very numerous population (definitely the most highly populated in the lowland part of Poland) of *Parmelina tiliacea*, also present are numerous specimens of other species of lichens, which are rare and threatened in the Polish Lowland. *Anaptychia ciliaris*, *Usnea* spp., *Bryoria* spp., *Ramalina* spp.;

→ as nature monuments – of single specimens of *Betula pendula* and their groups (beds) in forest communities with numerous specimens of various species of *Usnea* and *Bryoria* that have overgrown their trunks;

→ as a surface nature monument – an elevated section of *Leucobryo-Pinetum* in the area of Biała, abundantly overgrown with *Cladonia stellaris*.

In the early 1990's, the Governor of Bydgoszcz Province acknowledged that the majority of the above-indicated objects had been placed under protection as nature monuments (Dz.Urz. *[Official Gazette]* of the Bydgoszcz Province 1991 No. 15, Item 120; Official Gazette of the Bydgoszcz Province 1992 No. 8, Item 124; Official Gazette of the Bydgoszcz Province 1994 No. 20, Item 136). Those were single trees, their avenues and the roadside alleys with precious species of lichens, particularly *Usnea* and *Bryoria*; moreover, a surface nature monument was established – the location of *Cladonia stellaris* (cf. Lipnicki 1992, 1993a, b, 1997; Lipnicki & Wilcz 1993; Symonides 2007) (Fig. 1). The main purpose of protecting the trees with an abundant biota of lichens was to secure the locality of the populations of rare and threatened lichens. At the same time, it is the protection of the source of propagules, and thus also a chance to maintain the gene pool.

In 1993 in the territory of the Forest Inspectorate of Przymuszewo, a nature reserve was established. Its name is "Bór Chrobotkowy", and it is commonly referred to as "The Professor Z. Tobolewski Bór Chrobotkowy" (Monitor Polski

[Official Gazette of the Government of the Republic of Poland] of 1958, No. 4, Item 21) (Fig. 1). It is situated between Lubnia and Wiele. The object of protection was the classically developed community of *Cladonio-Pinetum* with abundant populations of rare and unique species of ground lichens, growing side by side with many common species. The territory of the reserve and its directly neighbouring areas are one of the two lowland localities of *Flavocetraria nivalis*. It is here that abundant populations of *Cladonia stellaris* grow, the species from the *Stereocaulon* genus, including *S. taeniarum* and *S. paschale, Cetraria* (such as *C. islandica* and *C. ericetorum*) as well as many other rare species of lichens. In total, in the area of the entire reserve, over 70 taxa of lichens were found, including approximately 50 species of ground lichens with the dominant specimens of *Cladonia*, typical of *Cladonio-Pinetum*.

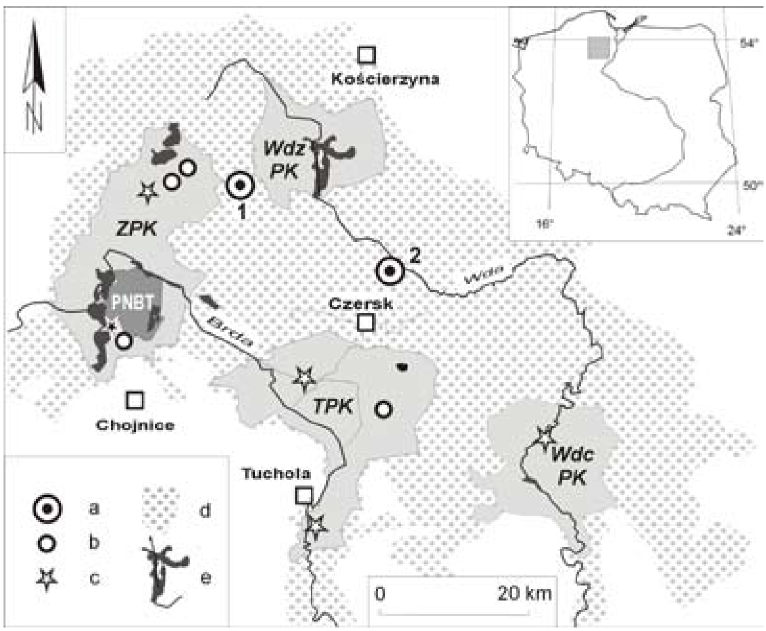

Fig. 1. The most important objects in Bory Tucholskie Forest area, where the main or one of the most important subject of protection are lichens:
a – nature reserve: 1. "The Professor Z. Tobolewski Bór Chrobotkowy", 2. natural and archeological reserve "Kręgi Kamienne [Circles of Stone]"; b – monuments of nature; c – permanent observation place of valuable lichen in Bory Tucholskie Forests; d – important cities; e – forest areas; f – lakes and rivers;
PNBT – Bory Tucholskie National Park; TPK – Tucholski Lanscape Park; ZPK – Zaborski Landscape Park, WdcPK – Wdecki Landscape Park, WdzPK – Wdzydzki Landscape Park

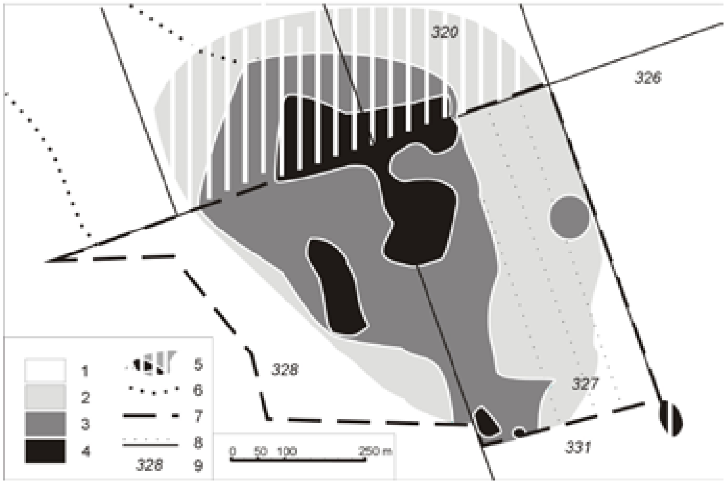

Fig. 2. Approximate lichenological values of nature reserve „Professor Z. Tobolewski Bór Chrobotkowy"
A. lichenological values: 1 – average, 2 – high, 3 – very high, 4 –outstanding;
B. Other signs: 5 – valuable areas in the immediate vicinity of the reserve; 6 – forest roads, 7 – the boundaries of the reserve; 8 – boundaries of the forest units , 9 – numbers of forest units

The reserve covers an area of 41.50 ha (Fig. 2). The most precious lichens were found in the middle and northern parts of the 327d district forest. It features the oldest tree stands. This part constitutes the main reservoir for the maintenance of the gene pool of both the precious and the common species. With the maturation and exposure to light of the *Cladonio-Pinetum* community, there will be conditions in the neighbouring divisions for the dissemination and maintenance of the population of precious lichens.

In other protected facilities in the territory of the Bory Tucholskie Forest, such as the "Bory Tucholskie" National Park, in the landscape parks and in the "Kręgi Kamienne [Circles of Stone]" reserve, the lichens constitute an important and highly cherished part of living nature (Lipnicki 2003; Grabarczyk & Lipnicki 2005).

Apart from the Bory Tucholskie Forest, one nature monument for the protection of lichens has been established so far – on the peripheries of the Wkrzańska Forest (Janczar 2012). Procedures have already been launched to establish subsequent ones – in the Krajeńskie Lakeland (Gruszka 2012).

CONCLUSIONS ARISING FROM THE FORMS OF THE PRACTICAL PROTECTION OF LICHENS APPLIED TO DATE

The threats to lichens indicated 80 years ago by Motyka (1934) are still present and relate not only to the territory of Poland. In the recent years, these threats have been emphasized by, inter alia, Scheidegger & Werth (2009), who presented the proposed strategy, which should be taken into consideration in the efforts to protect lichens. Like Motyka (1934), also other Polish lichenologists indicate the threats resulting from such phenomena as deforestation and the reconstruction of the species composition of forests.

Practice shows that one of the conditions for the maintenance of the threatened species, which once were very abundant, is the procedure of establishing nature protection for the areas, which still have conducive conditions for the life and development of flourishing populations of those organisms (cf. Szweykowski & Tobolewski 1959). Such procedure proved effective, for example, in the year 1993, when the "Bór Chrobotkowy" *[Cup Lichen Forest]* ground lichens reserve was established. In this reserve, the population of such species as *Cladonia stellaris* and *Cetraria islandica* has been visibly enriched over the past few years. In this facility one can also observe fluctuations in the variety and numbers of the populations of other lichens, which are manifested by both the increase in the number of specimens (the species mentioned above and *Stereocaulon* spp.) and the dimininution of others, which have so far been numerous in specimens, for instance *Cetraria ericetorum*. The status of the reserve facilitates the observation of changes and the analysis of their causes. One condition for a reserve to fulfil such expectations is its surface, the numbers and diversity of the population and the manner of management, which ensures – insofar as possible – the invariability of habitat conditions. Such assumptions were accepted during the submission of proposals for the establishment of this reserve. Their correctness was supported in practice. The effectiveness of such activities for the protection of lichens is also indicated by Scheidegger & Werth (2009).

Good results are also achieved by the protection of saxicolous lichens in the "Kręgi Kamienne [Circles of Stone]" reserve in Odry village. The reserve was established in the year 1958 (Monitor Polski *[Official Gazette of the Government of the Republic of Poland]* of 1958, No. 81, Item 465). The intention of the protection was to protect the boulders that form the circles as a religious cult monument from the Neolithic era as well as to protect the lichens and epilithic bryophytes.

20 years of experience from the Bory Tucholskie Forest enables evaluation of the efficiency of establishing nature monuments in order to protect the localities of rare lichen species. As in the establishment of reserves, also definitely positive results are shown by the protection of relatively flourishing populations. An example of this is the over 2km long alley which was placed under protection in 1991. The alley is formed by 141 trees growing on both sides of the road between Powałki and Jarcewo (Dz.Urz. *[Official Gazette]* of the Bydgoszcz Province 1991

No. 15, Item 120). Those include specimens of *Quercus petraea* with a circumference of 222–360 cm, *Acer platanoides* (110–357 cm) and *A. pseudoplatanus* (133–345 cm). The aim of the protection was achieved – abundant populations of precious lichens are preserved and stable, and their base – the impressive roadside tress, protected against felling.

The protection of *Betula pendula* specimens, on the trunks of which primarily *Usnea* and *Bryoria* occurred, yielded varying results. Precious epiphytic lichens are, in the majority of cases, still present on the bark of birch trees which grow in larger clusters and which constitute nature monuments. Young thalli appear both on the bark of those trees and on the trees and shrubs growing in the neighbouring areas. This phenomena is present in the localities, where no works – particularly clear-cutting – are conducted in the neighbouring areas. Very good examples of this are birch trees – nature monuments, which were protected by the "Bory Tucholskie" National Park established in 1996. If a neighbouring forest was felled, the lichens with fruticose thalli (*Usnea* and *Bryoria*) became totally extinct or their populations became reduced. It was probably caused by the change of the local microclimatic conditions.

The protection of single birch trees, particularly those with only a few thalli of *Usnea* or *Bryoria* on their trunks, did not live up to expectations. Many trees no longer have on their trunks any of the lichens that the monument was established to protect. One of the causes was the intentional plucking of thalli by "collectors" and – in the event of roadside birch trees – probably also the increase in the concentration of exhaust fumes.

Good results are also achieved by the protection of flourishing populations of lichens in the localities, which are not under formal administrative protection. The "Bory Tucholskie" National Park also has custody of the alley in Bachorze (on the border of the Park), and the Tucholski Landscape Park has custody of the populous locality of an epilithic lichen, *Aspicilia moenium*, in Fojutowo.

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LICHEN PROTECTION NEEDS NATURAL FOREST DISTURBANCES – EXAMPLES FROM SOME POLISH WESTERN CARPATHIAN NATIONAL PARKS

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Abstract. Results of author's investigations focused on threatened, red-listed lichen-forming fungi in Polish Western Carpathian forests naturally destroyed by gales and the activity of bark beetle *Ips typographus* are briefly characterized. Field explorations were made in 2008–2010 in the strictly protected areas of the Babia Góra, Gorce and Tatra National Parks covered with two main mountain forest communities: *Dentario glandulosae-Fagetum* and *Plagiothecio-Piceetum*. Frequency of particular species occupying spruce (*Picea abies*) standing dead wood and windthrows was calculated in relation to the spatial scale of forest disturbance. In all studied parks, 231 species of lichen-forming and lichenicolous fungi have been found in general, including 161 species on snags (wood and bark remnants together) and 195 on windthrows (root-system and log together). 66 taxa from the total amount (28%) are listed in the Polish Red List of extinct and threatened lichens. 32 of them have been found both on snags together with decorticated dead trees and on windthrows, and 14 are common in the three mountain parks. *Calicium trabinellum* (EN), *Chaenotheca xyloxena* (VU) and *Lecidea turgidula* (VU) reach ca 20% frequency on post bark-beetle snags, and 5 species are usually found on windthrows: *Arthorhaphis grisea* (22%; VU), *Psilolechia clavulifera* (46%; NT), *Trapeliopsis gelatinosa* (39%; NT), *Lichenomphalia umbellifera* (15%; NT) and *Micarea myriocarpa* (13%; NT). Almost all lichen epiphytes can optionally survive on lignum of snags as well as roots of windthrows. It shows that such natural disturbances in the forest composition resulting in an abundance of woody substrates support the lichen protection and should be used as much as possible elsewhere. The list of lichen indicators of ecological continuity of Western Carpathian forest habitats for lichens is also proposed based on the results of presented studies.

Key words. Nature protection, dead wood, national park, epixylic lichens, natural disasters, mountains, Poland

INTRODUCTION

Hurricanes and insect gradations are commonly considered as serious causes of woodlands destruction whereas such circumstances create a forest dynamic and its varied structure as well as much more diversity of microhabitats than in undisturbed woodlands. A lot of coarse woody debris such as snags, decorticated dead trees and windthrows are a great source of woody substrate occupied by many saproxylic organisms and wood-inhabiting lichen-forming fungi.

Relationships between the lichen biota and insect gradations or the lichen biota and gales have not been investigated to date in Poland, and everywhere in the world this problem is still neglected. Indeed recently several similar questions have been considered, however they are rather focused on an extension of a global knowledge of the role of different kinds of dead wood as a host for lichenized fungi (Holien 1998; Forsslund & Koffman 1998; Lőhmus & Lőhmus 2001; Nascimbene et al. 2008a, b; Spribille et al. 2008) or focused on the effect of different ways of woodland protection and its exploitation on the epixylic lichen diversity (Bader et al. 1995; Perhans et al. 2007; Cieśliński 2008). Several other works relate to the role of windthrows as an important habitat making the forest lichen biota richer (Jansová & Soldán 2006; Lőhmus et al. 2010).

Despite the spruce forests in the whole range of *Picea abies* distribution being today largely damaged by the bark beetle *Ips typographus*, investigations explaining the role of this insect for the lichens confined to this conifer host have not been undertaken, at least in the Carpathians. Similarly, strong wind as an ecological factor influencing the spatial scale of forest disturbances was not a subject of a larger lichenological interest in these mountains. Both phenomena are effective, however, in a great amount dead wood of different ages dead wood, particularly important for many red-listed and protected lichens. On the other hand, the presence of redlisted and threatened lichens in some forest area is often used as an indicator for woodland key habitats in general (Timonen et al. 2010) or an indicator of ecological continuity of woodland key habitats for lichens (Coppins & Coppins 2002). Such lichen indices have not been established as yet for the Carpathian forests.

The knowledge of the ecology of naturally disturbed woodlands and their impact on the occurrence and the dynamic of leaving forest components seems to be indispensable at least for the implementation of appropriate nature protection strategy and real conservation of particular red-listed species. Such knowledge should be particularly important for the managers of national parks, and could be used as an argument in the dialogue between votaries of the strict nature conservation and advocates of the restraint of spontaneous nature processes.

The two main aims of this work are: (1) to research the influence of gales and bark-beetle activity on the diversity and frequency of red-listed lichens regarded as threatened in Poland in relation to the spatial scale of disturbances within upper mountain spruce forest *Plagiothecio-Piceetum* and mixed spruce-fir-beech forests *Dentario glandulosae-Fagetum*, (2) to present the list of lichen specialists regarded as indices of ecological continuity of Western Carpathians woodland key habitats for lichens.

MATERIALS AND METHODS

Field studies. Due to sufficient abundance of snags and windthrows, the habitats for investigated lichens, it was necessary to choose the best preserved and natural, almost ancient forests with a long history of spontaneous ecological processes or at least such woodlands where the stands dynamic was recently minimally modified by the human activity. For this reason, field explorations in the period 2008–2010 were made in the strictly protected areas of the three Western Carpathian national parks: the Babia Góra, Gorce and Tatra. Within each of them, at least 100 years old spruce stands *Plagiothecio-Piceetum* and mixed spruce-fir-beech forests (regarded as *Dentario glandulosae-Fagetum* with its transitional zones) destroyed by the gales and the activity of bark beetle *Ips typographus* were chosen for investigations. Among other lichens also those threatened in Poland (according to Cieśliński et al. 2006, based on IUCN criteria) have been listed from more than 5 years old spruce (*Picea abies*) snags and windthrows in each of the three categories of the spatial-scale of forest decomposition: single, group and large-scale, separately for the two forest communities. More decayed woody substrates have been preferred, due to the greater potential lichen colonization. The species growing on snags were recorded separately for wood as well as bark remnants and these growing on windthrows were listed separately for root system and logs. Epilithic and epigeic lichens have been included within the group of 'lichens on root-systems'. The age of most investigated snags and windthrows was estimated based on well documented history of natural forest events marked in forest maps or described in archive documents as well as on oral information of national park workers. Due to the studies in the territories of the national parks as more taxa possibly have only been listed in the field, however those not or questionably identified there have been collected.

Laboratory studies. Species were determined with light microscopes and standard spot test thallus reactions with potassium hydroxide solution (K), sodium hypochloryte [commercial laundry bleach] (C) and paraphenylenediamine [solution in 95% ethyl alcohol] (PD). Hand-cut thallus and ascocarp sections were mounted in water and sometimes in KOH for their pigment reactions. Nitric acid (N) was used for the more precise measurement of spores and other hymenial and excipular elements, as well as for the better view of spore septation. Microscopic C+ reactions for some analysed ascoma sections have also been observed. For some sterile sorediate species, thin-layer chromatography (TLC) was performed in solvent C, according to Orange et al. (2001). Identified collections have been deposited in the herbarium of Gorce National Park (GPN). The nomenclature follows Index Fungorum (2012).

RESULTS

231 species of lichen-forming and lichenicolous fungi have been found on 784 individual objects including 161 taxa growing on 400 snags and 195 taxa on 384 windthrows. Lichen diversity in the large-scale post bark-beetle disturbed area within the community *Dentario glandulosae-Fagetum* was not investigated at all

since the lack of such available 'spruce' habitats in the three studied national parks, and the large-scale windthrows in the same type of forest was explored by only 18 individuals. In the Gorce National Park 95 species on snags and 105 species on windthrows have been listed, in the Babia Góra National Park 95 and 124 species, and in the Tatra National Park 144 and 166 species respectively. Among them 66 taxa (29% of all recorded species) found in the three mountain parks are regarded as threatened in Poland and included within the national Red List of Lichens (Cieśliński et al. 2006). 50 threatened species occupied snags and 49 species were recorded on windthrows. On wood of snags or windthrows 44 epixylic lichens were listed, including 32 taxa found on both categories of habitats. 14 of them are common for all investigated areas (Fig. 1) including *Calicium abietinum**, *C. glaucellum**, *C. trabinellum**, *Chaenotheca furfuracea*, *Ch. stemonea*, *Ch. trichialis*, *Ch. xyloxena**, *Elixia flexella**, *Hypogymnia farinacea*, *Lecanactis*

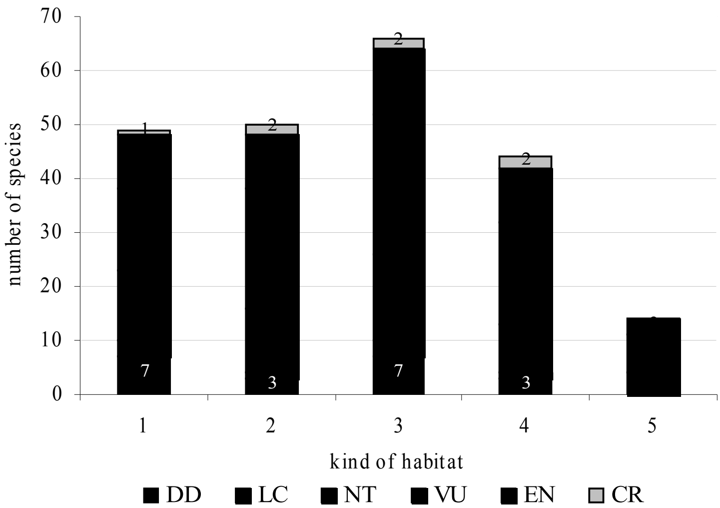

Fig. 1. Red-listed lichens in Poland found in post bark-beetle and windthrow areas of the three Western Carpathian national parks in relation to the kind of habitat: 1 – lichens on windthrows, 2 – lichens on snags, 3 – lichens on windthrows or snags, 4 – epixylic lichens on windthrows or snags, 5 – epixylic lichens both on windthrows and snags; the threat categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Last Concern, DD – Data Deficient.

abietina, *Lecanora sarcopidoides**, *Lecidea turgidula**, *Lichenomphalia umbllifera* and *Parmeliopsis hyperopta*. Only several of these species marked by asterisk are regarded as obligatory epixylic lichen-forming fungi. They are the core group of Carpathian lichens for which such woody substrates are essential to survive.

The highest diversity of threatened lichens (46 species) is found on root systems of windthrows, but almost as much species (45) as above is recorded on decorticated parts of snags. The amount of red-listed lichen species recorded on fallen logs is only 19, while on bark remnants over the snags 28 species have been identified. The list with the frequency of all threatened species in relation to the category of analysed habitats is presented in the Table 1.

Table 1. Frequency of threatened lichens found in the Polish Western Carpathians on spruce post bark-beetle snags and windthrows in relation to the habitat categories

Abbreviations: N – the number of all studied samples, L – the number of all lichen-forming taxa found on this kind of habitat, PRLL – Polish Red List of Lichens, # – lichenicolous fungus. Taxa found in all three explored national parks in the Polish Western Carpathians are in bold, and additionally these occupying both snags and windthrows are marked by **!** Species have been ordered follow the category of the threat.

Habitat / Species	Windthrows L=195		Snags L=161		PRLL
	root-system N=384	log N=353	wood N=400	bark N=287	
Calicium lenticulare Ach.	0.52		0.25	0.35	CR
Chrysothrix candelaris (L.) J.R. Laundon			1.0	0.35	CR
Calicium trabinellum **!** (Ach.) Ach.	3.91	0.57	18.5		EN
Chaenotheca brachypoda (Ach.) Tibell	0.26		0.25		EN
Chaenotheca brunneola (Ach.) Müll. Arg.			1.25		EN
Chaenotheca stemonea **!** (Ach.) Müll. Arg.	1.82		1.75	8.36	EN
Cladonia bellidiflora (Ach.) Schaer.	0.26				EN
Cyphelium tigillare (Ach.) Ach.	0.78		1.5		EN
Icmadophila ericetorum (L.) Zahlbr.	0.26	0.28	0.25		EN
Lecanactis abietina **!** (Ach.) Körb.		0.57	1.25	4.88	EN
Lecidoma demissum (Rutstr.) Schneider & Hertel	0.52				EN
Loxospora elatina (Ach.) A. Massal.	0.52	0.85	1.5	9.76	EN
Mycoblastus alpinus (Fr.) Kernst.			0.25	0.35	EN
Xylographa parallela (Ach.:Fr.) Behlen & Desberger	4.43	5.1	5.25		EN
#*Arthrorhaphis grisea* Th. Fr.	22.14				VU
Arthonia leucopellea (Ach.) Almq.				0.35	VU
Arthonia mediella Nyl.				0.35	VU
Arthrorhaphis citrinella (Ach.) Poelt	0.26				VU
Biatora efflorescens (Hedl.) Räsänen			0.5	0.70	VU
Bryoria spp.			4.0	3.83	VU
Calicium abietinum **!** Pers.	0.26		1.75	0.35	VU
Calicium glaucellum **!** Ach.	1.3		8.25		VU
Calicium salicinum Pers.			1.5		VU
Calicium viride Pers.		0.28	0.75	0.35	VU
Chaenotheca xyloxena **!** Nádv.	4.95	1.13	20.75		VU
Elixia flexella **!** (Ach.) Lumbsch	1.56		5.75		VU
Hypogymnia farinacea **!** Zopf	1.04		2.75	3.48	VU
Lecidea turgidula **!** Fr.	3.91	0.28	19.5		VU
Micarea cinerea (Schaer.) Hedl.			0.75		VU
Micarea hedlundii Coppins	2.86	1.13	1.0	1.05	VU
Mycoblastus sanquinarius (L.) Norman			2.75	4.18	VU

Ochrolechia androgyna s.lat.			0.25	1.05	VU
Opegrapha vulgata Ach.				0.35	VU
***Parmeliopsis hyperopta* !** (Ach.) Arnold	3.13	2.27	6.5	13.59	VU
Peltigera praetextata (Flörke *ex* Sommerf.) Zopf	0.26				VU
Thelocarpon impresellum Nyl.	0.52				VU
Thelocarpon intermediellum Nyl.	3.91		0.25		VU
Tuckermannopsis chlorophylla (Willd.) Hale			3.25	0.35	VU
Usnea hirta (L.) Weber *ex* F.H. Wigg.			0.25	0.35	VU
Usnea spp.	0.52		7.0	5.23	VU
***Chaenotheca furfuracea* !** (L.) Tibell	7.03	0.57	0.75	2.79	NT
***Chaenotheca trichialis* !** (Ach.) Th. Fr.	0.26		1.75	2.44	NT
Cystocoleus ebeneus (Dillwyn) Th waites				0.35	NT
Dibaeis baeomyces (L.) Rambold & Hertel	0.26				NT
Evernia prunastri (L.) Ach.			0.25		NT
Hypogymnia tubulosa (Schaer.) Hav.			0.75		NT
***Lecanora sarcopidoides* !** (A. Massal.) A.L. Sm.	0.26		4.25		NT
Lichenomphalia hudsoniana (H.S. Jenn.) Redhead, Lutzoni, Moncalvo & Vilgalys	1.3	0.28			NT
***Lichenomphalia umbellifera* !** (L.) Redhead, Lutzoni, Moncalvo & Vilgalys	14.58	7.65	6.5	3.48	NT
Micarea erratica (Körb.) Hertel, Rambold & Pietschm.	0.52				NT
Micarea melaena (Nyl.) Hedl.	1.56		1.0	2.79	NT
Micarea myriocarpa V. Wirth & Vězda *ex* Coppins	12.76				NT
Psilolechia clavulifera (Nyl.) Coppins	45.83		0.25		NT
Trapeliopsis gelatinosa (Flörke) Coppins & P. James	39.32	2.27		0.35	NT
Trapeliopsis viridescens (Schrad.) Coppins & P. James		0.28	0.5		NT
Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai	1.82	0.85	1.75	0.7	NT
Porpidia macrocarpa (DC.) Hertel & A.J. Schwab	7.03				LC
Psilolechia lucida (Ach.) M. Choisy	0.78				LC
Thelocarpon epibolum Nyl.	1.3	0.57	0.25		LC
Cladonia norvegica Třnsberg & Holien	0.26		0.25		DD
Porpidia cf. *superba* for. *sorediata* Fryday	0.26				DD
Trapeliopsis aeneofusca (Flörke ex Flot.) Coppins & P. James	1.82				DD
Trapeliopsis glaucolepidea (Nyl.) Gotth. Schneid.	3.13	0.57	0.5		DD
Vezdaea aestivalis (Ohlert) Tscherm.-Woess & Poelt	0.26				DD
Vezdaea stipitata Poelt & Döbbeler	0.26				DD
Xylographa vitiligo (Ach.) J.R. Laundon	1.04	0.57	2.75		DD
Total species	46	19	45	28	66

Among frequent red-listed lichens (Q>10%) recorded on post bark-beetle snags are *Calicium trabinellum* (19%; EN), *Chaenotheca xyloxena* (21%; VU) and *Lecidea turgidula* (20%; VU), and 5 others, *Psilolechia clavulifera* (46%; NT), *Trapeliopsis* *gelatinosa* (39%; NT), *Micarea myriocarpa* (13%; NT), *Lichenomphalia umbellifera* (15%; NT) and lichenicolous fungus *Arthorhaphis grisea* growing on squamules thalli of *Baeomyces rufus* (22%; VU) are frequently observed on root-systems of spruce windthrows. Further 15 threatened taxa occupying snags are common for the Tatra, Babia Góra and Gorce national parks similarly as 18 additional species to those mentioned above found on windthrows. The next lichens are much rarer, however, including, *Chaenotheca brunneola*, *Ch. stemonea* and *Lecanactis abietina*, which are regarded, as representing the category EN in Poland.

DISCUSSION

The list of fourteen lichen species, mainly obligatory epixyles, occupying both snags and windthrows in all studied mountain ranges (see Table 1), should be regarded as the most extend representatives of threatened national lichen biota on dead wood in forested regions of the Polish Western Carpathians, which are destroyed by natural disasters. Indeed, such results show the huge importance of these types of disturbances for the creation and the preservation of specific habitats supporting the conservation of threatened lichens. Such results simultaneously confirm the efficiency and necessity of strict nature protection for the security of natural processes continuity and fluctuations of all numerically unstable ecosystem components including lichens.

Recent investigations by Cieśliński (2008) in Central Poland strongly support the results presented here. In strictly protected nature reserves in the Puszcza Kozienicka Forest many more lichen species (including red-listed taxa) have been found than in the managed neighbouring stands.

The results, and especially a high frequency of some red-listed lichen species show that currently many of them are not threatened in these explored mountain ranges and also possibly in whole Western Carpathians. The natural enlargement of post insect gradation and windthrow areas in the national parks and the leaving of at least a small amount of snags, decorticated trees and up-ended root systems in naturally disturbed managed forests could promote the increase of many nationally threatened lichen species. The presence of a single distributed standing dead wood seems to be a matter of the utmost importance for the survival of such lichens (Fig. 2). The largest group of species including threatened lichen-forming fungi are confined to this kind of spatial scale forest disturbance both in upper mountain spruce forest *Plagiothecio-Piceetum* and in Carpathian beech forest *Dentario glandulosae-Fagetum*. In the case of windthrows, the distinct preferences towards some category of spatial disturbances are not so clear, but the higher diversity of lichen-forming fungi has been observed on fallen spruces distributed in groups. Generally, the upper mountain belt covered with *Plagiothecio-Piceetum* is richer in lichen species confined to dead wood, including red-listed lichens, than mixed, more ecologically stable Carpathian beech forest at lower altitu-

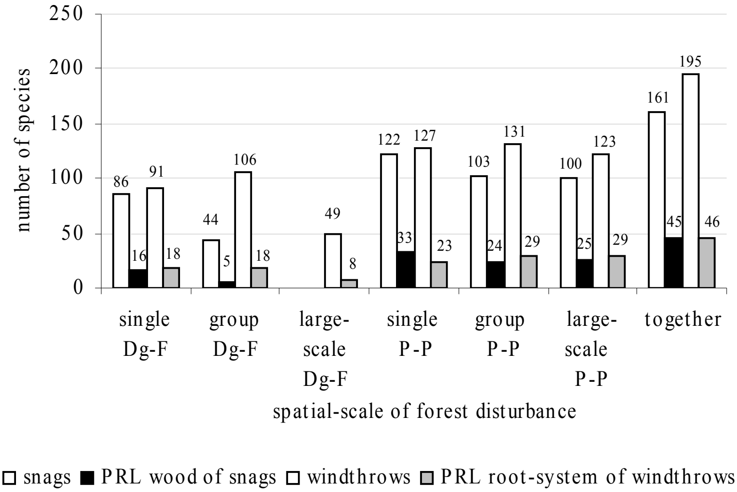

Fig. 2. Lichen diversity and the abundance of threatened species on wood of snags and windthrows in both explored forest communities in relation to the spatial-scale of forest disturbance: Dg-F – *Dentario glandulosae-Fagetum* (mixed mountain spruce-fir-beech forest); P-P – *Plagiothecio-Piceetum* (upper mountain spruce forest); PRLL – Polish Red List of Lichens.

des. This difference could result however from a varied number of studied snags and windthrows in the considered categories of habitats. Indeed, due to the lack of large-scale bark-beetle disturbances and larger windthrow disasters in the mixed spruce-fir-beech forests, only 89 snags and 134 windthrows of *Picea abies* have been investigated there while in the upper mountain spruce forest 311 and 250 objects respectively.

The root systems of fallen spruces appear to be a very important habitat for nationally threatened lichens, as well as for lichens in general, in contrast to the logs. It results probably from a longer woody decay of more or less underhanged and over-drayed roots, while the logs fallen on wet ground decompose faster because of the better conditions for the colonization of true fungi, bryophytes and vascular plants. As a consequence of this, on the root systems there are more various microhabitats available for lichens; some of them are confined directly to the woody substrate, some others occupy humus and small pebbles. Indeed, among 19 red-listed lichen-forming fungi found on logs of spruce windthrows in the three explored national parks not a single species was exclusive for this kind of habitat. All of them have been recorded also on root systems or snags. It suggests some practical methods for more effective lichen protection not only in national parks or nature reserves (though here particularly), but also in managed forests. It seems to be obvious, that the simple way to achieve this goal is to leave as many up-ended root systems in forest areas as possible even though the entire fallen trees (together with logs) cannot remain for economic reasons.

Another simple way to protect epixyles in managed forests is the differentiation of stands structure using the natural disasters effecting some amount of coarse woody debris. As shown by results of studies carried out in North American old-growth boreal forests, irregular forest types sustain higher species variation of epixylics, including lichens, than forests with a regular structure (Rheault et al. 2009).

New ecological and geographical data gathered during this study are important for the verification of the current threat of many species included in the Polish Red List of Lichens (Cieśliński et al. 2006). Undoubtedly, such species as *Psilolechia clavulifera*, *Arthrorhaphis grisea*, *Chaenotheca xyloxena*, *Lichenomphalia umbellifera*, *Micarea myriocarpa*, *Parmeliopsis hyperopta* and *Trapeliopsis gelatinosa*, are very common in Western Carpathians (Tabs 2 & 3). Because of the natural disasters causing a larger and larger surface of destroyed forest areas in this part of Poland, these abovementioned lichens could be deleted from the national list of threatened lichens or at least their threat category should be decreased.

Table 2. Frequency of more common Polish red-listed lichen species found on snags in Polish Western Carpathians in relation to the spatial scale of forest disturbance and to the explored forest communities

Q>10% at least in one forest disturbance category. Species common for all three mountain ranges are in bold. Abbreviations as in the Table 1 and Fig. 2.

Species	Dg-F		P-P			Total L=161 N=400	PRLL
	single L=86 N=58	group L=44 N=31	single L=122 N=92	group L=103 N=96	large L=100 N=123		
Chaenotheca xyloxena	50.0	29.03	29.35	12.5	4.76	20.75	VU
Lecidea turgidula	5.17		17.39	26.04	26.98	19.5	VU
Calicium trabinellum	10.34	6.45	25.0	23.96	15.87	18.5	EN
Calicium glaucellum	8.62		15.22	6.25	6.35	8.25	VU
Usnea spp.			14.13	8.33	5.56	7.0	VU
Lichenomphalia umbellifera	5.17		14.13	7.29	2.38	6.5	NT
Parmeliopsis hyperopta			9.78	11.46	4.76	6.5	VU
Elixia flexella	10.34	6.45	6.52	4.17	3.97	5.75	VU
Xylographa parallela			2.17	5.21	11.11	5.25	EN
Lecanora sarcopidoides	10.34	9.68		1.04	5.56	4.25	NT

Table 3. Frequency of more common Polish red-listed lichen species found on windthrows in Polish Western Carpathians in relation to the spatial-scale of forest disturbance and to the explored forest communities

Q>9.8% at least in one forest disturbance category. Species common for all three mountain ranges are in bold. Abbreviations as in the Table 1 and Figure 2.

Species	Dg-F			P-P			Total L=195 N=384	PRLL
	single L=91 N=51	group L=106 N=65	large L=49 N=18	single L=127 N=87	group L=131 N=91	large L=123 N=72		
Psilolechia clavulifera	45.10	47.69	66.67	52.87	42.86	34.72	45.83	NT
Trapeliopsis gelatinosa	23.53	40.00	55.56	49.43	40.66	31.94	39.32	NT
#Arthrorhaphis grisea	7.84	15.38	38.89	18.39	26.37	33.33	22.14	VU
Lichenomphalia umbellifera	5.88	6.15	11.11	17.24	18.68	20.83	14.58	NT
Micarea myriocarpa	5.88	10.77	16.67	19.54	15.38	6.94	12.76	NT
Chaenotheca furfuracea	9.80	13.85	11.11	5.75	4.40	2.78	7.03	NT
Porpidia macrocarpa	1.96	1.54		8.05	9.89	12.50	7.03	LC
Chaenotheca xyloxena	3.92	12.31	11.11	3.45	4.40		4.95	VU
Xylographa parallela					6.59	15.28	4.43	EN
Calicium trabinellum	1.96	4.62			9.89	2.78	3.91	EN
Lecidea turgidula		1.54		1.15	5.49	11.11	3.91	VU
Thelocarpon intermediellum		1.54	5.56	10.34	3.30	1.39	3.91	VU

The frequency near or more than 10% at least in one category of spatial forest disturbance could be regarded as sufficient criterion for the recognition of habitat preferences of some red-listed lichen-forming fungi. As indicated by data in the Tables 2 & 3, *Chaenotheca xyloxena*, *Elixia flexella* and *Lecanora sarcopidoides*, for example, prefer mixed forests at lower altitudes and a slow rate of forest disturbance; that is why they more frequently grow on singly distributed snags. To the contrary, *Lecidea turgidula* and *Xylographa parallela* distinctly prefer well-exposed snags and windthrows in upper mountain belt covered with large-scale disturbed spruce forests.

The studies presented here, conducted in strictly protected natural mountain forests, focused on dead wood-inhabiting threatened lichens, are a good basis for the indication of some epixyles and facultative epiphytes to treat them as indices of ecological continuity for woodland lichen habitats in Western Carpathians. Several other little known or overlooked species in Poland, thus not included yet in the recent national Red List of Lichens, could modestly increase this group (Table 4). Till now such indices, sometimes defined as 'indicators of old-growth forests', 'indicators of primeval forest', 'indicators of forest continuity' or 'indicators of woodland key habitats for lichens' were proposed for different regions in Europe (e.g., Tibell 1992; Kuusinen 1996; Andersson & Kriukelis 2002; Coppins & Coppins 2002; Czyżewska & Cieśliński 2003; Motiejűnaitë et al. 2004; Bradtka et al. 2010), but not for the Western Carpathians.

Table. 4. The list of lichen indices of ecological continuity of woodland lichen habitats for Western Carpathian mountain forests

Species	Habitat preferences
Biatora veteranorum	epixyle of spruce-fir-beech forests
Calicium abietinum	epixyle of mountain forests
Calicium glaucellum	epixyle of mountain forests
Calicium lenticulare	epixyle of spruce mountain forests
Calicium pinastri	epiphyte/epixyle of mountain forests
Calicium trabinellum	epixyle of spruce mountain forests
Calicium viride	epiphyte/epixyle of mountain forests
Chaenotheca brachypoda	epixyle of spruce-fir-beech forests
Chaenotheca brunneola	epixyle of spruce mountain forests
Chaenothecopsis viridireagens	lichenicolous fungus of spruce mountain forests
Chaenothecopsis consociata	lichenicolous fungus of spruce mountain forests
Cladonia bellidiflora	epixyle of spruce mountain forests
Cladonia norvegica	epixyle of spruce mountain forests
Cyphellium tigillare	epixyle of spruce mountain forests
Hypogymnia farinacea	epixyle/epiphyte of spruce mountain forests
Icmadophila ericetorum	epixyle of spruce mountain forests
Japewia subaurifera	epixyle/epiphyte of spruce mountain forests
Lecanactis abietina	epiphyte/epixyle of mountain forests
Lecanora phaeostigma	epixyle/epiphyte of spruce mountain forests
Lecanora subintricata	epixyle of mountain forests
Lecidea leprarioides	epixyle/epiphyte of spruce mountain forests
Lecidea pullata	epiphyte/epixyle of spruce mountain forests
Lecidea turgidula	epixyle of spruce mountain forests
Lichenomphalia hudsoniana	epigeic/epixyle of spruce mountain forests
Micarea cinerea	epixyle of spruce mountain forests
Micarea deminuta	epixyle of spruce mountain forests
Micarea hedlundii	epixyle of mountain forests
Micarea nigella	epixyle of mountain forests
Micarea tomentosa	epixyle of mountain forests
Microcalicium ahlneri	non-lichenized fungus of mountain forests
Microcalicium disseminatum	lichenicolous fungus of spruce mountain forests
Pycnora praestabilis	epixyle of spruce mountain forests
Trapeliopsis glaucolepidea s.str.	epigeic/epixyle of spruce mountain forests
Trapeliopsis viridescens	epixyle of spruce mountain forests
Xylographa parallela	epixyle of spruce mountain forests
Xylographa vitiligo	epixyle of spruce mountain forests

The above-mentioned different nomenclature implemented for selected lichen indices needs in fact further worldwide discussion on an identity of these terms. Here, the last mentioned idea has been adopted, as the most adequate for very complicated, insufficiently recognized historical circumstances related to the forest management and the origin of many Polish Carpathian spruce forests.

For the selection of epixylic indicators of ecological continuity for upper mountain woodland lichen habitats, lichenological data relating to the long-term protected, spruce upper mountain forests in the Babia Góra and Tatra National Parks have been used. For lichen indicators preferring lower mountain belt, the data from Gorce NP have mainly been considered since the Carpathian beech forest is natural there and strictly protected for a long time in the largest area in the whole Polish Western Carpathians. These woodlands satisfy conditions for old-growth forests (Czyżewska & Cieśliński 2003), and here and there they probably keep their ancient characters. Such area are rich in the coarse woody debris as well as red-listed and threatened habitat specialist lichens and at this stage can certainly be considered as woodland key habitats (Ek et al. 2002; Timonen et al. 2010).

The presented list (Table 4) includes very rare and stenotopic species as well as the lichen-forming fungi, which develop dynamically in consequence of natural forest disturbances, typical for ancient woodlands. Some of them are simultaneously considered as indicators of lowland old-growth forests (Czyżewska & Cieśliński 2003; Motiejűnaitë et al. 2004), but others are specific for mountains. Some of them prefer wood of snags and decorticated dead trees, others prefer decaying windthrows as their habitat. Some of them have distinct preferences towards the forest community or mountain belt, some others are more ecologically tolerant and for this reason the habitat preferences of listed species are differentiated. A full list of Carpathian lichen indicators should become complete in the future by epiphytes confined to deciduous trees and perhaps by other dead wood-inhabiting epixyles.

CONCLUSIONS

1. The naturally disturbed Western Carpathian woodlands are very important refuges for many red-listed lichens in Poland including those, which are considered as endangered and vulnerable. Many epiphytic lichens can survive in these disturbed 'dead forests' as facultative epixyles.
2. Spruce windthrows and post bark beetle standing dead wood are important habitats for dozens lichen specialist.
3. Because of more microhabitats, windthrows host more lichen-forming taxa than snags and dead decorticated trees together; root systems are particularly rich in red-listed lichens.
4. Spatial-scale of forest disturbances and the type of forest communities play a significant role in the abundance and the lichen species composition in gen-

eral, and particularly in the frequency of some red-listed species. Many nationally threatened lichens are common in these disturbed mountain woodlands (frequency >10%) showing that the strict protection of the natural forest disasters is the best way for their survival.

5. The presence of many rare and red-listed habitat specialist lichens found on standing or lying dead wood of *Picea abies* (snags together with decorticated dead trees and windthrows respectively) indicates woodland key habitats for lichens in disturbed natural or almost primeval mountain forests and these lichen specialists are proposed to be considered as indices of ecological continuity for woodland lichen habitats in Western Carpathians. The list includes 36 taxa, mainly epixylic of facultative epiphytic lichen-forming fungi and should become complete in the future by epiphytes confined to deciduous trees.

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THE LICHEN BIOTA OF ANTARCTIC SPECIALLY PROTECTED AREA NO. 151, LIONS RUMP (KING GEORGE ISLAND)

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Abstract. Lions Rump lies on the southern coast of King George Bay on King George Island in Antarctica. The part of the area, as an effect of Polish initiative, has been approved as protected area (ASPA No. 151). The aim of this study was to document the occurrence and distribution of lichens to provide the baseline data for long-term monitoring of the ongoing changes in this valuable area.

Key words: Antarctica, protected area, lichenized fungi, lichenicolous fungi, ASPA No.151

INTRODUCTION

Development of vegetation in the Antarctic is limited only to ice-free areas, which cover only 2–5 percent of whole of Antarctica (Olech 2010). Tundra ecosystem is poorly developed – consisting mainly of cryptogams such as lichens, bryophytes and algae (Lindsay 1971; Ochyra 1998; Olech 1993, 2002). Only 2 native species of flowering plants are found – *Deschampsia antarctica* Desv. and *Colobanthus quitensis* (Kunth) Bartl (Lewis Smith 1984).

Lichens are the most abundant and conspicuous terrestrial organisms in the Antarctic biome, constituting a main component of tundra communities. They are exquisitely adapted to severe climate conditions and a very short vegetation season (Schroeter et al. 1995; Olech 2004; Harańczyk et al. 2008).

In terrestrial ecosystems of the study area an important factor in nutrient cycling is the presence of animals. A special role is played by sea birds, especially penguin species, as their numerous presence determines the functioning of terrestrial biocoenoses. Seabirds feed in the sea and breed on land, bringing a huge amount of organic matter from sea to land, mainly in the form of guano (Eurola & Hakala 1977). This is of particular importance to vegetation. Nutrient enrichment in areas adjacent to penguin colonies, which causes a stimulation of a primary production and also changes in species composition and the development of luxuriant vegetation, is called the ornithocoprophilous effect. Particularly the development of ornithocoprophilous lichen communities, which locally cover large areas of rocks, is characteristic for maritime Antarctica (Tatur 2002; Olech 2004).

The organisms that form Antarctic tundra are delicate and fragile; their destruction results in major changes in the ecosystem. The growth rate of lichens, the main component of tundra, is extremely low, and so the development of communities is also extremely low. These are good reasons why Antarctic terrestrial systems should be specially protected (Olech 1997, 2004).

The Antarctic is outside the sovereign jurisdiction of any country. Nature conservation is largely based on provisions of the Antarctic Treaty and on the Scientific Committee for Antarctic Research (SCAR). Also the Committee of Environmental Protection (CEP) was established with the objective of providing relevant information for organizing meetings devoted to issues of environmental protection in Antarctica (Ciaputa et al. 2000; Olech 2004).

The Antarctic Treaty introduced the principles of protection of local natural features of special value. The most important of these were declared either a Specially Protected Area (SPA) or a Site of Special Scientific Interest (SSSI). Next these categories were replaced with the new category – an Antarctic Specially Protected Area (ASPA). Entrance to the ASPA is possible only with special permit, which may be issued for stated period only by appropriate national authorities as designated under Annex V Article 7 of the Protocol on Environmental Protection to the Antarctic Treaty. Only non – invasive methods of research may be used and only for a scientific purpose, which cannot be served elsewhere. Access to and movement within the Area shall, in any case, be limited in order to avoid damage of valuable biota in the Area.

STUDY AREA

Lions Rump is located on the southern coast of King George Bay, King George Island, in the South Shetlands (62°13'S, 58°08'W) and covers a relatively small terrain of 1.3 km^2 (Fig. 1) (Marsz 2000). The area was originally designated (1991) as a Site of Special Scientific Interest (SSSI No. 34) after a proposal by Poland on the grounds that it contains diverse biota and geological features and is a representative example of the terrestrial, limnological, and littoral habitats of the maritime Antarctic. The area was redesignated (2000) as an Antarctic Specially Protected Area (ASPA No. 151).

The ice-free terrain of Lions Rump exhibits differentiated geomorfological forms, including beaches, moraines, hills, cliffs and inland rocks. The highest point rises to an altitude above 190 m. Geologically, the area consists of Tertiary lavas and tuff (Birkenmajer 1980). Increased deglaciation process is recently observed in this area. Between the years 1998 and 2009 the ice wall of White Eagle Glacier shifted by approximate 500 metres (Fig. 2) (Olech 2010).

Large numbers of penguins, such as *Pygoscelis adeliae*, *P. antarctica* and *P. papua*, breed throughout the area. Moreover, 8 other bird species are found there. In lower locations marine mammals occur. In places occupied by large colonies of seals,

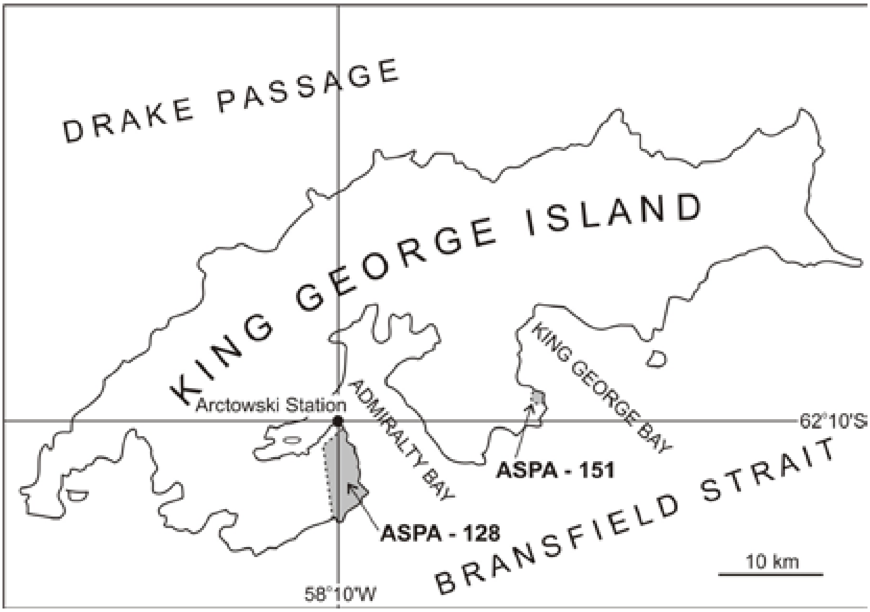

Fig. 1. Map of King George Island showing location of ASPA No. 151 (study area) and ASPA No. 128

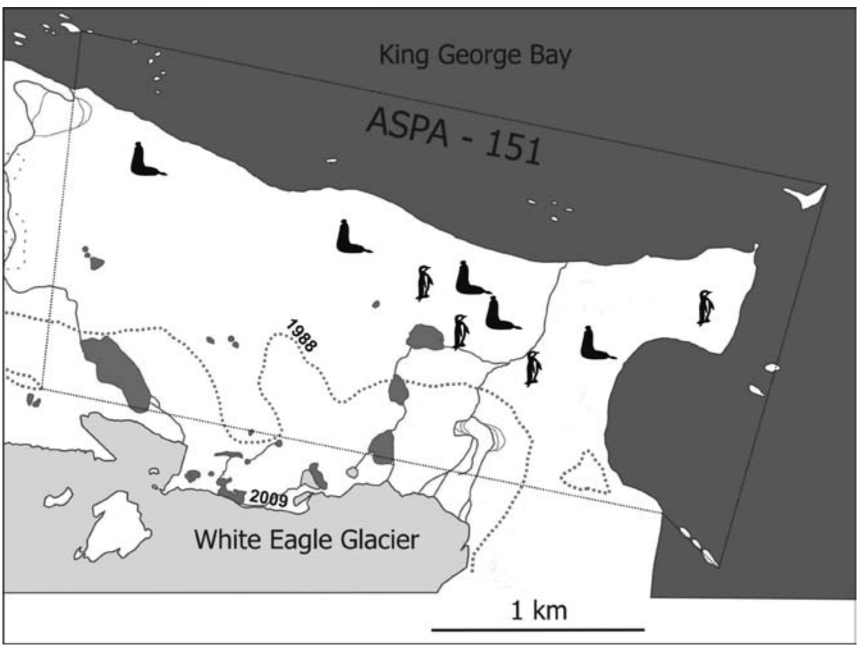

Fig. 2. Map of ASPA No. 151 in greater detail showing the White Eagle Glacier recession and the distribution of penguin and seal colonies

particularly elephant seals (*Mirounga leonina*) or fur seals (*Arctocephalus gazella*), tundra is often destroyed and its substrate enriched with nitrogen, that enhance the ornithocoprophilous effect.

The ASPA No. 151 is almost devoid of anthropogenic influences since neither research stations are located there nor do tourist excursions reach that far (Olech 2010).

MATERIAL AND METHODS

The first, scarce data was collected in this area in 1988 and 1990 during the short stays in Antarctica. As a result the preliminary list of lichens and lichenocolous fungi was prepared (Olech 1994) and it was used in the proposal by Poland to protect this area. The next field studies in the area between the sea level and glacier edge were conducted during two austral summers in the years 2007 and 2008. As in the case of the previous studies (Olech 1994), the cartogram method was used. Within the squares (250 × 250 m) a series of research stations were mapped out, which were described by geographical co-ordinates using a GARMINe Trex GPS device to enable and facilitate comparative studies in the future.

The following 72 sites were investigated and for each species particular site numbers were given (Table 1):

1. 62º08’05,8”S, 58º07’25,8”W – Cap Lions Rump, eutrophicated S rocks below penguin rookeries, 1-5m
2. 62º07’59,7”S, 58º07’26,8”W – Cap Lions Rump, eutrophicated N rocks near penguin rookeries, 2-15m
3. 62º08’00,5”S, 58º07’31,6”W – Cap Lions Rump, eutrophicated boulder at shore, 5m
4. 62º08’01,5”S, 58º07’36,2”W – Cap lions Rump, SE rocks near penguin rookeries, 5m
5. 62º08’06,0”S, 58º07’45,5”W – Boulder on gently sloping hill, 30m
6. 62º08’07,3”S, 58º07’44,4”W – Boulders and Stones on slope of hill, 15m
7. 62º08’04,9”S, 58º07’50,4”W – Boulders near penguin occurrence, 30m
8. 62º08’09,7”S, 58º07’49,1”W – Boulder on top of small ridge, 40m
9. 62º08’18,1”S, 58º07’51,7”W – Chopin Ridge rock, 190m
10. 62º08’15,1”S, 58º07’52,8”W – Plateau of Ridge, 100m
11. 62º08’03,8”S, 58º07’55,8”W – Boulders on lower slope of hill, 20m
12. 62º08’05,6”S, 58º07’58,1”W – Boulder on slope of the Green Hills, 15m
13. 62º08’07,2”S, 58º08’01,0”W – Boulders in creek, 30m
14. 62º08’11,1”S, 58º08’08,0”W – Boggy areas near stream, 35m
15. 62º08’10,1”S, 58º08’07,7”W – Boulders and stones on slope below late-lying snowbed, 40m
16. 62º08’08,4”S, 58º08’04,7”W – N slope of unnamed hill, 50m
17. 62º08’07,1”S, 58º08’06,1”W – Unnamed hill, 70m
18. 62º08’06,2”S, 58º08’06,5”W – Unnamed hill, 60m
19. 62º08’07,6”S, 58º08’10,5”W – Near lake, 65m
20. 62º08’07,6”S, 58º08’13,0”W – Near lake, 70m
21. 62º08’08,4”S, 58º08’15,5”W – Recently deglaciated area, ca 70m
22. 62º08’01,2”S, 58º08’10,9”W – Boulder on moraine, 20m
23. 62º08’02,3”S, 58º08’14,0”W – Glacier moraine, 25m
24. 62º07’59,1”S, 58º08’14,6”W – Glacier moraine, relict penguin colonies, 27m

25. 62º07’59,1”S, 58º08’15,1”W – Boulder, 30m
26. 62º07’57,0”S, 58º08’14,6”W – Boulders and stones, 17m
27. 62º07’57,1”S, 58º08’14,8”W – Boulder and stones on slope of ridge, 30m
28. 62º07’55,0”S, 58º08’16,7”W – Exposed rocks above shore, 14m
29. 62º07’57,1”S, 58º08’23,3”W – Eutrophicated rocks above sea, 1-5m
30. 62º07’59,0”S, 58º08’22,0”W – Rocks, 50m
31. 62º08’10,0”S, 58º08’33,7”W – Slope of ridge, 170m
32. 62º08’03,1”S, 58º08’29,2”W – Glacial moraine, 100m
33. 62º08’00,3”S, 58º08’27,6”W – Rocks on the top of unnamed hill, 130m
34. 62º08’02,0”S, 58º08’33,4”W – Boulders on slope, 116m
35. 62º08’06,3”S, 58º08’38,1”W – Boulders on glacier moraine, 157m
36. 62º08’05,4”S, 58º08’40,0”W – Stones on Glacier moraine, 154m
37. 62º08’00,4”S, 58º08’37,2”W – Boulders and Stones on Glacier moraine, 120m
38. 62º08’01,2”S, 58º09’18,8”W – Glacier moraine, 100m
39. 62º08’02,3”S, 58º09’11,3”W – Valley of Bystry Creek, 100m
40. 62º08’01,8”S, 58º09’04,6”W – Valley of Bystry Creek, 115m
41. 62º07’58,6”S, 58º’09”04,8W – Glacier moraine, ca 100m
42. 62º08’01,3”S, 58º08’52,3”W – Glacier moraine, 130m
43. 62º08’00,9”S, 58º08’48,3”W – Boulder on glacier moraine, 120m
44. 62º08’00,4”S, 58º08’40,3”W – Top of rocks with nest of bird *Catharacta arctica*, 130m
45. 62º08’02,3”S, 58º08’43,8”W – Glacier moraine, 118m
46. 62º08’02,7”S, 58º08’44,6”W – Stones on glacier moraine, 155m
47. 62º08’00,3”S, 58º08’44,6”W − Glacier moraine, 110m
48. 62º07’57,0”S, 58º09’03,4”W – Boulders on glacier moraine, 104m
49. 62º08’03,6”S, 58º08’22,4”W – Boulders on glacier moraine, 70m
50. 62º08’04,4”S, 58º08’27,0”W – Glacier moraine, 90m
51. 62º08’03,5”S, 58º08’36,4”W – Small rocks, 130m
52. 62º08’09,5”S, 58º08’22,4”W – Glacier moraine, 90m
53. 62º08’16,4”S, 58º08’17,6”W – Glacier moraine, 60m
54. 62º08’17,5”S, 58º08’18,9”W – Glacier moraine, 50m
55. 62º08’16,3”S, 58º07’59,1”W – Glacier moraine, 55m
56. 62º08’14,1”S, 58º07’59,3”W – Glacier moraine, 40m
57. 62º07’56,9”S, 58º09’14,5”W – Late melting depression, near Bystry Creek, 70m
58. 62º07’52,0”S, 58º08’54,6”W – Boulder on sea shore, 2m
59. 62º07’50,7”S, 58º09’01,2”W – Boulder on beach, 4m
60. 62º07’55,1”S, 58º09’05,3”W – Slightly horizontal rock, 85m
61. 62º07’55,9”S, 58º09’09,0”W – Glacier moraine, near Bystry Creek, 80m
62. 62º07’49,3”S, 58º09’18,8”W – SE slope of Sukiennice Hill, 36m
63. 62º07’46,5”S, 58º09’21,1”W – N slope of Sukiennice Hill, 40m
64. 62º07’53,0”S, 58º09’25,7”W – Glacier moraine near Bystry Creek, 70m
65. 62º07’52,5”S, 58º09’26,6”W – Glacier moraine, 50m
66. 62º07’54,3”S, 58º09’16,7”W – Glacier moraine, 80m
67. 62º07’56,0”S, 58º09’22,6”W – Top of glacier moraine, 100m
68. 62º07’57,4”S, 58º09’22,0”W − Glacier moraine, 95m
69. 62º07’58,4”S, 58º09’25,1”W − Glacier moraine, 100m
70. 62º08’00,3”S, 58º09’23,0”W – Depression on the margin of lake, 110m
71. 62º07’50,8”S, 58º09’25,4”W – Bystry Creek, 65m
72. 62º07’54,5”S, 58º09’36,0”W – Bystry Creek, 80m

Table 1. Lichen and lichenicolous fungi taxa recorded in ASPA No. 151
R – rock; M – moss; S – soil; L – thallus of lichen; *– lichenicolous fungus.

Species	Substrate	Location
Acarospora austroshetlandica (C.W. Dodge) Øvstedal	R	2
badiofusca (Nyl.) Th.Fr.	R	4
convoluta Darb.	R	28,29
macrocyclos Vain.	R	1,2,4,5,6,29,40,63,67
Amandinea augusta (Vain.) Søchting & Øvstedal	R	4
babingtonii (Hook.f. & Taylor) Søchting & Øvstedal	R	44
coniops (Wahlenb.) M. Choisy ex Scheid.	R	1,2,3,9,22,25,27,28,29,44,61,63
isabellina (Hue) Søchting & Øvstedal	R	44
latemarginata (Darb.)Søchting & Øvstedal	R	1,2,11
petermannii (Hue) Matzer, H. Mayrhofer & Scheid.	R	1,2,4,44
**Arthonia molendoi* (Frauenf.) R. Sant.	L	28
**rufidula* (Hue) D. Hawksw., R. Sant & Øvstedal	L	32,44,63
subantarctica Øvstedal	R	4
Aspicilia aquatica (Fr.) Körb.	R	22,23,26,27,31,33,36,37,40,41,42,45,46,48, 49,50, 51,57,58,61,64,65,67,68, 69,72
Austrolecia antarctica Hertel	R	9
Bacidia chrysocolla Olech, Czarnota et Llop	R	9,23,27,30,57,61,68,69
stipata I.M. Lamb	R	2,29,44
tuberculata Darb.	R	23
Bellemerea alpina (Sommerf.) Clauzade & Cl. Roux	R	61
subsorediosa (Lynge) R. Sant.	R	44
Buellia anisomera Vain.	R	26,30,34,44
darbishirei I.M. Lamb	R	9
falklandica Darb.	R	44
granulosa (Darb.) C.W. Dodge	R	1,2,28,29
illaetabilis I.M. Lamb	R	44
papillata (Sommerf.) Tuck.	M	24
perlata (Hue) Darb.	R	44
pycnogonoides Darb.	R	44
russa Darb.	R	2,30,33,60
Caloplaca ammiospila (Wahlenb.) H. Olivier	M	44
athallina Darb.	M	24

**bualliae* Olech & Søchting	L	61
cirrochrooides (Vain.) Zahlbr.	R	1,2,4,5,6,11,28,29
hertelii Sřchting, Øvstedal & Sancho	R	44
hookeri (C.W. Dodge) Søchting & Øvstedal	R	1,2,4,5,6,22,28,29,63
insignis Søchting & Øvstedal	R	37,44
isidioclada Zahlbr.	R	33,44
johnstonii (C.W. Dodge) Søchting & Olech	R	8,20,21,26,27,28,30,33,36,37,40,41,42,47,57, 58, 59,61,63,64
phaeocarpella (Nyl.) Zahlbr.	M	33
**psoromatis* Olech & Søchting	L	9,28,44
regalis (Vain.) Zahlbr.	R	1,2,3,4,5,6,11,12,28,30,39
**sauronii* Søchting & Øvstedal	L	44,68
saxicola (Hoffm.) Nordin	R	5,6,7,8,11,12,13,17,20,21, 25,26
schofieldii C.W. Dodge	R	26,61
soropelta (E.S. Hansen, Poelt & Søchting) Søchting	R,M,S	8,11,12,13,21,24,25,28, 29,40,61,67
sublobulata (Nyl.) Zahlbr.	R	1,2,5,6,7,8,9,10,11,12,22,23,24,25,27,28,29,30,31,32,33,34,35,36,37,39,40,41,42,43,44,45,46,49,50, 51,58,63,64,66,67
tetraspora (Nyl.) H. Olivier	M	44
tiroliensis Zahlbr.	M	24
Candelaria murrayi (C.W. Dodge) Poelt	R	5
Candelariella aurella (Hoffm.) Zahlbr.	R	8,12,23,25,26,27,28,32,37,40,42,44,45,48, 49, 51, 61,62,64,65
flava (C.W. Dodge & G.E. Baker) Castello & Nimis	R,M	24,29,44,50,58
vitellina (Hoffm.) Müll. Arg.	R,M	8,33,39,40,58,59
Carbonea assentiens (Nyl.) Hertel	R	9,10,26,27,30,32,33,34,35,36,37,44,58,59,61,62,63,64,67
vorticosa (Flörke) Hertel	R	61
Catillaria contristans (Nyl.) Zahlbr.	R	9
corymbosa (Hue) I.M. Lamb	R	44
**Cercidospora epipolytropa* (Mudd) Arnold	L	27,40
Cladonia borealis S. Stenroos	S,M	44
chlorophaea (Flörke ex Sommerf.) Spreng.	S,M	44
galindezi Øvstedal	S,M	4
pocillum (Ach.) Grognot	S,M	66
subulata (L.) Weber ex F.H. Wigg.	S,M	9
Collema tenax (Sw.) Ach. em. Degel	M,S	23,24
Cystocoleus ebeneus (Dillwyn) Thwaites	M,S	9

**Didimellopsis antarctica* Alstrup & Olech	L	4
Eiglera flavida (Hepp) Hafellner	R	32
Haematomma erythromma (Nyl.) Zahlbr.	R	1,2,4,28,29,30,33,37,44, 61,63
Huea cerussata (Hue) C.D. Dodge & G.E. Baker	R	23,26,27,30,37,44,59,62, 64,66,68,71,72
coralligera (Hue) C.D. Dodge & G.E. Baker	R	26
Lecania brialmontii (Vain.) Zahlbr.	R,M	2,4,28,29,44
gerlachei (Vain.) Darb.	R	2,28
glauca Øvstedal & Søchting	M	21,24,30,67
Lecanora dispersa (Pers.) Sommerf.	R	37,68
expectans Darb.	M	24
griseosorediata Øvstedal	R	44
intricata (Ach.) Ach.	R	27,37,40,43,59,68
physciella (Darb.) Hertel	R	44
polytropa (Ehrh. Ex Hoffm.) Rabenh.	R	9,20,26,27,30,32,34,35,37,40,41,57,58,59,61,62, 64,65,69,72
semipallida H. Magn.	R	6,8,11,12,13,17,39,50,61
Lecidea andersonii Filson	R	33,59
atrobrunnea (Ramond ex Lam. &DC.) Schaer.	R	59,63,68
lapicida (Ach.) Ach.	R	9,23,26,27,31,32,35,37,42,43,50,51,57,59,64.66, 68,69
spheniscidarum Hertel	R	30,33
Lecidella siplei (C.W. Dodge &G.E. Baker) May.Inoue	R	28
stigmatea (Ach.) Hertel & Leuckert	R	28,36,67
wulfenii (Hepp) Körb.	M	44
Lepraria alpina (de Lesd.) Tretiach & Baruffo	S	9,42,44,51,58
caerulescens (Hue) Botnen & Øvstedal	S,M	44
straminea Vain.	M,S	44
Leptogium puberulum Hue	M,R	9,10,22,23,32,33,41,44,51,57,62,64,66,67, 71,72
**Lichenoconium usneae* (Anzi) D. Hawksw.	L	32,63
Massalongia carnosa (Dicks.) Körb.	M	10,23,28,44
olechiana Alstrup et Søchting	S,M	9,23,44
Megaspora verrucosa (Ach.) Hafellner & V. Wirth	M	9,23,24,44
**Muellerella pygmaea* Körber) D. Hawksw.	L	61
Ochrolechia frigida (Sw.) Lynge	S,M	9,10,24,28,30,44
parella (L.) A. Massal.	R	9,28,30,33,44
Pannaria caespitosa P.M. Jørg.	R,M,S	9
Parmeliella austroshetlandica Øvstedal & Søchting	S,M	44

Pertusaria coccodes (Ach.) Nyl.	R	51
corallophora Vain.	R	30,44,63
excludens Nyl.	R	29,30,33,34,37,44,51,61
oculae-ranae Øvstedal & Søchting	R	44
pseudoculata Øvstedal	M	9,44
signyeae Øvstedal	R	9,28,44
**Phacopsis usneae* Dodge	L	9
Physcia caesia (Hoffm.) Fürnr.	M,S	2,6,30,37,44
dubia (Hoffm.) Lettau	R	28
Physconia muscigena (Ach.) Poelt	M,S	24,33,67
Placidium lachneoides (Breuss) Breuss	S	23,58
Placopsis antarctica D.J. Galloway, Lewis-Sm. & Quilhot	R	9,10,44,71,72
contortuplicata I.M. Lamb	R	9,10
Polyblastia gothica Th. Fr.	S	42
**Polycoccum rugulosarium* (Linds.) D. Hawksw.	L	4,63
Porpidia austroshetlandica Hertel	R	9,24,28,29,30,33,44,51,61
Protopannaria austro-orcadensis (Øvstedal) P.M.Jørg.	S,M	9,44
Psoroma ciliatum (Ach. Ex Fr.) Nyl. Ex Hue	M	9
cinnamomeum Malme	S,M	9,23,44,72
hypnorum (Vahl) Grey	M,S	9,10,28,44
saccharatum Scutari & Calvello	R	9
Ramalina terebrata Hook f. & Taylor	R	2,5,28
Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr.	R	22,26
geminatum Körb.	R	44
geographicum (L.) DC.	R	8,9,10,27,28,30,33,37,40,42,43,44,58,59,61,62
grande (Flörke) Arnold	R	33
polycarpum (Hepp) Th. Fr.	R	68
Rhizoplaca aspidophora (Vain.) Redon	R	3,30,35,61,63
melanophtalma (Ram.) Leuckert & Poelt	R	40
Rinodina cf. *occulta* (Körb.) Sheard	R	26
olivaceobrunnea C.W. Dodge & G.E. Baker	M,S	2,9,24,44
**Skyttea tephromelarum* Kalb. & Hafellner	L	63
Staurothelle frustulenta Vain.	R	42
gelida (Hook f. & Taylor) I.M. Lamb	R	9,23,26,27,30,37,40,41,48,49,57,58,59,62,63,66, 68,69,71,72
**Stigmidium fuscatae* (Arnold) R. Sant.	L	4

Tephromela atra (Huds.) Hafellner	R	4,9,22,23,27,28,35,36,37,44,51,58,61,63, 64,66,67
eatoni (Cromb.) Hertel	R	41
minor Øvstedal	R	33,35,41,51,58,61
Thelenella antarctica (I.M. Lamb) D.E. Eriksson	R	29
kerguelena (Nyl.) H. Mayrhofer	R	30,44
mawsonii (C.W. Dodge) H. Mayrhofer & McCarthy	R	44,65
**Thelocarpon cyaneum* Olech & Alstrup	L	42
Tremolecia atrata (Ach.) Hertel	R	61
Trimatothelopsis antarctica C.W. Dodge	R	4
Turgidosculum complicatulum (Nyl.) J. Kohlm. & E. Kohlm.	R	1,2,4,5,6,29
Umbilicaria africana (Jatta) Krog & Swinscow	R	30,33
antarctica Frey & I.M. Lamb	R	30,33,37,44,63
decussata (Vill.) Zahlbr.	R	61
kappeni Sancho, B.Schroeter &Valladares	R	30
Usnea antarctica Du Rietz	R,M	4,9,10,22,23,24,25,28,32,33,34,37,41,44, 51,58,63, 64,66,67,72
aurantiaco-atra (Jacq.) Bory	R	9,10
Verrucaria aethiobola Wahlenb.	R	29
elaeoplaca Vain.	R	4
psychrophila I.M. Lamb	R	1,28,29
tesselatula Nyl.	R	1,28,29
Xanthoria candelaria (L.) Th. Fr.	S,M,R	2,4,28,29,30,33,44
elegans (Link) Th. Fr.	R	30,33,37,44

Lichen and lichenicolous fungi nomenclature follows mainly Øvstedal & Lewis Smith (2001), Olech (2004), Søchting et al. (2004) and Osyczka et al. (2010). All materials were deposited in the Lichenological Herbarium of the Jagiellonian University (KRA).

RESULT AND DISCUSSION

As a result of investigation overall 156 taxa were recorded in the study area including 142 lichens (lichenized fungi) and 14 lichenicolous fungi (Table 1). A definite majority of them are widespread species, or even common, in the maritime Antarctic region. Among the taxa indicated in this area several appeared to be new to the whole King George Island, including: *Caloplaca insignis, C. sauronii, C. schofieldi, Lecidea andersonii, Lepraria alpina, Pertusaria oculae-ranae* and *Rinodina occulta* (Søchting et al. 2004).

The most numerous in species are the genera *Caloplaca* (19 species), *Buellia* (9), *Lecanora* (7) and *Pertusaria* (6). Three ecological lichen groups – epilithic, epibryophytic and epigeic – are found within the study area.

Epilithic lichens form the most numerous habitat group. A total of 98 species (70%) have been found, including 8 exclusive ones, such as *Acarospora austroshetlandica*, *A. badiofusca*, *Austrolecia antarctica*, *Bellemerea alpina*, *Caloplaca isidioclada*, *Lecanora physciella*, *Pertusaria oculae-ranae* and *Staurothelle frustulenta*. Epilithic lichens occur on coastal cliffs, boulders and pebbles on sea shores, rock faces and ridges further inland. Biota occurring on rocks is dominated by crustose lichen species.

A significant feature of the study area is the occurrence of many ornithocoprophilous species, also in other frequency classes. Numerous lichen species have adapted to tolerate high levels of nutrients, particularly nitrogen and phosphorus from the penguin guano, and they create specific ornithocoprophilous communities. In the most fertilized places following species, associated with large penguin colonies, occur: *Acarospora macrocyclos*, *Amandinea coniops*, *Buelia russa*, *Caloplaca cirrochrooides*, *C. hookeri*, *C. regalis*, *Physcia caesia*, *Rhizoplaca aspidophora* and *Xanthoria candelaria*. They prefer sites strongly influenced by birds.

Contrary, nitrophobic communities develop on rocky substrates far from direct influx of nutrients, further inland. They are formed of species, such as *Carbonea assentiens*, *Cystocoleus ebeneus, Pertusaria* spp., *Placopsis contortuplicata*, *Psoroma saccharatum, Rhizocarpon geographicum*, *Umbilicaria* spp. and *Usnea aurantiaco-atra*. In moist places *Staurothelle gelida* and also *Lecidea lapicida*, *Leptogium puberulum* and others frequently occur. It is worth noting that several common lichens found in the study area belong to the pioneer species, e.g., *Bacidia chrysocolla*, *Caloplaca johnstonii*, *C. sublobulata*, and *Candelariella aurella*. They are successful colonists of recently deglaciated areas.

A very interesting phenomenon in the study area is an occurrence of certain species, which are linked to the lichen biota of the continental Antarctic. This particularly concerns several species, such as *Lecidea andersonii* occurring in the ASPA No. 151, which is the only site of this species on King George Island. This endolithic lichen commonly occurs in a part of the continental Antarctica (Olech & Singh 2010), while on King George Island it occurs only in the study area. Also, *Buellia pycnogonoides*, which is found on King George Island only within the ASPA No. 151, and *Caloplaca saxicola*, frequent in the western part of the ASPA No. 151, rare on King George Island, not occurring on Livingston Island (Søchting et al. 2004) and being relatively frequent in the continental part of Antarctica. The most interesting is appearance of this species only on big isolated boulders within the study area.

Lichens occurring on mosses and plant debris (e.g. *Buellia papillata, Caloplaca ammiospila, C. athallina, C. tetraspora, C. tiroliensis, Lecania glauca, Lecidella wulfenii, Pertusaria pseudoculata*) are clearly much richer floristically than those found directly on the soil (e.g. *Placidium lachneoides*, *Polyblastia gothica*).

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MOLECULAR APPROACHES IN CONSERVATION OF LICHENS

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Abstract. Conservation biology focuses on maintaining unique species and their genetic diversity. In the paper molecular approaches used for analysis of lichen-forming fungi and their autotrophic partners are briefly reviewed. The impact of DNA data on species delimitation and introduction of the phylogenetic species concept in lichenology is also presented. The incongruence of DNA data with phenetic characters suggests that cryptic and semi-cryptic taxa may exist and in many cases distinct phylogenetic lineages were recognized as separate taxa based on subtle characters that correlate to these clades. In others, more data such as distribution or ecology were taken into account. With the help of molecular methods and the introduction of DNA barcoding, it is easier to determine genetically distinct taxa and the hidden biodiversity might be discovered. Moreover, our knowledge about selectivity of bionts and the diversity of compatible algal partners has increased and suggests that the number of photobionts may be higher than previously expected. Furthermore, photobiont switches may increase the geographical range and ecological niches of mycobionts by associating them with locally adapted photobionts in climatically different regions. The contribution of molecular data to knowledge on dispersal ability of species and genetic variation of populations is also discussed. The population and phylogeographic data have important implications to development of effective conservation strategies of lichens and wise management of rare and threatened species.

Key words: DNA barcoding, dispersal, ITS rDNA, lichenized fungi, mycobiont, phylogeography, photobiont, population, selectivity, species concept

INTRODUCTION

Lichens are symbiotic associations between two or more components: a lichen-forming fungus (mycobiont) and the eucaryotic green alga and/or cyanobacterium (photobiont). Lichens are named after the fungal partner that represents more than 16 000 of described species (Kirk et al. 2008). However, it is estimated that the number of lichenized fungi present worldwide is about 28 000 species (Lücking et al. 2009).

For many years characteristics such as morphology, chemistry, mode of dispersal, photobiont choice and biogeography have been used for species description. With the introduction of polymerase chain reaction (PCR) and rapid development of molecular techniques the researchers were given access to genetic information stored in organisms. New approaches and markers such as AFLP, RAPD, microsatellites polymorphism, nuclear and mitochondrial DNA sequencing were employed to study genetic variation within and among populations, species and supraspecific taxa. Patterns of genetic diversity studied at different levels raised questions about the concept of species (Grube & Kroken 2000) and lead to re-evaluation of phenotypic characters used for species delimitation (e.g. Divakar et al. 2006; Leavitt et al. 2011). Recent phylogenetic studies have shown that many taxa are hidden under a single species name (e.g., Kroken & Taylor 2001; Molina et al. 2004; Baloch & Grube 2009). It seems to be crucial to include molecular data in lichen species circumscription in order to better understand evolutionary processes and biodiversity of lichens (for review of the role of molecular data in understanding species level diversity in lichenized fungi see Lumbsch & Leavitt 2011).

There are 3 levels of biodiversity: genetic diversity, species diversity and ecosystem diversity. Conservation genetics is a broad-range discipline that focuses on several issues, among them variation between and within populations, geographic variation and species diversity. Conservation genetic studies are usually targeted on particular populations or species (Avise 2008). One of the most extensively studied rare lichens is *Lobaria pulmonaria* (e.g., Zoller et al. 1999; Walser et al. 2004) that is currently used as a model species for conservation studies of epiphytic lichens (Scheidegger & Werth 2009). Conservation biology attempts to maintain unique species and the genetic diversity within those species. Using molecular approaches it is easier to determine the level of biodiversity and genetic diversity of populations and based on these data effective conservation strategies of rare and endangered species might be established.

SPECIES

Species are fundamental units in many fields of biology including conservation biology. Although the conservation biology of lichens deals with more than one organism, in practice it is focused on the symbiotic phenotype, which is named after the mycobiont (Scheidegger & Goward 2002). In lichenized fungi, phenetic criteria have traditionally been used to define species (morphological species concept). However, Taylor et al. (2000) proposed a phylogenetic approach to recognize fungal species based on the concordance of multiple gene genealogies. This phylogenetic species concept applied in numerous studies showed that huge cryptic diversity may be underestimated by traditional methods used for species recognition (e.g., Grube & Kroken 2000; Kroken & Taylor 2001; Argüello et al. 2007; Baloch & Grube 2009; Divakar et al. 2010; Otálora et al. 2010).

The cryptic species concept was introduced to mycology by Hawksworth and Rossman (1997) and is currently used by many researchers on specimens so morphologically indistinguishable that they traditionally were treated as a single taxon (for a review of cryptic species concept and recent discussion on the topic see Crespo & Pérez-Ortega 2009 and Crespo & Lumbsch 2010). Morphological and chemical diversity is often interpreted as intraspecific variation and phylogenetic studies show distinct lineages under a single species name that leads to polyphyletic taxa (e.g., Molina et al. 2004; Muggia et al. 2008; Baloch & Grube 2009). More detailed investigation of morphological and/or chemical characters that were previously overlooked supports the distinction of some phylogenetic clades as species (e.g., Divakar et al. 2005; Czarnota & Guzow-Krzemińska 2010). It is especially important when one deals with organisms that are red-listed, e.g., as was suggested by molecular data (Crespo et al. 2002) *Parmelia saxatilis* s.l. was shown to be composed of several cryptic species that were recently delimited (i.e., Feuerer & Thell 2002; Molina et al. 2004, 2011). On the other hand, in some cases, such as *Agonimia allobata*, phenetic characters do not support distinction of these distinct lineages (Guzow-Krzemińska et al. 2012). For those taxa terms 'complex' or 'aggregate' should be used as recommended by Hawksworth (2010).

Recently, Vondrák et al. (2009) in their paper on *Caloplaca citrina* group introduced the 'semi-cryptic' species concept that refers to specimens that cannot be distinguished by their morphology, but which can be determined by other characters such as ecology and distribution. Molecular data also showed that *Xanthoparmelia tasmanica* s.l. contains at least 2 taxa that cannot be differentiated based on morphological or chemical features. They belong to two geographically distinct clades within the genus *Xanthoparmelia,* i.e. *X. tasmanica* seems to be exclusively Australasian, and the other species named *Xanthoparmelia hypofusca* is North American (Hodkinson & Lendemer 2011). However, there are still many taxa without any detectable characters that would support distinction of separate clades as species. With the introduction of new methods and using numerous molecular markers as well as morphological, chemical, ecological and geographical data species boundaries should be assessed in near future.

DNA BARCODING

The recognition of species in nature is often not straight forward. The idea of DNA barcoding was first introduced by Hebert et al. (2003) and is based on comparison of a short DNA fragment from an unknown organism to a database of sequences with the same DNA marker from verified reference specimens. The method should enable fast specimen identification, even when dealing with small, not well-developed or cryptic species.

Internal transcribed spacer (ITS) rDNA has been widely used in fungal taxonomy for many years, because it is characterized by a high degree of variation within the region and is flanked by more conserved sequences that are appropriate for primer design. ITS rDNA region has been proposed as a standard barcode for this group (for more information on DNA barcoding in fungi see Seifert 2009 and Begerow et al. 2010). However, there are also disadvantages of ITS as a barcode such as alignment difficulties or lack of resolution at the species level in some fungal groups, therefore supplementary barcodes are being developed. Moreover, ITS regions occur in large tandem arrays with multiple copies of ITS per cell that may differ from each other. There are also difficulties with the presence of erroneous sequences (e.g., from misidentified specimens or parasymbionts) in publicly available databases such as NCBI (Bridge et al. 2003; Hawksworth 2004).

The worldwide scale project named the Barcode of Life Data System (BOLD; www.barcodinglife.org) now includes BLAST-based identification of fungi using the ITS rDNA region (for detailed description of the BOLD system see Ratnasingham & Hebert 2007). Several DNA barcoding projects are in progress and are focused on different lichens, e.g., Parmeliaceae (www.ucm.es/info /systemol/ Investigadores/Ana_Crespo/proyectos.htm), *Arthonia, Lecania, Lecanora, Micarea* and *Verrucaria* in Finland (Myllys et al. 2010), lecideoid lichens in Norway (OLICH; http://nhm2.uio.no/lichens/ barcode/ INDEX.PHP? summary=1). The first attempts to use ITS rDNA barcoding for identification of *Usnea* lichens and 94 species from other genera collected from woodland habitats in Britain were recently published (Kelly et al. 2011). It was shown that simple BLAST analysis was usually accurate and about 80% of *Usnea* spp. and 92.1% of other species from floristic survey were correctly assigned. It suggests that as soon as the DNA barcoding approach becomes a routine application, it will accelerate biodiversity assessments and species inventories that will serve in development of conservation strategies.

PHOTOBIONTS

One should always keep in mind that in the case of lichens we deal with composite organisms. Although DNA barcoding projects are concentrated on the mycobionts, the algal partners also receive a lot of attention from researchers. The most common photobionts are usually members of the genus *Trebouxia* and cyanobacteria *Nostoc*. It is estimated that about 150 algal species occur in lichens (Honegger 2009). However, only a small percentage of lichens have been studied with respect to their photobionts, because characters important for species identification may be modified in the lichenized state (Honegger 2009). Due to the lack of easily recognized phenetic characters, the algal partner is usually recognized only at the genus level. With the introduction of molecular approaches and phylogenetic species concept for recognition of algae (e.g., Kroken & Taylor 2000; Helms et al. 2001) our knowledge about fungal-algal associations increased. The number of species considered as evolutionary lineages is usually higher than those recognized based on phenotypic criteria. Molecular data suggest that the diversity of the algal partners is underestimated as numerous distinct genotypes were found to occur in lichens and those might, in fact, represent cryptic species (e.g., Kroken & Taylor 2000; Cordeiro et al. 2005; Guzow-Krzemińska 2006).

Numerous studies focused on selectivity and showed that the diversity of compatible algal partners varies from a wide range of *Trebouxia* strains (e.g., Romeike et al. 2002; Blaha et al. 2006; Guzow-Krzemińska 2006) to a narrow one (e.g., Ohmura et al. 2006; Hauck et al. 2007). Moreover, recent observations suggest that the distribution of photobionts may be independent of the particular mycobiont species, and is rather related to specific conditions and lichen communities. These algal preferences may limit the ecological niches available to lichens and lead to the existence of specific lichen guilds (Peksa & Škaloud 2011).

LICHEN REPRODUCTION AND DISPERSAL

Knowledge on mating system and dispersal ability of species is crucial for development of optimal conservation strategies. Propagation, whether sexual or asexual, is a fundamental step in the life cycle of every organism. Many lichen-forming fungi reproduce sexually and develop fruiting bodies (e.g., apothecia) that are spore producing structures. Sexual reproduction in fungi is regulated by mating-type (*MAT*) genes. Heterothallic (cross-fertilized) species have only one out of two *MAT* alleles in a haploid mycelium, in contrast to homothallic (self-fertile) species that have either both *MAT* idiomorphs in a haploid mycelium or only one of them, the other being lost (for a review see Honegger & Scherrer 2008). The studies of the breeding system were initiated for some lichen species using finger printing techniques such as AFLP and RAPD (e.g., Murtagh et al. 1999, 2000; Dyer et al. 2001; Honegger et al. 2004; Seymour et al. 2005a; Honegger & Zippler 2007), but *MAT* locus has also been characterized for three *Cladonia* spp. (Seymour et al. 2005a) and several *Xanthoria* spp. (Scherrer et al. 2005). Based on molecular data, it was concluded that self-fertile species such as *X. parietina* and *X. elegans* bear many ascomata. On the other hand most heterothallic *Xanthoria* spp. such as *X. calcicola, X. polycarpa* and *X. capensis* have no, or few to many fruiting bodies, except for *X. polycarpa*, which always bears numerous apothecia (Honegger et al. 2004; Scherrer et al. 2005).

In heterothallic species, sexual reproduction is only possible when a compatible fungal partner of a different mating type is available. It might be problematic in small populations, in which genetic variation is relatively low. However, in many lichens the spores are often discharged from asci as clumps of eight (e.g., Honegger et al. 2004; Seymour et al. 2005b). It was hypothesized that it might be an adaptation to ensure that individuals of both mating types are dispersed together. It might facilitate sexual reproduction and consequent spore production (Seymour et al. 2005b).

The fungal spores are ejected from the ascus and in most cases dispersed aposymbiotically. In a few exceptions, hymenial algae are co-dispersed with ascospores (Ahmadjian 1993). The germinating fungal spore needs to reestablish the symbiotic association *de novo* with an appropriate algal strain (e.g., Sanders

& Lücking 2002). There are different sources of algal partners, e.g. free-living algae, diaspores of the same or other lichens or even lichen thalli (Beck et al. 1998). However, the photobiont can exhibit clear preferences for environmental factors and may form specific guilds (Peksa & Škaloud 2011).

In the case of lichens that reproduce by independent dispersal of each biont, the level of selectivity might be an important factor that delimits the occurrence of a particular lichen species (e.g., Beck et al. 2002) and mycobionts that accept a wider range of photobionts may survive unfavourable environmental conditions for a longer period of time (e.g., Romeike et al. 2002; Piercey-Normore 2006). However, the mycobiont may also survive on a substrate if it is able to form a temporary association with a non-compatible photobiont (Ott 1987). For other lichens, dispersing by vegetative propagule such as soredia and isidia, that facilitate clonal reproduction, or propagating by thallus fragmentation, an access to compatible algal strains is not such a limiting factor. However, Wornik and Grube (2010) based on analysis of *Physconia* species suggested that symbiont switches are likely to occur when fungi grow out from attached soredia and the maintenance of symbiotic associations is rather an option and not a strict consequence of joint bionts dispersal in lichens. On the other hand, Werth and Scheidegger (2012) reported co-dispersal and highly congruent genetic structures in the lichen-forming fungus *Lobaria pulmonaria* and its green-algal photobiont *Dictyochloropsis reticulata.*

The efficiency of the asexual distribution mode in *Lobaria pulmonaria* was studied using the molecular approach and considerable amounts of naturally dispersed diaspores were detected up to 50 m from the closest potential source. However, diaspores were only found in the direction of the prevailing wind (Walser et al. 2001). On the other hand, genetic studies of *Xanthoria parietina* (e.g., Lindblom & Ekman 2006, 2007) and *Lobaria pulmonaria* (e.g., Wagner et al. 2006; Werth et al. 2006) suggested that effective dispersal up to a few kilometres is not restricted, although ascospores disperse at longer distances than heavier vegetative propagules. *Cliostomum corrugatum* was also found to cross at least several kilometres and was mainly limited by the availability of the habitat, not dispersal (Lättman et al. 2009). As summarized by Scheidegger and Werth (2009), at the landscape level, vegetative and sexual populations may have different dispersal range and number of released diaspores. They also suggested that maintaining high levels of genetic diversity within populations might promote sexual reproduction in heterothallic species and the potential for long-distance dispersal of spores. As a consequence, it was recommended that populations with sexually reproducing individuals should receive a higher level of protection than strictly asexual populations (Zoller et al. 1999).

PHYLOGEOGRAPHY

Historical data about distribution of lichens are very important for conservation strategies development, however, the fossil records for lichen-forming fungi are not well documented, therefore the ancestry has to be inferred through indirect data e.g. obtained from population studies. The population biology of the target organism needs to be well known (for reviews on population genetics and its implication for conservation see Scheidegger & Werth 2009 and Werth 2010).

At the beginning, variation within lichen species was conducted using enzyme polymorphism (e.g., Hageman & Fahselt 1984; Brown et al. 1989), however, as this approach was found to be technically difficult, it was replaced by DNA-based methods. Restriction site patterns of the nuclear ribosomal small subunit RNA gene (SSU rDNA) were applied to the genus *Cladonia* and considerable variation within-population was detected in the *C. chlorophaea* complex (DePriest 1994). On the other hand, in *Cladina subtenuis* no variation in the SSU rDNA was found within populations but some was detected among populations (Beard & DePriest 1996). However, due to insufficient variability of PCR-RFLP patterns, other approaches were needed. Since then, sequencing of particular DNA regions has been widely used in population genetics of lichens.

With the help of molecular approaches, it is possible to reconstruct the biogeographic history of the species (e.g., Printzen 2008). However, recent studies present contradictory conclusions. In some cases, distant populations were found to be closely related, e.g. Högberg et al. (2002) suggested that European populations of *Letharia vulpina* originated from North America by long distance dispersal. Geml et al. (2010) showed transoceanic gene flow in *Flavocetraria* spp. as it was also reported for *Porpidia flavicunda* by Buschbom (2007). On the other hand, a little gene flow between continents was shown in populations of *Cavernularia hultenii* (Printzen et al. 2003) and *Lobaria pulmonaria* (Walser 2004). Moreover, Fernández-Mendoza et al. (2011) in the phylogeographic study of *Cetraria aculeata* suggested that rare photobiont switches may increase the geographical range and ecological niches of mycobionts by associating them with locally adapted photobionts in climatically different regions.

CONCLUSIONS

Conservation biology is focused on maintaining unique species and their genetic diversity. With the help of molecular approaches we are able to study genetic diversity at different levels of biodiversity. However, molecular data cannot replace morphological studies. Traditionally used characteristics such as morphology, anatomy or secondary chemistry are still essential for new species description, but in modern taxonomy all available approaches should be simultaneously applied to better understand evolutionary processes. The impact of DNA data on species delimitation and introduction of the phylogenetic species concept in lichenology led to re-evaluation of diagnostic characters used for species circumscription and detection of the hidden biodiversity. Recently developed DNA barcoding approach is a new tool for fast specimen identification, even when dealing with small, not well-developed or cryptic species. It should undoubtedly accelerate biodiversity assessments and species inventories that will serve in development of conservation strategies.

Conservation genetics may significantly contribute to the management of rare and threatened species. It helps us to better understand the biology of lichens, their dispersal ability, phylogeography and genetic variation that may be used to measure lichen diversity and rarity. Conservation of genetic variation is important to the health of populations because decreased genetic variability leads to reduction of its fitness and may limit sexual reproduction of heterothallic lichen species. More data will help us to understand how to maintain the endangered species and local populations.

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CHEMICAL AND MOLECULAR METHODS AND THEIR IMPACT ON THE ESTIMATION OF THREAT STATUS OF LICHENS IN POLAND

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Abstract. The paper presents the importance of chemical and molecular methods for the estimation of threat status of lichens in Poland. It is based on references and author's own studies. Three examples are presented. The cases of *Haematomma ochroleucum* and *Lecidea nylanderi* show the importance of the chemical method, thin layer chromatography (TLC), for the evaluation of their threat status in the country. The revision of herbarium material with TLC revealed that *H. ochroleucum* is much more rare than reported in the past, and perhaps critically endangered in Poland. In opposite, *L. nylanderi* was considered rare and endangered, but the species was proved to be much more common in the country and at present it can be considered as not endangered at all. In case of *Usnea florida* and *U. subfloridana*, molecular data suggest that the two species represent one taxon consisting of populations with two different reproductive strategies, sexual in the former and vegetative in the latter. After the inclusion of *U. subfloridana* into the concept of *U. florida*, the species can be treated as endangered, not critically endangered in Poland as previously considered.

Key words: thin layer chromatography, molecular data, threatened lichens, red lists

INTRODUCTION

Lichens, known also as lichenized fungi, are in many cases very sensitive to environmental changes caused by human impact. Sometimes lichens tend to spread due to human activity, but more often they decrease their ranges. There are several factors, which cause decline of lichens, e.g., industrial emission of pollutants, inappropriate forest management, elimination of single standing trees and roadside trees, changes in water conditions and others (see Cieśliński et al. 2003).

Changes of lichen biota are documented in Poland in red lists of lichens. So far three general (Cieśliński et al. 1986, 1992, 2003, 2006; NB: the last work is partly based on the paper from 2003 with the same list of species) and several such regional accounts have been published (for details see Cieśliński et al. 2003; see also Fałtynowicz & Kukwa 2003). The aims of those papers were to estimate the alteration in the lichen biota over time. However, the particular factors causing the decline of species vary and also the knowledge on their frequency in the country can increase. As a result also their threat status may be modified.

For the estimation if a particular lichen is threatened or not, at least an approximate number of its localities in the area must be known, the time when they were recorded and if they still exist or are only historical. Proper identifications of species are also crucial. Previously usually morphological and anatomical characters, and also the so-called 'spot test' with chemical reagents were used for the determination of lichens. That was often sufficient for the identification of most lichen species. However, in many cases the content of secondary metabolites should be used for a correct determination of certain species, which is especially important, e.g. in the identification of crustose sorediate lichens (see e.g., Kowalewska et al. 2000; Kukwa 2005a, 2006). One of the best methods detecting those substances is thin layer chromatography (TLC), which is also rather easy to use; for more details see Kubiak & Kukwa (2011). In the last two decades molecular methods also have considerably influenced the taxonomy and systematics of lichens; they help to define particular species in taxonomically difficult groups, e.g. in *Usnea* Dill. ex Adans. (Articus et al. 2002).

In this paper the author presents the impact of chemical and molecular methods for the estimation of threat status of lichens in Poland. This is shown in 3 examples based on references and author's own studies.

THIN LAYER CHROMATOGRAPHY AND *HAEMATOMMA OCHROLEUCUM*

Haematomma ochroleucum (Neck.) J. R. Laundon is a crustose lichen. Its thalli are often almost entirely sorediate, with sorediate areoles present at the thallus edges or only in young individuals. Prothallus is usually well developed, white, cottony and in some specimens also fibrillose. Apothecia are rarely produced by the species, with thalline exciple concolorous with the thallus and scarlet discs containing russulone; ascospores are 3–8-septate, 30-60 × 5-7 μm. The species always produces atranorin, zeorin and porphyrilic acid as the major secondary compounds; also usnic acid can be present, and samples containing this substance are traditionally classified as *H. ochroleucum* var. *ochroleucum*, whereas those lacking this metabolite as var. *porphyrium* (Pers.) J. R. Laundon. Often also bourgeanic acid is present in the thallus of the species, and sometimes other substances (Tønsberg 1992; Staiger & Kalb 1995; Brodo et al. 2008; Wolseley et al. 2009). The distinction of both varieties is sometimes questioned and needs more studies with molecular tools.

Haematomma ochroleucum was reported from several regions in Poland and could have been considered as a locally rather common epiphytic, rarely epilithic lichen (see Fałtynowicz 2003 and literature cited therein). Cieśliński et al. (1992) listed *Haematomma ochroleucum* in the Category Vulnerable (VU) and that situation would have not changed if the *Lecanora thysanophora* R. C. Harris had not been described. The latter species is chemically and, when sterile, also morphologically very similar to *H. ochroleucum*. *Lecanora thysanophora* also contains atranorin, zeorin, porphyrilic and usnic acids and has sorediate thalli with white, often fibrillose prothallus, but it differs in the production of unknown terepenoids called 'thysanophora unknowns'. In case of European material of the latter species, porphyrilic acid is also lacking. Fertile specimens of *L. thysanophora* can be distinguished by pale yellowish to greyish brown apothecial disc and non-septate ascospores (Harris et al. 2000).

Lecanora thysanophora was reported from Europe by Tønsberg (1999) and later by Tønsberg et al. (2001), Printzen et al. (2002) and Motiejūnaitė et al. (2003). The first Polish records were presented by Kowalewska and Kukwa (2003), who found specimens of this species in material determined as *Haematomma ochroleucum*. Subsequently it became clear that many records of the latter might have belonged to *L. thysanophora*. The revision of the majority of corticolous samples proved that *H. ochroleucum* was misidentified with *L. thysanophora* and some other morphologically similar lichen taxa (Kukwa 2005a). The author confirmed *H. ochroleucum* only in case of 2 collections. However, as not all Polish material was revised, its true frequency was not known at that time, and the species was included in the *Red list of lichens in Poland* in the category Data Deficient (DD) (see Cieśliński et al. 2006).

In the next step, the remaining herbarium material was recently revised and *H. ochroleucum* was confirmed only on 7 localities in the country (Zduńczyk & Kukwa 2012). As most of the collections have been made more than 20 years ago, the species should be treated as Critically Endangered (CR) in the next list of extinct and threatened lichens in Poland.

LECIDEA NYLANDERI, A CASE OF AN OVERLOOKED LICHEN

Lecidea nylaneri (Anzi) Th. Fr. is a sorediate and almost always sterile species. The thalli form patches on bark or wood up to several cm in diameter and consist almost entirely of diffuse soralia; only in young stages or at the margins esorediate areoles can be seen. Soralia are mostly bluish grey to whitish, sometimes with brown tinge due to the pigmentation of outer soredia. Apothecia are extremely rare in the species and, when present, lecideine, flat to slightly convex, pale to dark red-brown or brown, with thin true exciple. Ascospores are globose, 6–7 μm in diam. The species produces divaricatic acid, which presence, together with thallus morphology, is a diagnostic character in case the species forms sterile thalli (Tønsberg 1992; Aptroot et al. 2009).

The species was very rarely reported in Poland up to 2000 (see Kowalewska et al. 2000; Fałtynowicz 2003) and only few localities were known with the most recent one from 1972 (Czyżewska 1972). Therefore, *L. nylanderi* was regarded as Endangered (category E) by Cieśliński et al. (1992). There are several reasons why it has received so few reports from the country in the past. First of all, the species forms apothecia extremely rarely and its young thalli can be very small (sometimes only up to 1 cm in diam. as often seen in Poland). Then it could have been considered to represent only juvenile thalli of other lichens, and thus be omitted in field studies. The species is also morphologically very similar to the members of the genus *Lepraria* Ach., which were very much neglected by lichenologists up to the beginning of the 21th century (see e.g., Kukwa 2001, 2006). In such a case it could have been misidentified as one of those, e.g. *L. incana* (L.) Ach. (see Kowalewska et al. 2000) and not collected. The third and perhaps the most important reason was that thin layer chromatography (TLC) was not used in the determination of sterile sorediate lichens. In case of *Lecidea nylanderi* the recognition of secondary metabolites is crucial for identifying it as only then the species can be determined with certainty. The increase of number of its localities in Poland coincides with the introduction of this method into Polish lichenology and since then *L. nylanderi* has started to be repeatedly reported from different parts of the country (see e.g., Kowalewska et al. 2000; Bielczyk & Betleja 2003; Fałtynowicz 2003 and literature cited therein; Kukwa 2005b, 2009; Kukwa et al. 2008; Szymczyk & Kukwa 2008; Czarnota 2010; Kubiak 2011). Owing to its currently known distribution the species was excluded from the recent *Red list of lichens in Poland* (see Cieśliński et al. 2006).

WHEN TWO SPECIES BECOME ONE – MOLECULAR DATA AND A CASE OF *USNEA FLORIDA* AND *U. SUBFLORIDANA*

Members of the genus *Usnea* are well known and easily recognizable lichens, but also one of the most sensitive to air pollution. In Poland all species are considered to be threatened, many of them being of Regionally Extinct Category (RE), Critically Endangered Category (CR) or Endangered Category (EN) (Cieśliński et al. 2006). Among those, there are 2 species, *U. florida* (L.) Weber ex F.H. Wigg. and *U. subfloridana* Stirt, the former has been believed to be rarer and Critically Endangered (CR) and the latter more common and listed as Endangered (EN) (e.g., Fałtynowicz 2003; Cieśliński et al. 2006). With the exception of structures associated with different reproductive modes, both are morphologically (short and shrubby thalli with black bases, more or less papillate branches) and chemically (usnic acid with squamatic or thamnolic acids present; *U. subfloridana* can also contain squamatic and thamnolic acids in the same thallus) almost identical, and in juvenile stages practically almost indistinguishable. (Clerc 1984; Halonen et al. 1998, 1999; James et al. 2009). Concerning dispersal structures, *U. florida* develops apothecia and reproduces by ascospores, whereas *U. subfloridana* produces granular soredia (sometimes also isidiomorphs) and usually lacks apothecia. In terms of secondary chemistry, *U. florida* constantly contains alectorialic acid in apothecia, whereas this substance is known as an rare accessory metabolite in *U. subfloridana* (Clerc 1984; Halonen et al. 1998, 1999; Tõrra & Randlane

2007; James et al. 2009). Some rare forms of *U. subfloridana* producing apothecia usually develop less soralia and are thus intermediate with *U. florida* (James et al. 2009). Considering all differences and similarities both taxa can be treated as forming a pair species, with *U. florida* as a primary, sexually reproducing species and *U. subfloridana* as secondary species developing vegetative diaspores (see Articus et al. 2002). The existence of such pairs conforms to the theory called the species pair concept, which started with the work of Du Rietz (1924) and was later developed by Poelt (1963, 1970). According to this theory, *U. subfloridana* is a clonal taxon derived from a primary taxon *U. florida*, and actually could represent only an asexual form of the latter, which does not necessarily deserve the recognition at species level (see also Tehler 1982).

The problem whether such pairs represent one polymorphic species consisting of populations with different dispersal modes or two phylogenetically distinct taxa can be solved only with aid of molecular tools. For *U. florida* and *U. subfloridana* such study was conducted by Articus et al. (2002). Those authors used 6 specimens of the former and 5 of the latter species in phylogenetic analyses, which were based on 2 nuclear ribosomal DNA markers and the gene coding for β-tubulin. Their results showed that both, *U. florida* and *U. subfloridana*, were closely related, but formed one monophyletic clade of intermixed specimens, thus rejecting separation of 2 distinct taxa. Similar results were also presented on the phylogenetic tree by Saag et al. (2011). As the consequence, *U. florida* and *U. subfloridana* should be treated as 1 species with 2 different reproductive modes, with *U. florida* as the oldest available name for this taxon (Articus et al. 2002). That point of view has not been accepted by all and, e.g., James et al. (2009) claimed that *U. florida* and *U. subfloridana* should still be treated as separate due to their different distribution and the preferences of habitats. This opinion is, however, not necessarily justified since it is rather the microclimatic conditions that cause the development of certain reproductive structures than vice versa.

In the light of these results, there should be consequences for the threat status of *U. florida* in Poland. When *U. subfloridana* is included in the concept of *U. florida*, then the latter species appears more common and less in danger of extinction. Nevertheless, fertile populations of the taxon deserve more attention concerning conservation strategy than those reproducing asexually as they are much rarer and characteristic for ecosystems with high biodiversity (see Articus et al. 2002), and likely reservoir of genetic variability.

CONCLUSIONS

As it was exemplified, chemical and molecular methods by being excellent tools in lichens identification enable verification of some species frequency and range in Poland. Through this they are useful in estimating the real status of rare and threatened species. As a result, indirectly they can contribute to development of better conservation strategy of lichen species and their habitats.

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THE PRELIMINARY STUDY OF THE CHEMICAL VARIATION OF THE PROTECTED LICHEN SPECIES *RAMALINA FARINACEA* IN POLAND

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Abstract. This paper presents preliminary study on the chemical variations of *Ramalina farinacea* in Poland based on the material collected in Central and Western Pomerania of Poland. Five chemotypes were found, 3 of which have never reported in the literature before (all with usnic acid): with norstictic acid as a major secondary metabolite and protocetraric acid, with norstictic acid as a minor secondary substance and protocetraric acid, and with protocetraric acid and fatty acids. The most common chemotype (65% of studied specimens) contained usnic acid and protocetraric acid.

Key words: *Ramalina farinacea*, chemotypes, secondary lichen products, C & W Pomerania

INTRODUCTION

Ramalina farinacea (L.) Ach. is a common fruticose lichen characterized by flattened branches and marginal, circular to ellipsoid soralia (Smith et al. 2009). The species is a subject to strict species protection according to Regulation of the Minister of the Environment on species of wild growing fungi under protection (2004). It is treated as threatened in the category VU (vulnerable) in the Red list of the lichens in Poland (Cieśliński et al. 2006).

The species is a lichen that shows rather high chemical variation (Asahina 1966; Culberson & Hale 1973; Bowler & Smith 1976; Krog & James 1977; Tønsberg1982; Zedda 1999; Smith et al. 2009; Stocker-Wörgötter et al. 2004), but the chemistry has not been comprehensively studied throughout its distribution range so far and requires further study. Up to now the secondary metabolite contents of *Ramalina farinacea* was rarely examined in Central Europe; Poland makes no exceptions and up to our knowledge, the secondary metabolites have never been studied in the country. In this paper the results of study on the chemical variation of species in Central and Western Pomerania (N Poland) are presented.

MATERIAL AND METHODS

The material was studied from the Herbarium of Pomeranian Academy in Słupsk (SLTC) and included 60 specimens. The chemistry was investigated with the aid of thin layer chromatography (TLC) according to Orange et al. (2001). Localities of the specimens are given in the ATPOL grid square system (see Cieśliński & Fałtynowicz, eds 1993).

THE CHEMISTRY OF *RAMALINA FARINACEA* IN THE LITERATURE SOURCES

The chemical variation of *Ramalina farinacea* was investigated several times in different regions of the world. Bowler & Smith (1976) reported the occurrence of the chemotype with salazinic and norstictic acids; many of Hawaiian specimens contained also usnic acid, and a few exhibited traces of protocetraric acid and an unknown compound. That chemotype was regarded as common on the west coast of North America from Alaska to Baja California and is widespread throughout in Europe (Culberson & Hale 1973; Bowler & Smith 1976). The specimens with the salazinic acid were also reported from the Himalayas (Asahina 1966 after Bowler & Smith 1976).

In Europe the studies of *Ramalina farinacea* chemistry have been conducted by Krog & James (1977, after Tønsberg 1982). The authors distinguished four chemotypes in material from north-western Europe, containing (I) protocetraric acid, (II) salazinic acid ± norstictic acid and (III) hypoprotocetraric acid. The fourth chemotype was acid deficient with no medullary substances. The acid deficient race was not present in material studied from Sweden, Norway and Spain (Mallorca) by Tønsberg (1982), who found variolaric acid as accompanying substance in about 45% of studied specimens. It was present usually in large amounts and occurred in 48% of the specimens with protocetraric acid, in 26% of those with salazinic/norstictic acid and in 80% of those with hypoprotocetraric acid. Zedda (1999) also detected variolaric acid in material from Sardinia (Italy). In specimens studied by her 73.3% contained protocetraric acid, 19.8% salazinic and norstictic acid and 6.3% had no compounds detectable by TLC.

Stocker-Wörgötter et al. (2004) reported 2 new chemotypes from restricted habitats on the island of Sicily (Italy) with virensic acid and a very rare depsidone cyclographin. According to Stocker-Wörgötter et al. (2004) the differentiation in chemotypes coincided with species of trees, for example the chemototype with cyclographin as major compound (virensic acid in minor amounts) was common on *Quercus ilex*, whereas the the chemotype with virensic acid as major compound (cyclographin in minor amounts) grew on *Quercus pubescens*, protocetraric and variolaric acids chemotyp was found on *Quercus suber* and *Q. pubescens*. Apparently, it is an ecophysiological adaptation that goes along to the chemotypic differences (Stocker-Wörgötter et al. 2004).

Smith et al. (2009) reported following chemotypes from Biritish Isles: (I) with usnic and protocetraric acids, (II) usnic, salazinic and ± norstictic acids, (III) usnic and hypoprotocetraric acids and (IV) without lichen products.

CHEMISTRY OF SPECIMENS FROM CENTRAL AND WESTERN POMERANIA IN POLAND

Five chemotypes were found in material from northern Poland, 3 of them being new; in almost all studied specimens usnic acid was present. The most common chemotype was with usnic and protocetraric acids (39 specimens). The rarest chemotype is that containing only protocetraric acid (1 specimen); it is most probably only an acid deficient race of the chemotype containing usnic and protocetraric acids.

The following 3 chemical races have not been reported before: 15 specimens contained usnic and protocetraric acids together with norstictic acid in minor amounts. In the next chemotype the combination of usnic acid, norstictic acid as a major secondary metabolite and protocetraric acid was found; it has been found only three times on *Acer platanoides* and *Ulmus* sp. Another rare chemotype (2 specimens) with usnic acid, protocetraric acid, fatty acids grows on *Acer platanoides* and *Ulmus campestris.*

There were no significant differences between chemotypes in terms of habitat preferences due to the low number of specimens. The study on the chemotype variation of *Ramalina farinacea* will be continued and the larger material can provide more data on both, secondary metabolite content and its relation to the specific substrates.

Specimens containing usnic and protocetraric acids examined:

[**Ab-69**] – Równina Sławieńska Plain, S from Wodnica village (54°33’35”N, 16°51’30”N) near Ustka, by the road, on *Populus* sp., 05.*1979, leg. I. Izydorek (*SLTC). [**Ab-77**] – Równina Sławieńska Plain, NE of Stary Kraków settlement (54°26’13”N, 16°36’48”E), on bark, 04.1994, *leg. R. Kuligowski* (SLTC). [**Ab-78**] – Równina Sławieńska Plain, by the road Pałowo-Pieszcz, (54°27’08”N, 16°47’44”E), by road, on *Acer platanoides*, 02.06.1993, *leg. D. Morka* (SLTC). [**Ab-87**] – Równina Sławieńska Plain, NE of Boleszewo settlement (54°22’07”N, 16°34’36”E), 07.1994, *leg. R. Kuligowski* (SLTC). [**Ab-98**] – Równina Sławieńska Plain, Sławno forest inspectorate, forest division 355 (54°17’19”N, 16°47’56”E), in mixed forest, on *Quercus robur,* 27.10.1995, *leg. A. Domagalska* & *I. Izydorek* (SLTC); forest division 239 (54°17’19”N, 16°47’56”E), deciduous trees on the forest edge, on *Populus nigra*, 05.06.1995, *leg. A. Domagalska* & *I. Izydorek* (SLTC). [**Ab-99**] – Wysoczyzna Polanowska High Hill, road Warcino-Osowo, Warcino forest inspectorate, Warcino forestry, near forest division 120 (54°13’23”N, 16°51’26”E), on *Acer platanoides*, 14.10.1978, *leg. I. Izydorek* (SLTC); c. 800 m from Kępice (54°14’35,2”N, 16°53’21,6”E), on *Acer platanoides*, 14.10.1978, *leg. I. Izydorek* (SLTC, 3 specimens); road between Kępice and Warcino villages (54°13’34”N, 16°52’48”E), on *Acer platanoides,* 23.10.1976, *leg. I. Izydorek* (SLTC).

[**Ac–58**] – Pradolina Łeby i Redy Proto-Valley, Wejherowo town, Nowowiejskiego street (54°36'49"N, 18°15'26"E), on *Betula pubescens*, *leg. K. Osuch* (SLTC). [**Ac-62**] – Wysoczyzna Damnicka High Hill, no exact location (ca 54°35'00"N, 17°20'00"E), on *Acer pseudoplatanus*, 29.06.1987, *leg. J. Pietrasz* (SLTC); on *Quercus robur*, 05.10.1986, *leg. J. Pietrasz* (SLTC). [**Ac-64**] – Pradolina Łeby i Redy Proto-Valley, Lębork town, Topolowa street (54°32'16"N, 17°43'34"E), on *Populus serotina*, 16.08.1986, *leg. G. Repiski* (SLTC). [**Ac-70**] – Równina Sławieńska Plain, Słupsk town, Lasek Południowy forest (54°27'59,1"N, 17°01'30,2"E), roadside trees, on *Acer platanoides*, 20.11. 2002, *leg. A. Krupska* (SLTC); on *Acer pseudoplatanus*, 1976, *leg. I. Izydorek* (SLTC); E of Łosino village (54°24'45"N, 17°00'30"E), roadside, 17.10.1994, *leg. A. Hryciów* & *I. Izydorek* (SLTC); W from Płaszewko village on, Ustka forest inspectorate, forest division 189 (54°25'31"N, 17°04'16"E), roadside, on *Populus* sp., 18.07.1991, *leg. E. Szeflińska* & *I. Izydorek* (SLTC); Krzywań village (54°24'45"N, 17°08'53"E), ca 1 km on W, by the road in open situation, on *Acer platanoides*, 17.06.1991, *leg. E. Szefińska* & *I. Izydorek* (SLTC). [**Ac-71**] – Wysoczyzna Damnicka High Hill, E from Warblewo village (54°25'38"N, 17°10'39"E), by the road in open situation, on *Acer platanoides*, 17.07.1991, *leg. E. Szeflińska* & *I. Izydorek* (SLTC). [**Ac-72**] – Wysoczyzna Damnicka High Hill, 1 km E from Łabiszewo village, Łupawa forest inspectorate (54°24'58"N, 17°24'21"E), on *Acer platanoides*, 18.11.1991, *E. Szeflińska* & *I. Izydorek* (SLTC). [**Ac-73**] – Wysoczyzna Polanowska High Hill, Leśny Dwór forest inspectorate, Runowo forestry, forest division 391 (54°27'54"N, 17°32'44"E), on *Quercus sessilis*, 11.07.1978, *leg. I. Izydorek* (SLTC). [**Ac-81**] – Równina Sławieńska Plain, Słupsk town, Leśny Dwór forest inspectorate, forest division 597a (54°22'41"N, 17°09'29"E), deciduous forest, on *Quercus robur*, 18.11.2002, *leg. A. Krupska* & *I. Izydorek* (SLTC); Leśny Dwór forest inspectorate, Zaścianek forestry, forest division 65g (54°22'41"N, 17°09'29"E), beech forest, on *Fagus sylvatica*, 30.08.1978, *I. Izydorek* (SLTC); W of Niemczewo village (54°19'34"N, 17°16'39"E), near Dębnica Kaszubska village, roadside, on *Acer pseudoplatanus*, 12.06.1979, *leg. I. Izydorek* (SLTC). [**Ac-82**] – Wysoczyzna Polanowska High Hill, by the road W from Dobra village (54°22'49"N, 17°21'56"E), near Czarna Dąbrówka village, on *Tilia* sp., 13.05.1979, *leg. I. Izydorek* (SLTC); W of Gogolewko village (54°21'40"N, 17°25'45"E), near Czarna Dąbrówka village, on *Populus* sp., 13.05.1979, *leg. I. Izydorek s.n.* (SLTC). [**Ac-90**] – Wysoczyzna Polanowska High Hill, Myślimierz village (54°17'11"N, 17°02'27"E), near Suchorze village, roadside, on *Acer platanoides*, 22.05.1979, *leg. I. Izydorek* (SLTC). [**Bb-05**] – Równina Sławieńska Plain, Manowo forest inspectorate, forest division 181 (54°07'34"N, 16°18'05"E), mixed forest, on *Quercus robur*, 08.1995, *leg. M. Bugajska* (SLTC). [**Bb-09**] – Wysoczyzna Polanowska High Hill, Warcino forest inspectorate, Warcino forestry, Biesowiczki village (54°10'54"N, 16°53'59"E), near Biesowice village, by Wieprza old river bed, on *Populus* sp., 29.07.1976, *leg. I. Izydorek* (SLTC). [**Bb-17**] – Wysoczyzna Polanowska High Hill, Warcino forest inspectorate, Świerkowiec forestry, forest section no 137, by the road between Krąg and Polanów (54°07'08,8"N, 16°41'06,3"E), on *Acer platanoides*, 23.09.1977, *leg. I. Izydorek* (SLTC); ibid., on *Acer* sp., 23.09.1977, *leg. I. Izydorek* (SLTC, 2 specimens). [**Bc-39**] – Pojezierze Starogardzkie Lakeland, Starogard Gdański town, Lubichowska street (53°57'02"N, 18°31'06"E), on *Fraxinus excelsior*, 14.06.1986, *leg. I. Izydorek,* (SLTC); Starogard Gdański town, Park Miejski (53°58'04"N, 18°31'37"E), on *Acer negundo*, 07.2001, *leg. H. Jędrzejewska* (SLTC). [**Bc-71**] – Pojezierze Krajeńskie Lakeland, Debrzno town, Sportowa street (58°32'14"N, 17°13'30"E), on *Acer platanoides*, 02.11.1995, *leg. G. Twierkowska* (SLTC).

Specimens containing usnic, norstictic (in minor amounts) and protocetraric acids examined:

[**Ab-88**] – Równina Sławieńska Plain, 1.5 km of W Bzowo village (ca 54°21'45"N, 16°50'27"E), by the road, on bark, 23.11.1994, *leg. A. Hryciów* (SLTC). [**Ab-98**] – Równina Sławieńska Plain, Żukowo forest district, forest division 42 (ca 54°17'19"N, 16°47'56"E), deciduous forest, on bark, 23.11.1994, *leg. A. Hryciów* (SLTC). [**Ab-99**] – Wysoczyzna Polanowska High Hill, Warcino forestry, road between Kępice and Warcino villages, ca 800 m from Kępice (54°14'35"N, 16°53'21"E), on *Acer platanoides*, 14.10.1978, *leg. I. Izydorek* (SLTC); Warcino village (54°13'23"N, 16°51'26"E), ca 700 m N from village, by road, on *Acer platanoides*, 06.11.1976, *leg. I. Izydorek* (SLTC). [**Ac-62**] – Wysoczyzna Damnicka High Hill, no exact location, on *Acer pseudoplatanus*, 05.10.1986, *leg. J. Pietrasz* (SLTC). [**Ac-64**] – Pradolina Łeby i Redy Proto-Valley, Lębork town (54°32'10"N, 17°44'51"E), road to Bytów town, on *Tilia cordata,* 26.06.1997, *leg. D. Żuchowska* (SLTC); Lębork town, Sportowa street (54°31'42"N, 17°44'13"E), on *Ulmus campestris*, 26.06.1997, *leg. D. Żuchowska* (SLTC). [**Ac-70**] – Równina Sławieńska Plain, Słupsk town, Lasek Południowy forest (54°27'59"N, 17°01' 30"E), by road, on *Acer pseudoplatanus*, 20.11.2002, *leg. A. Krupska* & *I. Izydorek* (SLTC). [**Ac-81**] – Równina Sławieńska Plain, Słupsk town, Leśny Dwór forest inspectorate, forest division 594 (54°22'41"N, 17°09'29"E), oak alley, on *Quercus robur*, 04.11.2002, *leg. A. Krupska* & *I. Izydorek* (SLTC). [**Bb-05**] – Równina Sławieńska Plain, 2 km SW of Wyszebórz village (54°08'57"N, 16°19'42"E), by the road, on *Acer platanoides*, 06.1995, *leg. M. Bugajska* (SLTC). [**Bb-15**] – Wysoczyzna Polanowska High Hill, Manowo forest inspectorate, Mostowo forestry, forest division 345 (54°07'04"N, 16°21'43"E), by the road, on *Acer platanoides*, 06.06.1979, *leg. I. Izydorek* (SLTC, 3 specimens). [**Cb-06**] – Równina Wałecka Plain, Wałcz town, by the sport center (53°16' 41"N, 16°27'53"E), on *Acer* sp., 29.06.1979, *leg. J. Kropielnicki* (SLTC); Wałcz town, Chopina street (53°16'33,8"N, 16°27'24,8"E), on *Fraxinus excelsior*, 09.04.1980, *leg. J. Kropielnicki* (SLTC).

Specimens containing usnic, norstictic (in major amounts) and protocetraric acids examined:

[**Ac-70**] – Równina Sławieńska Plain, Słupsk town, Arciszewskiego street (54°26'23"N, 17°02'22"E), on *Acer platanoides,* 18.10.1976, *leg. M. Gruszczyńska* (SLTC). [**Ac-82**] – Wysoczyzna Polanowska High Hill, W of Dobra village (54°22'49,6"N, 17°21'56,6"E), near Łupawa river, roadside, on *Acer platanoides*, 09.05.1979, *leg. I. Izydorek* (SLTC). [**Ab-79**] – Równina Sławieńska Plain, ca 1.5 km E of Sycewice railway stadion (54°25'19,4"N, 16°51'43,9"E), elm alley, on *Ulmus sp.,* 10.03.1985, *leg. I. Izydorek* (SLTC).

Specimens containing usnic, protocetraric and fatty acids examined:

[**Ac-83**] – Wysoczyzna Polanowska High Hill, ca 2 km E of Uniechowo village, near Czarna Dąbrówka village (54°21'23"N, 17°33'41"E), by the road, on *Acer platanoides*, 30.10.1979, *leg. I. Izydorek* (SLTC). [**Bb-00**] – Wybrzeże Słowińskie Coast, Kołobrzeg town, Gottwalda street (54°10'17"N, 15°33'46"E), on *Ulmus campestris*, 09.04.1976, *leg. I. Budzelewski* (SLTC).

Specimen containing only protocetraric acid examined:

[**Ab-69**] – Równina Sławieńska and Równina Słupska Plains, Pęplinko settlement (54°32'07"N, 16°54'08"E), on wood, no date and collector (SLTC).

CONCLUSIONS

Ramalina farinacea shows rather high chemical variation in Western and Central Pomerania in Poland. Five chemotypes were found there, three of them being new. In Central Europe *Ramalina farinacea* is an object of chemical research very rare and up to our knowledge this paper presents the first research of chemical variation of this species in Poland. Because so little is known about the chemical variation this species, studies should be extended to other regions of the country, where more chemotypes can be discovered, especially in the mountains.

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CHALLENGES OF SAXICOLOUS LICHENS CONSERVATION – A CASE STUDY OF THE CARPATHIANS FOOTHILLS

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Abstract. Lichen surveys focused on various sandstone formations in different parts of the Carpathian foothills were aimed at an estimation and comparison of lichen diversity on protected versus unprotected outcrops and rocks. Altogether 98 different species were noted; 81 species were found on protected areas and 50 species on unprotected ones. Fourteen of all taxa occurring on the studied sandstones are threatened. Additionally sixteen of the recorded species are protected by law in Poland. Protected sandstone formations are proven to be hotspots of epilithic acidophilous lichen diversity and deserve special attention, with respect to lichen conservation. However, unprotected sites play an important role as alternative habitats for saxicolous lichens and especially for so-called species of special concern, in this case threatened and protected lichens.

Key words: threatened species, limestone outcrops, nature reserves, protected lichens, sandstone formations, Poland

INTRODUCTION

Saxicolous lichens have their center of distribution in southern Poland, across mountain ranges occurring there (the Carpathians and the Sudety Mts). Apart from the mountains their natural habitats are associated with limestone outcrops (in uplands), sandstone rocks and outcrops (in mountain foothills) and sandstone boulders (in lowlands). These formations are interesting elements of the landscape and often are geological or archeological monuments and therefore, most often protected as nature reserves. Passive lichen conservation is realized in this way by protecting and preserving these habitats and sites.

As refuges of saxicolous lichens these various sandstone formations are objects of interest to the lichenologist. Pioneer work focusing on lichen diversity on sandstone boulders in western Poland was that by Krawiec (1938) and was continued by others (Zielińska 1980; Karczmarz et al. 1988; Kiszka & Lipnicki 1994; Lipnicki 1994, 1998; Fałtynowicz 1997; Kukwa & Fałtynowicz 2002; Cieśliński & Czyżewska 2006).

The current lichen survey focused on sandstone formations in different parts of the Carpathian Foothills in the years 1994–2001 and included: Pogórze Ciężkowickie, Pogórze Dynowskie foothills, and especially the Pogórze Wiśnickie foothills. It was aimed at an estimation and comparison of lichen diversity on protected versus unprotected sandstone outcrops and rocks. During the study an approach was also made to test the hypothesis that passive protection of saxicolous lichens sites is a suitable and sufficient tool in their conservation.

MATERIAL AND METHODS

Lichens occurring on 4 protected areas (Skamieniałe Miasto nature reserve near Ciężkowice, Prządki nature reserve near Krosno, Kamienie Brodzińskiego and Kamień Grzyb nature reserves by Nowy Wiśnicz) and 2 unprotected sandstone formations (Kamień Grzyb rock in Bigorzówka and Diabelski Kamień outcrop in Smykan, Figs 1 & 2) in the Carpathian Foothills were analyzed. Detailed characteristics of the study area are found in Śliwa (2010 and literature cited therein). Lichen records and detailed characteristic of protected areas were previously presented in joint publications of Krzewicka & Śliwa 2000 and Śliwa et al. 2001 (note: few records were revised in comparison to the originally published).

Data concerning collection sites on unprotected formations are as follows: the Pogórze Wiśnickie foothills, Kamień Grzyb rock in Bigorzówka village near Raciechowic, 7 May 2000, *L. Śliwa 1115–1126* & *B. Krzewicka*; Diabelski Kamień outcrop in Smykan village near Szczyrzyce, 7 May 2000, *L. Śliwa 1127–1159* & *B. Krzewicka*.

Lichens were identified using routine microscopic and laboratory techniques. When necessary the TLC analyses were performed in solvent system A or/and C, following the methods of Orange et al. (2001). Voucher specimens are available at KRA and/or KRAM herbaria.

All lichens occurring on the investigated sandstone formations are included in this analysis, i.e. species growing directly on rock surface (also typical epiphytes if such were recorded) and occurring on patches of humus in the hollows and crevices.

Nomenclature basically follows Nordin et al. (2010) and Diederich et al. (2012).

RESULTS AND DISCUSSION

Altogether 98 different species were noted on sandstone formations; 81 species were found on protected areas (nature reserves: Skamieniałe Miasto – 24 species; Prządki – 63; Kamienie Brodzińskiego – 38; Kamień Grzyb – 9) and 50 species on unprotected areas (Kamień Grzyb rock – 15 species; Diabelski Kamień outcrop – 38) (see Table 1). Sixteen of the recorded species are protected by law and they were noted mainly on protected sites but 10 of them were recorded also on Diabelski Kamień outcrop. Only one protected species, *Parmelia saxatilis* was found on all of the examined sites. Five protected species were found exclusively on unprotected rocks. Five, *Parmelia omphalodes, P. saxatilis, Pseudevernia furfuracea*, *Umbilicaria deusta* and *U. hirsuta*, were noted both on protected and unprotected sandstones. Additionally fourteen of all taxa occurring on the studied sandstones are threatened according to the Red List of lichens in Poland (Cieśliński et al. 2006) and the majority occupy the protected formations: RE – 1 species, EN – 3, VU – 2, NT – 3, LC – 4 and DD – 1.

Among the analyzed rock-complexes the richest in lichen species is Prządki nature reserve, the area with the largest blocks of rock. Of the 81 species found in all protected formations studied, as many as 63 taxa occur in this particular area. Prządki nature reserve comprises a complex of sandstone rocks various in size, from huge blocks of rock reaching to several meters in height to smaller reaching up to 1 meter. Although the forest is encroaching into the reserve, the biggest rocks still have very good illumination conditions, especially at the uppermost parts, which are located above tree canopies. It is a touristic area but some of the rocks are inaccessible for visitors (due to their shape or size).

Medium-sized rock-complexs occur in Skamieniałe Miasto and Kamienie Brodzińskiego nature reserves, and Diabelski Kamień outcrop (Fig. 1). It is interesting that the same amount of lichens were found on unprotected rocks (Diabelski Kamień) as on the formations in Kamienie Brodzińskiego nature reserve, and more (one third of species) than in Skamieniałe Miasto nature reserve. In Kamienie Brodzińskiego and Skamieniałe Miasto, as a result of conservation management (no cutting activity), the rocks have started to be overgrown by the forest. Whereas, the Diabelski Kamień is located near the agricultural area, it is a more open situation: S-exposed slopes of the rock remain sunny. Additionally,

Fig. 1. Diabelski Kamień outcrop in Smykan (Photo B. Krzewicka)

Skamieniałe Miasto is a very popular place, frequently visited by individuals but also by large groups of tourists. Kamienie Brodzińskiego nature reserve, however, is not so touristic; and Diabelski Kamień is also visited but not so frequently as it is less famous.

The smallest sandstone formations are Kamień Grzyb nature reserve with 9 species and Kamień Grzyb rock (unprotected; Fig. 2) with 15 species of lichens occurring on their surfaces. The rocks in Kamień Grzyb nature reserve are located in the forest whereas the unprotected Kamień Grzyb rock is in an open area by the public road and near a farm. It is worth noting that along with the typical saxicolous lichens on the latter rock, on thin layers of soil (humus) grow numerous terricolous species that usually grow in open, well illuminated sites such as paths or ground roads.

Summarizing, lichen diversity varied depending on the size of the studied sandstone formations and their management, including touristic activity. In the case of large, formations (protected/unprotected) the number of species depends on illumination conditions and touristic activity. The small sized formations differ concerning the number of species, with higher numbers on unprotected sandstone rocks. Shading by trees predominantly restricts the occurrence of lichens on small protected formations.

Fig. 1. Kamień Grzyb rock in Bigorzówka (Photo B. Krzewicka)

Table 1. Lichens recorded on outcrops protected by law and unprotected ones in the Carpathian foothills

Source of information: I – Czwórnóg & Śliwa (1995); II – Krzewicka & Śliwa (2000); III – Śliwa et al. (2001); IV – herbarium material, leg. L. Śliwa & B. Krzewicka (*see also Śliwa 2010). Frequency scale: + – rare species; ++ – frequent; +++ – common. The status of threatened lichens after The Red List Categories: RE – Regionally Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient; the threat to lichens in Poland according to Cieśliński et al. (2006). Protection status (acc. to Regulation of the Minister of the Environment on species of wild growing fungi under protection, Dz. U. Nr 168, poz. 1765, 2004): sPR – strictly protected species.

Name of species	Protected areas				Unprotected areas		Threat and/or protection status in Poland
	Skamieniałe Miasto	Prządki	Kamienie Brodzińskiego	Kamień Grzyb	Kamień Grzyb rock	Diabelski Kamień outcrop	
	I	II	III	III	IV	IV	
Acarospora fuscata (Schrad.) Th.Fr.	+	++	++	++		+++	
Acarospora moenium (Vain.) Räsänen		+				+	
Bacidia trachona (Ach.) Lettau		+++	++				VU
Baeomyces rufus (Huds.) Rebent.		+++	++	+			
Caloplaca arnoldii subsp. *obliterata* (Pers.) Gaya [sub. *C. saxicola* (Hoffm.) Nordin]						+	
Caloplaca citrina (Hoffm.) Th.Fr.						+++	
Caloplaca holocarpa (Ach.) A.E. Wade		+				++	
Candelariella aurella (Hoffm.) Zahlbr.		+				+++	
Candelariella coralliza (Nyl.) H. Magn.	+	+	+				
Candelariella vitellina (Hoffm.) Müll. Arg.	+	+				++	
Candelariella xanthostigma (Ach.) Lettau						+	
Chrysothrix chlorina (Ach.) J. R. Laundon		+				++	
Cladonia caespiticia (Pers.) Flörke			+			++	EN
Cladonia chlorophaea (Sommerf.) Spreng.		++	++				
Cladonia coniocraea (Flörke) Spreng.		+++	+				
Cladonia deformis (L.) Hoffm.					+		
Cladonia digitata (L.) Hoffm.		++	+				
Cladonia fimbriata (L.) Fr.					++	+	
Cladonia floerkeana (Fr.) Flörke						++	
Cladonia furcata (Hudson) Schrader						++	
Cladonia macilenta Hoffm.		++	+		++	+	
Cladonia ochrochlora Flörke			+				
Cladonia pleurota (Flörke) Schaer.			+		++		
Cladonia pyxidata (L.) Hoffm.		++					
Cladonia squamosa Hoffm.	+				++		

Cystocoleus ebeneus (Dillwyn) Thwaites	+	+					NT
Diploschistes scruposus (Schreb.) Norman	+	+	++				
Flavoparmelia caperata (L.) Hale						+	sPR
Fuscidea pusilla Tønsberg			++				
Fuscidea sp.		+					
Hypocenomyce scalaris (Ach.) M. Choisy					+	+	
Imshaugia aleurites (Ach.) S.L.F. Meyer						+	sPR
Lecanora chlarotera Nyl.		+					
Lecanora conizaeoides Crombie			++				
Lecanora dispersa (Pers.) Sommerf.	+	+				++	
Lecanora muralis (Schreb.) Rabenh.	+					+++	
Lecanora orosthea (Ach. Ach. [sub. *Haematomma ochroleucum* (Neck.) J. R. Laundon]		+					DD
Lecanora polytropa (Hoffm.) Rabenh.		++	+				
Lecanora pulicaris (Pers.) Ach.		+					
Lecanora albellula Nyl. [sub. *Lecanora saligna* var. *sarcopis* (Ach.) Hillmann]		++					
Lecidea fuscoatra (L.) Ach.	+	++	++		++	+++	
Lepraria borealis Lothander & Tønsberg					+*		
Lepraria caesioalba (de Lesd.) J.R. Laundon		+	++	+	++*		
Lepraria eburnea J.R. Laundon		+					
Lepraria ecorticata (J.R. Laundon) Kukwa						+*	
Lepraria incana (L.) Ach.	+++	+++	+++	+		+++*	
Lepraria jackii Tønsberg		+					
Lepraria lobificans Nyl.		+++	++	+			
Lepraria membranacea (Dicks.) Vain.	+++	+++	+++			+++*	
Lepraria neglecta (Nyl.) Lettau	+++	+++	++	+	++*	+++*	
Melanelia disjuncta (Erichsen) Essl.						++	sPR
Melanelia stygia (L.) Essl.		+					sPR
Melanelixia subaurifera (Nyl.) O. Blanco et al.		+					sPR
Micarea peliocarpa (Anzi) Coppins & R. Sant.	+	+	+	+		+++	
Mycoblastus sp.		+					
Ochrolechia androgyna (Hoffm.) Arnold		+					
Ochrolechia parella (L.) A. Massal.		+					RE
Parmelia omphalodes (L.) Ach.		+++	++			++	EN, sPR
Parmelia saxatilis (L.) Ach.	+++	+++	+	+++	+++	+++	sPR
Parmelia sulcata Taylor		+					
Pertusaria corallina (L.) Arnold	+						NT
Pertusaria lactea (L.) Arnold		+					LC
Phlyctis argena (Spreng.) Flot.		+	+				
Physcia adscendens (Fr.) H. Olivier	+						
Placynthiella dasaea (Stirt.) Tønsberg		+			+++		

Placynthiella icmalea (Ach.) Coppins & P. James			+	+			
Placynthiella uliginosa (Schrad.) Coppins & P. James					++		
Platismatia glauca W.L. Culb. & C.F. Culb.	+	+					sPR
Porina chlorotica (Ach.) Müll. Arg.		+					
Porpidia crustulata (Ach.) Hertel & Knoph		+					
Porpidia soredizodes (Lamy ex Nyl.) J.R. Laundon		+					
Porpidia tuberculosa (Sm.) Hertel & Knoph	+						
Pseudevernia furfuracea (L.) Zopf		++	+			+	sPR
Psilolechia lucida (Ach.) M. Choisy	++	+					LC
Ramalina pollinaria (Westr.) Ach.						++	sPR
Rhizocarpon geographicum (L.) DC.	+	+					
Rhizocarpon grande (Flörke) Arnold		+					EN
Rhizocarpon obscuratum (Ach.) A. Massal.		+					
Rhizocarpon polycarpum (Hepp) Th. Fr.		+					
Sarcogyne regularis Körb.		+				+	
Scoliciosporum chlorococcum (Stenh.) Vězda			++				
Scoliciosporum umbrinum (Ach.) Arnold						+++	
Trapelia involuta (Taylor) Hertel		+	+				
Trapelia obtegens (Th.Fr.) Hertel			+				
Trapelia placodioides Coppins & P. James	+	+	+			+++	
Trapeliopsis flexuosa (Fr.) Coppins & P. James		+					
Trapeliopsis gelatinosa (Flörke) Coppins & P. James			+				NT
Trapeliopsis pseudogranulosa Coppins & P. James			+		++		
Umbilicaria deusta (L.) Baumg.		++	++			++	LC, sPR
Umbilicaria hirsuta (Westr.) Hoffm.	+		+			++	VU, sPR
Umbilicaria polyphylla (L.) Baumg.		+					LC, sPR
Verrucaria myriocarpa Hepp						+	
Verrucaria sp.		+					
Xanthoparmelia conspersa (Ach.) Hale	+++	+	++		+++	+++	
Xanthoparmelia loxodes (Nyl.) O. Blanco et al.	++	+	++				sPR
Xanthoparmelia pulla (Ach.) O. Blanco et al.						+	sPR
Xanthoparmelia stenophylla (Ach.) Ahti & D. Hawksw. [sub. *Xanthoparmelia somolënsis* (Gyeln.) Hale]			+				sPR
Total	24	63	38	9	15	38	14/16

CONCLUSIONS

In times of extensive environmental degradation, lichens have the best conditions for development in protected areas such as national parks, nature reserves and landscape parks. These areas guarantee preservation of lichens diversity (Cieśliński & Czyżewska 1992). The important role of nature reserves in conservation of the biota and especially of corticolous and terricolous lichens has been demonstrated by many authors (e.g., Lipnicki 1991, 1993; Kondratyuk & Navrotskaya 1995; Cieśliński 2000, 2009; Fałynowicz & Kukwa 2000; Kantvilas 2000; Zalewska & Rutkowski 2001; Czyżewska et al. 2002; Bielczyk & Betleja 2003; Slezáková 2006; Kubiak 2008, 2009; Kukwa 2009; Motiejūnaitė 2009). Compared to other ecological groups, such as epiphytes, saxicolous lichens are less at risk (Cieśliński & Czyżewska 2006). This applies especially to their relatively compact range within the mountainous area of our country. Much more threatened, are saxicolous species occurring in the mountain foothills, uplands and the lowlands (Cieśliński & Czyżewska 1992; Czyżewska 2003).

Protected sandstone formations are proven to be hotspots of epilithic acidophilous lichen diversity and deserve special attention, with respect to lichen conservation. However, unprotected formations play an important role as alternative habitats for saxicolous lichens and especially for so-called species of special concern, the threatened and protected lichens. As indicated in this study, protection status of small formations causes a succession of vascular vegetation and in this way lichens are eliminated due to a change of illumination conditions. To a somewhat lesser extent, the phenomenon applies to large formations and was noted as a reason for a threat to saxicolous lichens (Czwórnóg & Śliwa 1995; Krzewicka & Śliwa 2000). In protected areas lichens are also greatly endangered by intense penetration by tourists (and their often destructive activities) since such areas are more willingly visited than less attractive unprotected ones. Therefore, for these reasons unprotected rocky formations are considered by us as equally important refuges for saxicolous lichens in the study area.

This conclusion most likely applies to calcicolous lichens also. Apart from the mountains, where they are distributed thorough the Carpathians (Bielczyk 2006), calcicolous species occur on natural habitats in the area of limestone outcrops in the Wyżyna Krakowsko-Częstochowska and the Wyżyna Wieluńska uplands. The lichen biota of this area was studied in detail by Nowak (1960, 1961, 1967), who studied species richness, particular taxa distribution and lichen communities, and who demonstrated that calcareous rocks were unique substrate for lichens. As such they are also consider as threatened habitat types (Pykälä 2007, 2012) and, therefore, should receive more attention in reference to conservation of lichens.

More extensive studies are recommended, aimed at the estimation of the most suitable concepts and actions in managing saxicolous lichens for protection. Conservation measures need to be intensified to preserve the lichen biota of siliceous and the especially rich, lichen biota of calcareous rocks.

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LICHENS OF ZINC-LEAD POST-MINING AREAS IN THE OLKUSZ REGION – STATE OF PRESERVATION, THREATS AND NEEDS FOR PROTECTION

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Abstract. The paper presents the lichenological values of an area significantly degraded by mining and processing of zinc and lead ores in the Olkusz Ore-bearing Region. Its specific lichen biota is an example of lichen adaptation to extremely difficult environmental conditions. Pioneer and ephemeral species are numerous here (*Sarcosagium campestre*, *Vezdaea leprosa*, *V. aestivalis*, *Steinia geophana*, *Bacidia saxenii*, *Leptogium biatorinum*, *Verrucaria bryoctona* and *V. xyloxena*). There are species whose ability to accumulate high heavy metal concentrations in thalli has been proved, including a hyperaccumulator of zinc *Diploschistes muscorum* and species dependent on zinc and lead in the substrate (*Vezdaea leprosa*, *V. aestivalis* and *Bacidia saxenii*). In this region 3 species have their only localities in Poland (*Vezdaea leprosa*, *Agonimia vouauxii* and *Thelocarpon imperceptum*), others are rare in Poland (e.g. *Bacidia saxenii*, *Bacidina chloroticula*, *Cladonia conista*, *Verrucaria xyloxena* and lichenicolous fungus *Cladoniicola staurospora*). In the paper examples of threats to lichens are mentioned and the need for protection of their habitats is postulated.

Keywords: lichenized fungi, heavy metals, metalliferous substrates, transient habitats, environmental pollution, Southern Poland

INTRODUCTION

Areas highly polluted and degraded by industry, which seem to have little natural value, are often ignored in complex lichenological studies. Such research is usually restricted to lichenoindication methods, which show scarcity of epiphytes. Lichens are commonly used for biomonitoring of the environment, therefore their particular sensitivity to anthropogenic influence has been emphasized and they are frequently believed not to occur in an environment transformed by man. However, one of the most important features of lichens is their ability to survive in adverse or even extreme conditions, which characterise areas e.g. in the vicinity of steelworks and mines. The research carried out in the Olkusz region (a significantly industrially damaged area, which seems infertile and devoid of life,) shows that there are habitats of numerous interesting lichen species.

The Olkusz Ore-bearing Region (OOR), situated in the Wyżyna Śląsko-Krakowska upland (Fig. 1), is one of the longest mined areas in Poland. Ore exploitation and processing, which have taken place since the 12th century, have damaged the surface of the soil and natural vegetation and have also degraded the landscape. The area has an abundance of excavations, ore workings and mine waste heaps – a result of earlier and present technological processes. Soils found on such wasteland contain large, above average amounts of heavy metals (mainly zinc and lead), they are poor in nutrients and dry (Grodzińska & Szarek-Łukaszewska 2009; Grodzińska et al. 2010). Moreover, as mentioned in the above quoted papers, the air has been significantly contaminated by SO_2 and dust with high heavy metal concentrations.

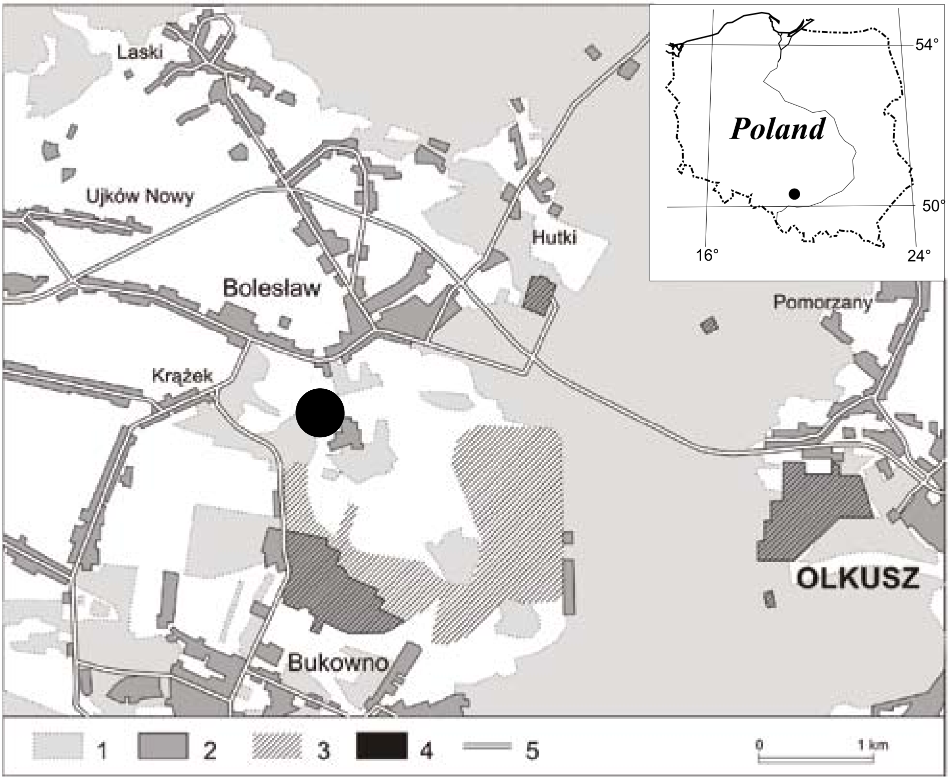

Fig. 1. The mining area in the Olkusz environs: 1 – forest, 2 – build-up area, 3 – industrial area, 4 – "Pleszczotka górska" – a site of ecological land use (50ş17'30"N, 19ş28'19"E), 5 –roads (after Kapusta et al. 2010, modified).

The area is full of natural contrasts. There are areas completely transformed by man and those, which have been less changed, with semi-natural plant communities. Calamine plant communities have formed in this region that are unique in Poland. Plants belonging to them tolerate metals or favour their high concentration in the soil (Szarek-Łukaszewska & Grodzińska 2011). The area is a refuge for valuable, often threatened plant and fungal species (e.g. Bielczyk et al. 2009; Mleczko et al. 2009; Kapusta et al. 2010; Nowak et al. 2011).

In the environment enriched with metal compounds lichens are the domineering element of biodiversity – they accompany plant communities or – together with mosses – they create separate communities (e.g. Wirth 1972; Purvis & Halls 1996; Cuny et al. 2004; Purvis & Pawlik-Skowrońska 2008). Substrates containing zinc and lead are favourable for lichen vegetation and some species seem to be restricted to this kind of habitat. Their primary sites, which are connected with natural outcrops of zinc-lead ores, occur on all continents, and in Europe – apart from Poland – they can be found in Germany, Holland, France, Belgium and Great Britain. However, nowadays they are rare. Most of them were formed artificially, as a result of exploitation and processing of metal ores.

The present paper is intended to describe the lichen biota of the Olkusz region and points to the unique character of the post-mining areas with respect to their maintenance and threats. It is also an attempt to establish whether the lichen biota requires any protection and, if so, how to protect it.

This paper is based on the results of research carried out in the years 2008-2011 as part of the project "Vegetation of calamine soils and its importance for biodiversity and landscape conservation in post-mining areas" (FM EEA PL 0265). The nomenclature of lichens follows Fałtynowicz (2003) and Smith et al. (2009).

GENERAL DESCRIPTION OF THE LICHEN BIOTA

The lichen biota of the Olkusz Ore Region has been formed under strong influence of various anthropogenic factors. It is characterised by:

- presence of pioneer and ephemeral species that have the ability to colonize open rock surfaces and soil in a fast and effective way (e.g. *Sarcosagium campestre*, *Vezdaea leprosa*, *V. aestivalis*, *Steinia geophana*, *Bacidia saxenii*, *Leptogium biatorinum*, *Verrucaria bryoctona* and *V. xyloxena*);
- occurrence of species whose ability to tolerate or/and accumulate heavy metals in thalli has been proved (*Hypocenomyce scalaris*, *Lepraria incana*, *L. elobata*, *L. jackii*, *Cladonia furcata*, *C. pocillum*, *C. fimbriata*, *Peltigera didactyla*, *Physcia adscendens*, *Hypogymnia physodes*, *Candelariella reflexa, Stereocaulon incrustatum* and *Diploschistes muscorum*);
- presence of species dependent on zinc and lead in the substratum (e.g. *Vezdaea leprosa*, *V. aestivalis*, *Bacidia saxenii*);
- dominance of species that constitute terricolous communities (epigeites and epibryophytes, some of them colonize thalli of other lichens and inhabit pebbles and pieces of wood in soil);
- definite dominance of crustose forms;
- morphological changes observed in macrolichens (deformation, dwarfing, crumbling of parts of thalli, clear changes of colour);
- sparseness of epiphytes, except the most toxin-tolerant ones (e.g. *Scoliciosporum chlorococcum* and *Lecanora conizaeoides*);

- small contribution of epixylites.

Another feature distinguishing the lichen biota of the OOR is the occurrence of rare and threatened species, which prove its unique character, e.g.:

- species that have not been recorded anywhere else in Poland (*Vezdaea leprosa*, *Agonimia vouauxii* and *Thelocarpon imperceptum*);
- very rare species in Poland, only recorded at single localities (e.g. *Bacidia saxenii*, *Bacidina chloroticula*, *Cladonia conista*, *Verrucaria xyloxena*, or the lichenicolous fungus *Cladoniicola staurospora* growing on squamules of *Cladonia* cf. *pyxidata*);
- taxa under legal protection in Poland (*Caloplaca cerina* var. *muscorum*, *Cetraria aculeata*, *C. islandica*, *Cladonia arbuscula* subsp. *mitis*, *Peltigera didactyla*, *P. rufescens*, *Pseudevernia furfuracea* and *Stereocaulon incrustatum*);
- species included in the red list of threatened lichens in Poland (Cieśliński et al. 2006): the Red List Categories – threatened species: *Stereocaulon incrustatum* (EN category), *Caloplaca cerina* var. *muscorum*, *Cetraria islandica* and *Endocarpon pusillum* (VU category); lower risk of threat: *Arthonia lapidicola* and *Thelidium papulare* (NT category); indeterminate threat degree: *Vezdaea aestivalis* (DD category).

PARTICULAR CHARACTER OF THE OOR LICHEN BIOTA

The OOR region is characterised by significant taxonomic diversity of the lichen biota. Altogether, 120 species were found, out of which 116 were lichenized fungi and 4 - lichenicolous fungi (Bielczyk & Kossowska 2012). The abundance of lichen species is possible due to the mosaic of habitats in the mining area. They include sands, zinc-lead wastes, substrate of different pH, moisture and insolation. The number of taxa found in this area is comparable with lists of lichens reported from similar areas in Europe: Belgium, Holland, France, Germany and Great Britain (cf. Purvis & Halls 1996; Heibel 1999).

Metallophytes, i.e. species that tolerates or favours high concentration of heavy metals in soil, are indicators of plant communities, which are naturally or secondarily enriched with heavy metals. Generally, due to their particular structure and biology, lichens are organisms adapted to survive in adverse habitats, also those contaminated by heavy metals. However, it is difficult to establish, which of the species growing in calamine areas, are obligatory metallophytes. Yet, it may be assumed that they all tolerate elevated content of heavy metals in the substrate and atmospheric air. Of them as many as 74 species (60%) were reported from other areas where the substrate contained zinc and lead (Purvis & Halls 1996; Heibel 1999; Cuny et al. 2004; Bánásova 2006; Smith et al. 2009; Rajakaruna et al. 2011). In many of them the ability to tolerate or/and accumulate these elements in thalli has been proved (Pawlik-Skowrońska et al. 2008; Pawlik-Skowrońska

& Bačkor 2011). Among lichens with bushy thalli and typical of environments with zinc and lead, species from the genus *Stereocaulon*, especially *S. nanodes,* are mentioned. However, in the OOR only *Stereocaulon incrustatum* (not reported from similar regions in Europe) has been recorded so far. The species is frequent in the studied area and forms large populations. According to the research done by Pawlik-Skowrońska et al. (2008), it accumulates significant amounts of heavy metals in its thalli. *Diploschistes muscorum,* considered a hyperaccumulator of zinc, is another very frequent species (Sarret et al. 1998). Vegetation of a number of crustose lichens, whose ability to accumulate heavy metals has not actually been shown, but seems to depend on them. They include: *Vezdaea leprosa* and *V. aestivalis*, which apart from metalliferous areas, also have their localities around galvanised isolation barriers by roads in Germany and Great Britain (Ernst 1995; Gilbert 2000). Similarly, *Bacidia saxenii* grows in large numbers below metal utility poles, as well as on zinc-plated tins and oil containers (Gilbert 1990).

Ecologically, the presence of lichens whose main or additional autotrophic component is cyanobacteria is worth mentioning. Due to their ability to liberate free nitrogen, they are an important link in a trophic chain, especially on calamine soils, poor in biogens. This group in calamine areas is represented by *Peltigera rufescens*, *P. didactyla*, *Stereocaulon incrustatum*, *Collema limosum*, *C. tenax* and *Leptogium biatorinum*.

A typical characteristic of lichen biota of the OOR is the presence of a group of pioneer lichens, which can quickly colonize open rock surfaces and soil. These species perform a very important role in ecosystems because they stabilize the substrate in the early stage of plant succession. Species most typical of substrates, which are contaminated by heavy metals and also unstable, situated in the vicinity of mines and steelworks, include ephemeral, retrial, and stress-tolerant lichens. They are difficult to find because of the very small size of their thalli. Additionally, some of them have a very short life cycle and atrophying ascomata, only formed in wet seasons (Gilbert 2004).

Rare and very rare species are valuable elements of the discussed area. Three of them, possessing small thalli, have their only localities in Poland here. ***Vezdaea leprosa*** – an ephemeral lichen, having very short life cycle, reaches its full development in late autumn and winter. In the OOR it occurs at very numerous localities; it grows on living and dying terricolous mosses, less often on parts of flowering plants and soil within thermophilic grasslands, wet grass communities and pine forests on post-mining wastes, less often among plants of abandoned ploughlands. Being connected with substratum rich in zinc and lead, it is a frequent component of lichen biota in environments contaminated by heavy metals; reported from Europe, Madeira, North America, South America and Asia from both natural and anthropogenic habitats (Chambers & Purvis 2009). ***Agonimia vouauxii*** – found at 13 localities in the OOR; it grew on plant debris within thermophilic grasslands and in wet grass communities formed on post-mining wastes, less often on sands and abandoned ploughlands. A species rare in Europe (Pykälä 2007), reported from anthropogenic habitats (Sérasiaux et al. 1999; Vondrák et al. 2010). ***Thelocarpon imperceptum*** – terricolous lichen, known from 1 locality on reclaimed mining excavation in the vicinity of the Bolesław town (Kiszka 2009). It is very rare in Europe, recorded in Switzerland and Russia, recently reported from Holland (van den Boom 2000) and Ukraine (cf. Khodosovtsevet et al. 2010).

In the analysed lichen biota, species, which are very rare in Poland, known so far from single localities should be distinguished. Some of these species were described only in recent years and their general distribution has not been examined yet. They add some new localities to the lichen biota of Poland and have an impact on the natural values of the discussed area, e.g. *Bacidia saxenii* (Czarnota & Coppins 2007), *Bacidina chloroticula*, *Cladonia conista*, *Verrucaria xyloxena* (cf. Fałtynowicz 2003) and lichenicolous fungus *Cladoniicola staurospora* (cf. Czyżewska & Kukwa 2009). Two very frequent in the OOR microlichens characteristic of post-mining sites in Europe (Gilbert & Purvis 2009; Orange et al. 2009) are also worth mentioning. One of them is ***Sarcosagium campestre*** – an ephemeral species, forming ascomata in wet and cold seasons of the year, in autumn and winter, usually from August to February (Gilbert 2004). In the discussed area it grows on soil, mosses and vascular plant debris, usually on thermophilic grasslands on post-mining wastes, occasionally in forests, on abandoned ploughlands and in wet grass communities. In Poland it is scattered in the lowlands and mountains (cf. Fałtynowicz 2003). The other is ***Verrucaria bryoctona*** **–** a species often found on moss and flowering plant debris, usually within thermophilic grasslands on post-mining wastes and sands, rarely among plants of abandoned ploughlands. In Poland the species was reported from single localities in the mountains (the Tatras, the Bieszczady Mts, the Gorce Mts), the Chęciny Region and numerous localities in the lowlands (Kujawy) (cf. Fałtynowicz 2003).

THREATS AND PROTECTION

Because of their particular biological and ecological characteristics, lichens are difficult to protect in practice. Life strategy of the majority of them consists in living in places of stable environmental conditions. The only effective form of protection is saving whole biotops in order to maintain their natural habitats. It mainly refers to epiphytes and epixylites, which generally do not occur in the OOR, and, in view of the local conditions, they are unlikely to recolonise, even in the distant future.

However, the core of the OOR lichen biota comprises less known terricolous lichens, usually including pioneer species, which quickly abandon old localities and gain new ones. A lot of them occur at numerous localities and their existence does not seem to be threatened. Moreover, some anthropogenic factors can contribute to their better development and spreading (e.g. uncovering new surfaces of soil, treading plants). Yet, very rare species may be threatened. One of the threats is allocating the land, assumed to be contaminated wasteland, for development (e.g. industrial buildings). Such activities can contribute directly – to extinction of these species or indirectly – to disappearance of their habitats. In the case of very rare species, protection of their localities as well as continuous monitoring are advisable, as it was suggested by Kiszka (2009) for *Thelocarpon imperceptum*.

It is extremely difficult to establish the status of endangerment for lichens with very small thalli. Firstly, the actual distribution of these lichens is insufficient. Secondly, their ecology and biology are not well known (usually species with large thalli and clear morphological features are used for experimental studies). After an analysis of lists of lichens threatened in several countries (Pišút et al. 2001; Scheidegger et al. 2002; Liška et al. 2008; Woods 2010), chosen species of terricolous lichens of the OOR were assigned the category LC (Least Concern) or DD (Data Deficient). Establishing whether these species are endangered in Poland and the decision to include them in the red list in a particular category require further field research in order to find more localities.

The most valuable elements of the lichen biota in the OOR are species occurring within ecologically specialized communities of low grasslands from the *Violetea calaminariae*-class. They comprise photophilous and thermophilic plants, favouring alkaline soils and tolerating heavy metals. Similar habitat requirements characterize lichens growing there. Proper lighting is guaranteed for macrolichens and in this aspect herbaceous plants are not an eliminating factor for them. However, microlichens possess particular phenology consisting in developing and forming ascomata after vegetation of plants, i.e. in autumn, early spring, and even in winter. This group of species, as all the calamine low grassland communities of the OOR, is threatened by careless and ecologically improper reclamation (cf. Kapusta et al. 2010). Such reclamation means populating mining workings and waste heaps mainly with pine, which, during the natural process of overgrowing, causes shading of habitats and elimination of xerothermic species, including terricolous lichens. The results of lichenological studies carried out within the area of ecological land use “Pleszczotka górska” [in Polish: użytek ekologiczny – ecological land use] could serve as an example here. This over one-hundred-year-old grassland, legally protected since 1997, suddenly started to overgrow with pine. As shown by Żegleń (2010), terricolous lichens occur there mainly in not shaded parts of the grassland. Moreover, accumulation of needles under the trees is a factor restricting their vegetation. In this case active protection consisting in cutting down trees and shrubs, as well as continuous monitoring are postulated.

CONCLUSIONS

Because of the occurrence of interesting species, including lichens, as well as the particular character of the conditions and uniqueness of biocoenoses, Polish calamine areas – together with monuments of industrial culture – form the cultural heritage of the region. In Europe there are examples of protection of nature in post-industrial areas. In Great Britain special categories for protection of post-industrial objects were created: SSSI (Site of the Special Scientific Interest) and SINC (Site of Importance for Nature Conservation). In the area of Belgium, France and Germany communities of metallophilic plants are subject to reclamation works; they are also under active protection. Along with post-mining monuments, they are a tourist attraction.

In Poland efforts to protect the areas with calamine plants often clash with local development plans and plans of the mines. So far, the only protected area is the above-mentioned "Pleszczotka górska". Other areas, despite their documented natural, scientific, sightseeing and historical values, have not been put under any kind of protection. The only hope for maintaining parts of them lies in including them into Natura 2000 net as habitat refuges – calamine grasslands.

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THE FIRST NATURE MONUMENT FOR THE PROTECTION OF LICHENS IN THE WEST POMERANIA PROVINCE

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Abstract: During the lichenous field studies in 2006 in the Wkrzańska Forest NW Poland some rare and protected by law species of lichens have been found. All the species are placed on the bark of ashes, which are the nature monument.

Key words: lichenized fungi, nature monument, law protection, Wkrzańska Forest, NW Poland

In the year 2006, in the Wkrzańska Forest and within its direct vicinity, the lichenous field studies were conducted intending to determine the aerosanitary conditions present in this area. The terrain exploration revealed that in several localities legally protected lichens occurred. Those lichens are rare on the national scale (Lipnicki, Janczar 2007; Gruszka, Janczar 2010).

The most valuable locality was situated by the road between Rzędziny and Łęgi in the municipal commune of Dobra Szczecińska in the Police Poviat [District] on the western border of Poland, approximately 3 km towards the South-West of the Nature Reserve of Świdwie (Fig. 1). On the neighbouring trunks of eight roadside *Fraxinus excelsior,* the occurrence of eight taxa of lichens was reported, all of which are placed on the Red List of lichens threatened in Poland (Cieśliński et al. 2006). They are under legal protection, and three of them (*Usnea hirta, U. subfloridana* and *U. filipendula*), in accordance with the Ordinance of the Minister of the Environment dated 2004 (Dz. U. *[Journal of Laws]* No. 168, Item 1765), require zonal protection (Tab. 1). The locality is situated by the local asphalt road leading from Rzędziny to Łęgi.

On the basis of the motion brought by R. Janczar, the Commune Council in Dobra Szczecińska passed, on the 23rd of October 2008, a resolution on the protection of this cluster of trees as a nature monument (Dz.U. *[Journal of Laws]* of the West Pomerania Province (*pol.* Voivodeship) No. 98 Item 2170). It is composed of a cluster of eight specimens of *Fraxinus excelsior* within the circumference of 173 – 223 cm and the height range of 16 – 21 m. It is the first nature monument for the protection of lichens established in the West Pomerania Province. So far it has only been in the Tuchola Forest that a nature monument was created for an identical purpose (Lipnicki 2003).

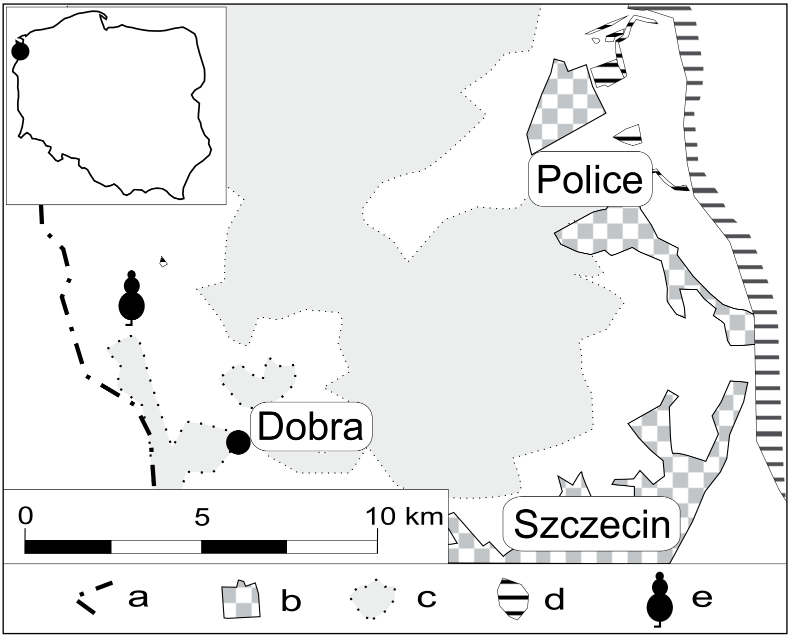

Fig. 1. The location of the nature monument in the commune of Dobra against the background of the forests of the Wkrzańska Forest
a – state boundary; b – urban areas; c – forest areas; d – water areas; e – nature monument

Until recently, Rzędziny and Łegi were typically farming settlements. Currently, these two places, and Łęgi in particular, have become a site for the construction of single-family housing estates (Kalita-Skwirzyńska, Opęchowski 2004). There was a danger that the roadside trees could be felled.

Table 1. List of the most valuable species

Species of lichen	Protected status P – partial E – exact; Z – zone	The threat categories in Poland*)
Evernia prunastri (L.) Ach.	P	NT
Pleurostica acetabulum (Neck.) Elix & Lumbsch	E	EN
Ramalina baltica Lettau	E	EN
Ramalina farinacea (L.) Ach.	E	VU
Ramalina fraxinea (L.) Ach.	E	EN
Ramalina pollinaria (Westr.) Ach.	E	VU
Usnea filipendula Stirton	EZ	VU
Usnea hirta (L.) F.H. Wigg.	EZ	VU
Usnea subfloridana Stirton	EZ	EN

*) – acc. to Cieśliński et al. (2006)

The number of the individual species varies significantly and can be presented in the following manner:
Evernia prunastri – numerous on five trees, on two trees there are single specimens,
Pleurostica acetabulum – one thallus,
Ramalina baltica – three thalli on one tree,
Ramalina farinacea – four thalli on one tree and two trees with one specimen on each,
Ramalina fraxinea – numerous on four trees, three thalli on one tree,
Ramalina pollinaria – four thalli on one tree, two specimens on three trees each, on one tree a single thallus,
Usnea filipendula – approx. 40 thalli on one tree, two specimens – on another tree,
Usnea hirta – two thalli on one tree,
Usnea subfloridana – five thalli on one tree.

The locality is under a constant lichenological monitoring, which consists of its constant inspection. At the opposite side of the road, where the nature monument is situated, on the bark of two *Fraxinus excelsior,* single specimens of *Evernia prunastri* and *Ramalina fraxinea* were observed in February 2012. With all certainty, these lichens were not present there before. It constitutes a good indicator, which means that the specimens living on the trees being a nature monument may be the source of propagules of valuable lichens. This provides support for the need to place valuable localities of lichen species under protection.

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SMALL MID-FOREST AND MID-FIELD PEAT BOGS AS A REFUGE OF RARE AND PROTECTED LICHEN SPECIES

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Abstract. The paper presents the condition of the lichen biota in eight small mid-forest and mid-field peat bogs located in the Łęczyńsko-Włodawskie Lakeland. Fifty-one lichen species were found, including 15 species under strict protection and 1 species under partial protection. Fifteen of the species are included in the "Red List of Threatened Species". Interestingly, the following protected species that are rare in the country and region were found: *Menegazzia terebrata*, *Usnea subfloridana*, *Ramalina farinacea*, *Vulpicida pinastri*, *Tuckermannopsis sepincola,* and *Flavoparmelia caperata,* as well as *Cladonia incrassata* – a species that is regarded as extremely rare in Poland.
The conservation status of the habitats as well as the large number of rare, threatened or protected species justify the attempts to establish protection of one of the objects studied on ecological grounds.

Key words: mid-forest and mid-field peat bogs, threatened, rare, protected species, Łęczyńsko-Włodawskie Lakeland, E Poland

INTRODUCTION

The Łęczyńsko-Włodawskie Lakeland is one of the regions that have many peat bogs. They play a fundamental role in the natural environment as they accumulate considerable amounts of organic matter and water over a long period and serve as retention reservoirs, thereby exerting an effect on the water balance in the region. Most of them exhibit high natural values; the most valuable objects are legally protected. Fens are predominant, and there are fewer transitional and raised bogs. In recent years, mid-field and mid-forest wetlands, including peat bogs, have received increasing attention. Some of such objects were previously regarded as so-called agricultural wasteland, while it is often suggested currently that they should be protected as ecological grounds. Their role in the conservation and enrichment of biodiversity of agricultural and forest areas has been appreciated (Grootjans, Wołejko 2007; Lamentowicz 2007; Łachacz, Olesiński 2000). The knowledge of the small peat bogs located within the closed depressions of the Łęczyńsko-Włodawskie Lakeland is only fragmentary and usually concerns vegetation (Fijałkowski et al. 1997; Wójciak et al. 2000) and soils (Urban 2002; Urban, Wójcikowska-Kapusta 2003).

Lichens are usually present in insignificant amounts in peat bog ecosystems. Most frequently, they grow on the bark of trees, shrubs, and shrublets and on decaying stumps and branches. Terrestrial lichen species grow on tops of dry hummocks and, where present, on dykes. In the absence of the hummock-hollow structure, terrestrial lichens do not occur due to excessive waterlogging. Peat bogs do not offer substratum for epilitic species. Since their lichen biota is relatively poor and the area is difficult to penetrate, peat bogs are seldom investigated by lichenologists. The few reports from the Lublin region originate from 20 or even 40 years ago (Bystrek, Górzyńska 1977; Bystrek, Motyka-Zgłobicka 1981; Fijałkowski et al. 1992, 1992a). Peat bog lichens in other regions of Poland were studied by e.g. Tobolewski (1954), Fałtynowicz (1983, 1996), Bielczyk & Betleja (2003) and Kościelniak, Kiszka (2004).

Literature data concerning lichens in the Łęczyńsko-Włodawskie Lakeland is general and does not provide specific information whether they originate directly from the peat bogs or their vicinity.

MATERIAL AND METHODS

Eight objects were selected for the study (Fig.1) – three mid-field peat bogs (Jelino, Albertów, Ostrówek Podyski) and five mid-forest peat bogs in the Sobibór Forestry Inspectorate (Stulno, Macoszyn, Podlaski, Luta) and Parczew Forestry Inspectorate (Krasne). In terms of the physical and geographical division, the objects are located in the Łęczyńsko-Włodawskie Lakeland, which is a mezoregion of Polesie (Kondracki 2001). The peat bogs cover an area of ca. 2 to 44 ha. They differ in the water level: from low (Ostrówek Podyski) to high (Jelino) or very high (Luta).

List and description of the localities:

1. Krasne – north-west of the village of Rogóźno, Ludwin Municipality, the Łęczyńskie Lakeland Landscape Park, Parczew Forestry Inspectorate, mid-forest peat bog, transitional peat bog, raised peat bog and fen, area of 3.5 ha.
2. Jelino – near the village of Zagłębocze, Sosnowica Municipality, a region of Natura 2000 – PLH060095, mid-field peat bog, transitional and raised bog, area of 8.9 ha.
3. Albertów ("Bagno Wytrzeszczone") – the village of Albertów, Puchaczów Municipality, prospective ecological grounds, mid-field peat bog, transitional peat bog, fen, area of 7.10 ha.
4. Ostrówek Podyski – north of Cyców, Cyców Municipality, a region of Natura 2000 "Jeziora Uściwierskie" – PLH060009, mid-field peat bog, transitional and raised peat bog, area of 44.0 ha.

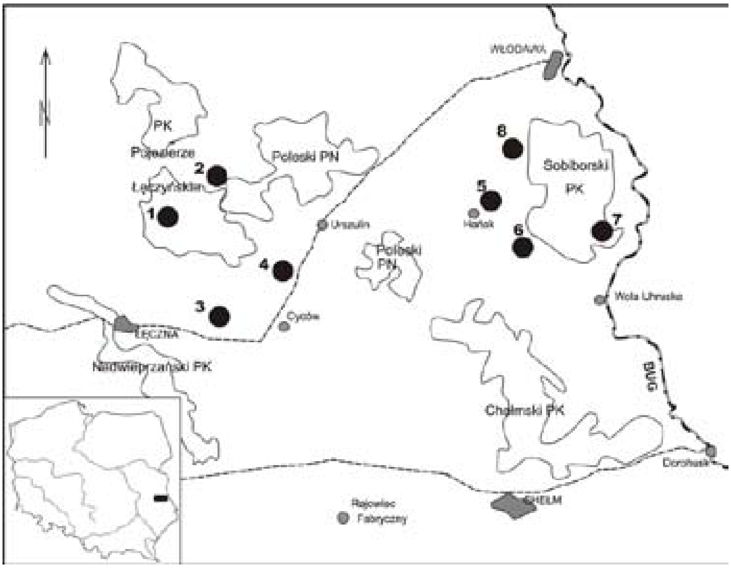

Fig. 1. Location of the peat bogs studied: 1 – Krasne, 2 – Jelino, 3 – Albertów, 4 – Ostrówek Podyski, 5 – Podlaski, 6 – Macoszyn, 7 – Stulno, 8 – Luta.

5. Podlaski – north-east of the village of Hański, Hańsk Municipality, Sobibór Forestry Inspectorate, the Poleski Area of Protected Landscape, mid-forest peat bog, transitional peat bog, raised peat bog and fen, area of 1.9 ha.
6. Macoszyn – west of the village of Macoszyn, Hańsk Municipality, within the region of the Natura 2000 "Lasy Sobiborskie" – PLH060043, Sobibór Forestry Inspectorate, the Poleski Area of Protected Landscape, mid-forest peat bog, transitional and raised peat bog, area of 2.0 ha.
7. Stulno – near the village of Stulno, Wola Uhruska Municipality, within the region of the Natura 2000 "Lasy Sobiborskie", Sobibór Forestry Inspectorate, the Sobiborski Landscape Park, mid-forest peat bog, transitional and raised peat bog, area of 3.8 ha.
8. Luta – north of the village of Luta, Włodawa Municipality, Sobibór Forestry Inspectorate, the Poleski Area of Protected Landscape, mid-forest peat bog, degraded peat bog (transitional, raised and fen), area 26.8 ha. During the investigations, the peat bog was waterlogged down to 80 cm depth.

The field study on the communities of vascular plants, bryophytes, and lichens was conducted in the years 2010-2011, during which 300 phytosociological relevés were made using the method of Braun-Blanquet (1951). The phytosociological classification and nomenclature of plant communities were based on the study of Matuszkiewicz (2005); the nomenclature of vascular plants followed Mirek et al. (2002), the bryophyte names were provided in accordance with Ochyra et al. (2003), and lichen names - with Diederich et al. (2011).

Lichens were investigated in the area of the peat bogs and in their immediate buffer zone – a ca. 30m wide belt – on all substratum types: bark of trees, shrubs, and shrublets, on wood, soil, and remains of dead herbaceous plants.

The primary aim of the study was to analyse the lichen biota and the habitat conditions in the eight mid-forest and mid-field peat bogs located in the Łęczyńsko-Włodawskie Lakeland and to indicate a method of their conservation. During the field study, special attention was paid to the localities of rare and legally protected species.

RESULTS

The objects studied are characterised by a high diversity of plant communities. 29 associations and 9 plant communities from the classes *Lemnetea*, *Potametea*, *Utricularietea intermedio-minoris*, *Phragmitetea*, *Scheuchzerio-Caricetea fuscae*, *Oxycocco-Sphagnetea*, *Molinio-Arrhenatheretea*, *Alnetea glutinosae* and *Vaccinio-Piceetea* were found. Localities of legally protected species e.g. *Drosera rotundifolia*, *Scheuchzeria palustris*, *Utricularia intermedia*, *U. minor*, *U. ochroleuca*, *U. vulgaris*, *Ledum palustre*, *Nymphaea alba*, *Menyanthes trifoliata*, *Frangula alnus*, *Aulacomium palustre*, *Polytrichum strictum* and numerous species from the genus *Sphagnum* were found.

Characteristics of the lichen biota

In total, 51 lichen species were found in the eight peat bogs. The list of species below presents their occurrence in the objects studied and the type of the substratum. The names of species that are legally protected and included in the red list (Cieśliński et al. 2006) are provided in bold fonts and marked with symbols denoting the conservation status and threat category: §§ - strict protection, § - partial protection, CR – critically endangered, EN – endangered, VU – vulnerable, NT – near threatened, and LC – least concern. The localities were marked with numbers corresponding to those in the figure: 1 – Krasne, 2 – Jelino, 3 – Albertów, 4 – Ostrówek Podyski, 5 – Podlaski, 6 – Macoszyn, 7 – Stulno, 8 – Luta.

Alphabetical list of the lichens

Anaptychia ciliaris (L.) Körb. – several small thalli growing on the bark of *Populus tremula* in one locality only: 4; §§, EN.

Chaenotheca ferruginea (Turner. ex Sm.) Mig. – a species growing sparsely on the bark of older pines in the forest adjacent to the peat bog; found in one object: 6.

Cladonia cenotea (Ach.) Schaer. – a species growing at the base of pine trunks and on decaying stumps; found in two objects: 1, 4.

Cladonia chlorophaea (Sommerf.) Spreng. – a species growing on soil and decaying stumps; found in two objects: 4, 5.

Cladonia coniocraea (Flörke) Spreng., non cons. – a common species growing on soil, decaying stumps and at the base of pine and birch trunks; found both in the peat bogs and in the buffer zone of six objects: 2, 4, 5, 6, 7, 8.

Cladonia cornuta (L.) Hoffm. – a species growing on wood in one object: 4.

Cladonia digitata (L.) Hoffm. – at the base of pine trunks in the buffer zone of one peatland: 6.

Cladonia fimbriata (L.) Fr. – fairly common on soil and wood in the peat bogs and their buffer zone; found in four objects: 2, 4, 6, 7.

Cladonia floerkeana (Fr.) Flörke – a species growing sparsely on decaying wood, both in the peat bogs and their buffer zone; found in four objects: 4, 5, 6, 8.

Cladonia glauca Flörke – a species growing on decaying stumps and at the base of pine trunks; found in three objects: 4, 5, 6.

Cladonia incrassata Flörke – a species, whose occurrence is strictly related to the peat bogs; it most often grows on decaying wood and soil; found in three objects: 2, 4, 6; EN.

Cladonia ochrochlora Flörke – occurs at the base of pine and birch trunks and on wood; found in three objects: 4, 5, 6.

Cladonia subulata (L.) F.H.Wigg. – a species growing on soil in the buffer zone and on dykes; found in two objects: 4, 6.

Evernia prunastri (L.) Ach. – growing on oak and birch bark fairly abundantly at the edges of the peat bogs, and single specimens were found within the peat bogs; found in two objects: 3, 6; §, NT.

Flavoparmelia caperata (L.) Hale – several thalli grew on birch and alder bark in one object only: 6; §§, EN.

Hypocenomyce caradocensis (Nyl.) P. James & Gotth. – a species rarely reported from the Łęczyńsko-Włodawskie Lakeland; it grows on pine wood; found in two objects: 6, 8.

Hypocenomyce scalaris (Ach.) M. Choisy – one of the most common species; it grows abundantly on pine and birch bark and on wood; found in all the objects.

Hypogymnia farinacea Zopf – an extremely rare species growing on birches; found in two objects: 3, 6; §§, VU.

Hypogymnia physodes (L.) Nyl. – the most widespread species growing on the bark of trees, shrubs, *Ledum palustre*, *Vaccinium uliginosum* and on wood; found in all the objects studied.

Hypogymnia tubulosa (Schaer.) Hav. – an extremely rare species growing on the bark of *Betula pendula* in one peat bog only: 6; §§, NT.

Imshaugia aleurites (Ach.) S.L.F. Meyer – a species growing on bark and decaying pine stumps; found in one object only: 6; §§.

Lecanora albella (Pers.) Ach. – a rare species growing sparsely on dry branches of *Alnus glutinosa*; found in peat bog 8; EN.

Lecanora albellula Nyl. – an insconspicuous species growing on the bark of deciduous trees and on *Ledum palustre* and *Vaccinium uliginosum*; found in two objects: 5, 6.

Lecanora argentata (Ach.) Malme – a species growing on *Betula pendula* bark; found in one object only: 4; LC.

Lecanora carpinea (L.) Vain. – a rare species in the area studied growing on *Alnus glutinosa* bark; found in one object only: 4.

Lecanora conizaeoides Cromb. – one of the most common species in the area growing on pine and birch bark; found in all the objects.

Lecanora expallens Ach. – a rare species in the study area growing on alder and birch bark; found in peat bog 6.

Lecanora intumescens (Rebent.) Rabenh. – a rare species in the study area growing on branches of dry alders and on birch; found in the Luta peat bog; EN.

Lecanora pulicaris (Pers.) Ach. – a common species growing on the bark of deciduous and coniferous trees; found in six objects: 1, 4, 5, 6, 7, 8.

Lecanora symmicta (Ach.) Ach. – a rare species in the study area growing on branches of dry *Alnus glutinosa* and *Betula pendula*; found in peat bog 8.

Lecanora varia (Hoffm.) Ach. – a rare species in the study area growing on *Betula pendula* bark; found in peat bog 6.

Lecidella elaeochroma (Ach.) Choisy – a rare species in the study area growing on *Populus tremula* bark; found in peat bog 4.

Lepraria incana (L.) Ach. – grows on dry hummocks, decaying wood and at the base of the *Pinus sylvestris* trunks; found in two objects: 4, 6.

Melanelixia fuliginosa (Fr. ex Duby) O. Blanco, A, Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – a rare species in the study area growing on *Betula pendula* bark; found in one peat bog: 6; §§.

Melanohalea exasperatula (Nyl.) O. Blanco, A, Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – a rare species in the study area growing on *Betula pendula* bark; found in one peat bog: 6; §§.

Menegazzia terebrata (Hoffm.) Körb. – an extremely rare species in the country and in the study area; one small thallus grows on *Betula pendula* bark; found in one peat bog: 6; §§, CR.

Micarea denigrata (Fr.) Hedl. – a typical species for decaying wood; found in four objects: 4, 6, 7, 8.

Parmelia sulcata Taylor – one of the most common foliose lichen species exhibiting preference for the bark of deciduous trees; it rarely occurs in the study area; found in three objects: 2, 4, 6.

Parmeliopsis ambigua (Wulfen) Nyl. – a rare species in the study area growing on *Betula pendula* bark and decaying stumps; found in one peat bog: 6; §§.

Placynthiella uliginosa (Schrad.) Coppins & P. James – a common species in poor initial habitats; in the study area, it was found only on the dyke within peat bog 4.

Pseudevernia furfuracea (L.) Zopf – a rare species in the study area growing on the bark of birch, pine, and on wood, found in two objects: 3, 6; §§.

Ramalina farinacea (L.) Ach. – a rare species in the study area growing on *Betula pendula* bark in the buffer zone of peat bog 6; §§, VU.

Scoliciosporum chlorococcum (Stenh.) Vězda – a rare species in the study area growing on *Pinus sylvestris* bark in the neighbourhood of peat bog 6.

Trapeliopsis flexuosa (Fr.) Coppins & P. James – a species growing on decaying wood within peat bog 6.

Trapeliopsis granulosa (Hoffm.) Lumbsch. – a species growing on soil and decaying wood; found in three objects: 2, 4, 6.

Tuckermannopsis sepincola (Ehrh.) Hale – a species growing sparsely on *Betula pendula* bark, mainly on thin branches; found in two objects: 7, 8; §§, EN.

Usnea hirta (L.) H.F. Wigg. – a rare species in the study area growing on the bark of several *Pinus sylvestris* trees in the buffer zone of peat bog 6; §§, VU.

Usnea subfloridana Stirt. – an extremely rare species in the study area growing on dead *Betula pubescens* within peat bog 7; §§, EN.

Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai – an extremely rare species in the study area growing on birch bark; found in one object: 6, §§, NT.

Xanthoria parietina (L.) Th. Fr. – it grows sparsely on the bark of deciduous trees; found in three objects: 4,6,9.

Xanthoria polycarpa (Hoffm.) Rieber. – a rare species in the study area growing on willow bark; found in one peat bog: 4.

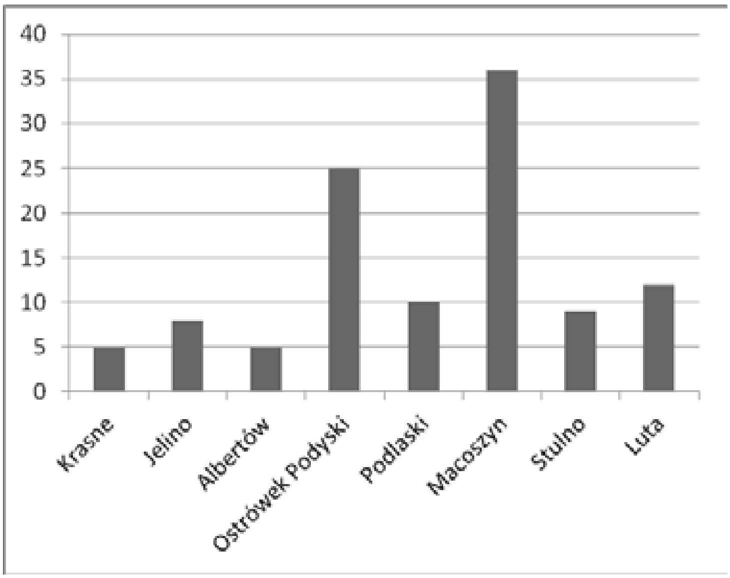

Fig. 2. Number of lichen species in the individual peat bogs

The number of species found in the individual localities ranges from 5 to 36 species (Fig.2). The largest number of species occurs in the Macoszyn mid-forest peat bog.

The study was conducted as part of the research project NN 305 410338.

SUMMARY

1. In the eight objects selected for the study, 51 lichen species were found.
2. Sixteen species, i.e. 31 % of the lichen biota are legally protected (15 species are under strict and 1 under partial protection).
3. Fifteen taxa are included in the "Red List of Threatened Species": 1 - CR (critically endangered), 7 - EN (endangered), 3 - VU (vulnerable), 3 - NT (near threatened), 1 - LC (least concern).
4. The number of species found in the individual localities is varied and ranges between 5 and 36.

5. The abundance of lichens, number of species, and frequency of occurrence predominantly depend on the number of habitats, water level, and the age of the peat bog. The area and type of the peat bogs (mid-forest or mid-field) are less significant. More species grow on raised bogs than on transitional bogs and fens. The largest number of species was found in the Macoszyn mid-forest peat bog, which covers an area of ca. 2 ha.
6. *Cladonia incrassata,* a species regarded as extremely rare in Poland and included in the Red List under the category of endangered species – EN, was found in three objects: Jelino, Macoszyn, and Ostrówek Podyski. Its occurrence is strictly associated with peat bogs. Most frequently, it grows on decaying wood, mainly at the base of stumps, where it is often covered by *Sphagnum* and *Polytrichum* mosses, and on dykes. Until recently, the species has not been reported from the Lublin region. The species is abundant in the Ostrówek Podyski mid-field object. The fast growing number of its localities is related to better exploration of peat bogs carried out by lichenologists. Monitoring of habitats conducted throughout the country since 2010 and coordinated by the Institute of Botany of the Polish Academy of Sciences has contributed greatly to this fact.
7. The presence of rare and protected species provides higher natural values of the study objects. The biggest number of species, including the rare and protected ones, was found in the Macoszyn mid-forest peat bog. One small specimen of *Menegazzia terebrata* was found here as well as other species under strict species protection (*Usnea hirta*, *Ramalina farinacea*, *Vulpicida pinastri*, *Parmeliopsis ambigua*, *Imshaugia aleurites*, *Hypogymnia farinacea*, *H. tubulosa*, *Melanohalea exasperatula*, *Melanelixia fuliginosa*, *Flavoparmelia caperata*, *Pseudevernia furfuracea*), one partially protected species (*Evernia prunastri*) and the extremely rare *Cladonia incrassata*. Due to its rich lichen biota juxtaposed with the small size of the object, this peat bog will be protected as an ecological ground.

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LICHENS AND LICHENICOLOUS FUNGI OF THE ECOLOGICAL SITE 'WËSKÓW BAGNA' IN THE WDZYDZKI LANDSCAPE PARK (N POLAND)

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Abstract. The lichen biota of the ecological site 'Wësków Bagna' (Wdzydzki Landscape Park, N Poland) was investigated. Altogether 61 lichen and 10 lichenicolous fungi species were found. Three of them are regarded as rare or quite rare in the northern part of Poland: *Biatora turgidula*, *Cladonia monomorpha* and *Roselliniella cladoniae*. Some other taxa are overlooked. They are: *Lecanora filamentosa*, *Fuscidea pusilla*, *Lecidea nylanderi*, *Violella fucata* and the lichenicolous fungi – *Epicladonia sandstedei* and *Tremella lichenicola*. Seven lichen species found in the ecological site are strictly protected in Poland while three other are under partial protection. Moreover, five lichen taxa are included in the red list of lichens in Poland.

Key words: lichen biota, protected species, endangered species, ecological site

INTRODUCTION

According to the Polish nature conservation act the remains of some ecosystems, such as small ponds in a woodland or field area are particularly worth protecting due to their significant role in supporting biodiversity (Protection of Nature Act - Ustawa o ochronie przyrody, Dz. U. 2004, Nr 92, poz. 880). Those places should be protected as ecological sites. They are often characterized by uniquely rich flora and fauna and can also be a refuge of rare and threatened species.

The ecological site 'Wësków Bagna' is an example of the form of nature conservation described above. It was established in January 2003 and is situated in the northern part of Wdzydzki Landscape Park (N Poland). The area covers two small dystrophic ponds together with surrounding peat bogs and an area of pine forest; in some places few deciduous trees also grew around the ponds. In total 54 plant taxa were found in the area of the ecological site 'Wësków Bagna' (see Norek, Schütz 2002). The aim of my studies was to identify the lichen biota in order to complete the information about that object.

MATERIAL AND METHODS

The fieldwork was carried out in September 2002. All the lichen species were noted down from the each type of substrate (tree bark, decaying wood, ground and pieces of bricks and concrete). Some of the taxa, which were hard to identify during the fieldwork (e.g. belonging to the genus *Lepraria* and *Cladonia chlorophaea*-complex), were collected and then identified in the lab, by using traditional methods or thin layer chromatography (according to Orange et al. 2001; Kubiak, Kukwa 2011). All lichenicolous fungi were noted as well. The nomenclature of the lichen species follows mainly Fałtynowicz, Kukwa (2006) and Czyżewska, Kukwa (2009). The exceptions are: *Cladonia floerkeana* and *C. macilenta* (see Diederich et al. 2012), *Lecanora filametosa* (see Pérez-Ortega et al. 2010) and *Violella fucata* (see Spribille et al. 2011).

Taxa are listed in alphabetical order. The lichenicolous fungi were marked with an asterisk (*). Categories of threat in Poland are given according to Cieśliński et al. (2006) as EN –Endangered, VU – Vulnerable and NT – Near Threatened. The abbreviation SP stands for the strictly protected species, whereas PP for the partially protected species (categories of protection according to Ministerial Ordinance - Rozporządzenie Ministra, Dz.U. 2004 Nr 168, poz. 1765).

RESULTS AND DISCUSSION

Altogether 61 lichen species (one of them, *Cladonia arbuscula* with two subspecies) and 10 species of lichenicolous fungi were found in the study area.

List of species

**Athelia arachnoidea* (Berk.) Jülich – on squamules of *Cladonia* sp. (*Quercus robur*), on thallus and apothecia of *Coenogonium pineti* (*Quercus robur*), on *Lepraria* sp. (*Quercus robur*)

Biatora turgidula (Fr.) Nyl. – VU; on bark of *Pinus sylvestris*

Cetraria aculeata (Schreb.) Ach. – PP; on ground

C. sepincola (Ehrh.) Ach. – EN; SP; on small twig of *Populus tremula*

Cladonia arbuscula subsp. *mitis* (Sandst.) Ruoss – PP; on ground, on wood

Cladonia arbuscula (Wallr.) Flot. emend Ruoss subsp. *squarrosa* (Wallr.) Ruoss – PP; on ground, on wood

C. cenotea (Ach.) Schaer. – on bark of *Pinus sylvestris*, on ground

C. cervicornis (Ach.) Flot. – on ground

C. chlorophaea (Flörke ex Sommerf.) Spreng. – on bark of *Quercus robur*

C. coccifera (L.) Willd. – on ground

C. coniocraea (Flörke) Spreng. (syn. *C. ochrochlora* Flörke) – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on wood, on fallen branch of *Pinus sylvestris*

C. cornuta (L.) Hoffm. – on bark of *Betula* sp., *Pinus sylvestris*, on ground

C. crispata (Ach.) Flot. – on ground

C. deformis (L.) Hoffm. – on ground, on wood
C. digitata (L.) Hoffm. – on bark of *Betula* sp., *Pinus sylvestris*, on wood, on fallen branch of *Pinus sylvestris*
C. fimbriata (L.) Fr. – on bark of *Betula* sp., *Pinus sylvestris*, *Quercus robur*, on fallen branch of *Pinus sylvestris*
C. floerkeana (Fr.) Flörke – on bark of *Betula* sp.
C. furcata (Huds.) Schrad. – on ground
C. glauca Flörke – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, on ground, on wood, on fallen branch of *Pinus sylvestris*
C. gracilis (L.) Willd. – on ground, on wood
C. grayi G.Merr. ex Sandst. – on bark of *Betula* sp., on ground, on wood
C. macilenta Hoffm. – on bark of *Betula* sp., on wood, on fallen branch of *Pinus sylvestris*
C. merochlorophaea Asahina – on bark of *Betula* sp., *Pinus sylvestris*, on ground, on wood, on fallen branch of *Pinus sylvestris*
C. monomorpha Aptroot, Sipman & van Herk – on ground
C. novochlorophaea (Sipman) Brodo & Ahti - on ground, on wood
C. phyllophora Hoffm. – on ground
C. pleurota (Flörke) Schaer. – on ground
C. rangiferina (L.) Weber ex F.H.Wigg. – PP; on ground
C. uncialis (L.) Weber ex F.H.Wigg. – on ground
**Clypeococcum hypocenomycis* D.Hawksw. – on *Hypocenomyce scalaris* (*Pinus sylvestris*, *Juniperus communis*, wood)
Coenogonium pineti (Ach.) Lücking & Lumbsch – on bark of *Populus tremula*, *Quercus robur*
**Epicladonia sandstedei* (Zopf) D.Hawksw. – on *Cladonia novochlorophaea* (on ground)
Fuscidea pusilla Tønsberg – on bark of *Populus tremula*
Hypocenomyce scalaris (Ach.) M.Choisy – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, on wood
Hypogymnia physodes (L.) Nyl. – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on *Ledum palustre*, on wood
H. tubulosa (Schaer.) Hav. – NT; SP; on bark of *Juniperus communis*, *Pinus sylvestris*, *Quercus robur*
Lecanora carpinea (L.) Vainio – on bark of *Pinus sylvestris*
L. conizaeoides Nyl. ex Cromb. – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on *Ledum palustre*, on wood
L. filametosa (Stirt.) Elix & Palice (syn. *L. ramulicola* (H.Magn) Printzen & P.May) – on bark of *Betula* sp.
L. pulicaris (Pers.) Ach. – on bark of *Populus tremula*
L. symmicta (Ach.) Ach. – on twig of *Betula* sp., on bark of *Juniperus communis*
Lecidea nylanderi (Anzi) Th.Fr. – on bark of *Betula* sp., *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on wood
Lepraria elobata Tønsberg – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*
L. incana (L.) Ach. – on bark of *Juniperus communis*, *Quercus robur*, on wood, on fallen branch of *Pinus sylvestris*
L. jackii Tønsberg – on bark of *Betula* sp., *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on wood, on fallen branch of *Pinus sylvestris*

L. rigidula (de Lesd.) Tønsberg – on bark of *Populus tremula*, *Quercus robur*
**Lichenoconium erodens* M.S.Christ. & D.Hawksw. – on *Cladonia gracilis* (ground), on *Lecanora conizaeoides* (*Pinus sylvestris*)
**L. lecanorae* (Jaap) D.Hawksw. – on *Lecanora conizaeoides* (*Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Ledum palustre*), on *Lecanora pulicaris* (*Populus tremula*)
**L. pyxidatae* (Oudem.) Petr. & Syd. – on *Cladonia cornuta* (*Pinus sylvestris*)
Micarea denigrata (Fr.) Hedl. – on bark of *Pinus sylvestris*
M. nitschkeana (J.Lahm ex Rabenh.) Harm. – on bark of *Betula* sp., *Juniperus communis*
M. prasina Fr. s.l. – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on wood
Ochrolechia microstictoides Räsänen – on bark of *Quercus robur*
Parmelia sulcata Taylor – on bark of *Populus tremula*, *Quercus robur*
Parmeliopsis ambigua (Wulfen) Nyl. – SP; on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on wood
Pertusaria amara (Ach.) Nyl. – on bark of *Quercus robur*
Physcia tenella (Scop.) DC. – on bark of *Populus tremula*
Placynthiella dasaea (Stirt.) Tønsberg – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, on ground and plant remains, on wood, on fallen branch of *Pinus sylvestris*
P. icmalea (Ach.) Coppins & P.James – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, on ground and plant remains, on wood, on fallen branch of *Pinus sylvestris*
Platismatia glauca (L.) W.L.Culb. & C.F.Culb. – SP; on bark of *Betula* sp., *Pinus sylvestris*, *Populus tremula*, *Quercus robur*, on wood
Pseudevernia furfuracea (L.) Zopf – SP; on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, on wood
**Roselliniella cladoniae* (Anzi) Matzer & Hafellner – on *Cladonia novochlorophaea* (ground)
Scoliciosporum chlorococcum (Graeve ex Stenh.) Vězda – on bark of *Populus tremula*
**Stigmidium* sp. – on *Cladonia fimbriata* (*Betula* sp.)
**Taeniolella beschiana* Diederich – on *Cladonia merochlorophaea* (*Betula* sp.)
Trapeliopsis flexuosa (Fr.) Coppins & P.James – on bark of *Betula* sp., *Juniperus communis*, *Pinus sylvestris*, on wood
T. granulosa (Hoffm.) Lumbsch – on bark of *Betula* sp., on fallen branch of *Pinus sylvestris*
**Tremella lichenicola* Diederich – on *Violella fucata* (*Juniperus communis*)
Usnea hirta (L.) Weber ex F.H.Wigg. – VU; SP; on bark of *Pinus sylvestris*
Verrucaria sp. – on concrete and bricks
Violella fucata (Stirt.) T.Sprib. (syn. *Mycoblastus fucatus* (Stirt.) Zahlbr.) – on bark of *Juniperus communis*, *Pinus sylvestris*, *Populus tremula*, on wood
Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J.Lai – NT; SP; on bark of *Betula* sp.

Epiphytic lichens were definitely the most frequent and variable ecological group; 47 lichen taxa growing on the bark of trees were noted in the studied area. Two common taxa, *Hypogymnia physodes* and *Lecanora conizaeoides* were also found on *Ledum palustre*. On the other hand, there were 22 lichen species growing on the ground. Most of them belong to the genus *Cladonia*. The only substrata available for epilitic lichens were fragments of bricks and concrete debris. There was one of *Verrucaria* species found on them, but the specimen was too small to identify.

Some of the species growing in the area of the ecological site may be regarded as rare, quite rare or rarely distinguished, especially in the northern part of Poland. *Biatora turgidula* is very rare in Western Pomerania, where it was known only from 5 localities (2 of them were dated before 1945) (see Fałtynowicz 1992; Fałtynowicz, Kukwa 2006). The species is slightly more frequent in north-east Poland; Cieśliński (2003) reported it from about 20 localities.

The next species, *Cladonia monomorpha* is not very common in Poland, perhaps due to lack of a sufficient number of suitable habitats (see Kowalewska, Kukwa 2004; Kowalewska et al. 2008). The specimen from 'Wësków Bagna' was published by Kowalewska, Kukwa (2004) as one of the first localities found in the northern part of the country. At present the taxon is known from about 80 localities in Poland, but only a few of them are situated in the north-west part of the country (see Kowalewska, Kukwa 2004; Kowalewska et al. 2008).

The other species, *Lecanora filamentosa* was treated as a synonym of *L. symmicta* or *L. cadubriae* (see Czarnota et al. 2010 and literature cited therein), but recently it was accepted as a separate species (Printzen, May 2002). The taxon is most probably not rare in Poland and possibly may appear to be more common than *L. symmicta* (see Czarnota et al. 2010; Kowalewska unpubl. data).

Three lichen species, *Fuscidea pusilla*, *Lecidea nylanderi* and *Violella fucata*, have only been recently distinguished in Poland. The first records of *Fuscidea pusilla* and *Violella fucata* from Northern Poland were published in 2000 (Fałtynowicz, Kukwa 2000; Kowalewska et al. 2000; Kukwa 2000). After that they appeared in some other papers (see e.g. Jando, Kukwa 2003; Kubiak 2005; Kukwa et al. 2008; Szymczyk, Kukwa 2008). Both the species could be overlooked during fieldwork due to their inconspicuous thalli (Śliwa, Tønsberg 1995; see also Kowalewska et al. 2000). According to Fałtynowicz (2003), *Lecidea nylanderi* is probably common in Poland, but not always distinguished. It can be also mistaken with other sterile crustose lichen taxa, e.g. belonging to the genus *Lepraria* Ach. (see e.g. Jando, Kukwa 2003). As the recent data has shown (e.g. Kowalewska et al. 2000; Kukwa 2005; Kubiak 2008; Kukwa et al. 2008; Kubiak et al. 2010), the species can indeed be rather common, but still worth mentioning.

Three lichenicolous fungi may be considered as worth mentioning as well; these are *Roselliniella cladoniae*, *Epicladonia sandstedei* and *Tremella lichenicola*. The first one seems to be rare in Poland. It was found as new to Poland only recently in few localities, including 'Wësków Bagna' (Kukwa, Kowalewska 2007). The species is also known from e.g. on Wiślana Sandbar, Bory Tucholskie Forest, Białowieża National Park and in Świętokrzyskie Mts (see Kukwa, Kowalewska 2007; Kukwa 2010; Kukwa et al. 2010). *Epicladonia sandstedei* was formerly regarded as rare in Poland, but at present it is supposed to be more frequent (see e.g. Kukwa 2004; Czyżewska et al. 2005; Kukwa, Czarnota 2006; Kukwa, Kowalewska 2007; Kukwa, Jabłońska 2008; Czyżewska, Kukwa 2009;

Kukwa, Flakus 2009; Kukwa et al. 2010). The majority of the known domestic localities *E. sandstedei* are situated in the north of Poland. The localities of *Tremella lichenicola* were published only in a few papers (Czyżewska, Kukwa 2009; Kukwa, Flakus 2009; Kukwa et al. 2010) but it seems to be more common in the areas with abundant occurrence of its host, *Violella fucata*.

Five taxa recorded in 'Wësków Bagna' are included in the red list of lichens in Poland (Cieśliński et al. 2006). *Cetraria sepincola* is listed as an endangered species (EN). Two, *Biatora turgidula* and *Usnea hirta*, are treated as vulnerable (VU), whereas two other, *Hypogymnia tubulosa* and *Vulpicida pinastri* are considered as near threatened (NT). Four of those taxa, except *B. turgidula*, are strictly protected in the country (see Rozporządzenie Ministra, Dz.U. 2004 Nr 168, poz. 1765). Additionally, there are three other species strictly protected by law: *Parmeliopsis ambigua*, *Platismatia glauca* and *Pseudevernia furfuracea*. Moreover, three terricolous lichens, *Cetraria aculeata*, *Cladonia arbuscula* and *C. rangiferina*, are under the partial protection. It is worth mentioning that the thalli of all lichens, including those rare and protected, were generally in a good condition and without any signs of damage in the ecological site. The lichen biota of that locality is scheduled to be re-studied in the future to trace changes in time; it is also planned to complete the data concerning the frequency of the lichen species found in the studied area.

In conclusion, the lichen biota of the ecological site 'Wësków Bagna' appeared to be quite diverse despite of its small area. The results of my research confirm the usefulness of establishing new ecological sites. Although that form of nature protection is of rather low priority, it definitely maintains the biodiversity and can also play an important role in the conservation of rare and threatened species.

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THE LICHENS OF "MIERKOWSKIE SUCHE BORY" NATURE RESERVE

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Abstract. The work contains a list of 80 species of lichens present in the reserve of "Mierkowskie Suche Bory". Epigeic lichens constitute more than half of them. The rarest of them include *Pycnothelia papillaria* and *Stereocaulon paschale*. The nature reserve is a precious facility for conducting studies on the natural dynamic tendencies of lichens in the succession processes occurring on inland dunes and in the formation of plant communities on extremely poor grounds.

Key words: lichenized fungi, nature reserve, protection, threat, forest, psammophilous grasslands, West Poland.

INTRODUCTION

The middle part of Western Poland, particularly the borderland of Lower Silesia, Łużyce and Greater Poland, is one of the areas, which are relatively poorly explored when it comes to lichens. The German lichenologists that explored the areas of the Lower Silesia (including Stein 1879; Eitner 1896) focused their attention primarily on the Sudety Mountains and Pogórze Sudeckie Foothills. In turn, in the works dedicated to Brandenburg, one can only find sporadic information on a few species of lichens found on the borderland of Lower Silesia and Dolne Łużyce (Lower Lusatia), i.e. over the mouth of the River Nysa Łużycka into the Oder. Hillmann (1936) as well as Hillmann and Grummann (1957) reported the following species of lichens, which - in their opinion - are of interest and which are present in the localities near the nature reserve of "Mierkowskie Suche Bory", from the areas of the Brody: *Cladonia cariosa* and *C. incrassata*. Currently, the presence of these lichens has not been confirmed. Tobolewski (1988) on the basis of the data obtained from K. Czyżewska provided information on the localities of *Pycnothelia papillaria*: between Świbniki and Nowa Ruda (approx. 9 km from the reserve) and from the neighbourhood of Żagań (approx. 25 km from the reserve). Both localities are situated in the mesoregion of the Żary Heights. From the localities, which are a few/a, few dozen kilometres away from the borders of the nature reserve, Czyżewska (1992) reported a dozen species of lichens growing in *Spergulo-Corynephoretum.*

The information on the lichens of the nature reserve of "Mierkowskie Suche Bory" presented in the work was gathered during the field studies and explorations conducted in the nature reserve in the years 2006-2011. Their fragmentary results were presented in the folder on the nature of the reserve (Lipnicki et al. 2006) as well as in the monograph dedicated to the nature of the "Bory Lubuskie" Forest Promotional Complex (Lipnicki 2007). The lichenobiotic composition of the reserve encompasses 80 species. They include both the protected and the threatened species, whose existence is well preserved by the protection status of the facility.

STUDY AREA

The "Mierkowskie Suche Bory" nature reserve (formerly referred to as „Mierkowskie Wydmy" nature reserve), with an area of 141.60 ha, was established in 2006. (Dz. Urz. *[Official Gazette]* of the Lubuskie Province No. 31 Item 649). It is situated in the territory of the Lubsko municipal commune in the Żary Poviat, in the forest complex under the administration of the Forest Inspectorate of Lubsko (Fig. 1). The entire area of the Forest Inspectorate constitutes the Bory Lubuskie Forest Promotional Complex. It is the southern section of the Wzniesienia Gubińskie Heights, which border - in the south - on the western section of the pradolina barucko-głogowska proto-valley (Kondracki 2002; Olejnik 2007).

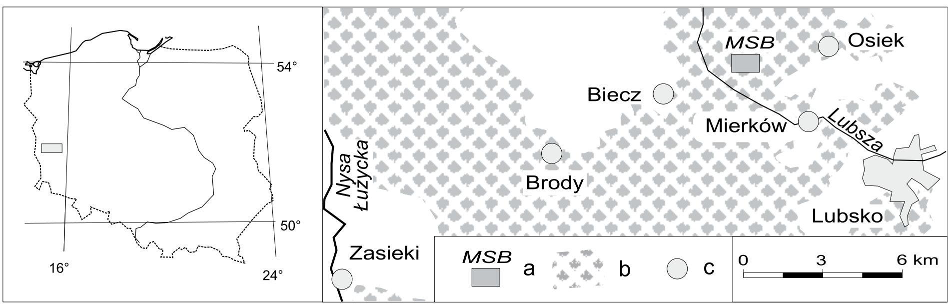

Fig. 1. The location of the "Mierkowskie Suche Bory" nature reserve (MSB): a – reserve; b – forests; c- towns and cities

The territory of the nature reserve along with the neighbouring "Bagna przy Rabym Kamieniu" ecological site is located within the borders of the special area of the Nature 2000 habitat protection under the name of Mierkowskie Wydmy Dunes – PLH080039, with a total area of 609.8 ha. Most areas of the nature reserve are covered by the naturally precious habitats mentioned in Appendix No. 1 to the Habitats Directive Nature 2000 (DZ. U. *[Official Gazette*] L 206 from 22.7.1992). Those are inland dunes with Corynephorus grasses of *Spergulo-Corynephoretum* marked with the code 2330 and the pine cup-lichen forest *Cladonio-Pinetum* – code 91T0.

The nature reserve encompasses one of the best-preserved compact complexes of inland dunes in Western Poland. The highest elevation is Białogóra with the height of 86.5 m a.s.l. At the same time, it functions as a vantage point. The remaining dune strips usually reach the height of 70-75 m a.s.l. The small valleys descend below 65 m a.s.l. (Fig. 2). The dunes were formed in the postglacial period as an effect of the blowout of large quantities of sand left over by the ice sheet. The sand was often blown away from the adjacent areas, where deflation hollow formed as a result of these processes. This depressions filled with water and subsequently became overgrown (Olejnik 2007). What remains of them are the peat bogs, e.g. The Bogs by Raby Kamień (outside of the nature reserve) or the forest communities associated with *Molinio-Pinetum*. About 90% of the nature reserve territory is occupied by forests; the remaining area is covered by the exposed parts of the dunes and forest paths.

In many top parts of the dune strips, the grasses of *Spergulo -Corynephoretum* have developed. They also fill the gaps in the wood stand of *Cladonio-Pinetum*

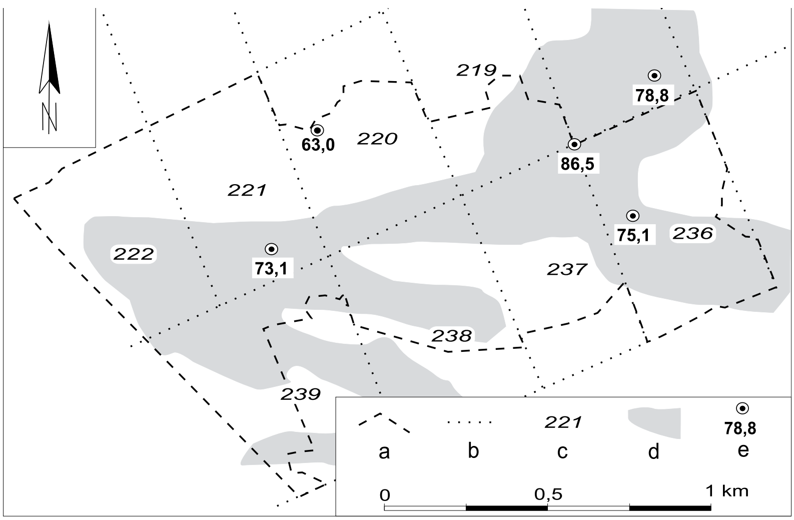

Fig. 2. Map of the reserve: a – reserve borders; b – district lines; c – numbers of forest districts; d – main dune strips; e – elevation points

in the sloped parts of the dunes. The grasslands are clearly varied: from initial forms with tiny share of vascular plants and bryophytes as well as with the presence of pioneer species of ground lichens through to the form, which is abundant in lichens and vascular plants typical of the community. The majority of patches are only settled by the xerophilous grass *Corynephorus canescens*, but its share is insignificant. In the top parts of the dune strips, particularly in the region of Białogóra, the patches of *Spergulo-Corynephoretum* are enriched by the biogroups of the dwarf *Pinus sylvestris* with twisted boughs and small height (from a few to a dozen metres).

Both on the tops and on the sloped parts of the dunes, particularly in their upper and steep parts, a dry cup-lichen forest has developed (*Cladonio-Pinetum* in the typical variant and – in smaller areas – in the fertile variant. On the dunes covered by psammophilous grasslands it occurs in the form of a typical variant with the dominance of lichens in the ground cover as well as small share of *Corynephorus canescens* **and** *Calluna vulgaris*. *Pinus sylvestris* occurs both in the trees and in the undergrowth; single seedlings are also found in the ground cover layer. The majority of the area is populated by self-sown pine. Moss layer develops in places with a slightly more fertile soil, particularly in flatter parts of the nature reserve – i.e. in parts, which are less exposed to the rapid flow of water from the slopes. The cover of bryophyte exceeds 60%, and the community is of the fertile variant with a small share of *Calluna vulgaris*, *Hieracium pilosella* as well as *Vaccinium myrtillus* and *V. vitis-idaea*. In the western part, particularly in some parts of the forest section no. 221, C*ladonio-Pinetum* takes the character of a heather variant – with a considerable share of *Calluna vulgaris* and mosses as well as with a small share of *Vaccinium* spp. and lichens. There is a small proportion of undergrowth in the wood stand. The wild pines are very characteristic at the height of 2-3 m. *Betula pendula* is more frequent than in other sections of the reserve.

Vast areas, particularly in the western part of the nature reserve, are covered by *Leucobryo-Pinetum* in two variants" dry and typical.

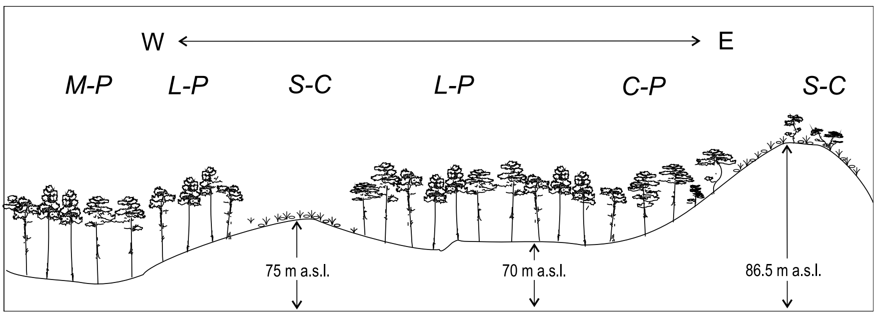

Fig. 3. Natural toposequence of plant communities in the Mierkowskie Suche Bory nature reserve: *S-C – Spergulo-Corynephoretum; C-P – Cladonio-Pinetum; L-P – Leucobryo-Pinetum*; *M-P – Molinio-Pinetum*

Fragmentarily also other communities develop, including degenerated patches of forests. Only in the lowest and slightly soggy (at least periodically) areas can one find small patches, which are physiognomically related to *Molinio-Pinetum* (Fig. 3).

MATERIAL AND METHODS

The first studies of the lichens of the nature reserve, which consisted in the compilation of taxa lists, were conducted in the year 2006 (Lipnicki 2007) and then in the year 2011, within the framework of inventorying the protected lichens' localities within the area of influence of the "Gubin" brown coal mine that was being planned (contract with Leaf Project Studio Reda Piotr) additionally, in the years 2007-2010 – during systematic observations in the indicated areas. The lichens that settle all the potential ground were explored, with particular attention given to the ground lichens as the dominant habitat group. The nomenclature was verified in accordance with Diederich et al. (2012); the names of certain taxa were based on Index Fungorum (http://www.indexfungorum).

RESULTS

80 species of lichens were found in the territory of the reserve. It is very likely that another 7 shall also be present, which occur in the vicinity (towards the north and north-east) of the "Mierkowskie Suche Bory"; the information gathered on their presence in the territory of the nature reserve was verified with a negative result.

The most numerous group is formed by the epigeic lichens – 42 species. Moreover, 22 species of epiphytic lichens and 16 of epilithic lichens were found, among which only 4 settle on the silicate ground.

22 species belong to the group of rare ones, i.e. protected and threatened in Poland. In the vast majority, they are lichens that occur commonly or often both in the area of the nature reserve and in other section of the Bory Lubuskie Forest, as well as in the remaining part of Poland. Attention should be given to some lichens, such as *Pycnothelia papillaria, Cetraria muricata, Stereocaulon tomentosum* and S. *paschale as well as the epiphytic lichen Vulpicida pinastri.* These species definitely contribute to the enhancement of the natural value of the reserve. The presence of *Cetraria muricata* is additionally precious because this atlantic-sub-atlantic psammophilous species is typical of the sub-atlantic Corynephorus grasslands and the locality in the nature reserve is situated in the eastern part of the geographical scope. *Cladonia portentosa* is of the same geographical value.

Ground lichens. In the territory of the reserve, there are 42 species of lichens that mainly grow on soil. The overwhelming majority of them belong to the common taxa. The list of the above-mentioned interesting species is complemented by *Cladonia pocillum.*

In the poorest sections of *Spergulo-Corynephoretum* (on the tops and on the slopes of dunes washed by precipitation water) the presence of *Stereocaulon condensatum* is characteristic, which forms small, elevated clusters with the diameter and height of a few centimetres and which binds the surface layers of sand. Such a function is also performed by other lichens, including *Cladonia foliacea*. As opposed to the analogous communities in other parts of Poland, particularly in the Bory Tucholskie Forest and in the Puszcza Notecka Forest (Lipnicki – own observations), the share of *Trapeliopsis granulosa* and the species from the *Placynthiella* genus is not large in these processes.

Cladonia mitis dominates in all of the grass patches (yet with a variable quantitative share). This community also includes *Cetraria aculeata*, *Cladonia macilenta*, *C. arbuscula*, *C. gracilis* and others, including (in small amounts) such species as *Cladonia pocillum*, *Stereocaulon tomentosum*, *Cetraria muricata* and *Pycnothelia papillaria*.

Cladonio-Pinetum is the dominant forest community in the territory of the reserve. Most of the lichen species "travel" from the patches that are adjacent to the *Spergulo-Corynephoretum* community. In comparison to the grasses, the share of *Cladonia mitis* is lower, while the share of "forest" species is higher – with *Cladonia gracilis*, *C. arbuscula, C. furcata* and others. In the areas with slightly more fertile soil, tufts of cup lichens from the section of *Cladina* – *Cladonia arbuscula*, *C. portentosa* and – yet with a decisively smaller share – *C. rangiferina* stand out from the bryophytes. Among the clusters of the lichens mentioned, there are also other cup lichens, most frequently being *Cladonia gracilis*. The most interesting lichens feature *Stereocaulon paschale.* Only in one point, i.e. beside the path from Białogóra towards the west, were a few specimens of *Cetraria islandica* found.

The share of ground lichens in *Leucobryo-Pinetum* is negligible and limited to the scattered clusters of *Cladonia arbuscula*, *C. furcata* and *C. gracilis* as well as single specimens of *C. fimbriata* and *C. pyxidata*.

Lichens of other localities. Due to low species diversity of the trees (dominance of *Pinus sylvestris* and few specimens of *Betula pendula* and – in the vicinity of the defunct railway tracks – *Quercus petraea*) the biota of epiphytic lichens is poor – with 26 species, including 22 being typical epiphytes. The bark of the trees, especially in the ground parts of the trunks, is also settled by ground lichens. The common, widely distributed taxa are in the majority. The most interesting ones include *Vulpicida pinastri* – one thallus was found only on the trunk of *Pinus sylvestris*. On several trunks of *Betula pendula* there are: *Platismatia glauca*, *Parmeliopsis ambigua*, *Tuckermannopsis chlorophylla* and *Imshaugia aleurites.*

On the dead wood, except for the epixylic *Cladonia cenotea*, there are epiphytic and – rarely – epiphytic lichens.

The accessible base for the epilithic lichens includes: pebbles, triangulation pillars and section posts. On the ground containing calcium carbonate there are 12 species of lichens. All of them belong to the common ones and typical of the artificial calcium ground. On the silicate ground there are 4 species of lichens. These include: *Buellia aethalea, Lecanora polytropa, Porpidia crustulata and Scoliciosporum umbrinum.*

Protected and threatened lichens. The status of the nature reserve guarantees the stability of conditions for the development of the protected and threatened lichens that occur in its areas. Among the 21 protected species, there are 13 which are under strict protection: *Hypogymnia tubulosa*, *Imshaugia aleurites*, *Parmeliopsis ambigua*, *Peltigera rufescens*, *Platismatia glauca*, *Pseudevernia furfuracea*, *Pycnothelia papillaria*, *Stereocaulon condensatum*, *S. paschale*, *S. tomentosum*, *Tuckermannopsis chlorophylla*, *Usnea hirta*, *Vulpicida pinastri* and eight – under partial protection: *Cetraria aculeata*, *C. islandica*, *C. muricata*, *Cladonia arbuscula*, *C. ciliata* var. *tenuis*, *C. mitis*, *C. portentosa*, *Evernia prunastri*. *Usnea hirta* is under strict zone protection.

Among the threatened species (Cieśliński et al. 2006) the nature reserve has representatives of the following ones, which belong to the categories of:

- CR (Critically Endangered) – *Stereocaulon paschale*,
- EN (Endangered) – *Pycnothelia papillaria* and *Stereocaulon tomentosum*,
- VU (Vulnerable) – *Cetraria aculeata, C. islandica*, *Stereocaulon condensatum* and *Tuckermannopsis chlorophylla*,
- NT (Near Threatened) – *Cetraria muricata*, *Evernia prunastri*, *Hypogymnia tubulosa* and *Vulpicida pinastri*.

The threatened species that occur in the territory of the reserve are simultaneously under legal protection.

LIST OF THE LICHEN SPECIES

The evaluation of the frequency of the specific lichen species presented in the list below is only an estimation; the nature reserve covers a small area and therefore separate points-localities were not isolated. Some lichens, particularly epilithic lichens and - to some extent - the epixylic lichens and epiphytic lichens, find very few grounds, which are suitable for them in the area of the nature reserve. Hence, within the entire facility, their frequency is determined as "rare" or "very rare".

The following abbreviations were used in the descriptions: *Bp – Betula pendula, Ps – Pinus sylvestris, Qp – Quercus petraea.*

Plant community: *C-P – Cladonio-Pinetum, S-C – Spregulo-Corynephoretum, L-P – Leucobryo-Pinetum, M-P – Molinio-Pinetum.* Protection status: §§ – strict protection, § – partial protection §§Z – strict zonal protection. The category of the threat: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened.

Amandinea punctata (Hoffm.) Coppins & Scheid. – on the bark of trees; in places frequent.

Aspicilia calcarea (L.) Körb. – on the concrete section post; very rare.

Baeomyces rufus (Hudson) Rebent. – on the sandy soil – on *C-P* and on the forest paths; rare.

Buellia aethalea (Ach.) Th. Fr. – on the silicate triangulation pillar; in the vicinity of a former railway line (forest section no. 239); very rare.

Caloplaca citrina (Hoffm.) Th. Fr. – on the concrete debris and on the posts; rare.

C. decipiens (Arnold) Blomb. & Forssell – on the concrete debris and on the section posts; rare.

C. holocarpa (Hoffm.) A.E. Wade – on the concrete section posts; very rare.

Caloplaca saxicola (Hoffm.) Nordin – on the concrete section posts; very rare.
Cetraria aculeata (Schreber) Fr. – on the sandy soil in *S-C* as well as in *C-P*; common; §.
C. islandica – on the soil in the area of Białogóra; very rare; VU, §.
C. muricata (Ach.) Eckfeldt – on the sandy soil in the most exposed and elevated parts of the dune strips; very rare. NT, **§.**
Cladonia arbuscula (Wallr.) Flotow – on the soil in *S-C*, *C-P* and *L-P*; common; §.
C. cenotea (Ach.) Schaerer – on rotting pine trunks; very rare.
C. chlorophaea (Flörke ex Sommerf.) Sprengel – on the fertile soil by forest paths; rare.
C. ciliata var. tenuis (Flörke) Ahti – on the soil in *C-P;* rare; §.
C. coccifera (L.) Willd. – on the soil in *S-C* as well as in *C-P*, on pine trunks; often, locally numerous.
*C. coniocraea (*Flörke) Sprengel – on the soil, on the bark of *Bp* and on the wood; often.
C. cornuta (L.) Hoffm. – on the soil, primarily in exposed areas; often.
C. deformis (L.) Hoffm. – on the soil; frequent.
C. digitata (L.) Hoffm. – on the soil, on the wood and at the base of the trunks of *Ps* and *Bp*; rare.
C. fimbriata (L.) Fr. – on the soil, on the bark of *Bp* and on the wood; often.
C. floerkeana (Fr.) Flörke – on the soil, particularly in exposed areas; common.
C. foliacea (Hudson) Willd. – on the sandy soil in *S-C* and in *C-P*; often.
C. furcata (Hudson) Schrader – on the soil in *S-C* and in *C-P*; often, but never numerous.
C. glauca Flörke – on the soil and on the wood; often.
C. gracilis (L.) Willd. – on the soil; common.
C. macilenta Hoffm. – on the soil, on the wood and on the tree bark; often.
C. merochlorophaea Asahina – on the soil in *S-C;* very rare.
C. mitis Sandst. – on the soil; common, particularly in *S-C*; §.
C. phyllophora Hoffm. – on the soil, primarily in *C-P*; often.
C. pleurota (Flörke) Schaer. – on the soil, primarily in pine greenwoods; often.
C. pocillum (Ach.) Grognot – on the soil in *S-C*; rare.
C. portentosa (Dufour) Coem. – on the soil in *C-P*; rare; §.
C. pyxidata (L.) Hoffm. – on the soil; common.
C. rangiferina (L.) F.H. Wigg. – on the soil in *S-C* (rarely) and in *C-P* (frequently).
C. rangiformis Hoffm. – on the sandy soil by the forest path and in *C-P*; rare.
C. squamosa Hoffm. – on the soil in *C-P*; frequent.
C. subulata (L.) F.H. Wigg. – on the soil in *C-P* and *S-C*; common.
C. uncialis (L.) F.H. Wigg. – on the soil in *C-P* and *S-C*; common.
C. verticillata (Hoffm.) Schaer. – on the soil in *S-C* and *C-P*; frequent.
Evernia prunastri (L.) Ach. – on the bark of *Bp* and *Qp*; rare; NT, §.
Hypocenomyce scalaris (Ach.) M. Choisy – on the bark of *Ps*; common.
Hypogymnia physodes (L.) Nyl. – on the bark of trees and on the wood; common.
H. tubulosa (Schaerer) Hav. – on the bark of *Bp*; very rare; NT, §§.
Imshaugia aleurites (Ach.) S.L.F. Meyer – on the bark of *Bp*; very rare; §§.
Lecanora albescens (Hoffm.) Flörke – on concrete; very rare.
L. conizaeoides Crombie – on the bark of *Bp* and *Ps*; frequent.
L. dispersa (Pers.) Sommerf. – on concrete; very rare.
L. expallens Ach. – on the bark of *Bp*; very rare.
L. polytropa (Hoffm.) Rabenh. – on the silicate pillar and on small stones; rare.
L. varia (Hoffm.) Ach. – on the wood; very rare.

Lepraria incana (L.) Ach. s.l. – on the bark of trees; common.
Micarea nitschkeana (Rabenh.) Harm. – on snags of *Ps*; very rare.
Parmelia sulcata Taylor – on the bark of *Bp*; rare.
Parmeliopsis ambigua (Wulfen) Nyl. – on the bark of *Bp*; very rare; §§.
Peltigera rufescens (Weiss) Humb. – on the soil on the forest path; very rare; §§.
Phaeophyscia nigricans (Flörke) Moberg – on concrete; very rare.
P. orbicularis (Necker) Moberg – on concrete; very rare.
Phlyctis argena (Spreng.) Flot. – on the bark of *Qp*; very rare.
Physcia adscendens (Fr.) H. Olivier – on concrete; very rare.
P. tenella (Scop.) DC. – on the bark *Qp*, at the base of the trunk; very rare.
Placynthiella icmalea (Ach.) Coppins & P. James – on the soil on the side of forest paths; rare.
P. uliginosa (Schrader) Coppins & P. James – on the soil on the side of the forest paths; rare.
Platismatia glauca (L.) W.L. Culb. & C.F. Culb. – on the bark of *Bp*; very rare; §§.
Porpidia crustulata (Ach.) Hertel & Knoph – on small pebbles in *S-C*; rare.
Pseudevernia furfuracea (L.) Zopf – on the bark of *Bp*; very rare; §§.
*Pycnothelia papillaria (*Ehrh.) L.M. Dufour – on the soil on the shoulder of the roads and in the cup-lichen forest; rare; EN, §§.
Scoliciosporum chlorococcum (Stenh.) Vězda – on the wood and on the bark of *Ps*; rare.
S. umbrinum (Ach.) Arnold – on the silicate triangulation pillar; very rare.
Stereocaulon condensatum Hoffm. – on the soil in *S-C*; common; VU, §§.
S. paschale (L.) Hoffm. – on the soil in *C-P*; very rare; CR, §§.
S. tomentosum Fr. – on the soil in *S-C*; very rare; EN, §§.
Trapeliopsis flexuosa (Fr.) Coppins & P. James – on the soil on the shoulder of the road; rare.
T. granulosa (Hoffm.) Lumbsch – on the soil in *S-C* and on the shoulder of the road; rare.
Tuckermannopsis chlorophylla (Willd.) Hale – on the bark of *Bp* in *L-P*; very rare; VU, §§.
Usnea hirta (L.) F.H. Wigg. – on the snags of *Ps* in young wood stands; very rare; VU, §§Z.
Verrucaria nigrescens Pers. – on concrete; very rare.
Vulpicida pinastri (Scop.) J.-E. Mattson & M. J. Lai – on the bark of *Bp*; very rare; NT, §§.
Xanthoria candelaria (L.) Th. Fr. – on the bark of *Bp*; very rare.
X. parietina (L.) Beltr. – on the bark of *Bp* and on concrete; very rare.

In the vicinity of the reserve of “Mierkowskie Suche Bory” (approx. 300 m) there are several additional localities (besides those found in the area of the reserve) of 7 threatened and protected lichen species. Furthermore, according to the information obtained from the foresters and local nature observers, these lichens were also found in the area of the nature reserve. However, attempts to find them in the field were in vain, hence their presence was not confirmed. However, it must be assumed that it is highly likely that these lichens may occur within the borders of the “Mierkowskie Suche Bory”. These include: *Bryoria crispa* (Motyka) Bystrek – EN, *B. subcana* (Nyl. ex Stizenb.) Brodo & D. Hawksw. – CR, B. *vrangiana* (Gyelnik) Brodo & D. Hawksw. – CR, *Peltigera canina* (L.) Willd. – VU, *Usnea filipendula* Stirton – VU, *Usnea hirtella* (Arnold) Mot. – CR and *Usnea subfloridana* Stirton – EN.

CONCLUSIONS

The "Mierkowskie Suche Bory" nature reserve is also a very valuable facility in terms of the phytosociological and lichenological aspects. It makes it possible to observe the share of epigeic lichens in the constitution of the plant communities that develop on very poor soils – *Spergulo-Corynephoretum and Cladonio-Pinetum.* The reserve makes it possible to observe the pioneer role of lichens in the consolidation of the surface layer of the extremely poor soil and in the formation of initial communities of lichens in *Spergulo-Corynephoretum and Cladonio-Pinetum.*

As a result of the studies and observations conducted in the years 2006-2011, 80 species of lichens were found. Fragmentary results were presented in the publications by Lipnicki et al. (2006) and Lipnicki (2007).

The dominant habitat group, with 42 species, is the epigeic lichens. Among them, the common and widely distributed taxa prevail. The status of the nature reserve, in which the management and other works are limited, is conducive to the maintenance of the localities of *Pycnothelia papillaria.* It is one of the most interesting ground lichens in the nature reserve, rare in Poland and placed under strict protection and incorporated into the Red List of lichens with the EN threat category (Cieśliński et al. 2006). What is also precious is the presence of rare, at least in Western Poland, *Stereocaulon tomentosum* and S. *paschale* – both species are under strict protection and belong to the threatened species.

Vulpicida pinastri is the most precious of all the 26 species of epiphytic lichens. The presence of some other precious taxa from the genera of *Usnea and Bryoria,* which currently occur in the neighbourhood of the nature reserve, may not be excluded.

21 species are legally protected: 8 species are under partial protection and 13 – under strict protection, while 1 of them – additionally under zone protection. From among the lichens placed on the Red List, there are 11 species in the reserve: 1 – CR, 2 – EN, 4 – VU and 4 – NT.

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CLADONIO-PINETUM FORESTS NEAR KODEŃ – THEIR NATURAL VALUES AND NEED FOR PROTECTION

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Abstract. The study provides a description of the lichen biota in a *Cladonio-Pinetum* forest located near Kodeń on the River Bug. The good conservation status of the habitat as well as the large number of rare, threatened or protected species justify the attempts to establish legal protection of the study area.

Key words: *Cladonio-Pinetum*, lichenized fungi, threat, protection, Polesie, E Poland

INTRODUCTION

Cladonio-Pinetum forests are present on almost the entire territory of Poland. According to Matuszkiewicz (2001), they cover an area of ca. 500 km^2, which constitutes 9% of all pine forests. The main area of the occurrence of this association is western and central Poland. They are the most abundant in some forest complexes, e.g. Bory Tucholskie, and in the Notecka, Kozienicka, Solska, Zielona and Kurpiowska primeval forests (Tobolewski 1963; Sokołowski 1980; Lipnicki 2003; Matuszkiewicz 2001). The inland *Cladonio-Pinetum* forest exhibits regional variability related to increasing continentalization of the climate. Therefore, two varieties of the *Cladonio-Pinetum* association can be distinguished – suboceanic and subcontinental. According to the classification of forest habitats, *Cladonio-Pinetum* forests belong to the type of dry pine forest. In accordance with the Forestry Habitat Management Guidelines (2004), two types of forest are distinguished for this ecotype: the inland dry pine forest and the subcontinental dry pine forest.

Cladonio-Pinetum forests are formed in the poorest and driest forest habitats. The tree stand of *Cladonio-Pinetum* is dominated by the Scots pine *Pinus sylvestris*, which exhibits relatively low density, does not reach high bonitation grades, and has low technical quality. The characteristic feature is a well-developed lichen-bryophyte layer dominated by lichens from the genus *Cladonia* and bryophytes from the genera *Dicranum* and *Pleurozium* (Matuszkiewicz 2001). The role of terrestrial lichens is of great importance for detailed diagnostics of vascular plant communities (Cieśliński 1979; Fałtynowicz 1986). They exert a significant impact on the forest microclimate by accumulation of large amounts of water in their thalli. Terrestrial lichens may store ca. 6 000 dm^3 of liquid water per one hectare of the pine forest (Lipnicki 2003). Epiphytic lichens retain significant amounts of water as well. Its gradual release provides balanced humidity in the forest, which has a huge effect on the function of the entire ecosystem.

Cladonio-Pinetum forests are most commonly regarded as a stage of succession leading to development of fresh pine forests or as a degraded form of poor variants of such pine forests. Conserved patches of inland *Cladonio-Pinetum* forests that appeared through natural succession are one of the habitats protected by the Habitats Directive of the Natura 2000 network under the symbol 91T0 (Danielewicz, Pawlaczyk 2004).

Cladonio-Pinetum forests can be found in the Lublin region as well; in the past, they were described by Fijałkowski (1993). A description of the *Cladonio-Pinetum* association in the Józefów Forestry Inspectorate was presented by Sokołowski (1970). This association within the Poleski National Park was briefly mentioned in the papers of Izdebski and Fijałkowski (2002) and Fijałkowski (2007). The *Cladonio-Pinetum* association was reported from the "Lasy Janowskie" Landscape Park by Fijałkowski (1997), and from the Sobiborski Landscape Park – by Wawer and Urban (1999). Urban and Wójciak (2002) reported the *Cladonio-Pinetum* forests from the Bug River valley. According to Fijałkowski (1993), the *Cladonio-Pinetum* association mainly occurs in the south-western and northern parts of the Lublin region, where it covers sandy hills, less frequently plain areas, and is associated with podzolic soils formed on loose sands. The *Cladonio-Pinetum* forests in the Lublin region are often found in fragmentary form and they usually display a mosaic-like arrangement among fresh pine forests. According to Fijałkowski (1993), this association is characterized by a relatively low crown density (up to 70%). It is dominated by *Pinus sylvestris* with an admixture of *Betula pendula* and *Quercus robur*. The herbaceous layer exhibits low density and is composed of *Corynephorus canescens*, *Vaccinium myrtillus*, *V. vitis-idaea*, *Melampyrum pratense*, *Calluna vulgaris* and *Hieracium pilosella*. The lichen-bryophyte layer is characterized by a large proportion of lichens and bryophytes.

Data on lichens growing in *Cladonio-Pinetum* forests in the Lublin region are scattered in reports concerning various forest complexes or various regions, e.g. the Łęczyńsko-Włodawskie Lakeland, or Roztocze (Bystrek, Górzyńska 1977, 1981).

The *Cladonio-Pinetum* forest is represented in the Natura 2000 network of the Lublin region to a limited extent. It has been demonstrated only in three refuges (established and prospective): the Puszcza Solska Range - PLH060034, Lasy Janowskie Range – PLH060031 and Roztocze Wschodnie Range – PLH060093.

According to the inventory data obtained in 2007, *Cladonio-Pinetum* forests cover as little as 139,19 ha, which constitutes only 0.033% of all the national forest area in the Lublin region. These data appear to be significantly underestimated.

They indicate that either the characteristic species of lichens are weakly recognized or the association is intentionally ignored due to the small areas they usually cover.

The problem of identification is probably related to the assumption that lichens in the *Cladonio-Pinetum* forest form dense, clearly visible, cushion-like turfs. In fact, most of the indicator species, particularly *Cladonia furcata*, *C. glauca,* and *C. gracilis*, are inconspicuous, even if they grow massively.

The biggest area of *Cladonio-Pinetum* forests, i.e. 111.18 ha, was found in the Sobibór Forest Inspectorate yet; they are not included in the list of habitats of the Lasy Sobiborskie Refuge. Private forests in the Lublin region, which occupy over 214 000 ha, are even more poorly recognized in this respect.

Based on long-term field observations and analyses of soil distribution maps, it can be concluded that *Cladonio-Pinetum* forests occur in both the north (near Kodeń, Sosnowica, Lasy Parczewskie) and the south of the region (Lasy Janowskie and Puszcza Solska).

Since lichens and *Cladonio-Pinetum* forests play an important role in the forest ecosystem, particularly as a water resource, detailed investigations of these communities and monitoring of best-developed complexes is advisable. Such monitoring has already been initiated within the Natura 2000 network (Węgrzyn, Masłowska 2010).

Well-developed and conserved *Cladonio-Pinetum* forests are found near Kodeń. They are situated between the refuges Dolina Środkowego Bugu – PLH060003 and Poleska Dolina Bugu – PLH060032.

In recent years, detailed investigations of lichens growing in the valley have been carried out by Matwiejuk (2008, 2011). The data about lichen species reported from the Kodeń area presented in this paper will extend the knowledge of the lichens from the Bug River valley.

MATERIAL AND METHODS

In 2011, investigations of plant communities were carried out in the northern part of the forest complex situated south of the village of Kodeń (Fig.1). The analysis involved an area of ca. 200 ha. In terms of administration, the object is located in the Kodeń Municipality, Bialsk County, and Lublin Voivodeship. According to the physico-geographical division proposed by Kondracki (2002), it is situated on the Kodeń Plain, a mezoregion of Polesie. According to the geobotanical division of Szafer (1977), it is located in the Baltic Sea Division, Subdivision of the *Great Valleys Belt, and Polesie Lubelskie Province. In the* ATPOL *grid* square system (Zając 1979), the area is situated in square GD-54.

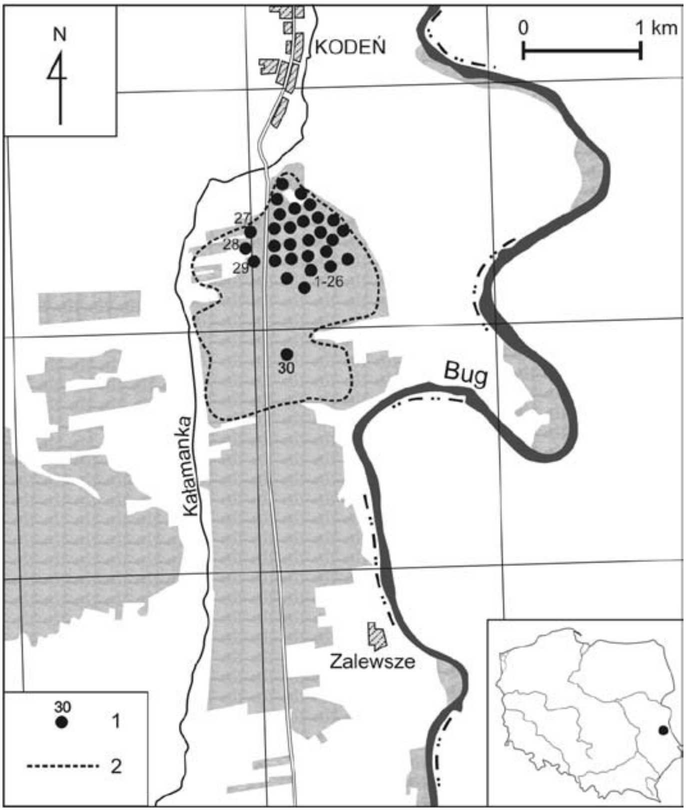

Fig. 1. Location of the study area: 1 – localities of the phytosociological relevés, 2 – boundary of the area to be protected

The forest complex studied is located on a meadow terrace (142.6-145.8 m a.s.l.) rising from 4.0 to 6.5 m above the Bug River. Its western side is dissected by the valleys of the Rivers Czapelka and Kałamanka (tributaries of the River Bug). In the east, it borders two inundation terraces: the lower rises up to 2.5 m high and the higher reaches up to 4.0 m over the average level of water in the Bug river-bed (Szwajgier et al. 2002). The terrain of the *Cladonio-Pinetum* forest is generally flat. However, low elevations and depressions are found here (remnants of sand mining pits), particularly in its western part. Podzolic soil formed from loose sands constitutes the soil cover.

In 2011, 30 phytosociological relevés of 100 m^2 patches were made using the method of Braun-Blanquet (1951). The geographical coordinates of the centre of each patch were measured using the GPS and marked on the map. The phytosociological classification and nomenclature of plant communities were based on the study of Matuszkiewicz (2005); the nomenclature of vascular plants followed Mirek et al. (2002), the bryophyte names were provided in accordance with Ochyra et al. (2003), and lichen names - with Diederich et al. (2011) and

Bystrek (1986). During the study, great richness of terrestrial and arboreal lichen species was found. Preliminary lichenological studies were also conducted in the southern part of the forest complex, in which there were numerous patches of well-developed *Cladonio-Pinetum* forests.

The primary aim of this study was to present the condition of the lichen biota in the forest complex located near the village of Kodeń, taking into account the habitat conditions, and to suggest methods of conservation. During the field study, special attention was paid to the localities of rare and legally protected species.

STUDY RESULTS

The study demonstrated that *Vaccinio-Piceetea* forest communities were predominant in the study area. They are classified as the *Cladonio-Pinetum* association. A much smaller area (mainly along roadsides and within clearings) is covered by sand calcareous grasslands represented by the association *Spergulo morisonii-Corynephoretum canescentis*. In similar localities, there are patches of synusial lichen communities (mostly synusiae of cladonia and cetraria). The 40-60% dense tree-stand in the *Cladonio-Pinetum* forest studied is mainly composed of *Pinus sylvestris* (usually 20-30 years old) characterized by low increment and the lowest bonitation grades. The admixture is composed of sparsely growing *Betula pendula* and *Pinus banksiana* occurring even more sparsely. The poor shrub layer comprises *Juniperus communis* and *Quercus robur*, as well *Pinus sylvestris*, *Pinus banksiana* and *Betula pendula* saplings. The 5-30% dense herbaceous layer is mainly composed of *Corynephorus canescens*, *Festuca ovina*, *Rumex acetosella*, and *Agrostis capillaris* as well as *Thymus serpyllum*, *Helichrysum arenarium*, *Solidago virgaaurea*, *Hieracium pilosella* and *Koeleria glauca*. Only a few patches are overgrown by *Lycopodium clavatum* and *Calamagrostis epigejos.* The lichen and bryophyte layer exhibits a density of 80-100%, and 20-50% in some patches.

Characteristics of the lichen biota

The forest complex studied is characterized by a rich and diverse lichen biota. 64 taxa were found in the area; 38 grew on soil, 32 on tree and shrub bark, and 13 on wood. In several cases, subspecies and varieties are provided in the list.

The high values of the lichen biota are evidenced by the presence of 15 strictly protected species and 8 species that are under partial protection (Regulation of the Ministry of Environment 2004) as well as 15 species from the red list (Cieśliński et al. 2006). Special emphasis should be placed on the presence of the *Bryoria motykana* species, regarded as extinct, which grow on several birch trees in the study area.

List of the lichens

The alphabetical list below presents lichens found in the object. It includes the number and position of the localities where the lichens occur as well as their abundance, protection status and threat category. The substratum type is specified for species that do not grow on soil. Symbols: §§ - species under strict protection, § - species under partial protection, RE – regionally extinct species, EN – endangered species, VU – vulnerable, NT – near threatened.

Bryoria fuscescens (Gyeln.) Brodo & Hawksw. – growing sparsely on birch bark – 3 localities (22, 24, 30); §§, VU;

Bryoria motykana Bystr. – growing sparsely on birch bark – 3 localities (22, 23, 30); §§, RE;

Cetraria aculeata (Schreb.) Fr. – occasionally abundant in localities with a low tree density – 7 localities (4, 6, 16, 19, 25, 26, 28); §;

Cetraria ericetorum Opiz – occasionally very abundant in some localities with a low tree density – 18 localities (2, 4-9, 12-16, 19, 21, 23, 24, 28, 30); §, NT;

Cetraria islandica (L.) Ach. – abundant, 6 localities (10, 15, 16, 19, 21, 23); §, VU;

Cetraria islandica var. *sorediata* (Schaer.) Ach. – a very rare species in the Lublin region; in the study object, it grows together with the typical variety and various cladonia species – 3 localities (10, 16, 17); §, VU;

Cladonia mitis Sandst. – very abundant, 26 localities (1,2, 4-16, 18, 19, 22-30); in half of the localities, it covers the area of 60-90% of the patches investigated; §;

Cladonia arbuscula (Wallr.) Flot. ssp. *squarrosa* (Wallr.) Ruoss – very abundant, 7 localities (6, 8, 12, 15, 23, 25, 28); §;

Cladonia cariosa (Ach.) Spreng. – a few podecia, 1 locality (29);

Cladonia chlorophaea (Sommerf.) Spreng. – growing sparsely on soil and wood, 3 localities (1, 21, 24);

Cladonia coniocraea (Flörke) Spreng., non cons. – abundant, on soil and wood, 16 localities (2-9, 12, 18, 19, 21, 23, 25, 27, 30);

Cladonia cornuta (L.) Hoffm. – growing, 3 localities (2, 19, 28);

Cladonia crispata (Ach.) Flot. – abundant, 12 localities (6, 12, 16, 17, 20, 24-30);

Cladonia deformis (L.) Hoffm. – growing, 14 localities (1, 2, 4, 5, 8, 11-13, 18, 19, 26, 28-30);

Cladonia digitata (L.) Hoffm. – growing sparsely on wood and at the base of old birch trunks, 4 localities (19, 28-30);

Cladonia fimbriata (L.) Fr. – abundant on soil, wood, and at the base of birch trunks, 16 localities (7-9, 11, 12, 16-18, 21-26, 28, 30);

Cladonia floerkeana Flörke – growing sparsely on soil, at the base of birch trunks, and on wood, 11 localities (5-8, 14-16, 19, 28-30);

Cladonia furcata (Huds.) Schrad. – occasionally abundant, 13 localities (3, 4, 8, 10, 11, 13, 15, 16, 18, 21-23, 30);

Cladonia furcata subsp. *subrangiformis* (Sandst.) Abbayes – growing, 2 localities (16, 19);

Cladonia glauca Flörke – geowing, 24 localities (1-4, 7-16, 19, 20, 24-30);

Cladonia gracilis (L.) Willd. – occasionally abundant, 19 localities (1, 4, 5, 8-11, 13-16, 18, 19, 21, 23, 26, 28-30);

Cladonia macilenta Hoffm. – growing, 1 locality (17);

Cladonia ochrochlora Flörke – growing, 1 locality (29);

Cladonia phyllophora Hoffm. – abundant, in all the localities;

Cladonia pleurota (Flörke) Schaer. – a few podecia, 1 locality (19);

Cladonia portentosa (Dufour.) Coem. – growing, 6 localities (12, 18, 21, 23, 24, 29); §;

Cladonia pyxidata (L.) Hoffm. – growing, 2 localities (3, 18);

Cladonia pyxidata subsp. *pocillum* (Ach.) Schaer. – a few podecia, 1 locality (2);

Cladonia rangiferina (L.) F.H. Wigg. – growing, 1 locality (3);
Cladonia rei Schaer. – growing, 1 locality (16);
Cladonia scabriuscula (Delise) Nyl. – abundant, 3 localities (7, 18, 23);
Cladonia squamosa Hoffm. – growing, 2 localities (3, 27);
Cladonia subulata (L.) Weber in F.H. Wigg. – occasionally abundant, in all the localities;
Cladonia sulphurina (Michx.) Fr. – a few podecia, 1 locality (9); NT;
Cladonia uncialis (L.) F.H. Wigg. – occasionally very abundant, 11 localities (4-6, 8, 10-12, 15, 18, 26, 28-30);
Cladonia vericillata (Hoffm.) Schaer. – growing, 9 localities (1, 7, 11, 18, 19, 21, 24, 28, 29);
Evernia prunastri (L.) Ach. – growing sparsely on birch bark and wood, 7 localities (1, 10, 21, 23, 28-30); §, NT;
Hypocenomyce scalaris (Ach.) M. Choisy – abundant, on pine and birch bark and wood, in all the localities;
Hypogymnia physodes (L.) Nyl. – abundant, on pine and birch bark and wood, in all the localities;
Hypogymnia tubulosa (Schaer.) Hav. – growing sparsely on birch bark – 2 localities (23, 24); §§, NT;
Imshaugia aleurites (Ach.) S.L.F. Meyer – growing sparsely on pine bark, 2 localities (28, 30); §§;
Lecanora albellula Nyl. – growing sparsely on *Betula pendula* bark, 2 localities (10, 29);
Lecanora conizaeoides Cromb. – growing sparcely on pine bark, in all the localities;
Lecanora pulicaris (Pers.) Ach. – growing sparsely on pine bark and *Juniperus communis*, 2 localities (28, 30),
Lecanora symmicta (Ach.) Ach. – growing, on a birch branch, 1 locality (5);
Lepraria incana (L.) Ach. – growing, on wood, 2 localities (3, 17);
Micarea denigrata (Fr.) Hedl. – growing, on wood, 3 localities (27, 29, 30);
Parmelia sulcata Taylor – growing sparsely on birch bark, 4 localities (10, 27, 29, 30);
Parmeliopsis ambigua (Wulfen) Nyl. – growing sparsely on pine bark, 2 localities (7, 28); §§;
Peltigera didactyla (With.) J.R. Laundon – abundant on both sides of the forest road, 2 localities (1, 29); §§;
Placynthiella uliginosa (Schrad.) Coppins & P. James – occasionally abundant, at exposed sites, 18 localities (1, 2, 4, 5, 7, 8, 9, 10, 14, 16, 19, 22, 23, 25, 26, 28-30);
Platismatia glauca (L.) W.L. Culb. & C.F. Culb. – growing sparsely on birch bark, 3 localities (24-26); §§;
Pseudevernia furfuracea (L.) Zopf – occasionally abundant, on pine and birch bark, 6 localities (10, 14, 16, 21, 25, 30); §§;
Ramalina farinacea (L.) Ach. – growing sparsely on birch bark, 5 localities (10, 22, 24, 26, 30); §§, VU;
Scoliciosporum chlorococcum (Stenh.) Vězda – growing sparsely on pine bark, 1 locality (1);
Stereocaulom condensatum Hoffm. – abundant, 1 locality (11); §§, VU;
Trapeliopsis flexuosa (Fr.) Coppins & P. James – growing, on wood, 2 localities (4, 22);
Trapeliopsis granulosa (Hoffm.) Lumbsch – growing, 10 localities (2, 5, 7-9, 16, 19, 21, 26, 28);
Tuckermannopsis chlorophylla (Willd.) Hale – growing, on birch bark and wood, 1 locality (5); §§, VU;

Tuckermannopsis sepincola (Ehrh.) Hale – growing sparsely on birch and pine branches and on wood, 3 localities (1, 7, 29); §§, EN;

Usnea hirta (Ach.) F.H. Wigg. – growing, on birch and pine bark, 7 localities (10, 14, 18, 22, 24, 26, 30); §§, VU;

Usnea subfloridana Stirt. – growing sparsely on birch bark, 3 localities (21, 24, 25); §§, EN;

Vulpicida pinastri (Scop.) J.-E. Mattsson & M. J. Lai – growing sparsely at the base of birch trunks, and on wood, 2 localities (3, 30); §§, NT;

Xanthoria parietina (L.) Th. Fr. – growing, on birch bark and wood, 4 localities (22, 25, 27, 30).

Characteristics of bryophytes

Terrestrial bryophytes are an important element in the *Cladonio-Pinetum* forest. Their percentage share in the lichen-bryophyte layer ranges from 10 to 100%. *Pleurozium schreberii*, *Polytrichum juniperinum*, *Polytrichum piliferum*, *Dicranum scoparium*, *Dicranum undulatum* and *Ceratodon purpureus* mosses are predominant among the 13 species found. *Niphotrichum canescens* grows abundantly in exposed places, particularly along the road. *Pohlia nutans*, *Hypnum cupressiforme*, *Brachytecium albicans* and *Buxbaumia aphylla* can be found less frequently and less abundantly. The presence of the liverwort *Ptilidium ciliare*, a rare species in the Lublin region, is noteworthy. In turn, the inconspicuous *Cephaloziella divaricata* is widespread in the area.

CONCLUSION

The *Cladonio-Pinetum* forest ecosystem is interesting and important for conservation of forest biodiversity in Poland. Their characteristic feature is the abundant lichen-bryophyte layer composed of great numbers of legally protected lichen species, which have a significant impact on the forest microclimate.

Cladonio-Pinetum forests are a highly threatened formation. They tend to disappear all over the country. Most frequently, expansion of flowering plants that replace lichens is observed. The main cause lies in eutrophication of habitats related to deposition of nitrogen compounds from the air and climatic changes. Conserved patches of inland *Cladonio-Pinetum* forest are one of the habitats protected by the Habitat Directive of the Natura 2000 network under the symbol 91T0. In order to prevent direct destruction, use of the best-conserved fragments of this community should be excluded and maintenance measures undertaken. This view gains increasing popularity with foresters, due to low productivity of forests in the driest and poorest habitats e.g. on dunes. Within Bory Tucholskie, "Professor Zygmunt Tobolewski *Cladonio-Pinetum* forest" Reserve has been established to protect a fragment of the forest that is extremely rich in rare lichen species (Lipnicki 2003).

The forest complex near Kodeń is characterized by a rich and diverse biota of lichens. 64 taxa were found in the area; 38 grew on soil, 32 on tree and shrub bark, and 13 on wood. Among the 15 strictly protected species occurring in the area, special emphasis should be placed the presence of the *Bryoria motykana* and *B. fuscecsens* species, which are extremely rare in the Lublin region. Eight of the species reported from the area are under partial protection. Additionally, 15 taxa are included in the red list of extinct and threatened species. The presence of *Bryoria motykana*, a species that is regarded as regionally extinct – RE category, on several birch branches, is noteworthy.

In the bryophyte layer, species that are rare in the Lublin region – partially protected *Ptilidium ciliare* and *Buxbaumia aphylla* can be found.

Protected species of vascular plants found in the study area include *Diphasiastrum complanatum*, *Lycopodium clavatum*, *Neottia nidus-avis*, *Epipactis latifolia*, and *Helichrysum arenarium.*

The material collected will facilitate monitoring the changes in the lichen biota and vegetation cover of the *Cladonio-Pinetum* forest. After five years, the authors are planning to conduct a comparative study of the localities where phytosociological relevés were made. Phytosociological studies will be continued in the current year in the southern part of the forest.

The natural values, particularly the richness of the lichen biota, and the attractive location in the immediate vicinity of the Bug River valley are the primary arguments for legal protection of the *Cladonio-Pinetum* forest complex. In cooperation with the Chotyłów Forestry Inspectorate, the authors are planning to submit an application to the Regional Directorate of Environmental Protection to establish a nature reserve in the study area.

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THE CONSERVATION STATUS OF *CLADONIO-PINETUM* JURASZEK 1927 IN MAZOWIECKI LANDSCAPE PARK AND ADJACENT AREAS (POLAND)

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Abstract. The dry acidophilous Scots pine *Cladonio-Pinetum* forests are a valuable, but declining Natura 2000 habitat, composed of many protected lichen species. In the area of Mazowiecki Landscape Park and adjacent forest complexes the research on the changes of association and the factors influencing it was performed in 2011. The aim was to compare eleven original relevés recorded by Juraszek in 1927 with new inventory compiled on the same spots and 5 additional ones in adjacent areas. In each locality, one forest phytosociological relevé (400 m^2) and 3 micro-samples (0.25 m^2) were made. A total of 27 large samples and 48 micro-samples were studied. Detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) were performed to investigate the trends of changes in lichen diverse forest patches and to assess the factors influencing terrestrial lichen diversity. The decline of *Cladonio-Pinetum* forests was observed influenced mainly characteristic lichens composition. The important factors, which have negative effect on lichen diverse forests are increasing level of anthropogenic NO_x emission, deeper layer of litter, denser cover of trees and decrease of dust and sand particles in the soils, connected to anthropogenic contamination.

Keywords. phytosociology, forest community, lichen community, lichenized fungi, forest ecology

INTRODUCTION

Dry acidophilous Scots pine forests (*Cladonio-Pinetum*) are the most xerophytic type of pine forest, characterized by poverty of vascular plant species. Only the tree and lichen-moss layers are well developed. In addition to pine trees (*Pinus sylvestris* L.), the oak (*Quercus robur* L.) is found, however it does not reach the normal growth and lives almost always only in bush form. The main feature of this association is the abundance of lichens (Juraszek 1927).

Lichens play an important role in the transfer of solar energy into the biosphere and the circulation of matter, especially in the early stages of secondary succession in dry pine forests, increasing the fertility of the habitat (Wilkoń-Michalska et al. 1998). Terrestrial lichens massively colonize the poorest sandy habitats and also degraded forest phytocenoses, affected by human activity, such as grazing and litter racking (Fałtynowicz 1986). The hypothesis of partial naturalness of *Cladonio-Pinetum* association in Central Europe is now considered to be most probable (Danielewicz, Pawlaczyk 2004). *Cladonia* rich pine forests are widespread in Europe (Kelly, Connoly 2000; Solon 2003; Ermakov, Morozova 2011), however in a large part of the continent they became threatened (Celiński et al. 1997; Van Tol et al. 1998; Prieditis 2002; Danielewicz, Pawlaczyk 2004; Szczygielski 2007). Due to that fact, and that *Cladonio-Pinetum* association plays an important role in the conservation of many lichen species, it is regarded as a part of the Natura 2000 network (Kabucis et al. 2000; Kolbek, Chytrý 2010), which needs appropriate and effective methods for their active preservation (Danielewicz, Pawlaczyk 2004).

The *Cladonio-Pinetum* forests of the study area were studied in the 'twenties' of the 20th century by Juraszek (1927). The author did not state the characteristic species of this association, nor did Kobendza (1930). The list of characteristic species for the community from the Warsaw area was given by Zielińska (1967) and later from the territory of Poland by Matuszkiewicz and Matuszkiewicz (1996). Juraszek (1927) indicated that in most cases the lichen-dominated communities were developed in small local patches, and much more common was the form dominated by mosses. The area of the heliophilous form of these associations was described by Juraszek (1927) from the Radość neighbourhood, connected to the severe throughfell management. Now the information of the occurrence of *Cladonio-Pinetum* in the study site is crucially lacking.

The aim of the study is to assess the present conservation status of the oldest recorded patches of *Cladonio-Pinetum* association in the world, localized within the area, where the community was described by Juraszek (1927).

MATERIALS AND METHODS

Field research has been carried out in the area located east from Warsaw boundaries, in the following geographical mesoregions: Kotlina Warszawska basin, Równina Wołomińska plain, Dolina Środkowej Wisły valley and Równina Garwolińska plain (Kondracki 2009).

Fig. 1 designated eleven localities recorded by Juraszek in the 'twenties' of the 20th century (J1-J11), which were obtained from old maps of the Polish Military Institute of Geography (WIG 1924-1937). The Geographical Information System was applied to in order to obtain their coordinates and to reconstitute their locations with a reasonably high accuracy, probably less than 200 m. In these localities 11 new present phytosociological relevés (P1-P11) were taken for comparison. The decision to move one of the spots (Maciołki) by about 400 m to the northwest was taken due to the fact that former locality was destroyed by brickyard buildings. In addition to this, 5 new locations (N12-N16) were surveyed in order to assess the other present patches of *Cladonia* diverse forests in the study

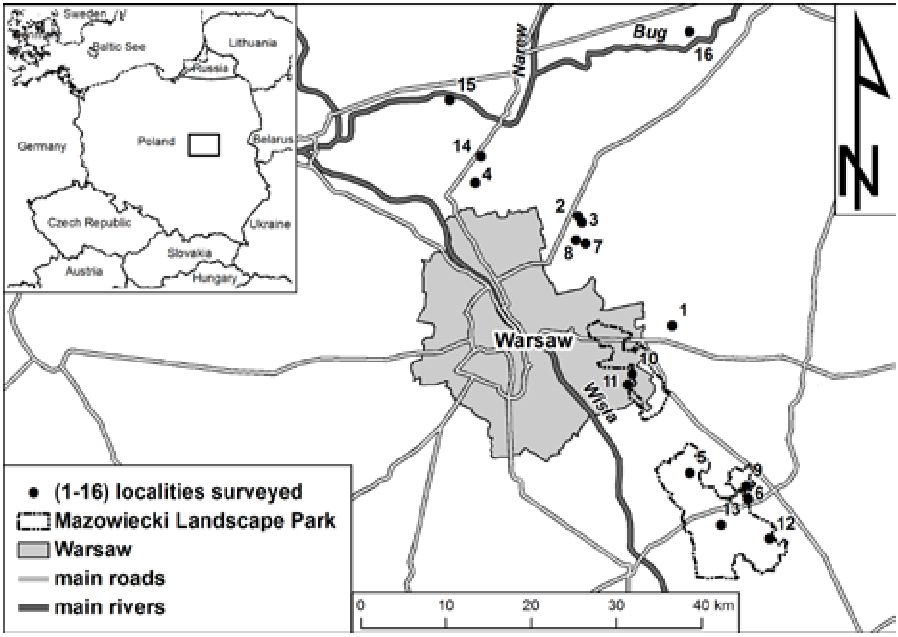

Fig. 1. Positions of surveyed locations (1-11 – old localities of Juraszek and present inventory of them, 12-16 – new localities)

area. All sixteen localities were surveyed from August to September 2011 (Fig. 1). At each of them a 400 m^2 relevé was taken using extended (Barkmann et al. 1964) Braun-Blanquet scale (Braun-Blanquet 1928). As a next step also three 0.25 m^2 micro-samples with fully extended (Barkmann et al. 1964) Braun-Blanquet scale were performed. At the micro-sample level the depths of the first two soil horizons were measured: organic matter and surface soil layers. In addition, from each micro-sample, soils from the depth between 5 and 10 cm were taken for the laboratory analysis. The mass % of gravel, sand and dust were checked according to norm BN-78/9180-11 and pH was measured in laboratory with electronic pH-meter. The NO_x concentrations in each of the studied stands were obtained from WIOŚ database (2011); as such pollution data is sufficient for these types of analyses (Davies et al. 2007; Mayer et al 2009).

Canonical correspondence analysis (CCA) and Detrended correspondence analysis (DCA) analysis were performed in CANOCO 4.5 program package (Ter Braak, Šmilauer 2002). Historical and new datasets were compared with DCA. The forest layers were flattened and the cover percentages were obtained using the average cover values method in the classes' transformation (Maarel 1979) in order to avoid inaccuracy between these two datasets (the transformation of historical data was performed in the following way: 5 – 90%, 4 – 65%, 3 – 35%, 2 – 15%, 1 – 2.5%, + – 0.1%). To depict the relationships between the floristic composition of the relevés and environmental variables, the CCA was used. As the ranges of environmental values are not wide and have a linear structure, no additional transformation of the data was applied. The species data was transferred into coverage values with the average cover values method in the classes transformation (Maarel 1979). The tree coverage data was used as an environmental variable and because of the fact only forest floor species were analysed. The significance of the species - environment relations was checked with Monte Carlo test (499 runs).

The nomenclature of vascular plants follows the Checklist by Marhold & Hindák (1998) and the lichens are as in the Checklist by Bielczyk et al. (2004); however several species and sub-species from problematic groups of the genus *Cladonia* spp. were not distinguished (Hennipman, Sipman 1978; Hammer 1995; Stenroos, Depriest 1998). *Cladonia macilenta* Hoffm. ssp. *macilenta* and *C. macilenta* Hoffm. ssp. *floerkeana* (Fr.) V.Wirth were treated as *Cladonia macilenta* agg. (Christensen 1987) and cup-shape podetia *Cladoniae* of *Cladonia chlorophaea* (Flörke ex Sommerf.) Spreng., *C. merochlorophaea* (Asahina), *C. pyxidata* (L.) Hoffm. were treated as *Cladonia chlorophaea* agg. from *Cladonia chlorophaea* group (Ahti 1966; Ferry, Pickering 1989; Kotelko, Piercey-Normore 2009). Nomenclature of mosses is according to Hill et al. (2006).

RESULTS

The field survey revealed that *Cladonia* diverse pine forests (*Cladonio-Pinetum* and *Peucedano-Pinetum* with domination of lichens) are scattered phytocenoses in the study area now. There are four larger patches identified. Two first are located on 'Dąbrowiecka Góra' and 'Biała Góra' dunes near Celestynów village, in the State Forests area and are managed as Natura 2000 habitat. The next two are located in the old blown-sand fields and sandpit areas near Michałów-Reginów village and in the vicinity of Mostówka village. The Michałów-Reginów site is moderately disturbed from the long time by private throughfall and patches of well-developed *Cladonio-Pinetum* phytocenoses are to be found. The area is however under the pressure of a wide spreading residential development and some patches have already been cleared. The Mostówka stand is located in Natura 2000 site 'Wydmy Lucynowsko-Mostowieckie', where the forests were strongly disturbed by the forest fire in 1993. There are also found many small patches, covering c. 100-1000 m^2, which are located mainly on the sandy forest dirt road edges, escarpments, old small sand pits, traditionally throughfelled wood patches and other disturbed forest fragments. Such spots occur on dunes in southern and northern parts of the study area. Some patches are located on the slope of the plateau (south from Regut) and on its sandy parts (east from Karczew). In the central part of the study area no *Cladonia* diverse patches of pine forests were found despite their presence here in the past (cf. Juraszek 1927). The decline of the terrestrial lichens is clearly visible here, especially in the forest complex located between Marki and Nadma and in the southern part of 'Słupecka Forest' complex. All of the surveyed localities with relevés were located on the sand. An interesting finding is the presence of charcoal in soil samples found at 14 localities. At the remaining two localities, very thin soil layers were measured, which indicates the regeneration process after complete soil layer devastation.

Five lichen species protected in Poland were recorded: *Cetraria aculeata* (Schreb.) Fr., *C. islandica* (L.) Ach., *Cladonia arbuscula* (Wallr.) Flot. em. Ruoss ssp. *squarrosa* (Wallr.) Ruoss, *C. ciliata* Stirt. var. *tenuis* (Flörke) Ahti and *C. rangiferina* (L.) Weber ex F.H.Wigg. The lack of previously recorded lichenized fungus *Cladonia stellaris* (Opiz) Pouzar & Vězda was also recorded. This species is placed on the 'Red List' as endangered (Cieśliński et al. 2006). *Cladonia arbuscula* ssp. *arbuscula* and *C. arbuscula* ssp. *squarrosa* were joined into one *C. arbuscula* as Juraszek (1927) recorded only *Cladonia arbuscula* s.lat.

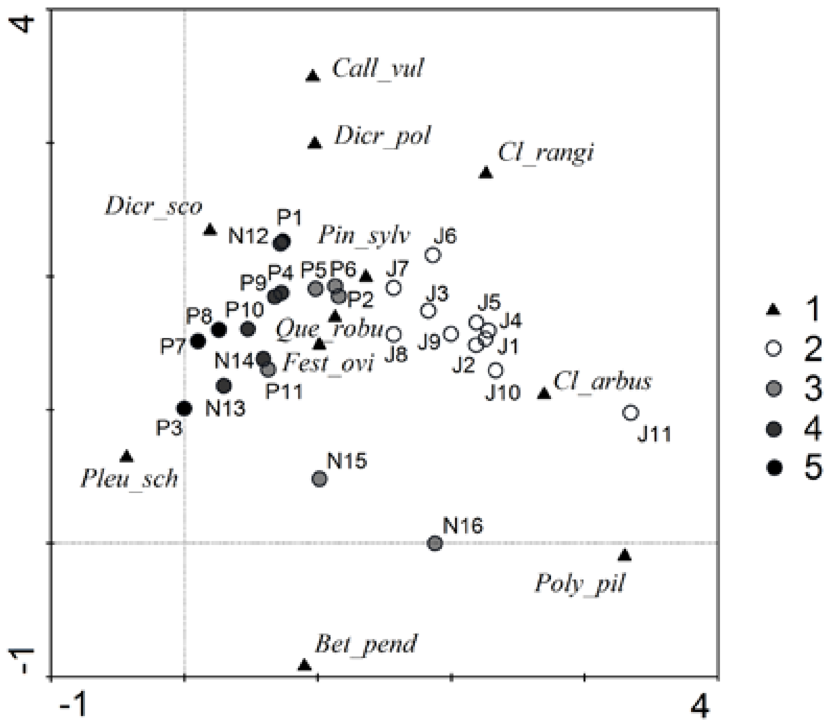

Fig. 2. DCA **ordination diagram** of 27 large relevés referring to dry acidophilous Scots pine forests. Comparisons between historical and inventory relevés are shown

Legend: 1 – species, 2 – historical localities of Juraszek (1927), 3 – present relevés with lichen cover more than 25%, 4 – present relevés with lichen cover between 5 and 25%, 5 – present relevés with lichen cover less than 5 %; J1-J11 – Juraszek (1927) historical localities, P1-P11 – present inventory of old Juraszek localities, N12-N16 – new localities.

The DCA graph (Fig. 2) shows, that the main differences between old and new datasets are the decrease of the cover of *Cladonia arbuscula* ssp. *squarrosa* and *C. rangiferina* and increase of *Pleurozium schreberi* (Brid.) Mitt. and *Dicranum scoparium* Hedw. In general, the horizontal axis on the graph shows the gradient of fertility of habitats and the vertical one shows the swap between forest and partially open conditions on the stands. The smallest change is observed in P6 locality, where *Cladonio-Pinetum* forests are still present in larger areas. The N15 and N16 localities positioned in the lower part of the graph, however show many similarities with old relevés (high *Cladonia arbuscula* ssp. *squarrosa* coverage) of *Cladonio-Pinetum* forests. The main difference is the dominance of birch in the relevés, which was not present in historical data. Two patches are characterized by the very thin litter and surface soil layers. Two of the historical (J10 and J11) are also the most marked in this direction. The patches of forest with the lowest lichen cover are P1, P3, P7 and P8.

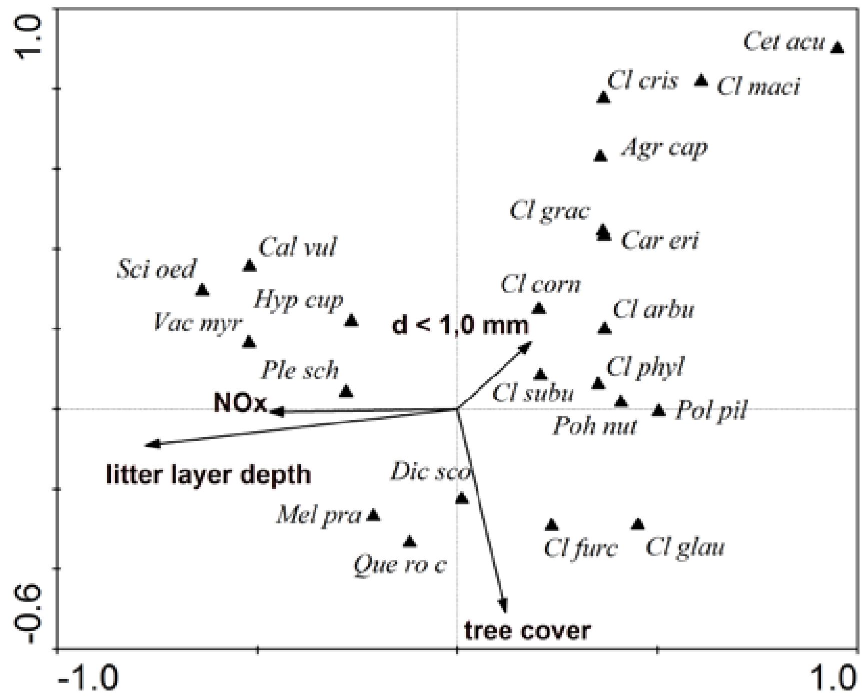

Fig. 3. CCA **ordination diagram** of 48 micro-samples of dry acidophilous Scots pine forests. Relationship between floristic composition and environmental variables is showed

The CCA analyses (Fig. 3) of the present micro-sample data revealed, that there are four environmental values playing important roles in the dynamic of the analysed species: **litter layer depth** (p-value = 0.002), **NO_x** concentration (p-value = 0.014), **tree cover** taken from large releves (p-value = 0.022) and **d < 1.0 mm** the total content of sand and dust in soil (p-value = 0.030). Lichens species, for example *Cladonia arbuscula* ssp. *squarrosa* and *C. gracilis* (L.) Willd. prefer low litter layer depth and low NO_x atmospheric concentrations, they are slightly affected by the forest canopy closure, in fact they prefer more open habitats and habitats with the highest sand and dust contend, avoiding soils with larger particles. The opposite trend is visible for some vascular plant species, like *Vaccinium myrtillus* L., *Melampyrum pretense* L., *Quercus robur* and *Calluna vulgaris* (L.) Hull., as well as mosses, *Pleurozium schreberi* and *Hypnum cupressiforme* Hedw. The micro-sample canopy closure, pH, topsoil depth, litter layer cover and bare soil cover appear not to be statistically relevant factors in this study.

Table 1. Synoptic table with percentage frequency and modified fidelity index phi coefficient (3 columns),
1- historical localities of JURASZEK 1927 (J1-J11), 2-new inventory of old Juraszek stands in present (P1-P11), 3-*Cladonio-Pinetum* stands (P6-P11, N12-N16)

Group No.	1	2	3
No. of relevés	11	11	11
ChAss. *Cladonio-Pinetum* (including ChAss. reg)			
Cladonia arbuscula s.lat.	100 ---	73 ---	100 ---
Cladonia cornuta	. ---	43 ---	82 $^{83.2}$
Cladonia furcata	. ---	73 $^{75.6}$	91 $^{91.3}$
Cladonia gracilis	18 ---	55 ---	91 ^{73}
Cladonia rangiferina	100 --	73 ---	73 ---
Cladonia squamosa var. *squamosa*	. ---	9 ---	27 ---
Cladonia stellaris	18 ---	. ---	. ---
Cladonia ciliata var. tenuis	. ---	. ---	9 ---
ChAss. *Peucedano-Pinetum*			
Convallaria majalis	. ---	18 ---	9 ---
Polygonatum odoratum	9 ---	27 ---	9 ---
Solidago virgaurea	18 ---	18 ---	18 ---
Peucedanum oreoselinum	18 ---	. ---	. ---
ChAss. *Leucobryo-Pinetum*			
Deschampsia flexousa	. ---	9 ---	18 ---
ChO. *Cladonio-Vaccinietalia*			
Dicranum polysetum	45 ---	100 ---	73 ---
ChCl. *Vaccinio-Piceetea*			
Melampyrum pratense	. ---	82 $^{83.2}$	45 ---
Dicranum scoparium	9 ---	100 $^{91.3}$	100 $^{91.3}$
Pleurozium schreberi	36 ---	100 ---	91 ---
Vaccinium myrtillus	. ---	55 ---	18 ---
Vaccinium vitis-idaea	. ---	27 ---	9 ---
ChCl. *Koelerio glaucae-Corynephoretea cansectentis*			
Agrostis vinealis	45 ---	36 ---	36 ---
Festuca ovina s.str.	73 ---	91 ---	64 ---

Rumex acetosella s.lat.	55 ---	45 ---	27 ---
Cephaloziella divaricata	. ---	. ---	27 ---
Ceratodon purpureus	. ---	18 ---	45 ---
Polytrichum piliferum	73 ---	36 ---	45 ---
Cladonia macilenta ssp. *floerkeana*	. ---	18 ---	18 ---
Cladonia macilenta ssp. *macilenta*	. ---	55 ---	91 $^{91.3}$
Cladonia subulata	. ---	45 ---	82 $^{83.2}$
Cladonia cervicornis ssp. *verticillata*	. ---	18 ---	18 ---
Cladonia pleurota	. ---	9 ---	18 ---
Cladonia uncialis	18 ---	55 ---	73 ---
Corynephorus canescens	55 ---	9 ---	27 ---
Jasione montana	18 ---	. ---	. ---
Thymus serpyllum	55 ---	9 ---	. ---
Cetraria aculeata	27 ---	9 ---	18 ---
Cladonia phyllophora	. ---	55 $^{61.2}$	91 $^{91.3}$
Koeleria glauca	27 ---	. ---	. ---
Ch.Cl. *Nardo-Callunetea*			
Pohlia nutans	9 ---	82 $^{73.0}$	55 ---
Carex ericetorum	73 ---	36 ---	36 ---
Hieracium pilosella	36 ---	27 ---	27 ---
Calluna vulgaris	45 ---	64 ---	45 ---
Placynthiella oligotropha	. ---	18 ---	27 ---
Arctostaphylos uva-ursi	55 ---	. ---	. ---

The synoptic table shows comparison between column one (J1-J11) and two (P1-P11), also comparison between columns one (J1-J11) and three, which represent stands with presence of the *Cladonio-Pinetum* (P6-P11, N12-N17). Chosen characteristic species are following the Matuszkiewicz (2008). Uncharacteristic species were removed from the list. Historical relevés made by Juraszek (1927) are by occurrence of characteristic species mainly in the association *Cladonio-Pinetum*. It is obviously, that stands of *Cladonio-Pinetum* in column 3 are a more primary. Many taxa from the association *Koelerio glaucae-Corynephoretea cansectentis* occur there as the relevés were situated mainly on the top of the dunes in open habitats. Column 2 shows taxa mainly devided into association *Cladonio-Pinetum* and class *Vaccinio-Piceetea,* which confirm their degradation.

DISCUSSION

High litter layer depth and higher anthropogenic atmospheric nitrogen concentration appeared as the most relevant factors decreasing many lichen species coverage in the study area (Fig. 3). High litter layer depth is connected to carbon accumulation in the habitat and higher anthropogenic nitrogen concentration is responsible for the additional nitrogen input into it. This explains the fact that the main process observed in the area of study is the succession of previous phytocenoses into more fertile ones and the decline of the amount of patches of this habitat. In general, anthropogenic nitrogen input can be caused by direct forest fertilization (Fałtynowicz 1986; Rodenkirchen 1992), or from atmospheric pollution (Van Tol et al. 1998; Ewald 2004; Ketner-Oostra 2004, 2006). The direct impact of fertilizers on lichens tends to be negative (Vagts et al. 1994; Vagst, Kinder 1999). However some vascular plants and more nitrogen demanding bryophyte species are promoted (Fałtynowicz 1986; Rodenkirchen 1992; Økland 1995; Veer 1997; Vagst, Kinder 1999; Ketner-Oostra 2004), which leads to lichen extinction probably primarily because of the competition processes. Decrease of lichen and increase of grass species are also detected within larger forest complexes (Økland 1995; Szczygielski 2007). Decline of terrestrial lichen diversity can also be observed in the vicinity of bigger European cities and industrial areas with higher atmospheric nitrogen concentrations (Van Tol et al. 1998; Ketner-Oostra 2004). Due to this fact in Central Europe the cities with large epigeic lichen diversity are becoming increasingly rare (Adamska 2010).

The abandonment of traditional management of the habitats, which was single tree cutting, clearcuts, periodic agricultural use, cattle grazing and litter raking is visible in the area of the studies. Such practices were responsible for decrease of amount of litter on the forest floor and in the forest soil (Fałtynowicz 1986; Danielewicz, Pawlaczyk 2004). Moreover it is known, that litter raking is responsible for removing nutrients from the ecosystem (Kreutzer 1979) and for decline the biogenic elements content of forest soils (Dzwonko, Gawroński 2002; Prietzel, Kaiser 2005), which promotes cryptogamic synusia and reduces the abundance of vascular plants (Fałtynowicz 1986). In the study area, the low litter layer depth is significantly promoting lichen species (Fig. 3). In surface soil samples from the majority of the considered patches charcoal pieces were found, which indicates fire disturbance in historical times. Another direct impact can be also trampling and land-use changes (Watson, Brise 1991). Land use change is observed in the study area for example in N14 locality and trampling impact is the highest at localities in the vicinity of P10 and P11 (Fig. 2). The stand without forest management tends to have more open habitats that are characterized with higher lichen cover on N15 and P6 (Fig. 2). This happens probably because of more microhabitat diversity in natural regeneration patches. The higher terrestrial lichen diversity was observed also by Solon (2007) in the old and dry semi-natural pine stands of the Kampinoski National Park, which were entering the disintegration phase.

From the very beginning the heterogeneous origin of these associations was pointed out. Some of the stands were connected to the forests and others to severely deforested areas (Juraszek 1927). Kobendza (1930) believed that this is a relatively short-lived association, emerging as a result of planting pine trees on the clearcuts on sandy dune areas, but Zielińska (1967) indicated, that many of the patches were stable and showed no tendency to evolve into the moss undergrowth forests. This hypothesis was denied by Sokołowski (1980), who expected, that all of the patches in Poland are degraded phytocenoses of *Peucedano-Pinetum*, *Leucobryo-Pinetum* and *Pino-Quercetum* (Table 1). Fałtynowicz (1986) indicated that both options are possible. However due to the significant deterioration of soil as a result of past agricultural use, grazing by cattle and pigs, later preference of pine and litter raking for cattle, the natural and man-made communities were indistinguishable. In our opinion, at the study area, the patches with higher lichen cover, located on the tops of dunes can be deemed to meet the criteria for natural ones, especially if there is no forest management present or they originate from natural regeneration.

CONCLUSIONS

Inventory of *Cladonia* rich pine forest showed the decline of numbers of the patches with high lichen cover and increase of these with mosses and vascular plants. Five lichen species protected in Poland were recorded: *Cetraria aculeata*, *C. islandica*, *Cladonia arbuscula s.lat.*, *C. ciliata* var. *tenuis* and *C. rangiferina*. One of the endangered species, *Cladonia stellaris*, has disappeared. Disturbance is the most important factor and has been playing an important role in the past, as suggested by presence of charcoal in surface soil or very low depth of surface soil layer. Trampling and land use change are negatively affecting *Cladonia* diverse forests in the study area. The relevant factor connected to decrease of lichen cover is higher atmospheric nitrogen concentration. This indicates, that habitat patches located at a greater distance from the cities may be easier to maintain, however more research is needed in this area. Now, because of the influence of anthropogenic nitrogen, it is not possible to state whether the surveyed localities will survive. Due to that fact it is suggested, that all *Cladonia* diverse forest patches should be considered as important for habitat conservation. Low litter layer depth significantly promotes the occurrence of lichens in the study area. This positively corresponds with the present knowledge and litter raking management of *Cladonia* abundant habitats should be considered as potential maintenance method for the conservation, however more research is needed in this area.

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THE PROTECTED AND THREATENED LICHENS ON THE BARK OF *LARIX DECIDUA* IN THE SELECTED LOCALITIES IN THE MIDDLE PART OF WESTERN POLAND

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Abstract: The work presents the results of the observation of large-thallus lichens settlement on the bark of Larix decidua in Western Poland after the year 1990. Most of the species include lichens, which are vulnerable to air pollution. Some of them were reported to no longer exist in this region of Poland a few decades ago. Their recolonization is testimony to the improvement of the aero sanitary conditions. The most precious lichens include the specimens of the genera *Usnea* and *Bryoria*, which occur in masses in some of the localities.

Key words: recolonization, epiphytic lichens, protection species, threat species, *Larix decidua*, West Poland

INTRODUCTION

Changes in the species composition of the lichen biota, particularly in the 2nd half of the 20th century, were primarily manifested by the drastic decrease of the number of localities of a large group of lichens. This problem constituted the leading subject of the scientific research and publications by many lichenologists – see: Hodkinson (2012) and Fałtynowicz (1993, 2012). The fundamental cause of the extinction of lichens was the exacerbation of the aero sanitary conditions. This phenomenon was particularly evident in the urban areas and the regions of industrial centres. The naturalists were definitely more concerned by the extinction of lichens in the forest areas, including those under large-scale forms of nature protection, for instance in national parks and nature reserves. The most noticeable and alarming fact was the dying out of the lichens with fruticose and foliose thalli.

In the 1990's single specimens of protected lichens with fruticose and foliose thalli were observed to appear on the snags of *Larix decidua* in Western Poland (Lipnicki 1994, 2007). These were mainly small specimens of *Usnea filipendula*, *Platismatia glauca* and *Tuckermannopsis chlorophylla*.

In the first decade of the 21st century, the presence of rich-specimen populations of lichens with fruticose and foliose thalli was confirmed on the branches and trunks of 20- to 50-year old *Larix decidua* in numerous localities in the middle part of Western Poland. The localities were situated in the biggest forest complexes. Some of these localities were earlier (in the 1980's and 1990's) examined or at least investigated in terms of lichenology. 20-30 years ago the only lichens with a fruticose thallus were: several specimens of *Evernia prunastri* and *Pseudevernia furfuracea* as well as – in one locality – one specimen of *Usnea filipendula*. The majority of the protected species of lichens, which occur at present was not found in these localities. Some have never been reported to exist in that part of Poland.

The lichenobiotic composition of the *Larix decidua* has so far not been the subject of separate studies. On the bark of the related species of *Larix polonica* Halicz and Cieśliński (1967) confirmed the presence of 84 species of lichens, more than half of which were foliose and fruticose in nature. Czyżewska (1974) mentions 23 species of lichens from the Trębaczew reserve and 10 species of lichens from the Modrzewina reserve that occur on the bark of *Larix polonica*.

THE STUDY AREA AND METHODS

The materials were gathered on the basis of inspections conducted from mid-1990 in some forest complexes of Western Poland: Puszcza Barlinecko-Gorzowska Forest, Puszcza Notecka Forest, Puszcza Rzepińska Forest, Puszcza Drawska Forest, Bory Lubuskie Forest and Bory Krajeńskie Forest. More precise studies were commenced in 2006. In order to seek the cultivation sites of *Larix decidua* with large-thallus epiphytic lichens, the information obtained from the workers of the forest administration and from other naturalists, such as Piotr Kobierski, was used. The inflow of information from the workers of the forest administration intensified after the year 2004, when the Ordinance of the Minister of the Environment from the 9th of July 2004 on the protection of wild fungi species (Dz.U. *[Official Gazette]* 2004 No. 168, Item 1765). On the basis of this reports and following own observations, more than 50 cultivation sites (localities) were inspected, with the area from approx. 0.5 ha to several ha, with *Larix decidua* being the dominant species in the timber stand. 28 localities were put under closer scrutiny (Fig. 1). These localities distinguished themselves by a considerable share of protected lichens, mainly from the genera *Bryoria* and *Usnea*. The analyses of the species composition of epiphytes, including the results of the observations of its changes that commenced a few years ago in the chosen forest areas, enable one to draw preliminary conclusions concerning the directions in the settlement of *Larix decidua* by the protected species of lichens.

The location of the localities according to mesoregions (Kondracki 2002) – the number of the locality in the list corresponds to the number of the locality in Fig. 1.

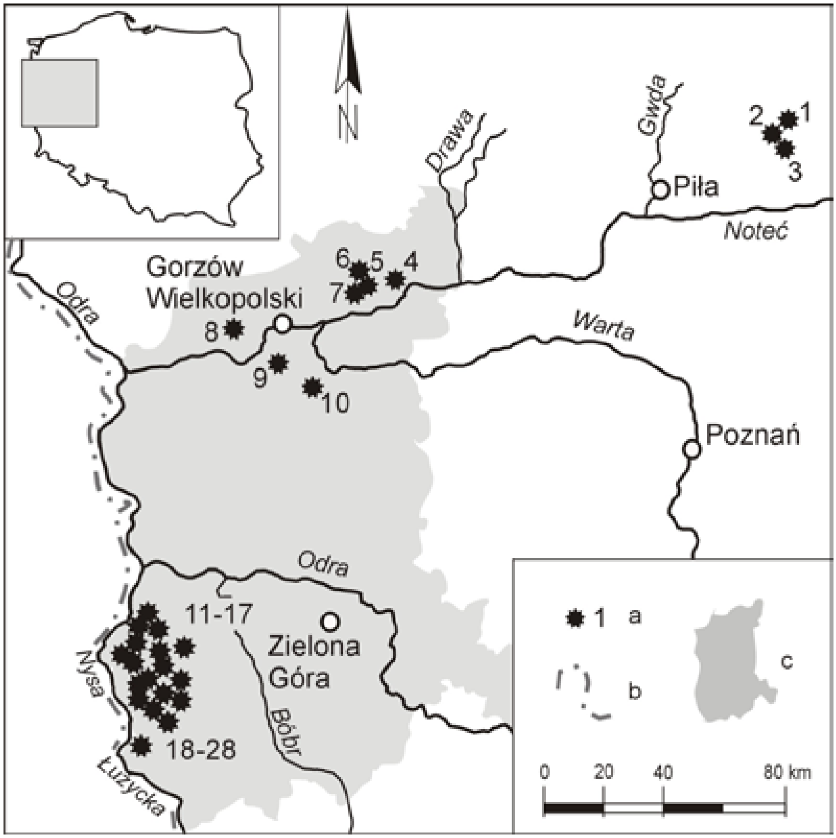

Fig. 1. Location of the localities
a – locality and its number, b – country border, c – delineation of the Lubuskie Province

List of the localities (Fig. 1):

I. The Krajeńskie Lakeland
1. The Forest Inspectorate of Złotów N 53°23´11´´ E 17°12´27´´
2. The Forest Inspectorate of Lutowo N 53°26´6´´ E 17°26´40´´
3. The Forest Inspectorate of Runowo N 53°20´18´´ E 17°24´41´´

II. The Dobiegniewskie Lakeland
4. The Forest Inspectorate of Smolarz N 52°52´56´´ E 15°49´48´´

III. The Gorzowska Plain
5. The Forest Inspectorate of Strzelce Kraj. N 52°54´32´´ E 15°22´38´´
6. The Forest Inspectorate of Strzelce Kraj. N 52°51´21´´ E 15°25´50´´
7. The Forest Inspectorate of Strzelce Kraj. N 52°49´22´´ E 15°23´45´´
8. The Forest Inspectorate of Bogdaniec N 52°42´49´´ E 15°6´19´´

IV. The Gorzowska Valley
9. The Forest Inspectorate of Lubniewice N 52°36´31´´ E 15°14´14´´

V. The Łagowskie Lakeland

10. The Forest Inspectorate of Skwierzyna N 52°35´7˝ E 15°25´54˝

VI. The Gubin Heights

11. The Forest Inspectorate of Lubsko N 51°54´50˝ E 14°44´39˝
12. The Forest Inspectorate of Lubsko N 51°53´42˝ E 14°43´16˝
13. The Forest Inspectorate of Lubsko N 51°52´8˝ E 14°52´13˝
14. The Forest Inspectorate of Lubsko N 51°49´54˝ E 14°53´42˝
15. The Forest Inspectorate of Lubsko N 51°49´54˝ E 14°53´41˝
16. The Forest Inspectorate of Lubsko N 51°49´51˝ E 14°54´37˝
17. The Forest Inspectorate of Lubsko N 51°49´46˝ E 14°54´3˝

VII. The Zasiecka Valley

18. The Forest Inspectorate of Lubsko N 51°48´6˝ E 14°52´12˝
19. The Forest Inspectorate of Lubsko N 51°47´57˝ E 14°49´10˝
20. The Forest Inspectorate of Lubsko N 51°47´08˝ E 14°45´38˝
21. The Forest Inspectorate of Lubsko N 51°45´12˝ E 14°41´53˝
22. The Forest Inspectorate of Lubsko N 51°45´37˝ E 14°41´40˝
23. The Forest Inspectorate of Lubsko N 51°44´42˝ E 14°42'46˝
24. The Forest Inspectorate of Lubsko N 51°44´26˝ E 14°45´15˝
25. The Forest Inspectorate of Lubsko N 51°44´15˝ E 14°42´26˝
26. The Forest Inspectorate of Lubsko N 51°42´27˝ E 14°48´51˝
27. The Forest Inspectorate of Lubsko N 51°41´11˝ E 14°48´32˝
28. The Forest Inspectorate of Lubsko N 51°40´32˝ E 14°45´20˝

Table 1 contains the selected properties of the 15 species of large-thallus epiphytic lichens occurring on the snags and trunks of *Larix decidua.* These lichens were found in at least 3 localities. The following abbreviations and indications have been used:

- in the "Frequency" column: r – rare, o – often, c – common, v – very common;
- in the column "Abundance of positions, where the lichen occurs": f – few, n – numerous, vn – very numerous;
- in the column entitled "Photophilous": sh.w – shaded wedding, l.ph – light photophilous, m.ph – mildly photophilous, s.ph – strongly photophilous, e.ph – extremely photophilous, xer – xerophilous; primarily based on: Wirth (1995) and Fabiszewski, Szczepańska (2010); additionally, for the determination of the photophilous character, the analyses by Lipnicki (1998) were used.
- in the column "Preferred pH of the substrate": * – the degree of the scale on the basis of the non-published observation results by Lipnicki;
- in the column "The Red List Category": CR – Critically Endangered, EN – Endangered, VU - Vulnerable, NT – Near Threatened; based on Cieśliński et al. (2008).

RESULTS

On the snags and trunks of *Larix decidua* 36 lichen species were found. Among them, there are 21 protected species. Those occurring in at least 3 localities have been presented in Table 1.

Tab. 1. The list of most precious lichen species settling primarily on the snags and trunks of *Larix decidua* (found in at least 3 localities)

Species	Frequency	Abundance of positions, where the lichen occurs	Photophilous	Preferred pH of the substrate	Degree of lichenoindication scale	The Red List Category	Strict protection
Bryoria crispa (Motyka) Bystrek	o	f	l.ph → s.ph	4-5	6	EN	+
Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw.	o	n	l.ph → s.ph	4-5	6	VU	+
Bryoria subcana (Stizenb.) Brodo & D. Hawksw.	r	f	l.ph → s.ph	4-5	6*	CR	+
Evernia prunastri (L.) Ach.	v	vn	m.ph → xer	5-6	5	NT	+
Hypogymnia tubulosa (Schaerer) Hav.	c	n/vn	m.ph → ext.ph	5-6	6*	NT	+
Melanelixia fuliginosa (Duby) O. Blanco et al.	o	f	m.ph	5-6	5		+
Parmeliopsis ambigua (Wulfen) Nyl.	c	f/n	sh.w → m.ph	< 4	5		+
Platismatia glauca (L.) W.L. Culb. & C.F. Culb.	v	n/vn	m.ph → ext.ph	4-5	5		+
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	r	f	m.ph → s.ph	5-6	5	EN	+
Pseudevernia furfuracea (L.) Zopf	v	vn	m.ph → ext	< 4	6		+
Tuckermannopsis chlorophylla (Ehrh.) Hale	c	n	m.ph → ext	4-5	6*	VU	+
Usnea filipendula Stirton	v	vn	l.ph → s.ph	4-5	9	VU	+
Usnea hirta (L.) F.H. Wigg.	v	n/vn	l.ph → s.ph	4-5	8	VU	+
Usnea subfloridana Stirton	v	n/vn	l.ph → s.ph	4-5	9	EN	+
Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai	c	f/n	sh.w → m.ph	< 4	5*	NT	+

The remaining protected lichens, found in 1-2 localities:
Bryoria vrangiana (Gyelnik) Brodo & D. Hawksw., *Imshaugia aleurites* (Ach.) S. L. F. Meyer, *Melanohalea exasperatula* (Nyl.) O. Blanco et. al., *Ramalina farinacea* (L.) Ach. *Usnea hirtella* (Arnold) Motyka i *U. fulvoreagens* (Räsänen) Räsänen.

Besides the protected species on the trunks and snags of *Larix decidua* one can also encounter:
- commonly: *Hypogymnia physodes* (L.) Nyl., *Lecanora conizaeoides* Crombie, *Parmelia sulcata* Taylor, *Hypocenomyce scalaris* (Ach.) M. Choisy, *Lepraria incana* (L.) Ach., *Phaeophyscia orbicularis* (Necker) Moberg;
- frequently: *Buellia punctata* (Hoffm.) A. Massal., *Cladonia coniocraea* (Flörke) Sprengel, *Physcia adscendens* (Fr.) H. Olivier, *P. tenella* (Scop.) DC., *Xanthoria candelaria* (L.) Th. Fr., *X. parietina* (L.) Beltr.;
- rarely: *Caloplaca holocarpa* (Ach.) A. E. Wade, *Phlyctis argena* (Spreng.) Flot., *Xanthoria polycarpa* (Hoffm.) Rieber.

The settlement of *Larix decidua* by the lichens with fruticose and foliose thalli begins from the trees growing on the edges of the young forests, small pole woods and high pole woods. They are initiated by *Hypogymnia physodes* and in many cases it is the only large-thallus lichen. The first fruticose lichen to appear is usually *Pseudevernia furfuracea*. Next, it is usually the *Evernia prunastri* and *Usnea hirta* that begin to settle. In the forests with considerable light exposure, for instance in complete monocultures of *Larix decidua* or others, yet with a significant share of larch, in which - as a result of thinning - the access of light to lower parts of trees has been decisively increased, the lichens appear almost simultaneously in the marginal and the internal sections of the wood stands. The settlement by the lichens usually begins from the lower snags, which first become extinct and cease to produce needles. It very often happens that the above-mentioned lichens which have settled before and which are increasing the number of their populations are joined by *Usnea filipendula*, *U. subfloridana*, *Bryoria fuscescens*, *B. crispa, Hypogymnia tubulosa*, *Platismatia glauca* and others (Table 1).

The lichen colonization of the snags of young specimens of *Pinus sylvestris,* which accompany larch trees, occurs (if at all) usually when the populations on the larch trees are already fairly abundant.

In the wood stands, where the specimens of *Larix decidua* are fully colonized by the protected species of lichens, the following occur abundantly *Evernia prunastri*, *Pseudevernia furfuracea* and *Usnea filipendula* (cf. Tab. 1). In some wood stands they are also accompanied by *Hypogymnia tubulosa*, *Usnea hirta*, *U. subfloridana* and *Platismatia glauca*. As a rule, specimen-rich populations are formed by *Bryoria fuscescens*, *Tuckermannopsis chlorophylla*, and locally also by *Vulpicida pinastri.*

DISCUSSION AND CONCLUSIONS

Because of the size, the lichens with a foliose and a fruticose thallus constitute a relatively good object of study. At the same time, they are the most vulnerable ones as regards air pollution. In the lichenoindicative scale (Hawksworth & Rose 1970) they are placed as the most vulnerable ones – on the 6th-10th level of the table. They disappear with a very small concentration of SO_2 in the air. This scale was adapted to the conditions present in Poland by Kiszka (1990).

In the last 2 or 3 decades of the 20th century in Western Europe, activities have been initiated to improve the sanitary condition of the air. The processes of cities re-colonization by the lichens, particularly the peripheral district of the cities, became the example of the positive effects of those initiatives. Such phenomena were observed in the following cities: London (Rose & Hawksworth 1981; Hawksworth & McManus 1989; Larsen et al. 2004), Paris (Seaward, Letrouit-Galinou 1991; Letrouit-Galinou et al. 1992) and Turin (Piervittori et al. 1996). Another positive changes were forced by the draft Directive of the European Council No. 96/62/EC dated the 27th of September 1996 on ambient air quality assessment and management (Dz.U. *[Official Gazette]* L 296 from 21.11.1996) and the subsequent versions of the directives of this document, imposing the specific requirements for all the member states. Fałtynowicz (2004) reported the appearance of some large-thallus species of lichens protected in the southern part of Western Poland – in Wrocław, in Rudawy Janowickie and Bory Dolnośląskie Forests.

The increasing number of localities of legally protected lichens in the territory of Western Poland is the evidence that the aero sanitary conditions are improving (Fig. 2). The causes are to be found, for example, in the political and economic changes occurring over the last 30 years. German reunification in 1990 was tantamount to the introduction of the EU principles into the territory of the former German Democratic Republic (GDR), including the regulations concerning atmospheric air protection. In the presence of the predominantly westerly winds in Poland (Fig. 3) the load of supra-local air pollution, blown in from the plants located across the western border of Poland, has decreased. The constitutional changes in Poland, which occurred during the late 1980's and early 1990's, translated into the economic changes. In many regions of the country, the industrial plants, which had once constituted the local sources of air pollution emissions, ceased to operate. Poland, on the basis of the Treaty of Accession, has been a member of the European Union since the 1st of May 2004, thus becoming obligated to successively implement the regulations concerning the quality of atmospheric air.

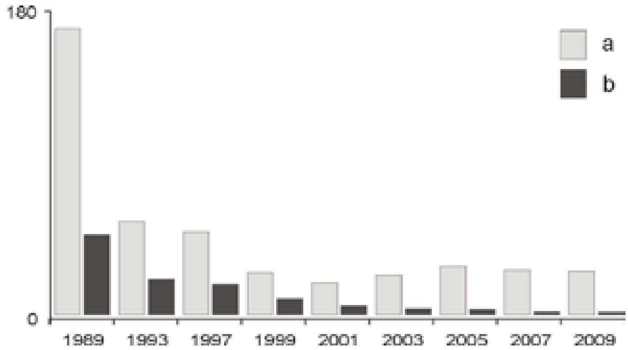

Fig. 2. The volume of gas emissions without CO_2 (a) and dust emissions (b) in thousands of mg/year in the Lubuskie Province in the years 1989-2009 (based on the data obtained from the Provincial Inspectorate for Environmental Protection in Zielona Góra)

The first signs of the changes in the aero sanitary conditions in the forests of north-west Poland were noticed in the Bory Tucholskie Forest – in the area that is currently located within the boundaries of the Bory Tucholskie National Park (Lipnicki 2003, 2007 and mat. npbl.). The observations of selected localities of rare lichens, which were initiated there in the second half of 1970's, and included such lichens as *Usnea filipendula*, made it possible to discern the gradual deterioration of the health condition of their thalli. Their ends were becoming brownish, died and subsequently fell off. As a result, the size and number of the specimens have clearly diminished. New specimens did not appear. In the early 1990's this process was halted, and after the passing of another couple of years it was observed that the thalli no longer showed signs of dying, the sizes and number of specimens on the trunk were clearly increasing and new juvenile specimens on the trunks of the same and neighbouring trees were appearing.

The appearance of large-thallus lichens, which are protected and threatened in many localities in Western Poland, is the testimony to the decisive improvement of the aero sanitary conditions in this part of the country (Fig. 2). Some of them "return", because they have already been reported to exist in those regions, but the information on their presence usually comes from former decades (Egeling 1883; Schultz-Korth 1931; Hillmann 1936; Motyka 1936-1938; Tobolewski 1952, 1988; Hillmann, Grummann 1957; Dziabaszewski 1962; Tobolewski, Kupczyk 1976; cf. also Fałtynowicz 1992).

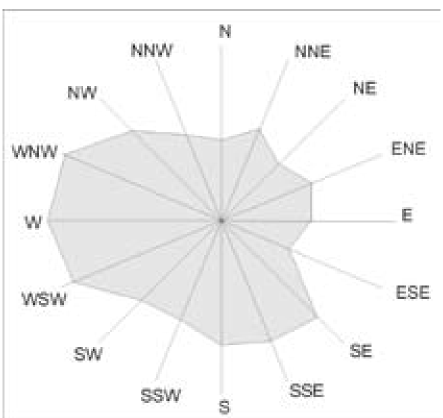

Fig. 3. The annual wind rose in the locality from the UPML model located in the area of Gorzów Wielkopolski in 2005 (in accordance with the "Air Protection Programme..." 2007)

Larix decidua is not among the trees whose bark is particularly favoured by lichens. The data included in the Checklist by Fałtynowicz indicate that so far in Poland only slightly over 100 species of lichens settling on this phorophyte have been found. For comparison: on the bark of *Picea* –

approx. 250 species, *Pinus* – approx. 450 species. From the Check List (Fałtynowicz 2003) it follows that approx. 20 species of lichens found so far on the bark of the larch tree have foliose thalli, and 30 species – fruticose thalli. The rest (approx. 50) – include crustose and leprose lichens. Among the lichens with a fruticose thallus, there are 19 species of *Usnea* and 5 – *Bryoria*.

Apart from the improvement of the aero sanitary conditions, it is also the chemical and biological properties of the tree that are conducive to the currently observed process of settlement by the interesting species of lichens on the snags and trunks of *Larix decidua*. All the lichens mentioned in Table 1 are clearly acidophilous and prefer the pH of the bark that ranges from <4 to 6, with the dominance of pH within the range of 4-5. It is the typical pH for the bark of *Pinus sylvestris* and *Larix decidua* (http://www.uzytkowanielasu...). The fact that the photophilous lichens (Table 1) prefer, in the first instance, the bark of *Larix decidua* follows from the fact that, contrary to the pine and other coniferous trees, the branches of larch trees are deprived of needles for at least half a year. This results in decidedly more advantageous lighting conditions, particularly in the lower part of the tree.

The already commenced observations of large-thallus epiphytic lichens under legal protection in Poland that settle in the bark of *Larix decidua* will be continued in the indicated localities in the middle part of Western Poland. Currently, consultations with the participation of lichenologists are already conducted in many Forest Inspectorates (for example in the Forest Inspectorate of Lubsko) prior to the commencement of any planned and more serious, necessary procedures on the larch wood stands. During field explorations, the methods and scope of the procedures are established which are aimed to fully secure the localities of the protected epiphytic lichens and to facilitate the dispersion of the diasporas of those organisms. The positive results of such activities are already visible.

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USNEA AND *BRYORIA* ON *LARIX DECIDUA* IN THE WKRZAŃSKA FOREST

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Abstract. During the field studies in the Wkrzańska Forest (north-western Poland) 3 species of lichens from the *Usneaceae* family have been found. All the three species (*Usnea subfloridana, U. filipendula* and *Bryoria implexa*) were situated on the bark of the larches and they are protected by law. The lichens of *Usneaceae* family have been lately reported once from this area.

Key words: lichenized fungi, protected, Wkrzańska Forest, *Larix decidua*, NW Poland

INTRODUCTION

The studies, published after 1945, which were dedicated to epiphytic lichens occurring within the area of the Wkrzańska Forest, indicated only one locality where the lichens of the *Usneaceae* species were reported to occur (Lipnicki & Janczar 2007; Gruszka & Janczar 2010; janczar 2012). This locality is situated in the area of Rędziny village, and is composed of a cluster of eight roadside ash trees. The unpublished information on other potential localities of these epiphytes was examined and verified; it concerned the thalli of other lichens.

The purpose of the explorations conducted in the years 2009-2011 was to find new localities of the lichens of the *Usnea* and *Bryoria* species in the area of the Wkrzańska Forest. These lichens are under strict legal protection (Dz. Ust. [Journal of Laws] 2004 No. 168, Item 1765). Seven new localities were found. In all of the localities, the *Usnea* and *Bryoria* species occur on the bark of trunks and branches of *Larix decidua*.

STUDY AREA

The Wkrzańska Forest is a large forest complex situated on the borderland of Poland and Germany. It covers an area of approx. 155 thousand ha. Nearly 1/3 of the Forest is situated in the territory of Poland, between the Szczecin agglomeration in the south and the south bank of the Szczecin Lagoon (Stachak

& Zachasz 2009) (Fig. 1). The Polish section of the Forest in the west adjoins the border of the country and in the east reaches down to the Lower Oder Valley. With regard to land administration, the area is placed under the authority of the Forest Inspectorate in Trzebież, which is incorporated into the Regional Directorate of State Forests in Szczecin (Wilderness Protection Programme 1997).

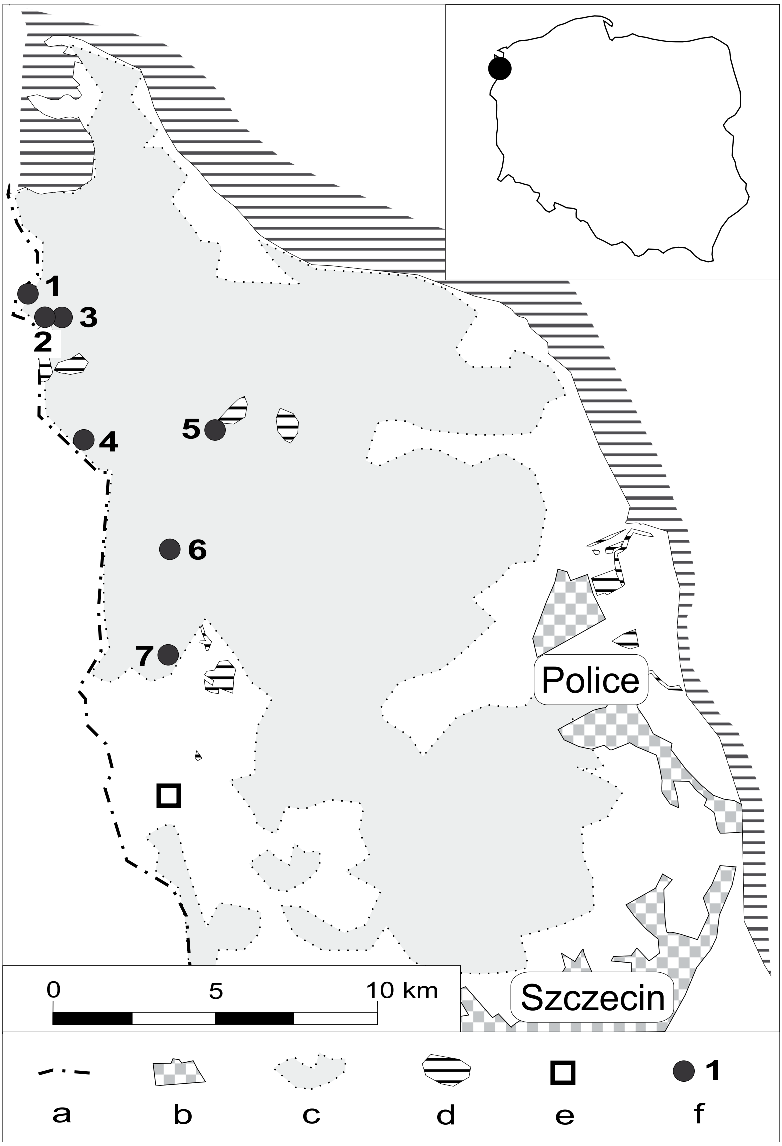

Fig. 1. Localities of *Usnea* and *Bryoria* on *Larix deciduae* in the Wkrzańska Forest
a – state boundary; b – urban areas; c – forest areas; d – water areas; e – the locality of *Usnea* known to date; f – new localities of *Usnea* and *Bryoria*

The Wkrzańska Forest, according to the physical-geographic regionalization of Poland (KONDRACKI 2000) is situated within the range of 3 physical-geographic mesoregions: The Police Plain (313.23), also referred to as the Wkrzańska Plain – from the River Wkra (German Uecker) that flows in Germany, The Lower Oder Valley (313.24) and the Szczecin Hills (313.26), which constitute part of the macroregion of the Pobrzeże Szczecińskie (Coast Land) (313.2-3), in the sub-province of the Southern Baltic Coast Land (313).

In terms of the nature-forest regionalization, the examined area is located in the 1st Baltic Land of the 2nd District of the Szczecin Lowland in the mesoregion of the Wkrzańska and Goleniowska Forests as well as in the mesoregion of the Szczecin Plains (ROZWAŁKA 2003).

The climate of this region is shaped by its direct proximity to the Szczecin Lagoon, the topographic diversity, and the presence of rivers, lakes and forests.

Winds from the west prevail in the area of the Wkrzańska Forest (Fig. 2). In summertime they cool the air and in wintertime they warm it (WOŚ 1999). The directions of winds are of crucial importance in the determination of the aerosanitary factors that condition the presence of the lichens particularly vulnerable to air pollution.

The effects of the glacier in the Szczecin Upland in the south-east part of the Wkrzańska Forest were, above all, the marly glacial tills, which, over the course of time, gave rise to the arctic initial soils. The warming of the climate and the appearing forests led to the formation of a top humus soil and the creation of protorendzinas. The soils derived from loams, which are poorly permeable and weathering resistant, have remained at this stage of development until today. The evolution of sand soils, occurring in the remaining part of the Wkrzańska Forest, was directed towards brown soils (overgrown with deciduous forests) or rusty and podsolic soils (overgrown with coniferous forests) (BOROWIEC 1993).

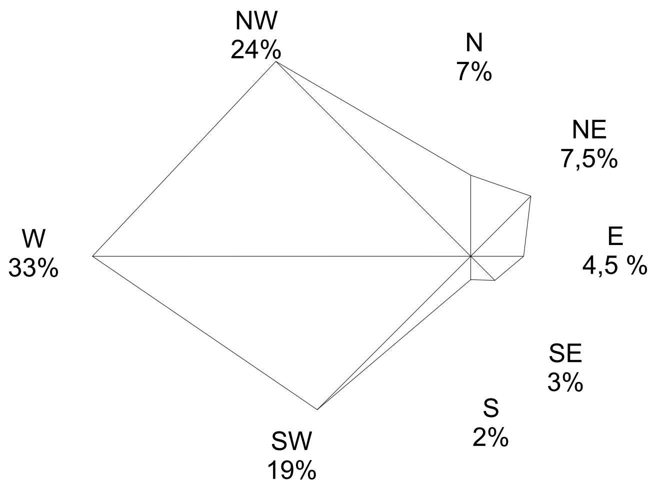

Fig. 2. Wind rose for the Police region (acc. to TOMSIA 1991)

The hydrographic network of the Wkrzańska Forest has been shaped by the River Oder together with its small tributaries, the Szczecin Lagoon and the tiny rivers and streams that flow into it, as well as by the lakes, which are distributed unevenly across the area. The lakes are of glacial origin and constitute bodies of water that filled the concave forms of the postglacial surface (Grzelak-Kostulska 1997).

Although the natural character of the Wkrzańska Forest has undergone changes, the predominant pine stands correspond to the habitat conditions. The pine occupies 80.3% of the forest area and forms homogenous wood stands with a small percentage of birch, larch and oak, frequently with undergrowth of spruce, beech and oak, and on more fertile habitats it occurs in combination with larch, spruce, beech, oak and hornbeam, forming mixed wood stands (Jasnowska 2010).

MATERIAL AND METHODS

The field explorations were conducted in the years 2009-2011 in the area of the entire Wkrzańska Forest, with particular emphasis on the places where *Larix decidua* occurs. This species reaches the northern boundary in Poland and occurs in the natural state only in the Tatra Mountains (Tomanek 1980). Within the area of the Wkrzańska Forest it occupies 0.2% of the surface share and occurs in the territory of the entire Forest Inspectorate, primarily on the habitats of: *Leucobryo-Pinetum* and *Fago-Quercetum petraea*e (Forest Management Plan 2007-2016).

The research material encompassed the thalli of lichens – that had fallen from the trees and fragments of live ones. During the marking process, the monograph by Motyka (1962) as well as the following keys were used: Nowak, Tobolewski (1975) and also Lipnicki (2003). The correctness of the markings was verified in the Division of Biology and Environmental Protection of the Faculty of Physical Culture in Gorzów Wielkopolski.

RESULTS

In the western part of the Polish section of the Wkrzańska Forest, 7 localities were found, where 3 species of the lichens from the *Usnea* genus occur: *U. subfloridana, U. filipendula* and *Bryoria implexa* (Tab. 1) (Fig. 1).

List and description of the localities:

A. The locality known to date (Fig. 2, e): By the asphalt road from Łęgi to Rzędziny, at a distance of approx. 3 km towards the South-West of the Świdwie Nature Reserve; on the bark of ash trees that form the natural protected site.

B. New localities – on the bark of *Larix decidua* (Fig. 2, f):

1. Myślibórz Mały, 1 km towards the North, in the 30-year-old tree stand on the habitat of a mixed fresh coniferous forest. Percentage share of species: 60% – *Pinus sylvestris*, 30% – *Larix decidua*, 10% – *Betula pendula.*

Table 1. List of localities and species

Locality	Species of lichen	The threat categories in Poland*	The length of the thallus [cm]	The height of position of the thalli [cm]	The number of thalli
1. Myślibórz Mały	*Usnea filipendula*	VU	0.5 – 1.5	50 – l20	2
	Usnea subfloridana	EN	1.5 – 4.5	50 – 220	6
2. Myślibórz Mały - Gajówka	*Usnea filipendula*	VU	0.5 – 1.5	120 – 180	4
	Usnea subfloridana	EN	1.5 – 2.5	140 – 160	2
3. The Nowowarpieńskie Meadows (Łąki Nowowarpieńskie)	*Usnea filipendula*	VU	7.5	320	1
	Usnea subfloridana	EN	2.5	150	1
4. Głogi	*Usnea filipendula*	VU	3 – 4	160 – 180	8
	Usnea subfloridana	EN	3 – 4	160 – 180	8
5. Lake Piaski (Jezioro Piaski)	*Usnea filipendula*	VU	0.5 – 12	70 – 250	approx. 50
	Usnea subfloridana	EN	0.8 – 6	70 – 350	9
	Bryoria implexa	CR	6 – 15	170 – 180	6
6. Poddymin	*Usnea subfloridana*	EN	2.5	160	1
7. Lake Świdwie (Jezioro Świdwie)	*Usnea filipendula*	VU	2 – 5	100 – 190	6

*) – acc. to Cieśliński et al. (2006)

2. Myślibórz Mały – Gajówka, 200 km towards the North-West, by the road leading from Myślibórz Wielki to Karszno, in the 20-year-old tree stand on the habitat of a mixed fresh coniferous forest. Percentage share of species: 100% – *Pinus sylvestris*, single species of *Larix decidua*, *Quercus petraea* and *Fagus sylvatica*.
3. The Nowowarpieńskie Meadows, 1 km towards the South-West, in the 30-year-old tree stand on the habitat of a mixed fresh coniferous forest. Percentage share of species: 40% – *Pinus sylvestris*, 30% – *Betula pendula*, 30% – *Picea abies*, locally *Larix decidua*.
4. The Głogi Sacred Ground (*Uroczysko Głogi*), towards the North, in the area of the non-existent Dobiesław village, in the 18-year-old tree stand on the habitat of a mixed fresh coniferous forest. Percentage share of species: 60% – *Pinus sylvestris*, 20%p – *Picea abies*, 20% – *Betula pendula*, single species of *Larix decidua*.

5. Lake Piaski, towards the South-West, in the 34-year-old tree stand on the habitat of a mixed fresh coniferous forest. Percentage share of species: 70% – *Pinus sylvestris*, 30% – *Picea abies*, single specimens of *Larix decidua*.
6. Lake Piaski, towards the East, by the regional road no. 115, in the 24-year-old tree stand on the habitat of a mixed fresh coniferous forest. Percentage share of species: 100% – *Pinus sylvestris*, single species of *Betula pendula*, *Fagus sylvatica* and *Larix decidua*.
7. Lake Świdwie, towards the North-West, in the tree stand on post-agricultural land on the habitat of a 40-year-old fresh coniferous forest. Percentage share of species: 100% – *Pinus sylvestris*, single species of *Picea abies*, *Fagus sylvatica*, *Quercus robur* and *Larix decidua*.

CONCLUSIONS

In the lichenological publications from the years 1945-2006, there is no information on the occurrence of lichens of the *Usneaceae* family in the area of the Wkrzańska Forest (Fałtynowicz 1992). The first information concerning this subject appeared in the year 2007 (Lipnicki, Janczar 2007, Gruszka, Janczar 2010). This locality is situated in the area of Rędziny village, and is composed of a group of roadside ash trees (*Fraxinus excelsior*).

The work features 7 new localities of the lichens of the *Usneaceae* family: *Usnea filipendula. U. subfloridana* and *Bryoria implexa* within the area of the Wkrzańska Forest. All occur on the bark of *Larix decidua.* They are under strict species protection and belong to species threatened in Poland (Cieśliński et al. 2006). The largest number of thalli (approx. 65) was reported in the locality of Lake Piaski. In the remaining six localities, the number of thalli is considerably lower and ranges from one in Poddymin to 16 in Głogi. The presence of these lichens on the bark of other forophytes within the area of the localities examined was not reported.

The area under investigation is influenced by pollution from the Szczecin agglomeration and traffic pollution. The main source of industrial pollution, and the gaseous pollutants in particular, is the "Police" Chemical Plant. The compounds of sulphur, nitrogen, fluorine and other compounds particularly effect the change of the aerosanitary and soil conditions. One favourable circumstance that reduces the influence of those pollutants on the life and nature of the Wkrzańska Forest is the relatively small share of winds blowing from the emission sources (Fig. 2).

The appearance of lichens species from the *Usneaceae* family in the area of the Wkrzańska Forest, which were unreported for a long time and which are particularly vulnerable to atmospheric air pollution, shows a substantial improvement of the aerosanitary conditions in this region. One of the contributing factors was undoubtedly the more restrictive and conscious policy of the relevant authorities of the "Police" Chemical Plant, who managed to considerably reduce the emission of chemical compounds into the atmosphere due to the application of new technologies. The localities of the lichens presented in the work are situated at distances of 13 – 20 km from the "Police" Chemical Plant.

The results of the studies performed so far indicate the necessity to continue such studies and monitor the changes occurring in the lichenobiotic composition of the Wkrzańska Forest.

The reported localities of the lichens from the *Usneaceae* family will be accurately inventoried and placed under protection. The Forest Inspectorate in Trzebież which administers that region is planning to demarcate protected areas with a radius of approx. 50 m around each such locality. All the works in connection with the forest management will be conducted in a manner that is non-invasive for the lichens present there.

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SECONDARY SUCCESSION WITH THE PARTICIPATION OF PROTECTED SPECIES OF LICHENS IN THE CHARRED AREAS OF THE FOREST INSPECTORATE OF LUBSKO

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Abstract. The studies were conducted in the years of 2010-2011 in the territory of the Forest Inspectorate of Lubsko. The presence of 65 species of tree and ground lichens was reported, all of which participated in the secondary succession of the areas that suffered destruction as a result of fires. It was reported that there were rare and 25 protected species, which mainly grow on the bark of birch trees planted in the firebreaks.

Key words: succession, lichens, protection, charred areas, The Lubuskie Forests, Western Poland.

INTRODUCTION

The examined phenomena of succession occupy an important place in contemporary ecology. Numerous authors present their theories and views on the subject of ecosystem conversions and the development of biocoenoses (Trojan 1975; Collier et al. 1978; Odum 1982; Remmert 1985; Faliński 1986; Luken 1990; Czachorowski 1994; Krebs 1996; Falińska 1998; Strzałko, Mossor-Pietraszewska 1999; Chojnacki 2000; Walker, del Moral 2003; Mackenzie et al. 2005; Więckowski 2008; Stawicka et al. 2010). Undoubtedly, a significant role in the process of both the primary and the secondary succession is played by the lichens as pioneer species (Fałtynowicz 1986; Lipnicki 1998; Shugart 2003). In the area of the Forest Inspectorate of Lubsko (Fig. 1) in recent years, mass appearance of epiphytic lichens has been observed on the areas reclaimed after the fires. In addition to the protected tree species, also numerous are the protected ground lichens (Lipnicki 2007).

A fire constitutes one of the most serious disasters for forest ecosystems. Fire and high temperature lead to the death of all living organisms and the destruction of all parts of the biotope (Szczygieł, Ubysz 2003). The Forests of the Inspectorate in Lubsko are characterized by high fire susceptibility, and are therefore rated as a 1st fire risk class in Poland. Over the course of the last 40 years, the tree stands have frequently been destroyed by fires. The largest of them to occur in the

Forest Inspectorate of Lubsko were in the following years:

- 1976 - 633 ha,
- 1982 - 1,162 ha,
- 1992 - 599 ha.

The main causes of the fires in the State Forests were: arson (43%) and recklessness of the adults (25%). The fires whose cause has not been determined still constitute a high percentage of all fires (22% of them and 22% of the area of burned wood stands) (Piwnicki, Szczygieł 2011).

Fig. 1. The location of the Forest Inspectorate of Lubsko

MATERIALS AND METHODS

The research works were commenced in the summer of 2010. The areas of the Forest Inspectorate of Lubsko, which suffered most from forest fires, were explored. On each of the charred areas (Fig. 2) localities were demarcated and the inventory of tree and ground lichens was taken, with particular consideration of the protected species. The majority of the material was marked directly in the field, whereas the ambiguous specimens were identified in the laboratory by means of typical methods used in lichenology. The nomenclature of the lichen species is based on Diederich et al. (2012). The threat categories in Poland, with reference to the particular species, were defined on the basis of Cieśliński et al. (2006) and the following abbreviations were adopted: RE – Regionally Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened.

All the collected and marked specimens were placed in the herbarium of the Laboratory of Biology and Nature Protection of the Faculty of Physical Culture in Gorzów Wielkopolski, E. Piasecki University School of Physical Education in Poznań.

Fig. 2. The administrative division of the Forest Inspectorate with the indication of places, which suffered the largest fires

RESULTS

In the territory of the Forest Inspectorate of Lubsko, which covers the area of 32,221.79 ha, 18 forest divisions have been sectioned off. The most serious and extensive fires engulfed the following ones: Marianka, Zasieki and Tuplice as well as a small part of Ciemny Las; in each of these areas 20 localities were demarcated, which were situated, above all, on the brinks of the forests along the firebreaks. The demarcated localities are characterized by high sun exposure, the wood stand is dominated by compact arrangements of common pine, and on their edges there are rather thinly planted silver birch trees.

During the field explorations, the lichenobiotic composition of the charred areas was reviewed in detail. 65 species of lichens, all of which are growing on the bark of *Betula pendula* and *Pinus sylvestris* as well as on the soil, were reported to occur in those places.

List of the species found:

(the following abbreviations have been used: *Bp* – *Betula pendula*; *Ps* – *Pinus sylvestris*; EN – endangered species; VU – vulnerable; NT – near threatened)

Amandinea punctata (Hoffm.) Coppins & Scheid. – on the bark of *Bp*

Baeomyces rufus (Hudson) Rebent. – on the soil

Bryoria fuscescens var. fuscescens (Gyeln.) Brodo & D. Hawksw. – on the bark of *Bp*, a rare species in Poland, under strict protection, VU
B. implexa (Hoffm.) Brodo & D. Hawksw. – on the bark of *Bp*, a rare species in Poland, under strict protection, VU, primeval forest relict
B. subcana (Stizenb.) Brodo & D. Hawksw. – on the bark of *Bp*, a rare species in Poland, under strict protection, VU, primeval forest relict
Cetraria aculeata (Schreber) Fr. – on the soil, a species under partial protection
C. islandica (L.) Ach. – on the soil, a species under partial protection, VU
C. muricata (Ach.) Eckfeldt – on the soil, a species under partial protection
Cladonia arbuscula (Wallr.) Eckfeldt – on the soil, a species under partial protection
C. chlorophaea (Sommerf.) Sprengel – on the soil
C. coccifera (L.) Willd. – on the soil
C. coniocraea (Flörke) Sprengel – on the soil
C. cornuta (L.) Hoffm. – on the soil
C. digitata (L.) Hoffm. – on the soil
C. fimbriata (L.) Fr. – on the soil
C. floerkeana (Fr.) Flörke – on the soil
C. foliacea (Hudson) Willd. – on the soil
C. furcata (Hudson) Schrader – on the soil
C. glauca Flörke – on the soil
C. gracilis (L.) Willd. – on the soil
C. macilenta Hoffm. – on the soil
C. mitis Sandst. – on the soil
C. phyllophora Hoffm. – on the soil
C. portentosa (Dufour) Coem. – on the soil, a species under partial protection
C. pyxidata (L.) Hoffm. – on the soil
C. rangiferina (L.) F.H. Wigg. – on the soil, a species under partial protection
C. rangiformis Hoffm. – on the soil
C. squamosa Hoffm. – on the soil
C. subulata (L.) F.H. Wigg. – on the soil
C. uncialis (L.) F. H. Wigg. – on the soil
C. verticillata (Hoffm.) Schaer. – on the soil
Evernia prunastri (L.) Ach. – on the bark of *Bp*, a species under partial protection, NT
Hypocenomyce scalaris (Ach.) M. Choisy – on the bark of *Bp* and *Ps*
Hypogymnia physodes (L.) Nyl. – on the bark of *Bp* and *Ps*
H.tubulosa (Schaerer) Hav. – on the bark of *Bp*, a rare species in Poland, under strict protection, NT
Lecanora conizaeoides Crombie – on the bark of *Bp* and *Ps*
L. expallens Ach. – on the bark of *Ps*
Lepraria sp. – on the bark of *Bp* and *Ps*
Melanelixia fuliginosa (Duby) O. Blanco et all. subsp. *glabratula* (Lamy) J. R. Laundon – on the bark of *Bp* and *Ps*, a species under strict protection
Parmelia sulcata Taylor – on the bark of *Bp* and *Ps*
Parmeliopsis ambigua (Wulfen) Nyl. – on the bark of *Bp*, a species under strict protection
Peltigera didactyla (With.) J. R. Laundon – on the soil, a species under strict protection
P. membranacea (Ach.) Nyl. – on the soil, a species under strict protection
P. rufescens (Weiss) Humb. – on the soil, a species under strict protection
Phaeophyscia orbicularis (Necker) Moberg – on the bark of *Bp*

Phlyctis argena (Spreng.) Flot. – on the bark of *Bp*
Physcia adscendens (Fr.) H. Olivier – on the bark of *Bp*
P. tenella (Scop.) DC. – on the bark of *Bp*
Placynthiella icmalea (Ach.) Coppins & P. James – on the wood
P. uliginosa (Schrader) Coppins & P. James – on the soil
Platismatia glauca (L.) W.L. Culb. & C.F. Culb. – on the bark of *Bp*, a species under strict protection
Pseudevernia furfuracea (L.) Zopf – on the bark of *Bp*, a species under strict protection
Pycnothelia papillaria (Ehrh.) L.M. Dufour – on the soil, a rare species in Poland, under strict protection, EN
Scoliciosporum chlorococcum (Stenh.) Vězda – on the bark of *Bp* and *Ps*
Stereocaulon condensatum Hoffm. – on the soil, a rare species in Poland, under strict protection, VU
Trapeliopsis flexuosa (Fr.) Coppins & P. James – on the soil
T. granulosa (Hoffm.) Lumbsch – on the soil
Tuckermannopsis chlorophylla (Willd.) Hale – on the bark of *Bp,* a species under strict protection, VU
T. sepincola (Ehrh.) Hale – on the bark of *Bp*, a species under strict protection, rare in Poland, EN
Usnea filipendula Stirton – on the bark of *Bp*, a species under zone protection, rare in Poland, VU
U. hirta (L.) F.H. Wigg. – on the bark of *Bp*, a species under zone protection, rare in Poland, VU
U. subfloridana Stirton – on the bark of *Bp*, a species under zone protection, rare in Poland, EN
Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai – on the bark of *Bp*, a species under strict protection, rare in Poland, NT
Xanthoria candelaria (L.) Th. Fr. – on the bark of *Bp*
X. parietina (L.) Beltr. – on the bark of *Bp*

Protected species (Dz. U. *[Journal of Laws]* No. 168, Item 1765) constitute an important component in the lichenobiotic composition of the areas examined. Frequently one can encounter such lichens as: *Bryoria fuscescens var. fuscescens, B. subcana*, *B. implexa, Cetraria aculeata, C. islandica, C. muricata, Cladonia arbuscula*, *C. portentosa, C. rangiferina, Evernia prunastri, Hypogymnia tubulosa, Melanelixia fuliginosa, Parmeliopsis ambigua, Peltigera didactyla, P. membranacea, P. rufescens, Platismatia glauca, Pseudevernia furfuracea, Pycnothelia papillaria, Stereocaulon condensatum, Tuckermanopsis chlorophylla*, *T. sepincola, Usnea filipendula*, *U. hirta*, *U. subfloridana*, *Vulpicida pinastri.* The particular value of the birch trees arrangements, owing to the share of protected lichens, is underlined by the abundant presence of *Usnea* and *Bryoria* on the bark of these trees. Their thalli reach the size of even 10 to 20 centimetres.

From among the 33 species from the "Red List of Lichens in Poland" (Cieśliński et al. 2006) no taxa belonging to the following categories were found: CR (Critically Endangered) and LC (slightly endangered); however, species belonging to the following categories were found: EN (Endangered, 3 species: *Pycnothelia pa-*

pillaria, Tuckermannopsis sepincola, Usnea subfloridana), VU (Vulnerable, 8 species: *Bryoria fuscescens var. fuscescens, B. implexa, B. subcana*, *Cetraria islandica, Stereocaulon condensatum, Tuckermanopsis chlorophylla, Usnea filipendula, U. hirta*) and NT (Near Threatened, 3 species: *Evernia prunastri, Hypogymnia tubulosa, Vulpicida pinastri*).

Moreover, single specimens that are counted as primeval forest relicts (Cieśliński 2003) were also reported: *Bryoria impexa* and *B. subcana*. They constitute a very precious component of the lichenobiotic composition of those areas.

Epiphytes are represented by a numerous group of lichens: *Amandinea punctata*, *Bryoria fuscescens var. fuscescens, B. implexa*, *B. subcana, Evernia prunastri, Hypocenomyce scalaris, Hypogymnia physodes*, *H. tubulosa, Lecanora conizaeoides, L. expallens, Lepraria incana*, *Melanelixia fuliginosa, Parmelia sulcata, Parmeliopsis ambigua, Phaeophyscia orbicularis, Phlyctis argena, Physcia adscendens, Ph. tenella, Platismatia glauca, Pseudevernia furfuracea, Scoliciosporum chlorococcum, Tuckermannopsis chlorophylla*, *T. sepincola, Usnea filipendula*, *U. hirta, U. subfloridana*, *Vulpicida pinastri*, *Xanthoria candelaria*, *X. parietina.* On the basis of earlier studies and observations (Lipnicki 2007) one can conclude that the lichens growing on the bark of birch and pine trees have only begun to appear in the last few decades. Currently, they take the form of numerous initial thalli as well as well-formed specimens.

The ground lichens include: *Cetraria aculeata, C. islandica, C. muricata, Cladonia arbuscula*, *C. chlorophaea, C. coccifera, C. coniocraea, C. cornuta, C. digitata, C. fimbriata, C. floerkeana, C. foliacea, C. furcata, C. glauca, C. gracilis, C. macilenta, C. mitis, C. phyllophora, C. portentosa, C. pyxidata, C. rangiferina, C. rangiformis, C. squamosa, C. subulata, C. uncialis, C. verticillata, Peltigera didactyla, P. membranacea, P. rufescens, Placynthiella icmalea, P. uliginosa, Pycnothelia papillaria, Stereocaulon condensatum, Trapeliopsis flexuosa, T. granulosa.* The species composition with a considerable share of cup lichens indicates the pioneer nature of the soil (Fałtynowicz 1986).

DISCUSSION AND CONCLUSIONS

The secondary succession is a process, which occurs in fallow lands, charred areas, etc. where the previously present vegetation has suffered destruction – degeneration (Faliński 1991). The areas deprived of a wood stand are, in the first instance, dominated by the pioneer species (lichens), which E. Piasecki University School of Physical Education in Poznań by taking advantage of and converting the extreme environmental conditions E. Piasecki University School of Physical Education in Poznań create optimum conditions for the life of other organisms, populations and - in the long run - the whole biocoenoses (Lipnicki 1990). The occurrence of such an abundant group of epigeits clearly indicates the successive nature of the charred areas in the Forest Inspectorate of Lubsko. The still poorly developed wood stand (of approx. 20-30 years) and the special procedures consisting in the thinning out of the birches planted in the firebreaks guarantee that the ground lichens have good access to sunlight, which in turn leads to the formation of favourable conditions for their growth. Moreover, the poor soil is not conducive to the development of vascular plants, and the lack of, for instance, high grasses prevents the appearance of the so-called "windshield-wiper effect" (Faliński 1998), during which the removal of diasporas or the freshly-developing, young thalli could be possible thanks to the moving blades of grass (Lipnicki 1998).

The aerosanitary conditions in these areas, which have been improving for approx 3 decades, are also conducive to the settlement and development of epiphytes. This is primarily related to the lack of pollution influence from Germany as well as the poor industrialization of the entire region. Therefore, the share of taxa, which are vulnerable, rare or even threatened by extinction, indicates that there are conductive conditions for their growth. Undoubtedly, the procedures performed by the foresters (pruning, thinning out the wood stand) have an enormous influence on the occurrence (in a very good form indeed) of the photophilous species from the genera: *Bryoria* or *Usnea*.

As a matter of fact, on all of the three charred areas in the Forest Inspectorate of Lubsko one can show the existence of precious lichen species; however, the largest share of them has been reported on the areas destroyed in the 1980's and 1990's. This is understandable when one takes into consideration the process of natural secondary succession. The period of approx. 20 – 30 years after a natural disaster is a time limit that allows a perfect development of the thalli of lichens, because the tree crowns are still poorly developed, while the underground still poorly dominated by other elements of vegetation. The areas "devoured" by the fire in 1996 are currently overgrown with fairly compact, multi-species trees, whose crowns cast heavy shadows, which does not favour the growth of lichens, both the tree and the ground ones. A considerably poorer lichenobiotic composition was observed here, when compared to the two other areas. Therefore, it can be concluded that reasonable forest management has a huge influence on the existence of precious, protected species of lichens. In order to substantiate the above hypothesis, study areas were demarcated, where further monitoring of the quantitative and qualitative changes will be performed with regard to the conditions of the thalli and the species composition of the lichens. The studies conducted so far have proven that the natural disaster has an essential influence on the appearance of the lichens as pioneer organisms on the fire-destroyed areas.

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THE LICHEN BIOTA OF PROTECTED TERRITORIES IN RYAZAN REGION (CENTRAL RUSSIA)

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Abstract. The lichen biota of protected territories in Ryazan region (Central Russia) includes 297 species from 95 genera. The representativeness and specificity of federal and regional level protected territories, the main genera spectrum of lichen biota and substrate preferences of species in different plant communities are discussed. The most common species, macrolichens included in regional Red Data Book (22 species) and other rare lichens, indicators of old-growth forest communities are reported. 5 species are new for all Russia territory: *Caloplaca atroalba* (Tuck.) Zahlbr., *C. lacteoides* Nav.-Ros. et Hladun, *Lecania inundata* (Hepp ex Körb.) M. Mayrhofer, *Verrucaria myriocarpa* Hepp ex Lönnr., *Verrucaria nigroumbrina* (A. Massal.).

Key words: lichens, lichen distribution, horology, substrate's groups.

INTRODUCTION

The Ryazan region, covering 39,600 km^2, is located in the central part of the Russian Plain (55°22′–53°19′N, 38°38′–42°31′E) (Fig.1). There are 155 specially protected natural territories of different categories in Ryazan region. The Oksky Biosphere State Natural Reserve (below referred to as the Oksky Reserve), "Meshchersky" National Park and the "Ryazansky" State Natural Wildlife Reserve of federal importance are subject to federal level protection. 49 State Natural Wildlife Reserves and 103 Natural relics are protected at a regional level. The total area of protected natural territories is over 370,000 ha, which is about 9 % of the Ryazan region area (Kazakova, Sobolev 2004).

At the start of our investigation the Preliminary list of lichens in the Oksky Reserve was known to include 143 species only (Zhdanov, Volosnova 2008).

The goal of the research is to evaluate the diversity of the lichen biota of the protected territories in the Ryazan region and its representativeness in relation to the lichen biota of the whole Ryazan region. The targets were: to pick objects for surveying taking into account their zonality and diversity of habitats; to discover species composition of lichens and allied fungi; conduct brief taxonomic, ecology and substrate and horological analysis; to find the most usual, widely spread as well as rare and indicator species.

STUDY AREA

The southern and southwestern parts of the Ryazan region are on the Central Russian Upland (elevation 170–236 m a.s.l.), the eastern part is situated in the Oksko-Donskaya Plain (140–198 m a.s.l.) and Mescherskaya Lowland (100–136 m a.s.l.). The climate is moderately continental, with an average January temperature of −11°C, and an average July temperature of +19°C. The annual precipitation is from 760 mm in the northern part and high-elevation southwest to 500 mm and lower in the south (Krivtsov 2004).

Fig. 1. Ryazan region on the map of Russia

The northern part of the region is in the mixed coniferous-broadleaved forest zone, the middle part in the broadleaved forest zone, and the southern part in the forest-steppe zone (Fig. 2). The natural landscape of the broadleaved forest and forest-steppe zones is highly altered by human activities.

In the coniferous-broadleaved forest zone, pine, pine-birch and mixed forests with participation of pines, oaks, limes, aspens, maples, and rarely spruces predominate. In the zones of broadleaved forests and forest-steppe, in the place of formerly common oak forests, secondary birch-aspen forests with an admixture of oaks, limes, maples, and ash-trees developed. Groves of oaks with participation of limes and other deciduous species are rarely seen.

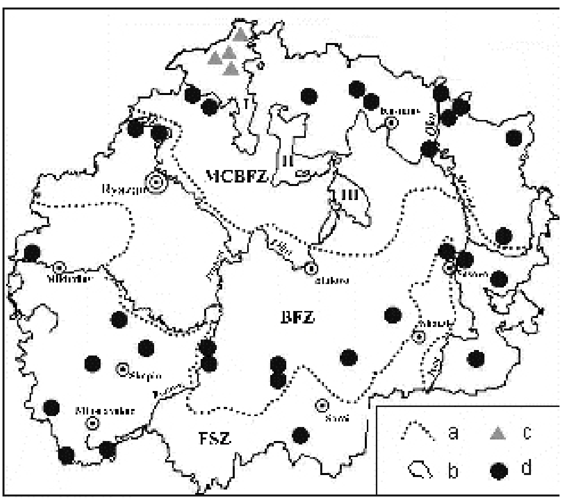

Fig. 2. Natural zones and specially protected natural territories (SPNT)
a – borders of natural zones and subzones; b – SPNT of federal importance ; c – SPNT of regional importance within the National Park "Meshchersky"; d – SPNT of regional importance outside other SPNT. Natural zonal distribution: MCBFZ – Subzone of mixed coniferous-broadleaved forest zone; BFZ – Subzone of broadleaved forest zone; FSZ – Forest-steppe zone.
SPNT of federal importance: I – National Park "Meshchersky"; II – Oksky Biosphere State Natural Reserve; III – State Natural Wildlife Reserve of federal importance "Ryazansky".

MATERIALS AND METHODS

From 2009 to 2011, studies of lichen biota diversity in the Ryazan region were performed. These included surveys of all natural federally protected territories and selectively 35 regionally protected objects (Fig. 2). The object selection was performed with regard to the natural zones and plant community variety. From the lichenological position, of the greatest interest are various forest communities (including waterlogged ones) and stony steppe communities with emerging limestone and sandstones.

The studies were accomplished with a route method, collections and cameral treatment of materials – with routing lichenological techniques (Oxner 1974; Vainstein et al. 1990; Orange et al. 2001). In total, over 1 500 specimens were collected and identified. A complete revision of the lichen herbarium of the Oksky Reserve was also done, including an essential part of collections previously not identified.

The identifications were validated in the lichenological herbaria of the RAS V.L. Komarov Botanical Institute (LE-L) and PAS W. Szafer Botanical Institute (KRAM-L). The specimens are kept in the herbaria of the Ryazan State University (RSU) and Oksky Reserve, and some duplicates are in the herbarium of the Polar-Alpine Botanical Garden-Institute (KPABG) and LE-L. The nomenclature follows Urbanavichyus (2010).

RESULTS AND DISCUSSION

As a result of the studies performed in specially protected natural territories (further SPNT), 297 lichen species and allied fungi have been detected, which constitutes 87.7% of the total of the Ryazan region lichen biota. This agrees with some estimates (Davis et al. 1990): protection of most preserved areas of plant communities enables protection of 85-90% of species variety from extinction. 98 species are characteristic of SPNT only and do not occur in the region beyond their limits.

Federal level SPNT lichen biota includes 226 species, of which 84 do not occur within the limits of the regional level SPNT. At the same time, in regional level SPNT 213 species were detected, of which 71 did not occur in the territories of higher, federal level of protection. The representativeness and specificity of the SPNT network are shown in Fig. 3.

The species found belong to 95 genera, of which 21 are main ones (Fig. 4). These genera include 182 species, which makes 61.3% of those newly found. We may also note that a significant role in the lichen biota studied belongs to parmelioid lichens. In spite of the fact that one genus only (*Melanohalea*) belongs to the spectrum of the most important ones, the total of parmelioid lichen genera is as high as 18. These include 32 species, which makes 10.8% of the total list.

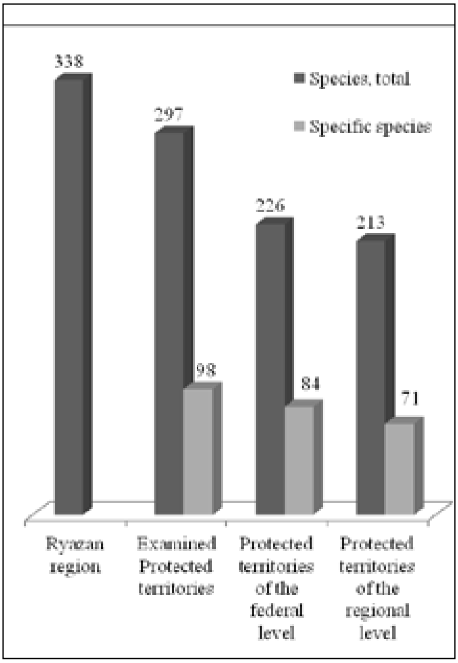

Fig. 3. The representativeness and specificity of the SPNT network in Ryazan region

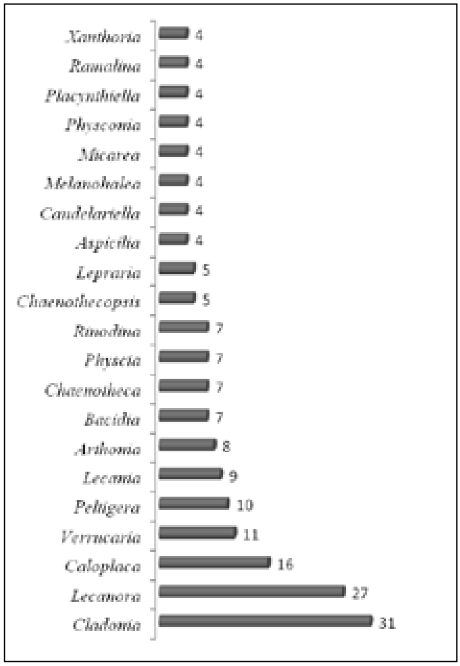

Fig. 4. The main genera spectrum of SPNT lichen biota

Substrate preferences of the species found are shown in Fig. 5. Strict substrate specificity is demonstrated by 244 species (82.2%). 42 species occur simultaneously on two substrate types (for instance, on bark and wood, on soil and wood), and 11 species adapt to 3 and more substrate types. The main substrate groups are corticolous (118 species), saxicolous (58 species), terricolous (36 species), corticolous-lignicolous (32 species) and obligate lignicolous (24 species). The rest of the groups are only insignificantly represented.

Distribution of species found by habitat types is shown in Fig. 6. The highest species diversity is characteristic of mixed (coniferous-broad leaved) forests. This habitat type provides lichens with a wide choice of wood substrates: bark of coniferous and deciduous species, brushwood (including that with moss), and wood with different degree of decomposition (from dry to decaying). The prevalent substrate groups here are corticolous, corticolous-lignicolous and obligate lignicolous, and the same is observed in broad-leaved (with oaks, limes and maples), small-leaved (aspen, birch), alder forests and in bogs.

The greatest diversity of terricolous lichens is seen in pine forests, wasteland with sparse growth of pines and in steppe slopes with stone emergence (limestone or sandstone). The last habitat is a focus of most saxicolous species detected.

Rather wide and diverse is the substrate choice for settling of lichens in small villages and settlements, which are within the limits of protected natural territories: bark of various tree species, wood of constructions, natural and artificial stone substrates (concrete, brick). Besides, in these settlements, age-old farmhouse

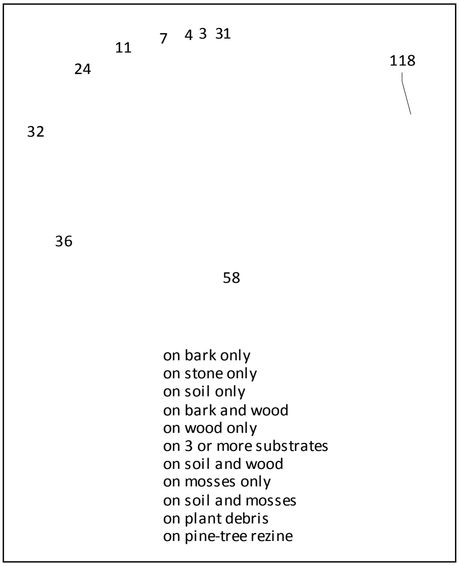

Fig. 5. Substrate preferences of indentified species

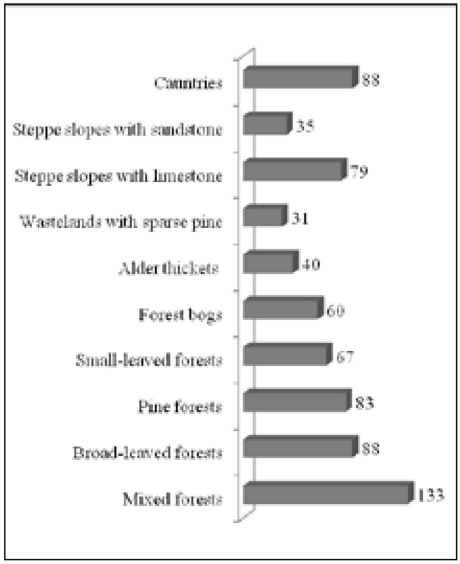

Fig. 6. Distribution of indentified species found by habitat types

parks or separately standing (single) old trees, where many rare and interesting lichen species and allied fungi are growing. All of this calls forth a fairly high index of lichen diversity in the communities surveyed.

Among the most common in the protected territories are the following lichens: *Amandinea punctata, Aspicilia moenium*, *Caloplaca cerina, Caloplaca crenulatella, C. pyracea, Candelariella aurella, C. xanthostigma*, *C. vitellina*, *Chaenotheca ferruginea, Cladonia cenotea, C. chlorophaea* s.l., *C. coniocraea*, *C. fimbriata, C. macilenta*, *Evernia mesomorpha, E. prunastri, Hypocenomyce scalaris, Hypogymnia physodes, Lecanora albellula, L. allophana, L. pulicaris, L. symmicta, Parmelia sulcata, Parmeliopsis ambigua, Phaeophyscia orbicularis, P. nigricans, Phlyctis argena, Physcia adscendens, P. aipolia, P. dubia, P. stellaris, P. tenella, Physconia distorta, P. enteroxantha, Pycnora sorophora, Scoliciosporum chlorococcum, S. sarothamni, Verrucaria muralis, Vulpicida pinastri, Xanthoria parietina, X. polycarpa*.

Most of the species mentioned grow on tree bark and wood. Genus *Cladonia* species inhabit not only tree bases, wood, plant debris, but the soil too. *Aspicilia moenium, Caloplaca crenulatella, Candelariella aurella, C. xanthostigma*, *C. vitellina*, *Verrucaria muralis* adapt to various stone substrates, both natural ones (limestone, sandstones) and artificial (concrete, brick).

In the protected territories, most of rare lichen species for the Ryazan region (and sometimes for more extensive territories) occur. The Red data book for the Ryazan region includes 22 species of macrolichens (Muchnik, Konoreva 2011), and within the limits of protected territories 19 are seen. Of these, 4 species grow on stony steppe slopes: *Cladonia subrangiformis, C. symphycarpa, Collema crispum* and *Neofuscelia pulla*. The remaining inhabit mixed or broad-leaved forests:

Bryoria fuscescens, B. nadvornikiana, B. subcana, Cladonia parasitica, C. ramulosa, Flavoparmelia caperata, Imshaugia aleurites, Leptogium cyanescens, Parmeliopsis hyperopta, Usnea dasypoga, U. subfloridana, Ramalina fraxinea, Peltigera lepidophora, P. neckeri, P. neopolydactyla.

The network of protected natural territories includes areas of old growth and only slightly disturbed forest communities with diverse and interesting lichen biota. Just with these areas are associated findings of indicator species for old-growth forests (Andersson et al. 2009): *Acrocordia gemmata*, *Bacidia rubella*, *Biatoridium monasteriense, Chaenotheca stemonea, Chaenothecopsis nana, Chaenothecopsis nigra, Chaenothecopsis viridireagens*, *Cladonia parasitica, Leptogium cyanescens, Phlyctis agelaea.*

Only in protected areas of mixed or broad-leaved forests, rare for the middle belt of European Russia in whole *Absconditella lignicola, Arthonia didyma, Bacidia vermifera, Bacidia viridescens, Calicium pinastri, Lecanora subintricata*, *Lecanora thysanophora*, *Mycobilimbia carneoalbida, Naetrocymbe rhyponta*, *Psilolechia lucida, Sarea difformis*, *Thelocarpon laureri* are seen. In addition to these species inhabiting diverse wood substrates or plant debris, in the mixed forest, a very rare saxicolous species *Verrucaria aquatilis* is detected, which lives on small limestone stones in the forest brook.

Extremely interesting is the lichen biota of steppe areas with emergence of limestone or, infrequently, of sandstone. Apart of the species mentioned, included in the regional Red data book, rare to the middle belt of European Russia *Caloplaca granulosa*, *Caloplaca polycarpa*, *Cladonia acuminata, C. cryptochlorophaea, Endocarpon pusillum, L. rabenhorstii, L. sylvestris*, *Rinodina lecanorina, R. milvina, Staurothele frustulenta, Trapelia placodioides* are detected in stony steppe communities. Of special note should be findings of new species to all of the territory of Russia: *Lecanora percrenata* Hook (Muchnik, Śliwa 2011), *Caloplaca atroalba* (Tuck.) Zahlbr., *C. lacteoides* Nav.-Ros. et Hladun, *Lecania inundata* (Hepp ex Körb.) M. Mayrhofer, *Verrucaria myriocarpa* Hepp ex Lönnr., *Verrucaria nigroumbrina* (A. Massal.) Servít. The above mentioned new and several rare species are now described in separate papers.

Two rare species (*Cyphelium notarisii* and *Thelomma ocellatum*) are collected only on the treated wood of fences in villages within the limits of protected territories. Old trees in old-age farm parks are the habitats for species protected in the Ryazan region: *Ramalina fraxinea* and *Usnea dasypoga*. On single standing old trees, a rarity the middle belt of European Russia *Xanthoria* cf. *ucrainica* is collected.

Thus, the diversity of habitat types in specially protected natural territories of Ryazan' region ensures a rather high diversity and representativeness of lichen biota. Additional measures of protection should be undertaken in relation to three lichen species included into the regional Red data book (*Cladonia glauca, Peltigera extenuata, Usnea lapponica*), which are not found so far within the limits of the protected territories existing (Muchnik, Konoreva 2011).

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THE CONDITION OF LICHEN BIOTA IN "ŚWINIA GÓRA" NATURE RESERVE (KIELECKO-SANDOMIERSKA UPLAND)

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Abstract. The lichenological study was conducted in the "Świnia Góra" Nature Reserve. The study was intended to present the current state of lichen biota and changes that have occurred in the species composition. A total of 152 species of lichens, lichenicolous and saprobic fungi were found in the investigated area. Biota of the reserve has been significantly impoverished. There are currently not confirmed about 70 species.

Key words: lichens, lichenicolous fungi, rare species, protected and threatened species, Central Poland

INTRODUCTION

Nature reserves, landscape and national parks are established to protect natural habitats in which rare species live against destruction and damage. However, in many cases only reserve protection is not enough. The natural environment is still subject to a variety of anthropogenic factors, not only local but also the supra local. The consequences are unfavourable changes in natural systems, leading to regression and extinction of many species.

The "Świnia Góra" Nature Reserve was established to protect natural forests with mixed tree stand that are a remnant of the Świętokrzyska Forest. Despite many years of protection, the area is subject to the negative influence of anthropogenic factors, especially local ones, such as intensive forest management on adjacent areas.

The first mention of lichens from the forest complex, in which the "Świnia Góra" reserve is placed, comes from the work of Tyszkiewiczowa (1935). The author conducted research in the north-eastern part of the Kielecko-Sandomierska Upland in the Świętokrzyska Forest. The first lichenological work of the "Świnia Góra" reserve comes from 1960 (Nowak 1960). The next works: Halicz & Cieśliński (1967), Bystrek & Cieśliński (1976) and Cieśliński & Bystrek (1982) are contributory. In the years 1960-1989 thorough lichenologial research in the reserve was conducted by Cieśliński and Toborowicz (1992), who drew attention to the adverse effects in the biota of lichens.

The paper presents the current state of the biota of lichens and lichenicolous fungi in the reserve. The study will determine whether changes in the composition of lichen species in this area have actually been negative.

STUDY AREA

The "Świnia Góra" Natural Reserve, with a total area 50.78 ha, is located in the Suchedniowsko-Oblęgorski Landscape Park in the Bliżyn municipality (Fig. 1). It is located at 20°42'01"E longitude and 51°03'24"N latitude. This area is situa-

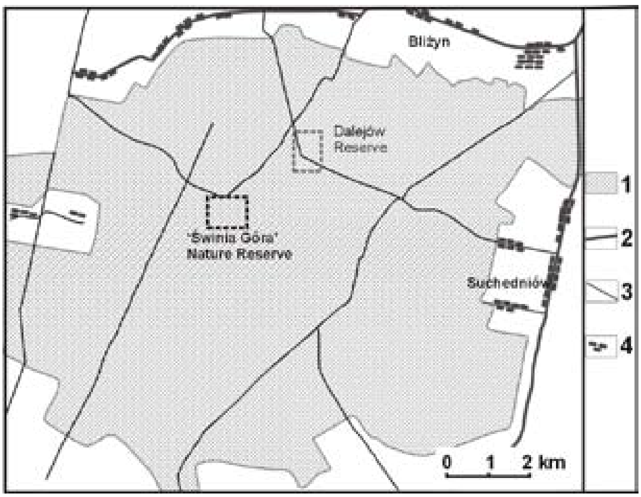

Fig. 1. "Świnia Góra" Nature Reserve – locality of study area sites (based on maps of 1: 50 000 "Around Kielce", topographic and tourist map)
1 – forest; 2 – main road; 3 – local road; 4 – buildings.

ted in the macroregion of Kielecko-Sandomierska Upland and in the mezoregion of Suchedniowski Plateau (Kondracki 2002). In the system of ATPOL squares (Cieśliński & Fałtynowicz 1993) the research area is located in Ee 54 square.

"Świnia Góra" reserve was established on the basis of the Minister of Forestry and Wood Industry Ordinance No. 291 of 10.28.1953 (Monitor Polski 1953 no. 104 entry 1403). It is intended to protect natural mixed forests.

The object of research is characterized by mild topography, dominated by small hills intersected by wide valleys. The geological structure of the area consists of Devonian sandstones. The soils there are poor, the original quartz-acidic silicate soils and secondary industrial soils are rich in calcium carbonate (Adamczyk 1965). The mosaic arrangement of soil affects the variety of vegetation. In the reserve the largest areas of forest are occupied by communities of: *Dentario glandulosae-Fagetum, Querco roboris-Pinetum* and *Sphagno girgensohnii-Piceetum* (Fabijanowski & Zarzycki 1965).

MATERIAL AND METHODS

The first phase of work included finding all the information about lichens identified in the past on the investigated area. It was done on the basis of published data and the revision of available historical herbarium materials, collected in 1988-1989 by I. Rugała, J. Stępień, K. Toborowicz and S. Cieśliński. Several species in Table 1 are marked with a questionable "+?". Information about their occurrence on the study area comes from the work of Cieśliński and Toborowicz (1992). The authors had already considered them to be extinct lichens. Probably data on the occurrence of these species in the reserve was included in the unpublished work of Libera (1975), which the authors (Cieśliński & Toborowicz 1992) drew historical data from.

The second phase included field research conducted in 2010. The area was divided into four research sites. Lichen species have been recorded at each site from all environmental groups (epiphytic, epixylic, epilithic and epigheic) and from all available substrates. For species that are easy to identify in the field, the notation is limited to the original note. Others were identified in the laboratory with standard methods used in lichenology and thin layer chromatography (TLC) (Orange et al. 2001). Nomenclature of lichen species was taken according to: Smith et al. (2009) and Diederich et al. (2012), species of *Usnea* genus according to: Fałtynowicz (2003), and species of lichenicolous fungi according to: Czyżewska and Kukwa (2009).

Historical and currently collected specimens are deposited in the herbarium of lichens at J. Kochanowski University in Kielce (KTC).

RESULTS AND DISCUSSION

132 species of lichens and lichenicolous fungi were found, occurring in the past in the area of the "Świnia Góra" reserve, from the analysis of published materials, and historical revision of herbarium specimens (Tab. 1). From reserve area Nowak (1960) lists about 50 species of lichens. Most of them the author (Nowak 1960) describes as common lichens, growing also in other areas in Poland (Tab. 1). Among the epiphytes he also mentions rare species: *Lecanora albella*, *Menegazzia terebrata, Usnea ceratina* and *Bryoria furcellata* [*Alectoria nidulifera*], which probably was erroneously listed in this area. Then the number of terrestrial and rock lichens in the reserve was recorded. In contributing works from 70s and –80s of the XX century (Halicz & Cieśliński 1967; Bystrek & Cieśliński 1976; Cieśliński & Bystrek 1982) several epiphytes are listed in the investigated reserve, including the protected and endangered species of *Bryoria* and *Usnea* genus (Tab.1).

As a result of research carried out in the 90s of the XX century (Cieśliński & Toborowicz 1992) and the revision of historical herbarium materials of this period (1988, 1989) about 100 species of lichens and lichenicolous fungi have been recorded in the reserve (Tab. 1). The biota was dominated by epiphytes and epixilites. On rocks only two species were found, and on soil there had been none. As widespread lichen the authors (Cieśliński & Toborowicz 1992) have included among others: *Graphis scripta* and *Pyrenula nitida*. Less frequent: *Pseudevernia furfuracea, Platismatia glauca, Tuckermanopsis chlorophylla, Evernia prunastri, Parmeliopsis ambigua, Imshaugia aleurites* and the *Cladonia* genus species. The authors (Cieśliński & Toborowicz 1992) distinguished a large group of lichens, which were then found only on single sites and had a thallus with clearly decreased vitality, such as: *Cetrelia olivetorum, Chrysothrix candelaris, Gyalecta truncingena, Menegazzia terebrata, Peltigera praetextata* and *Thelotrema lapadinum*.

Table 1. List of lichens and lichenicolous fungi in the "Świnia Góra" Nature Reserve on the basis on literature (1960; 1967, 1976, 1982; 1992), historical herbarial materials (1988, 1989) and own research (2010)

Species	Found in years			
	1960	1967, 1976, 1982	1988, 1989, 1992	2010
Absconditella lignicola Vězda & Pišút	-	-	+	+ (2)
Acarospora fuscata (Nyl.) Arnold	+	-	-	-
Acrocordia gemmata (Ach.) A. Massal.	-	-	+	-
Agonimia repleta Czarnota & Coppins	-	-	-	+ (2)
Arthonia byssacea (Weigel) Almq.	-	-	+	-
Arthonia didyma Körb.	-	-	-	+ (1)
Arthonia mediella Nyl.	-	-	+	-
Arthonia ruana A. Massal.	-	-	+	+ (1)
Arthonia spadicea Leight.	-	-	+	+ (3)
Arthonia vinosa Leight.	-	-	+	+ (1)
Aspicilia cinerea (L.) Körb.	+	-	-	-
Bacidia rubella (Hoffm.) A. Massal.	+	-	+	+ (2)
Bacidia subincompta (Nyl.) Arnold	-	-	-	+ (2)
Biatora efflorescens (Hedl.) Räsänen	-	-	-	+ (1)
Biatora globulosa (Flörke) Fr.	-	-	+	-
Bilimbia sabuletorum (Schreb.) Arnold	-	-	-	+ (1)
Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw [*B. crispa* (Motyka) Brystek; *Alectoria crispa* Motyka; *A. positiva* (Gyeln.) Mot.]	+	+	-	-
Bryoria implexa (Hoffm.) Brodo & D. Hawksw. [*B. vrangiana* (Gyeln.) Brodo & D. Hawksw; *Alectoria vrangiana* Gyeln.]	-	+?	-	-
Bryoria subcana (Nyl. Ex Stizenb.) Brodo & D. Hawksw.	-	+	-	-
Buellia griseovirens (Turner & Borrer ex Sm.) Almb.	-	-	+	+ (1)
Buellia schaereri De Not.	-	-	+	-
Calicium salicinum Pers.	+	-	+	+ (1)
Calicium viride Pres.	-	+?	-	-

Candelariella vitellina (Hoff.) Müll. Arg.	+	-	-	-
Cetraria sepincola (Ehrh.)Ach.	-	+?	-	-
Cetrelia olivetorum (Nyl.) W.L. Culb. & C.F. Culb.	-	-	+	-
Chaenotheca brachypoda (Ach.) Tibell	-	-	+	-
Chaenotheca brunneola (Ach.) Müll. Arg.	-	-	-	+ (2)
Chaenotheca chlorella (Ach.) Müll. Arg.	-	-	+	-
Chaenotheca chrysocephala (Turner ex Ach.) Th. Fr.	-	-	+	+ (1)
Chaenotheca ferruginea (Turner ex Sm.) Mig.	-	-	+	+ (1)
Chaenotheca furfuracea (L.) Tibell	-	-	-	+ (1)
Chaenotheca stemonea (Ach.) Müll. Arg.	-	-	-	+ (1)
Chaenotheca xyloxena Nádv.	-	-	+	-
+*Chaenothecopsis pusilla* (Ach.) A.F.W. Schmidt	-	-	-	+ (1)
+*Chaenothecopsis savonica* (Räsänen) Tibell	-	-	-	+ (1)
Chrysothrix candelaris (L.) J. R. Laundon	-	-	+	-
Cladonia arbuscula (Wallr.) Flot. subsp. *squarrosa* (Wallr.) Ruoss	+	-	-	-
Cladonia cenotea (Ach.) Schaer.	-	-	+	+ (1)
Cladonia coniocraea (Flörke) Spreng.	-	-	+	+ (2)
Cladonia cornuta (L.) Hoffm.	-	+?	-	-
Cladonia crispata var. *crispata* (Ach.) Flot.	-	-	+	-
Cladonia deformis (L.) Hoffm.	+	-	-	-
Cladonia digitata (L.) Hoffm.	-	-	+	+ (1)
Cladonia furcata (Huds.) Schrad. subsp. *furcata*	+	-	-	-
Cladonia gracilis (L.) Willd.	+	-	-	-
Cladonia macilenta Hoffm.	+	-	+	+ (1)
Cladonia ochrochlora Flörke	-	-	+	+ (1)
Cladonia phyllophora Hoffm.	+	-	-	-
Cladonia pyxidata (L.) Hoffm.	+	-	-	-
Cladonia squamosa (Scop.) Hoffm.	+	-	-	-
**Clypeococcum hypocenomycis* D. Hawksw.	-	-	+	+ (1)
Dimerella pineti (Ach.) Vězda	-	-	+	+ (3)
Evernia divaricata (L.) Ach.	-	+?	-	-
Evernia prunastri (L.) Ach.	+	-	+	+ (1)
Flavoparmelia caperata (L.) Hale	+	-	-	-
Graphis scripta (L.) Ach.	-	-	+	+ (2)
Gyalecta truncigena (Ach.) Hepp	-	-	+	+ (1)
Hypocenomyce anthracophila (Nyl.) P. James & Gotth. Schneid.	-	-	+	-
Hypocenomyce caradocensis (Leight. ex Nyl.) P. James & Gotth. Schneid.	-	-	+	-
Hypocenomyce scalaris (Ach. Ex Lilj.) M. Choisy	+	-	+	+ (1)
Hypogymnia physodes (L.) Nyl.	+	+	+	+ (2)
Hypogymnia tubulosa (Schaer.) Hav.	+	+	+	+ (2)
Imshaugia aleurites (Ach.) S.L.F. Meyer	-	-	+	+ (1)
Lecanora albella (Pers.) Ach.	+	-	-	-
Lecanora albellula (Nyl.) Th. Fr.	-	-	+	+ (1)
Lecanora argentata (Ach.) Malme	-	-	+	+ (2)
Lecanora carpinea (L). Vain.	+	-	-	+ (1)

Lecanora chlarotera Nyl.	+	-	-	-
Lecanora conizaeoides Nyl. ex Cromb.	-	-	+	+ (2)
Lecanora intumescens (Rebent.) Rabenh.	-	-	+	-
Lecanora pulicaris (Pers.) Ach.	+	-	+	+ (1)
Lecanora subrugosa Nyl.	-	+?	-	-
Lecanora varia (Hoffm.) Ach.	-	+?	-	-
Lecidella elaeochroma (Ach.) M. Choisy	+	-	+	+ (1)
Lepraria elobata Tønsberg	-	-	+	+ (2)
Lepraria incana (L.) Ach.	-	-	+	+ (3)
Lepraria jackii Tønsberg	-	-	+	+ (1)
Lepraria lobificans Nyl.	-	-	+	+ (3)
**Lichenoconium erodens* M.S. Christ & D. Hawksw.	-	-	+	+ (2)
**Lichenoconium lecanorae* (Jaap) D. Hawksw.	-	-	-	+ (1)
Lobaria pulmonaria (L.) Hoffm.	-	+?	-	-
Melanelixia fuliginosa (Fr. ex Duby) O. Blanco et al. subsp. *glabratula* (Lamy) J.R. Laundon	+	-	+	+ (1)
Melanohalea exasperatula (Nyl.) O. Blanco et al.	-	+?	-	-
Menegazzia terebrata (Hoffm.) A. Massal.	+	-	+	-
Micarea adnata Coppins	-	-	-	+ (1)
Micarea botryoides (Nyl.) Coppins	-	-	-	+ (2)
Micarea denigrata (Fr.) Hedl.	-	-	+	-
Micarea hedlundii Coppins	-	-	-	+ (1)
Micarea melaena (Nyl.) Hedl.	-	-	+	+ (1)
Micarea micrococca (Körb.) Gams ex Coppins	-	-	+	+ (3)
Micarea misella (Nyl.) Hedl.	-	-	+	+ (2)
Micarea nigella Coppins	-	-	-	+ (1)
Micarea prasina Fr.	-	+	+	+ (3)
**Monodictys epilepraria* Kukwa & Diederich	-	-	-	+ (2)
Mycoblastus fucatus (Stirt.) Zahlbr.	-	-	+	+ (1)
[+]*Mycocalicium subtile* (Pers.) Szatala	-	-	-	+ (1)
Ochrolechia sp.	-	-	+	-
Opegrapha rufescens Pers.	-	+	-	-
Opegrapha varia Pers.	-	-	+	+ (1)
Opegrapha viridis (Ach.) Nyl.	-	-	+	-
Opegrapha niveoatra (Borrer) Laundon	-	-	+	+ (3)
Parmelia saxatilis (L.) Ach.	-	-	+	+ (1)
Parmelia sulcata Taylor	-	-	+	+ (1)
Parmeliopsis ambigua (Wulfen) Nyl.	+	-	+	+ (1)
Peltigera praetextata (Flörke ex Sommerf.) Zopf	+	-	+	-
Pertusaria albescens (Huds.) M. Choisy & Werner	+	-	-	-
Pertusaria amara (Ach.) Nyl.	-	-	+	+ (1)
Pertusaria coccodes (Ach.) Nyl.	-	-	+	-
Pertusaria coronata (Ach.) Th. Fr.	-	-	+	-
Pertusaria hemisphaerica (Flörke) Erichsen	-	-	+	-
Pertusaria leioplaca DC.	-	-	+	-
Pertusaria pertusa (Weigel) Tuck.	-	-	+	-

Phaeophyscia orbicularis (Neck.) Moberg	-	+?	-	-
Phlyctis argena (Spreng.) Flot.	+	-	+	+ (1)
Physcia adscendens H. Olivier	-	+?	-	+ (1)
Physcia aipolia (Ehrh. ex Humb) Fürnr.	-	+?	-	-
Physcia stellaris (L.) Nyl.	-	-	+	-
Physcia tenella (Scop.) DC.	-	-	+	-
Placynthiella dasaea (Stirt.) Tønsberg	-	-	+	+ (2)
Placynthiella icmalea (Ach.) Coppins & P. James	-	-	+	+ (3)
Placynthiella oligotropha (Vain.) Coppins & P. James	-	+?	-	-
Placynthiella uliginosa (Schrad.) Coppins & P. James	+	-	+	-
Platismatia glauca (L.) W.L. Culb. & C.F. Culb.	+	+	+	-
Porina aenea (Wallr.) Zahlbr.	-	-	+	+ (3)
Porina leptalea (Durieu & Mont.) A.L. Sm.	-	-	+	+ (2)
Porpidia crustulata (Ach.) Hertel & Knoph	+	-	-	-
Porpidia tuberculosa (Sm.) Hertel & Knoph	-	-	+	-
Pseudevernia furfuracea (L.) Zopf	+	+	+	+ (2)
Psilolechia clavulifera (Nyl.) Coppins	-	-	+	+ (2)
Pyrenula nitida (Weigel) Ach.	-	-	+	+ (1)
Ramalina farinacea (L.) Ach.	+	-	-	+ (1)
Ramalina pollinaria (Westr.) Ach.	-	-	+	-
Rhizocarpon distinctum Th. Fr.	+	-	-	-
Ropalospora viridis (Tønsberg) Tønsberg	-	-	+	+ (1)
Scoliciosporum chlorococcum (Graeve ex Stenh.) Vězda	+	-	+	+ (1)
Thelotrema lepadinum (Ach.) Ach.	-	-	+	-
Trapelia obtegens (Th. Fr.) Hertel	-	-	+	-
Trapeliopsis flexuosa (Fr.) Coppins & P. James	-	-	-	+ (1)
Trapeliopsis granulosa (Hoffm.) Lumbsch	-	-	+	+ (2)
**Tremella cladoniae* Diederich & M.S. Christ	-	-	-	+ (2)
**Tremella lichenicola* Diederich	-	-	+	+ (1)
Tuckermanopsis chlorophylla (Willd.) Hale	+	-	+	-
Usnea ceratina Ach.	+	-	-	-
Usnea filipendula Stirt. [*U. hirtella* Motyka]	+	+	+	-
Usnea hirta (L.) Weber ex F.H. Wigg.	-	+	-	-
Usnea rigida (Ach.) Motyka [*U. glauca* Motyka]	-	+?	-	-
Usnea subfloridana Stirt. [*U. comosa* (L.) Vain]	+	+	-	-
Verrucaria dolosa Hepp.	-	-	-	+ (1)
Vulpicidia pinastri (Scop.) J.-E. Mattsson & M.J. Lai	-	+	-	-
Xanthoparmelia conspersa (Ehrh. ex Ach.) Hale	+	-	-	-
Xanthoria parietina (L.) Th. Fr.	-	-	+	-

Found in years: 1960 – acc. to Nowak (1960); 1967, 1976, 1982 – acc. to Halicz & Cieśliński (1967), Bystrek & Cieśliński (1976), Cieśliński & Bystrek (1982); 1988, 1989, 1992 – historical herbarial materials of Rugała, Stępień, Toborowicz, Cieśliński (1988, 1989) and acc. to Cieśliński & Toborowicz (1992); ? – data probably of Libera (1975).
Frequency of species: 1 – rare; 2 – scattered; 3 – common; * – lichenicolous fungus; + – saprobic fungus.

During the studies conducted in 2010 79 species were found on the examined area. In total (in the past and at present) 152 species of lichens, lichenicolous and saprobic fungi were found. There is currently no confirmation of 73 species, 48 of which have probably disappeared from the area of the reserve. Some of them were already considered to be extinct in the 90s of the XX century (Cieśliński & Toborowicz 1992), for example *Evernia divaricata, Lobaria pulmonaria, Flavoparmelia caperata*, *Ramalina farinacea*, species of *Bryoria* and *Usnea* genus. Others were then on single sites. Among the species that currently have not been confirmed and which may be considered to be extinct in the area are for example: *Acrocordia gemmata, Arthonia byssacea, A. mediella, Cetraria sepincola, Cetrelia olivetorum, Chrysothrix candelaris, Chaenotheca brachypoda, Lecanora intumescens, Menegazzia terebrata, Opegrapha rufescens, O. viridis, Peltigera praetextata, Ramalina pollinaria, Tuckermanopsis chlorophylla, Thelotrema lepadinum* and the species of *Pertusaria* genus (Tab. 1). Some of the epigheic and epilithic lichens should probably be listed as extinct. These species were already no longer found in the reserve in the 90s of the XX century. Due to the largely prevalent shading conditions in the forest and high forest floor layer, these species do not have appropriate locations for development.

25 species were considered to be present in the study area including: *Buellia schaererii, Chaenotheca chlorella, Ch. xyloxena, Hypocenomyce antracophila, H. caradocensis, Lecania globulosa, Lecanora chlarotera, L. subrugosa, L. varia, Pertusaria albescens, Phaeophyscia orbicularis, Physcia stellaris, Placynthiella uliginosa, Platismatia glauca, Ramalina farinacea, Xanthoria parietina, Porpidia tuberculosa* and *Trapelia obtegens.*

At present 79 species of lichens, lichenicolous and saprobic fungi have been found in the studied reserve. Most are epiphytes and epixilites. Only two species were growing on rocks: *Dimerella pineti* and *Verrucaria dolosa*. There was no lichen on soil.

A group of 59 species were found in the past and has now been confirmed. Most of them are very rare and scattered lichens on the study area (Tab. 1). Among these are some species, which are endangered in Poland (Cieśliński et al. 2006), for example: *Bacidia rubella, Calicium salicinum, Evernia prunastri, Gyalecta truncigena, Pyrenula nitida* and *Psilolechia clavulifera*. Not many species may be considered to be common in the study area.

As a result of the present study 20 species previously not reported in the biota of "Świnia Góra" reserve were found (Tab.1). They grow on decaying wood, bark of trees and on rock.

Within a few decades the biota of lichens and lichenicolous fungi of "Świnia Góra" reserve has been significantly impoverished. During the present study more than 70 species have not been confirmed. The species that have become extinct in the study area are mainly epiphytes with fruticose and foliose thallus, under legal protection. Currently, the species of *Bryoria, Cetraria* and *Usnea* genus have not been found (Tab. 1). Many species, which have become extinct in the reserve, belonged to lichens of the Critically Endangered (CR) category and the Endangered (EN) category in Poland (Cieśliński et al. 2006), eg: *Usnea ceratina, U. rigida, Menegazzia terebrata, Evernia divaricata, Chrysothrix candelaris, Bryoria implexa* and *B. subcana*. Some of them are Regionally Extinct (RE), or Critically Endangered and Endangered, also in large forest areas adjacent to the reserve, eg Góry Świętokrzyskie Mts, Kozienicka Forest (Cieśliński & Łubek 2003; Cieśliński 2003), for example: *Lecanora albella, Arthonia byssacea, Chaenotheca brachypoda, Chrysothrix candelaris, Opegrapha rufescens, Pertusaria coronata* and *P. pertusa*. Currently in the lichens' biota of the investigated reserve there is no species of category Critically Endangered (CR), and groups of species of the categories Endangered (EN) and Vulnerable (VU) have significantly decreased.

Among the 30 species documented in "Świnia Góra" reserve, that are under strict and partial protection (Journal of Laws 2004 No. 168, entry 1765), the majority have now not been confirmed. Extinct are for example: *Lobaria pulmonaria, Flavoparmelia caperata, Evernia divaricata, Chrysothrix candelaris, Peltigera praetextata* and *Menegazzia terebrata*. Only the following are now to be found: *Evernia prunastri, Hypogymnia tubulosa, Imshaugia aleurites, Melanelixia fulginosa* subsp. *glabratula, Parmelia saxatilis, Parmeliopsis ambigua* and *Pseudevernia furfuracea.*

From the available information concerning the occurrence of lichens on different types of substrates it may be established that the biota of each substrates has been reduced (Fig. 2). In the past, most species occurred on the bark of trees such as: oak – more than 40 species, sycamore – 25, hornbeam – 18 and larch – 16. The biota of these trees incurred the greatest losses, in the cases of oak and hornbeam about 70% of species became extinct, sycamore and larch – 60%. Other trees have a comparable number of epiphytes comparable with the numbers of the

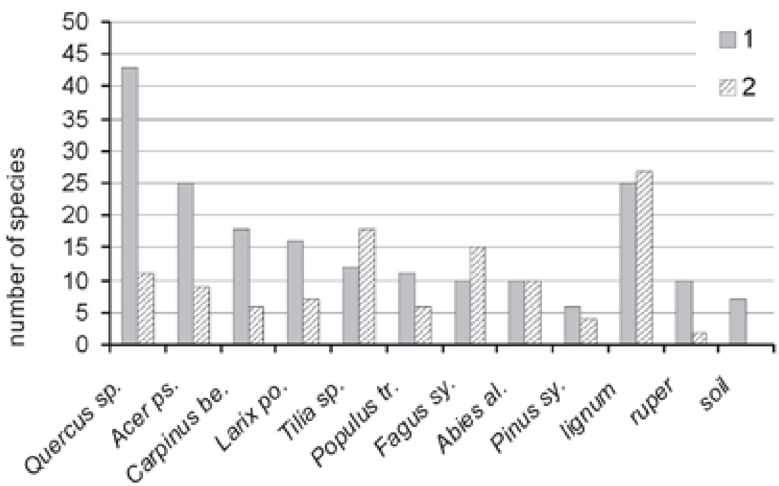

Fig. 2. Number of species found in the past and at the present on different substrates in the "Świnia Góra" Nature Reserve
1 – species found in the past; 2 – species found at present.

past. Among them of especial interest are: *Agonimia repleta, Arthonia spadicea, Bacidia rubella, Bacidia subincompta, Biatora efflorescens, Chaenotheca stemonea, Gyalecta truncigena, Porina leptalea* and *Pyrenula nitida.*

Among the different types of substrates available for lichens decaying wood deserves special attention (Fig. 2). Both in the past and at present a similar number of species was recorded. Lack of direct human influences permits the logs and stumps lying on the forest floor to decompose naturally. They represent important habitat for epixylic lichens. It is confirmed by valuable species that have been currently found eg: *Chaenotheca brunneola, Micarea adnata, M. botryoides, M. hedlundii* and *M. nigella*. The largest losses have been observed in biota growing on rocks and soil.

CONCLUSIONS

Studies conducted in "Świnia Góra" reserve in 2010, confirm the negative changes that occur in the natural environment. Despite strict protection of the area, species diversity of biota has significantly declined compared to data from the years 1960–1992. A similar phenomenon also occurs in other groups of organisms. This situation is probably affected by several factors. Cutting of trees, which is conducted in forests located in the vicinity of the reserve, causes thinning of the natural buffer zone. Thus the gas and dust atmosphere pollution from nearby buildings and local roads more easily penetrate to the interior of the reserve. The specific microclimate and high atmospheric humidity that prevail in the reserve facilitates retention of pollutants, including those carried by wind for long distances. Other negative factors probably are tourism and penetration by the local people. The reserve is located near the road used by Forest Service vehicles and vehicles transporting felled timber.

Despite the significant losses, lichen biota occurring here is still very interesting. It many very rare species of lichens in Poland were found here, including those having the indicators of lowland forests (Czyżewska & Cieśliński 2003), for example: *Agonimia repleta, Arthonia didyma, A. vinosa, Bacidia rubella, Chaenotheca brunneola, Gyalecta truncigena, Micarea adnata, M. hedlundii, M. melaena, Porina leptalea* and *Psilolechia clavulifera.* In order to protect other natural environment resources of the reserve, forest management would be reduced in areas adjacent. This area should be permanently monitored for the condition of biota of lichens and lichenicolous fungi.

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LICHENS OF THE "KRUCZY KAMIEŃ" NATURE RESERVE IN THE GÓRY KAMIENNE MOUNTAINS (CENTRAL SUDETY MOUNTAINS)

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Abstract. The paper present the results of lichenological research carried out in the 'Kruczy Kamień' nature reserve in the Góry Kamienne Mountains in the Sudety Mts. The 'Kruczy Kamień' is floral-landscape reserve including the upper part of the mountain called Krucza Skała (alt. 681 m) with its southern slope. 112 species of lichens have been found in the reserve. 18 of these lichens are protected in Poland. Some of the species, e.g. *Arthonia calcarea, Leprocaulon microscopicum, Parmelia omphalodes, Pertusaria aspergilla, Lasallia pustulata* are very rare or threatened in Poland. *Caloplaca chrysodeta* is a newcomer in the Sudety Mts.
Due to the legal protection of the reserve, lichen biota has developed uninterruptedly for a very long period of time, which also contributed to an increase in its biodiversity.

Key words: lichenized fungi, protection species, nature reserve, Sudety Mts, Poland

INTRODUCTION

The 'Kruczy Kamień' nature reserve is situated in the Central Sudety Mts, in the Góry Kamienne Mts, in the central southern part of the Góry Krucze Mts. It was established in 1954 and covers a small area of 10.21 ha (Monitor Polski no. 46, item 651/1955). The 'Kruczy Kamień' is a floral-landscape reserve including the upper part of the mountain called Krucza Skała (alt. 681 m) with its southern slope, falling with a steep cliff, of about 100 metres high to the Dolina Krucza Valley. The Krucza Skała Mt is a mountain of a very interesting geological structure. It is formed by acidic, extrusive volcanic rocks, described as orthoclase porphyries (trachytes) or rhyolites (Grocholski & Jarzmański 1975), intrusively perforating sedimentary rocks of rotliegend, and deeper underlying Upper Carbon conglomerates (Staffa 1996). The rocks are exposed on the southern and western slopes forming picturesque rocks and high tower rocks reaching 30 m.

Steep porphyry walls of south-western exposition are a convenient habitat for thermophilic plants development. The presence of numerous rare and protected species was noted there, such as *Asplenium adiantum nigrum, Allium montanum*, *Carlina acaulis, Festuca pallens, Frangula alnus*, *Jovibarba sobolifera, Rosa gallica, Sedum maximum* and *Vincetoxicum officinale.* The mountain is entirely overgrown with spruce monoculture with a small addition of *Betula pendula*, *Fagus sylvatica*, *Quercus robur*, *Pinus sylvestris,* as well as *Sorbus aucuparia* and *Acer pseudoplatanus* on steeper sites. In 1995, entomologists from University of Wrocław undertook there the restoration of the Apollo butterfly *Parnassins apollo silesianus,* which is rare in Poland and had been lost in the Sudety Mountains (Staffa 1996).

The Krucza Skała Mt with the Dolina Krucza Valley were previously a popular destination of excursions and walks for the people living in nearby Lubawka (Staffa 1996). A no longer existing view pavilion called Belweder had been constructed under the peak of the mountain. However, the viewpoint with a bench situated on it and the steep cliff edges protected with a railing still exist at the peak. The green tourist route from Lubawka to Kruszów runs beside the peak of the mountain. Moreover, on the northern slopes of the Krucza Skała Mt, a ski jump was built in 1924, and it is currently the biggest jump in the Sudety Mts after subsequent modernisations and repairs. Unfortunately, the absolute lack of utilisation contributes to gradual dilapidation of the object.

The biota of lichens of the Krucza Skała Mt, and also of the 'Kruczy Kamień' reserve, has not been elaborated so far. There is also a lack of any papers concerning the Góry Krucze Mountains and the Góry Kamienne Mountains lichens in the literature available. Thus, the present paper gives the first, valuable information concerning the current lichen biota of that area.

MATERIAL AND METHODS

The field works were conducted in September 2011. The occurrence of species was recorded on various types of substrates: soil, humus, wood, stones and trees bark.

The standard methods of morphological, anatomical and chemo taxonomical analyses were used in the laboratory procedures. Lichens were determined based on the keys established by Nowak & Tobolewski (1975), Smith et al. (2009), Wirth (1995), and different genera of monographs, e.g. Czarnota (2007). The species difficult to analyse with routine methods (e.g. from *Lepraria* genus) were identified based on the analyses of chemical composition obtained from thin layer chromatography (TLC) (Orange et al. 2001). The nomenclature of lichens was accepted following case studies by Smith et al. (2009), and Diederich et al. (2011). The information concerning possible legal status and genus of inhabited bases were included in the list of species elaborated.

LIST OF TAXA

Protection status in Poland according to Regulation of the Minister of the Environment on species of wild growing fungi under protection (2004). The threat to lichens in Poland according to Cieśliński et al. (2006) and in Polish part of the Sudety Mts according to Kossowska (2003). In the text the asterisk (*) indicates a lichenicolous lichen.

The status of threatened lichens according to The Red List Categories: RE – Regionally Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern.

***Acarospora** fuscata* (Schrad.) Th. Fr. – on volcanic rock.

***Amandinea** punctata* (Hoffm.) Coppins & Scheid. – on volcanic rock and bark of *Acer pseudoplatanus.*

***Arthonia** calcarea* (Sm.) Ertz & Diederich – on calcite on sandstone rock; CR/RE.

A. radiata (Pers.) Ach. – on bark of *Acer pseudoplatanus.*

***Aspicilia** caesiocinerea* (Nyl. ex. Malbr.) Arnold – on volcanic rock; −/VU.

A. cinerea (L.) Körb. – on volcanic rock.

***Buellia** aethalea* (Ach.) Th. Fr. – on volcanic rock.

***Caloplaca** chrysodeta* (Räsänen) Dombr. – on sandstone rock.

C. cirrochroa (Ach .) Th. Fr. – on calcite on sandstone rock; NT/−.

C. flavocitrina (Nyl.) H. Olivier – on calcite on sandstone rock.

C. holocarpa (Ach.) A. E. Wade – on calcite on sandstone rock.

C. saxicola (Hoffm.) Nordin – on calcite on sandstone rock.

***Candelariella** vitellina* (Hoffm.) Miill. Arg. – on volcanic rock.

C. xanthostigma (Ach.) Lettau – on bark of *Fagus sylvatica*.

***Cetraria** islandica* (L.) Ach.– on soil and humus between rocks, partially protected species, threat category VU/−.

***Chrysothrix** chlorina* (L.) J.R. Laundon – on volcanic rock.

***Cladonia** arbuscula* (Wallr.) Flot. subsp. *arbuscula* – on soil in grassland and on soil and humus between rocks, partially protected species.

C. chlorophaea (Sommerf.) Spreng. s. lat. – on soil and humus between rocks.

C. coccifera (L.) Willd. s. lat. – on soil and humus between rocks.

C. coniocraea (Flörke) Spreng. – on soil and humus between rocks.

C. crispata (Ach.) Flot. – on soil in grassland and on soil and humus between rocks.

C. digitata (L.) Hoffm. – on soil and humus between rocks.

C. fimbriata (L.) Fr. – on soil and humus between rocks and on wood in the grassland.

C. furcata (Huds.) Schrad. subsp. *furcata* – on soil in grassland and on soil and humus between rocks.

C. macilenta Hoffm. – on soil and humus between rocks.

C. pleurota (Flörke) Schaer. – on soil and humus between rocks.

C. polydactyla (Flörke) Spreng. – on soil and humus between rocks.

C. portentosa (Dufour) Coem. – on soil in grassland and on soil and humus between rocks, partially protected species.

C. ramulosa (With.) J.R. Laundon – on soil in grassland and on soil and humus between rocks: –/VU.

C. rangiferina (L.) F. H. Wigg. – on soil in grassland and on soil and humus between rocks, partially protected species.

C. rei Schaer. – on soil in grassland and on soil and humus between rocks.

C. squamosa Hoffm. – on soil and humus between rocks.

C. subulata (L.) F. H. Wigg. – on soil in grassland and on soil and humus between rocks.

C. uncialis (L.) F. H. Wigg. – on soil in grassland and on soil and humus between rocks.

C. verticillata (Hoffm.) Schaer. – on soil and humus between rocks.

***Coenogonium** pineti* (Schrad. ex Ach.) Lūcking & Lumbsch – on bark of *Acer pseudoplatanus*.

***Collema** auriforme* (With.) Coppins & J.R. Laundon – on mosses and on sandstone rock; NT/VU.

C. tenax (Sw.) Ach. – on sandstone rock.

***Diploschistes** gypsaceus* (Ach.) Zahlbr. – on calcite on sandstone rock; VU/LC.

**D. muscorum* (Scop.) R. Sant. – on thallus of *Cladonia verticillata* growing on soil and humus between rocks.

D. scruposus (Schreb.) Norman – on volcanic rock.

***Diplotomma** alboatrum* (Hoffm.) Flot. – on calcite on sandstone rock; VU/–.

***Hypocenomyce** scalaris* (Ach.) M. Choisy – on volcanic rock and bark of *Betula pendula, Picea abies* and *Pinus sylvestris*.

***Hypogymnia** physodes* (L.) Nyl. – on bark of *Acer pseudoplatanus*, *Betula pendula, Fagus sylvatica, Picea abies* and *Pinus sylvestris*.

H. tubulosa (Schaer.) Hav. – on bark of *Picea abies*, strictly protected species; NT/VU.

***Imshaugia** aleurites* (Ach.) S.L.F.Meyer – on bark of *Pinus sylvestris*, strictly protected species; –/VU.

***Lasallia** pustulata* (L.) Mérat – on volcanic rock, strictly protected species; EN/–.

***Lecanora** albescens* (Hoffm.) Flörke – on calcite on sandstone rock.

L. argentata (Ach.) Malme – on bark of *Acer pseudoplatanus*.

L. conizaeoides Crombie – on wood and bark of *Betula pendula, Picea abies* and *Pinus sylvestris*.

L. dispersa (Pers.) Sommerf. – on calcite on sandstone rock.

L. polytropa (Hoffm.) Rabenh. – on volcanic rock.

L. rupicola (L.) Zahlbr. – on volcanic rock.

L. varia (Hoffm.) Ach. – on bark of *Fagus sylvatica*.

***Lecidea** fuscoatra* (L.) Ach. – on volcanic rock.

***Lecidella** stigmatea* (Ach.) Hertel & Leuckert – on calcite on sandstone rock.

***Lepraria** caesioalba* (B. de Lesd.) J. R. Laundon – on volcanic rock.

L. incana (L.) Ach. – on bark of *Betula pendula, Fagus sylvatica, Picea abies* and *Pinus sylvestris*.

L. elobata Tønsberg – on bark of *Acer pseudoplatanus*, *Fagus sylvatica, Betula pendula, Picea abies* and *Pinus sylvestris*.
L. lobificans Nyl. – on bark of *Acer pseudoplatanus*, *Betula pendula, Picea abies* and *Pinus sylvestris*.
L. membranacea (Dicks.) Vain. – on volcanic rock.
Leprocaulon *microscopicum* (ViII.) Gams ex D. Hawksw. – on volcanic rock, soil, humus and mosses between rocks; RE/RE.
Leptogium *gelatinosum* (With.) J.R. Laundon – on mosses and on calcite on sandstone rock; VU/–.
Lichenomphalia *umbellifera* (L.: Fr.) Redhead, Lutzoni, Moncalvo & Vilgalys – on humus and mosses on volcanic rocks; NT/–.
Melanelixia *fuliginosa* (Fr. ex Duby) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch subsp. *fuliginosa* – on volcanic rock and bark of *Acer pseudoplatanus*, strictly protected species.
Melanelia *disjuncta* (Erichsen) Essl. – on volcanic rock, strictly protected species; VU/–.
Micarea *denigrata* (Fr.) Hedl. – on wood in grassland.
M. lithinella (Nyl.) Hedl. – on volcanic rock.
M. peliocarpa (Anzi) Coppins & R. Sant. – on wood in grassland; –/VU.
M. prasina Fr. – on bark of *Pinus sylvestris*.
Neofuscelia *loxodes* (Nyl.) O. Blanco *et al.* – on volcanic rock.
Parmelia *omphalodes* (L.) Ach. – on volcanic rock, strictly protected species; EN/VU.
P. saxatilis (L.) Ach. – on volcanic rock, strictly protected species.
P. sulcata Taylor – on bark of *Fagus sylvatica*.
Parmeliopsis *ambigua* (Wulfen) Nyl. – on bark of *Betula pendula*, strictly protected species;
Peltigera *rufescens* (Weiss) Humb. – on soil in grassland, strictly protected species.
Pertusaria *aspergilla* (Ach .) J.R. Laundon – on volcanic rock; VU/–.
Physcia *adscensens* H. Olivier – on bark of *Acer pseudoplatanus* and *Fagus sylvatica*.
P. caesia (Hoffm .) Fürnr. – on sandstone rock.
P. dubia (Hoffm.) Lettau – on sandstone rock.
P. tenella (Scop.) DC. – on bark of *Acer pseudoplatanus* and *Fagus sylvatica*.
Placynthiella *dasaea* (Stirt.) Tönsberg – on volcanic rock, wood, soil and humus between rocks.
P. icmalea (Ach.) Coppins & P. James – on volcanic rock, wood, soil and humus between rocks.
P. oligotropha (J.R. Laundon) Coppins & P. James – on soil and humus between rocks.
P. uliginosa (Schrad.) Coppins & P. James – on soil and humus between rocks.
Porina *aenea* (Wallr.) Zahlbr. – on bark of *Acer pseudoplatanus*.

P. chlorotica (Ach.) Müll. Arg. – on volcanic rock.
Porpidia *crustulata* (Ach.) Hertel & Knoph – on volcanic rock.
P. tuberculosa (Srn.) Hertel & Knoph – on volcanic rock.
Protoparmelia *badia* (Hoffm.) Hafellner – on volcanic rock; NT/−.
Pseudevernia *furfuracea* (L.) Zopf – on bark of *Picea abies*, strictly protected species;
Psilolechia *lucida* (Ach.) M. Choisy – on sandstone rock; LC/−.
Ramalina *pollinaria* (Westr.) Ach. – on volcanic rock, strictly protected species; VU/EN.
Rhizocarpon *geographicum* (L.) DC. – on volcanic rock.
Rh. lecanorinum Anders – on volcanic rock; VU/−.
Rh. reductum Th. Fr. – on volcanic rock.
Sarcogyne *regularis* Körb. – on calcite on sandstone rock.
Scoliciosporum *chlorococcum* (Stenh.) Vězda – on bark of *Picea abies*.
S. umbrinum (Ach.) Arnold – on volcanic rock.
Trapelia *coarctata* (Turner ex Sm.) M. Choisy – on volcanic rock.
T. glebulosa (Sm.) J.R. Laundon – on volcanic rock.
T. obtegens (Th. Fr.) Hertel – on volcanic rock.
T. placodioides Coppins & P. James – on volcanic rock.
Trapeliopsis *gelatinosa* (Flörke) Coppins & P. James – on soil and humus between rocks; NT/VU.
T. granulosa (Hoffm.) Lumbsch – on soil and humus between rocks.
T. pseudogranulosa Coppins & P. James – on soil and humus between rocks.
Umbilicaria *hirsuta* (Sw. ex Westr.) Hoffm. – on volcanic rock and bark of *Fagus sylvatica*, strictly protected species; VU/−.
Xanthoria *candelaria* (L.) Th. Fr. – on bark of *Fagus sylvatica*.
X. parietina (L.) Th. Fr. – on bark of *Fagus sylvativa*.
Xanthoparmelia *conspersa* (Ach.) Hale – on volcanic rock;
X. pulla (Ach.) O. Blanco *et al.* – on volcanic rock, strictly protected species; NT/−.
X. stenophylla (Ach.) Ahti & D. Hawksw. – on volcanic rock, strictly protected species.

RESULTS AND DISCUSSION

As a result of examinations conducted in the 'Kruczy Kamień' reserve, the presence of 112 lichen taxa was noted, including 59 growing on rocks, 25 on trees bark, 28 on the soil and humus, and 8 on other types of bases (wood, mosses, lichens).

The most abundant, and at the same time most interesting group of lichens observed in the area of the reserve are epilithic lichens. Due to a complicated geological structure, the reserve is characterised by the presence of rocks of different age, origin, chemical composition and reaction. Therefore, various, when regarding the base preferences, epilithic lichens were noted. Species of fertile habitats, preferring rocks rich in mineral compounds are predominantly (Wirth 1992; Fabiszewski & Szczepańska 2010), of neutral or slightly acidic reaction (pH 5-7), such as *Acarospora fuscata*, *Aspicilia caesiocinerea, Buellia aethalea, Xanthoparmelia conspersa, Neofuscelia loxodes* and *Physcia dubia.* Besides them, also taxa connected with poorer and more acidic rocks are observed, e.g. *Chrysothrix chlorina*, *Lecanora polytropa*, *Parmelia omphalodes*, *Porina chlorotica*, *Porpidia crustulata* and *Rhizocarpon geographicum.* In the places of porphyries contact with rotliegend rocks, some small sparite interstratified rock are observed. Calciphyte lichens grow on them, preferring clearly the base of basic reaction, such as *Caloplaca flavocitrina*, *C. holocarpa, C. saxicola, Collema auriforme, C. tenax, Diploschistes gypsaceus, Diplotomma alboatrum, Lecanora albescens, Leptogium gelatinosum* and *Sarcogyne regularis.* Among calciphyte lichens, a species new for the Sudetes – *Caloplaca chrysodeta* – was noted.

In the reserve area, within rock outcrops, numerous terrestrial lichens are also present, growing especially in cracks on the layer of humus or plant debris. They are mainly taxa from *Cladonia, Placynthiella* and *Trapeliopsis* genera. Among the terrestrial lichens *Cladonia verticillata* were observed there, with small thallus of *Diploschistes muscorum*. This is a new type of substrata for this lichenicolous lichen (Czyżewska & Kukwa 2009). The biota of epilithic lichens, due to dominance in spruce tree stand, is neither too abundant nor diversified. The common and air contamination tolerant species are predominant, e.g. *Coenogonium pineti, Hypocenomyce scalaris, Lecanora conizaeoides, Lepraria* spp., *Micarea prasina* and *Scolisiosporum chlorococcum*. An interesting detail is *Umbilicaria hirsuta* rock species growing on beech bark, on the viewpoint of the Krucza Skała Mt. The reason of that untypical phenomenon is probably considerable saturation of the bark with fine rock particles.

The presence of 18 species legally protected in Poland was noted in the area of the reserve. A few of them belong to relatively rare and endangered in the country and in the Sudetes, e.g. *Melanelia disjuncta, Parmelia omphalodes, Ramalina pollinaria, Xanthoparmelia pulla* and *X. stenophylla.* These lichens prefer specific conditions – high insolation and small habitat humidity, thus they develop best on the volcanic rocks of south-western exposition. Their populations are however partially endangered due to tourist movement. The tourist route runs through the Krucza Skała Mt. slope, and is frequently visited by the people living in nearby Lubawka. Moreover, the viewpoint on the peak, in addition causes tourists to stop, admire the views, and to climb the rocks. Therefore, the thalli are endangered by treading and are preserved in the best manner only in places less accessible to people.

In the area of the reserve, 21 species entered in 'Red list of the lichens in Poland' (Cieśliński et al. 2006) were noted, including categories LC – 1, NT – 7, VU – 9, EN – 2 and CR – 1. 11 of the recorded species are threatened in the Polish part of the Sudety Mts (Kossowska 2003). Moreover, in cracks of rock walls, *Leprocaulon microscopicum* has been found in one locality – the taxon previously considered extinct in Poland (RE category). It was known in the XIX century only from the Sudety Mts (Flotow 1850, Körber 1855). The detailed description of that species and its habitat is included in another paper of the author (Szczepańska 2012, in press). Also another taxon – *Pertusaria aspergilla,* deserves attention. That species was noted in the Sudety Mts only by Flotow (1850) on the area of Kotlina Jeleniogórska Valley. Thus, this currently its second site in the Sudetes and the first noted nowadays.

The lichen biota of the 'Kruczy Kamień' reserve is very precious and abundant. Over one hundred lichen species were noted in that small area, including numerous interesting, threatened and protected species in Poland. This growth concentration is connected with the extraordinary geological structure and presence of rocks of differentiated reaction, from slightly acidic, through neutral to alkaline ones. Moreover, the specific habitat conditions are present in the reserve, which is proved by the development there of thermophilic plants. Due to the south-western exposure aspect of rock walls of that area, characterised by a rather severe climate, species requiring warm and dry sites of Atlantic or subatlantic ranges have appeared there. Also the aesthetic values of rocks present in the reserve are significant. Because that area used to be the preferred destination of tourists and neighbouring residents, and also because of reserve protection, the porphyries rocks of the Krucza Skała Mt were not subjected to exploitation for industrial purposes. Lichen biota would have thus developed uninterruptedly for a very long period of time, which also probably contributed to an increase in its biodiversity.

Currently, despite tourist movement in the vicinity that in the reserve is quite considerable, lichens growing in the reserve seen to be endangered in a moderate extent. Steep rock walls are not penetrated by people, and thus habitats are stable and safe for further growth and development of differentiated lichen biota.

CONCLUSIONS

The paper present the results of lichenological research carried out in the 'Kruczy Kamień' nature reserve in the Góry Kamienne Mountains in the Central Sudety Mountains. The 'Kruczy Kamień' is very small, floral-landscape reserve including the upper part of the mountain called Krucza Skała (681 m) with its southern slope. The Krucza Skała Mt is a mountain of a very interesting geological structure. It is formed by acidic, extrusive volcanic rocks, sedimentary rocks of rotliegend, and Upper Carbon conglomerates. The rocks are exposed on southern and western slopes forming picturesque rocks and high tower rocks reaching 30 m. Steep volcanic walls are a convenient habitat for development of thermophilic plants. The mountain is entirely overgrown with spruce monoculture with a small addition of deciduous trees.

In the 'Kruczy Kamień' reserve 112 species of lichens have been found. Among them, 59 were growing on rocks, 25 on trees, 28 on the soil, 7 on wood or mosses and 1 on another lichen thallus. 18 of these lichens are protected in Poland, 21 are endangered in the country and 11 are threatened in the Polish part of the Sudety Mts. One taxon – *Caloplaca chrysodeta* is new to the area of the Sudety Mts. Two another species – *Leprocaulon microscopicum* and *Pertusaria aspergilla* are very interesting and rare in the Sudety Mts.

The lichen biota of the 'Kruczy Kamień' reserve is very precious and abundant. The quantity and diversity are connected with the extraordinary geological structure and presence of rocks of differentiated reaction. Because the area used to be the preferred destination of tourists and neighbouring residents, and also because of reserve protection, the volcanic rocks of the 'Krucza Skała' Mt were spared exploitation for industrial purposes. Lichen biota would have thus developed uninterruptedly for a very long period of time, which probably also contributed to an increase in its biodiversity.

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PROTECTED AND THREATENED LICHENS IN THE WZNIESIENIA ŁÓDZKIE LANDSCAPE PARK (CENTRAL POLAND)

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Abstract. This paper presents 55 species of protected and threatened lichens (30.22% of the total biota) found in the Wzniesienia Łódzkie Landscape Park, of which 26 species are strictly protected and 6 partially protected. The landscape park is also a refuge for 40 species of threatened lichens in Poland belonging to the following categories: CR – 3 lichen species, EN – 6, VU – 14, NT – 10, LC – 3, DD – 4.

Key words: lichenized fungi, conservation, threat, Wzniesienia Łódzkie Heights, Poland

INTRODUCTION

Landscape parks are a very good subject for the study of the biota of lichens. Landscape parks – in addition to national park and nature reserves – are a very valuable network of protected areas in Poland. These areas, representing as they do nearly all physical-geographical areas, have natural and cultural value and protect natural and anthropogenic ecosystems and the localities of rare and threatened species covered by legal protection (Symonides 2008).

There are a few landscape parks fully developed in lichenological terms such as Pszczewski Landscape Park in west Poland (Lipnicki 1991), Bolimowski Landscape Park in Central Poland (Czyżewska 1999, 2002, 2003a, b; Czyżewska et al. 2008), Kozienicki Landscape Park (Cieśliński 1978, 1997, 2007, 2008, 2009; Czyżewska & Cieśliński 2003; Czyżewska et al. 2008), and Knyszyński Landscape Park in north-east Poland (Bystrek & Kolanko 2000; Czyżewska et al. 2002; Czyżewska & Cieśliński 2003; see also Czyżewska 2003b, Czyżewska et al. 2008, Motiejūnaitė & Czyżewska 2008).

Among landscape parks that are fully documented lichenologically we should also include the Wzniesienia Łódzkie Landscape Park (WŁLP). Resources of protected and threatened lichens growing in the Wzniesienia Łódzkie Landscape Park are presented in this paper.

STUDY AREA

The study area according to Kondracki (2000) is located in Central Poland in the macroregion of the Wzniesienia Południowomazowieckie Heights, in the transition zone between the Niziny Środkowopolskie lowlands and the Wyżyna Małopolska upland, in the mesoregion of Wzniesienia Łódzkie Heights.

The study was conducted in the most representative part of the escarpment zone of Wzniesienia Łódzkie Heights covered by protection in the landscape park established on the 31st of December 1996. The area of WŁLP along with its buffer zone covers 10 767 ha. A piece of the park measuring 1 205 ha (Las Łagiewnicki Forest) lies within the borders of the city of Łódź, the remainder being between Łódź, Stryków and Brzeziny (Fig. 1). Within the landscape park the following other forms of conservation have been created: the Las Łagiewnicki Forest, Struga Dobieszkowska and Parowy Janinowskie nature reserves; 12 landscape-nature protected complexes, ecological lands and Natura 2000 Network – Buczyna Janinowska (uroczysko Janinów range), Wola Cyrusowa and Źródła Grzmiącej, and numerous nature monuments. The Wzniesienia Łódzkie Landscape Park encompasses a unique upland landscape of the escarpment zone of Wzniesienia Łódzkie Heights in Central Poland, which constitutes the northernmost extension of the southern Polish uplands, the spring areas of many rivers and streams with upland features and forest trees: *Fagus sylvatica*, *Abies alba, Acer pseudoplatanus* and *Picea abies* at the northern border of its geographical range.

Currently 28% of the park area is covered by natural and anthropogenic forest, habitats of epiphytic and epixylic lichens. The phytocoenoses itself regardless of its natural state bears traces of an impact of natural forest economic management (various forms of degeneration including the existence of *Pinus sylvestris* and *Betula pendula* in all phytocoenoses of deciduous forest).

The natural lichen habitats include old, over 100-year-old forests such as oak-linden-hornbeam forest *Tilio-Carpinetum* (in Las Łagiewnicki Forest and in the Tadzin and Janinów ranges), acidophilous beech forest *Luzulo pilosae-Fagetum* growing here at the northernmost extent of its geographical range which is preserved in the uroczysko Janinów range, mixed oak-pine forest *Querco roboris-Pinetum* – uroczysko Tadzin range, streamside alder-ash forest *Circaeo-Alnetum* which is well recognized in "Struga Dobieszkowska" reserve in the Mrożyca river valley and uroczysko Tadzin range. Only in Las Łagiewnicki Forest does acidophilous oak forest *Calamagrostio-Quercetum* occur growing in WŁLP at the eastern border of its geographical range (Kurowski ed. 1998).

The landscape park is also characterized by a large accumulation of boulders and stones – substrates for saxicolous lichens (Fig. 1).

MATERIAL AND METHODS

Data on protected and threatened lichens come from several sources from field studies conducted in the years 2004-2011, published literature (Kuziel & Halicz 1979; Hachułka 2005, 2007, 2011; Krzewicka & Hachułka 2008; Kukwa et al. 2012) and herbarium collections. The lichen materials were identified by routine lichenological methods. Voucher specimens are available at the Herbarium Universitatis Lodziensis (LOD-L). Lichen nomenclature follows Thüs & Schultz (2009) and Diederich et al. (2012).

PROTECTED LICHENS

The lichen biota of Wzniesienia Łódzkie Landscape Park has currently 182 taxa, of which 32 (17.58% of the total number) are under legal protection. Out of them there are 26 strictly protected and 6 partially protected (Tab. 1).

Table 1. Protected lichen species in the Wzniesienia Łódzkie Landscape Park
(after Ordinance of the Minister ... 2004)

Species under strict protection – ++, partial protection – +

Species	Status of protection in Poland	Substrate preferency	Number of localities
Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw.	++	epiphytic/epixylic	6
Cetrelia monachorum (Zahlbr.) W.L. Culb. & C.F. Culb.	++	epiphytic	1
Chrysothrix candelaris (L.) J. R. Laundon	++	epiphytic	1
Flavoparmelia caperata (L.) Hale	++	epiphytic	1
Hypogymnia tubulosa (Schaer.) Hav.	++	epiphytic	21
Melanelia disjuncta (Erichsen) Essl.	++	epilithic	2
Melanelixia fuliginosa (Duby) O. Blanco et al. subsp. *glabratula* (Lamy) J. R. Laundon	++	epiphytic	9
Melanelixia subaurifera (Nyl.) O. Blanco et al.	++	epiphytic	3
Melanohalea exasperatula (Nyl.) O. Blanco et al.	++	epiphytic	13
Parmelia saxatilis (L.) Ach.	++	epiphytic	41
Parmelina tiliacea (Hoffm.) Hale	++	epiphytic	2
Parmeliopsis ambigua (Wulfen) Nyl.	++	epiphytic/epixylic	18
Peltigera didactyla (With.) J. R. Laundon	++	epigeic	6
Platismatia glauca (L.) W.L. Culb. & C. F. Culb.	++	epiphytic	46
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	++	epiphytic	2
Pseudevernia furfuracea (L.) Zopf	++	epiphytic	27
Ramalina farinacea (L.) Ach.	++	epiphytic	1

Ramalina fraxinea (L.) Ach.	++	epiphytic	1
Ramalina pollinaria (Westr.) Ach.	++	epiphytic	4
Tuckermannopsis chlorophylla (Willd.) Hale	++	epiphytic	6
Tuckermannopsis sepincola (Ehrh.) Hale	++	epiphytic/epixylic	1
Usnea hirta (L.) F. H. Wigg.	++	epiphytic/epixylic	6
Vulpicida pinastri (Scop.) J.-E. Mattson & M. J. Lai	++	epiphytic	2
Xanthoparmelia loxodes (Nyl.) O. Blanco, A. Crespo, Elix, D. Hawksw. & Lumbsch	++	epilithic	3
Xanthoparmelia pulla (Ach.) O. Blanco et al.	++	epilithic	3
Xanthoparmelia stenophylla (Ach.) Ahti & D. Hawksw.	++	epilithic	5
Cetraria aculeata (Scherb.) Fr.	+	epigeic	3
Cetraria ericetorum Opiz	+	epigeic	1
Cetraria islandica (L.) Ach.	+	epigeic	5
Cladonia mitis (Sandst.)	+	epigeic	4
Cladonia rangiferina (L.) F. H. Wigg.	+	epigeic	1
Evernia prunastri (L.) Ach.	+	epiphytic	21

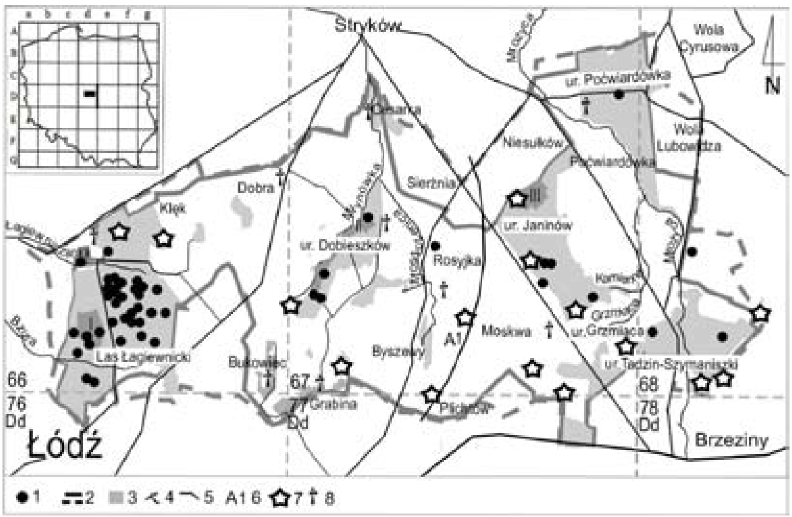

Fig. 1. Known distribution of protected lichen *Platismatia glauca* in the Wzniesienia Łódzkie Landscape Park.
1 – site; 2 – border of park and buffer zone; 3 – forests; 4 – rivers; 5 – roads; 6 – motorway A1 (under construction); 7 – boulders and their groupings; 8 – historic cemetery; ur. – uroczysko (range); nature reserves: I – Las Łagiewnicki, II – Struga Dobieszkowska, III – Parowy Janinowskie.

Among lichens under strict protection there is a group of forest epiphytes connected with old oaks growing in Las Łagiewnicki Forest i.e. *Chrysothrix candelaris*, *Cetrelia monachorum* and *Flavoparmelia caperata*, as well as roadside trees: *Melanohalea exasperatula*, *Parmelina tiliacea*, *Pleurosticta acetabulum*, *Ramalina* *fraxinea* and *Tuckermannopsis sepincola*. All these species except for *M. exasperatula* (13 sites of occurrence) have a single site of occurrence (Tab. 1) and their thalli show a reduced vitality.

Among noteworthy forest species are a large accumulation of *Platismatia glauca* and *Parmelia saxatilis* (Tab.1). They grow mainly in Las Łagiewnicki Forest (Fig. 1) on the trunks and the tree crowns, which shows a presence of well-developed, large thalli found on the branches and on twigs lying on the ground. On the bark of roadside and field trees, mainly birches, ash and apple trees, often occur *Hypogymnia tubulosa* (21 sites of occurrence) with associated *Pseudevernia furfuracea*.

In the landscape park there also occur 4 species of lichens under strict protection, which grow on field boulders and cemetery wall stones. These are *Melanelia disjuncta* and species of the genus *Xanthoparmelia*.

Out of six partially protected species only epiphytic *Evernia prunastri* has been found on 21 sites. The remaining are terrestrial lichens of genera *Cetraria* and *Cladonia* found only in Tadzin and Grzmiąca forest ranges on 1-4 sites of occurrences (Tab. 1).

THREATENED LICHENS

In the Wzniesienia Łódzkie Landscape Park 40 species grow (22% of the total number of species) included in the Red List of extinct and threatened lichens in Poland (acc. to Cieśliński et al. 2006). The status of threatened lichens listed in WŁLP is shown in Table 2.

This group is formed by 23 threatened species (CR – 3, EN – 6, VU – 14), 13 species with a lower risk species of threat (NT – 10, LC – 3) and indeterminate threat degree (DD – 4). This group is dominated by epiphytic (23 species; 57.5%) and epilithic lichens (13 species; 32.5%), and epixylic and terrestrial lichens (2 species each), which indicates the natural character of the park, its habitats and substrates.

Among the epiphytic lichens there are species growing on forest and roadside and solitary trees. Only in Las Łagiewnicki Forest are there a few obligatory forest lichens: *Chrysothrix candelaris* (Critically Endangered Category), *Calicium adspersum*, *Cetrelia monachorum* (Fig. 2) and *Flavoparmelia caperata* (Endangered Category). The first three species are also indicators of lowland old-growth forests (Czyżewska & Cieśliński 2003). The Endangered Category also includes *Pleurosticta acetabulum* and *Ramalina fraxinea* (Fig. 2) obligatory lichens of roadside trees.

The feature that singles WŁLP out is a numerous group of saxicolous lichens (Tab. 2, Fig. 2) on granite erratic presented in terrestrial and aquatic habitats.

Table 2. Threatened lichen species in the Wzniesienia Łódzkie Landscape Park
The Red List Categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.

Species	Status of threat in Poland	Substrate preferency	Number of localities
Bacidina egenula (Nyl.) Vězda	CR	epilithic	1
Chrysothrix candelaris (L.) J.R. Laundon	CR	epiphytic	1
Pertusaria pseudocorallina (Lilj.) Arnold	CR	epilithic	2
Calicium adspersum Pers.	EN	epiphytic	2
Cetrelia monachorum (Zahlbr.) W.L. Culb. & C.F. Culb.	EN	epiphytic	1
Flavoparmelia caperata (L.) Hale	EN	epiphytic	1
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	EN	epiphytic	1
Ramalina fraxinea (L.) Ach.	EN	epiphytic	1
Tuckermannopsis sepincola (Ehrh.) Hale	EN	epixylic	1
Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw.	VU	epiphytic/epixylic	6
Cetraria islandica (L.) Ach.	VU	epigeic	5
Chaenotheca xyloxena Nádv.	VU	epixylic	1
Hydropunctaria rheitrophila (Zschacke) Keller, Gueidan & Thüs	VU	epilithic	9
Melanelia disjuncta (Erichsen) Essl.	VU	epilithic	2
Parmelina tiliacea (Hoffm.) Hale	VU	epiphytic	2
Pertusaria coronata (Ach.) Th. Fr.	VU	epiphytic	1
Ramalina farinacea (L.) Ach.	VU	epiphytic	1
Ramalina pollinaria (Westr.) Ach.	VU	epiphytic	4
Tuckermannopsis chlorophylla (Willd.) Hale	VU	epiphytic	6
Usnea hirta (L.) F. H. Wigg.	VU	epiphytic/epixylic	6
Verrucaria aquatilis Mudd	VU	epilithic	6
Verrucaria hydrela Ach.	VU	epilithic	10
Verrucaria viridula (Schrad.) Ach.	VU	epilithic	1
Cetraria ericetorum Opiz	NT	epigeic	1
Chaenotheca furfuracea (L.) Tibell	NT	epiphytic	4
Chaenotheca trichialis (Ach.) Th. Fr.	NT	epiphytic	2
Evernia prunastri (L.) Ach.	NT	epiphytic	21
Graphis scripta (L.) Ach.	NT	epiphytic	5
Hypogymnia tubulosa (Schaer.) Hav.	NT	epiphytic	21
Pertusaria coccodes (Ach.) Nyl.	NT	epiphytic	1
Pertusaria cf. *leioplaca* DC.	NT	epiphytic	1
Verrucaria praetermissa (Trevis.) Anzi	NT	epilithic	2
Vulpicida pinastri (Scop.) J.-E. Mattson & M.J. Lai	NT	epiphytic	2
Acaraspora smaragdula (Wahlenb.) A. Massal.	LC	epilithic	2
Psilolechia lucida (Ach.) M. Choisy	LC	epilithic	1
Strangospora pinicola (A. Massal.) Körb.	LC	epiphytic/epixylic	19
Lecanora persimilis (Th. Fr.) Nyl.	DD	epiphytic	2
Thelidium aquaticum Servít	DD	epilithic	2
Verrucaria murina Leight.	DD	epilithic	5
Verrucaria sublobulata Eitner ex Servít	DD	epilithic	2

RESOURCES OF PROTECTED AND THREATENED LICHENS IN THE WZNIESIENIA ŁÓDZKIE LANDSCAPE PARK

Wzniesienia Łódzkie Landscape Park, though located within an urban agglomeration under the influence of the Łódź inhabitants and other anthropogenic factors owing to its unique natural resources and physic-geographic location, is becoming a refuge for 55 species of protected and threatened lichens at the Polish level (30.22% of the total number of species). Among them 32 taxa are under legal protection whereas 40 have threatened status. 18 species under strict protection also belong to the group of threatened lichens included in the Red List of threatened lichens in Poland CR, EN, VU and NT (cf. Tabs 1 & 2).

Under Polish lowlands conditions WŁLP encompasses particularly a large group of valued saxicolous species enjoying protected and/or threatened status (Tabs 1 & 2; Fig. 2), which at the same time supplement knowledge of their distribution in the country.

Species new to Polish lowlands are freshwater lichens *Thelidium aquaticum*, *Verrucaria sublobulata* and *Pertusaria pseudocorallina* (Fig. 2) – growing on siliceous rocks, on the lichen within the mountain range (Bielczyk ed. 2003; Fałtynowicz 2003). The site of this species in the escarpment zone of Wzniesienia Łódzkie Heights is the most northern location in the country.

Acarospora smaragdula (Fig. 2) in the lowlands is known only on erratic from "Kręgi Kamienne" reserve in Bory Tucholskie Forests (Kiszka & Lipnicki 1994). In WŁLP this species can be found on boulder in Grzmiąca Stara and in Grabina built in the cemetery wall.

Species new to Central Poland are 2 freshwater saxicolous, *Verrucaria hydrela* and *V. praetermissa*. *Hydropunctaria rheitrophila* (Fig. 2), *Verrucaria aquatilis* and *V. viridula* hitherto recognized only from Wyżyna Wieluńska upland (Nowak 1967), whereas *Melanelia disjuncta* – from Świętokrzyski National Park (Łubek 2007).

Valuable as regards chorology, habitat and conservation value epilithic lichens in WŁLP have few sites of occurrence (Tab. 2) except of *Verrucaria hydrela* (10 localities) and *Hydropunctaria rheitrophila* (9). Their survival is threatened due to removal of boulders and their groupings, destruction of buildings using erratics and their transfer to domestic gardens for ornamental purposes. In Grabina village a historic cemetery was destroyed along with *Pertusaria pseudocorallina* and *Xanthoparmelia loxodes.*

The pouring of liquid contaminants into rivers is also observed resulting for example in the uroczysko Dobieszków range in the deterioration of freshwater lichen thalli *Hydropunctaria rheitrophila*, *Verrucaria aquatilis*, *V. hydrela* (VU) and *V. praetermissa* (NT).

The landscape park is a refuge for a numerous group of epiphytic lichens growing on forest and roadside trees included in the Red List of threatened lichens in Poland in the following categories: CR, EN, VU, NT, LC and DD. In terms

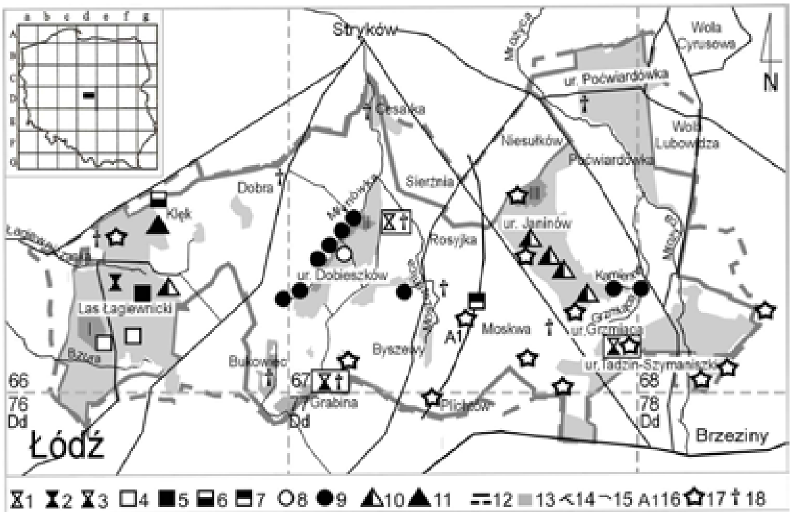

Fig. 2. Distribution of selected threatened lichens in the Wzniesienia Łódzkie Landscape Park. CR Category: 1 – *Bacidina egenula,* 2 – *Chrysothrix candelaris,* 3 – *Pertusaria pseudocorallina;* EN Category: 4 – *Calicium adspersum,* 5 – *Cetrelia monachorum,* 6 – *Pleurosticta acetabulum,* 7 – *Ramalina fraxinea*; VU Category: 8 – *Chaenotheca xyloxena,* 9 – *Hydropunctaria rheitrophila;* NT Category: 10 – *Graphis scripta,* 11 – *Pertusaria* cf. *leioplaca;* 12 – border of park and buffer zone; 13 – forests; 14 – rivers; 15 – roads; 16 – motorway A1 (under construction); 17 – boulders and their groupings; 18 – historic cemetery; ur. – uroczysko (range); nature reserves: I – Las Łagiewnicki, II – Struga Dobieszkowska, III – Parowy Janinowskie.

of their distribution worthy of note is the small number of sites of occurrence except for *Evernia prunastri* and *Hypogymnia tubulosa* (21 sites of occurrence) and *Strangospora pinicola* (19).

The most valuable species for the biota park listed exclusively in large forest complexes growing on over 100-year-old trees, have small, residual thalli, yet they are still a source of propagules, for example *Chrysothrix candelaris* (CR), *Calicium adspersum, Cetrelia monachorum, Flavoparmelia caperata* (EN) growing on old trees in Las Łagiewnicki Forest, *Chaenotheca trichialis* (NT) – on oaks, and also *Graphis scripta, Pertusaria* cf. *leioplaca* (NT) – on beeches and hornbeams in Las Łagiewnicki Forest and uroczysko Janinów range (Fig. 2). Highly threatened in WŁLP are epiphytes on roadside trees, e.g. *Ramalina fraxinea* recorded on *Acer pseudoplatanus* in 2005 and destroyed with the start of construction of the A1 motorway, part of which passes through the park. As a result of road modernization there is a probability that *Pleurosticta acetabulum* on roadside ash trees – the only site of occurrence in the park – might be destroyed.

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THE THREATENED AND PROTECTED SPECIES OF LICHENS IN THE RIVER BUG VALLEY LANDSCAPE PARK

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Abstract. Field studies in the River Bug Valley Landscape Park were carried out in the years 2000 – 2007. 156 species of lichens were found in the 90 localities. Species threatened and protected in Poland were found in 31 localities (including 46 species). Among 33 species on the Polish Red List were found: CR (Critically Endangered) - 1 species, EN (Endangered) - 10 species, VU (Vulnerable) - 11 species, NT (Near Threatened) - 10 species, LC (Least Concern) – 1 species. 25 species are strictly protected in Poland and 7 – partially protected. Protected species constitute 29.5% of all biota in the River Bug Valley Landscape Park. The most interesting among them, are: *Chrysothrix candelaris, Arthrorhaphis citrinella, Cladonia caespiticia, C. botrytes, Flavoparmelia caperata, Physconia distorta, Pycnothelia papillaria, Chaenotheca phaeocephala.*

Key words: lichens, protected species, protected areas

INTRODUCTION

The River Bug Valley Landscape Park (NPK) is situated in the central – eastern part of Province of Masovia. It includes the left-bank part of the valley of the Lower Bug from the mouth of the River Toczna to the mouth of the River Liwiec, in the vicinity of Kamieńczyk, and length of the Lower Narew. It is one of the largest landscape parks in Poland; it protects about 120 km of the River Bug. The Park covers 74136.5 ha.

The park has a very diverse landscape. The main value of this area is very good preservation of large lowland meandering river valley with numerous oxbows, islands and slopes.

The great area of park covers with many complex forests. The dominants are pine forests (*Leucobryo – Pinetum* and rarely *Cladonio – Pinetum*). The swampy parts of lowland are overgrown with alder carr (*Ribo nigri – Alnetum*) and ash-alder carr (*Circaeo – Alnetum*). However, the more fertile soils are overgrown with usually small, expances of ash–elm forests (*Ficario – Ulmetum*) and oak-lime-horn-beam forest (*Tilio – Carpinetum*).

Rare forest plant species worthy of attention include: *Daphne mezereum*, *Aquilegia vulgaris*, *Lilium martagon*, *Aruncus sylvestris*, *Digitalis grandiflora*, *Epipactis helleborine* and *Linnaea borealis*.

In this area were found five species from the Red List of Plants in Poland (Kaźmierczakowa, Zarzycki 2001): *Diphasiastrum tristachyum*, *Ostericum palustre*, *Polemonium caeruleum*, *Succisella inflexa*, *Cyperus flavescens*.

Part of the park's territory belongs to Natura 2000.

Publications concerning lichens of the park are sparse and relate to its smaller areas (Fabiszewski 1964, Jastrzębska 2005a, b, 2006, 2007, 2009).

MATERIAL AND METHODS

The study in the River Bug Valley Landscape Park was carried out in the years 2000-2007. On the basis of the preliminary field observations 90 localities were determined. They represented all types of plant communities and all accessible habitats. A list was prepared of lichen species, whose identification was undoubted. Nature reserves (Dębniak, Kaliniak, Sterdyń, Podjabłońskie, Bojarski Grąd, Moczydło, Czaplowizna) were studied in detail. Threatened and protected lichens were found in the 31 localities.

Taxa which required study of their anatomical structure were collected and placed in the Departament of Botany, Siedlce University of Natural Sciences and Humanities.

Collected material was determined based on Nowak's and Tobolewski's (1975) key and on Purvis et. al. (1992).

Nomenclature of lichens was taken from Diederich et. al. (2012), and the risk categories – according to the Red List of Extinct and Endangered Lichens in Poland (Cieśliński et. al. 2006).

The list of species is given in alphabetic order. The following abbreviations were used: *Bp – Betula pendula, Qr – Quercus robur, Pt – Populus tremula, Cb – Carpinus betulus*, *Tc – Tilia cordata*, *Fe – Fraxinus exscelsior*, *Ps- Pinus sylvestris*, *Ag – Alnus glutinosa*, *L-P – Leucobryo-Pinetum*, *C-P – Cladonio-Pinetum*, *T-C – Tilio-Carpinetum*, *Q-P – Querco-Pinetum*, *P-Q – Potentillo albae-Quercetum*, *R-A – Ribo nigri-Alnetum*, § – partial protection, §§ – strict protection, cat. – risk category (CR – Critically endangered, EN – Endangered, VU – Vulnerable, NT – Near threatened, LC – Least concern).

The frequency scale used: rarely – 2-4 localities, often – 5-8 localities (in large numbers on the locality), very often – over 8 localities.

List of localities: 1. Stoczek Węgrowski (*C-P*), 2. Lipki Stare – Ugoszcz (*C-P*), 3. Ugoszcz – Rostki (*L-P*), 4. Ugoszcz (cemetery), 5. Ugoszcz (*L-P* near of cemetery), 6. Międzyleś – Stoczek Węgrowski (*C-P*), 7. Bartków Stary (*P-Q*), 8. Szczeglacin (Kaliniak reserve – *T-C*), 9. Korczew (roadside trees - *Fe*), 10. Korczew (Dębniak reserve – *T-C*), 11. Krupy (*L-P*), 12. Jakubiki (*L-P*), 13. Ceranów (*T-C*), 14. Ceranów (*L-P*), 15. Ceranów (avenue of *Tc*), 16. Sterdyń reserve (*P-Q*), 17. Sterdyń reserve (*T-C*), 18. Moczydło reserve, 19. Bojarski Grąd reserve (*T-C*), 20. Podjabłońskie reserve (*P-Q*), 21. Przekop (roadside trees - *Fe*), 22. Tchórzowa (*L-P*), 23. Kosów Lacki (road side trees - *Pn*), 24. Maliszewa (*C-P*), 25. Maliszewa (*C-P*, dunes), 26. Lipki Stare (wooden fences), 27. Stoczek Węgrowski (roadside trees - *Pn*), 28. Gruszczyno (*L-P*), 29. Czaplowizna reserve (*R-A*), 30. Czaplowizna reserve (*L-P*), 31. Czaplowizna reserve (*Q-P*).

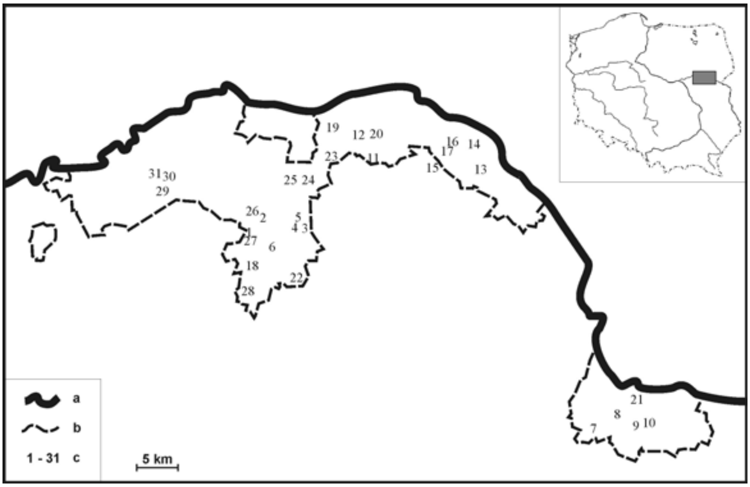


Fig. 1. Distribution of localities. a – Bug, b – borders of National Landscape Park, c – number of locality

RESULTS

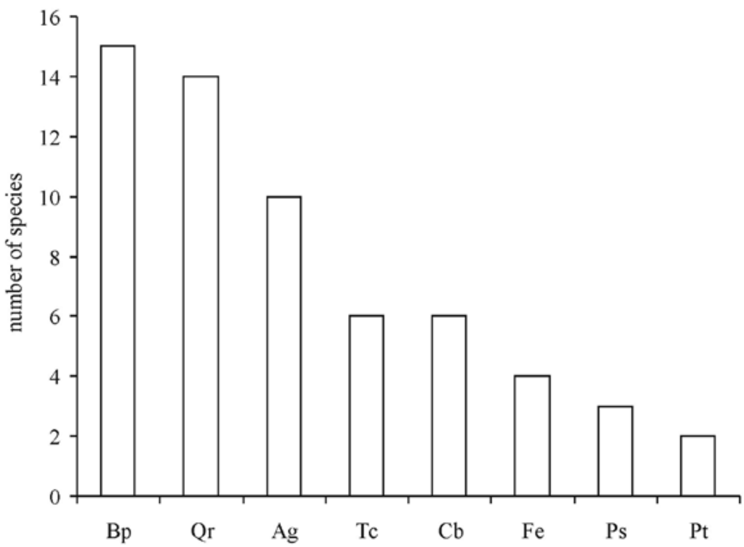
As a result of studies in the River Bug Valley Landscape Park 156 species of lichens were found in 90 localities. The most frequent were species common in Poland, for example: *Lecanora conizaeoides*, *L. carpinea*, *L. pulicaris*, *L. argentata*, *Hypogymnia physodes*, *Parmelia sulcata*, *Scoliciosporum chlorococcum*, *Hypocenomyce scalaris*, *Xanthoria parietina*, *X. polycarpa* and a dozen or so species of the genus *Cladonia*.

Species of lichens threatened and protected in Poland were found in 31 localities (Fig.1.). Among 33 species from the Red list of lichens in Poland (Cieśliński et. al. 2006) were representatives of categories: CR (Critically Endangered) - 1 species, EN (Endangered) - 10 species, VU (Vulnerable) - 11 species, NT (Near Threatened) - 10 species, LC (Least Concern) – 1 species. Among lichens protected in Poland (Journal of Laws 2004 No 168, entry 1765) in the Park were found 25 strictly protected species and 7 – partially protected. They constitute 29.5% of all biota in the River Bug Valley Landscape Park. The lichens were growing on bark of trees, soil and rotting wood.

Among threatened and protected species the most frequent were epiphytic lichens (32 species). They inhabited the bark of trees in forest communities (28 species) and roadside trees (12 species). Most of them inhabited bark of *Betula pendula* (15 species), *Quercus robur* (14 species) and *Alnus glutinisa* (10 species) (Fig.2), in forest communities. Several species (*Bryoria fuscescens, Tuckermannopsis chlorophylla, T. sepincola, Usnea filipendula, Vulpicida pinastri*) were found exclusively on bark of single *Betula pendula.* Interesting lichen biota inhabited trunks and branches of *Quercus robur.* Only on bark of *Quercus robur* were: *Chrysothrix candelaris*, *Chaenotheca furfuracea*, *C. trichialis*, *Parmelina tiliacea* i *Pertusaria coccodes*.

Lichens on roadside trees were very poor. Several rare species (*Physconia distorta*, *Ramalina pollinaria*, *R. fraxinea*) were found on *Tilia cordata* in Ceranów village. On roadside *Fraxinus excelsior* in the vicinity of Przekop village *Anaptychia ciliaris* were noted. More species of lichens grew on single birch trees of the cemetery in Ugoszcz village (Jastrzębska 2005a).

Fig. 2. The number threatened and protected species of lichens on individual trees (explanations of abbreviations in "Material and methods")



The second largest ecologic group was of rare and protected epigeic lichens (12 species). They were mainly in *Cladonio-Pinetum* and *Leucobryo-Pinetum*. Lichens of the genus *Cladonia* and *Cetraria* (e.g.: *Cladonia ciliata*, *C. arbuscula*, *C. rangiferina*, *Cetraria aculeata*, *C. islandica*) dominated there. In the single localities were noted: *Cladonia stellaris*, *Arthrorhaphis citrinella*, *Pycnothelia papillaria*, *Dibaeis baeomyces* and *Stereocaulon condensatum*.

The rotting wood was inhabited by 10 species of lichens. The most valuable of them were *Cladonia botrytes* and *C. caespiticia*. These species were noted very rarely and exclusively in this site.

Exclusively in forest communities in the River Bug Valley Landscape Park were found 30 species of lichens threatened and protected in Poland. The most frequently found of them were: *Leucobryo-Pinetum* – 19 species and *Cladonio-Pinetum* – 14 species. In the remaining phytocoenoses the list of species is similar: *Potentillo albae-Quercetum* – 11, *Tilio-Carpinetum* – 10, *Ribo nigri-Alnetum* – 10, *Querco-Pinetum* – 9.

LIST OF SPECIES

[Explanations of abbreviations – in "Material and methods"; in brackets – numbers of localities]

Anaptychia ciliaris (L.) Korb. – once, on bark of *Fe* (21), §§, EN.

Arthonia ruana A. Massal. – rarely, in *T-C* and *R-A* on bark of *Cb* and *Ag* (8, 13, 17, 29), NT.

Arthrorhaphis citrinella (Ach.) Poelt. – once, on soil in *C-P* (24),VU.

Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw. – once, on bark of *Bp* in *L-P* (31), §§, VU.

Calicium glaucellum Ach. – once, on bark of *Ag* in *R-A* (29), VU.

Cetraria aculeata (Schreb.) Ach. – often, in *C-P* and *L-P* (2, 5, 12, 25, 30), §.

C. islandica (L.) Ach. – very often, in *C-P* and *L-P* (1, 2, 5, 11, 12, 14, 24, 25, 30), §,VU.

Chaenotheca furfuracea (L.) Tibell. – rarely, on bark of *Qr* in *P-Q* (7, 16), NT.

C. *phaeocephala* (Turner) Th. Fr. – once, on bark of *Ag* in *R-A* (29), EN.

C. *trichialis* (Ach.) Th. Fr. – once, on bark of *Qr* in *T-C* (10), NT.

Chrysothrix candelaris (L.) J. R. Laundon. – once, on bark of *Qr* in *P-Q* (16), §§, CR.

Cladonia arbuscula (Wallr.) Flot. Em Ruoss. – often, in *C-P* and *L-P* (5, 11, 12, 14, 22, 24, 25, 30), §.

C. botrytes (Hagen) Willd. – rarely, on rotting wood in *C-P* (2, 24), EN.

C. caespiticia (Pers.) Florke. – once, on rotting wood in *L-P* (5), EN.

C. ciliata Stirt. – once, on soil in *L-P* (30), §.

C. mitis Sandst. – often, in *C-P* and *L-P* together with *C. ciliata* (1, 2, 5, 24, 25, 30), §.

C. rangiferina (L.) Weber in F. H. Wigg . – often, on soil in *C-P* and *L-P* (1, 5, 11, 12, 14, 24, 25, 30), §.

C. stellaris (Opiz) Pouzar & Vezda – rarely, on soil in *L-P* (2, 30), §§, EN.

Dibaeis baeomyces (L.) Rambold & Hertel. – rarely, on soil in *C-P* (2, 25), NT.

Evernia prunastri (L.) Ach. – very often, on bark of *Qr*, *Tc*, *Ag*, *Bp*, *Fe*, *Pt* and on rotting wood (6, 7, 9, 10, 15, 16, 18, 19, 20, 21, 26, 27, 28, 29, 30, 31), §, NT.

Flavoparmelia caperata (L.) Hale – on some localities, but very abundant, on bark of *Qr*, *Tc*, *Cb*, *Bp*, *Ag* and on rotting wood in *P-Q* i *R-A* (16, 26, 29), §§, EN.

Graphis scripta (L.) Ach. – rarely, on bark of *Cb* and *Ag* in *T-C* i *R-A* (8, 13, 17, 29), NT.

Hypogymnia tubulosa (Schaer.) Hav. – rarely, on bark of *Bp* and on rotting wood (4, 26), §§, NT.

Imshaugia aleurites (Ach.) S. L. F. Meyer. – often, on bark of *Bp*, *Ag*, *Qr* and on rotting wood (4, 16, 19, 26, 29, 30), §§.

Lecanora subrugosa Nyl. – rarely, on bark of *Qr*, *Bp*, *Ag* (5, 6, 20, 29), LC.

Melanelixia fuliginosa (Fr. ex Duby) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw., Lumbsch subsp. *fuliginosa* – rarely, on road side trees (9, 23), §§.

M. subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw., Lumbsch – often, on bark of *Bp*, *Qr*, *Tc*, *Ag*, and on rotting wood and on road side trees (14, 15, 17, 26, 29), §§.

Melanohalea exasperatula (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw., Lumbsch – very often, on bark of *Cb*, *Qr*, *Fe*, *Ag* and on road side trees (8, 9, 10, 13, 17, 20, 26, 29, 31), §§.

Parmelina tiliacea (Hoffm.) Hale. – once, on stump of *Qr* by the forest road (10), §§, VU.

Parmeliopsis ambigua (Wulfen in Jacq.) Nyl. – rarely, on bark of *Ps*, *Bp*, *Qr* and on rotting wood (4, 20, 26, 30), §§.

Peltigera rufescens (Weis.) Humb. – rarely, on soil in *L-P* (3, 14, 30), §§.

Pertusaria coccodes (Ach.) Nyl. – rarely, on bark of *Qr* in *P-Q* (7, 10), NT.

P. leioplaca DC. in Lam. & DC. – rarely, on bark of *Cb* in *T-C* (13, 17), NT.

Physconia distorta (With.) J. R. Laundon. – once, on bark of road side *Tc* (15), EN.

Platismatia glauca (L.) W. L. Culb. & C. F. Culb. – often, on bark of *Bp* and on rotting wood, in *C-P* and *L-P* (2, 3, 4, 6, 26), §§.

Pseudevernia furfuracea (L.) Zopf. – often, on bark of *Ps*, in *C-P* and *L-P* (3, 4, 14, 24, 25, 30, 31), §§.

Pycnothelia papillaria (Ehrh.) Dufour. – once, on soil in *C-P* (25), §§, EN.

Ramalina farinacea (L.) Ach. – often, on bark of *Qr* in *P-Q* and *Q-P*, and on rotting wood (7, 16, 20, 26, 31), §§, VU.

R. fraxinea (L.) Ach. – rarely, on road side trees: *Fe*, *Tc*, *Pt* (9, 15, 23), §§, EN

R. pollinaria (Westr.) Ach. – once, on bark of road side *Tc* (15), §§, VU.

Stereocaulon condensatum Hoffm. – rarely, on soil in *C-L* (5, 25), §§, VU.

Tuckermannopsis chlorophylla (Willd.) Hale – rarely, on bark of *Bp* in *L-P* and *Q-P* (5, 31), §§, VU.

T. sepincola (Ehrh.) Hale – once, on sprig of *Bp* in *L-P* (5), §§, EN.

Usnea filipendula Stirt. - once, on bark of *Bp* in *Q-P* (31), §§, VU.

U. hirta (L.) Weber ex F. H. Wigg. – often, on bark of *Ps* and *Bp* in *C-P* and *L-P* (3, 4, 11, 14, 30, 31), §§, VU.

Vulpicida pinastri (Scop.) J. E. Mattsson & M. J. Lai. – rarely, on bark of *Bp* in *P-Q* and *T-C* (19, 20), §§, NT.

DISCUSSION

First reports on lichens from The River Bug Valley Landscape Park were given in the paper by Fabiszewski (1964). He presented a dozen or so species common in Poland and some rare species (e.g. *Bryoria subcana*, *Usnea subfloridana*). The majority of localities were destroyed (roadside trees and forest trees were taken out, wooden fences were destroyed). The rare species of lichens were not found.

This study was carried out in the years 2000-2007. Within this study 156 species of lichens were found. 46 of these – are lichens protected (32 species) or threatened (33 species) in Poland.

The most species of protected and threatened lichens were in nature reserves (Fig.3), where 31 species were noted. They constitute 67.4% of all the lichen biota in the Park. Outside the area of reserves were found mainly terricolous species (in *L-P* and *C-P*), e.g.: *Arthrorhaphis citrinella*, *Pycnothelia papillaria*, *Dibaeis baeomyces*, and epiphytic lichens of roadside trees (*Anaptychia ciliaris*, *Hypogymnia tubulosa*, *Ramalina fraxinea*, *R. pollinaria*, *Physconia distorta*). They were growing usually in single localities in the form of little thalli.

Exclusively in nature reserves, in single localities, were found eight species: *Chrysothrix candelaris, Chaenotheca trichialis, C. phaeocephala, Cladonia ciliata, Vulpicida pinastri, Bryoria fuscescens, Calicium glaucellum, Usnea filipendula*. These species occurred in large numbers in reserves. Their thalli were in good condition and were very impressive. *Flavoparmelia caperata*, for example, outside reserves were found only once, and it thalli was very small. This lichen in "Sterdyń" reserve and "Czaplowizna" reserve was noted very often and grew over a lot of trees (*Alnus glutinosa, Tilia cordata, Quercus robur, Betula pendula, Carpinus betulus*).

The most protected and threatened species were in "Czaplowizna" reserve – 25 species. They inhabited bark of *Alnus glutinosa, Betula pendula, Pinus sylvestris, Carpinus betulus* and soil in *Leucobryo-Pinetum*, *Querco-Pinetum* or *Ribo nigri-Alnetum*. The most frequent were overgrown trunks of *Alnus glutinosa* (Fig. 2). Multicoloured thalli of *Flavoparmelia caperata, Graphis scripta, Calicium glaucellum*, *Chaenotheca phaeocephala* and *Evernia prunastri* often covered whole trunks of trees. Only in "Czaplowizna" reserve were: *Bryoria fuscescens, Calicium glaucellum, Chaenotheca phaeocephala, Usnea filipendula* and *Cladonia ciliata*.

This reserve is the most varied in species of lichens because it is very large (approx. 213 hectares). There are a lot of plant communities (pine forests, alder carr, ash-alder carr), too. They offer favourable habitats for existence of lichens. The others reserves are more habitat homogeneous.

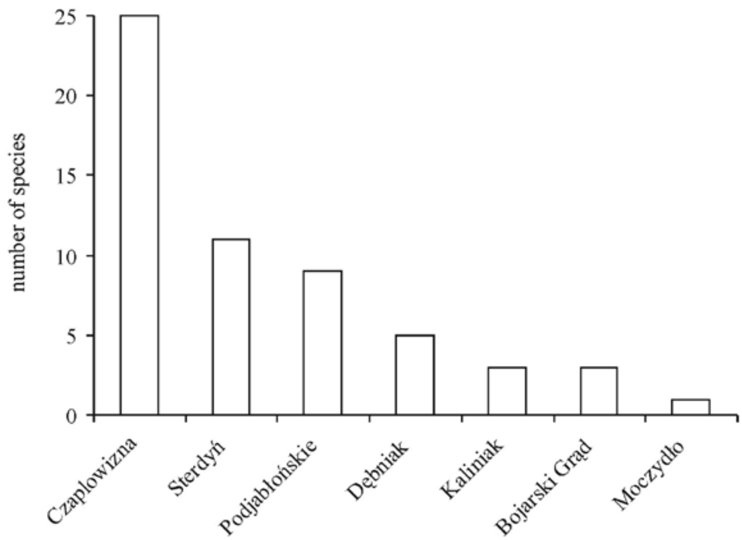


Fig. 3. The number threatened and protected species of lichens in nature reserves

The least rare and protected species of lichens were noted in “Kaliniak” reserve (3 species) and “Bojarski Grąd” reserve (3 species) as well as the small “Moczydło” ornithological reserve, because in these reserves are significantly shaded.

In the Park one lichen species was found – an indicator of lowland old-growth forests in Poland. It is *Chrysothrix candelaris* (in “Sterdyń” reserve). Its presence is due to the agricultural nature of Park, where arable fields and meadows are divided by small forest complexes, probably. Only the most valuable, almost natural parts of forest communities are protected.

The list of protected and threatened lichens in the River Bug Valley Landscape Park is perhaps not impressive but contains taxa that deserve special attention.

First of them is *Chrysothrix candelaris*, sterile species, very rare, critically endangered. It usually inhabits cracks of bark, mainly old bark of oaks in old-growth forests. In Białowieża Old-growth Forest this species is very frequent (Cieśliński 2003). In the studied area it was found once on bark of *Quercus robur* in “Sterdyń” reserve (Jastrzębska 2007).

The next valuable species is *Arthrorhaphis citrinella*. This is a small, mountain, terricolous species. It was noted down once in Park in *Cladonio-Pinetum*. In lowland Poland was found rarely (Cieśliński 2003, Fałtynowicz 1992, Lipnicki 1993, Zielińska 1967).

A very rare species, endangered in Poland is *Cladonia caespiticia*. It was found once on rotting wood (Jastrzębska 2005a). This species was recorded in lowland Poland rarely: in Białowieża Old-growth Forest (Cieśliński 2003, Czyżewska et al. 2001), Suwałki-Augustów Lakeland (Karczmarz et al 1988), West Pomerania (Fałtynowicz 1992), and vicinity of Słupsk (Izydorek 1996).

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PROTECTED AND THREATENED LICHEN SPECIES OF THE NIDZICA PRIMEVAL FOREST (N POLAND)

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Abstract. This paper presents a list of protected and threatened species of lichens found in the Nidzica Primeval Forest (N Poland). It encompasses 145 taxa identified by various authors between 1919 and 2011. The article also overviews unpublished results of the author's research carried out in 1999-2011.

Key words: lichens, lichenized fungi, threat, protection, diversity, forest, Poland

INTRODUCTION

The Region of Warmia and Mazury is renowned for its extraordinary natural diversity. Forests, which occupy nearly 30% of the region's area, provide habitat for many protected and threatened lichen species, thus contributing to biodiversity preservation (Zalewska et al. 2011). Although the past 30 years have witnessed intensified research into lichens, those efforts produced only several monographs (Zalewska 2000; Cieśliński 2003; Zalewska et al. 2004), and the resulting knowledge about lichen resources remains scarce. The first efforts to comprehensively catalogue lichen species in three primeval forests of Warmia and Mazury (Borecka Forest, Pisz Forest and Romnicka Forest) were made by Cieśliński and Czyżewska (2002) and Cieśliński (2003). Their works do not cover the Nidzica Primeval Forest, an extensive forest complex covering the south-western part of the region (Zaręba 1981). Although a relatively high number of lichen species have been reported from the forest (Zalewska et al. 2011), the number of publications that provide a general or a detailed overview of lichen biota remains low, and information about Nidzica's lichens is scattered throughout numerous reports. The objective of this study was to review lichenological data regarding the Nidzica Primeval Forest, and to evaluate protected and threatened lichen resources in the area.

STUDY AREA

The Nidzica Primeval Forest (reference Zaręba 1981) is an extensive forest complex (59,000 ha) comprising several parts with indigenous names of Lasy

Purdzkie, Lasy Ramuckie, Lasy Napiwodzkie and Lasy Korpelskie (Niedziałkowski 1948). The Nidzica Forest is a remnant of a much larger forest, known as the Galindian Primeval Forest in the Middle Ages. The discussed area is situated in the south-western part of the Masurian Lakeland (Fig. 1), in the Olsztyn Lakeland and, partially, the Masurian Plain (Kondracki 2001). It is characterized by diverse relief features that date back to the last glacial period. The predominant landforms are sandur plains with numerous fluvioglacial valleys and terminal moraines. The region abounds in lakes, and its characteristic feature is nutrient-poor habitats in pine forests. Areas with more fertile soils are overgrown by mixed forests and oak-linden-hornbeam forests. Ash-alder and boggy alder forests occupy river banks and lake shores. Well-preserved oak-linden-hornbeam forests and old-growth forests are found only in the nature reserves of "Dęby Napiwodzkie", "Koniuszanka II" and "Las Warmiński" (Dąbrowski et al. 1999). Small endorheic lakes transformed into peatlands are vital enclaves of phytocenotic diversity, in particular in the vicinity of floristically depleted pine woods (Namura-Ochalska 2010). The predominant part of the Nidzica Primeval Forest, known as the

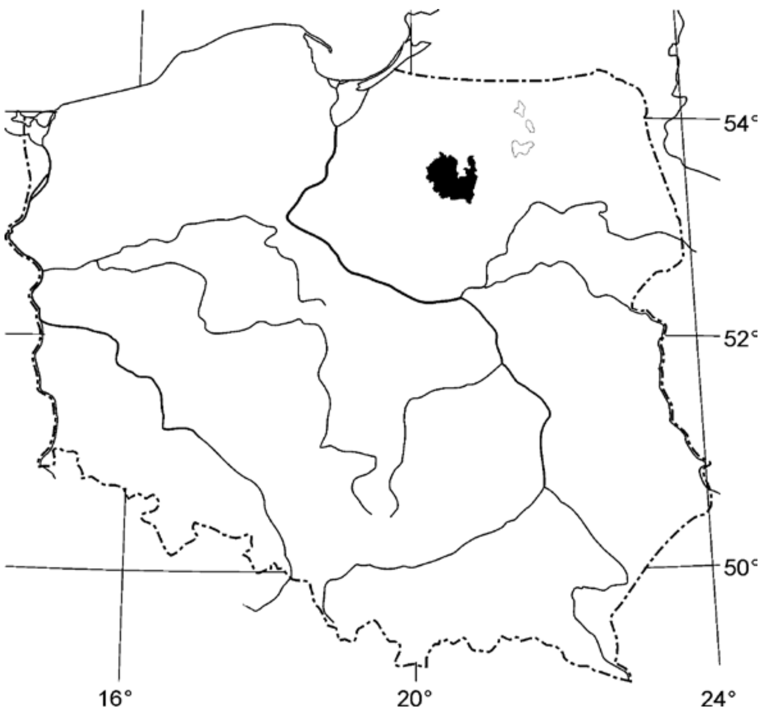

Fig. 1. Location of the Nidzica Primeval Forest in Poland

Napiwodzko-Ramucka Refuge (32612.8 ha), receives protection under the NATURA 2000 programme that aims to protect the most valuable natural habitats (Hołdyński, Krupa 2009).

The first report on the occurrence of lichens in the Nidzica Primeval Forest comes from Lettau (1919). The study reports localities of *Bryoria subcana*, *Peltigera didactyla* and *Usnea certina*. Successive articles published before 2003 were also contributory studies (Tobolewski, Kupczyk 1976; Fałtynowicz 1992; Fałtynowicz, Sulma 1994; Juśkiewicz, Endler 2000; Kubiak, Ryś 2000; Czarnota 2002; Kubiak 2002). In 2003, Cieśliński published a study dedicated to the lichens of north-eastern Poland with extensive coverage of lichen taxa in the Nidzica Primeval Forest. His study synthesizes the available sources of information, and it lacks detailed data about lichen localities and the habitat requirements of individual taxa. Cieśliński (2003) noted that due to the extensiveness of the surveyed territory, his study offered merely a venture point for follow-up research. The lichen biota of the Nidzica Primeval Forest were further discussed by Czyżewska & Cieśliński (2003), whose work contains information about lichen species – indicators of lowland old-growth forests, in the "Las Warmiński" reserve in the Ramuki Primeval Forest. Although research into lichens has been intensified in the past decade (Krzewicka, Czarnota 2004; Kukwa 2004, 2005, 2006, 2008, 2011; Ryś 2005; Kubiak 2006, 2010a, b; Czarnota 2007; Kukwa, Kubiak 2007; Kukwa, Syrek 2008; Kubiak, Zalewska 2009; Kubiak et al. 2010; Kubiak 2011a, b, c), detailed studies remain scarce. The works of Hołdyński et al. (2010) and Kubiak (2011a, b) somewhat compensate for this deficiency.

MATERIALS AND METHODS

This article agglomerates the data found in various studies published between 1919 and 2011, which are dedicated to the lichen biota of the Nidzica Primeval Forest. It also relies on the results of the author's unpublished research carried out in 1999-2011. Those materials have been subjected to taxonomic revision – this paper does not account for synonymized species, and it identifies taxa that were recently recognized as separate species. The article reviews taxa characteristic of forests as well as lichens found in a broader range of habitats, including in peripheral areas and adjacent habitats. Species nomenclature follows Fałtynowicz (2003) and Diederich et al. (2012), excluding *Cetrelia monachorum* (Obermayer, Mayrhoffer 2007), *Hertelidea botryosa* (Printzen, Kantvilas 2004) and *Melanelixia glabratula* (Arup, Sandler Berlin 2011). The species name is followed by the information about the taxon's conservation status, threat category in Poland and occurrence frequency in the Nidzica Primeval Forest. Threat categories are given according to the system proposed by Cieśliński et al. (2006). A five-point scale for grading species frequency (F) was adopted where: 1 – species reported from 1 – 3 localities (very rare), 2 – species reported from 4 – 10 localities (rare), 3 – species reported from 11 – 20 localities (dispersed), 4 – species reported from 21 – 50 localities (frequent), and 5 – species reported from more than 50 localities (very frequent and common). Reference sources for each taxon are given in square brackets. The following classification of lichen taxa was adopted in this paper: SP – strictly protected species, PP – partially protected species – CR – critically endangered species, EN – endangered species, VU – vulnerable species, LC – least concern species, NT – near threatened species, and DD – data deficient species.

RESULTS

A. General characteristics of the studied biota

To date, a total of 316 lichen species have been noted in the Nidzica Primeval Forest (Zalewska et al. 2011). Protected and threatened species account for nearly 46% of the identified biota. The analysed area was the habitat of 49 protected taxa, including 41 strictly protected and 8 partially protected species. 128 of the identified taxa are classified as threatened species in Poland (40.5% of the biota). They represent the following endangered categories: CR – 11 species, EN – 44, VU – 40, NT – 24, LC – 4 and DD – 5. Nearly half of the taxa reported from the Nidzica Primeval Forest (70) were very rare lichens. There were also 28 rare species, 26 dispersed taxa, 13 frequent species, and only 7 very frequent and common taxa. In the Region of Warmia and Mazury, many protected and threatened species are found exclusively in the Nidzica Primeval Forest, among them: *Biatora albohyalina*, *B. vernalis*, *Bryoria subcana*, *Catillaria chalybeia*, *Cyphelium inquinans*, *Hydropunctaria rheitrophila*, *Peltigera monticola*, *Phaeophyscia ciliata*, *P. endophoenicea*, *Pyrrhospora quernea*, *Ramalina obtusata*, *Stereocaulon nanodes*, *Trapeliopsis glaucolepidea*, *T. viridescens*, *Usnea ceratina*, *Xanthoparmelia pulla* and *X. stenophylla*. The surveyed area features the only localities of *Phaeophyscia endophoenicea* and *Biatora vernalis* in northern Poland (see Kubiak 2010b & Ohlert 1870), and the only localities of *Catillaria chalybeia* and *Hydropunctaria rheitrophila* in the north-eastern part of the country (Fałtynowicz 2003;). The presence of *Bryoria subcana* and *Usnea ceratina* was not observed in the Nidzica Primeval Forest for nearly 100 years (Lettau 1919). Those species can be regarded as extinct in the studied area as well as in the entire region of Warmia and Mazury.

B. Protection perspectives

The Act of the 16th of April 2004 on natural environment protection (Dz.U. 2004 Nr 92 poz. 880) provisions a number of forms of conservation that serve to preserve its resources. The most important form of protection, implemented on the area of the Nidzica Primeval Forest, involves territorial protection in the form of nature reserves. The area of the Nidzica Primeval Forest includes 11 nature reserves, the total area of which constitutes 5% of the Forest area. Only three of them are forest reserves – "Dęby Napiwodzkie", "Las Warmiński" and "Koniuszanka II". Despite having the status of partial reserves, these objects constitute on the area of the Forest significant refuges of stenotypic forest lichens, including a numerous group of protected species and these at risk of extinction (Hołdyński et al. 2009, Kubiak 2011a). Out of 145 species listed in this work, 116 were noted in the area of the nature reserves. It should be emphasized, however, that so far there has been no appropriate evaluation of lichen diversity in the area of production forests. A lack of established areas of strict protection prevents many species from finding appropriately numerous habitats and substrates specific to them in general and presumably also in nature reserves. It refers in particular to epixylic lichens owing to scarce resources and diversity of dead wood. The state of dead wood resources in the nature reserves results from a relatively short history of these objects as nature reserves (established in the 70-ies and 80-ies of the XX century), and probably from not always justified removal of this substrate from forests as part of forest tending (Kubiak, Sucharzewska 2012). Resources of lichens in the other types of reserves, i.e. landscape and floristic ones, likewise these of 13 ecological lands located in the Nidzica Primeval Forest (with a total area of 111.5 ha), are not known so far. The area of the Forest lacks ecological lands established with the aim to protect forest communities (see Endler et al. 2006), for most of the existing ones serve to preserve water-marshland ecosystems.

Hopes for the conservation of the most valuable, also from the lichneological standpoint, forest communities and for the regeneration of communities deformed by thus far conducted forest management are fostered by the NATURA 2000 programme. In particular, in the stipulations of the Habitat Directive that demand restoration of the lost values of habitats being the focus of interest to the European Union. NATURA 2000 special areas of conservation (SACs) being of significance to the Community cover over 55% of the Nidzica Primeval Forest area. In the area of the Napiwodzko-Ramucka Refuge there were identified at least 24 natural habitats listed in Appendix I of the Habitat Directive, that occupy 31.4% of its area. Amongst the forest communities, the greatest area is occupied by communities of oak-hornbeam forests – 7.51%.

A relatively common form of protection in the Nidzica Primeval Forest is nature monuments in the form of impressive solitary trees or tree groups (Dąbrowski et al. 1999). The role and significance of these objects in the conservation of lichen biota resources of this forest complex also remain almost completely unknown. This pertains especially to objects located on the area of production forests.

The Regulation of the Minister of Environment of the 9th of July 2004 on the wild species of fungi (Dz.U. 2004 nr 168 poz. 1765) imposes an obligation of establishing protection zones of a refuge or a locality in respect of four lichen species: *Lobaria pulmonaria*, *Usnea subfloridana*, *U. hirta*, and *U. filipendula*. The mainstay of any action undertaken in this respect is the identification of the locality of these species. A model example of steps documenting the localities of a protected species for the needs of establishing zones of its protection is the *L. pulmonaria* protection Project implemented on the area of State-Owned Forests, covering also the area of the Nidzica Primeval Forest (Ryś 2005). The State-Owned Forests, however, often evade the responsibility of executing the zone protection of lichens (Bohdan 2010). In spite of the fact that 25 localities (trees) of *Lobaria pulmonaria* have been identified on the area of the Nidzica Primeval Forest (Forest Inspectorates: Nowe Ramuki, Jedwabno and Nidzica) and respectively documented (Ryś 2005), so far barely one protection zone of this species has been established on the area of the Jedwabno Forest Inspectorate (Regionalna Dyrekcja …).

C. List of species

[Explanation of abbreviations used in the "Materials and methods"]

Acrocordia gemmata (Ach.) A. Massal. – VU, F3 [Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009, Kubiak 2011a, b]

Anaptychia ciliaris (L.) Körb. – EN, F2 [Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009]

Arthonia arthonioides (Ach.) A. L. Sm. – CR, F1

A. byssacea (Weigel) Almq. – EN, F2 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Krzewicka, Czarnota 2004; Hołdyński et al. 2009; Kubiak 2011b]

A. didyma Körb. – EN, F2 [Hołdyński et al. 2009; Kubiak 2011a]

A. fusca (A. Massal.) Hepp – NT, F1

A. mediella Nyl. – VU, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011b]

A. ruana A. Massal. – NT, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]

A. vinosa Leight. – NT, F2 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]

Aspicilia gibbosa (Ach.) Körb. – EN, F1 [Cieśliński 2003]

Bacidia arceutina (Ach.) Arnold – EN, F2 [Hołdyński et al. 2009; Kubiak 2011a, b]

B. beckhausii Körb. – VU, F1 [Cieśliński 2003]

B. biatorina (Körb.) Vain. – EN, F2 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]

B. fraxinea Lönnr. – DD, F1 [Hołdyński et al. 2009]

B. rubella (Hoffm.) A. Massal. – VU, F3 [Kubiak 2002; Cieśliński 2003; Hołdyński et al.; Kubiak 2011a, b]

B. subincompta (Nyl.) Arnold – EN, F3 [Kubiak 2002; Hołdyński et al. 2009; Kubiak 2011a]

Bacidina sulphurella (Samp.) Hauck & Wirth – specimens of this species were determined in the past as *B. arnoldiana* (Körb.) Wirth & Vězda; *B. arnoldiana* was classified by Cieślinski et al. (2006) as lichens threatened with extinction in the country and placed in the category Near Thereatened – NT, F3 [Hołdyński et al. 2009; Kubiak 2011a, b]

Biatora albohyalina (Nyl.) Bagl. & Carestia – EN, F1 [Hołdyński et al. 2009]

B. *efflorescens* (Hedl.) Erichsen – VU, F4 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak et al. 2010; Kubiak 2011a, b]

B. *globulosa* (Flörke) Fr. – VU, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]

B. *ocelliformis* (Nyl.) Arnold – VU, F2 [Hołdyński et al. 2009; Kubiak 2011a]

B. *vernalis* (L.) Fr. – VU, F1 [Kubiak 2011b]

Biatoridium monasteriense Körb. – NT, F1 [Hołdyński et al. 2009]

Bryoria capillaris (Ach.) Brodo & D. Hawksw. – CR, F1 [Hołdyński et al. 2009]

B. *fuscescens* (Gyeln.) Brodo & D. Hawksw. – VU, F3 [Cieśliński 2003; Kubiak 2011a]

B. *implexa* (Hoffm.) Brodo & D. Hawksw. – CR, F1 [Cieśliński 2003]

B. *subcana* (Nyl. Ex Stizenb.) Brodo & D. Hawksw. – EN, F1 [Lettau 1919]

B. *vrangiana* (Gyeln.) Brodo & Hawksw. – SP, CR, F1 [Cieśliński 2003]

Calicium adspersum Pers. – EN, F3 [Kubiak 2002; Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]

C. *glaucellum* Ach. – VU, F2 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]

C. *salicinum* Pers. – VU, F4 [Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]

C. *trabinellum* (Ach.) Ach. – EN, F1 [Hołdyński et al. 2009]

C. *viride* Pers. – VU, F4 [Kubiak 2002; Cieśliński 2003; Czyżewska, Cieśliński 2003, Hołdyński et al. 2009; Kubiak 2011a, b]

Caloplaca obscurella (Körb.) Th. Fr. – NT, F1 [Hołdyński et al. 2009]

Catilaria chalybeia (Borrer) A. Massal – VU, F1 [Cieśliński 2003]

Catinaria atropurpurea (Schaer.) Vězda & Poelt – EN, F1

Cetraria aculeata (Schreb.) Fr. – PP, F1 [Juśkiewicz, Endler 2000; Cieśliński 2003]

C. *chlorophylla* (Willd.) Vain. – SP, VU, F3 [Cieśliński 2003; Hołdyński et al. 2009]

C. *islandica* (L.) Ach. – PP, VU, F2 [Juśkiewicz, Endler 2000; Cieśliński 2003; Hołdyński et al. 2009]

C. *muricata* (Ach.) Eckfeldt – PP, NT, F1 [Cieśliński 2003]

C. *sepincola* (Ehrh.) Ach. – SP, EN, F2 [Tobolewski, Kupczyk 1976; Cieśliński 2003, Hołdyński et al. 2009]

Cetrelia monachorum (Zahlbr.) Culb. & C. Culb. – SP, VU, F1

C. *olivetorum* (Nyl.) W. L. Culb. & C. F. Culb. – SP, EN, F1 [Hołdyński et al. 2009; Kubiak 2011a]

Chaenotheca brachypoda (Ach.) Tibell – EN, F1 [Hołdyński et al. 2009]

Ch. *bruneolla* (Ach.) Müll. Arg. – EN, F1 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009]

Ch. *chlorella* (Ach.) Müll. Arg. – CR, F1 [Hołdyński et al. 2009; Kubiak 2011a]

Ch. *furfuracea* (L.) Tibell – NT, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011b]

Ch. phaeocephala (Turner) Th. Fr. – EN, F1 [Kubiak 2002; Hołdyński et al. 2009; Kubiak 2011a]
Ch. stemonea (Ach.) Müll. Arg. – EN, F3 [Kubiak 2002; Hołdyński et al. 2009; Kubiak 2011a, b]
Ch. trichialis (Ach.) Th. Fr. – NT, F4 [Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
Ch. xyloxena Nádv. – VU, F2 [Hołdyński et al. 2009]
Chrysothrix candelaris (L.) J. R. Laundon – SP, CR, F4 [Kubiak 2002; Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
Cladonia arbuscula (Wallr.) Flot. subsp. *squarrosa* (Wallr.) Ruoss – PP, F3 [Cieśliński 2003; Hołdyński et al. 2009]
C. botrytes (K.G. Hagen) Willd. – EN, F1 [Tobolewski, Kupczyk 1976; Cieśliński 2003]
C. ciliata Stirt. – PP, F2 [Cieśliński 2003]
C. mitis Sandst. – PP, F2 [Juśkiewicz, Endler 2000; Cieśliński 2003, Hołdyński et al. 2009]
C. incrassata Flörke – EN, F1
C. parasitica (Hoffm.) Hoffm. – EN, F3 [Cieśliński 2003; Hołdyński et al. 2009]
C. rangiferina (L.) F.H. Wigg. – PP, F3 [Cieśliński 2003; Hołdyński et al. 2009]
Cliostomum corrugatum (Ach.) Fr. – CR, F1 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
Cyphelium inqiunans (Sm.) Trevis. – CR, F1 [Hołdyński et al. 2009]
Evernia prunastri (L.) Ach. – PP, NT, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
Fellhanera gyrophorica Sérus., Coppins, Diederich & Scheidegger – LC, F3 [Hołdyński et al. 2009; Kubiak 2011b]
Flavoparmelia caperata (L.) Hale – SP, EN, F2 [Kubiak 2002; Hołdyński et al. 2009; Kubiak 2011a]
Graphis scripta (L.) Ach. – NT, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
Gyalecta truncigena (Ach.) Hepp – EN, F1 [Hołdyński et al. 2009]
Hertelidea botrytosa (Fr.) Printzen & Kantvilas – VU, F1
Hydropunctaria rheitrophila (Zschacke) Keller, Gueidan & Thüs – VU, F1
Hypogymnia farinacea Zopf – VU, F1 [Kubiak 2002]
H. tubulosa (Schaer.) Hav. – NT, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
Imshaugia aleurites (Ach.) S. L. F. Meyer – SP, F4 [Cieśliński 2003; Hołdyński et al. 2009]
Lecania fuscella (Schaer.) A. Massal. – NT, F1 [Cieśliński 2003]
Lecanora albella (Pers.) Ach. – EN, F2 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
L. intumescens (Rebent.) Rabenh. – EN, F1 [Cieśliński 2003]
L. persimilis (Th. Fr.) Nyl. – DD, F2 [Hołdyński et al. 2009; Kubiak 2011a]

L. *sambuci* (Pers.) Nyl. – DD, F1 [Hołdyński et al. 2009]
L. *sarcopidoides* (A. Massal.) A.L. Sm. – NT, F1 [Kubiak 2002; Hołdyński et al. 2009]
Lobaria pulmonaria (L.) Hoffm. – SP, EN, F2 [Kubiak, Ryś 2000; Ryś 2005; Hołdyński et al. 2009, Kubiak 2011a, b]
Loxospora elatina (Ach.) A. Massal. – EN, F2 [Hołdyński et al. 2009; Kubiak 2011a]
Melanelia sorediata (Ach.) Goward & Ahti – SP, F1 [Cieśliński 2003]
Melanelixia glabratula (Lamy) Sandler & Arup – SP, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
M. subargentifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – SP, VU, F1 [Cieśliński 2003; Hołdyński et al. 2009]
M. subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – SP, F1 [Cieśliński 2003]
Melanohalea exasperatula (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – SP, F3 [Cieśliński 2003; Hołdyński et al. 2009]
Micarea elachista (Körb.) Coppins & R. Sandst. – EN, F2 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Czarnota 2007; Hołdyński et al. 2009]
M. melaena (Nyl.) Hedl. – NT, F3 [Czarnota 2002, 2007; Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009]
Ochrolechia alboflavescens (Wulfen) Zahlbr. – CR, F1 [Hołdyński et al. 2009; Kukwa 2011]
O. bahusiensis H. Magn. – VU, F3 [Fałtynowicz, Sulma 1994; Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009; Kukwa 2011; Kubiak 2011a]
Opegrapha niveoatra (Borrer) J. R. Laundon – VU, F2 [Cieśliński 2003; Hołdyński et al. 2009]
O. rufescens Pers. – VU, F1 [Hołdyński et al. 2009]
O. varia Pers. – NT, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
O. vermicellifera (Kunze) J. R. Laundon – EN, F1 [Hołdyński et al. 2009, Kubiak 2011a]
O. viridis (Ach.) Behlen & Desberger – VU, F4 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
O. vulgata (Ach.) Ach. – VU, F1
Pachyphiale fagicola (Hepp) Zwackh – VU, F1 [Kubiak 2002; Hołdyński et al. 2009; Kubiak 2011a]
Parmelia saxatilis (L.) Ach. – SP, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
Parmelina tiliacea (Hoffm.) Hale – SP, VU, F1 [Cieśliński 2003]
Parmeliopsis ambigua (Wulfen) Nyl. – SP, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
Peltigera canina (L.) Willd. – SP, VU, F1 [Cieśliński 2003]

P. didactyla (With.) J. R. Laundon – SP, F2 [Lettau 1919; Cieśliński 2003; Hołdyński et al. 2009]
P. monticola Vitik. – SP, DD, F1 [Cieśliński 2003]
P. neckeri Müll. Arg. – SP, NT, F1 [Cieśliński 2003]
P. praetextata (Sommerf.) Zopf – SP, VU, F3 [Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
P. rufescens (Weiss) Humb. – SP, F2 [Juśkiewicz, Endler 2000; Cieśliński 2003]
Pertusaria coccodes (Ach.) Nyl. – NT, F4 [Fałtynowicz, Sulma 1994; Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
P. coronata (Ach.) Th. Fr. – VU, F1 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009]
P. flavida (DC.) J. R. Laundon – EN, F2 [Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
P. hemisphaerica (Flörke) Erichsen EN, F1 [Fałtynowicz 1992; Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009]
P. leioplaca DC. – NT, F4 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]
P. pertusa (Weigel) Tuck. – VU, F2 [Cieśliński 2003; Hołdyński et al. 2009]
P. pupillaris (Nyl.) Th. Fr. – NT, F2 [Kubiak et al. 2010; Hołdyński et al. 2009; Kubiak 2011a, b]
Phaeophyscia ciliata (Hoffm.) Moberg – EN, F1 [Hołdyński et al. 2009]
Ph. endophoenicea (Harm.) Moberg – EN, F2 [Hołdyński et al. 2009; Kubiak 2010b, 2011b]
Ph. sciastra (Ach.) Moberg – LC, F1 [Cieśliński 2003]
Phlyctis agelaea (Ach.) Flot. – EN, F1 [Fałtynowicz, Sulma 1994; Cieśliński 2003]
Physconia distorta (With.) J. R. Laundon – EN, F1 [Cieśliński 2003]
Ph. perisidiosa (Erichsen) Moberg – EN, F1 [Cieśliński 2003; Hołdyński et al. 2009]
Platismatia glauca (L.) W. L. Culb. & C. F. Culb. – SP, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
Pleurosticta acetabulum (Neck.) Elix & Lumbsch – SP, EN, F2 [Cieśliński 2003]
Porpidia cinereoatra (Ach.) Hertel & Knoph – LC, F1 [Cieśliński 2003]
Pseudevernia furfuracea (L.) Zopf. – SP, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
Psilolechia lucida (Ach.) M. Choisy – LC, F1 [Kubiak 2002; Hołdyński et al. 2009]
Pyrenula nitida (Weigel) Ach. – VU, F3 [Kubiak 2002; Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
P. nitidella (Schaer.) Müll. Arg. – EN, F2 [Kubiak 2002; Cieśliński 2003; Czyżewska, Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]
Pyrrhospora quernea (Dicks.) Körb. – CR, F1 [Kubiak et al. 2010]

Ramalina farinacea (L.) Ach. – SP, VU, F5 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]

R. fastigiata (Pers.) Ach. – SP, EN, F4 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]

R. fraxinea (L.) Ach. – SP, EN, F4 [Cieśliński 2003; Hołdyński et al. 2009]

R. obtusata (Arnold) Bitter – SP, EN, F1

R. pollinaria (Westr.) Ach. – SP, VU, F4 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a, b]

Rinodina exigua (Ach.) Gray – VU, F1 [Cieśliński 2003]

Stereocaulon nanodes Tuck. – SP, EN, F1 [Cieśliński 2003]

S. tomentosum Fr. – SP, EN, F1 [Cieśliński 2003]

Thelidium minutulum Körb. – NT, F1 [Hołdyński et al. 2009]

Trapeliopsis glaucolepidea (Nyl.) Gotth. Schneid. – DD, F1 [Hołdyński et al. 2009; Kubiak et al. 2010; Kubiak 2011a]

T. viridescens (Schrad.) Coppins & P. James – NT, F1 [Hołdyński et al. 2009]

Usnea ceratina Ach. – SP, CR, F1 [Lettau 1919; Cieśliński 2003]

U. filipendula Stirt. – SP, VU, F3 [Cieśliński 2003; Hołdyński et al. 2009]

U. hirta (L.) F. H. Wigg. – SP, VU, F4 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]

U. subfloridana Stirt. – SP, EN, F3 [Cieśliński 2003; Hołdyński et al. 2009; Kubiak 2011a]

Verrucaria hydrella Ach. – VU, F1

V. praetermissa (Trevis) Anzi – NT, F1 [Hołdyński et al. 2009]

Vulpicida pinastri (Scop.) J.-E. Mattson & M. J. Lai – SP, NT, F2 [Cieśliński 2003; Hołdyński et al. 2009]

Xanthoparmelia mougeotii (D. Dietr.) Hale – SP, VU, F1 [Cieśliński 2003]

X. stenophylla (Ach.) Ahti & D. Hawksw. – SP, F1 [Cieśliński 2003]

CONCLUSION

Nidzica Primeval Forest constitutes a very important refuge for diverse lichen biota, which comprise many protected species and lichens that are threatened with extinction in Poland. Information about the extinction or decline in the abundance of some taxa of lichens indicates that the current system of protection of the natural resources of this area does not guarantee their sustainability. The only effective form of protection of lichens in forest areas seems to be protection of their natural habitats, with the fullness of natural, typical for individual ecosystems biocenotic properties. Such protection can be provided by national parks and strictly protected nature reserves, which cover a large area of forest, which are still missing in this part of the country.

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THE PROTECTED AND THREATENED LICHENS OF THE ROADSIDE TREES IN THE KRAJEŃSKIE LAKELAND

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Abstract. The publication presents the results of studies conducted on lichens of the roadside trees in the Krajeńskie Lakeland. From among the species found, 25 were ranked as the most rare ones. 20 species of them are under strict protection, 1 under partial protection and 18 are among the threatened species in Poland. The work presents the attempts to protect the valuable rows of roadside trees made so far and also the proposals to establish subsequent nature monument status for the protection of lichens in the study area.

Key words: lichens, roadside trees, protected species, threatened species, the Krajeńskie Lakeland, nature monument.

INTRODUCTION

A common element of the landscape, at least recently, has been the roadside tree rows, particularly in open landscapes. Planted by humans, they have become an integral part of the natural environment, playing an important role in the enrichment and maintenance of biodiversity.

The role of the tree rows is particularly important when dealing with the fragmentation of the landscape, cause by such phenomena as deforestation, traffic routes and economic management.

The linear landscape elements, such as tree rows, constitute important movement routes for many animals between their breeding colonies and feeding grounds, as well as important seasonal migration trails between summer and winter hiding places. By connecting forest complexes, they become migration corridors for such animals as tiny mammals, birds and insects. The tree rows constitute the place of shelter, feeding, reproduction and nesting for various organisms, including those under protection, such as bats, saproxylic beetles (Gutowski, Ruta 2004; Gawroński, Oleksa 2006; Lesiński 2006, 2007, 2008).

The bark of the roadside trees is also an important base for the settlement of numerous epiphytic lichens. Only the work by Rydzak (1970) is entirely dedicated to this issue. The need for the protection of, among other things, the roadside trees as a precious lichen locality was already postulated by Motyka (1934).

In the majority of works, roadside tree covers are mentioned as one of the many localities, without being described in detail or distinguished because of their lichenological value (inter alia Fałtynowicz, Miądlikowska 1990; Lipnicki 1990; Matwiejuk 2009a,b; Czarnota, Wojnarowicz 2008). Not many publications indicate the potential lichenological attractiveness of these localities (Szymczyk, Zalewska 2008; Izydorek 2010). Part of the studies refers only to the aspects of bio monitoring (Loppi 1996; Winn 1999; Mendil et al. 2005; Mamor, Randlane 2007; Çiçek et al. 2008; Ali et al. 2011).

The purpose of the present publication is to present the special care species occurring on the roadside trees of the Krajeńskie Lakeland.

STUDY AREA

The mesoregion of the Krajeńskie Lakeland (314.69) is situated in the north-west part of Poland. It belongs to the Mid-European Lowland province, South-Baltic Coastlands sub-province and the land of South Pomeranian Lakeland. It is surrounded by the Gwda Valley (314.68), the Brda Valley (314.72) and the Middle Noteć Valley (315.33), and from the north it is encased by the Charzykowska Plain (314.67) and the Bory Tucholskie Forest (314.71). It covers an area of approx. 4,380 km^2 (Kondracki 2001). The area of the Krajeńskie Lakeland is situated within the administrative borders of the following provinces (Voivodeships): Pomerania Province, Kujawy-Pomerania Province and West Pomerania Province, between 53°05' and 53°50' N latitude and between 16°45' and 17°50' E longitude (Umiński 1991). The largest town (approx. 40 thousand inhabitants) is Chojnice, located in the north of the mesoregion. Other more important localities may include the following: Człuchów, Czarne, Debrzno and Złotów.

The vascular flora of the middle part of the Krajeńskie Lakeland was estimated at 853 species (Latowski et al. 1971), of which the segetal vegetation included 269 taxa (Sobisz, Ratuszniak 2003).

Over 70% of the area of the mesoregion is an agricultural landscape (Waldon 2008). According to the data by Trampler et al. (1990) the forestation rate of the Krajeńskie Lakeland is 27.3%. In the western part of the region, the largest forest complexes include: the forests in the vicinity of Złotów, near Krajenka and Skórka. In the central part of the Krajeńskie Lakeland – the forests by the River Łobżonka, and in the north part – by the River Szczyra as well as in the area of Człuchowo and Chojnice.

The dominant forest communities include pine forests, although there are also communities of deciduous forests. The timber stand is composed primarily of *Pinus sylvestris* (over 85%), in the undergrowth the following species prevail: *Juniperus communis*, *Frangula alnus* and *Corylus avellana* and the undergrowth of *Quercus* sp., *Fagus sylvatica* and *Acer* sp. (Umiński 1991). The frequently encountered forest communities include: black alder bog forest, streamside alder-ash forest and streamside elm-ash forest as well as the acidophilous oak-beech forest (acidophilous oak wood). The fertile oak-linden-hornbeam forests (*Galio silvatici-Carpinetum*) is formed by dense complexes in the middle part of the Krajeńskie Lakeland. Those that are not so frequent and only fragmentarily developed include: the Pomerania beech wood and the luminous oak wood (Boiński 1973).

The road network of the Krajeńskie Lakeland is relatively well developed and is characterized by an average level of communications access. The territory of the Lakeland is intersected by 3 national roads: No. 10 (Szczecin-Płońsk), No. 22 (Kostrzyn n. Odrą-Elbląg) No. 25 (Bobolice-Oleśnica). The network of national roads will be supplemented by good-quality hard surface roads (Umiński 1991). In connection with the increasing volume of traffic and due to the financial support from the European Union, by-passes come into existence that run outside of the cities and towns, and part of the municipal commune and poviat roads are successively being widened and modernized.

STUDY METHODS

The studies were conducted in the years of 2009-2011. They consisted of a detailed inventory of the lichens growing on the roadside trees. During the works, all the species, which are threatened and which are subject to legal protection were reported to exist.

In the alphabetic list of species, the following information has been detailed: Latin name, general characteristics of distribution and number, notes resulting from the lichen observations. The following abbreviations and symbols have been used:

- the category of the threat according to Cieśliński et al. (2006): EN – endangered, VU – vulnerable, NT – near threatened;

- the protection status – on the basis of the Ordinance of the Minister of the Environment of the 9th of July 2004 on the protection of wild fungi species (Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765): §§ - subject to total protection, § - subject to partial protection;

Nomenclature of the lichens – according to Diederich et al. (2012).

The graphical distribution of the localities of chosen species has been presented in Fig. 1.

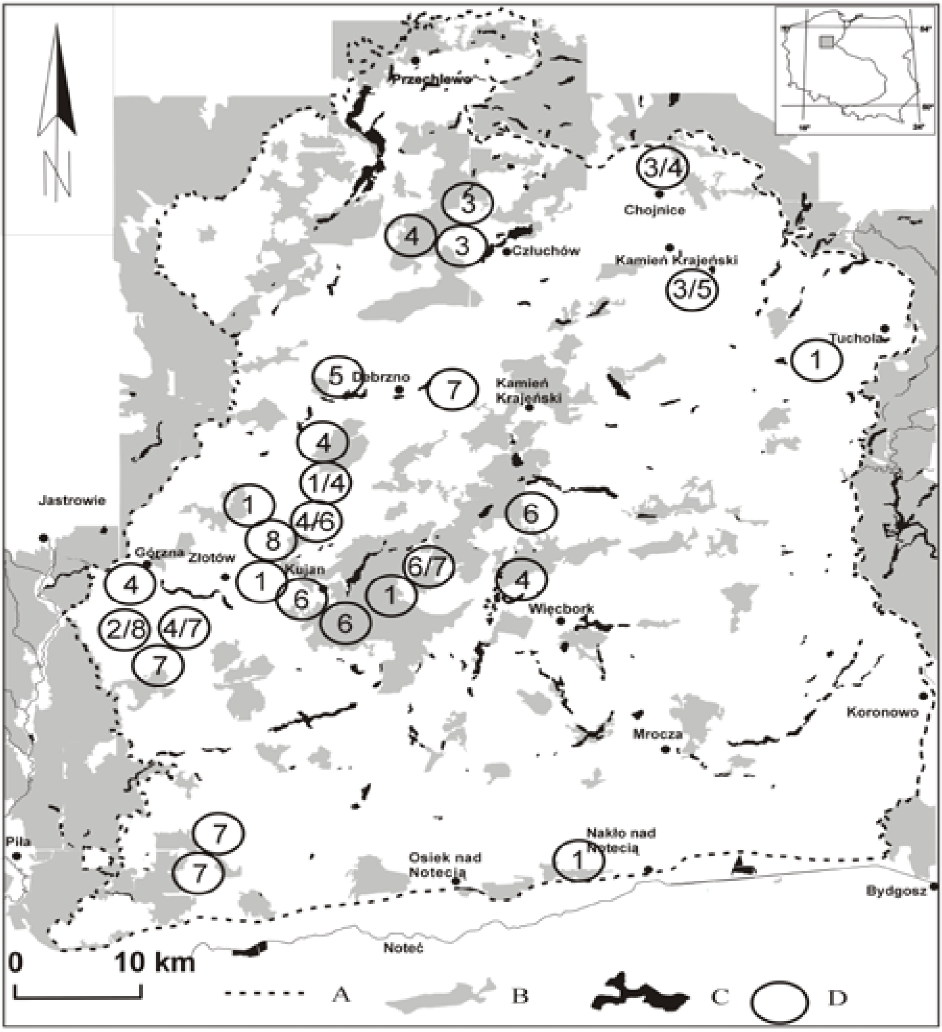

Fig. 1. The distribution of the chosen species of protected and threatened lichens on the roadside trees of the Krajeńskie Lakeland: 1 – *Anaptychia ciliaris*, 2 – *Bryoria fuscescens* 3 – *Parmelia saxatilis*, 4 – *Parmelina tiliacea*, 5 – *Pertusaria coccodes*, 6 – *Usnea filipendula* 7 – *Usnea hirta*, 8 – *Vulpicida pinastri*;
A – borders of the Krajeńskie Lakeland, B – forest areas, C – water bodies, D – lichen localities.

RESULTS OF THE STUDIES

From among the taxa found, 25 species are particularly precious. 18 are featured in the Red List of extinct and threatened lichens in Poland (Cieśliński et al. 2006): in the EN Endangered category – 5 species, VU Vulnerable – 8 species, NT Near Threatened – 5 species. From among the species which are under legal protection in Poland (Dz.U. *[Official Gazette]* 2004 No. 168, Item 1765), 20 species are under strict protection, and 1 species is under partial protection, i.e. – *Evernia prunastri*.

CHARACTERISTICS OF SPECIES

Anaptychia ciliaris (L.) Körb. (§§), EN – a very rare species in the region, found exclusively on *Acer platanoides* in 5 localities by the roads with moderate and small traffic volume. All the specimens developed single, small thalli without fruiting bodies and signs of dying. Localities: (1) road no. 189 (Jastrowie-Więcbork), beside the crossing of roads to Złotowo, Międzybłocie and Kujan; (2) between Nowa Wiśniewka and Łąkie; (3) between Sypniewo and Jeleń; (4) on 2 trees by the road no. 241 (Tuchola-Rogoźno) between Tuchola and Mędromierze Małe; (5) the road from Samostrzel towards Bnino;

Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw. (§§), VU – one small thallus on *Betula pendula*. Locality: (1) the road from Dolnik towards the Głubczyn village;

Evernia prunastri (L.) Ach. (§), NT – common and widely distributed on the roadside trees, on many phorophytes (especially on *Acer platanoides*) it occurs in masses;

Hypogymnia tubulosa (Schaer.) Hav. (§§), NT – numerous localities scattered all across the region by roads with small traffic volume, usually found in the form of small single thalli without signs of degeneration;

Melanelixia fuliginosa subsp. *fuliginosa* (Duby) O. Blanco et all. (§§) – it is scattered all across the Lakeland region, usually in the form of single thalli;

Melanohalea elegantula (Zahlbr.) O. Blanco et all. (§§), VU – very rare on roadside trees, found in the form of single thalli. Localities: (1) on *Tilia cordata*, *Fraxinus excelsior* and *Acer platanoides* by the road no. 241 (Tuchola-Rogoźno) between Tuchola and Mędromierze Małe; (2) on *Carpinus betulus* between Trudna and Łąkie;

Melanohalea exasperatula (Nyl.) O. Blanco et all. (§§) – generally common in the entire area, usually occurs in the form of a few - a few dozen thalli, also found on the bark of *Acer platanoides*;

Parmelia saxatilis (L.) Ach. (§§) – found in 4 localities, in each locality it occurs in the form of several clustered thalli. Localities: (1) on *Populus* sp. by the road between Chrząstowo and Biskupnica; (2) on *Fagus silvatica* in Pakotulsko; (3) on *Acer platanoides* between Jarcewo and Powałki; (4) on the bark of *Carpinus betulus* in the region of Mała Cerkwica (near Kamień Krajeński);

Parmelina tiliacea (Hoffm.) Hale (§§), VU – rare species in the region, by roads with medium traffic volume, usually in the form of a few - a few dozen thalli, scattered on the trunk, primarily in the lower parts of the trunk. Localities: (1) on *Acer platanoides* between Jarcewo and Powałki; (2) on *Acer platanoides* between Nowa Wiśniewka and Łąkie; (3) on a few dozen trees in Augustowo by the road to Krajenka; (4) on *Carpinus betulus* between Kiełpino and Łąkie; (5) on *Fraxinus excelsior* in Stawnica; (6) in Biskupnica on *Tilia* sp., (in masses); (7) on two *Fraxinus excelsior* in Górzna by the road towards Jastrowie. (8) on *Acer platanoides* on the road leading to Iłowo to the crossroads with the road Lutowo-Lipka;

Parmeliopsis ambigua (Wulfen) Nyl. (§§) – found on *Carpinus betulus* in 3 localities in the form of single thalli in the middle parts of the trunk. Localities: (1) by the road from Iłowo to the crossing with the road Lutowo-Lipka, on *Carpinus betulus* between Lipka and Czyżkowo; (2) between Łąkie and Lipka, (3) the road from Drożdzienica to the crossing with the road between Duża Cerkwica and Mała Cerkwica;

Pertusaria coccodes (Ach.) Nyl. NT – very rare in the area of the Lakeland, found on *Carpinus betulus*. Localities: (1) between Trudna and Łąkie in the neighbourhood of Zdrojewo; (2) by the road from Mała Cerkwica to Zalesie;

Pertusaria leioplaca DC. NT – a single locality in the roadside *Carpinus betulus* between Trudna and Łąkie in the area of Zdrojewo;

Pertusaria pertusa (Weigel) Tuck. NT – found on *Carpinus betulus*; (1) between Trudna and Łąkie in the vicinity of Zdrojewo; (2) between Mała Cerkwica and Radzim;

Physconia perisidiosa (Erichsen) Moberg EN – found in 3 localities beside less occupied roads, surrounded by forests. Localities: (1) on *Ulmus* sp. by the road from Iłowa to the crossing with the road Lutowo-Lipka; (2) on *Acer platanoides* by the road between Mała and Duża Cerkwica, (3) the road from Sępolno Krajeńskie to Tuchola between Trzciany and Pamiętowo;

Platismatia glauca (L.) W.L. Culb. & C.F. Culb (§§) – rare species, spread on the roadside trees. It occurs in the form of small single thalli in places with small traffic volume, most frequently surrounded by forests, far from residential places;

Pleurosticta acetabulum (Neck.) Elix & Lumbsch (§§), EN – often and very widespread in the region, very abundant in many localities, primarily with developed fruiting bodies;

Pseudevernia furfuracea (L.) Zopf (§§) – quite often in the region, by the roads with medium and small traffic density, on some trees occurring in masses. The majority of thalli showed signs of severe degeneration;

Ramalina farinacea (L.) Ach. (§§), VU – the most common specimen of the genus in the region, most often found in the form of a few - a few dozen specimens on the trunk;

Ramalina fastigiata (Pers.) Ach. (§§), EN – common in the region, most often found in the form of single thalli, in the middle and upper parts of tree trunks;

Ramalina fraxinea (L.) Ach. (§§), EN – common in the region, most often found in the form of several thalli, only a few specimens have not developed fruiting bodies;

Ramalina pollinaria (Westr.) Ach. (§§), VU – not very often, usually occurs in the form of single thalli along with other specimens of the genus;

Tuckermannopsis chlorophylla (Willd.) Hale (§§), VU – not numerous, scattered all across the region, most frequently on the bark of *Acer platanoides* as well as on the bark of trees from the genus of *Ulmus* sp., in the form of small single thalli;

Usnea filipendula Stirt. (§§), zonal, VU – found in 5 localities by the roads with small and medium traffic volume in the form of small single thalli. Localities: (1) on *Fraxinus excelsior* in Stawnica; (2) Adamowo village on *Quercus* sp.; (3) on *Acer platanoides* by the road Wiśniewa – Radońsk; (4) the road no. 189 (Jastrowie-Więcbork) near Kujan; *(5)* between Rudna and the crossing with the road Jastrowie-Więcbork;

Usnea hirta (L.) Weber ex F.H. Wigg. (§§), zonal, VU – found in six localities by the roads with small traffic volume; (1) the road from Dolnik towards the Głubczyn Village; (2) the road between Stare Gronowo and Poręba; (3) on the exit road from Zelgniewo towards Piła on *Quercus rubra*, (4) on *Tilia* sp. by the internal road in the centre of Zelgniewo; (5) Adamowo Village on *Quercus* sp.; (6) the road between Krajenka and Podróżna on the bark of *Ulmus* sp.;

Vulpicida pinastri (Scop.) J.-E. Mattson & M. J. Lai (§§) – found on *Betula pendula*, in both cases in the form of small, poorly stained thalli, without developed soralia and with signs of dying. Localities: (1) the road from Dolnik towards the Głubczyn Village; (2) the road to Lipka between Złotowo and Łączyn;

ROADSIDE TREE ROW PROTECTION

On the basis of the provisions of Article 40, Articles 44 and 60, Section 1 and Section 2 of the Act of the 16th of April 2004 on Protection of Nature (Dz.U. *[Official Gazette]* 2004 No. 92, Item 880 with subsequent amendments) the presence of precious species (e.g. lichens) and the high number of the populations of some of them, may constitute the basis for the establishment of nature monuments encompassing the row of roadside trees. The management procedures in the indicated facilities should incorporate only the necessary conditioning works, such as the removal of dry, dead boughs from the side of the road and the cutting of root offshoots. So far, in the territory of the Krajeńskie Lakeland, 1 natural monument have been established due to its unique lichenological value:

- the row of trees over 2 km long between Jarcewo and Powałki

The Municipal Commune Councils, which have the authority to establish nature monuments, often fail to decide on their establishment. Their argument for such behaviour is the necessity to fell the trees because of the modernization and widening of the road, poor health of the trees (the tree row from Sępolno towards Jemielno) or they act without any justification (the tree row between Głubczyn and Krajenka).

With regard to the occurrence of rare lichen species, it is advisable to preserve and place under protection the following sections of the roadside tree rows:

- between Prusinowo and Rozwory (near Debrzno)
- between Scholastykowo and Debrzno
- between Dąbrówka and Drożdzienica (near Sępólno Krajeńskie)
- between Więcbork and Jastrzębiec

- the group of trees in Biernatka (near Człuchów)
- between Szczytno and Lisiewo (near Przechlewo)

DISCUSSION

In the majority of cases, the necessity to remove roadside trees is justified by the threat to road safety. The Act of the 16th of April 2004 on Protection of Nature (Dz. U. *[Official Gazette]* 2004 No. 92, Item 880), in Article 86 Points 4 and 5 permits the removal of trees, which pose a threat to people and property in the existing building facilities, and which threaten the safety of road and railway traffic. However, the lack of objective criteria for such threats leads - in practice - to a free interpretation of the provision and too often causes the authorities to take too hasty decisions about the felling of trees. There is no doubt that some roadside trees (weak, dry) are a potential risk to road users; however, after application of proper procedures and periodic controls they could continue to grow for many years. In our country, unfortunately, the felling or drastic conditioning of roadside trees (as it is referred to) is becoming the fundamental action to improve the safety of road traffic.

In other countries, a lot of attention is paid to the elimination of such a situation (Worobiec, Liżewska 2008). Solutions for the protection of road users are sought, but the cutting down of trees is assumed to be the last resort. Unfortunately, in Poland an excuse is most often resorted to, saying that a tree is a nuisance. No other solution, which may be more difficult and more expensive, is sought. There are situations when there is no other solution; however, the felling of roadside trees should be performed only in isolated cases.

In the territory of the Krajeńskie Lakeland, the trunks of road-side trees are the place where many protected and threatened lichens occur. Establishing these trees as nature monuments will contribute to the efficient protection of the lichenological biodiversity. The repairing and compensation activities of the tree-fellers are, in fact, impossible because the transportation of lichens to new localities is not effective.

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NEW RECORDS OF LICHENIZED AND LICHENICOLOUS FUNGI FROM TATRA NATIONAL PARK (W CARPATHIANS)

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Abstract. Fifteen lichenized and 7 lichenicolus fungi new to the whole Tatra Mts, next 7 species new for only the Polish side of this mountain range are reported. Three other sorediate lichen species rarely reported from Polish Carpathians are also included. *Agonimia flabelliformis* is recorded as new for Poland and the Carpathians. Some noteworthy species are briefly commented on including taxonomic remarks, ecological data and their distribution in the Carpathians. Among lichens are early colonizers of woody substrates (e.g., *Lecanora aitema*, *L. compallens*, *L. sarcopidoides*, *Lecidella subviridis*, *Micarea nowakii*) and siliceous rocks (e.g., *Absconditella delutula*, *Thelocarpon intermediellum*), as well as representatives growing on more decayed lignum (e.g., *Absconditella pauxilla*, *Biatora veteranorum*, *Micarea nigella*), remnants of bark on dead spruce trees (*Arthonia mediella*) and ephemeral species found on up-ended root systems (e.g., *Agonimia repleta*). All the species presented have been found in 2010 in the strictly protected areas of the Tatra National Park during an exploration of main forest communities more or less destroyed by the activity of bark beetle *Ips typographus* and storm winds.

Key words: lichens, Ascomycota, Basidiomycota, lichen diversity, national park, nature conservation, Poland

INTRODUCTION

The nature of Tatra Mts, the highest range in the whole Carpathians, is one of the better known in Central Europe. Lichenologically, this mountain range has been intensively explored since the 19th century mainly by Polish, Slovak, Czech and Hungarian lichenologists (see references in Olech 2004 and Lisická 2005). About 1 350 species of lichenized and lichenicolous fungi have been recognized to date from the whole Tatra range; ca 1 180 species from the Slovak part and ca 1 000 taxa from the Polish part (Bielczyk 2003; Flakus 2004, 2006, 2007; Krzewicka 2004; Kukwa 2004; Olech 2004; Lisická 2005; Flakus & Bielczyk 2006; Śliwa 2006; Śliwa & Kukwa 2008; Węgrzyn 2008, 2009; Kukwa & Flakus 2009; Śliwa & Flakus 2011). Recent author's investigations in the area of Tatra National Park show, however, that other 22 taxa found in spruce stands destroyed by the activity of bark beetle *Ips typographus* have never been reported from these mountains and a further 7 species have been discovered for only the Polish side of this range; *Agonimia flabelliformis* is additionally new for Poland and the whole

Carpathians. Three sorediate, usually sterile and still poorly known species in Poland, Fuscidea pusilla, Lecidea nylanderi and Lecidella subviridis which have recently been found in Tatra Mts by other lichenologists (Flakus pers. inform.) are listed here to show their larger distribution in the Carpathians.

The majority of these species are regarded as microlichens or they are usually found in a sterile form, thus they could be overlooked so far being probably more widespread here. Some of them are known as growing exclusively on wood of decaying spruce snags and trunks of dead trees or on root systems of windthrows. It suggests that they could appear in this region just after some essential changes of ecological conditions. One of them could be an accumulation of basal substrate, for example a large amount of coniferous dead wood in different stages of decomposition or large-scale windthrows. Such circumstances are present today in many places of the Polish side of the Tatra Mts covered with upper mountain spruce forests, especially in areas of the Tatra National Park strictly protected for a long time.

The aim of this paper is to present the list of lichenized and lichenicolous fungi new for the whole Tatra range as well as only in the Polish part within the boundaries of the Tatra National Park, found in 2010.

MATERIAL AND METHODS

The material was examined using standard microscopic techniques. Apothecial hand-made sections were mounted in water and details of anatomy were measured in KOH. For some externally developed species standard spot test reactions with K, C and P were studied, and for sterile sorediate species, thin-layer chromatography (TLC) was performed in solvent C, according to Orange et al. (2001). The nomenclature follows Index Fungorum (www.indexfungorum.org [date of exploration 2.01.2012]), for *Bacidina sulphurella* – Hauck and Wirth (2010), for the genus *Violella* – Spribille et al. (2011). Collected specimens are deposited in the herbarium of Gorce National Park (GPN). The localities of particular specimens are listed in the modified ATPOL grid square system according to Cieśliński & Fałtynowicz (1993). Lichenicolous fungi are asterisked (*).

THE SPECIES

For all examined specimens the main locality is: POLAND. Western Carpathians, Tatra Mts, Tatra National Park. In the case of many findings of some species, only its selected specimens have been presented. If not otherwise stated, the species is reported here as new for the whole Tatra Mts.

Absconditella delutula (Nyl.) Coppins & H. Kilias

Similarly as in other recently explored regions in the Polish Western Carpathians (Gorce, Beskid Wyspowy) (Czarnota & Kukwa 2008) this ephemeral species has been found on small siliceous pebbles over root systems of spruce windthrows within rather shady and humid forested microhabitats.

Specimens examined. All on small granite pebbles. Ge-50 – forest section no. 71a, Dolina Białki valley, Siwarne forest area, 49°14′18.2″N, 20°05′30″E, alt. 1080 m, 8.07.2010, *leg. P. Czarnota* 6766; forest section no. 102a, Dolina Suchej Wody valley, S of Wyżni Toporowy Staw lake, 49°16′39.5″N, 20°01′43.5″E, alt. 1140 m, 14.07.2010, *leg. P. Czarnota* 6891.

Absconditella pauxilla Vězda & Vivant

Among other mostly lignicolous, morphologically similar representatives of the genus *Absconditella*, *A. pauxilla* is distinguished by acicular, narrow ascospores. The most similar *A. annexa* (Arnold) Vězda has more septate (5–7) and wider, rather fusiform ascospores.

This inconspicuous ephemeral species was reported only twice from Poland, from its northern, seaside region (Czarnota & Kukwa 2008). In Central Europe *A. pauxilla* is known only in the Czech Republic (Palice 1999), and here it is presumably new for the Carpathians. Current world distribution and ecological preferences of this species are presented by Czarnota and Kukwa (2008).

Specimen examined. Gd-59 – forest section no. 211j, Dolina Strążyska valley, close to Ścieżka pod Reglami hiking track below Koński Żleb area, 49°15′42.1″N, 19°56′08″E, alt. 1160 m, on wood of log of spruce windthrow, 13.07.2010, *leg. P. Czarnota* 6870.

Agonimia flabelliformis Halda, Czarnota & Guzow-Krzemińska

This recently described species (Guzow-Krzemińska et al. 2012) mostly resembles 8-spored *Agonimia allobata* (Stizenb.) P. James by its superficial, globose and smooth perithecia with a pale collar around ostiolum. The main difference is in the structure of the thallus, which is distinctly raised, coralloid to palmate in *A. flabelliformis*, while in *A. allobata* it is warted to subsquamulose. Such flabelliform thallus characterizes also *Verrucaria viridigrana* Breuss, but its ascospores are simple, not muriform as in *A. flabelliformis*. Sometimes also some forms of *Placynthiella icmalea* develops coralloid thallus, which is frequently sterile, but than simple C+ red reaction make the distinction available since *P. icmalea* produces gyrophoric acid and *A. flabelliformis* has no extrolites detected by TLC. For more taxonomic details see Guzow-Krzemińska et al. (2012).

Agonimia flabelliformis is known from several European countries: the Czech Republic, Germany and Great Britain (Guzow-Krzemińska et al. 2012), and here it is reported for the first time from Poland and the Carpathians, extending its range to the East. This species sometimes has an epibryophytic character, but it is also found directly on decaying wood or bark, as in this Tatra case, or on bark of living trees in different forest communities.

Specimen examined. Gd-59 – forest section no. 201i, valley of Biały Potok stream, 49°16′14.8″N, 19°57′24.1″E and 49°16′15.8″N, 19°57′25.1″E, alt. 1020 m, on roots of *Picea abies* within mixed spruce and beech forest, 12.08.2010, *leg. P. Czarnota* 7110 & 7116.

Agonimia repleta Czarnota & Coppins

This microlichen is reported from the Carpathians several times being found as an epiphyte on bark of roots and at the base of various deciduous trees as well as on bryophytes over rocks and trunks (e.g. Bielczyk 2003; Svoboda et al. 2007; Vondrák et al. 2010). In contrast to other 8-spored members of *Agonimia*, especially to *A. allobata* with sometimes similar minutely squamulose thallus, perithecia of *A. repleta* are smaller, usually pyriform with rough surface.

Specimens examined. **Gd-59** – forest section no. 201i, valley of Biały Potok stream, 49°16′14.8″N, 19°57′24.1″E and 49°16′15.8″N, 19°57′25.1″E], alt. 1020 m, on mosses roots of *Picea abies* within mixed spruce-beech forest, 12.08.2010, *leg. P. Czarnota* 7110, together with *A. flabelliformis* & 7119.

Arthonia digitatae* Hafellner

This lichenicolous fungus seems to be one of the commonest parasites of *Cladonia digitata* in the Western Carpathians (see also Kukwa et al. 2010) as often found on this host as *Taeniolella beschiana* Diederich and *Phaeopyxis punctum* (A. Massal.) Rambold, Triebel & Coppins. Squamules of *C. digitata* infected by *A. digitata* are discoloured, being firstly pinkish beige to brownish beige and later brown, and sometimes covered with minute dark brown apothecia producing 1-septate spores. It is probably widespread in whole Carpathian range, but overlooked since the minute apothecia are not always developed.

Specimens examined (selected). All on squamules of *Cladonia digitata*. **Gd-59** – forest section no. 212d, Dolina Strążyska valley, close to Siklawica waterfall, 49°15′35.1″N, 19°55′50.1″E, alt. 1080 m, 13.07.2010, *leg. P. Czarnota* 6855. **Ge-50** – forest section no. 65f, Dolina Białki valley, 49°14′58.2″N, 20°05′13.1″E, alt. 1305 m, 30.06.2010, *leg*. P. *Czarnota* 6630; ibid., forest section no. 60f, Dolina Roztoki valley, below Roztocka Czuba Mt., 49°13′51.7″N, 20°05′07.1″E, alt. 1180 m, 9.07.2010, *leg. P. Czarnota* 6834; ibid., forest section no. 143a, Dolina Suchej Wody valley, 49°15′19.2″N, 20°01′25.4″E, alt. 1310 m, 14.07.2010, *leg. P. Czarnota* 6918.

Arthonia mediella Nyl.

New for the Polish side of Tatra Mts.

Specimen examined. **Ge-50** – forest section no. 143a, Dolina Suchej Wody valley, 49°15′04.9″N, 20°01′18.4″E, alt. 1340 m, on bark of dead spruce, 14.07.2010, *leg. P. Czarnota* 6924.

Arthonia spadicea Leight.

New for the Polish side of Tatra Mts.

Specimen examined. **Gd-59** – forest section no. 208h, Dolina ku Dziurze Valley, 49°16′20.1″N, 19°56′26.8″E, alt. 1020 m, on wood of decorticated spruce trunk, 12.08.2010, *leg. P. Czarnota* 7108.

Bacidina sulphurella (Samp.) Hauck & Wirth

This sorediate species has recently been separated from the *Bacidia arnoldiana* group (Brand et al. 2009) and soon newly combined (Hauck & Wirth 2010), thus under this name it was not published yet from the Tatra Mts, although it was formerly collected there and reported as corticolous examples of *Bacidina arnoldiana* (see Lisická 2005; Śliwa 2006). Correct data on its occurrence in the whole Tatra Mts need critical revision of *B. arnoldiana* group stored anywhere, focused on the shape of macroconidia and habitat preferences. Revisions of such materials from some neighbouring ranges of Polish Western Beskidy Mts show that *B. sulphurella* is a common epiphytic and epixylic lichen, while the occurrence of almost exclusively epilithic *B. arnoldiana* s. str. is restricted to the area of calcareous sandstones or limestones (Czarnota 2010). From this reason, recovery of this latter species in the Tatra Mts is also feasible.

Specimens examined. On bark of decaying roots of windfallen spruces within Carpathian beech forest. **Gd-59** – Forest section no. 208a, Dolina ku Dziurze Valley, 49°16′28.8″N, 19°56′22.2″E, alt. 960 m, 12.08.2010, *leg. P. Czarnota* 7103; ibid., forest section no. 201k, valley of Biały Potok stream, 49°16′09.5″N, 19°57′28″E, alt. 1080 m, 12.08.2010, *leg. P. Czarnota* 7129.

Biatora chrysantha (Zahlbr.) Printzen

New for the Polish part of Tatra Mts.

Specimen examined. **Gd-59** – forest section no. 201i, valley of Biały Potok stream, 49°16′14.8″N, 19°57′24.1″E, alt. 1020 m, on decaying bark of spruce snag, 12.08.2010, *leg. P. Czarnota* 7109.

Biatora veteranorum Coppins & Sérus.

This species mentioned so far as *Catillaria alba* Coppins & Vězda in Polish lichen checklists (Fałtynowicz 2003; Bielczyk 2003) has recently been re-named, based on molecular studies (Sérusiaux et al. 2010). Its many findings are known in an anamorphic stage, as stipitate, white pruinose pycnidia rising from an inconspicuous, endoxylic thallus. In the Tatra Mts also its fertile collections have been found, which correspond well with the description of *C. alba* by Vězda (1993) and Sérusiaux et al. (2010). Recent author's explorations of other mountain ranges show that the species occurs through the Polish Carpathians, from the Gorce Mts up to the Bieszczady Mts (Bielczyk 2003; Czarnota 2010).

Specimens examined. **Gd-59** – forest section no. 218b, N slope of Samkowa Czuba Mt., W of Młyniska glade in Strążyska Valley, 49°16′32.4″N, 19°55′43.7″E, alt. 1040 m, on hard wood of dead spruce tree, 12.08.2010, *leg. P. Czarnota* 7050; ibid., forest section no. 218g, Suchy Żleb area, W of Samkowe Siodło pass, 49°16′17.3″N, 19°55′16.2″E, alt. 1140 m, on lignum of spruce snag, 12.08.2010, *leg. P. Czarnota* 7068; ibid., forest section no. 219f, Dolina ku Dziurze Valley, 49°16′14.5″N, 19°55′11.5″E, alt. 1100 m, on lignum of decaying trunk of windfallen spruce, 12.08.2010, *leg. P. Czarnota* 7085.

Chaenothecopsis nigra* Tibell

Specimen examined. **Ge-50** – forest section no. 72g, Dolina Roztoki valley, below Roztocka Turniczka Mt., 49°13′50.7″N, 20°04′58.9″E, alt. 1180 m, on free-living algae on roots of spruce windthrow, 9.07.2010, *leg. P. Czarnota* 6847.

Chaenothecopsis savonica* (Räsänen) Tibell

New for the Polish part of Tatra Mts.

Specimens examined. **Gd-59** – forest section no. 219f, Dolina ku Dziurze Valley, 49°16′14.5″N, 19°55′11.5″E, alt. 1100 m, on lignum of spruce windthrow decaying trunk close to *Chaenotheca xyloxena*, 12.08.2010, *leg. P. Czarnota* 7089; ibid., forest section no. 201i, valley of Biały Potok stream, 49°16′10.2″N, 19°57′27.8″E, alt. 1070 m, on lignum of spruce snag close to *Chaenotheca xyloxena*,12.08.2010, *leg. P. Czarnota* 7127.

Fuscidea pusilla Tønsberg

This sorediate, sterile species is well known in Europe, and several its localities have been reported also from the Carpathians (Śliwa & Tønsberg 1995; Bielczyk 2003; Kościelniak & Kiszka 2003; Kondratyuk & Coppins 2000). In the Tatra mountains, similarly to the neighbouring ranges of the Polish Western Beskidy Mts, it appears frequently on hard wood of dead spruces standing in well exposed places, being one of the first lichen colonizers of this kind of substrate.

Similar in appearance *Ropalospora virids* (Tønsberg) Tønsberg prefers the bark of deciduous trees, and moreover differs in the presence of perlatolic acid, while *F. pusilla* produces divaricatic acid (Tønsberg 1992). In conditions of the much destroyed spruce forests in the Tatra Mts, *F. pusilla* occurs usually together with other similar sorediate species such as: *Loxospora elatina* (Ach.) A. Massal., *Violella fucata* (Stirt.) T. Sprib. and *Pycnora sorophora* (Vain.) Hafellner. They differ, however, in their distinct chemistry, easily detected in simple spot test reactions with C, K or P, and moreover the thalli of *L. elatina* and *P. sorophora* are rather yellowish than greenish as in *F. pusilla*.

Fuscidea pusilla was found in the Tatra Mts last time (Flakus pers. inform.) and here is listed to show its larger distribution in this mountain range.

Specimens examined (selected). All on wood of decorticated spruce trunks. **Gd-59** – forest section no. 216c, Dolina Strążyska valley, close to Siklawica waterfall below Wielki Bacuch area, 49°15′36.6″N, 19°55′48.9″E, alt. 1100 m, 13.07.2010, *leg. P. Czarnota* 6862; ibid., forest section no. 280i, Dolina Kościeliska valley, near Iwanowski Potok stream below Smytniańskie Turnie range, 49°13′53.3″N, 19°51′02.2″E, alt. 1200 m, 22.07.2010, *leg. P. Czarnota* 6948. **Ge-50** – forest section no. 70i, Dolina Białki valley, Las pod Wołoszynem forest area, 49°14′29.9″N, 20°05′18.5″E, alt. 1210 m, 8.07.2010, *leg. P. Czarnota* 6791. **Ge-60** – forest section no. 53f, Dolina Rybiego Potoku valley, below Opalone Mt., 49°13′12.8″N, 20°05′07.2″E, alt. 1350 m, 2.07.2010, *leg. P. Czarnota* 6715.

Lecanora aitema (Ach.) Hepp

Recently Czarnota et al. (2010) show that the species was rarely collected in the Polish Carpathians more than 50 years ago and recognized under *Lecanora symmicta* (Ach.) Ach. In the same work its habit is photographed as well as the notes differentiating *L. aitema* from *L. symmicta* are included. Both taxa characterize the presence of usnic acid and zeorin and similar anatomy, but in general they differ in apothecial pigmentation, which is dark grey to blackish in *L. aitema* and pale, yellowish beige in *L. symmicta*. Here the first current locality of *L. aitema* in Poland is reported.

Specimen examined. **Gd-59** – forest section no. 280i, valley of Iwanowski Potok stream below Iwaniacka Przełęcz pass, 49°13′55.9″N, 19°50′22.0″E, alt. 1390 m, on wood of root of spruce windthrow, 22.07.2010, *leg. P. Czarnota* 6982.

Lecanora compallens Herk & Aptroot

This sterile, yellowish pigmented, sorediate lichen resembling *Lecanora expallens* has been identified here by the presence of usnic acid and zeorin detected by TLC.

From the Carpathians the species is presumably reported only from Polish Western Beskidy Mts (Czarnota 2010).

Specimens examined. **Gd-59** – forest section no. 280j, Dolina Kościeliska valley, near Iwanowski Potok stream below Rzędy Smytniańskie range, 49°13′55.1″N, 19°50′31.9″E, alt. 1330 m, on wood of decorticated spruce snag, 22.07.2010, *leg. P. Czarnota* 6978. **Ge-50** – forest section no. 60f, Dolina Roztoki valley, below Roztocka Czuba Mt., 49°13′51.7″N, 20°05′08.5″E, alt. 1180 m, on wood of spruce snag, 9.07.2010, *leg. P. Czarnota* 6825.

Lecanora sarcopidoides (A. Massal.) A.L. Sm.

New for the Polish side of Tatra Mts.

Specimen examined. **Gd-59** – forest section no. 201i, valley of Biały Potok stream, 49°16′14.8″N, 19°57′24.1″E, alt. 1020 m, on hard wood of spruce snag within Carpathian beech forest, 12.08.2010, *leg. P. Czarnota* 7112.

Lecidea leprarioides Tønsberg

New for the Polish side of Tatra Mts.

Specimens examined (selected). **Gd-59** – forest section no. 211c, above Czerwona Przełęcz pass below Suchy Wierch Mt., 49°15′40.7″N, 19°56′32.3″E, alt. 1380 m, on branch of dead spruce, 13.07.2010, *leg. P. Czarnota* 6886. **Ge-50** – forest section no. 60f, Dolina Roztoki valley, below Roztocka Czuba Mt., 49°13′51.7″N, 20°05′07.1″E, alt. 1180 m, on wood of decorticated spruce trunk, 9.07.2010, *leg. P. Czarnota* 6831. **Ge-60** – forest section no. 47a, Dolina Rybiego Potoku valley, close to Włosienica glade, 49°12′52.1″N, 20°04′54.2″E, alt. 1290 m, on wood of decorticated spruce trunk, 1.07.2010, *leg. P. Czarnota* 6671.

Lecidea nylanderi (Anzi) Th. Fr.

The species is very common in upper mountain spruce stands in Polish Western Carpathians, however so far rarely reported (see Czarnota 2010), perhaps due to its similarity to some species of *Lepraria* more so as *L. nylanderi* produces divaricatic acid present also in *Lepraria incana*. Here it is included to show its large extent also in the Tatra Mts.

Specimens examined (selected). **Ge-50** – forest section no. 70i, Dolina Białki valley, Las pod Wołoszynem forest area, 49°14′29.9″N, 20°05′18.5″E, alt. 1210 m, on wood of decorticated spruce trunk, 8.07.2010, *leg. P. Czarnota* 6795; ibid., forest section no. 65f, Dolina Białki valley, close to Wołoszyński Stawek lake, 49°14′52″N, 20°05′11.7″E, alt. 1240 m, on bark of dead spruce, 8.07.2010, *leg. P. Czarnota* 6813. **Ge-60** – forest section no. 53f, Dolina Rybiego Potoku valley, below Opalone Mt., 49°13′08.92″N, 20°05′05.99″E, alt. 1320 m, on wood of decorticated spruce snag, 2.07.2010, *leg. P. Czarnota* 6704 & 6705.

Lecidella subviridis Tønsberg

This, sorediate, yellowish-green, usually sterile lichen is morphologically similar to *Lecanora expallens* and *Lecidella flavosorediata*, and in addition its thallus similarly turns C+ orange due to the presence of xanthones. Atranorin is the main chemical character distinguishing *L. subviridis* from both species (Tønsberg 1992). The diagnostic chemical compound was detected here by TLC.

Lecidella subviridis is known from several ranges of Polish Western Carpathians (see Czarnota 2010) and recently has been found also in Tatra Mts (Flakus pers. inform.), but elsewhere seems so be rare being confined rather to lower mountain belts covered with mixed beech-spruce forests. Here it is included to show its large extent in the Tatra Mts.

Specimens examined. On wood of spruce snags. **Gd-59** – forest section no. 280j, near Iwanowski Potok stream below Rzędy Smytniańskie range, 49°13′53.6″N, 19°50′30.5″E, alt. 1340 m, 22.07.2010, *leg. P. Czarnota* 6970. **Ge-50** – forest section no. 60f, Dolina Roztoki valley, below Roztocka Czuba Mt., 49°13′51.7″N, 20°05′08.5″E, alt. 1180 m, 9.07.2010, *leg. P. Czarnota* 6820.

Micarea anterior (Nyl.) Hedl.

Specimens examined. On wood of decorticated spruce snag. **Ge-60** – forest section no. 47a, Dolina Rybiego Potoku valley, close to Włosienica glade, 49°12′49.1″N, 20°04′52″E, alt. 1300 m, 1.07.2010, *leg. P. Czarnota* 6648; ibid., forest section no. 53f, below Opalone Mt., 49°13′14.9″N, 20°05′09.3″E, alt. 1335 m, 2.07.2010, *leg. P. Czarnota* 6720 & 6723.

Micarea byssacea (Th. Fr.) Czarnota, Guzow-Krzemińska & Coppins

This species, recently separated from other members of the *Micarea prasina* complex based on the correlation of molecular and morphological evidences (Czarnota & Guzow-Krzemińska 2010) seems to be widespread and locally common in temperate Europe. Its current distribution could be estimated, however, only after taxonomic revision of all gatherings named *Micarea prasina* and *M. micrococca*. In the Carpathians *M. byssacea* has been confirmed to date in Níske Tatry Mts (Slovakia) and in several ranges of the Polish Western Beskidy Mts (Czarnota & Guzow-Krzemińska 2010).

The detailed description and illustrated habit of *M. byssacea* is presented in Czarnota & Guzow-Krzemińska (2010), and the key for all Polish *Micarea* including this species is provided by Czarnota (2011). The most important characteristics, distinguishing it from other members of *M. prasina* complex, are methoxymicareic acid together with plane, usually adnate and lead coloured apothecia.

Specimens examined. All on wood of decorticated spruce trunk. **Gd-59** – forest section no. 282c, Dolina Kościeliska valley, W of Ornak glade, 49°13′46.8″N, 19°51′12″E, alt. 1150 m, 22.07.2010, *leg. P. Czarnota* 6951; forest section no. 226i, Dolina Kościeliska valley, near Iwanowski Potok stream below Smytniańskie Turnie range, 49°13′53.3″N, 19°51′02.2″E, alt. 1200 m, 22.07.2010, *leg. P. Czarnota* 6943. **Ge-50** – forest section no. 60f, Dolina Roztoki valley, below Roztocka Czuba Mt., 49°13′51.7″N, 20°05′07.1″E, alt. 1180 m, 9.07.2010, *leg. P. Czarnota* 6830. **Ge-60** – forest section no. 48b, Dolina Rybiego Potoku valley below Żabie range, 49°12′24″N, 20°04′45.3″E, alt. 1400 m, 7.07.2010, *leg. P. Czarnota* 6757.

Micarea nigella Coppins

Specimens examined. **Ge-50** – forest section no. 72g, Dolina Roztoki valley, below Roztocka Turniczka Mt., 49°13′50.7″N, 20°04′58.9″E, alt. 1180 m, on decaying root of windfallen spruce, 9.07.2010, *leg. P. Czarnota* 6846; ibid., forest section no. 102a, Dolina Suchej Wody valley, S of Wyżni Toporowy Staw lake, 49°16′38.3″N, 20°01′44.5″E, alt. 1140 m, on roots of windfallen spruce, 14.07.2010, *leg. P. Czarnota* 6894. **Ge-60** – forest section no. 47a, Dolina Rybiego Potoku valley, close to Włosienica glade, 49°12′49.1″N, 20°04′52″E, alt. 1300 m, on wood of decorticated spruce snag, 1.07.2010, *leg. P. Czarnota* 6648.

Micarea nowakii Czarnota & Coppins

Specimens examined (selected). **Ge-50** – forest section no. 70i, Dolina Białki valley, Las pod Wołoszynem forest area, 49°14′29.9″N, 20°05′18.5″E, alt. 1210 m, on wood of decorticated spruce trunk, 8.07.2010, *leg. P. Czarnota* 6792. **Ge-60** – forest section no. 47a, Dolina Rybiego Potoku valley, close to Włosienica glade, 49°12′48.1″N, 20°04′51.4″E, alt. 1300 m, on wood of windfallen spruce log, 1.07.2010, *leg. P. Czarnota* 6661; ibid., forest section no. 53f, below Opalone Mt., 49°13′08.61″N, 20°05′05.59″E, alt. 1320 m, on wood of decorticated spruce snag, 2.07.2010, *leg. P. Czarnota* 6701.

Micarea tomentosa Czarnota & Coppins

This recently described member of *Micarea prasina* group (Czarnota 2007; Czarnota & Guzow-Krzemińska 2010) has so far been reported from several European localities in Sweden, Poland and Slovakia, including those from the Carpathian's Pieniny Mts and Slovenský raj (Czarnota 2007; Thor & Svensson 2008).

It resembles *Micarea prasina* Fr. in its colour and thallus structure, as well as apothecial features, but more developed, usually shortly stalked and at least partially tomentose greyish pycnidia differentiate the species from *M. prasina* forming small pycnidia, which are glossy, sessile or immersed between goniocysts. Due to the stalked, tomentose pycnidia, *M. tomentosa* could be erroneously identified also as *M. hedlundii*, as it was in the past (see Czarnota 2007; Thor & Svensson 2008).

Specimen examined. **Ge-60** – forest section no. 55a, Dolina Rybiego Potoku valley, above Włosienica glade, 49°12′49.9″N, 20°04′45.4″E, alt. 1320 m, on wood of decorticated spruce snag, 1.07.2010, *leg. P. Czarnota* 6676.

***Monodyctis epilepraria** Kukwa & Diederich

Specimens examined. All on *Lepraria* spp. over wood of decorticated spruce snags. **Gd-59** – forest section no. 212d, Dolina Strążyska valley, close to Siklawica waterfall, 49°15′35.1″N, 19°55′50.1″E, alt. 1080 m, 13.07.2010, *leg. P. Czarnota* 6857. **Ge-50** – forest section no. 72g, Dolina Roztoki valley, below Roztocka Turniczka Mt., 49°13′49.5″N, 20°04′59.8″E, alt. 1180 m, 9.07.2010, *leg. P. Czarnota* 6842. **Ge-60** – forest section no. 53f, Dolina Rybiego Potoku valley, below Opalone Mt., 49°13′14.9″N, 20°05′09.3″E, alt. 1335 m, 2.07.2010, *leg. P. Czarnota* 6722.

***Phaeopyxis punctum** (A. Massal.) Rambold, Triebel & Coppins

Specimens examined (selected). All on squamules of *Cladonia digitata*. **Gd-59** – forest section no. 211b, close to Czerwona Przełęcz pass below Suchy Wierch Mt., 49°15′44.7″N,19°56′33.4″E, alt. 1310 m, 13.07.2010, *leg. P. Czarnota* 6880. **Ge-50** – forest section no. 65f, Dolina Białki valley, 49°14′58.2″N, 20°05′13.1″E, alt. 1305 m, 30.06.2010, *leg. P. Czarnota* 6629. **Ge-60** – forest section no. 47a, Dolina Rybiego Potoku valley, close to Włosienica glade, 49°12′47.9″N, 20°04′51.1″E, alt. 1300 m, 1.07.2010, *leg. P. Czarnota* 6633.

Steinia geophana (Nyl.) Stein

New for Polish side of Tatra Mts.

Specimen examined. **Ge-60** – forest section no. 55d, Dolina Rybiego Potoku valley, above Włosienica glade, 49°12′53.4″N, 20°04′35.5″E, alt. 1320 m, on humus over root system of spruce windthrow, 1.07.2010, *leg. P. Czarnota* 7150.

***Taeniolella trapeliopseos** Diederich

This rarely recorded in Europe lichenicolous hyphomycete fungus (Diederich 1990; Kukwa & Czarnota 2006; Šoun et al. 2006; Kukwa & Jabłońska 2008; Suija et al. 2008), growing exclusively on members of the genus *Trapeliopsis*, has recently been reported from the Polish Western Beskidy Mts (Kukwa et al. 2010) as new for the Carpathians. Its second locality in the whole mountain range is reported here.

Specimen examined. **Ge-50** – forest section no. 142l, Dolina Suchej Wody valley, 49°15′41.3″N, 20°01′36.5″E, alt. 1240 m, on *Trapeliopsis* sp. over roots o
f
spruce windthrow, 14.07.2010, *leg. P. Czarnota* 6905.

Thelocarpon intermediellum Nyl.

Specimens examined. **Gd-59** – forest section no. 282c, Dolina Kościeliska valley, W of Ornak glade, 49°13′46.6″N, 19°51′13.3″E, alt. 1150 m, on granite pebbles over root-system of spruce windthrow, 22.07.2010, *leg. P. Czarnota* 6936; ibid., forest section no. 261h, Tomanowa Dolina valley, Zadni Smreczyński Grzbiet range, 49°13′17.2″N, 19°53′03.7″E, alt. 1360 m, on lignum, 3.08.2010, *leg. P. Czarnota* 7005.

Trapelia obtegens (Th. Fr.) Hertel

Specimen examined. **Ge-50** – forest section no. 70i, Dolina Białki valley, Las pod Wołoszynem forest area, 49°14′31.2″N, 20°05′21.3″E, alt. 1200 m, on granite pebble over root system of spruce windthrow, 8.07.2010, *leg. P. Czarnota* 6790.

******Tremella cladoniae*** Diederich & M.S. Christ.

Specimen examined. **Ge-60** – forest section no. 47a, Dolina Rybiego Potoku valley, close to Włosienica glade, 49°12′51.5″N, 20°04′53.1″E, alt. 1300 m, on *Cladonia* sp. over decaying spruce snag, 1.07.2010, *leg. P. Czarnota* 6655.

******Tremella lichenicola*** Diederich

Specimens examined. All on thallus of *Violella fucata* on decorticated spruce trunks. **Gd-59** – forest section no. 261h, Tomanowa Dolina valley, Zadni Smreczyński Grzbiet range, 49°13′17.2″N, 19°53′03.7″E, alt. 1360 m, 3.08.2010, *leg. P. Czarnota* 7001. **Ge-50** – forest section no. 72g, Dolina Roztoki valley, below Roztocka Turniczka Mt., 49°13′49.5″N, 20°04′59.8″E, alt. 1180 m, 9.07.2010, *leg. P. Czarnota* 6844; ibid., forest section no. 143a, Dolina Suchej Wody valley, 49°15′27.3″N, 20°01′30.2″E, alt. 1280 m, 14.07.2010, *leg. P. Czarnota* 6913.

CONCLUSIONS

1. The great number of new taxa of lichen forming and lichenicolous fungi presented here shows that the area of Tatra National Park is still not sufficiently lichenologically explored.
2. As the result of periodical natural forest disturbances caused by the activity of bark beetle *Ips typographus* and wind storms numerous woody microhabitats are created in the Tatra Mts, which are important for many lichen epixyles rarely found to date anywhere in Poland.
3. For some lichenized fungi listed in this paper, e.g. *Agonimia flabelliformis*, *Fuscidea pusilla*, *Lecanora compallens*, *Lecidea leprarioides*, *Lecidea nylanderi*, *Lecidella subviridis* and *Micarea nowakii* and for many others, especially ephemeral species, e.g. *Absconditella delutula*, *A. pauxilla* and *Steinia geophana*, such naturally disturbed spruce forest areas could be the centres of their occurrence in the Carpathians.

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RED LIST OF THREATENED LICHENS IN THE BIESZCZADY NATIONAL PARK

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Abstract. The first regional list of threatened lichens is presented. The list is a result of investigation conducted in the Bieszczady National Park. The status of thread to the listed lichen species has been determined according to the Red List Categories by IUCN (2001, version 3.1). The Red List included 123 taxa, which constitute 23.5% of the local biota. The status of threatened biota has the following Red List Categories: Regionally Extinct (RE) – 23 species, Critically Endangered (CR) – 11, Endangered (EN) – 11, Vulnerable (VU) – 17, Near Threatened (NT) – 9, Least Concern (LC) – 23 and Data Deficient (DD) – 29. A lot of lichens are assigned to a lower category in the Bieszczady National Park than in other regions of Poland.

Key words: lichenized fungi, threatened species, red list, Eastern Carpathians, Bieszczady Mts, Southern Poland

INTRODUCTION

The Bieszczady Mountains, and especially the Bieszczady National Park (BdNP), is a place of particular lichenological values. It is an effect of the presence of large forest areas, as well as the post-war history – the region was depopulated for a long time which, subsequently, led to reduction in human impact on the environment.

In 2007, in the area of the Bieszczady National Park, quite strong degeneration and dying out of thalli were observed in many epiphytic species. Both common lichens (e.g. *Hypogymnia physodes*, *Parmelia sulcata*, *P. saxatilis* and *Evernia prunastri*) and valuable species were affected. Serious damage to thalli was noticed in, populations of Menegazzia *terebrata*, *Lobaria pulmonaria*, *Usnea* spp., *Bryoria* spp. and *Ramalina* spp numerous in the Park. Presently, the process of degeneration seems to have decreased and large and healthy populations of sensitive species are being found in the discussed area.

This paper complements numerous, already existing regional lists of the Beskid Sądecki Mts (Śliwa 1998), Upper Silesia (Kiszka & Leśniański 1999), Lower Silesia (Kossowska & Fabiszewski 2004) – according to the Red Book Categories, Gdańsk Pomerania (Fałtynowicz & Kukwa 2003), the Bory Tucholskie Forests (Lipnicki 2003), North-Eastern Poland (Cieśliński 2003a), the Puszcza Bialowieska Forest (Czyżewska & Cieśliński 2003a), the Puszcza Pilicka

Forest (Czyżewska 2003), the Puszcza Kozienicka Forest (Cieśliński 2003b), The Góry Świętokrzyskie Mts (Cieśliński & Łubek 2003), the Gorce Mts (Czarnota 2003), Opole Silesia and Upper Silesia (Kiszka & Leśniański 2003), the Polish part of Sudety Mts (Kossowska 2003), East Sudety Mountains (Szczepańska 2009) – according to the Red List Categories (Fig. 1). Comments on the Red Lists of threatened lichens at regional levels see Czyżewska and Cieśliński (2003b). The present paper follows the methodology, concept and arrangement of the above publications.

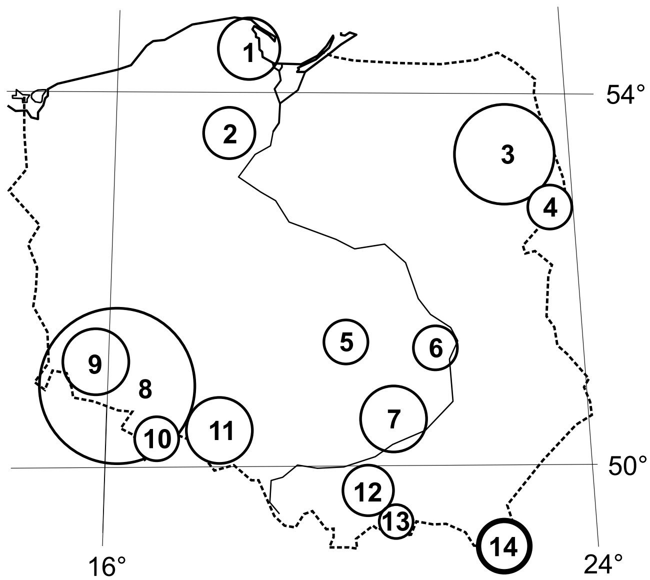

Fig. 1. The Red Lists of threatened lichens at local levels in Poland.
The investigated area: 1 – Gdańsk Pomerania; 2 – Bory Tucholskie Forests; 3 – North-Eastern Poland; 4 – Puszcza Białowieska Forest; 5 – Puszcza Pilicka Forest; 6 – Puszcza Kozienicka Forest; 7 – Góry Świętokrzyskie Mts; 8 – Lower Silesia; 9 – the Polish part of Sudety Mts; 10 – the Śnieżnik Massif and the Bialskie Mountains (Easter Sudety Mts); 11 – Opole Silesia and Upper Silesia; 12 – the Gorce Mts; 13 – the Beskid Sądecki Mts; 14 – the Bieszczady National Park (here in this paper).

THE STUDY AREA

The Bieszczady National Park is located in western part of the Eastern Beskidy Mts (Kondracki 2001) and covers the highest part of the Eastern Carpathians within the borders of Poland. It is characterised by parallel mountain ranges, with the highest peak at 1346 m a.s.l. The Park includes two vertical vegetation zones: the lower mountain zone which occupies the biggest area of the Park and the "połonina" zone above 1250 m a.s.l.

Lichenologically, the lower mountain zone, mainly covered with forests, is the most valuable. Beech forests *Dentario glandulose-Fagetum* dominate here and stretch up to the upper forest line, where they form dwarfed beech forest, so called "Krummholz" beech tree, very abundant in heliophilous lichen species. Other types of forests include: *Luzulo nemorosae-Fagetum* and *Lunario-Aceretum*, Eastern Carpathian tall-herb sycamore forests (*Aceri-Fagetum*) – characteristic of upper parts, as well as alder forests: *Caltho-Alnetum* and *Alnetum incanae carpaticum*. It is important that the majority of the Bieszczady forests are of natural character, and some of them are considered to be primeval (Winnicki & Zemanek 2009). The remains of resettled and destroyed villages, which used to lie in the valleys, perform a particular role in formation of lichen habitats (single old trees, abandoned orchards, old graveyards).

Due to the occurrence of numerous rock outcrops, the "połonina" zone has become a refuge for many epilithic and terricolous lichens, including some valuable alpine species.

At present, the Bieszczady National Park covers the area of 29 201 ha, and 70% of it (including the whole "połonina" zone) is under strict protection.

MATERIAL AND METHODS

Lichenological research was undertaken in the Bieszczady National Park in the 1950s and 1960s (Tobolewski & Glanc 1957, 1958; Glanc & Tobolewski 1959, 1960, 1962). The results of it (303 lichen species), as well as later lichenological studies based on the herbarium collection (see Kościelniak 2007a) served as the material for comparison with the present state of the biota. The present-day data are a result of studies carried out in the Park since 2000. They have significantly extended the list of species known from this area and confirmed the occurrence of the majority of species reported in the past. Moreover, they were used to compile lists of Polish lichens in the Eastern Carpathians (Kościelniak & Kiszka 2003, 2005), and published in a number of papers (e.g. Kiszka & Kościelniak 2001, 2002; .Kościelniak & Kiszka 2007; Kościelniak 2007b, 2011). The list presented in this paper contains some unpublished data collected by the author. The complete list of lichens and allied fungi of the Bieszczady National Park comprises over 530 species.

The nomenclature follows Smith et al. (2009), Bielczyk (ed. 2003) and Bielczyk et al. (2004), Randlane et al. (2009), Kukwa et al. (2012).

The threat to species was determined according to the categories of Red List (IUCN 2001) used for regional level (Ginsburg 2001):

The threat categories

Locally extinct species

RE – Regionally Extinct. Taxon is RE when there are no doubts that the last individual potentially able to reproduce has become extinct or disappeared from a region. The last records of the species come from about 50 years ago and despite search of appropriate habitats, it has not been found again.

Threatened species

CR – **Critically Endangered**. Taxon is CR when according to the latest available data it is at the highest risk of extinction in the wild and meets any of the following criteria:

A. An observed, estimated, inferred or suspected population size reduction of ≥ 80% over last 50 years;

B. Area of occupancy estimated to be less than 10 km^2 and estimates indicating:

a. Severely fragmented or known to exist at only a single location.

b. Continuing decline, observed, inferred or projected, in any of the following: extent of occurrence, area of occupancy or area, extent and/or quality of habitat.

EN – **Endangered**. Taxon is EN when according to the latest available data it is at a very high risk of extinction in the wild and meets any of the following criteria:

A. An observed, estimated, inferred or suspected population size reduction of ≥ 50% over last 50 years;

B. Area of occupancy estimated to cover the whole area of the Park and estimates indicating:

a. Severely fragmented or known to exist at only five locations.

b. Continuing decline, observed, inferred or projected, in any of the following: extent of occurrence, area of occupancy or area, extent and/or quality of habitat.

VU – **Vulnerable**. Taxon is VU when according to the latest available data it is at high risk of extinction in the wild and meets any of the following criteria:

A. An observed, estimated, inferred or suspected population size reduction of ≥ 30% over last 50 years;

B. Area of occupancy estimated to cover the whole area of the Park and estimates indicating:

a. Severely fragmented or known to exist at only ten locations.

b. Continuing decline, observed, inferred or projected, in any of the following: extent of occurrence, area of occupancy or area, extent and/or quality of habitat.

Lower risk species of threat

NT – **Near Threatened**. Taxon is NT when it cannot be classified within the categories: CR, EN or VU, but there are data indicating that its populations are approaching the Vulnerable category (VU).

LC – **Least Concern**. Taxon is LC when it cannot be classified among the endangered species because it is still frequent and widely distributed in a region.

Indeterminate threat degree

DD – **Data Deficient**. It is not a high category of threat (CR, EN, VU) nor lower risk (NT, LC). A taxon is DD when the present information is insufficient to determine directly or indirectly a risk of its extinction. Taxa assigned to that category require further survey. When adequate data are collected it may appear that species assigned to that category can be moved to one of the above-mentioned groups of endangerment.

LIST OF SPECIES

Name of species	The threatened category						
Absconditella *celata* Döbbeler & Poelt	.	.	.	.	.	.	DD
A. delutula (Ach.) Coppins & H. Kilias	.	.	.	.	.	.	DD
Agonimia *tristicula* (Nyl.) Zahlbr.	.	.	.	.	.	.	DD
Alectoria *ochroleuca* (Hoffm.) A. Massal.	.	.	.	VU	.	.	.
Anaptychia *ciliaris* (L.) Körb.	.	.	.	.	.	LC	.
Arthonia *byssacea* (Weigel) Almq.	.	.	EN	.	.	.	.
A. didyma Körb.	.	.	EN	.	.	.	.
A. mediella Nyl.	.	.	.	.	.	.	DD
A. punctiformis Ach.	.	.	.	.	.	LC	.
Arthothelium *spectabile* Flot. ex A. Massal.	.	.	.	.	NT	.	.
Arthrorhaphis *citrinella (Ach.)* Poelt	.	.	.	.	.	LC	.
Bacidia *circumspecta* (Norrl. & Nyl.) Malme	.	.	.	.	NT	.	.
Belonia *herculina* (Rehm ex Lojka) Hazsl.	.	.	.	.	.	LC	.
Bryophagus *gloeocapsa* Nitschke ex Arnold	.	.	.	.	.	LC	.
Bryoria *bicolor* (Ehrh.) Brodo & D. Hawksw.	.	CR	.	.	.	.	.
B. catharinae (Räsänen) Bystrek	RE	.	.	.	.	.	.
B. chalybeiformis (L.) Brodo & D. Hawksw.	RE	.	.	.	.	.	.
B. implexa (Hoffm.) Brodo & D. Hawksw.	RE	.	.	.	.	.	.
B. smithii (Du Rietz) Brodo & D .Hawksw.	RE	.	.	.	.	.	.
B. subcana (Nyl. ex Stizenb.) Brodo & D. Hawksw.	.	.	EN	.	.	.	.
B. tatarkiewiczii (Bystrek) Bystrek	.	.	EN	.	.	.	.
B. vrangiana (Gyel.) Brodo & D. Hawksw.	.	.	EN	.	.	.	.
Buellia *leptocline* (Flot.) A. Massal.	.	.	.	.	.	.	DD
Calicium *trabinellum* (Ach.) Ach.	.	.	.	.	.	.	DD
Caloplaca *tiroliensis* Zahlbr.	.	.	.	.	.	.	DD
Calvitimela *armeniaca* (DC.) Hafellner	.	.	.	.	.	.	DD
Catillaria *chalybeia* (Borrer) A. Massal.	.	.	.	.	.	LC	.
C. erysiboides (Nyl.) Th.Fr.	.	.	.	.	.	LC	.
Catinaria *atropurpurea* (Schaer.) Vĕzda & Poelt	.	.	EN	.	.	.	.
Cetraria *aculeata* (Schreb.) Fr.	.	.	.	.	NT	.	.
C. sepincola (Ehrh.) Ach.	.	.	.	.	.	LC	.
Cetrelia chicitae (W. L. Culb) W. L. Culb. & C. F. Culb.	.	.	.	.	.	.	DD
Chaenotheca *brachypoda* (Ach.) Tibell	.	.	.	.	.	.	DD
C. gracilenta (Ach.) (Ach.) J.-E. Mattsson & Middelb.	.	.	.	.	.	.	DD
C. hispidula (Ach.) Zahlbr.	.	.	.	.	.	.	DD
Chrysothrix *candelaris* (L.) J. R. Laundon	.	CR	.	.	.	.	.
Cladonia *botrytes* (K.G.Hagen) Willd.	.	.	.	.	NT	.	.

C. caespiticia (Pers.) Flörke	.	.	.	.	.	LC	.
C. symphycarpia (Flörke) Fr.	.	.	.	.	.	LC	.
C. turgida Hoffm.	.	.	.	.	.	LC	.
Cliostomum *griffithii* (Sm.) Coppins	.	.	.	VU	.	.	.
Cyphelium *karelicum* (Vain.) Räsänen	RE	.	.	.	.	.	.
Dermatocarpon *miniatum* (L.) W. Mann	.	.	EN	.	.	.	.
Dimerella *lutea* (Dicks.) Trevis.	.	.	.	.	.	.	DD
Elixia *flexella* (Ach.) Lumbsch	.	.	.	.	.	LC	.
Evernia *divaricata* (L.) Ach.	.	CR	.	.	.	.	.
Flavopunctelia *flaventior* (Stirt.) Hale	.	.	.	VU	.	.	.
Fuscopannaria *praetermissa* (Nyl.) P. M. Jørg.	.	.	EN	.	.	.	.
Gyalecta *flotowii* Körb.	.	.	EN	.	.	.	.
G. jenensis (Batsch) Zahlbr.	.	.	.	.	.	LC	.
G. truncigena (Ach.) Hepp	.	.	EN	.	.	.	.
Heterodermia *speciosa* (Wulfen) Trevis.	RE	.	.	.	.	.	.
Hypogymnia *vittata* (Ach.) Parrique	.	.	.	VU	.	.	.
Icmadophila *ericetorum* (L.) Zahlbr.	.	CR	.	.	.	.	.
Lecanactis *dilleniana* (Ach.) Körb.	.	.	.	.	.	LC	.
Lecanora *albella* (Pers.) Ach.	.	.	.	VU	.	.	.
L. sulphurea (Hoffm.) Ach.	.	.	.	.	.	.	DD
Lecidea *erythrophaea* Flörke	.	.	.	VU	.	.	.
Leptogium *cyanescens* (Rabenh.) Körb.	.	.	.	VU	.	.	.
L. saturninum (Dicks.) Nyl.	RE	.	.	.	.	.	.
Lobaria *pulmonaria* (L.) Hoffm.	.	.	.	.	.	LC	.
L. scrobiculata (Scop.) DC.	RE	.	.	.	.	.	.
Megalaria *laureri* (Hepp ex Th. Fr.) Hafellner	.	.	.	.	.	.	DD
Megaspora *verrucosa* (Ach.) Hafellner & V. Wirth	.	.	.	.	.	.	DD
Melanelia *hepatizon* (Ach.) Thell	.	.	.	.	.	LC	.
M. sorediata (Ach.) Goward & Ahti	.	.	.	VU	.	.	.
M. stygia (L.) Essl.	.	.	.	.	.	.	DD
Melanohalea *elegantula* (Zahlbr.) O. Blanco et al.	.	.	.	VU	.	.	.
M. exasperata (de Not.) O. Blanco et. al.	.	.	.	VU	.	.	.
M. laciniatula (Flagey ex H.Olivier) O. Blanco et al.	.	.	.	.	.	.	DD
Melaspilea *granitophila* (Th. Fr.) Coppins	.	.	.	.	.	.	DD
Menegazzia *terebrata* (Hoffm.) Körb.	.	.	.	.	.	LC	.
Nephroma *bellum* (Spreng.) Tuck.	RE	.	.	.	.	.	.
N. resupinatum (L.) Ach.	RE	.	.	.	.	.	.
Ochrolechia *androgyna* (Hoffm.) Arnold	.	.	.	.	NT	.	.
O. pallescens (L.) A. Massal.	.	.	EN	.	.	.	.
Ophioparma *ventosa* (L.) Norman	RE	.	.	.	.	.	.
Pachyphiale *fagicola* (Hepp) Zwackh	.	.	.	.	NT	.	.
Pannaria *conoplea* (Pers.) Bory	RE	.	.	.	.	.	.
Parmelina *quercina* (Willd.) Hale	.	CR	.	.	.	.	.
Parmeliopsis *hyperopta* (Ach.) Arnold	.	.	.	.	.	LC	.
Parmotrema *arnoldii* (Du Rietz) Hale	.	CR	.	.	.	.	.
P. crinitum (Ach.) M. Choisy	.	CR	.	.	.	.	.

P. perlatum (Huds.) M. Choisy	.	CR	.	.	.	.	.
P. stuppeum (Taylor) Hale	.	CR	.	.	.	.	.
***Peltigera** aphthosa* (L.) Willd.	RE	.	.	.	.	.	.
P. collina (Ach.) Schrad.	RE	.	.	.	.	.	.
P. leucophlebia (Nyl.) Gyelnik	RE	.	.	.	.	.	.
P. neckeri Hepp ex Müll. Arg.	RE	.	.	.	.	.	.
***Pertusaria** alpina* Hepp ex H. E. Ahles	.	.	.	.	.	.	DD
P. aspergilla (Ach.) J. R. Laundon	.	.	.	.	.	LC	.
P. trachythallina Erichsen	RE	.	.	.	.	.	.
***Phaeophyscia** cernohorskyi* (Nádv.) Essl.	.	.	.	.	.	.	DD
P. pusilloides (Zahlbr.) Essl.	.	.	.	.	.	.	DD
***Physconia** muscigena* (Ach.) Poelt	.	.	.	.	NT	.	.
P. perisidiosa (Erichsen) Moberg	.	.	.	.	.	LC	.
***Pleurosticta** acetabulum* (Necker) Elix & Lumbsch	.	.	.	VU	.	.	.
***Porina** leptalea* (Durieu & Mont.) A. L. Sm.	.	.	.	.	NT	.	.
P. mammillosa (Th.Fr.) Zahlbr.	.	.	.	.		.	DD
P. quentheri (Flot.) Zahlbr.	.	.	.	.	NT	.	.
***Protopannaria** pezizoides* (Weber) P. M. Jørg. & S. Ekman	.	.	.	.	.	.	DD
***Pycnothelia** papillaria* Dufour	.	CR	.	.	.	.	.
***Pyrenula** chlorospila* Arnold.	.	.	.	.	.	.	DD
P. laevigata (Pers.) Arnold	.	.	.	VU	.	.	.
P. nitidella (Flörke ex Schaer.) Müll. Arg.	.	.	.	VU	.	.	.
***Ramalina** fraxinea* (L.) Ach.	.	.	.	VU	.	.	.
Rimularia furvella (Nyl. ex Mudd) Hertel & Rambold	.	.	.	.	.	LC	.
***Rinodina** albana* (A.Massal.) A. Massal.	.	.	.	.	.	.	DD
R. mniaraea (Ach.) Körb.	.	.	.	.	.	.	DD
R. olivaceobrunnea Dodge et Baker	.	.	.	.	.	.	DD
***Stereocaulon** dactylophyllum* Flörke	RE	.	.	.	.	.	.
S. tomentosum Fr.	.	CR	.	.	.	.	.
***Tuckermannopsis** chlorophylla* (Willd.) Hale	.	.	.	.	.	LC	.
***Tuckneraria** laureri* (Kremp.) Randlane & Thell	.	.	.	.	.	.	DD
***Usnea** ceratina* Ach.	RE	.	.	.	.	.	.
U. intermedia (A. Massal.) Jatta	.	.	.	VU	.	.	.
U. florida (L.) Weber ex F. H. Wigg.	.	.	.	VU	.	.	.
U. longissima Ach.	RE	.	.	.	.	.	.
U. plicata (L.) Weber ex F. H. Wigg.	RE	.	.	.	.	.	.
U. silesiaca Motyka	RE	.	.	.	.	.	.
U. wasmuthii Räsänen	RE	.	.	.	.	.	.
***Verrucaria** annulifera* Eitner	.	.	.	.	.	LC	.
***Xylographa** parallela* (Ach.) Behlen & Desberger	.	.	.	VU	.	.	.

THREATS

The list of lichens threatened in the Bieszczady National Park comprises 123 species, which is 23.5% of the whole biota, including 23 species (19 %) considered to be Regionally Extinct (RE), Critically Endangered (CR) – 11 (9 %), Endangered (EN) – 11 (9 %), Vulnerable (VU) – 17 (14 %), Near Threatened (NT) – 9 (7%), Least Concern (LC) – 23 (19 %) and Data Deficient (DD) – 29 (23%). One of the most important characteristics of the Bieszczady National Park, as in the case of the Białowieża National Park (Czyżewska & Cieśliński 2003b), is a large contribution of species, which are endangered in Poland and are not threatened or have there a low threat category locally. In the Bieszczady forests, many of them create large, well-developed populations. Two of them are especially worth mentioning: *Lobaria pulmonaria*, occurring in the Park very frequently (also fertile specimens) and *Menegazzia terebrata*. In many sites there are numerous thalli of *Usnea subfloridana*, *U. filipendula* and *Cetrelia* spp. Other forest species, which are in good form in the Bieszczady National Park include: *Belonia herculina*, *Caloplaca herbidella*, *Hypotrachyna revoluta*, *Parmelia submontana*, *Parmeliella triptophylla*, *Peltigera horizontalis*, *Thelotrema lepadinum*, *Usnea faginea* and *U. florida*. Moreover, numerous occurrence of a very rare in Poland oceanic species *Normandina pulchella* may be considered a curiosity of the Bieszczady National Park (and the whole area of the Bieszczady Mts). It can be found here both in primeval forests and on fruit trees in abandoned orchards. Another group of taxa is connected with open country and includes: *Acrocordia gemmata*, *Bacidia rubella*, *Flavoparmelia caperata*, *Parmelina tiliacea*, *Punctelia jeckeri*, *P. subrudecta*, *Physconia distorta*.

The above mentioned species are either not threatened in the Bieszczady National Park or their threat status is low. The group comprising lichens considered to be extinct is numerous (23 out of 67 species not confirmed so far). The group includes mainly taxa from the genera *Bryoria*, *Usnea*, *Nephroma* and *Peltigera*. Some of them are considered extinct in Poland (Cieśliński et al. 2006). The Critically Endangered category includes 11 taxa, mainly species, which at present occur at single localities and form small populations. For the majority of them considerable decrease in the number of localities was observed, e.g., *Icmadophila ericetorum*, *Parmotrema crinitum* and *P. stuppeum*. Categories EN and VU were assigned to species reported from several localities but their numbers tend to decrease, which might be connected with the disappearance of old trees, both in forests and in open country (e.g., *Melanohalea exasperata*, *Usnea intermedia* and *U. florida*). Categories LC and NT include those species, which until recently were not threatened in the Park, but since 2007 have started to show signs of degeneration in many places in the Park.

The category DD (29 taxa) comprises species occurring at single localities in the past, which have not been confirmed so far, although finding them is still possible. However, the author tried to restrict to minimum the list of species reported recently from single localities in Poland if knowledge about their distribution seemed insufficient.

CONCLUSIONS

The most important threats to the lichen biota of the Bieszczady National Park include:

- Inflow of polluted air – this factor is probably responsible for the recently observed degeneration of thalli of epiphytic lichens. The source of pollution is unknown but chemical analyses showed elevated sulphur concentration in thalli of *Hypogymnia physodes* in the last decade.
- Rapidly growing tourist traffic causing greater and greater emission of fumes as well as treading lichen habitats, which is particularly visible in the upper parts of the "połonina" zone.
- Succession processes, e.g. overgrowing of rock debris and bilberry mats in the "połonina" zone and overgrowing of abandoned villages with forest.
- Dying out of old fir stand in the Górny San Valley and very old trees in the open country.

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PROTECTED AND THREATENED LICHENS IN THE CITY OF TORUŃ

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Abstract. The paper presents the list of 58 protected and threatened species of lichens recorded in the city of Toruń, both at present (52 taxa) and reported in historical references – literature and herbarium materials. The information about the occurrence of special concern lichens was collated in a cartogram within the grid of ATPOL 1×1 km squares with the description of habitat conditions prevailing within a given square of the city. Based on the occurrence of threatened species, the floristic valuation was presented for individual sites within the city area.

Key words: lichens of towns and cities, protection, threat, Red List, Toruń, Poland

INTRODUCTION

Nearly half of the world's population live in towns and cities. In Poland, more than 61% of the population are residents of urban areas. Unfortunately, the work of such experts as architects, urban planners or ecologists is not coordinated during the process of urbanization and development of complex urban systems (Zimny 2005). This leads to deterioration of living conditions, often at the expense of residents' health and quality of life (Diaz et al. 1999; Jaffe et al. 2003).

According to Grodziński (1980), disturbances that arise in the ecological system can be detected by methods based on biotests. Lichens are good bioindicators of environmental changes, especially those most sensitive and demanding in terms of habitat conditions – taxa included in the species protection programme and included on the Red List as threatened lichens. Lichens are highly sensitive to habitat changes occurring under the influence of human activity, and the problem of their protection has been the subject of many studies (i.a. Motyka 1934; Cieśliński & Czyżewska 1992; Fałtynowicz 1997; Czyżewska 2003; Lipnicki 2003), also in urban areas (e.g. Kiszka 1998, 1999; Matwiejuk 2001; Kubiak 2005). Therefore lichens are included among highly threatened organisms. According to Cieśliński et al. (2006), over 55% of the total number of lichens found in Poland are taxa threatened to certain extent.

THE STUDY AREA

According to the physical and geographical regionalization of Poland, Toruń is situated in the mesoregion of the Kotlina Toruńska Basin, the macroregion of the Pradolina Toruńsko-Eberswaldzka Proto-Valley, included within the subprovince of the Pojezierza Południowobałtyckie - South Baltic Lakelands. The city of Toruń is situated between 52°58' and 53°04' of latitude north, and between 18°32' and 18°43' of longitude east. Within the current administrative limits, the city covers an area of over 115 km^2 and has 191,227 inhabitants. Toruń is situated on river terraces and dunes. Green areas, including forests, cover 30% of the city area. One of the most important natural areas is the forest reserve Kępa Bazarowa of 32.4 ha in area (lowland willow-poplar floodplain forest) situated on the left bank of the River Vistula, opposite the Old City (cf. Andrzejewski & Kot 2006).

In recent years, the air quality in Toruń greatly improved after the „Polchem" Chemical Factory was closed in 2001. At the same time, however, atmospheric dust loading increased.

Toruń is situated in a warm temperate climate zone – a transitional climate between the oceanic climate of Western Europe and the continental climate of Eastern Europe and Asia. Generally the climate of Toruń is characterised by low mean values of precipitation and many days of warm weather, and considerable insolation (cf. Wójcik & Marciniak 2006).

MATERIAL AND METHODS

Lichenological studies were conducted in 2005-2011. The study area is located within the administrative limits of the city of Toruń. The material consisted of threatened and protected lichens. Collection of lichens was performed from all possible substrates of their occurrence. The collection was carried out according to the system of 1×1 km ATPOL squares modified for lichenological purposes (Cieśliński & Fałtynowicz 1993). Historical data on the species composition and the occurrence of lichens in Toruń from the 1950s and the 1980s (Wilkoń-Michalska et al. 1988), data according to Klinggraeff (1880) and Ceynowa-Giełdoń (2001), as well as modern data were compiled on cartograms. The identification keys by Smith et al. (2009) and other monographs were used to identify the lichens. The nomenclature follows Diederich et al. (2012). For taxonomic identification of the genus *Stereocaulon*, the method of thin-layer chromatography (TLC) was applied according Orange et al. (2001).

The floristic value (cf. Jackowiak 1998) defined as a measure (index) of contribution of lichens from particular categories of threat was calculated using the formula:

Wf = 10xRE + 7xCR + 5xEN + 3xVU + 2xNT + 1xLC, where: RE – the total number of extinct species, CR – the total number of critically endangered species, EN – the total number of endangered species, VU – the total number of vulnerable species, NT – the total number of near threatened species, LC – the total number of least concern species. The collected herbarium material has been deposited at the Herbarium of the Institute of Ecology and Environment Protection Nicolaus Copernicus University in Toruń (TRN).

RESULTS

Based on the current data and historical sources, the occurrence of protected species (Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765) and taxa from the Red List of lichens in Poland (Cieśliński et al. 2006) was determined in the area of Toruń – in total 58 species (cf. List of species). The so-called species of special concern constitute nearly 30% of the known biota of lichens in Toruń.

LIST OF SPECIES

The Red List Categories: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient; §§ – strictly protected species, § – partially protected species; numerical data – the number of current sites (1×1 km ATPOL squares) – sites confirmed at present.

Arthonia atra (Pers.) A. Schneid. – on the bark of *Populus nigra* in Kępa Bazarowa Reserve; 1 site; EN.

Bacidia incompta (Borrer) Anzi – on the bark of *Populus nigra* in Kępa Bazarowa Reserve; 1 site; EN.

Biatora globulosa (Flörke) Fr. – on the bark of *Acer platanoides* in pine forest; 2 sites; VU.

Bryoria cf. *fuscescens* (Gyeln) Brodo & D.Hawksw. – on the bark of *Betula pendula* in pine forest on the left bank of the Vistula River; 1 site; VU; §§.

Cetraria aculeata (Schreb.) Fr. - on soil in psammophilous grassland and dry pine forest; 22 sites; §; cf. Wilkoń-Michalska et al. (1988).

Cetraria ericetorum Opiz – on soil in psammophilous grassland and dry pine forest; 1 site; NT ; §.

Cetraria islandica (L.) Ach. – on soil in psammophilous grassland and dry pine forest; 37 sites; VU; §; cf. Wilkoń-Michalska et al. (1988).

Cetraria muricata (Ach.) Eckfeldt – on soil in psammophilous grassland and dry pine forest; 1 site; NT; §.

Chaenotheca brachypoda (Ach.) Tibell – on the bark of *Populus nigra* in Kępa Bazarowa Reserve; 2 sites; EN.

Chaenotheca chlorella (Ach.) Müll. Arg. – on the bark of *Salix alba* in Kępa Bazarowa Reserve; 1 site; CR.

Chaenotheca trichialis (Ach.) Th. Fr. – on the bark of *Populus nigra* and *Salix alba* in Kępa Bazarowa Reserve; 2 site; NT.

Cladonia arbuscula (Wallr.) Flot. subsp. *arbuscula* – on soil in psammophilous grassland and dry pine forest; 12 sites; §; cf. Wilkoń-Michalska et al. (1988).

Cladonia mitis Sandst. – on soil in psammophilous grassland and dry pine forest; 29 sites; §; cf. Wilkoń-Michalska et al. (1988).

Cladonia ciliata Stirt. – on soil in psammophilous grassland and dry pine forest; 2 sites; §; cf. Wilkoń-Michalska et al. (1988).

Cladonia portentosa (Dufour) Coem. – on soil in psammophilous grassland and dry pine forest; 2 sites; §.

Cladonia rangiferina (L.) F. H. Wigg. – on soil in psammophilous grassland and dry pine forest; 7 sites; §; cf. Wilkoń-Michalska et al. (1988).

Collema bachmanianum (Fink) Degel. – on calcareous soil; NT; cf. Ceynowa-Giełdon (2001).

Evernia prunastri (L.) Ach. – on the bark of *Acer*, *Betula, Populus, Quercus* and *Salix* in dry pine forest and the City Park; 14 sites; NT; §; cf. Wilkoń-Michalska et al. (1988).

Hypogymnia tubulosa (Schaer.) Hav. – on the bark of *Betula, Populus, Quercus, Salix* and *Tilia* in dry pine forest and the City Park; 14 sites; NT; §§; cf. Wilkoń-Michalska et al. (1988).

Lecanora persimilis (Th. Fr.) Nyl. – on the bark of *Acer, Betula, Carpinus, Fraxinus, Populus, Robinia, Salix,* on the wood and concrete especially in the city centre; 26 sites; DD.

Lecanora subrugosa Nyl. – on the bark of *Acer* and *Fraxinus;* LC; cf. Wilkoń-Michalska et al. (1988).

Lempholemma chalazanum (Ach.) B. de Lesd. – on calcareous soil in a compact settlement area; 1 site; NT.

Lobaria pulmonaria (L.) Hoffm. – EN; §§; cf. Klinggraeff (1880).

Melanelixia fuliginosa (Duby) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch subsp. *fuliginosa* – on the bark of *Acer*, *Aesculus, Populus, Salix* and *Tilia* in dry pine forest and the City Park; 5 sites; §§.

Melanelixia cf. *subargentifera* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – on the bark of *Acer* near the Vistula River; 1 site; VU; §§.

Melanohalea exasperatula (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch – on the bark of *Acer*, *Betula* and *Populus* in Kępa Bazarowa Reserve and forest near the Vistula River; 7 sites; §§; cf. Wilkoń-Michalska et al. (1988).

Opegrapha varia Pers. – on the bark of *Acer platanoides* in Barbarka Forest; 1 site; NT.

Parmelina tiliacea (Hoffm.) Hale - on the bark of *Acer platanoides* in Toruń-Czerniewice Forest; 1 site; §§; VU.

Parmeliopsis ambigua (Wulfen) Nyl. – on the bark of *Betula* and *Quercus* in dry pine forest (Barbarka and Toruń-Czerniewice; 10 sites; §§; cf. Wilkoń-Michalska et al. (1988).

Peltigera canina (L.) Willd – on soil in psammophilous grassland; 2 sites; VU, §§.

Peltigera didactyla (With.) J. R. Laundon – on soil in psammophilous grassland and in dry pine forest; 8 sites; §§.

Peltigera ponojensis Gyeln. – on soil in dry pine forest; 1 site; §§.

Peltigera rufescens (Weiss) Humb. – on soil in psammophilous grassland; 7 sites; §§; cf. Wilkoń-Michalska et al. (1988).

Physconia perisidiosa (Erichsen) Moberg – on the bark of *Acer* and *Populus* in Forest Toruń-Czerniewice and Barbarka; 3 sites; EN.

Piccolia ochrophora (Nyl.) Hafellner – on the bark of *Populus nigra*, especially in Kępa Bazarowa Reserve; 3 sites; VU.

Platismatia glauca (L.) W. L. Culb. & C. F. Culb. – on the bark and wood of *Betula, Quercus* and *Salix* in dry pine forest; 11 sites; §§.

Pleurosticta acetabulum (Neck.) Elix & Lumbsch – on the bark of *Acer, Fraxinus* and *Tilia* in Forest Toruń-Czerniewice and Barbarka; 3 sites; EN; §§; cf. Wilkoń-Michalska et al. (1988).

Pseudevernia furfuracea (L.) Zopf – on the bark of *Acer, Betula, Populus* and *Tilia* in dry pine forest; 8 sites; §§; cf. Wilkoń-Michalska et al. (1988).

Ramalina farinacea (L.) Ach. – on the bark of *Acer* and *Fraxinus* in forest; 3 sites; VU; §§; cf. Wilkoń-Michalska et al. (1988).

Ramalina fraxinea (L.) Ach. – EN; §§; cf. Wilkoń-Michalska et al. (1988).

Ramalina pollinaria (Westr.) Ach. – on the bark of *Acer platanoides* in Barbarka Forest; 2 sites; VU; §§; cf. Wilkoń-Michalska et al. (1988).

Rhizocarpon cf. *umbilicatum* (Ramond) Flagey – on a gothic brick on a well-lit wall of medieval-castle ruins (Zamek Dybowski); 1 site; CR.

Rinodina colobina (Ach.) Th. Fr. – on the bark of *Populus nigra* on the right bank of the Vistula River; 1 site; EN.

Rinodina conradii Körb. – on old shoe leather in psammophilous grassland; 1 site; EN.

Rinodina exigua (Ach.) Gray – on the bark of *Populus nigra* on the right bank of the Vistula River; 2 sites; VU; cf. Wilkoń-Michalska et al. (1988).

Staurothele frustulenta Vain. – on the concrete walls; 3 sites; VU.

Stereocaulon condensatum Hoffm. - on soil in psammophilous grassland; 5 sites; VU; §§.

Stereocaulon incrustatum Flörke – EN; §§; cf. Klinggraeff (1880).

Stereocaulon nanodes Tuck. – on disintegrated, siliceous rocks from a railway track in dry pine forest; 1 site; EN; §§.

Stereocaulon tomentosum Fr. – on soil between disintegrated, siliceous rocks from a railway track in dry pine forest; 1 site; EN; §§.

Strangospora pinicola (A. Massal.) Körb. – on the bark of *Acer, Aesculus, Betula, Populus, Quercus, Robinia, Salix, Tilia* and *Ulmus* in forests and parks; 25 sites; LC; cf. Wilkoń-Michalska et al. (1988).

Thelidium minutulum Körb. – on the concrete and on old shoe leather; 2 sites; NT.

Tuckermannopsis chlorophylla (Willd.) Hale – on the bark of *Acer, Betula, Populus, Quercus,* and *Tilia* in dry pine forest; 8 sites; VU; §§; cf. Wilkoń-Michalska et al. (1988).

Tuckermannopsis sepincola (Ehrh.) Hale. – EN; §§; cf. Wilkoń-Michalska et al. (1988).

Usnea filipendula Stirt. – on the bark of *Acer* and *Tilia* in forest and a roadside; 2 sites; VU; §§.

Usnea hirta (L.) F. H. Wigg. – on the bark of *Betula* and *Tilia* in forest and a roadside; 2 sites; VU; §§; cf. Wilkoń-Michalska et al. (1988).

Verrucaria cf. *murina* Leight. – on old concrete walls; 2 sites; DD; (det. Krzewicka).

Vulpicida pinastri (Scop.) J.- E. Mattsson & M. J. Lai - on the bark of *Betula* and *Fraxinus* in dry pine forest; 4 sites; NT, §§.

DISCUSSION

The group of taxa particularly sensitive to anthropopressure are species legally protected in Poland (Journal of Laws. 2004 No 168, Entry. 1765).

They are good indicators of unfavourable changes occurring in the analysed areas. Therefore, the contribution of these species is an important characteristic describing the area of lichenological studies, including urban areas.

The largest (proportionally to the present-day biota) number of protected lichens – 7 species – was found in Toruń in the 1950s, i.e. nearly 30% in the City Park located in the city centre. In the 1980s, the percentage contribution of protected taxa decreased to 21% of the current biota – 15 lichen species. At that time, as many as four protected species (including 2 strictly protected species) were found in the forest called "Barbarka".

Furthermore, the list of protected and Red List species includes also taxa known from the literature sources with not information about the exact places of their occurrence and this applies to *Lobaria pulmonaria* and *Sterecaulon incrustatum* (Klinggraeff 1880). Ceynowa-Giełdoń (2001) also contributed to the list of special concern species from Toruń by reporting the occurrence of *Collema bachmanianum* (cf. the list of species).

At present, the occurrence of 34 protected species of lichens was confirmed (cf. the list of species), which constitutes 17% of the present-day biota. The aforementioned figure includes 24 strictly protected taxa. The strictly protected species occurred at 43 sites, i.e. 30% of the entire study area. They were most abundant at the site located near Łódzka Street, in forest areas and on the left bank of the River Vistula, where half of them were recorded. Among those species, taxa from the genera *Stereocaulon* and *Usnea* – *Usnea hirta* and *Usnea filipendula* deserve special attention. The former species was also reported by Wilkoń-Michalska (1988) and the latter one was found for the first time in the city area. Unfortunately, it was not possible to find *Ramalina fraxinea* after more than 50 years (recorded in Toruń in the 1950s).

Partially protected species occurred at 53 sites, which constitutes 37% of the entire study area. Those mostly epigeic species were found mainly in psammophilous grasslands on dune-like structures, which are frequent in Toruń.

For comparison: 20 protected species of lichens were found in the city of Poznań (Kepel 1999), and only 16 in the city of Przemyśl (Kiszka 1998). Matwiejuk (2001, 2007) reported 30 protected taxa from the city of Białystok, which is a similar number to that recorded in Toruń. The largest number, i.e. 38 legally protected taxa, was recorded by Kubiak (2005) in the city of Olsztyn. The occurrence of hygrophilous species in Olsztyn, such as *Pleurosticta acetabulum* or *Ramalina* spp., is particularly interesting. Probably their occurrence could be attributed to specific climatic conditions prevailing in this city (Kubiak 2005).

In addition to the presence of protected lichens, also threatened species from the Polish Red List of lichens are a very valuable indication of the natural environment quality (Cieśliński et al. 2006). This group constitutes the most valuable element of the lichen biota in the analysed area.

So far 44 threatened species (acc. to Cieśliński et al. 2006) were found in Toruń, which constitutes 22% of the urban lichen biota.

Based on the historical data from the 1950s (Wilkoń-Michalska et al. 1988) related to lichen species with a known distribution, the occurrence of 5 threatened species was confirmed, i.e. 20% of the current biota. Those species occurred at 10 research sites. As many as 3 taxa were recorded in the City Park and in the nature reserve Kępa Bazarowa.

According to historical data from the 1980s, the occurrence of 9 threatened species of lichens (13% of the present-day biota) was plotted in particular research squares at 14 sites located at a certain distance from the city centre, which is 16% of the study area. As many as 3 species were found at the site in the north-western part of the city in the forest "Barbarka".

At present, 37 species from the Red List were identified in the city area. They represent all categories of threat, except for regionally extinct (RE). The Critically Endangered Category (CR) is represented by 2 taxa recorded at present in Toruń i.e. *Chaenotheca chlorella* and *Rhizocarpon umbilicatum.* The Endangered Category (EN – species with high risk of extinction) is represented by 13 taxa, including 9 taxa recorded at present – *Arthonia atra, Bacidia incompta, Chaenotheca brachypoda, Physconia perisidiosa, Pleurosticta acetabulum, Rinodina colobina, R. conradii*, *Stereocaulon nanodes* and *S. tomentosum*, as well as 4 species not currently found in Toruń: *Tuckermannopsis sepincola, Lobaria pulmonaria, Ramalina fraxinea* and *Stereocaulon incrustatum*.

The category vulnerable (VU) is represented by 15 species, all of them occurring in Toruń at present. There are 10 species near threatened (NT), all of them found at present. The Least Concern category (LC) is represented by two taxa, including one confirmed at present – *Strangospora pinicola*. Two species are classified as Data Deficient (DD), identified only at present – *Lecanora persimilis* and *Verrucaria* cf. *murina.* In total, species in different categories of threat make up 20% of all taxa found during the current research. As many as 7% of all taxa were included in the category vulnerable (VU). Each of the two categories – endangered (EN) and near threatened (NT) – is represented by 5% of all present-day species.

Lichens classified in different categories of threat are a frequent criterion of environmental evaluation and monitoring (Aptroot and Sparrius 2002). For example, Kubiak (2004) defined a lichenological value for individual sites in the city of Olsztyn by calculating the so-called floristic value (Wf) according to the study of Jackowiak (1998). This makes it possible to designate areas of special nature values; in the case of Olsztyn it was the area of Urban Forest and forest peat bogs.

A similar method was applied in Toruń. The index Wf was calculated for all sites where species from the Red List were found. On this basis, areas with the highest lichenological, and consequently, natural value were identified within the city area. These special places in Toruń are as follows: the Nature Reserve Kępa Bazarowa, the vicinity of Łódzka Street and the railway station PKP Toruń-Czerniewice. Also the forest "Barbarka" near the northwestern boundary of the city got a high value. The Red List species occurred in Toruń in 82 squares, i.e. about 60% of all sites (Fig. 1.). As in the case of Olsztyn, in areas with high values of the Wf index, also lichens that are indicators of the natural state of forests occurred, and this particularly applies to the nature reserve Kępa Bazarowa (Cieśliński 2003).

CONCLUSIONS

Habitat diversity in the city of Toruń – dunes, forests – is favourable for the occurrence of numerous species of threatened and protected lichens.

In total, the occurrence of 58 threatened and protected lichen species was determined in the study area, both at present and based on the literature data.

On the basis of floristic valuation, which consisted in analysing the occurrence of special concern species, particularly valuable natural areas were designated in Toruń.

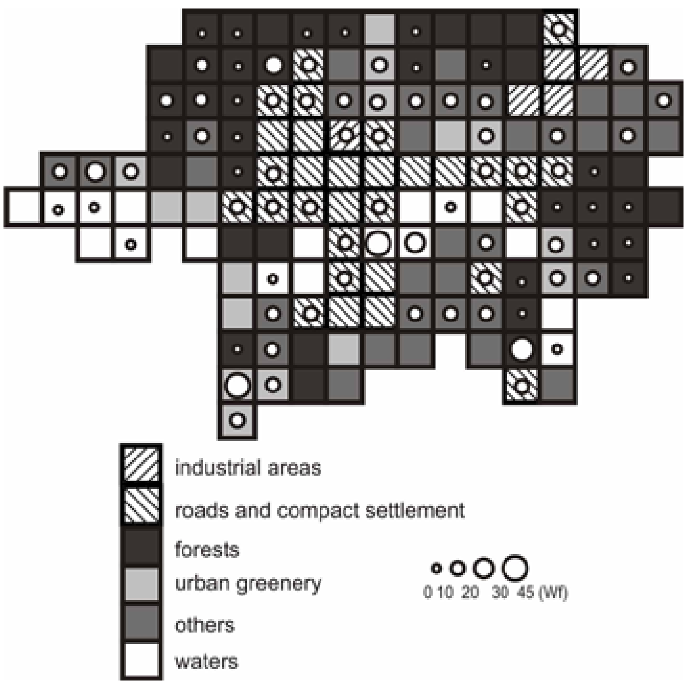

Fig. 1. Values of the floristic index (Wf) for individual sites in the area of Toruń

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STATE AND CHANGES OF PROTECTED AND THREATENED LICHEN BIOTA IN BIELSKO-BIAŁA AGAINST BACKGROUND OF THE ADJACENT AREAS

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Abstract. The paper presents the results of lichen biota research conducted in 2004-2006 in Bielsko-Biała. Among the 44 taxa there were found 12 species under legal protection and/or placed on the so-called red list of lichens in Poland and in the region. The results were compared to previous studies in the vicinity of the city: Silesian Beskid Mts (Beskid Śląski), Small Beskid Mts (Beskid Mały), Silesian Foothills (Pogórze Śląskie). Analysis indicated the participation of special concern species as a method of estimating the degree of anthropogenic pressure influence on the environment.

Key words: lichens, protected species, threatened species, extinction, recolonisation, Bielsko-Biała, Southern Poland

INTRODUCTION

Since publication the first version of the list of endangered plants in Poland (Zarzycki et al. 1992) lichens have been already considered as a group of organisms with the greatest degree of risk, while the non-mountain areas of Upper Silesia – is a region with the greatest intensity of this phenomenon (Czyżewska 2003). In this context, in 2004-2006 in the area of Bielsko-Biała a study of epiphytic lichen biota was conducted. The study focused on identification and condition evaluation of macrolichens for their air pollution bioindication significance (Bielec 2011). The influence of urban conditions on the state of lichen biota was analysed and the obtained data were compared with the results of other researchers.

As the great taxonomic diversity provided by the authors makes it difficult to compare, Kinnunen et al. (2003) proposed the standardization of test methods by reducing the number of analysed species. In this paper as an evaluation method of natural state is accepted the distinction of species of special concern: protected and endangered ones. The share of these lichens was thus considered as a good indicator for estimating the degree of naturalness or the degree of anthropogenic transformation of the area (Lipnicki 1993; Cieśliński, 2003) and its natural values worthy protection (Cieśliński, Czyżewska 2002).

MATERIAL AND METHODS

The samples were collected using a grid of points equally spaced on a built up area of research, expanded by forests and green land within the city boundaries (Bielec 2011). Epiphytic lichens were collected from one or a few the most abundantly overgrown phorophytes within approximately 150 m. The data obtained with 117 stations.

Species of special concern are distinguished on the basis of:

- Ordinance of the Minister of the Environment of 2004 (Dz. U. *[Official Gazette]* 2004 No. 168, Item 1765) – protected lichens;
- Cieśliński i in. (2006) – lichens endangered in the country;
- Kiszka, Leśniański (2003) – lichens endangered in the region.

Designated risk categories as following:

RE – Regionally extinct, CR – Critically endangered/ On the verge of extinction, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least concern; DD – Data deficient.

STUDY AREA

Bielsko-Biała is a city in southern Poland with an area of 125 km^2, inhabited by 175 thousand people (2010). It is located in the foothills of the Silesian and Small Beskid Mts in the valley of the River Biała, at an average altitude of about 300 m a.s.l. The average annual temperature is 8°C in a built up area and 4°C in the peripheral parts; a total annual precipitation of about 1000 mm. In winter the winds are south-westerly and southerly (including gusty foehn winds), in summer: westerly and north-westerly, in spring and autumn: easterly and south-easterly.

The environment of Bielsko-Biała is affected by large-scale urban proximity: Upper Silesia, Rybnik Coal District and the District of Ostrava-Karwin. The city is within areas with an average contamination of the investigated gas and dust substances, including heavy metals. The worst air quality conditions prevail in the centre, in the valley. Urban green areas include meadows, river valleys, parks, gardens, as well as wooded slopes and mountain ranges - reaching over 1000 m a.s.l. In the south the city is adjacent to the two huge forest complexes of a mountainous character (Silesian Beskid Mts and Small Beskid Mts). There are large protected areas: Landscape Parks and Natura 2000 terrains (Blarowski et al. 1997; Ochrona Środowiska 2001-2006; Program rewitalizacji… 2007).

RESULTS

The list of epiphytic lichens in Bielsko-Biała, as the results of field researches in 2004-2006, contains 44 taxa. Among them are species under strict protection – 7, partial protection – 1, as well as endangered in the country – 4 and endangered in the region – 9 species (Table 1).

Table 1. List of protected and endangered species of epiphytic lichens, found in Bielsko-Biała during the investigations in 2004-2006

Species	Legal protection	Threat in Poland	Threat in the region	Number of phorophytes
Bacidina arnoldiana (Körb.) V.Wirth & Vězda		NT		2
Candelariella reflexa (Nyl.) Lettau			DD	2
Evernia prunastri (L.) Ach.	partial	NT	NT	1
Melanelixia fuliginosa (Duby) O.Blanco et al. subsp. *fuliginosa*	strict			5
Melanohalea exasperatula (Nyl.) O.Blanco et al.	strict			5
Parmelia saxatilis (L.) Ach.	strict		LC	6
Parmelina tiliacea (Hoffm.) Hale	strict	VU	EN	1
Parmeliopsis ambigua (Wulfen) Nyl.	strict		LC	2
Physcia stellaris (L.) Nyl.			NT	1
Physconia enteroxantha (Nyl.) Poelt			NT	1
Platismatia glauca (L.) W.L.Culb. & C.F.Culb.	strict		LC	1
Punctelia subrudecta (Nyl.) Krog	strict	VU	EN	4

The frequency of protected and endangered species on examined sites was low and amounted from 1 to 6% of all records (Table 2). Lichens of special care were analysed in terms of local conditions, reflecting the type of spatial management. Most common taxon – *Melanelixia fuliginosa*, clearly preferred forest habitats. In three others there was only one occurrence – only in the southern, afforested and submontane parts of the city. *Candelariella reflexa*, as the only one of this group, was found in the zone of strong industrial influence.

By comparison the number of records for all species found in the city is presented (Table 2: Background 1) and the most frequently encountered, toxytolerant *Physcia tenella* (Scop.) DC. (Table 2: Background 2).

Town lichens most often inhabited residential districts of sparse and low-rise housing, then habitats along roads and highways, as well as agricultural regions, but the special-care species were most commonly noted in wooded areas (Table 2).

Table 2. Number of stations and notations found in the area of Bielsko-Biała in 2004-2006

Lichen species	Number of stations	Frequency on examined sites	Records in each category of local space development						
			I	C	B	S	A	G	F
[Background 1 – Tło 1]	[117]	[100%]	28	167	40	183	107	55	137
[Background 2 – Tło 2: *Physcia tenella*]	[50]	[43%]	8	26	4	30	19	12	7
Melanelixia fuliginosa	7	6%		2		2		1	8
Melanohalea exasperatula	6	5%		1		3	2		4
Parmelia saxatilis	6	5%				4	1		5
Punctelia subrudecta	6	5%		2		2	1		2
Candelariella reflexa	3	3%	1	1		3	1		
Bacidina arnoldiana	2	2%		1		1			1
Parmeliopsis ambigua	2	2%							2
Evernia prunastri	1	1%							1
Parmelina tiliacea	1	1%				1	1		
Physcia stellaris	1	1%							1
Physconia enteroxantha	1	1%		1		1			
Platismatia glauca	1	1%							1

[Background 1: total of all workstations]; [Background 2: most often noted species]; I - industrial area; C - communication routes pressure; B - inner-city or blocks of flats; S - suburb or residential housing; A - agricultural areas; G - urban greenery, coppices or wasteland; F - forests or tree-covered areas.

DISCUSSION

Lichenobiota in Bielsko-Biała has not previously been the subject of detailed research. Several localities now included in the administrative territory of the city were reported by Kiszka (1967). For comparative analysis the results of investigations carried out in adjacent regions were used:

- in the Small Beskid Mts (Beskid Mały), with localities in the vicinity of the boundaries of Bielsko-Biała - Nowak (1965, 1974);
- in the Żywiecka Basin (Kotlina Żywiecka), with localities in the suburban villages – Kiszka (1970);
- in the Silesian Foothills (Pogórze Śląskie), in the proximity of northern city boundaries – based on unpublished material of Leśniański herbarium specimens from the years 2000-2005.

Data from the period 1965-2005 provide information about the presence of 28 epiphytic lichens species in the region of Bielsko-Biała, which were not found in the city in 2004-2006 during own study. Nowak (1965, 1974) and Kiszka (1967) reported seven species currently under strict protection, and 16 species threatened in the country and in the region (Table 3). Kiszka (1970) did not specify such taxa, neither Leśniański in his collection (2000-2005 unpl.).

Table 3. Protected and endangered species, previously listed in the current boundaries of Bielsko-Biała or in the immediate vicinity, but actually not found in the city

Lichen species	Strict protection	Threat category		Stations by data source	
		in Poland	in the region	Nowak (1965, 1974)	Kiszka (1967)
Arthonia radiata			EN	Czupel	
Biatora efflorescens		VU	VU		Szyndzielnia, Klimczok
Bryoria bicolor	+	CR	EN		Klimczok
Calicium abietinum		VU	EN		Szyndzielnia
Caloplaca cerina		VU	EN		Olszówka Górna
Cetrelia olivetorum	+	EN	EN		Szyndzielnia, Potok Białka, Klimczok
Chaenotheca chrysocephala			VU		potok Wapienica
Ch. furfuracea		NT	VU		Szyndzielnia
Ch. stemonea		EN	EN		potok Wapienica
Flavoparmelia caperata	+	EN	EN		Cuberniok
Graphis scripta		NT	VU	Czupel	Szyndzielnia
Gyalecta flotowii		CR	CR		Szyndzielnia
Hypogymnia farinacea	+	VU	EN		Klimczok
H. tubulosa	+	NT	VU		Szyndzielnia, Klimczok
H. vittata	+	CR	EN		Klimczok
Imshaugia aleurites	+		LC	Magurka	Dębowiec

Comparison of historical data (Nowak 1965, 1974; Kiszka 1967) enables one to draw conclusions regarding changes in the lichenobiota state. With very high probability over 40 years in the area of Bielsko-Biała the decline of 16 epiphytic species currently with "protected" or "endangered" status took place. Currently the presence of only 12 such species has been revealed. There has been a simplification in species composition and a reduction in number of taxa (Czyżewska 2003). This could be due to the relatively small area of the city and the specific urban habitats. In this context the presence of *Punctelia subrudecta* seems to be particularly valuable. The disappearance of this species from the Silesian Beskid Mts was ascertained by Kiszka already in 1966 and confirmed in 1996.

Many more epiphytic lichen species were recorded previously from the whole area of the regions adjacent to Bielsko-Biała, than from the city and its immediate surroundings:

- from the Silesian Beskid Mts (Motyka 1930; Kiszka 1967) – a total of 183 species;
- from the Small Beskid Mts (Nowak 1965, 1974) – over 100 species;
- from the Żywiecka Basin (Kiszka, 1970) – 80 species;
- from the Silesian Foothills (2000-2005 Leśniański unpl.) – 68 species.

For comparison: in Bielsko-Biała (by own research) specified 44 taxa.

In the review of comparative studies special attention is paid to species that demonstrated high attendance or a status of "frequent" or "common", whereas they cannot be found in the city at present. Having regard to entire geographical regions adjacent to the city, there were 55 such taxa colonizing tree bark, of which 17 are strictly protected and 35 have some threat status in the country and in the region (Table 4). All species are typical epiphytes, except for *Peltigera horizontalis* and *P. praetextata*.

None of these species has been found even in the forests with a significant naturalness, for example in the Wapienica Valley or in patches of Carpathian beech forest on mountain slopes.

Merely historical dates form the list of species of special concern currently not observed in Bielsko-Biała and defined by cited authors as frequent. However, according to contemporary data source (Leśniański 2000-2005 unpl) at the Silesian Foothills the most common are: *Physcia caesia* (threat in Poland: VU) and *Strangospora pinicola* (threat in Poland: LC, threat in the region: NT), with just three percent frequency.

Throughout the decades the occurrence of other species has changed, too.

For instance *Platismatia glauca*, described by Kiszka (1967) as common, currently has been found in Bielsko-Biała only as a thallus initialised, which may suggest this species made a recolonisation. Similarly, the author reported numerous stands of *Evernia prunastri* or *Parmelina tiliacea*, which currently also have been found within the city woodland only in the form of a single juvenile thallus.

There were also less common lichens, but once dispersed in the terrains surrounding the city and important for lichenoindication, such as *Ramalina farinacea*, *R. fastigiata*, *Usnea subfloridana* and *Lobaria pulmonaria* - currently not identified at the study area. On the Red List of endangered lichens in Opole Silesia and Upper Silesia (Kiszka, Leśniański 2003) these species included to threat category: "Endangered" and "On the verge of extinction", even though approximately 30-40 years earlier (Nowak 1965,1974; Kiszka 1967) they were not difficult to find.

Lichenocoenosis impoverishment and acidophilous or apophytic lichens domination intensified by dozens of years of the development in the region of industry, tourism and urban infrastructure, as well as unlimited forest exploitation and high level of pollution, mainly gaseous (Nowak 1965, 1972; Rao, Le Blanc 1966; Kiszka 1967, 1977, 1994; Hawksworth, Rose 1970; Bylińska, Seaward 1993; Czyżewska 2003).

Probably the process of lichenobiota degeneration stopped in the 80's-90's of last century, due to an economic-policy transformation and more strict emissions standards. There were reports about the process of recolonisation in the West (Rose, Hawksworth 1981; Seaward 1997) and in Poland (Lipnicki 1994; Fałtynowicz 2004; Adamska 2008). Return of certain species to the previous positions, increasing lichen frequency and of trunk coverage, as well as improving

Table 4. List of lichens found on tree bark with high frequency, drawn from the results of research conducted between 1965-2005 in the regions bordering Bielsko-Biała, but not detected in the city during own research

Species	Frequency	Legal protection	Threat category	
			in Poland	in region
Arthonia radiata	frequent (K)			EN
Biatora efflorescens	frequent (K)		VU	VU
Bryoria fuscescens	frequent (K)	strict	VU	EN
Buellia disciformis	frequent (K)		VU	VU
Cetrelia olivetorum	very frequent (K)	strict	EN	EN
Chaenotheca chrysocephala	frequent (K)			VU
Ch. furfuracea	15 stands (K)		NT	VU
Flavoparmelia caperata	10 stands (N); frequent (K)	strict	EN	EN
Graphis scripta	14 stands (N); common (K)		NT	VU
Hypogymnia farinacea	frequent (K)	strict	VU	EN
H. tubulosa	frequent (K)	strict	NT	VU
Lecanactis abietina	10 stands (K)		EN	EN
Lecanora albella	frequent (K)		EN	EN
L. intumescens	frequent (K)		EN	EN
Lobaria pulmonaria	frequent (K)	strict	EN	CR
Melanelia subaurifera	frequent (K)	strict		VU
Melanelixia glabra	frequent (K)	strict	EN	LC
M. subargentifera	frequent (K)	strict	VU	EN
Menegazzia terebrata	frequent (K)	strict	CR	CR
Ochrolechia androgyna	common (K)		VU	VU
Opegrapha niveoatra	11 stands (K)		VU	
O. varia	13 stands (K)		NT	VU
Parmeliopsis hyperopta	frequent (K)	strict	VU	VU
Peltigera horizontalis *	frequent (K)	strict	EN	EN
P. praetextata *	13 stands (K)	strict	VU	VU
Pertusaria amara	very frequent (K)			LC
P. coronata	frequent (K)		VU	EN
P. hemisphaerica	frequent (K)		VU	EN
Physconia detersa	frequent (K)		VU	VU
P. distorta	13 stands (N); frequent (K)		EN	EN
Pseudevernia furfuracea	11 stands (N); very frequent (K)	strict		LC
Pyrenula nitida	10 stands (N)		VU	EN
Thelotrema lepadinum	frequent (K)	strict	EN	EN
Usnea filipendula	frequent (K)	strict	VU	CR
Vulpicida pinastri	15 stands (N); frequent (K)	strict	NT	EN

The total number of stations in the studies: N - Nowak (1965,1974) – 106; K - Kiszka (1967) – 156; * non epiphytic species.

health of thalli were found. This phenomenon was also observed in Bielsko-Biała where initialised lichen thallus of sensitive taxa, such as *Physcia stellaris*, appeared.

SUMMARY AND CONCLUSION

Among the 44 epiphytic lichen taxa found in Bielsko-Biała, 8 species are under legal protection (7 strict and 1 partial), and 10 are on the red list of endangered lichens in Poland (Cieśliński et al. 2006) or in the Upper Silesia and Opole Silesia (Kiszka, Leśniański 2003). *Parmelina tiliacea* has the status of VU (Vulnerable) in the country, and also *Punctelia subrudecta*, that additionally in the region has the category EN (Endangered). Remaining taxons are less threatened.

Species showing a greater sensitivity to pollution, such as *Physcia stellaris*, *Platismatia glauca*, *Evernia prunastri* and *Parmelina tiliacea* were noted in present study at only certain individual stations (Table 2). This reflects the difficulties to which the organisms of less contamination resistance must face in urban conditions.

However, the presence of sensitive lichens' juvenile thalli may be a sign of beginning their expansion into anthropogenic habitats. Due to lack of a list of lichens from earlier periods for this area, the results of research in adjacent regions were used for comparative purposes: the Silesian Beskid Mts and the Żywiecka Basin (Kiszka 1967, 1970), the Small Beskid Mts (Nowak 1965, 1974) and the Silesian Foothills (Leśniański 2000-2005 unpl.). In the source materials there is a list of 54 species, which were once common or frequent, but which actually have not been found in the city, even in mountainous and forested areas. As many as 17 of them are under strict protection and 35 taxa have endangered status in the country and in the region.

Historical data (Nowak 1965, 1974; Kiszka 1967, 1970) may suggest that in over 40 years, from the close proximity of Bielsko-Biała, 28 taxa of epiphytes disappeared, including 16 on the current status of protected and endangered – while nowadays only 12 such species have been found.

Numerical relations of special-concern species (A) to common species (B) in the main aspects of the analyses and comparisons are as follows:

- results of own investigations: (A 12): (B 44) = 27%;
- taxa from the city periphery and defined neighbourhood currently not found: (A 16): (B 28) = 57%;
- species formerly frequent in the region: (A 35): (B 55) = 65%.

The obtained proportions may indicate degeneration of urban lichenocoenosis, where sensitive, legally protected and threatened lichen species gave way to hemerofophilous, toxitolerant and apophytic ones.

Thus, participation of special-concern and especially interesting species may demonstrate the degree of natural habitats and environments transformation, as already postulated: Lipnicki (1993), Cieśliński, Czyżewska (2002) and Cieśliński (2003).

Current research epiphytic lichens statuses in Bielsko-Biała are the starting point for the subsequent observation of recolonisation that is particularly important in relation to protected and threatened species. The juvenile thalli presence of *Evernia prunastri*, *Physcia stellaris* and *Platismatia glauca* noted as present on the wooded periphery of the city. Moreover *Punctelia subrudecta* have been found - taxon previously recognized by Kiszka (1966, 1996) as extinct in the Silesian Beskid Mts. Further investigation should reveal the underlying causes of these processes and simultaneously respond to crucial question: whether recolonisation processes, particularly in relation to protected and endangered taxa, are the result of the improvement of atmospheric air condition, or they are a manifestation of apophytisation and synanthropisation of lichens.

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THE VALUE OF LARCH (LARIX MILL.) PLANTATIONS FOR THE PROTECTION OF THREATENED LICHENS IN SOUTHERN EAST GERMANY AND ADJACENT AREAS

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During the 20th century, air pollution was the main factor causing threat to lichens in Central Europe. Southern East Germany and adjacent Poland and Czech Republic were situated in the centre of pollution in Europe, resulting in the loss of most epiphytic lichen species here. With the decline of air pollution, many species are reinvading, and the relative importance of other factors than pollution for the formation of lichen vegetation has increased during the last few years. One main factor affecting epiphytic lichen diversity is forestry. It is sufficiently known that there are several lichens, whose occurrence depends on the presence of forests with natural structure with long habitat continuity at their stands. However, pristine forests, the more so without previous impact of significant pollution, have become extremely rare in Central Europe today. By far the largest part of the forested area is covered by plantation forests. These are often very poor in epiphytic lichens.

However, larch plantations have been found to be an exception. Larch has been planted in particular in the 80ies in areas, which were heavily affected by air pollution at that time, e.g. in the Erzgebirge Mts., the Lusatian lowlands or the Iser Mts. Following the decline of air pollution, a massive colonisation of these plantations with epiphytic lichens has taken place now. Many larch plantations provide at least half a dozen of *Usnea* species, which are mostly considered as endangered. Most of the recent records of the German Red List category 1 and 2 species *Usnea glabrata*, *U. glabrescens*, *U. barbata*, *U. fulvoreagens*, *U. lapponica*, *U. wasmuthii*, *Evernia mesomorpha*, *E. divaricata*, *Bryoria capillaris*, *B. implexa* and *B. nadvornikiana* in southern East Germany originate from larch plantations. There are also single records of species that are generally rare in Central Europe, as e.g. *Usnea flavocardia*, *Parmotrema reticulatum*, *Nephromopsis laureri* and *Bryoria subcana*.

Thus, the larch plantations prove to be an important habitat for endangered lichens in parts of Central Europe. One might therefore consider including larch into the forestry systems also in future, in order to partly compensate for the negative effects of intensive forestry on lichen diversity. However, only a certain group of lichens can be protected this way; this concerns mainly species of the *Parmelietum furfuraceae* and the *Bryorio-Usneetum*. For species that depend on old, undisturbed broadleaf forests, appropriate reservations have to be organized; they cannot be compensated for by larch plantations.

THREATS OF LICHENS OF ANTHROPOGENIC ROCK SUBSTRATES IN THE SURROUNDINGS OF THE MEDIEVAL CASTLES IN THE SUDETY MTS

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The research work anticipates demonstrating the richness and diversity of lichen biota within the medieval castles located in the region of the Sudety Mts. It could be said that these objects constitute specific „islands of biodiversity" in an area poor in calcium carbonates, because most of them are built of non-calcareus stone blocks from the nearest neighbourhood and joined with lime mortar. Seepage of calcium carbonate enriched the habitat of the rock also below the walls, creating the opportunity to develop specific, heterogeneous lichen biota. Preliminary observations from Chojnik and Bolków castles seem to confirm the thesis about the importance of old castles, which create new habitats: a number of the lichen species observed there, do not occur on natural rock outcrops in the region.

The undertaken thesis also aims to verify the relationship between lichen biota of natural limestone outcrops at Góry Kaczawskie Mts and Pogórze Kaczawskie Foothills (the only place of occurrence carbonate rocks in the Western Sudety Mts) and species composition of artificial substrates in the surroundings of castles in the researched area.

As a result of these researches it is expected to answer the questions:

- what habitat conditions prevail within the medieval castles built in the mountains, and which of them favour the growth of lichens?
- if artificial calcareous substrates are colonized only by common species existing on this type of substrate or whether they are associated with the lichen biota of natural carbonate outcrops occurring in the region?
- which species colonize "calcareous islands" in the naturally poor in calcium carbonate environment? And what are their biological properties?
- whether the lichens of investigated objects are endangered? What threat factors are there?

Till now about 50 species of lichens have been determined, but analyses are in progress. More comprehensive results will be presented at the conference.

PROTECTED AND ENDANGERED LICHENS OF THE ALPINE AND SUBALPINE BELTS IN BABIA GÓRA MASSIF

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Babia Góra massif, entirely within the borders of the Babia Góra National Park, is the highest range of the West Beskids, Carpathians. Altitudinal vegetation zones, entirely developed to the alpine belt, have a direct influence on the unique characteristics of the lichen biota in this area.

The paper presents results of research conducted within the area of the Babia Góra National Park in the years 2008 – 2010, concerning the state of preservation of protected and endangered lichens occurring in the alpine and subalpine belts in the Babia Góra massif.

The regional red list of endangered lichens for the Babia Góra has not yet been prepared. It is because, despite numerous lichenological studies carried out in this area since the 19th century (Nowak 1998), the research never covered the whole Babia Góra massif. The current study results will be used to prepare such list.

Current data on lichen occurrence and distribution in the area of Babia Góra were compared with previously published data. The number of lichen species recorded in the alpine and subalpine belts till now is 155, of which 27 species are under strict or partial conservation regimes in Poland. According to the Red list of the lichens in Poland (Cieśliński et al. 2006) 71 species have the status of threat. Among them the numbers of lichen species belonging to the particular threat categories are as follows: RE-1, CR-10, EN-19, VU-23, NT-8, LC-9 and DD-1.

A large group of species recorded in this area in the 19th and 20th centuries has not been confirmed during the present study, e.g. *Belonia incarnata*, *Bryophagus gloeocapsa*, *Catolechia wahlenbergii*, *Lithographa tesserata*, *Mycobilimbia berengeriana*, *Peltigera aphthosa*, *Polyblastia palescens*, *P. sendtneri*, *Porina mammillosa*, *Solorina crocea*, *S. saccata*, *Sphaerophorus fragilis*, *Stereocaulon nanodes, Thamnolia vermicularis* subsp. *vermicularis*. On the contrary, species *Cladonia amaurocraea* and *Cl. bellidiflora*, previously deemed to be extinct, currently have been considered again.

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PROTECTION OF LICHEN SPECIES ALONG ROADSIDE TREE ROWS IN THE REGION OF WARMIA AND MAZURY

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The Region of Warmia and Mazury is renowned for its exceptional scenic values and landscape amenities. The abundant natural resources of the area include not only extensive woodlands, lakes and wetlands, but also beautiful old roadside trees. Roadside trees, which are part of the traditional landscape in Warmia and Mazury, can be found alongside district and regional roads. In the rural landscape, old roadside trees provide habitat for a wide range of lichen species, thus contributing to the preservation of biodiversity. The most valuable tree rows should be preserved in their natural, unchanged state in order to effectively protect lichen resources in the region.

A preliminary study of selected tree rows, conducted in 2000–2002 and 2009–2011, revealed the presence of approximately 120 lichen species, including 45 red-listed and 22 legally protected species. The rarest macrolichens reported from the research area were: *Anaptychia ciliaris*, *Flavoparmelia caperata*, *Melanelixia subargentifera, Melanohalea elegantula, Parmelina tiliacea*, *Pleurosticta acetabulum*, *Punctelia jeckeri*, *P. subrudecta* and *Ramalina baltica*. Attention should also be paid to the following microlichens: *Catilaria nigroclavata, Caloplaca obscurella, Lecanian aegeli* and *Strangospora pinicola*. Interestingly, some species known from forest habitats, such as *Acrocordia gemmata*, *Chaenotheca phaeocephala*, *Chrysothrix candelaris* and *Cliostomum corrugatum,* were also noted in roadside trees.

As a member state of the European Union, Poland can use EU funds to finance road construction and transport infrastructure projects. According to Zarząd Dróg Wojewódzkich (Regional Roads Authority) in Olsztyn, over 300 km of roads were and are to be reconstructed and modernized in 2007–2013. The estimated total cost of the project is PLN 900 million (80% EU funds). According to the current EU guidelines, the roadside border area, referred to as the safety zone, must be free of fixed objects such as pillars, poles and trees. In the region of Warmia and Mazury, a total of 30,000 roadside trees were removed in 2004–2008 from the safety zones of regional roads, and another 15,000 trees are to be removed by the year 2013. The number of trees removed from the safety zones of district roads remains unknown. If this alarming rate of habitat loss continues, the majority of valuable lichen species reported from roadside tree rows may become critically endangered.

The joint efforts of several environmental organizations have resulted in amendments to the Nature Conservation Act, and administrative control over roadside tree management was regained in July 2010. In line with the current regulations, all legally protected species found on trees intended for removal have to be listed. The relevant changes have been introduced to most of the road constructions projects, which required the removal of all trees from the roadsides, developed before the Act was amended. In this way the process of planned elimination of valuable lichen populations has been partially inhibited. However, the attitude of local governments and road construction companies to the preservation of old tree rows in the vicinity of roads remains negative. We can only hope that the expected changes to the technical specifications for road modernization will support the protection of roadside trees, which are important habitats for lichens and other wildlife species.

PROTECTED AND THREATENED LICHENS IN PETROLEUM AND NATURAL GAS EXTRACTION REGION KRNIGZ LMG (LUBIATÓW, MIĘDZYCHÓD, GROTÓW)

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This paper presents the partial compilation of the result of the lichenological works performed in the years 2005-2011 within the area of the Lubiatów-Międzychód-Grotów (LMG) petroleum and natural gas extraction region in the middle part of the Puszcza Notecka Forest. The studies were conducted on the basis of the project entitled: The lichen indicative evaluation of the influence of petroleum and natural gas extraction on the animated nature of the middle part of the Puszcza Notecka Forest – "stage zero", performed on commission by PGNiG SA Branch in Zielona Góra.

Within the area covered by the study, approximately 200 species of lichens were reported to exist on various grounds. These species were from different ecological groups. Among them there are as many as 40 protected species (9 – under partial protection: *Cetraria aculeata*, *C. islandica*, *C. muricata*, *Cladonia arbuscula*, *C. mitis*, *C. ciliata* var. *tenis*, *C. portentosa*, *C. rangiferina*, *Evernia prunastri*; 31 – under strict protection: *Cetraria chlorophylla*, *Cladonia stellaris*, *Hypogymnia tubulosa*, *Imshaugia aleurites*, *Melanohalea elegantula*, *M. exasperatula*, *Melanelixia fuliginosa*, *M. subargentifera*, *Parmelia saxatilis*, *P. tiliacea*, *Parmeliopsis ambigua*, *Peltigera canina*, *P. didactyla*, *P. horizontalis*, *P. membranacea*, *P. polydactylon*, *P. rufescens*, *Platismatia glauca*, *Pleurosticta acetabulum*, *Pseudevernia furfuracea*, *Punctelia subrudecta*, *Ramalina farinacea*, *R. fastigiata*, *R. fraxinea*, *R. pollinaria*, *Stereocaulon condensatum*, *S. tomentosum*, *Usnea filipendula*, *U. hirta*, *U. subfloridana*, *Xanthoparmelia conspersa*; 3 species are under zone protection: *Usnea filipendula*, *U. hirta*, *U. subfloridana*).

From among the species of lichens found, 37 are categorized as threatened and placed on the so-called "Red List". (Cieśliński et al. 2006). These include lichens, which belong to the following categories:

CR (Critically Endangered) – *Cliostomum corrugatum*;

EN (Endangered) – *Calicium adspersum*, *Chaenotheca stemonea*, *Cladonia stellaris*, *Peltigera horizontalis*, *Pleurosticta acetabulum*, *Ramalina fastigiata*, *R. fraxinea*, *Stereocaulon tomentosum*, *Usnea subfloridana*;

VU (Vulnerable) – *Buellia alboatra*, *Calicium viride*, *Cetraria chlorophylla*, *C. islandica*, *Melanohalea elegantula*, *Melanelixia subargentifera*, *Miriquidica leucophaea*, *Opegrapha* cfr. *vulgata* var. *subsiderella*, *Opegrapha viridis*, *Parmelina tiliacea*, *Peltigera canina*, *Punctelia subrudecta*, *Ramalina farinacea*, *R. pollinaria*, *Rhizocarpon lecanorinum*, *Stereocaulon condensatum*, *Usnea filipendula*, *U. hirta*;

NT (Near Threatended) – *Cetraria muricata*, *Chaenotheca furfuracea*, *Cladonia sulphurina*, *Evernia prunastri*, *Hypogymnia tubulosa*;

LC (Least Concern) – *Psilolechia lucida*;

DD (Data Deficient) – *Haematomma coccineum* var. *ochroleucum*, *Peltigera membranacea*, *Peltigera polydactylon*.

The presence of these taxa, as also the rare and threatened ones, is testimony to the natural links being maintained in good condition as well as to the stabilization of natural conditions. At the same time, their presence may be evidence of the relatively small aberrations of natural conditions.

The present abundant list of precious species of lichens (protected and threatened) proves that the aero sanitary conditions are good. It is assumed that comparative studies will be conducted upon the start-up of extraction. The changes, if any, in the number of localities of the mentioned lichens will reflect environmental degradation as a result of increase in the pollution levels in the air.

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GENETIC VARIABILITY OF PHOTOBIONTS IN POLISH POPULATIONS OF THE ENDANGERED SPECIES *LASALLIA PUSTULATA* (L.) MÉRAT.

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Understanding the population biology of lichen-forming fungi and their photobionts can help to design effective conservation strategies (Scheidegger, Werth 2009). Here we aim at understanding the genetic diversity of the photobiont in *Lasallia pustulata.*

L. pustulata is a foliose, umbilicate lichen. It forms thalli that are typically 3–6 cm, but sometimes up to 40 cm in diameter. Dispersal is mainly achieved by isidia. Apothecia are very rare. The photobiont is a coccoid green alga of the genus *Trebouxia*. *L. pustulata* grows on nutrient–rich rocks or standing stones at elevations of 400–800m (occasionally up to 2000 m). The centre of distribution is in Europe, with a range from Scandinavia to the Mediterranean, and France to the European part of Russia. In Poland *L. pustulata* has a patchy distribution and it has been reported from the Środkowomałopolska Uplands, the western part of the Carpathian Mts., the *Świętokrzyskie Mts.* and the *Iłżeckie* Foothills (Faltynowicz 2003; Sepski 1984). The densest occurrence is in the Sudety Mts. In Poland *L. pustulata* is regarded as a rare species, it is legally protected and has the category EN within the Polish Red List of Lichens (Cieślinski et al. 2006).

The objective of our work was to estimate the genetic diversity of photobionts in populations of *L. pustulata* in Poland. Our assumption is that mycobionts, which specialize in forming symbioses only with specific algal strains (genotypes) are more vulnerable to environmental change than mycobionts, which are more flexible in their selection of photobiont strains. We compared specimens from 8 populations (from Karkonosze Mts, Izery Mts, Rudawy Janowickie Mts. and Krucze Mts.). From each population we sampled 5 – 31 specimens and generated sequences of the ITS rDNA (121 sequences in total). The length of the alignment was 579 base pairs. The alignment was generated in MUSCLE (Edgar 2004), and analyzed in DnaSP (Librado, Rozas 2009) and NETWORK (Bandelt et al 1999).

We found a total of 14 ITS rDNA haplotypes. Within a single population we found 1–8 haplotypes. The most common haplotype was found in 7 of the 8 populations and was recovered 69 times in total. BLAST searches in GenBank showed that this haplotype is also found in other lichen species e.g. in *Cetraria aculeatea* or *Lecidea* *lapicida*. Some haplotypes were found only in a single population (Chojnik Hill). The median joining network shows that there are at least 3 photobiont lineages that are separated by more than 15 mutational steps. It is possible that these lineages constitute different species. As shown in other studies (Fernandez–Mendoza et al. 2011) our results confirm that a single species of lichenized fungus can form symbioses with more than one photobiont strain. Since *L. pustulata* mainly reproduces asexually by isidia we expected low genetic diversity in the photobiont. However, our study reveals that genetically highly divergent lineages, possibly different species, of *Trebouxia* can be involved in the symbiosis. This suggests that *L. pustulata* potentially also reproduces with conidiospores that form de novo thalli with algae available in the environment. It is unlikely that ascospores are involved in reproduction because we found only very few specimens with apothecia.

Populations of *L. pustulata* in Poland have been declining as a consequence of sulphur dioxide pollution. Since this type of pollutions is no longer a major threat, populations seem to be recovering. We were able to collect *L. pustulata* from more sites than we expected. We hypothesize that it is the flexibility of the mycobiont to form symbiosis with many different strains of *Trebouxia*, and the capacity of the mycobiont to reproduce with conidiospores, which enables *Lasallia pustulata* to effectively colonize new habitats.

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THREATENED AND PROTECTED SPECIES OF THE GENUS CALOPLACA IN POLAND

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The genus *Caloplaca* is a large group of lichens represented by ca. 800 species in the world, 72 of which are known in Poland. Among the Polish *Caloplaca* species there is only one - *C. marina*, protected by law. It is a marine species, occurring on seashore rocks. A further 22 species of *Caloplaca* (30% of all Polish taxa) are placed on the Red List of the Lichens in Poland (Cieśliński et al. 2006). Most of them are saxicolous (10 species), 7 are corticolous, and 5 are muscicolous or terricolous. Among the red-listed species 3 are considered as regionally extinct (category RE; *C. ferruginea*, *C. nivalis*, *C. rubelliana*), 2 - as critically endangered (CR; *C. conversa*, *C. crenularia*), 7 - as endangered (EN; *C. cerinella*, *C. chlorina*, *C. flavorubescens*, *C. luteoalba*, *C. marina*, *C. schoeferi*, *C. sinapisperma*), 6 – as vulnerable (VU; *C. cerina*, *C. herbidella*, *C. ochracea*, *C. stillicidiorum* s. lat., *C. tiroliensis*, *C. variabilis*), 2 - as near threatened (NT; *C. cirrochroa*, *C. obscurella*) and 2 – as data deficient (DD; *C. saxifragarum*, *C. vitellinula*). Additional species are included in various Regional Red Lists of Lichens: *C. alociza*, *C. aurantia*, *C. chrysodeta*, *C. coronata*, *C. crenulatella*, *C. demissa*, *C. dolomiticola*, *C. holocarpa*, *C. lactea*, *C. lobulata*, *C. teicholyta* and *C. xantholyta* (see Czyżewska ed. 2003). Ongoing revisionary work on *Caloplaca* in Poland, however, has resulted in a new insight into the knowledge of the genus diversity and particular species range in the country due to application of a more recent species concept and new tools of identification. Some taxa appeared to be much more widespread than previously estimated, therefore should not be considered endangered. Many species new to the country were also recorded. Some of them are extremely rare and as such should be included in the new revision of the Red List under an appropriate category.

A GENUS *LYROMMA* (*LYROMMATACEAE*, LICHENIZED ASCOMYCOTA) IN BOLIVIA

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The genus *Lyromma* belongs to the foliicolous lichenized fungi currently classified in the *Lyrommataceae*. As a result of our taxonomical study of the genus in Bolivia for the first time both perithecia and pycnidia of *Lyromma dolichobellum, L. nectandrae*, *L. ornatum, L. palmae* and *L. pilosum* were observed associated together on the same thalli in natural conditions. Accordingly a new concept of anomorph-teleomorph relationship in the genus, and a revised key to species determination are presented. Moreover two new species are described, and several new records are mentioned from Bolivia and Brazil. The results of the studies on lichen diversity will be highly beneficial in developing better biodiversity protection in Bolivia.

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THE ENDANGERED LICHEN FLORA OF COPPER SHALE SPOIL HEAPS IN GERMANY

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Copper shale (German: Kupferschiefer) of the Zechstein formation (apr. 250 million years old) was brought to the surface by mining activities for seveal hundred years. The centre of this type of copper mining was in the Mansfeld region in central Germany east of the Harz Mountains with minor attempts in other parts of Germany too. The mining activities came to an end with the political and economic changes in 1990.

Spoil heaps older than 100 years are normally covered with a special lichen vegetation as the heaps are often free of higher vegetation because of the high content of heavy metals (e.g. copper, plumb) in the deposits. The lichen flora of these surfaces contains a number of otherwise rare lichen species. *Lecidea inops* is within Germany only known from these spoil heaps and the species is regarded as a specific indicator of copper mineralization. Other interesting species are found in the genera *Acarospora* and *Silobia* (e.g. *A. bullata*, *A. peliscypha*, *S. smaragdula*). Phytosociologically the lichen community growing on Kupferschiefer belongs to the Lecideetum inopis.

Despite the large number of remaining spoil heaps their lichen flora is endangered mainly because of human spare time activities. The spoil heaps attract collectors of fossils and minerals who can destroy large parts of the instable surfaces by walking around and searching for specimens. Further the spoil heaps are also (mis-)used as training areas by cross-country motorcyclists. Some of the larger heaps are also re-used as building material for road constraction.

Nevertheless, the spoil heaps still host more than 100 lichen species, a good part of them are red-listed in Germany or the province of Saxony-Anhalt.