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THE LICHEN BIOTA OF WARMIA AND MAZURY FOREST ARBORETUM IN KUDYPY (NORTH POLAND)

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ABSTRACT. The study presents the results of lichenological researches carried out in the Warmia and Mazury Forest Arboretum in Kudypy (northern Poland). The inventory of lichens was conducted after the first 20 years of its existence. In total, 109 species of lichens spontaneously growing on natural and anthropogenic substrata have been recorded. Among them, protected species and lichens threatened with extinction in the country are distinguished.

KEY WORDS: lichens, lichenized fungi, diversity, forest arboretum, Poland

INTRODUCTION

Botanical gardens and arboretums are objects that gather documented collections of plants from various geographic regions and climatic zones. Usually rich collections serve scientific, didactic and educational purposes, as well as these of threatened species protection. In order to provide appropriate conditions to plants that originate from highly diversified habitats, the natural environment of these objects is frequently subjected to significant transformations. As a result, with a relatively small area, a mosaic of habitats is formed that is spontaneously inhabited by other groups of organisms, including e.g. macromycetes (Lisiewska and Nowicka 1979, Lisiewska 2004, Szczepkowski 2007) and lichens. Out of 46 botanical gardens and arboretums located in Poland (Puchalski 2002), inventories of lichen species have been elaborated only in a few of them (Glanc 1969, Kiszka 1992, 1997, 2002 a, b, Kossowska 1997 , Kubiak and Szczepkowski 2006). The first information on the occurrence of lichens on the area of the Warmia and Mazury Forest Arboretum in Kudypy was published as soon as it had been opened – however, it refers to barely six species in total: *Biatora efflorescens*, *B. epixanthoides*, *Calicium parvum*, *Caloplaca flavocitrina*, *Lecanora thysanophora*, and *Rinodina degeliana* (Kukwa and Kubiak 2007, Kubiak 2010, 2011 a, Kubiak et al. 2010). In the case of the last species, it was one of the first records of this lichen in Poland (Kukwa and Kubiak 2007).

This study was aimed at elaborating a species inventory of lichens at the Warmia and Mazury Forest Arboretum in Kudypy and developing a general characteristics of lichen biota of this object after 20 years of its existence.

STUDY AREA

The Warmia and Mazury Forest Arboretum in Kudypy is located on the area of the Kudypy Forest District, in the Olsztyn Lakeland. It is one of the youngest objects of this type in the country. The first trees and bushes were planted in the Arboretum in 1992, however, in the first years since establishment the object's development was relatively slow. It involved, most of all, preparation of infrastructure – fences, routes and footpaths. More dynamic development and enrichment of the collection have been observed since 1997 (Tumiłowicz et al. 2002). Initially, the Arboretum was established on the area of 7.54 ha, but in 2004 it was enlarged to a total area of 15.69 ha (Tumiłowicz et al. 2007).

The arboretum is located in the zone of the ground moraine of the Baltic glacial period, on the edge of a small valley coated with shallow peats. It encompasses a rolling terrain with varied topographic profile and an altitude difference of 120 to 132 meters above see level (Tumiłowicz et al. 2002, 2007). In the vast majority, the terrain is overgrown with subcontinental oak-linden-hornbeam forest *Tilio cordatae-Carpinetum betuli* with a wide trophic amplitude. It is constituted by Scots pine forest stand at the age of 90-170 years that includes also English oak (*Quercus robur*) and Norway spruce (*Picea abies*) – over 200 years of age, with an admixture of small-leaved linden (*Tilia cordata*), European hornbeam (*Carpinus betulus*), and Norway maple (*Acer platanoides*). In the north-eastern, boggy part of the Arboretum there occurs a complex of high sedge communities (*Magnocaricion*) and peat-bogs (*Scheuchzerio-Caricetea fuscae*), with the initial form of alder forest. The natural vegetation of the Arboretum includes ca. 200 species of vascular plants, liverworts and mosses, including 18 native species of trees and bushes (Tumiłowicz et al. 2007).

The establishment of the Arboretum and introduction of a collection of species of trees and bushes of foreign origin required substantial transformations of the forest stands. They consisted in cutting down 5-10-are patches, as well as in complete or partial removal of trees and bushes of the lower layer. Saved were only the most valuable fragments of the forest stand. On the area of the Arboretum, the forest stand is subject to systematic redevelopment correspondingly to the introduction of new tree species (Tumiłowicz et al. 2007).

The Arboretum in Kudypy works on the assumption that it preserves the character of a cultural forest park with three principal sections – dendrological collections, natural fragments of oak-linden-hornbeam forest (with the area of 0.33 ha), and flora of the lowland Poland. Contemporarily, it includes ca. 1000 taxa of trees and bushes and ca. 400 species of herbaceous plants (Kuszewska and Szumarski 2006). It has also a rich infrastructure of roofs, benches and small bridges (including a long pier leading through boggy areas), as well as an administrative building.

MATERIAL AND METHODS

Data presented in this manuscript were collected in 2006-2010, however the filed studies were especially intensified in 2006-2007. In order to identify the species resources of lichen biota of the object, the itinerary method was used. The method was applied on the entire area of the Arboretum. Species whose identification was possible in the field study were recorded without collecting herbarial documentation. In the case of the other taxa, the collection of specimens was limited to the indispensable minimum that enabled conducting in-depth analyses at the laboratory. During identification of the collected material, especially in the case of sterile crustose lichens, results of the morphological and anatomical analyses and these of standard spot tests were completed with results of chromatographic analyses (TLC) that enabled differentiating secondary metabolites of lichenized fungi (Orange et al. 2001).

The collected herbarial material was deposited in a lichen herbarium of the Department of Mycology, University of Warmia and Mazury in Olsztyn (OLTC). Species names were adopted after Fałtynowicz (2003), except for the following taxa: *Bacidia hemipolia* f. *pallida* (Czarnota and Coppins 2007), *Bacidina sulphurella*, *Biatora globulosa*, *Lecanora semipallida*, *Melanohalea exasperatula*, *Myriospora hepii*, *Opegrapha niveoatra*, *Porina aenea*, *Rinodina degeliana* (Smith et al. 2009), *Coenogonium pineti* (Kauff and Büdel 2005), *Melanelixia glabratula* (Arup and Sandler Berlin 2011), *Ochrolechia bahusiensis* (Kukwa 2009), *Verrucaria* s.l. (Krzewicka 2012), and *Violella fucata* (Spribille et al. 2011). Categories of lichen threat category were provided after Cieśliński et al. (2006).

RESULTS

In total, 109 lichen species were recorded on the area of the Arboretum (Table 1). The most diversified ecological group were epiphytes – 83 species in total. Amongst these, the highest number was noted on the bark of oak – 56 taxa, followed by hornbeam – 29, maple – 22, lime and alder – 16 each, spruce – 11, pine – 10, ash – 6 as well as birch, rowan tree and hazel – 5 each. All these data refer to native species, because no lichens were noted on the introduced species of trees and bushes owing to their young age. A significantly less diversified group, counting 23 taxa, were epixylites. Out of them, 20 species were recorded on natural substrata, whereas eight on wooden constructions of anthropogenic origin. Epixylic lichens are – on the area of the Arboretum – a little specific ecological group. Only six taxa were recorded exclusively on wood, the others were growing also on other substrata. In addition, on the investigated area there were discriminated 20 epilithic species, of which 11 were noted on carbonate rocks, whereas the other on quartzite boulders. Terricolous lichens were represented by as little as two hemerophilous species of the genus *Peltigera*: *P. didactyla* and *P. rufescens*.

On the area of the Arboretum, a total of 32 species of lichens were identified that are threatened with extinction in Poland (29% of lichen biota of the Arboretum). The attached list of identified taxa (Table 1) contains 17 species protected in Poland, including 16 species under strict and one species under partial protection. In addition, three species of lichens were recorded which – according to the binding Regulation of the Minister of Environment of the 9 July 2004 on protected wild species of fungi – require establishing protection zones of sanctuary or locality within a 50-m radius – *Usnea filipendula*, *U. hirta*, and *U. subfloridana*.

DISCUSSION

The lichen biota preserved on the area of the Arboretum in Kudypy is rich and diversified. The number of taxa noted herein is comparable with the number of species known from diversified and well preserved forest communities in the Olsztyn Lake District, even these protected in nature reserves (Kubiak 2011 b). The lichen biota of the Arboretum includes a large group of lichens typical of old forests with a natural character. Some of them were granted the status of indicators of lowland old-growth forests in Poland (Czyżewska and Cieśliński 2003). This group includes: *Calicium viride*, *Chaenotheca chlorella*, *Chrysothrix candelaris*, *Fellhanera gyrophorica*, *Micarea elachista*, *Opegrapha viridis*, and *Pertusaria coronata*. Furthermore, a number of species were noted that were typical of regenerating managed forest (cf. Cieśliński 2003) – *Acrocordia gemmata*, *Arthonia mediella*, *A. spadicea*, *Bacidia subincompta*, *Calicium salicinum*, *Chaenotheca chrysocephala*, *Ch. furfuracea*, *Ch. stemonea*, *Ch. trichialis*, *Ch. xyloxena*, *Graphis scripta*, *Lecanora thysanophora*, *Ochrolechia bahusiensis*, *Opegrapha niveoatra*, *Pertusaria leioplaca*, *Usnea filipendula*, and *U. subfloridana*. In turn, lichens characterising well-preserved, shady and dump forests were represented by *Bacidia hemipolia* f. *pallida* (Czarnota and Coppins 2007) and *Biatora epixanthoides* (Kukwa and Szymczyk 2006). The vast majority of the above-mentioned species (19) was noted on the bark

Table 1. Lichens of the Warmia and Mazury Forest Arboretum in Kudypy

Species	Substrates	Species protection and category of threat
1	2	3
Acrocordia gemmata (Ach.) A. Massal.	*Quercus*	VU
Anisomerydium polypori (M.B. Ellis & Everh.) M.E. Barr	*Acer*, *Carpinus*, *Ulmus*	
Arthonia mediella Nyl.	*Quercus*	VU
A. spadicea Leight.	*Quercus*	
Aspicilia moenium (Vain.) G. Thor & Timdal	calcareous stone	
Bacidia hemipolia f. *pallida* Czarnota & Coppins	*Quercus*	
B. subincompta (Nyl.) Arnold	*Quercus*	EN
Bacidina chloroticula (Nyl.) Vězda & Poelt in Vězda	stone	
B. egenula (Nyl.) Vězda	calcareous stone	CR
B. sulphurella (Samp.) M. Hauck & V. Wirth	*Acer*, *Quercus*, *Tilia*, *Ulmus*, lignum N	
Bagliettoa baldensis (A. Massal.) Vězda	calcareous stone	
Biatora efflorescens (Held.) Erichsen	*Acer*, *Alnus*, *Carpinus*, *Quercus*, *Tilia*	VU
B. epixanthoides (Nyl.) Diederich	*Ulmus*	
B. globulosa (Flörke) Fr.	*Acer*, *Quercus*	VU
Buellia griseovirens (Turner & Borrer ex Sm.) Almb.	*Acer*, *Alnus*, *Carpinus*, *Fraxinus*, *Quercus*	
Calicium parvum Tibell	*Pinus*	
C. salicinum Pers.	*Quercus*	VU
C. viride Pers.	*Carpinus*, *Quercus*	VU
Caloplaca flavocitrina (Nyl.) A.E. Wade	calcareous stone	
Cetraria chlorophylla (Willd.) Vain.	*Quercus*	SP, VU
Chenotheca chlorella (Ach.) Müll. Arg.	*Carpinus*	CR
Ch. chrysocephala (Ach.) Th. Fr.	*Alnus*, *Carpinus*, *Picea*, *Quercus*	
Ch. ferruginea (Turner ex Sm.) Mig.	*Picea*, *Pinus*	
Ch. furfuracea (L.) Tibell	*Quercus*	NT
Ch. stemonea (Ach.) Müll. Arg.	*Quercus*	EN
Ch. trichialis (Ach.) Th. Fr.	*Quercus*, *Picea*	NT
Ch. xyloxena Nádv.	*Quercus*, lignum N	VU
Chrysothrix candelaris (L.) J.R. Laundon	*Quercus*	SP, CR
Cladonia cenotea (Ach.) Schaer.	lignum N	
C. chlorophaea (Flörke ex Sommerf.) Spreng.	*Carpinus*, *Quercus*	
C. coniocraea auct.	*Alnus*, *Betula*, *Picea*, *Quercus*, lignum N	
C. digitata (L.) Hoffm.	*Pinus*, lignum N	
C. fimbriata (L.) Fr.	*Acer*, *Betula*, *Quercus*	
C. macilenta Hoffm.	lignum N	
C. ochrochlora Flörke	*Tilia*, lignum N	
Coenogonium pineti (Ach.) Lücking & Lumbsch	*Acer*, *Alnus*, *Picea*, *Pinus*, *Quercus*, *Tilia*	
Evernia prunastri (L.) Ach.	*Quercus*, *Tilia*, lignum A	PP, NT

Table 1 – cont.

1	2	3
Fellhanera gyrophorica Sérus., Coppins, Diederich & Scheid.	*Acer*	LC
F. subtilis (Vězda) Diederich & Sérus. in Sérus.	*Picea*	
Fuscidea arboricola Coppins & Tønsberg in Tønsberg	*Carpinus*, *Sorbus*	
Graphis scripta (L.) Ach.	*Carpinus*	NT
Hypocenomyce scalaris (Ach.) Choisy	*Alnus*, *Picea*, *Pinus*, *Quercus*, lignum N	
Hypogymnia physodes (L.) Nyl.	*Alnus*,*Carpinus*, *Fraxinus*, *Picea*, *Pinus*, *Quercus*, *Sorbus*, *Tilia*, lignum N-A, stone	
H. tubulosa (Schaer.) Hav.	*Quercus*, *Tilia*, lignum N	SP, NT
Lecania cytrella (Ach.) Th. Fr.	lignum A	
L. naegelii (Hepp) Diederich & P. Boom	*Quercus*, stone	
Lecanora argentata (Ach.) Malme	*Acer*, *Carpinus*	
L. carpinea (L.) Vain.	*Acer*	
L. conizaeoides Nyl. in Cromb.	*Alnus*, *Quercus*	
L. dispersa (Pers.) Sommerf.	calcareous stone	
L. expallens Ach.	*Acer*, *Alnus*, *Carpinus*, *Corylus*, *Fraxinus*, *Quercus*, *Tilia*	
L. persimilis (Th. Fr.) Nyl.	*Quercus*	DD
L. pulicaris (Pers.) Ach.	*Corylus*	
L. semipallida H. Magn.	calcareous stone	
L. thysanophora R.C. Harris	*Quercus*	
Lecidea nylanderii (Anzi) Th. Fe.	*Alnus*	
Lecidella elaeochroma (Ach.) Choisy	*Acer*	
L. stigmatea (Ach.) Hertel & Leuckert	calcareous stone	
Lepraria eburnea J.R. Laundon	*Quercus*	
L. elobata Tønsberg	*Betula*, *Carpinus*, *Fraxinus*, *Sorbus*, *Tilia*, lignum N-A	
L. incana (L.) Ach.	*Acer*, *Alnus*, *Betula*, *Carpinus*, *Fraxinus*, *Picea*, *Pinus*, *Quercus*, *Sorbus*, *Tilia*, lignum N-A	
L. jackii Tønsberg	*Betula*, *Pinus*, *Quercus*, lignum N	
L. lobificans Nyl.	*Acer*, *Alnus*, *Carpinus*, *Corylus*, *Quercus*, *Ulmus*	
Melanohalea exasperatula (De Not.) O. Blanco et al.	*Quercus*	SP
Melanelixia glabratula (Lamy) Sandler & Arup	*Acer*, *Carpinus*, *Corylus*, *Quercus*, *Tilia*	SP
Micarea elachista (Körb.) Coppins & R. Sant. in Coppins	*Pinus*	EN
M. misella (Nyl.) Hedl.	lignum N	
M. prasina s. lat.	*Acer*, *Alnus*, *Quercus*, lignum N, charcoal	
Myriospora heppii (Nägeli ex Körb.) Hue	calcareous stone	
Ochrolechia bahusiensis H. Magn.	*Picea*, *Tilia*	VU
O. microstictoides Räsänen	*Carpinus*	
Opegrapha niveoatra (Borrer) J.R. Laundon	*Quercus*	VU
O. viridis (Pers. ex Ach.) Behlen & Desberger	*Alnus*, *Carpinus*, *Quercus*	VU

Table 1 – cont.

1	2	3
Parmelia saxatilis (L.) Ach.	*Carpinus*	SP
P. sulcata Taylor	*Acer*, *Carpinus*, *Quercus*, *Tilia*, lignum N-A, stone	
Parmeliopsis ambiqua (Wulfen in Jacq.) Nyl.	*Alnus*, *Picea*, *Pinus*, *Quercus*	SP
Peltigera didactyla (With.) J.R. Laundon	lignum N, soil	SP
P. rufescens (Weiss) Humb.	soil	SP
Pertusaria amara (Ach.) Nyl.	*Carpinus*, *Quercus*	
P. coccodes (Ach.) Nyl.	*Acer*, *Carpinus*, *Quercus*	NT
P. coronata (Ach.) Th. Fr.	*Quercus*	VU
P. leioplaca DC. in Lam. & DC.	*Carpinus*	NT
Phlyctis argena (Ach.) Flot.	*Acer*, *Carpinus*, *Quercus*	
Physcia stellaris (L.) Nyl.	*Quercus*	
Ph. tenella (Scop.) DC. in Lam. & DC.	stone	
Placynthiella icmalea (Ach.) Coppins & P. James	*Tilia*, lignum N, charcoal	
Platismatia glauca (L.) W.L. Club. & C.F. Club.	*Alnus*, *Carpinus*, *Quercus*, *Tilia*, lignum N	SP
Porina aenea (Wallr.) Zahlbr.	*Carpinus*, *Ulmus*	
Porpidia soredizodes (Lany ex Nyl.) J.R. Laundon	stone	
Protoparmeliopsis muralis (Schreb.) Choisy	stone	
Pseudevernia furfuracea (L.) Zopf.	*Carpinus*, *Quercus*	SP
Ramalina farinacea (L.) Ach.	*Acer*	SP, VU
R. pollinaria (Westr.) Ach.	*Quercus*	SP, VU
Rinodina degeliana Coppins	*Acer*, *Carpinus*, *Corylus*	
Ropalospora viridis (Tønsberg) Tønsberg	*Acer*, *Carpinus*	
Sarcogyne regularis Körb.	calcareous stone	
Scoliciosporum chlorococcum (Graeve ex Stenh.) Vězda	*Quercus*	
S. sarothamni (Vain.) Vězda	*Quercus*	
S. umbrinum (Ach.) Arnold	stone	
Trapeliopsis flexuosa (Fr.) Coppins & P. James	lignum N-A, charcoal	
T. granulosa (Hoffm.) Lumbsch	lignum N	
Usnea filipendula Strit.	*Quercus*	SP, VU
U. hirta (L.) Weber ex F.H. Wigg.	lignum A	SP, VU
U. subfloridana Strit.	*Quercus*, *Tilia*	SP, EN
Verrucaria cataleptoides (Nyl.) Nyl.	calcareous stone	
V. muralis Ach.	calcareous stone	
Violella fucata (Stirt.) T. Sprib.	*Fraxinus*, *Quercus*, *Sorbus*	
Xanthoria parietina (L.) Th. Fr.	stone	
X. polycarpa (Hoffm.) Rieber	*Quercus*	

Abbreviations: lignum N – wood of natural origin (stumps, fallen branches), lignum A – antropogenic wooden constructions; EN – endangered species, VU – vulnerable species, NT – near threatened species, LC – least concern species; SP – strictly protected species, PP – partially protected species.

of old oaks. This confirms a well-known and very significant role of this phorophyte in modelling the diversity of local lichen biota in forests (Rutkowski 1995, Cieśliński et al. 1996, Cieśliński 2003). On the other phorophytes, the number of the discussed species was considerably lower: *Carpinus* – 6, *Picea* – 3, *Alnus* and *Tilia* – 2 each, *Acer*, *Pinus* and *Ulmus* – 1 each.

The lichen biota of the Arboretum is, in majority, constituted by species being consistent with the habitat – epiphytes and epixylites, both typical of the local forest communities. Apart from them, such a status may be granted to a few epilithic species, in Poland usually noted on silicate boulders inside forest communities – *Bacidina chloroticula*, *Porpidia soredizodes*, or at more exposed sites, on forest border – *Myriospora hepii*, *Scoliciosporum umbrinum* (Cieśliński 2003, Fałtynowicz 2003).

On the area of the Arboretum, many new habitats and substrata were established providing conditions for the development of anthropophytes – namely species not recorded herein before establishment of the Arboretum. A biotope of this type, having a relatively large contribution in the modeling of the contemporary species diversity of lichens in the Arboretum, is a rock garden. Calciferous rocks used for its formation are an element that is naturally not occurring in the landscape of the Warmia and Mazury region. The presence of this substrate affords the possibility for the development to a group of calciphilous lichens, usually colonizing anthropogenic substrata including e.g. concrete and masonry mortar. Out of the lichens noted in the Arboretum on calciferous boulders, worthy of notice is *Bacidina egenula*. It is a lichen very rare in Poland, known mainly from the south of the country (Fałtynowicz 2003). Its locality in the Arboretum is the second locality known so far in the Polish lowland (Kukwa et al. 2008). Another interesting species is *Bagliettoa baldensis* – a lichen also known mainly from the south of the country (Fałtynowicz 2003, Krzewicka 2012). Its location in the north-eastern Poland has so far been recorded only by Sparrius (2003) from Białowieża.

Interesting lichenological discoveries on the areas of botanical gardens and arboretums are not incidental (Ladd 2004, Kubiak and Szczepkowski 2006, Douglas et al. 2009). At a relatively small (5.3 ha) but very diversified area of a new Botanical Garden in Zurich, Aptroot and Honegger (2006) noted 149 species, which constituted almost 10% of lichen biota of Switzerland (Clerc 2004). It is worth emphasising that their study revealed also lichen species new to this country.

Complete documentation of species resources of lichen biota of such objects as botanical gardens and arboretums, apart from the principal cognitive purposes, forms grounds for successive monitoring studies (Kiszka 2002 a). They may address both lichen biota spontaneously colonizing different types of substrata, as well as specimens artificially introduced (transplanted) by man, which is facilitated by partly closed character of these objects (Aptroot and Honegger 2006). Botanical gardens and arboretums constitute an interesting area for observations and investigations on the response of particular lichen species to transformations of the natural environment (Härkönen and Vänskä 2004).

The Arboretum in Kudypy seems to be a fine example in this respect owing to the preservation of natural communities with diversified lichen biota. In the future, subsequent, new to the Arboretum species of lichens shall be expected that will be bound both with various types of rocky substratum and with infrastructure of the object, as well as epiphytes developing on newly-planted, introduced species of trees and bushes. Such studies will, additionally, enable evaluating responses of the recorded stenotopic forest lichens to changes in the natural environment triggered by the establishment of the Arboretum.

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