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The influence of forest management on lichens in the Kozienicka Forest (Central Poland)

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The changes in the lichen flora in the Zagożdżon reserve in the Kozienicka Forest (Central Poland) over the period of 30 years (1969-1971 and 1999-2001) are discussed in the article. The problem is examined in the context of the modifications in the structure and species composition of the forest communities in the reserve brought about by forest management procedures.

Key words: forest management, dynamics of lichens (lichenized fungi), Zagożdżon reserve, Kozienicka Forest, Central Poland

INTRODUCTION

Industrial emissions, forest management, changes in humidity relations, rock exploitation, urbanization and collecting economy are the main human-induced factors that affect the flora of lichens in many districts and regions. Changes resulting from atmospheric pollution have been studied most extensively, especially in the case of local or regional flora. Little attention, however, has been paid to the dynamics of lichens brought about by various forms of forest management, such as cutting and cultivation treatment or the introduction of the shrub layer in dry coniferous forests. The influence of mineral fertilisation of forest communities, chiefly dry pine forests *Cladonio-Pinetum*, on qualitative and quantitative changes in the ground cover in which lichens occur has been examined more frequently (cf. Fałtynowicz 1982, 1986). Forest management procedures often trigger off profound changes in the phytoclimate of forest communities, affecting especially light and humidity conditions to which lichens are particularly sensitive. The Zagożdżon reserve in the Kozienicka Forest turned out to be an excellent area of study on the dynamics of lichens in the context of such activities.

The earliest data on the lichens in the Kozienicka Forest date back to the end of the 19th century. Berdau (1876) lists a number of common species from the "Kozienicka forests." Proper lichenological studies were launched almost a century later (1969-1971) in the Zagożdżon reserve (Cieśliński 1977, 1978). It is the part of the Kozienicka Forest the lichenological profile of which has been studied the most. The first preliminary list of lichens that comprises the entire Kozienicka Forest was published by Cieśliński (1997).

The following objectives were particularly emphasised in the study:

- to determine the contemporary level of richness of lichens in the Zagożdżon reserve,
- to determine the dynamics of the flora of lichens over the last 30 years in the context of the changes in the floristic composition and the structure of the tree stand in the reserve brought about by sanitation and forest tree breeding treatment,
- to determine the degree of naturalness of the forest communities on the basis of the contemporary condition of the flora of lichens.

Furthermore, the analysis documents the role of old trees in the preservation of the species diversity of lichens.

STUDY AREA

The Kozienicka Forest comprises a considerable forest area in the fork of the Vistula river and the Radomka river in the lowland in central Poland. The forest has been broken up and greatly deformed as a result of long-lasting human economy. Those sections of the Forest that are preserved the best form a protected reserve, of which Zagożdżon is the oldest. Forest communities in the reserve had been particularly cared for by foresters prior to its formal recognition as a protected area. No forest management procedures had been carried there out until it was established. The Forest, on the other hand, has been protected as a landscape park since 1983. The Forest Promotion Complex "Kozienicka Forest Communities" was set up in 1994.

The Zagożdżon reserve was established in 1962 to protect forest communities in which the fir approached its northern occurrence limit. It has the status of a reserve with partial protection, and its area covers 65.67 ha. When the reserve was established, its forest communities were characterised by formidable tree stands with the prevalent fir, over 100 years old. The trees were 40 m tall, and their breast height diameter exceeded 100 cm (Krawczyk and Zielony 1997). Other trees in the tree stand were: *Pinus sylvestris, Quercus robur, Q. sessilis, Carpinus betulus*, and less common: *Acer pseudoplatanus, A. platanoides, Ulmus scabra, Tilia cordata, Populus tremula, Betula pendula.* The forest communities in the reserve were considered to be preserved the best in the entire Kozienicka Forest. They were formed by the most common oak-linden-hornbeam associations *Tilio-Carpinetum corydaletosum* and *T.-C. abietosum*, with a slight area participation of *Querco-Abietetum, Leucobryo-Pinetum typicum submontane* and *L.-P. molinietosum submontane* (Bróż 1973).

A series of events highly detrimental for the forest communities in the reserve started in 1972. A snowbreak caused considerable damage in spring. Consequently, the gradation of insect pests, principally of *Choristoneura murinana* Hb., intensified.

As a result of cutting, almost all fir trees were removed from the reserve. Only 30% of the old tree stand remained, chiefly pine and oak, as well as single individuals of other tree species. The volume of wood removed from the reserve between 1974 and 1988 was 28 200 m^3 (Krawczyk and Zielony 1997, Fig. 1). The changes in the structure and species composition of the tree stand brought about a mass occurrence of the hornbeam. It was removed as part of the sanitation treatment, especially in those areas of the forest where it developed excessively, and fir and oak were planted (Krawczyk and Zielony 1997). Intense dynamic changes are still taking place in the forest communities. They are at different stages of regeneration and the undergrowth of hornbeam, fir and maple occurs in them, which only makes phytosociological analyses more difficult.

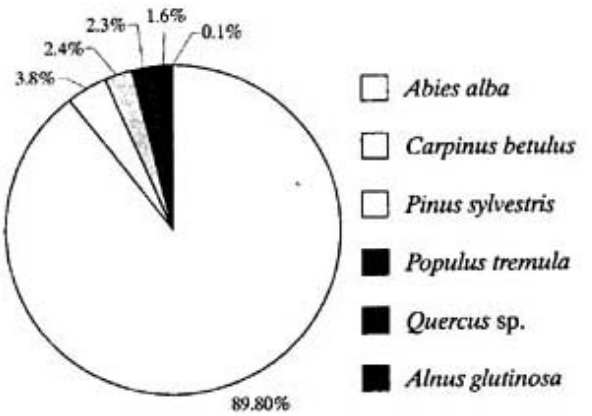

Fig. 1. Volume (in percent) of trees removed from the reserve between 1974-1988 as part of sanitation cutting (Krawczyk and Zielony 1997).

A power plant was constructed and launched on the eastern border of the Forest in the 1970s. Kozienice, the largest power plant in Poland, with the capacity of 2600 MW, fuelled with hard coal, emits great quantities of harmful gases (SO_2, NO_x) and dusts (Falencka-Jabłońska 1997). The Zagożdżon reserve is situated 13-14 km SSW of the power plant. A minimal participation of N winds (Fig. 2) is the reason why the inflow of pollution emitted by the power plant to the part of the Kozienicka Forest where the reserve is located is slight (Falencka-Jabłońska 1997).

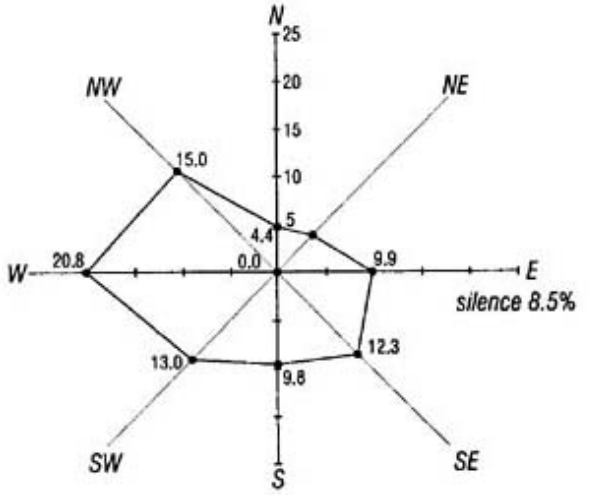

Fig. 2. Wind rose for the Kozienicka Forest (Falencka-Jabłońska 1997).

MATERIAL AND METHODS

The starting point for this study were the results of the lichenological studies conducted in the Zagożdżon reserve between 1969 and 1971. They were repeated 30 years later (1999-2001) following the cutting and forest breeding procedures between 1974-1988 connected with the fir dieback as a result of the gradations of *Choristoneura murinana* Hb. The herbarial material from 1969-1971 was reviewed to adjust it to contemporary taxonomic principles and lichen nomenclature (Vězda and Li-

ška 1999; Scholz 2000). A verified list of species occurring in the reserve is presented is Table 2. Following the revision, the species cited in Cieśliński (1978) as *Bacidia friesiana* (Hepp) Anzi is *Lecania naegelii* (Hepp) Diederich et P. Boom [=*Bacidia naegelii* (Hepp) Zahlbr.], and *Peltigera horizontalis* (Huds.) Baumg. is *P. praetextata* (Flörke ex Sommerf.) Zopf.

The species recorded in the reserve are presented in Table 2 in three groups:
- persistent in the reserve,
- recorded in 1999-2001, new in the reserve,
- occurred in 1969-1971, not confirmed in the latest study.

The following abbreviations of the names of substrate types were used in the Table: Bark of trees: Ab - *Abies alba*, Ac - *Acer pseudoplatanus*, Al - *Alnus glutinosa*, Ap - *Acer platanoides*, B - *Betula pendula*, C - *Carpinus betulus*, P - *Pinus sylvestris*, Pt - *Populus tremula*, Q - *Quercus* sp., Ti - *Tilia cordata*, L - *Lignum* (wood), T – *Terra* (soil). The number and abundance of individual species was determined: +! - very rare species, vestigial populations, + - rare species, single localities, ++ - frequent, +++ - common.

A critical verification of threatened species followed the Red List categories (IUCN 2001, Ginsburg 2001): RE – Regionally Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient.

Nomenclature of lichens species follows Vězda and Liška (1999), Scholz (2000).

The herbarial material of lichens, both old and newly collected, from the Zagożdżon reserve, is deposited in the herbarium at the Department of Botany of the Świętokrzyska Academy (KTC).

RESULTS

The list of lichens in the Zagożdżon reserve comprises 136 species. Epiphytic and epixylic species definitely prevail. The participation of terricolous species is slight. No epilithic species were recorded. The flora of lichens in the reserve has profoundly changed over the 30 years studied (Tab. 1).

Table 1
Dynamics of the flora of lichens in the Zagożdżon reserve

Groups of species	Number of species
1. Species persistent in the reserve	75
2. Species recorded between 1999-2001, new in the reserve	35
Total number of species occurring currently	110
3. Species not confirmed between 1999-2001	26
Total number of species recorded in the reserve	136

Species persistent in the reserve

The lichens recorded for the first time between 1969-1971 still constitute the major body of the present flora of lichens in the reserve. Apart from widespread species, such as, for instance, *Hypogymnia physodes, Hypocenomyce scalaris, Parmelia sulcata, Cladonia coniocraea, Phlyctis argena*, there are interesting typical forest species which are rare and sensitive to anthropopressure, endangered in Poland or even extinct in some regions. They persist in the reserve despite the enormity of modifications that have taken place in the structure of the forest communities. Their list is extensive, with species such as: *Arthonia byssacea, Arthonia spadicea, Bacidia subincompta, Bryoria fuscescens, Cetraria chlorophylla, Cetrelia cetrarioides, Chrysothrix candelaris, Chaenotheca trichialis, Flavoparmelia caperata, Graphis scripta, Hypogymnia tubulosa, Lecania globulosa, Menegazzia terebrata, Ochrolechia androgyna, Opegrapha vermicellifera, O. vulgata* var. *subsiderella, Pertusaria flavida, Pyrenula nitida, Usnea filipendula, U. subfloridana* and others (Tab. 2). The species are mostly stenotopic. Their persistence in the reserve shows that ecological niches that meet their life requirements can still be found in the forest environment. Except *Graphis scripta, Opegrapha vermicellifera*, such species are very rare now, recorded on individual trees, and the majority of them produce vestigial thalli.

The lichens whose number has increased are very few. As the present study shows, common species that are indicative of expansive tendencies, such as *Lecanora conizaeoides, Scoliciosporum chlorococcum*, belong to this group. The abundance and number of other lichens, such as *Chaenotheca ferruginea, Dimerella pineti, Cladonia chlorophaea, Buellia griseovirens*, have also increased, although to a significantly smaller degree.

Species new in the flora of lichens in the reserve

The list of species recorded in the reserve for the first time between 1999-2001 is extensive. The presence of some of them comes as a result of the changes that have taken place in the structure and the species composition of the forest communities. Typical synanthropic species (heliophilous, nitrophilous, koniophilous species) that would usually grow on trees outside forest communities (apophytes) have appeared. They were recorded on branches of uprooted trees (oak), on aspens or other exposed ancient trees with decaying outer bark. These were: *Candelariella xanthostigma, Physcia tenella, Ph. adscendens, Physconia enteroxantha, Ph. detersa, Phaeophyscia orbicularis, Xanthoria parietina.* Apart from *Physconia detersa,* other lichens are common and frequent in the Kozienicka Forest. It was found in trace amounts, on individual trees in the reserve.

New lichens are species that are expansive and increase their range, are often encountered in timber forests, and their number has been growing, for instance *Lecanora expallens, Porina aenea, Lecanora saligna,* or *Peltigera rufescens* in the group of terricolous species (ditch escarpment).

Species new for science, described only in the last few years or differentiated in Poland only recently, are another, fairly numerous group. They are, for instance, *Ce-*

trelia olivetorum, Hypocenomyce anthracophila, Micarea hedlundii, M. misella, Mycoblastus fucatus, Ochrolechia microstictoides, Placynthiella icmalea.

Epiphytes and epixyles deserve special attention. Recorded in the latest study, they usually occur in well preserved, natural forest communities. These lichens have been becoming less frequent in Poland, and have altogether disappeared in some regions. They may have been overlooked in the field studies in 1969-1971 on account of their rare occurrence and the small size of the thalli they produce. It is possible that the phytoclimatic changes in the reserve have been favourable for the expansion of these species, in particular lichens related to dead wood. The amount of this substrate has increased, mainly as stumps and barkless tree trunks. The following species have been included in this group: *Arthonia arthonioides, A. mediella, A. radiata, Arthothelium ruanum, Bacidia rubella, Catillaria nigroclavata, Chaenotheca chlorella, Ch. xyloxena, Micarea melaena, Punctelia subrudecta, Strangospora ochrophora.* Their presence in the reserve contributes to its natural character and enhances its value.

Some other species that occur in the reserve now were most probably overlooked in the past or have appeared in the recent years. These lichens are fairly frequent in this district and in Poland. These are: *Chaenotheca chrysocephala, Lecanora umbrina, Micarea denigrata, Trapeliopsis flexuosa*, and lichens occurring less frequently: *Mycobilimbia sabuletorum* and *Lecanora leptyrodes.*

Lichens not confirmed in the present study

The flora of lichens in the reserve has suffered considerable damage over the 30 years studied. The occurrence of as many as 26 species has not been confirmed: every fifth species does not grow in the reserve. The 19 species that are most probably extinct in the reserve are: *Acrocordia gemmata, Arthonia dispersa, Bryoria implexa, B. subcana, Cetraria sepincola, Cladonia botrytes, C. parasitica, Cliostomum griffithii, Evernia mesomorpha, Haematomma ochroleucum* ssp. *ochroleucum, Lobaria pulmonaria, Opegrapha rufescens, O. viridis, Peltigera canina, P. praetextata, Pertusaria coronata, P. pertusa, Pyrenula nitidella, Usnea laricina.* These lichens are characterised by a high sensitivity to all types of habitat changes. They are on the Polish list of threatened lichens. The majority of them produce big thalli, and, as a half of them were fruticose and foliose lichens, could not be overlooked in the course of the field studies. These lichens were very rare in 1969-1971, and were collected in individual localities.

Succession changes of vegetation have most probably eliminated the following terricolous species: *Cladonia subcervicornis* ssp. *verticillata, Cl. gracilis, Cl. phyllophora, Cl. subulata.* They were recorded on a local land elevation near the S border of the reserve in the past. The lichens listed still grow on a small dune overgrown with pine plantings some 0.5 km S of the reserve. Some terricolous species may appear ephemerally in exposed places (ditches, roadsides) whose plant cover has been damaged, and they recede as the density of the plant cover increases in the process of succession.

Two other species, *Lecanora symmicta* and *L. varia*, were not recorded in the present study. They most probably grow in the reserve, and further explorations are necessary.

Table 2
List of species of lichens in the Zagożdżon reserve

Species	Substrate		Abundance and frequency		Threat	
	1969-1971	1999-2001	1969--1971	1999--2001	in the Kozienicka Forest Cieśliński (2003)	in Poland Cieśliński et al. (2003)
1	2	3	4	5	6	7
Species persistent in the reserve						
Amandinea punctata (Hoffm.) Coppins et Scheid.	Q	Ac,Q,L	+	+		
Arthonia byssacea (Weigel) Almq.	Q	Q	+!	+!	CR	EN
A. spadicea Leight.	C	Q	+	+	NT	
Bacidia subincompta (Nyl.) Arnold	C	Ap	+	+	EN	EN
Biatora ocelliformis (Nyl.) Arnold	C	Ac,C	+	+	DD	VU
Bryoria fuscescens (Gyeln.) Brodo et D.Hawksw.	Ab,B,P,Q	B	+++	+!	CR	VU
Buellia griseovirens (Turner et Borrer ex Sm.) Almb.	Ac,Ap	Ac,Ap,C,L,Pt,Q	+	++		
Calicium adspersum Pers.	Q	Q	+!	+!	CR	EN
C. salicinum Pers.	Ap,L,Q,Ti	Ap,L,Q	++	++	VU	VU
Cetraria chlorophylla (Willd.) Vain.	Ab,B,P	Ab,L	+++	+!	EN	VU
Cetrelia cetrarioides (Delise ex Duby) W.L.Culb. et C.F.Culb.	Al,C,Q	C	++	+!	CR	EN
Chaenotheca ferruginea (Turner et Borrer) Mig.	Ab,P	Ab,C,L,Q	+!	++	LC	
Ch. trichialis (Ach.) Th.Fr.	Q,Ti	Ac,L,Q	+	+	VU	NT
Chrysothrix candelaris (L.)J.R.Laundon	Ab,Q	Q,Ti	++	+	CR	CR
Cladonia cenotea (Ach.)Schaer.	L,P	L,Q	+	+		
Cl. chlorophaea (Flörke ex Sommerf.) Spreng.	T	B,L,Q	+	++		
Cl. coniocraea auct.	Ab,Al,B,P	Ab,Al,B,C,L,P,Q	++	+++		
Cl. comuta (L.) Hoffm.	Q,T	L	+	+		
Cl. deformis (L.) Hoffm.	P	L	+	+		
Cl. digitata (L.) Hoffm.	Ab,P	Ab,B,L,P,Q,T	+++	+++		
Cl. fimbriata (L.) Fr.	Ab,B,T	L,Q,T	+	+		
Cl. furcata (Huds.) Schrad.	T	T	+	+		
Cl. glauca Flörke	T	L	+	+		
Cl. macilenta Hoffm.	Ab,L,T	L,Q	++	++		
Cl. ochrochlora Flörke	Ab,B,C,P	Al,B,L	++	++		
Dimerella pineti (Ach.) Vezda	Ab,C	Ac,C,L	+	++		
Evernia prunastri (L.) Ach.	Ab,C,Q	Ac,Q, Ti	+++	+	NT	NT
Flavoparmelia caperata (L.) Hale	Ab,Al,C,Q	Q	++	+	CR	EN
Graphis scripta (L.) Ach.	Ab,Al,C,Pt	Ac,Al,Ap,C,Q	+++	++	VU	NT
Hypocenomyce scalaris (Ach. ex Lilj.) M. Choisy	Ab,B,P,Q	Ab,Ap,B,C, L,P,Q	+++	+++		
Hypogymnia physodes (L.) Nyl.	Ab,Ac,Ap,B, C,P,Q,Ti	Ab,Ac,Ap,B,C,L,P, Q,Ti	+++	+++		
H. tubulosa (Schaer.) Hav.	Ab,B,Q	Ab,Ac,B,Q	++	+	EN	NT
Imshaugia aleurites (Ach.) S.L.F.Mey	Ab,B,P	P	++	+!	NT	
Lecania globulosa (Flörke) P.Boom et Sérus.	Ac,C	Q	++	+	VU	VU
L. naegelii (Hepp) Diederich et P.Boom	C,Pt	Pt	+	+!	DD	
Lecanora allophana Nyl.	Ab,Pt	C,Pt,Q	+	++		
L. argentata (Ach.) Malme	C	Ac,Ap,C,Pt	+++	++	LC	
L. carpinea (L.) Vain.	C,Pt,Q	Ap,C,Q	++	+		
L. chlarotera Nyl.	Pt,Q	Pt	+	+	LC	
L. conizaeoides Nyl. ex Crombie	Ab	Ab,Ac,Ap,B,C,L,P, Q,Ti	+	+++		
L. pulicaris (Pers.) Ach.	Ab,B,C	Ac,Ap,C,P,Pt,Q,Ti	++	++		
Lecidella elaeochroma (Ach.)M.Choisy	C,Pt	Ac,C,Pt	+	+		
Lepraria lobificans Nyl.	Q,Ti	Ac,C,Q,Ti	+	++		
Melanelia glabratula (Lamy) Essl.	Ab,Al,B,C,Q	Ac,Al,Ap,C	+++	+	LC	
x/Melaspilea gibberulosa (Ach.)Zwackh	Ac,C	Ap	+	+	EN	
Menegazzia terebrata (Hoffm.) A. Massal.	C	Q	+	+!	CR	CR
Micarea prasina Fr.	B	L,Q	+	+		

Tab. 2 cont.

Ochrolechia androgyna (Hoffm.) Arnold	Ab	B,Q	+	+	EN	VU
O. subviridis (Hoëg) Erichsen	Ab	Ap,C	+	+	EN	VU
Opegrapha varia Pers. var. *varia*	Q	C,L,Q	+	+	VU	NT
O. vermicellifera (Kunze) J.R. Laundon	Ac,C,Q	Ac,C,Q,Ti	+	++	VU	EN
O. vulgata Ach. var. *subsiderella* Nyl.	Ab,C	C,Q	+	+	VU	VU
Parmelia saxatilis (L.)Ach.	B	C,Q	+	+	NT	
P. sulcata Taylor	Ab,Al,C,Q, Ti	Ac,Ap,C,Pt,Q,Ti	+++	++		
Parmeliopsis ambigua (Wulfen) Nyl.	Ab,B,P	Q	++	+!	NT	
Pertusaria albescens (Huds.) M.Choisy et Werner	C,Q	Q	+	+	NT	
P. amara (Ach.) Nyl.	Ab,Al,B,C, Pt,Q	Ac,Ap,Al,C,Pt,Q	+++	++	LC	
Pertusaria coccodes (Ach.) Nyl.	Ab,C,Q	Ap,C,Q	+++	+	VU	NT
P. flavida (DC.) J.R.Laundon	Q	Q	+	+	EN	EN
P. leioplaca DC.	C,Pt	C,Pt	+	+	VU	NT
Phlyctis argena (Spreng.) Flot.	Ab,Ac,Al.,C, Pt,Q,Ti	Ac,Al,Ap,C,Pt,Q,Ti	+++	+++		
Placynthiella oligotropha J.R. Laundon Coppins et P.James	T	T	+	+		
P. uliginosa (Schrad.) Coppins et P. James	T	L,Q,T	+	++		
Platismatia glauca (L.) W.L.Culb et C.F.Culb.	Ab,Ac,Ap,B, Q	Ac,B,L	++	+	NT	
Pseudevernia furfuracea (L.) Zopf.	Ab,B,P,Q	Ab,B,Q	+++	+	NT	
Pyrenula nitida (Wegel) Ach.	C	C	++	++	EN	U
Ramalina farinacea (L.) Ach.	Ab,C,Q	Ac,Ap,C,Q	++	+	EN	VU
R. pollinaria (Westr.) Ach.	Ab,C,Q	Ac,C,Q	++	+	VU	VU
Rinodina pyrina (Ach.) Arnold	Q	Q	+!	+!	NT	α
Scoliciosporum chlorococcum (Graewe ex Stenh.) Vězda Coppins et P.James	Ab,Al.,B,Q	Ab,Ac,Ap,B,C	++	+++		
Trapeliopsis granulosa (Hoffm.) Lumbsch	L	B,L,T,Ti	+	++		
Usnea filipendula Stirt.	Ab	B,Q	+	+	CR	VU
U. hirta (L.)Weber ex F.H.Wigg.	Ab,B,P,Q	B,Q	++	+!	EN	VU
U. subfloridana Stirt.	Ab,B,C,P,Q, B	B	++	+!	CR	EN
Vulpicida pinastri (Scop.) Mattson et M.J.Lai	Q	Q	+	+!	VU	NT
Species recorded in 1999-2001, new in the reserve						
Arthonia arthonioides (Ach.) A.L.Sm.		Q		+	CR	CR
A. mediella Nyl.		C,L,Q		+	VU	VU
A. radiata (Pers.) Ach.		C		+!	EN	
Arthothelium ruanum (A.Massal.) Körb.		Ac,C		+	VU	NT
Bacidia rubella (Hoffm.)A.Massal.		Ap		+	EN	VU
Candelariella xanthostigma (Ach.) Lettau		Ap		+!		
Catillaria nigroclavata (Nyl.) Schuler		Pt		+!	DD	
Cetrelia olivetorum (Nyl.) W.L.Culb. et C.F.Culb.		Q		+!	CR	EN
Chaenotheca chlorella (Ach.)Müll.Arg.		L		+!	CR	CR
Ch. chrysocephala (Turner ex Ach.) Th. Fr.		Q		+	LC	
Ch. xyloxena Nádv.		L		+	EN	VU
Hypocenomyce anthracophila (Nyl.) P.James et Gotth. Schneid.		P		+	DD	
Lecanora expallens Ach.		Ab,Ac,Ap,C,Q,Ti		++		
L. leptyrodes (Nyl.) Degel.		Pt		+	DD	
L. saligna (Schrad.) Zahlbr.		Ac,L,Q,Ti		+		
Lecanora umbrina (Ach.). A.Massal.		Pt		+		
Micarea denigrata (Fr.) Hedl.		L,P		+		
M. hedlundii Coppins		L		+	DD	VU
M. meluena (Nyl.) Hedl.		B,L		+	EN	NT
M. misella (Nyl.) Hedl.		L		+	DD	
Mycobilimbia sabuletorum (Schreb.) Hafellner		Ap		+	NT	
Mycoblastus fucatus (Stirt.) Zahlbr.		Ac,C,Q		++		
Ochrolechia microstictoides Räsänen		B		+	DD	
Peltigera rufescens (Weiss) Humb.		T		+		
Phaeophyscia orbicularis (Neck) Moberg		Q		+		

Tab. 2 cont.

Physcia adscendens (Fr.) H.Olivier		Ac,Pt		+		
Ph. tenella (Scop.) DC.		Ac,Q		+		
Physconia detersa (Nyl.) Poelt		Q		+	VU	VU
Ph. enteroxantha (Nyl.) Poelt		Q		+!	LC	
Placynthiella icmalea (Ach.) Coppins et P. James		L		+		
Porina aenea (Wallr.) Zahlbr.		Ap,C		+		
Punctelia subrudecta (Nyl.) Krog		C,Q		+!	CR	VU
Strangospora ochrophora (Nyl.) R. Anderson		Pt		+	EN	VU
Trapeliopsis flexuosa (Fr.) Coppins et P. James		L		+		
Xanthoria parietina (L.) Th. Fr.		Pt		+		
Species occurring in 1969-1971, not confirmed in the present study						
Acrocordia gemmata (Ach.) A.Massal.		Ab,Ac,C,Q		++	EN	VU
Arthonia dispersa (Schrad.) Nyl.		Ac		+!	RE	VU
Bryoria implexa (Hoffm.) Brodo et D. Hawksw.		P		+!	RE	CR
B. subcana (Nyl. ex Stizenb.) Brodo et D. Hawksw.		Ab,P		+	RE	CR
Cetraria sepincola (Ehrh.) Ach.		B		+	CR	EN
Cladonia botrytes (K.G.Hagen) Willd.		L		+!	CR	EN
Cl. cervicornis (Ach.) Flot. ssp. *verticillata* (Hoffm.) Ahti		T		+		
Cl. gracilis (L.) Willd.		T		+		
Cl. parasitica (Hoffm.) Hoffm.		Ab		+!	CR	EN
Cl. phyllophora Hoffm.		T		+		
Cl. subulata (L.) Weber ex F.H. Wigg.		T		+		
Cliostomum griffithii (Sm.) Coppins		C		+	RE	VU
Evernia mesomorpha Nyl.		Ab,P		+	RE	CR
Haematomma ochroleucum (Neck.) J.R. Laundon var. *ochroleucum*		C		+	DD	DD
Lecanora subrugosa Nyl.		Ab,C,Pt		+	VU	LC
L. symmicta (Ach.) Ach.		P		+		
L. varia (Hoffm.) Ach.		B		+		
Lobaria pulmonaria (L.) Hoffm.		C		+!	RE	EN
Opegrapha rufescens Pers.		Ab,C		+	CR	VU
O. viridis (Pers. ex Ach.) Behlen et Desberger		C		+	CR	VU
Peltigera canina (L.) Willd.		Al		+!	CR	VU
Peltigera praetextata (Flörke ex Sommerf.) Zopf		Q		+!	CR	VU
Pertusaria coronata (Ach.) Th. Fr.		Q		+!	RE	VU
P. pertusa (Weigel) Tuck.		C		+!	RE	VU
Pyrenula nitidella (Flörke ex Schaer.) Müll. Arg.		C		+!	RE	EN
Usnea laricina auct.		B,Q		+!	RE	EN

Explanations: x/ - lichenicolous fungi

DISCUSSION

The process of recession of some species and the expansion of some other is a phenomenon common in nature; it is, however, slow. It is intensified by human activities. Changes in the phytoclimate of the forest communities, connected with the almost complete removal of fir trees, are responsible for the modifications in the flora of lichens, and probably some other groups of organisms, in the reserve. Light and humidity conditions to which lichens are very sensitive have been particularly affected.

The range of the changes in the flora of lichens in the reserve over the 30 years studied is broad. Only slightly over 50% (75) of the total number of species have persisted since 1969-1971. The rest (61) are lichens that have entered, receded or were not noticed in the course of the studies between 1969-1971.

Regardless of the loss suffered by the flora of lichens in the reserve, its condition can still be considered good. The participation of stenotopic lichens whose habitat requirements are high and which occur in well preserved forest areas is high. Species typical of old-growth forests whose occurrence is related to forests of natural origin (Cieśliński 2003) are among them. These are: *Arthonia arthonioides, A. byssacea, Cetrelia cetrarioides, C. olivetorum, Calicium adspersum, Chaenotheca chlorella, Melaspilea gibberulosa, Menegazzia terebrata, Opegrapha vermicellifera, Pertusaria flavida.* The accumulation of these lichens in a small area makes the reserve a special place in the lowland in Poland. The temporal persistence of stenotopic forest species is indicative of the preservation of ecological niches characteristic of natural forest ecosystems.

Apart from the species listed above, the high lichenological value of the forest communities in the reserve is emphasised by the presence of a number of species typical of forests, rare or endangered in Poland. These are: *Arthonia mediella, Bacidia subincompta, Bryoria fuscesens, Chaenotheca xyloxena, Calicium salicinum, Chrysothrix candelaris, Flavoparmelia caperata, Graphis scripta, Opegrapha vulgata* var. *subsiderella, Pertusaria coccodes, Pyrenula nitida, Ramalina farinacea, Usnea filipendula, Usnea subfloridana.* These lichens, together with the species typical of old-growth forests, constitute a particularly valuable component of the flora of lichens in the reserve and emphasise the uniqueness of natural conditions in the protected area. A feature typical of the Zagożdżon reserve is a great accumulation of such species within a small area. The forest communities of the reserve are still a refuge of the epiphytic forest flora in the lowland in central Poland. Only few of them represent more widespread species that show a full life activity, for instance *Opegrapha vermicellifera, Graphis scripta, Pyrenula nitida.* The remaining species belong to very rare lichens, recorded only in one locality. They should be considered threatened, as they form vestigial, strongly isolated populations, which only makes them more in danger of extinction. Localities of some of these species are tens, or sometimes hundreds, kilometres apart, for instance *Menegazzia terebrata, Chrysothrix candelaris, Arthonia byssacea, A. arthonioides*. Species that produce vestigial thalli most probably represent the final stage of disappearance.

The persistence of several stenotopic forest species, despite the changes that have taken place in the forest communities, is conditioned by a high accumulation of old, sometimes monumental oaks and hornbeams, or less often sycamores and maple trees, in the reserve. These lichens persist on these trees. They are indicative of the ecological continuum of the forest communities in the reserve (Hawksworth and Hill 1984). These data show the role of old trees for the preservation of the species diversity of lichens. The location of the reserve in the middle of a significant forest complex of the Kozienicka Forest also encourages the preservation of forest species of lichens with high habitat requirements. The surrounding cushion created by the forest buffers local dangers.

The overall quantitative and qualitative changes of lichens in the reserve have been accompanied by modifications in the communities of epiphytes of individual tree species (Fig. 3). The greatest loss has been suffered by the flora of coniferous trees, first of all the fir, and the pine to a smaller degree. Lichens that were recorded on fir trees in the past were not species specific of this tree. Now, the majority of them

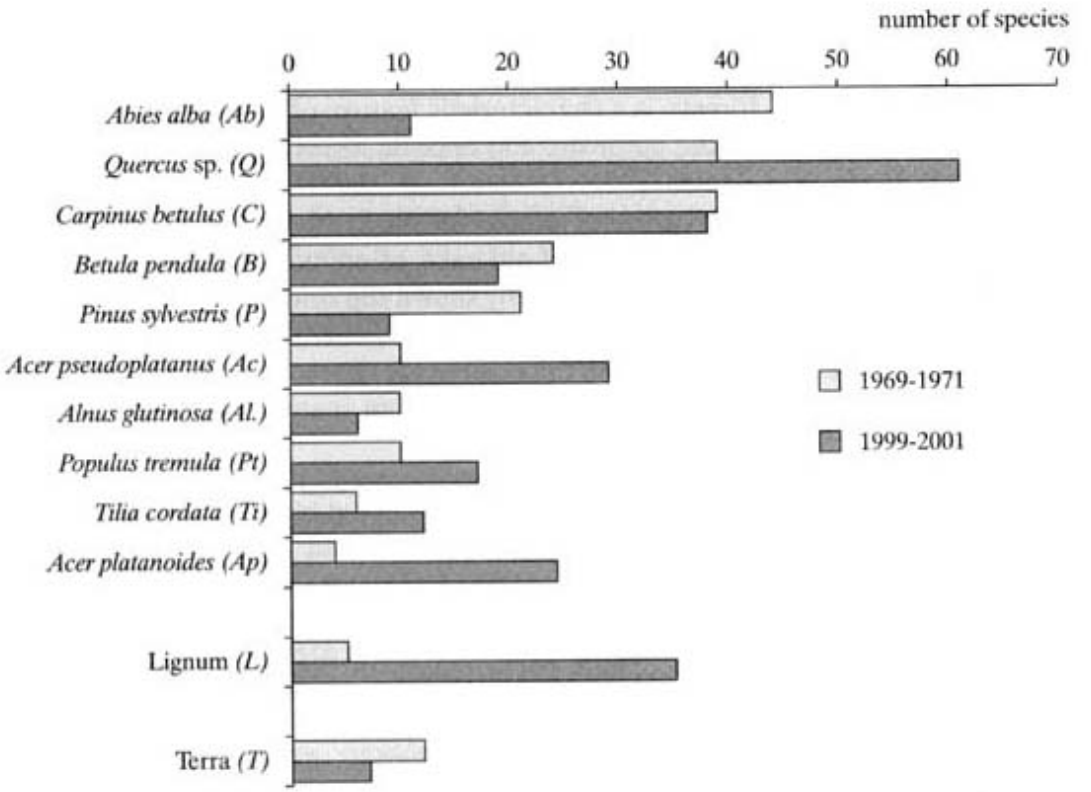

Fig. 3. Changes in the structure of the flora of lichens in the Zagożdżon reserve over 30 years.

grow on the bark of other tree species (Tab. 2), mainly deciduous trees. The flora of oak, sycamore and maple, as well as that of dead wood, has been enriched.

The present condition of the flora of lichens in the reserve, and the persistence of several species sensitive to gas pollution (SO_2, NO_x) in particular, shows that the impact of the emission of the power plant in Kozienice on the forest communities in the reserve is slight. The SW parts of the Forest are directly influenced by the emissions from the power plant (Falencka-Jabłońska 1997). The impoverishment of the flora of lichens in the reserve comes therefore as an effect of the changes in the phytoclimate of the forest communities resulting from cutting and forest breeding procedures in the tree stands, as well as an overall deterioration of the condition of the natural environment in Poland in the 1970s and 1980s.

The intense development of the new generation of the forest will contribute to further modifications in the communities of epiphytes and epixyles. The increasing degree of shading of oak trunks on account of an intense development of the undergrowth of fir and hornbeam trees may bring about a recession of some heliophilous species of lichens.

SUMMARY AND CONCLUSION

1. The Zagożdżon reserve is a good area of study on the dynamics of the flora of lichens in the context of the species composition and the structure of the forest communities brought about by forest management procedures.

2. Despite far-reaching changes in the structure of the tree stand following the removal of fir trees, a high degree of preservation of epiphytes and epixyles, which are typical of natural forests, is a characteristic feature of the study area. The reserve is still a refuge of the epiphytic and epixylic forest flora in the lowland in central Poland.
3. The persistence of lichens typical of natural forests in the reserve is a result of the preservation and high participation of old oaks, often monumental, in the forest communities. The study has unequivocally shown the role of old trees in the preservation of taxonomic and ecological diversity of lichens.
4. The lichens that have receded from the reserve are characterised by a high sensitivity to anthropopressure, and have receded from many other forest areas in Poland.
5. The majority of lichens typical of old-growth forests and other species typical of forests are very rare in the reserve. They form small, isolated populations whose life activity is distinctly reduced and which have features of receding lichens.
6. Non-forest lichens, usually growing on trees outside forest communities (apophytes), penetrate the forest, which is a symptom of synanthropisation of the forest communities in the reserve. Their participation in the epiphytic flora of the reserve, however, is slight.

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Wpływ gospodarki leśnej na florę porostów w Puszczy Kozienickiej (Polska Centralna)

Streszczenie

Analizowano zmiany we florze porostów rezerwatu Zagożdżon w ciągu 30 lat (Tab. 1 i 2). Podstawę stanowiły wyniki badań lichenologicznych prowadzonych w rezerwacie w latach 1969-1971 (Cieśliński 1978) i w 1999-2001. Zagadnienia te rozpatrywano w nawiązaniu do zmian w strukturze zbiorowisk leśnych rezerwatu. W 1972 roku duże szkody w drzewostanie wyrządził śniegołom, a następnie gradacja zwojek jodłowych *Choristoneura murinana* Hb. W ramach zabiegów sanitarnych prawie całkowicie usunięto z rezerwatu jodłę (Fig. 1). W związku z ekspansją graba prowadzone są zabiegi hodowlane. Zbiorowiska leśne rezerwatu podlegają nadal intensywnym przemianom dynamicznym, znajdują się w różnych fazach regeneracji. Zakres przemian we florze porostów w ciągu 30 lat jest duży (Tab. 1 i 2). Co piąty gatunek ustąpił z rezerwatu. Są to porosty charakteryzujące się wysoką wrażliwością na antropopresję. Największe straty poniosła flora porostów jodły (Fig. 3) Mimo głębokich przeobrażeń w składzie gatunkowym i w strukturze drzewostanów rezerwatu flora porostów w dalszym ciągu wyróżnia się występowaniem wielu gatunków charakteryzujących lasy naturalne, w tym tzw. porostów puszczańskich. Trwanie w rezerwacie Zagożdżon leśnych gatunków stenotopowych wynika z dużego nagromadzenia w zbiorowiskach leśnych sędziwych dębów, grabów, sporadycznie pozostałych gatunków drzew liściastych. Obecnie drzewa te wyróżniają się najbogatszą florą porostów (Fig. 3.). Dużym zróżnicowaniem gatunkowym charakteryzują się zbiorowiska porostów rozwijające się na martwym drewnie (Fig. 3). Podłoże to jest obecnie bardziej rozpowszechnione w rezerwacie, głównie w postaci pniaków po ściętych drzewach. Rezerwat nadal stanowi refugium leśnej flory porostów epifitycznych i epiksylicznych na niżu Polski Centralnej. Badania wykazały, że oddziaływanie emisji elektrowni Kozienice na florę porostów rezerwatu jest niewielkie.