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Jan BYSTREK, Katarzyna KOLANKO

Effect of Anthropopressure on Epiphytic Flora of Lichens as Exemplified by the Białowieża Primeval Forest

Wpływ antropopresji na nadrzewną florę porostów na przykładzie Puszczy Białowieskiej

It is a doubtless fact that plants are an expression of the natural environment and they are the first to react to the changes taking place in eco-systems.

Lichens occupy the foremost place among the organisms most sensitive to the changes caused by man's activity, especially to the pollution of the atmosphere, particularly to acidification of atmospheric water, which is the source of water for this group of organisms. Their cumulative properties increase sensitivity to air pollution.

Dying out of epiphytic lichens is one of the early signs of an increase of anthropopressure on the natural environment. Disappearance of epiphytic lichens, especially in tree crowns results in shaken balance in the circulation of atmospheric water of the interior of a forest.

In biological monitoring, lichens have been used for a long time and they have been often used both in laboratory and field investigations. The degree of sensitivity of many species could be found out. Bioindicative zones have been marked on the basis of the reaction of lichens, which was sometimes supplemented by the reaction of arboreal bryophytes (5, 6).

PURPOSE AND MATERIALS OF THE WORK

Like in comparative studies of epiphytic lichen flora of the Lublin region (3, 4, 5), our aim was to follow the changes in the epiphytic flora of lichens in the Białowieża Primeval Forest in the last 40 years, on the basis of a comparative analysis of several most common macrolichens species growing in the Białowieża forest not long ago. This analysis was carried out on the basis of the data published previously (15–18) and the present studies by Tobolewski and Cieśliński conducted in 1988 (9). All the analyzed taxons are kept in the herbarium of the Institute of Taxonomy Plants at the Maria Curie-Skłodowska University. Our aim was to find the sites given by Lecewicz or Rydzak or to draw

a comparison with the data provided by Tobolewski and Cieśliński, because the majority of these species (Table 1) belonged to the dominants which are most common in the epiphytic flora.

A COMPARATIVE ANALYSIS OF EPIPHYTIC LICHENFLORA

Cieśliński and Tobolewski (9) quote 206 epiphytic species in the Białowieża Forest and its outskirts. The sites of several more are enumerated by Krawiec (15), Lecewicz (16) and Rydzak (17, 18). A new species (*U. carpinea* Bystr.) was described which comes from the Białowieża Forest. Previous studies pointed out the abundance of macrolichens from the families of *Lobariaceae, Parmeliaceae* and *Usneaceae*. They grew from the trunk base up to the earliest twigs and in the tree crowns they formed groups of many species the composition of which was close to that of *Usneetum comosae* and *Evernietum divaricatae*. All the species known from the Białowieża Forest from the genera of *Bryoria, Cetraria, Hypogymnia, Ramalina, Usnea* and *Ps. furfuracea* grew commonly and even abundantly in the tree crowns. It often happened that *Bryoria* and *Hypogymnia* grew on thallus of other lichens as epilichenophytes.

The forests of the Białowieża Forest were characterized by a number of curiosities in the epiphytic lichen flora: *Br. furcellata, Br. smithii, Br. fuscidula, Br. motykana, Br. mirabilis, Br. setacea, E. divaricata*, whose thallus hung abundantly down from the branches of coniferous and deciduous trees. *E. mesomorpha, L. pulmonaria* growing most frequently on considerable area of many trunks, *L. scrobiculata, L. laetevirens, M. terabrata, R. crinalis* and the species of *Usnea*, especially abundant in tree crowns as well as numerous species which have not been mentioned in the present paper.

H. physodes was most common in the epiphytic macrolichens flora of lichens. This ubiquist species grew on each tree in the tree layer and in the undergrowth (especially *Juniperus* and *Corylus*) in all the forest communities and on the trees growing in isolation. It grew on trunks and branches from the base up to the earlier twigs and even needles. It was commonly found out on thallus of other lichens. It grew, commonly too, on the rotting wood, and in places also on brushwood (*Vaccinium, Calluna*), on moss tussocks and on woody polypore. It was also observed on concrete posts and mossy stones. The following varieties were found out in herbarium materials: var. *physodes*, var. *labrosa* var. *platyphylla* and var. *subcrustacea*.

The following grew commonly together with the former species and on identical habitats: *Ps. furfuracea* (var. *furfuracea*, var. *ceratea*, var. *scobicina*, var. *isidiophora*, var. *olivetorina*, less frequently var. *candidula*, *Pl. glauca*, *E. prunastri* (var. *prunastri*, var. *sorediifera*, var. *marginata*, less frequently var. *gracilis* and var. *robusta*. These groups also included very common species but the ones which "avoided" pine bark and were especially numerous on deciduous trees. These were: *P. sulcata*, *R. farinacea* (var. *multifida*, var. *luxurians*, less frequently var. *gracilenta*, var. *pendulina*, var. *phalerata* and var. *subphalerata*.

Common in the whole area, but growing mostly in smaller proportions were the species of *Bryoria*, *Menegazzia terebrata*, *R. pollinaria* var. *humilis* and numerous species of *Usnea* (*U. dasypoga*, *U. fulvoreagens*, *U. laricina*, *U. hirta*, *U. subflorida*, *U. prostrata*).

Besides, a very good condition of thallus was a characteristic feature of the arboreal lichen flora. They reached considerable size which often exceeded the measurements in the diagnoses. It was discussed by Krawiec and Lecewicz. The evidence is provided in the herbarium (LBL-L). Their good condition is also testified to by great intra-species variability of all the examined species.

Another peculiarity was also the occurrence of both boreal, subatlantic, lowland and subalpine species. The Białowieża Forest was characterized by common occurrence of the species which are very rarely found in other areas of Poland as well as by the abundance of specimens on particular localities.

The present state of the epiphytic lichen flora is completely different. Among the species listed in Table 1, the most common ones include the following: *E. prunastri*, *H. physodes*, *P. sulcata*, *R. farinacea*, *Ps. furfuracea*, *Pl. glauca*, *R. pollinaria*, *C. chlorophylla*, *U. hirta*. Are quoted because of numerous sites (9): *H. tubulosa*, *C. olivetorum*, *C. cetrarioides*, *M. terebrata*, *L. pulmonaria*, *U. dasypoga*, *U. subfloridana*, *Br. crispa* and *Br. implexa* were observed in several dozen of localities.

Others, previously common in the Białowieża Forest, are now left only on singular sites, often in the form of single thalluses or small groups. Cieśliński and Tobolewski (9) mention the following: *Br. subcana* from 13, *E. divaricata* from 9, *U. laricina* from 6, *R. fastigiata*, *R. crinalis*, *U. ceratina*, *U. florida* from 3, *U. fulvoreagens* from 2, and *L. scrobiculata*, *P. olivacea*, *U. prostrata*, *U. wasmuthii* from only one site.

The condition of thalluses of most analyzed species is rather poor, including all those (9) which are enumerated as having only sporadic sites. A lowered condition was also observed in common species including

H. physodes, P. sulcata, E. prunastri, R. farinacea, Ps. furfuracea and *U. hirta.* It was manifested in numerous outside damages, smaller height, change of habitat as well as inner ones, especially dying out of the green component and browning of the parenchyma, which is especially visible in *P. sulcata.*

Table 1. Arboreal macrolichens in the Białowieża Forest

Species	*Picea abies*			*Pinus sylvestris*			Deciduous tree			Total		
	1	2	3	1	2	3	1	2	3	1	2	3
1	2			3			4			5		
Bryoria cana (L.) Bystr.	+	+	.	.	.	.	+	+	.	+	+	.
Br. capillaris (Ach.) Brodo et Hawksw.	.	+	.	.	+	.	.	.	.	.	+	.
Br. crispa Bystr.	+	+	+	+	+	+	+	+	+	+	+	+
Br. furcellata (Fr.) Brodo et Hawksw.	.	.	.	.	.	.	+	+	.	+	+	.
Br. fuscencens (Gyel.) Brodo et Hawksw.	+	+	.	+	+	.	+	+	.	+	+	.
Br. fuscidula (Arn.) Bystr.	.	.	.	.	+	.	.	+	.	.	+	.
Br. implexa (Nyl. ex Stizbg.) Bystr.	+	+	+	+	+	+	+	+	+	+	+	+
Br. jubata (L.) Bystr.	.	.	.	.	+	.	+	+	.	+	+	.
Br. mirabilis (Mot.) Bystr.	.	+	.	.	.	.	.	.	.	.	+	.
Br. motykana (Bystr.) Bystr.	.	+	.	.	+	.	.	+	.	.	+	.
Br. positiva (Gyel.) Bystr.	+	+	.	+	+	.	+	+	.	+	+	.
Br. setacea (Ach.) Brodo et Hawksw.	+	+	.	+	+	.	.	+	.	+	+	.
Br. smithii (DR) Brodo et Hawksw.	.	+	.	+	+	.	+	+	.	+	+	.
Br. subcana (Nyl. ex Stizbg.) Bystr.	+	+	+	+	+	.	+	+	+	+	+	+
Br. vrangiana (Gyel.) Brodo et Hawksw.	.	+	.	.	+	.	.	.	.	.	+	.
Cetraria chlorophylla (Willd.) Vain.	+	+	+	+	+	+	+	+	+	+	+	+
Evernia divaricata (L.) Ach.	+	+	.	+	+	.	+	+	+	+	+	+
E. mesomorpha Nyl.	.	.	.	.	+	.	.	+	.	.	+	.
E. prunastri (L.) Ach.	+	+	+	+	+	.	+	+	+	+	+	+
var. *pendula* (Nyl.) Mot.	.	+	.	.	.	.	.	+	.	.	+	.
var. *robusta* Suza	.	+	.	.	.	.	.	+	.	.	+	.
Hypogymnia physodes (L.) Nyl.	+	+	+	+	+	+	+	+	+	+	+	+
H. tubulosa (Schaer.) Hav.	+	+	+	+	+	+	+	+	+	+	+	+
H. vittata (Ach.) Nyl.	+	+	.	.	.	.	.	.	.	+	+	.
Lobaria laetevirens (Lightf.) Zahlbr.	.	.	.	.	.	.	.	.	+	.	.	+
L. polmonaria (L.) Hoffm.	+	+	.	+	+	.	+	+	+	+	+	+
L. scrobiculata (Scop.) DC.	+	+	.	.	.	.	+	+	+	+	+	+
Menegazzia terebrata (Hoffm.) Mass.	+	+	+	.	.	.	+	+	+	+	+	+
Parmelia sulcata (Th. Fr.) Tayl.	+	+	+	.	.	.	+	+	+	+	+	+
Platismatia glauca (L.) Culb.	+	+	+	+	+	+	+	+	+	+	+	+
Pseudoparmelia caperata (L.) Hale M.	+	+	+	.	.	.	+	+	+	+	+	+
Pseudevernia furfuracea (L.) Ach. s.l.	+	+	+	+	+	+	+	+	+	+	+	+
Romalia baltica Lett.	.	.	.	.	.	.	.	+	.	.	+	.
R. crinalis Ach.	+	+	.	+	+	.	+	+	.	+	+	.
R. farinacea (L.) Ach.	+	+	+	.	.	.	+	+	+	+	+	+
R. obtusata (Arn.) Bitt.	.	.	.	.	.	.	.	+	.	.	+	+

Table 1 continued

1	2			3			4			5		
R. fastigiata (Liljebl.) Ach.	.	.	.	.	.	.	+	+	+	+	+	+
R. fraxinea (L.) Ach.	.	.	.	.	.	.	+	+	+	+	+	+
R. pollinaria (Westr.) Ach.	+	+	.	.	.	.	+	+	+	+	+	+
var. *multipartita* Erichs.	.	+	.	.	.	.	.	+	.	.	+	.
Usnea barbata (L.) Mot.	.	+	.	.	.	.	+	+	.	.	+	.
U. capillaris Mot.	.	+	.	.	.	.	.	.	.	.	+	.
U. carpinea Bystr.	.	.	.	.	.	.	+	+	.	+	+	.
U. caucasica Vain.	+	+	.	.	.	.	+	+	.	+	+	.
U. cavernosa Tuck	+	+	.	+	.	.	+	+	.	+	+	.
U. dasypoga (Ach.) Röhl. s.l.	+	+	+	+	+	+	+	+	+	+	+	+
U. distincta Mot.	+	+	.	.	.	.	+	+	.	+	+	.
U. esthonica Räs.	+	+	.	.	.	.	+	+	.	+	+	.
U. faginea Mot.	.	+	.	.	.	.	.	+	.	.	+	.
U. florida (L.) Hoffm.	+	+	+	+	.	.	+	+	+	+	+	+
ssp. *arbuscula* Mot.	.	+	.	.	.	.	.	+	.	.	+	.
U. foveata Vain.	.	+	.	.	.	.	.	+	.	.	+	.
U. fulvoreagens (Raäs.) Mot.	+	+	+	+	.	.	+	+	+	+	+	+
U. glabrata (Ach.) Vain.	.	+	.	.	.	.	.	+	.	.	+	.
U. glabrescens (Nyl.) Mot.	.	+	.	+	+	.	+	+	.	+	+	.
U. hirta (L.) Mot. s.l.	+	+	+	+	+	+	+	+	+	+	+	+
U. hirtella (Arn.) Mot.	.	+	.	.	.	.	.	+	.	.	+	.
U. laricina Vain.	+	+	.	.	+	+	+	+	+	+	+	+
U. leiopoga Mot.	.	+	.	.	.	.	.	+	.	.	+	.
U. leucosticta Vain.	.	+	.	.	.	.	.	.	.	.	+	.
U. longissima Ach.	+	+	.	.	.	.	+	+	.	+	+	.
U. monstruosa Vain.	.	+	.	.	.	.	.	.	.	.	+	.
U. neglecta Mot.	.	.	.	.	.	.	.	+	.	.	+	.
U. plicata (L.) Wigg. em. Mot.	.	+	.	.	.	.	.	+	.	.	+	.
U. prostrata Vain.	.	+	.	+	+	.	+	+	.	+	+	.
U. rugulosa Vain.	.	+	.	.	+	.	.	+	.	.	+	.
U. scabrata Nyl.	.	+	.	.	.	.	.	.	.	.	+	.
U. silesiaca Mot.	.	.	.	.	.	.	.	+	.	.	+	.
U. silvatica Mot.	+	+	.	.	.	.	+	+	.	+	+	.
U. scrobiculata Mot.	.	+	.	.	.	.	.	+	.	.	+	.
U. sorediifera Mot.	+	+	.	.	.	.	+	+	.	.	+	.
U. sublaxa Vain.	.	+	.	+	+	.	.	+	.	+	+	.
U. subfloridana Stirt. s.l.	+	+	+	+	+	+	+	+	+	+	+	+
U. uncinulata Mot.	.	+	.	.	+	.	.	+	.	.	+	.
U. wasmuthii Räs.	+	+	.	+	+	.	+	+	+	+	+	+

Explanation: 1 — sites quoted in literature, 2 — species collected in the herbarium of LRL-L, 3 — present state according to Cieśliński and Tobolewski and the species in the herbarium of these authors.

The number of specimens on particular sites and the number of species in all the arboreal communities decreased. This process also caused their decay. Radical changes took place in tree crowns, from where the greatest

number of species disappeared including almost all *Usneaceae*. The flora of the spruce was most susceptible to these changes. This fact was observed by Cieśliński and Tobolewski. It was also confirmed in the examinations of the red list of *Usneaceae* and *Parmelicaeae*.

A number of formerly known species were not found again (9). These include the most sensitive ones which were found among the dying out ones already before, including the species known in lowland Poland only from the Białowieża Forest (*Br. furcellata, U. capillaris, U. monstruosa, U. graciosa, U. scrobiculata, U. silvatica, U. carpinea*). Several others were not observed either such as: *Br. fuscescens, Br. fuscidula, Br. mirabilis, Br. motykana, Br. positiva, Br. setacea, E. mesomorpha, U. cavernosa, U. faginea, U. glabrata, U. glauca* (Table 1).

Cieśliński and Tobolewski (9) estimate the losses of the flora at 50% only on spruces and this refers mainly to *Parmeliaceae* and *Usneaceae*.

Considering the herbarial materials, the losses are by far greater on all the tree species (Table 1).

The losses in the epiphytic lichen flora cannot be calculated and estimated without any consideration to the changes in the abundance and frequency of the occurrence on particular sites.

The loss of biomass in the phytocenosis of the Białowieża Forest is much more tragic and it is caused by dying out of many thousands of individuals, mainly in the tree crowns. The phenomenon of losing genera took place, which was caused by limitation of the number of individuals and decrease of ontogenetic variability. Some part of the evolution got lost. The structure of biosphere got simplified and degraded.

Such a great loss of biomass results in falling out of one link in the circulation of the matter and energy, unbalanced circulation of atmospheric water and the temperature of the forest interior, and in removing the natural filter protecting the forest against toxic substances. The consequence is a considerable decrease of the conditions of tree stands.

It is hard to be optimistic and maintain that the losses in lichen flora of the Białowieża Forest are small because they cover only the species with narrow ecological amplitude and only from two genera (9).

Parmeliaceae and *Usneaceae* were the dominating species in the arboreal lichen flora both in respect of the number of species (about 30%) and the frequency of their occurrence.

The condition of several others which still survive is not optimistic, either.

One can not ignore the signals of mass dying out of arboreal lichens in an estimation of the condition of the Białowieża Forest and its natural

character, because the Białowieża Forest is generally considered to be a clean area and in monitoring studies it is usually regarded as the model area.

It is without any doubt that like in other areas the main factors which eliminate lichens from the Białowieża Forest is an increase of the air pollution, especially growth of acidification of atmospheric water locally together with the activity of industrial plants located at the outskirts of the Białowieża Forest. Burning pit-coal in households as well as the development of transport also contributed to this situation.

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STRESZCZENIE

Proces wymierania nadrzewnej flory w warunkach zwiększonej antropopresji jest zjawiskiem powszechnie znanym. Ma on szczególną wymowę w odniesieniu do obszarów chronionych, a zwłaszcza do Puszczy Białowieskiej, uważanej powszechnie za obszar czysty i najmniej zagrożony w całej Polsce, wzorcowy w monitoringu biologicznym i chemicznym.

Wykazano, że tylko wśród *macrolichenes* nadrzewnych zmniejszyła się ostatnio lista gatunków o 50–75% (tab. 1). Jako pierwsze wymarły gatunki bardzo rzadkie (tu pospolite), będące osobliwością nadrzewnej lichenoflory. Wśród ginących dominują *Usneaceae* i *Parmeliaceae*, najbardziej pospolite w koronach drzew.

Tak masowe wymieranie porostów stanowi poważne ostrzeżenie. Wyginęło setki tysięcy osobników, nastąpił znaczny ubytek biomasy w fitocenozie puszczy, zginęła znaczna część dorobku ewolucji, dochodzi do degradacji biosfery. Pękło jedno z ogniw w łańcuchu obiegu materii i energii, zachwiany został obieg wody atmosferycznej w lesie, zniszczony naturalny filtr chroniący las przed imisją substancji toksycznych. Zagrożeniem dla nadrzewnej lichenoflory jest niska kondycja plech pozostałych przy życiu, sygnalizowana przez Cieślińskiego i Tobolewskiego (9), objawiająca się również znacznym stopniem martwych komórek symbiotycznego glonu.

Na czerwonej liście gatunków wymarłych znalazły się prawie wszystkie gatunki *Bryoria, Usnea* oraz *Evernia mesomorpha*, a wśród gatunków ginących, znanych obecnie z pojedynczych stanowisk, są: *Evernia divaricata, Lobaria scrobiculata, Usnea florida, U. prostrata* i inne.