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ORIGINAL RESEARCH PAPER

Contribution to the lichen biota of the Stawy Milickie nature reserve and its adjacent area (Lower Silesia, southwestern Poland)

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Abstract
The paper presents the results of lichenological investigations conducted in the eastern part of the Stawy Milickie nature reserve and its buffer zone (Barycz Valley, southwestern Poland). The study area is a famous waterfowl refuge, consisting of several fishpond complexes, together with adjacent forests, meadows, and villages. In total 72 lichen taxa were recorded, growing on bark and branches of trees and shrubs, stumps, wood, soil, and anthropogenic rock substrates (mortar, concrete, bricks, etc.). Six species, namely *Evernia prunastri*, *Flavoparmelia caperata*, *Hypogymnia tubulosa*, *Parmelina tiliacea*, *Physconia distorta*, and *Pleurosticta acetabulum*, are threatened in Poland. As represented by single young thalli, they indicate the recent improvement of environmental conditions. The lichen biota of the study area is typical for the lowland regions of western and southwestern Poland.

Keywords
lichens; lichenized fungi; species diversity; habitat groups; Barycz Valley

Introduction

In terms of lichenology Lower Silesia is very unequally recognized. The vast majority of publications concerning this region relates to its mountainous parts, namely the Sudety Mountains and their foreland. There is very little and incomplete information about the occurrence of lichens in the lowland part of the region. These "white spots" considerably impede research on the dynamics of lichen biota in the lowlands, which are exposed to significant anthropogenic pressure. Filling those gaps is particularly important due to the observed in many regions "great return" of epiphytes, after the almost complete extinction at the end of the twentieth century [1–4].

At the beginning of the studies on lichen biota in the lowland part of Lower Silesia the Stawy Milickie (Milicz Ponds) nature reserve was chosen. The aim of the study was to determine the lichen richness and diversity in the area with a large variety of potential habitats and relatively low anthropogenic impact (extensive fishery management and forestry). The results of the studies, in connection with the similar research conducted in other parts of the region, will be the basis for the further analysis of the lichen biota dynamics.

Study area

The study area is located in the northern part of Lower Silesia, approx. 50 km north of Wrocław and 100 km south of Poznań, within the Dolina Baryczy Landscape Park

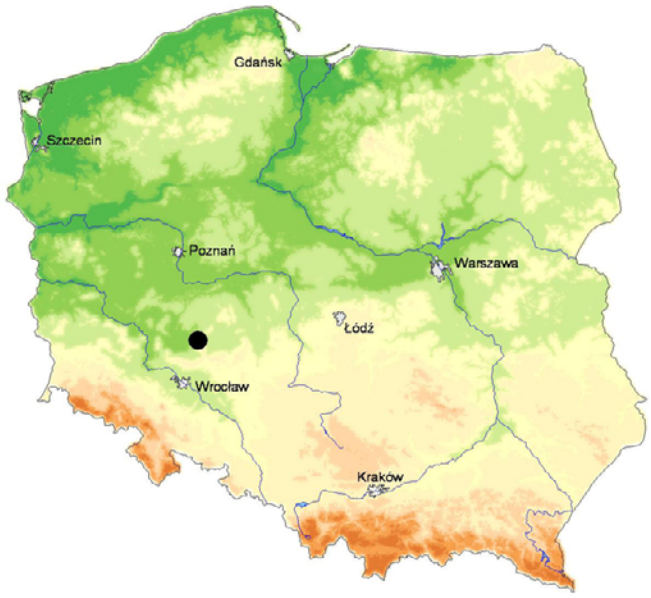


Fig. 1 Location of the Stawy Milickie nature reserve on the map of Poland (black circle).

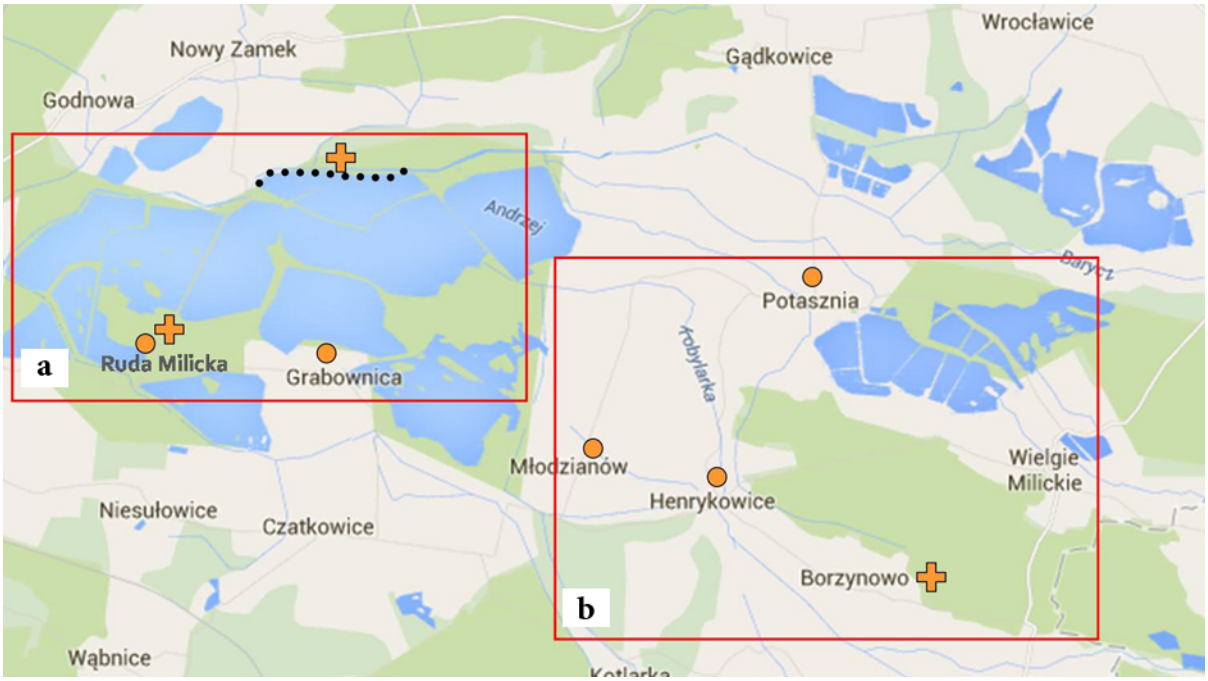
(Fig. 1). Created in 1963, the Stawy Milickie nature reserve consists of five separate complexes of fish ponds: Stawno, Potasznia, Ruda Sułowska, Radziądz, and Jamnik, located on the eastern and western side of Milicz town, and adjacent fields, forests, and meadows. Nature reserve covers in total an area of 5324 ha. The main purpose of the reserve is to protect numerous species of rare mud and water birds for which the ponds are their natural habitat.

According to the classification by Kondracki [5] the area of the reserve lies within the macroregion Obniżenie Milicko-Glogowskie and consists the Kotlina Żmigrodzka, the Kotlina Milicka, and the Wzgórza Krośnickie, being a part of the Wał Trzebnicki.

The biggest complex of ponds in the reserve is the Stawno complex situated to the east of Milicz, which covers an area of 1629 ha. There are approx. 30 smaller and larger ponds, supplied by the rivers Barycz, Rybnica, and Prądnia and separated by dikes.

Material and methods

The study was conducted in the years 2014–2015 in the eastern part of the Stawy Milickie nature reserve (the Stawno complex), in selected villages in the buffer zone of the reserve: Ruda Milicka, Grabownica, Potasznia, Młodzianów, and Henrykowice, and in the forest complex between the villages Henrykowice, Borzynowo, and Wielgie Milickie (Fig. 2).



● – investigated villages; ✚ – investigated abandoned farms; ⋰⋱ – investigated stretch of the Barycz river-side.

Fig. 2 Study area. **a** Western part (the Stawno complex). **b** Eastern part (buffer zone with a forest complex).

The whole lichen biota of this area was analyzed and divided into habitat groups: epiphytic, epigeic, epixylic, and epilithic. Throughout the reserve, the research was carried out on a nature trail, selected dikes, and along the Barycz River on the stretch of approx. 2 km long. In the villages, we analyzed fences and walls of buildings (especially old and abandoned farms), roadside trees, wooden structures, etc. In the studied forest complex three research sectors (A, B, and C) were selected, differing in terms of location and habitat conditions. The distribution of the research sites is shown on Fig. 3 (Stawno complex in the western part of the investigated area) and Fig. 4 (eastern part of the investigated area). Descriptions of the sites are given in Tab. 1.

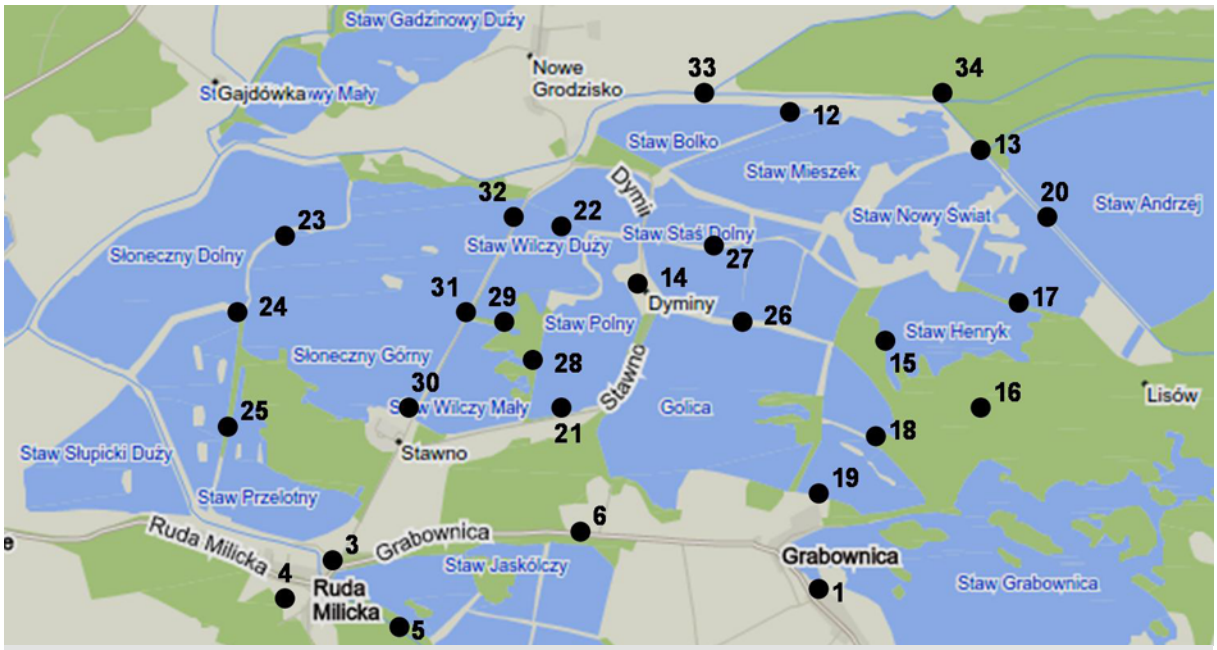


Fig. 3 Research sites in the Stawno complex of the Stawy Milickie nature reserve.

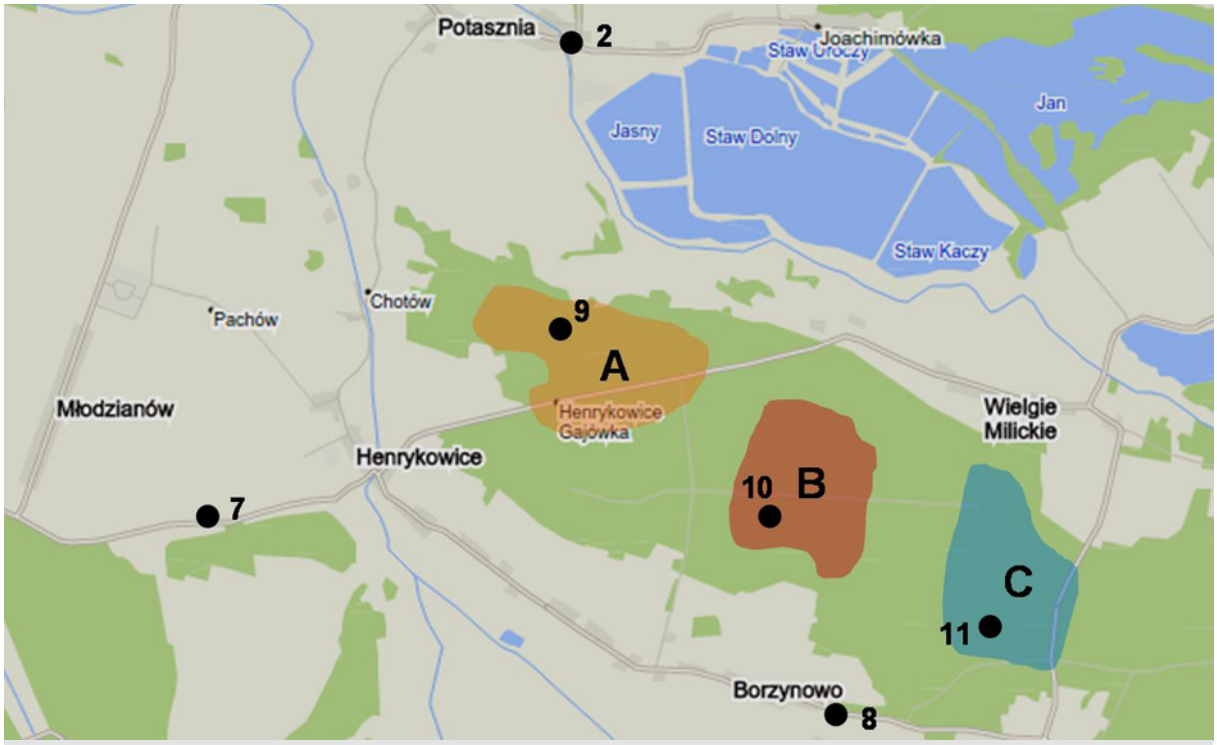


Fig. 4 Research sites in the buffer zone of the Stawy Milickie nature reserve and sectors (A, B, C) distinguished within the forest complex.

Tab. 1 Description of the research sites.

No.	Location
1	Grabownica village
2	Potasznia village
3	Ruda Milicka village
4	Ruda Milicka village – forest-guard lodge
5	Ruda Milicka village – ornithological station of the University of Wrocław
6	Road between Grabownica and Ruda Milicka villages
7	Road between Młodzianów nad Henrykowice villages
8	Surroundings of Borzynowo village – ruined farm
9	Forest complex – sector A
10	Forest complex – sector B
11	Forest complex – sector C
12	Dike by the Bolko II pond
13	Dike between the Bolko II, Nowy Świat, and Andrzej ponds
14	Dike between the Golica, Polny and Machnickie ponds
15	Dike by the Henryk pond
16	Forest by the Henryk pond
17	Dike between the Henryk and Nowy Świat Górny ponds
18	Dike by the Machnickie ponds
19	Dike between the Machnicki Górny pond and a glade
20	Dike between the Nowy Świat and Andrzej ponds
21	Dike by the Polny pond
22	Dike between the Polny pond and the nature trail
23	Dike between the Słoneczny Górny and Słoneczny Dolny ponds
24	Dike between the Słoneczny Górny, Słoneczny Dolny, and Słupicki Nowy ponds
25	Dike between the Słupicki Nowy and Staw Przelotny ponds
26	Dike between the Staś Górny and Golica ponds
27	Dike between the Staś Górny and Słowian ponds
28	Dike between the Wilczy Mały and Polny ponds
29	Dike between the Wilczy Mały and Wilczy Duży ponds
30	Southern end of the nature trail
31	Middle part of the nature trail
32	Northern end of the nature trail
33	Bank of the Barycz River
34	Dam on the Barycz River

Lichens protected by law [6] and other easy to identify species were listed in the field without collection. In other cases small fragments of the thalli were collected for further detailed analysis in a laboratory.

The collected material was identified based on standard methods, using the stereoscopic and a light microscope. Lichens of the genus *Lepraria* were examined using thin layer chromatography (TLC) in accordance with the methods described by Orange et al. [7]. Nomenclature of the species follows Index Fungorum [8], Smith et al. [9], and Arup et al. [10]. All collected specimens were deposited in the lichen herbarium of the Department of Botany, University of Wrocław.

Results

List of species

In the investigated part of the Stawy Milickie nature reserve and its buffer zone 72 lichen species have been found (Tab. 2). Among them epiphytes definitely dominated (41 species). The share of lichens growing on wood (23 species) and rocks (20 species) in the analyzed lichen biota was much smaller. Terricolous lichens (nine species) were the least numerous habitat group and occurred almost only in the forest complex. Nearly one third of the recorded species were found in two or more types of habitat.

Habitat preferences of lichen biota

Epiphytic lichens. The differentiation of potential phorophytes for epiphytic lichens is huge in the study area. Within the Stawno complex there were tree stands consisting mainly of oak *Quercus robur*, poplar *Populus* spp., willow *Salix* spp. and elm *Ulmus* sp.; there was also a small area covered with alder carr *Ribo nigri-Alnetum* [11]. In the analyzed forest complex, pine *Pinus sylvestris* prevailed, accompanied by *Q. robur*, birch *Betula pendula*, spruce *Picea abies*, and hornbeam *Carpinus betulus*. In the investigated villages deciduous trees dominated, namely: *Q. robur*, *B. pendula*, *C. betulus*, rowan *Sorbus acuparia*, and lindens *Tilia* spp.

The lichen biota of particular phorophytes differed substantially (Fig. 5). The richest lichen vegetation was found to be connected with *Q. robur* (31 species), *Salix* spp. (16), *B. pendula* (9), and *P. sylvestris* (8). Among analyzed trees *Q. robur* was characterized by the richest and the most diverse lichen biota. Among the species found on trunks there were the only fruticose epiphytes of the study area: *Evernia prunastri* and *Psedevernia furfuracea*,

Tab. 2 List of lichen species recorded in the Stawy Milickie nature reserve.

Species	Sites and numbers of records	Substrate
Acarospora fuscata (Nyl.) Arnold	8(1)	S: tile
A. smaragdula (Wahlenb.) A. Massal.	31(1)	S: brick
Amandinea punctata (Hoffm.) Coppins & Scheid.	2(1), 5(1), 18(1), 23(1), 24(1), 26(1), 28(1), 31(2), 32(1), 33(6)	C: bark of *Alnus glutinosa*, *Betula pendula*, *Qurecus* sp., *Salix* sp.
		X: dead branches
Athallia holocarpa (Hoffm.) Arup, Frödén & Søchting	31(1)	C: bark of *Quercus* sp.
Calogaya decipiens (Hoffm.) Arup, Frödén & Søchting	5(1)	S: stone wall
C. cfr. *pusilla* (A. Massal.) Arup, Frödén & Søchting	1(1)	S: concrete
Candelaria concolor (Dicks.) Stein	16(1)	C: bark of *Quercus* sp.
Candelariella aurella (Hoffm.) Zahlbr.	4(1), 5(2), 31(1), 34(1)	C: bark of *Quercus* sp.
		S: concrete, metal
C. reflexa (Nyl.) Lettau	3(1)	C: bark of *Quercus* sp.
C. xanthostigma (Pers. ex Ach.) Lettau	31(2)	C: bark of *Quercus* sp., *Salix* sp.
Cetraria islandica (L.) Ach.	11(1)	T: sandy soil
Chaenotheca ferruginea (Turner ex Sm.) Mig.	3(1)	C: bark of *Quercus* sp.
Cladonia arbuscula (Wallr.) Flot.	9(3), 10(2), 11(5)	T: sandy soil
C. cenotea (Ach.) Schaer.	11(3)	X: dead branches, stumps
C. chlorophaea (Flörke ex Sommerf.) Spreng.	9(5), 11(6), 32(1)	C: bark of *Pinus sylvestris*, *Quercus* sp.
		X: stumps, logs, dead branches
C. coniocraea (Flörke) Spreng.	11(5), 15(1), 19(1), 27(1)	X: dead branches, stumps
C. deformis (L.) Hoffm.	9(2), 11(2)	T: sandy soil
		X: rotten stump
C. digitata (L.) Hoffm.	9(1), 11(2)	C: bark of *Pinus sylvestris*
		X: rotten stumps, logs, dead branches
C. floerkeana (Fr.) Flörke	9(1)	X: rotten stump
C. furcata (Huds.) Schrad.	9(5), 11(5)	T: sandy soil
C. gracilis (L.) Willd.	9(3), 10(1), 11(4)	T: sandy soil
		X: rotten wood
C. macilenta Hoffm.	9(2), 10(1), 11(5)	X: rotten stumps, logs
C. ochrochlora Flörke	23(1)	X: rotten stump
C. phyllophora Hoffm.	11(1)	X: rotten stump
C. pyxidata (L.) Hoffm.	10(1), 11(1)	C: bark of *Betula pendula*
		T: humus
C. rangiferina (L.) F.H. Wigg.	9(2), 10(2), 11(3)	T: sandy soil
C. subulata (L.) F.H. Wigg.	11(1)	X: rotten wood

Tab. 2 Continued

Species	Sites and numbers of records	Substrate
C. uncialis (L.) F.H. Wigg.	9(2), 11(2)	T: sandy soil
Dimerella pineti (Ach.) Lücking & Lumbsch	10(1)	C: bark of *Quercus* sp.
Evernia prunastri (L.) Ach.	3(3), 4(1), 13(1), 16(7), 17(1), 30(1), 31(1), 32(1)	C: bark of *Quercus* sp.
		X: wooden handrail
Flavoparmelia caperata (L.) Hale	3(2), 10(1)	C: bark of *Betula pendula*, *Malus domestica*, *Pinus sylvestris*
Flavoplaca citrina (Hoffm.) Arup, Frödén & Søchting	11(1), 33(1), 34(1)	S: concrete
		X: rotten wood
Hafellia disciformis (Fr.) Marbach & H. Mayrhofer	2(1)	C: bark of *Quercus* sp.
Hypocenomyce scalaris (Ach. ex Lilj.) M. Choisy	26(1)31(1), 9(1), 10(2), 11(2)	C: bark of *Betula pendula*, *Pinus sylvestris*, *Salix* sp.
		X: rotten stump
Hypogymnia physodes (L.) Nyl.	1(1), 2(1), 3(4), 9(6), 10(4), 11(10), 17(2), 22(1), 25(1), 30(1), 32(3), 33(2)	C: bark of *Carpinus betulus*, *Fraxinus excelsior*, *Quercus* sp., *Salix* sp., *Sorbus aucuparia*
		X: dead branches, wooden handrail
H. tubulosa (Schaer.) Hav.	10(1)	C: bark of *Pinus sylvestris*
Lecania cyrtella (Ach.) Th. Fr.	33(3)	C: bark of *Populus* sp., *Salix* sp.
		X: dead twigs
Lecanora albescens (Hoffm.) Flörke	1(1), 4(1), 5(1), 34(2)	S: concrete
L. cfr. *cenisia* Ach.	34(1)	S: bricks
L. conizaeoides Nyl. in. Cromb.	4(1), 5(1), 9(1), 11(1),18(2), 25(2), 30(1), 32(3), 33(8)	C: bark of *Pinus sylvestris*, *Quercus* sp., *Salix* sp.
		X: dead branches, wooden handrail
L. dispersa (Pers.) Sommerf.	4(1), 5(1), 31(1), 32(2), 34(1)	C: bark of *Quercus* sp.
		S: concrete
L. saligna (Schrad.) Zahlbr.	18(1), 24(1), 28(1)	C: bark of *Betula pendula*, *Salix* sp.
		X: dead branches
Lecidella stigmatea (Ach.) Hertel & Leuckert	32(1), 34(1)	S: concrete
Lepraria elobata Tønsberg	3(1), 7(1), 9(3), 10(2), 11(1), 14(1), 16(1), 23(1), 26(3), 30(1)	C: bark of *Pinus sylvestris*, *Quercus* sp.
L. incana (L.) Ach.	7(1), 10(1)	C: bark of *Quercus* sp.
L. jackii Tønsberg	9(1), 10(1)	C: bark of *Quercus* sp.
		T: soil
L. lobificans Nyl.	9(1), 10(2), 11(1), 23(1), 30(1)	C: bark of *Betula pendula*, *Quercus* sp.
Melanohalea exasperatula (Nyl.) O. Blanco et al.	31(1), 33(1)	C: bark of *Quercus* sp., *Salix* sp.
Micarea prasina Fr. s. lat.	33(1)	X: dead branches

Tab. 2 Continued

Species	Sites and numbers of records	Substrate
Parmelia sulcata Taylor	1(1), 3(4), 5(1), 9(3), 11(1), 15(3), 18(2), 21(1), 25(3), 28(1), 31(2), 32(2), 33(12)	C: bark of *Malus domestica*, *Pinus sylvestris*, *Quercus* sp., *Salix* sp., *Ulmus* sp.
		X: dead branches, wooden handrail
Parmelina tilliacea (Hoffm.) Hale	3(1)	C: bark of *Fraxinus excelsior*
Parmeliopsis ambigua (Wulfen) Nyl.	4(1), 11(1)	X: dead branches, wooden handrail
Pheophyscia orbicularis (Neck.) Moberg	1(1), 4(1), 5(1), 6(1), 8(1), 16(1), 18(1), 25(1), 31(3), 32(3), 33(6)	C: bark of *Quercus* sp., *Salix* sp.
		S: concrete, tile
		X: dead branches
Physcia adscendens H. Olivier	1(1), 2(2), 3(2), 5(1), 9(1), 18(1), 23(1), 25(2), 31(2), 32(1), 33(16)	C: bark of *Betula pendula*, *Populus* sp., *Sambucus nigra*, *Quercus* sp., *Salix* sp.
		X: dead branches
Ph. aipolia (Ehrh. ex Humb.) Fürnr.	3(1)	C: bark of *Quercus* sp.
Ph. caesia (Hoffm.) Fürnr.	1(1), 5(1), 8(1), 34(2)	S: concrete, tile
Ph. tenella (Scop.) DC.	1(2), 2(2), 3(2), 5(1), 6(1), 8(1), 9(1), 15(1), 17(1), 18(3), 23(2), 24(1), 25(5), 28(1), 30(1), 31(3), 32(2), 33(11)	C: bark of *Betula pendula*, *Fraxinus excelsior*, *Populus* sp., *Quercus* sp., *Salix* sp., *Sambucus nigra*
		S: tile
		X: dead branches
Physconia distorta (With.) J.R. Laudon	2(1), 31(1)	C: bark of *Populus* sp., *Quercus* sp.
Ph. grisea (Lam.) Poelt	31(2)	C: bark of *Quercus* sp.
Ph. enteroxantha (Nyl.) Poelt	33(1)	X: dead twig of *Salix* sp.
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	4(1)	C: bark of *Quercus* sp.
Polycauliona candelaria (L.) Frödén, Arup & Søchting	1(2), 2(1), 5(1), 23(1), 31(3), 33(5)	C: bark of *Populus* sp., *Quercus* sp., *Salix* sp.
		S: concrete
		X: dead branches
P. polycarpa (Hoffm.) Frödén, Arup & Sřchting	1(1), 33(2)	C: bark of *Salix* sp.
		S: concrete
		X: dead branches
Protoparmeliopsis muralis (Schreb.) M. Choisy	4(1), 5(1), 25(1), 30(1), 34(1)	S: concrete, bricks, mortar
Pseudevernia furfuracea (L.) Zopf	3(3), 4(1), 9(1), 11(2)	C: bark of *Quercus* sp.
		X: dead branches
Rusavskia elegans (Link) S. Y. Kondr. & Kärnefelt	1(1), 5(1)	S: concrete, eternit
Sarcogyne regularis Körb.	1(1), 5(1), 25(1)	S: concrete
Scoliciosporum chlorococcum (Graeve ex Stenh.) Vězda	11(1)	X: dead branches
Trapeliopsis flexuosa (Fr.) Coppins & P. James	3(1)	X: wooden handrail
T. granulosa (Hoffm.) Lumbsch	11(1)	X: rotten stump

Tab. 2 Continued

Species	Sites and numbers of records	Substrate
Xanthoria calcicola Oxner	1(1)	S: concrete
X. parietina (L.) Th. Fr.	1(2), 2(2), 3(2), 6(1), 9(1), 18(2), 23(4), 24(3), 25(2), 28(1), 29(1), 30(2), 31(2), 32(3), 33(11)	C: bark of *Quercus* sp., *Salix* sp., *Betula pendula*, *Sambucus nigra*, *Fraxinus excelsior*, *Malus domestica*, *Pinus sylvestris*
		S: concrete
		X: dead branches

C – living trees; S – rock-like substrates; T – soil; X – wooden substrates.

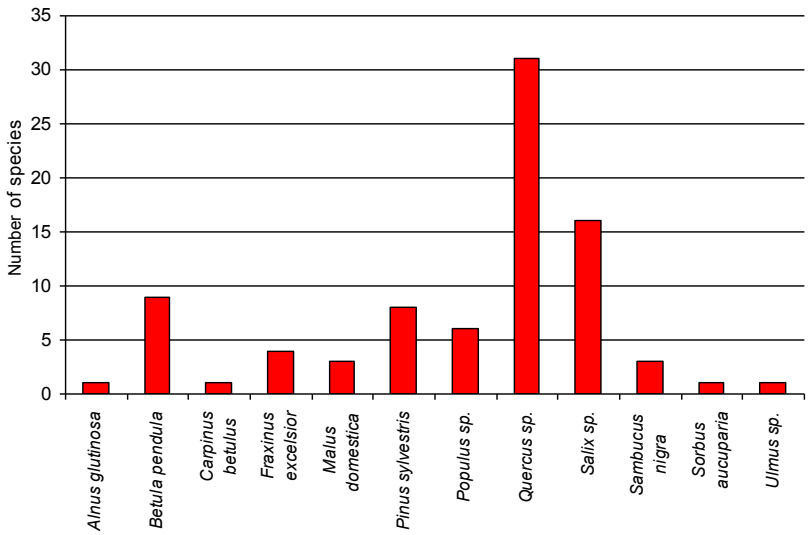


Fig. 5 The number of species recorded on particular phorophytes.

not recorded on other trees. The lush lichen vegetation on oak trees may be affected by their strongly cracked, subneutrophilous bark [12].

The group of epiphytes in the research area stood out both in terms of the number of species and the diversity of morphological forms. Most of them were foliose lichens (approx. 44%). The proportion of crustose species was slightly lower (32%). In addition, fruticose (two species), leprose (4), and squamulose (1) lichens were recorded on trunks, as well as three *Cladonia* species on the bark in the basal part of trees.

Epixylic lichens. Potential substrates for epixylic lichens in the study area were both decaying wood in the forest (e.g., stumps, logs, and fallen branches) and all kinds of wooden structures (fences, bridges, walls, buildings, etc.). These objects were very common and often colonized by lichens.

Most of the 23 species found on dead wood were facultative epixylic lichens, growing also on other substrates, soil (especially the genus *Cladonia*), or tree trunks (e.g., *Hypogymnia physodes*, *Lecanora conizaeoides*, *Parmelia sulcata*, and *Parmeliopsis ambigua*). Typical lignicolous species were represented by *Micarea prasina* s. l. and *Trapeliopsis flexuosa*.

Among the lichens recoded on wood *Cladonia* species dominated (48%). The proportion of crustose (26%) and foliose (22%) lichens was slightly lower. Species with squamulose thalli were the least numerous (4%).

Epilithic lichens. Natural rocks were not found in the study area. However, anthropogenic rocky substrates (mortar, bricks, tiles, and concrete) were numerous and widespread. For obvious reasons, such substrates occurred mainly in villages and, less frequently, in the area of the Stawno complex, however, were almost absent within the studied forest.

Epilithic lichen biota of the investigated area turned out to be quite homogeneous and not very numerous. Due to the chemical properties of most substrates, calciphilous lichens such as *Calogaya decipiens*, *C.* cfr. *pusilla*, *Candelariella aurella*, *Flavoplaca citrina*, *Lecanora albescens*, *L. dispersa*, *Lecidella stigmatea*, *Sarcogyne regularis*, and *Xanthoria calcicola* quantitatively dominated. On the non-calcareous substrates

(bricks and tiles) single records of species typical for siliceous rocks were noted: *Acarospora fuscata*, *A. smaragdula*, and *Lecanora* cfr. *cenisia*. Among the lichens found on the concrete, there was a high proportion of nitrophilous species, such as: *Pheophyscia orbicularis*, *Physcia caesia*, *Ph. tenella*, *Polycauliona candelaria*, *Protoparmeliopsis muralis*, *Rusavskia elegans*, and *Xanthoria parietina*.

Morphological diversity of epilithic lichens in the study area was limited to only two forms, crustose (12 species) and foliose (8).

Epigeic lichens. Terricolous lichens were recorded mainly on dry and poor sandy soil, characteristic for the investigated forest – pinewood with patches with a large proportion of terricolous lichens, physionomically related to the *Cladonio-Pinetum*. In these patches species of the genus *Cladonia* (*C. arbuscula*, *C. deformis*, *C. furcata*, *C. gracilis*, *C. pyxidata*, *C. rangiferina*, and *C. uncialis*) dominated, together with *Cetraria islandica*.

Other analyzed habitats seemed to be not suitable for the development of epigeic lichen biota, therefore terricolous lichens were recorded there only occasionally. Because of high humidity and fertility of the habitats in the Stawno complex, the exposed soil was colonized there mainly by mosses and liverworts. In this part of the study area only three species of terricolous lichens were recorded, namely *Cladonia chlorophea*, *C. coniocrea*, and *C. ochrochlora*.

Discussion

The Stawno complex in the eastern part of the Stawy Milickie nature reserve and its buffer zone have not been lichenologically explored till now. The only source of information on historical lichen biota in this area is the study by Glanc et al. [13] that applies to the Barycz district in the Kraina Wielkopolsko-Kujawska region according to geobotanical regionalization of Poland [14]. The area in which the lichenological inventory was then conducted included only the western part of the reserve. However, the geological and climatic uniformity of both areas and the lack of significant geographical barriers facilitated the extrapolation of the diversity of the lichen biota of the whole region in the 70s of the twentieth century, and compare it to the current situation (Tab. 3).

In the last 45 years the total number of lichens has decreased. What is more, there has also been the decrease in their diversity, which is expressed in the share of different groups of lichens varied in terms of habitat and morphological forms. Epiphytes and epixylic lichens incurred the biggest quantitative losses. Compared with the previous studies [13], forty-seven species of this group, especially lichens of fruticose and filamentous thalli, such as *Usnea hirta* and species of the genus *Ramalina*, have not been identified in our research.

A smaller number of species recorded in our study may be a result of the relatively restricted study area, the limited number of potential habitats (e.g., the lack of natural rock substrates in a form of glacial erratics) and incomparable character of forest communities. However, the main cause of the smaller number of lichens recorded in our study is probably connected with a change of habitat conditions and anthropogenic transformation of the whole environment, which can be observed throughout the region [15,16]. It includes, among others, the development of roads and the increased traffic congestion. All these changes resulted in the increase of air pollution and dustiness, causing the current dominance of common lichens on a wide ecological scale, e.g., *Lecanora conizaeoides* and *Hypogymnia physodes*, and also high proportion of nitrophilous lichens (*Physcia adscendens*, *Ph. tenella*, and *Xanthoria parietina*).

Similar status of lichen biota has been also reported recently from the forest reserves in southern Wielkopolska, which is adjacent to our study area [17,18].

Tab. 3 Comparison of the number of species in particular habitat groups of lichens in 1970 [13] and 2015.

	Barycz District (1970)	Stawy Milickie (2015)
Epiphytes and epixyles	96	49
Epilithes	41	20
Epigeites	17	9
All species	140	73

Tab. 4 The number of epiphytic and epixylic lichens recorded in the Stawy Milickie reserve and in the forest reserves of southern Wielkopolska [17,18].

Stawy Milickie	Dębno	Bodzewko	Czerwona Róża	Pępowo
49	40	14	20	34

Tab. 5 Lichen species threatened in Poland [19] occurring in the Stawy Milickie nature reserve.

Category of threat	Number of species	Name of species
EN	3	*Flavoparmelia caperata*, *Physconia distorta*, *Pleurosticta acetabulum*
VU	1	*Parmelina tiliacea*
NT	2	*Evernia prunastri*, *Hypogymnia tubulosa*

EN – endangered; VU – vulnerable; NT – near threatened.

Tab. 6 Protected lichen species occurring in the Stawy Milickie nature reserve.

Protection status	Number of species	Name of species
Strictly protected	1	*Parmelina tiliacea*
Partially protected	5	*Cetraria islandica*, *Cladonia rangiferina*, *Flavoparmelia caperata*, *Hypogymnia tubulosa*, *Pleurosticta acetabulum*

Despite the completely different character of the nature reserves (oak-hornbeam forest, acidophilus oak wood, mixed coniferous forest), the number of epiphytes and epixyles discovered there is comparable or smaller than in the Stawy Milickie nature reserve (Tab. 4). These two habitat groups of lichens are considered to be the most sensitive indicators of the environment state. Therefore it seems that the results of the study reflect the general lichen biota condition of western part of Polish lowlands and indicate that the reserve and its buffer zone are under the moderate impact of the human pressure. At this point, it should also be highlighted that in the study some vulnerable species were recorded, which are included to the red list of Polish lichens [19] (Tab. 5). In addition, six of the recorded species are protected by law in Poland [6] (Tab. 6).

Conclusions

- The presented results of lichenological investigations conducted in the eastern part of the Stawy Milickie nature reserve document the current state of lichen biota typical for the lowland part of Lower Silesia, as well as provide reliable data for further studies of its dynamics.
- The observed impoverishment in lichen diversity over the last decades is primarily associated with various human activities in this area. Transformations of the natural environment in the reserve (creation of new ponds, tourist centers, etc.) and other changes of habitat conditions have led to the disappearance of some lichen species recorded here in the late sixties of twentieth century [13], particularly sensitive macrolichens like *Anaptyhia cillaris*, *Bryoria crispa*, *Platismatia glauca*, *Melanohalea exasperata*, *M. elegantula*, or *Melanelixia glabratula*.
- During the study several vulnerable lichen species were recorded, namely *Evernia prunastri*, *Flavoparmelia caperata*, *Hypogymnia tubulosa*, *Parmelina tiliacea*, and *Pleurosticta acetabulum*. They were generally represented by single young thalli, with only the exception of *Evernia prunastri*, which was widespread on the investigated area and particularly abundant in a plot of an alder carr. Their appearance may be the sign of the recent improvement of the environmental conditions in the region.
- The Stawy Milickie nature reserve, being a vast area under protection and with a large variety of potential habitats, is a suitable object for long-term studies on the dynamics of lichen biota. For this purpose further lichenological investigations in this and adjacent areas will be undertaken, including permanent monitoring of epiphytic lichens.

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