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Botanical and mycological research of the Bielański Forest (Central Poland) during the twentieth century and current times

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Abstract

The Bielański Forest is one of the most valuable remnants of natural vegetation in Warsaw, being the subject of research since the 18th century. This article presents the research on vegetation cover and mycobiota of the Forest, conducted in the 20th century and to the present. The studies are discussed chronologically and divided by the biota of fungi and lichens, the flora of bryophytes and vascular plants, plant communities, veteran trees, and the issues of protecting these resources. The scope and completeness of the research results are discussed, particularly in the context of the forest's conservation status. Significant differences in the completeness of data were found between the individual groups of living organisms discussed. The identification of the vascular flora and plant communities is relatively complete, both in terms of historical and contemporary data. The assessment of the forest's conservation based on these components shows that it is a site that has undergone profound and unfavorable changes. The forest's flora includes common species, while the rare species are only locally rare. The identification of the bryophyte resources is similar to that of the vascular flora. Additionally, this group includes species considered as relics of primeval forests. The current state of knowledge about mycobiota resources is unsatisfactory. It requires compilation, analysis, and publication of existing data. A thorough assessment of the contemporary fungal biota would be useful, allowing for the identification of its changes in relation to historical data. It is also worthwhile to continue the relatively recent research on the lichen biota. The state of the fungal and lichen biota, despite existing deficiencies, currently gives an image of the relatively best condition of the Forest. The knowledge of the ancient trees and deadwood in the Bielański Forest is quite good, but it is worth supplementing it with, for example, maps showing their distribution. In future mycobiota studies, it would also be worthwhile to pay special attention to epiphytic and saproxylic microhabitats. The Bielański Forest also offers opportunities for historical research. Based on the species found here over nearly three centuries, it is possible to describe the forest's transformations resulting from the conditions in which it functioned.

Key words

research review, vascular plants, bryophytes, fungi, lichens, Mazovia

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Introduction

The Bielański Forest in Warsaw, has a long history of research. The first well-documented floristic data from this area come from the first half of the 18th century from the work of Christian Henryk Erndtnel (1730). The list of 36 taxa provided by him from Bielany was recently presented along with a critical analysis of it (Ciurzycki et al. 2025a). In the 19th century, many researchers worked at this site, collecting data, among whom Józef Rostafiński stands out. In his study of the Polish flora, he listed 45 species from Bielany (Rostafiński 1872). These data were recently presented along with corrections for later incorrect citations of this author (Ciurzycki et al. 2025b). Both lists, although modest in terms of the number of species, are valuable because most of these species no longer occur in Bielany, and among those that have disappeared are rare and very rare ones.

The 20th century was a time of great environmental changes in the Bielański Forest area. After World War I and Poland's regaining independence, the presence of Russian barracks in the vicinity of the Bielański Forest, which had lasted since the first half of the 19th century, came to an end. However, the pressure associated with this was replaced by the influence of tourism and recreation. Although this influence dates back to the first half of the 19th century, it gradually increased. The creation of the first cultural park in Poland on Bielany after World War II, in 1950, which became a place for mass recreation for Warsaw residents, was a manifestation of this (Baum and Stasiak 1963; Kosacka 1963; Chojnacki et al. 2010). The past century was also a period of significant habitat changes within the Bielański Forest area, particularly alterations in water relations. Between 1886 and 1903, a main sewage collector for Warsaw was constructed through the Forest, incorporating the Bielański Creek. Later, in 1926–1927, a flood protection levee was built, separating the Forest from the Vistula River and its natural floods. Even later, in the 1970s, a segment of the Wisłostrada expressway embankment was built right at the forest border (Czechowicz 1963; Trojan 1982; Chojnacki and Mróz 1984). During the interwar period, efforts were made to protect the Bielański Forest. These works and research continued into the 1960s, and finally, in 1973, a nature reserve was established here (Gajl and Kobendza 1932; Baum et al. 1982).

The aim of this work is to present the history of research on the flora, vegetation, and mycobiota of the Bielański Forest in the 20th century and in the first two decades of the 21st century. The most significant findings of studies on the transformations of plant communities, forest stands, and monument trees are also presented. In addition, the current state of knowledge, preservation, and protection of flora in individual groups of plants and fungal biota, as well as the prospects for further research in the Bielański Forest, were determined.

Material and methods

The study examines the occurrence of vascular plants and bryophytes as well as fungi and lichens based on available works from the 20th and the first two decades of the 21st century that focus on the Bielański Forest. It incorporates a comparative analysis of sources as described in detail by Ciurzycki et al. (2025a, b). Names of species from the discussed historical works are given in the text in their contemporary form, except for selected cases where older synonyms are also provided. The current names are given according to critical lists of vascular plants (Mirek et al. 2020), liverworts (Szweykowski 2006), bryophytes (Ochyra et al. 2003), lichens (Fałtynowicz 2003), and fungi (according to the Index Fungorum). The names used in the text are without their authors, except when presenting different taxonomic perspectives, in which case the names are given with authors. Historical names of plant communities are given exactly as they were originally spelled in the cited work. Modern names are given according to Matuszkiewicz (2008).

The area of flora, mycobiota, and vegetation analysis primarily covered the Bielański Forest itself, but also Bielany in a historical sense, understood as the Bielański Forest and its immediate surroundings. Additionally, the study includes contemporary Bielany, which currently refers to a district of Warsaw, covering a much larger area. In this sense, the territory also includes, in selected studies, other sites near the Bielański Forest, such as nearby Młociny, Wawrzyszew, Marymont, and the current Kaskada Park. Sub-sections in the Results chapter were organized differently for various taxonomic groups based on

the chronological development of research topics related to them.

Results

Research on vascular flora and vegetation during the interwar period

After numerous floristic studies in the 19th century, particularly in the 80s and 90s, a gap occurred during the first two decades of the 20th century. Research was resumed when, in revived Poland, the Department of Plant Systematics was established at the University of Warsaw. At that time, the head of this unit, Prof. Bolesław Hryniewiecki (1875–1963), played the roles of initiator and organizer of the work. He was a graduate of the University of Dorpat (currently Tartu), later a professor at the University of Odessa, a versatile botanist, author of works in the field of anatomy and plant systematics, floristics, and the history of botany, as well as an advocate for nature conservation (Skirgiełło 2001; Majewski 2010). Among the various topics related to plant cover, he initially focused not on continuing floristic research but on studying plant communities (Hryniewiecki 1937). In 1922, when Roman Kobendza (1886–1955) began studying botany at the University of Warsaw and collecting material for his doctoral thesis, Hryniewiecki pointed out a new method of studying plant assemblages that was emerging at the time and encouraged him to develop a phytosociological study of the Kampinos Forest (Hryniewiecki 1958). Kobendza, who later became a professor and head of the Department of Forest Botany at Warsaw University of Life Sciences (WULS-SGGW; Marciszewska et al. 2016), conducted his field studies in the 1920s not only in the Kampinos Forest but also in the Bielański Forest, located at its eastern edge.

One of the first studies from this period is the popular-science *Przewodnik florystyczny po okolicach i parkach Warszawy*, authored by Kobendza and Kołodziejczyk and prefaced by Hryniewiecki (Kobendza and Kołodziejczyk 1922). Among the sites identified as interesting for botanical excursions, Bielany was included and presented in the most detail. It describes the Bielański Forest south of the monastery, divided into the lower and higher terraces, as well as its northern part, the Vistula River bank, and further Młociny. Among several common plant species, in the Bielański Forest, in the pine stand, on the higher terrace, *Pulsatilla patens* was found – a species that has not been later recorded in Warsaw since World War II (Sudnik-Wójcikowska 1987), and is currently rare and endangered in Poland (Kaźmierczakowa et al. 2016).

Co-author of the above guide, Dr. January Kołodziejczyk (1889–1949), was involved in floristics, the history of botany, nature conservation, and the popularization of botanical knowledge (Hryniewiecki 1949). Earlier, he wrote a fairly extensive study titled *Krajobrazy roślinne nad Wisłą* (Kołodziejczyk 1921). In this work, he mentions, among other things, a "beautiful oak grove" in the Bielański Forest. In the description of the oak grove understory, he lists *Digitalis grandiflora*; however, it is not clear from the description whether this refers specifically to a location in the Bielański Forest or to oak understories "along the Vistula" in general. In a later monograph on the flora of Warsaw, the species was also recorded in oak stands but in a different, remote location on the right bank of Warsaw in the Anin and Wawer forests (Sudnik-Wójcikowska 1987). In another brief note on the flora of the Warsaw area, Kołodziejczyk (1922) mentions the location of *Ornithogalum umbellatum* –"which before the war still grew on the slopes of the monastery garden in Bielany". The species likely escaped from cultivation, much like in other locations in Warsaw and nearby areas, being not native, as also discussed later by Kobendza (1929). Subsequently, the species was recorded in other Warsaw locations as an ergasiophyte (an escaped cultivated plant) near allotment gardens (Sudnik-Wójcikowska 1987).

Roman Kobendza, prior to publishing the results of his extensive phytosociological studies from the Kampinos Forest (Kobendza 1930), issued a short botanical monograph of Bielany (Kobendza 1929). The work provides a description of the plant communities in the Bielański Forest and its neighboring non-forest habitats, as well as information on their vascular flora. In the main part, the author described six forest types and included a sketch of their distribution (at a scale of approximately 1:22,000). The characterization of the dominant *Alneto-Quercetum* forest on the lower terrace reveals the presence in the ground layer of species considered by the author in a subsequent chapter on flora as rarer and declining, for example, *Isopyrum thalictroides, Corydalis solida, Asarum europaeum*, *Paris*

quadrifolia, and *Pulmonaria obscura*. The next floodplain terrace community of relatively small area – the typical alder forest *Alnetum typicum* – mainly consisted of common wetland species in the ground layer. The area dominant in the central part of the Forest, the hornbeam-oak forest *Carpineto-Quercetum*, contained quite rare species such as *Phyteuma spicatum* and *Sanicula europaea*. In the description of the woody layers of this community, the author notes the almost complete absence of shrubs. The next three communities described were then heavily disturbed. The *Quercetum* oak forest, which dominated in the north, consisted of a stand of sessile oak with almost no shrub layer and very sparse flora in the herb layer, dominated by two species typical of trampled sites: *Poa annua* and *Polygonum aviculare*, along with the crop weed *Elymus repens*. In the southwestern part, over a large area, a *Querceto-Pinetum* forest with an oak-pine stand was present, also dominated by the mentioned apophyte species in the ground layer. In the ground layer of the *Pinetum* community at its edges, *Poa annua* grass prevailed, mixed with meadow and ruderal species.

Kobendza (1929) also described the influence of the Vistula River on the Forest and, among the non-forest plant communities present in its vicinity, mentioned ruderal ones as well. In the non-forest communities, the presence of, among others, currently rare, endangered, and protected species is noteworthy. In the description of the sedge meadow, the author listed orchids: *Dactylorhiza incarnata* and *D. majalis* (as *Orchis incarnatus* and *O. latifolia*). From the bentgrass meadow, he mentioned common *Helichrysum arenarium* and the rare *Viola rupestris* (*V. arenaria*). In the description of the blown sands located further south of Wawrzyszew, he mentioned *Pulsatilla pratensis* with a comment that this is the closest site to Warsaw. He also described an "acacia grove" along the Warsaw-Młociny road (now Marymoncka Street), which was "established by the Russians probably to shield the barracks and training area". The southern part of this black locust forest was occupied for the construction of the then-built Physical Education Institute (AWF), while in the northern part, this forest remains to this day. In the description of the area left after the demolition of the military settlement houses during the First World War, he listed numerous shrub species that remained from the backyard gardens. Among the cultivated ones, he mentioned *Staphylea pinnata* (now strictly protected as the species), which at that time occurred in this anthropogenic habitat.

In the above-discussed work, apart from information on plant communities, Kobendza also drew attention to the decline of species. In a separate chapter, he listed 31 vascular plant species recorded from Bielany by Rostafiński (1872) and their contemporary occurrences based on his own observations (Kobendza 1929), noting that at that time, 15 remained. However, this list contains errors in citing Rostafiński's data and is primarily incomplete, as Rostafiński (1872) listed 45 species from Bielany. A complete listing of these species, together with analysis, was only recently presented (Ciurzycki et al. 2025b). It shows that out of 45 species recorded from Bielany in the 19th century, Kobendza listed 19 in various places of his publication of 1929. Nevertheless, such a result cannot be considered complete because Kobendza's (1929) work was also incomplete in the data he collected himself. His study is only a brief phytosociological sketch, containing 7 relevés from an area of about 130 ha. In these phytosociological relevés and descriptions of forest communities, Kobendza listed a total of 147 vascular plant species. This was probably no more than half of the Forest's flora. A list published half a century later included 414 species (Sudnik-Wójcikowska 1982). In other studies, 286 species were recorded in 141 phytosociological relevés (Solińska-Górnicka and Symonides 1990). Kobendza (1929) mentioned a further 141 species in the remaining chapters, bringing the total to 287 plant taxa, including those located in the Forest. However, this probably represented about half of the flora of that broader area. Despite its fragmentary nature, Kobendza's work (1929), as the only one from that period, is currently a valuable source. It was later used many times for analyses of changes in the plant cover of the Bielański Forest and still remains helpful in this regard.

Shortly after the botanical study of Bielański Forest by Kobendza (1929), he published an article on rare species in the vicinity of Warsaw (Kobendza 1934). In this work, Bielański Forest was mentioned only in relation to one species, *Isopyrum thalictroides*. Among the rarer species listed in the work was, among others, *Iris sibirica*, but not from Bielany, although it had been previously recorded here by Błoński (1892). The fact that, at the turn of the 20th century, the most rare species

gradually disappeared from Bielański Forest was already reflected at that time.

Research on bryoflora from the interwar period to the late 1970s

In the 1930s, bryological research was also undertaken at the Department of Plant Systematics and Geography at the University of Warsaw, under the supervision of B. Hryniewiecki. He was an excellent expert on the flowering flora, but at that time, intensive work in this area was carried out at the Kraków research center. In this situation, he encouraged young researchers to focus on various groups of broadly understood spore-bearing plants, which were then less extensively studied, and he intended to specialise his department in this direction (Majewski 2010). The first data on the occurrence of bryophytes during this period were provided by Kobendza in the above-mentioned botanical monograph of Bielany (1929). His phytosociological tables and the accompanying text contain information about the presence of 21 moss species (Kobendza 1929). These are mainly forest mosses, with only two (*Polytrichum piliferum* and *P. juniperinum*) being typical for open sandy areas. In 1937, a monograph titled *Bryophytes around Warsaw*, prepared under the supervision of Hryniewiecki, was published (Hryniewiecki et al. 1937). This work includes a history of bryological research written by him (Hryniewiecki 1937) and studies of the following groups of bryophytes: liverhorns by Irena Rejmentówna, leafy mosses by Krystyna Stefanowicz-Owczarska, and peat mosses by Karolina Lublinerówna. In this publication, with reference to Bielany, one liverhorn – *Lophocolea bidentata* – was mentioned (Rejmentówna 1937). A total of 20 moss species were listed, mostly common, and four species not previously or subsequently recorded, including very rare species in the lowlands, such as *Didymodon acutus* and *D. vinealis*, as well as *Mnium marginatum* and *Polytrichastrum longisetum* (Stefanowicz-Owczarska 1937). No peat mosses were identified in this work (Lublinerówna 1937).

Research on the flora of spore-bearing plants was continued at the University of Warsaw after the Second World War. The study of bryoflora was conducted at that time by Prof. Irena Rejment-Grochowska (1911–1979), Dr. Dygna Sobotka (1927–1981), and Dr. Jadwiga Mickiewicz (1931–2025). Based on numerous bryological studies at the department, mainly in the 1960s and 1970s, many diploma theses concerning bryoflora were produced. However, data from Bielany were not published regularly. Among these works, there was the elaboration of the Warsaw escarpment, which also included Bielany (Skalińska 1965). Although only three sites were described in that area: one at the end of the escarpment in Młociny and two in Bielany (outside the reserve), 56 species were collected from them, including 13 previously unreported from Bielany. Among the most interesting species that were noted only once from there are *Lophocolea minor*, *Niphotrichum canescens*, and species previously recorded mainly in the 19th century, but no later: *Eurhynchiastrum pulchellum*, *Homalia trichomanoides*, *Leucodon sciuroides*, *Pohlia wahlenbergii*, *Rhodobryum roseum*, and *Tortula subulata*. The most valuable diploma thesis from that period is the monographic study of the bryoflora of the Bielański Forest itself (Bojanowska 1977). This is the first and, to date, the only detailed flora of bryophytes for this site, unfortunately remaining in manuscript form only. It lists 65 bryophyte species along with information on their habitats and their distribution across 71 sites within the reserve. Among the identified species, 17 were then new to Bielany. Some of them were also not reported later. Among the rarest and most interesting species are *Anomodon attenuatus*, *Bryum subapiculatum*, *Fissidens osmundoides*, *Orthotrichum gymnostomum*, *Oxyrrhynchium speciosum*, and *Pohlia annotina*. A comprehensive list of bryophyte species with sites in Bielany, encompassing both the interwar period and the aforementioned works, was compiled by Ciurzycki (2018).

Research focused on the concept of protection of the Forest

Efforts to protect the Bielański Forest began during the interwar period, and this was one of the goals of Kobendza's first botanical monograph of Bielany (1929). Kobendza was also a co-author of another monograph entirely dedicated to the need to protect the Bielański Forest (Gajl and Kobendza 1932). This work includes a chapter on the utilisation of the Bielański Forest and the anthropogenic pressures occurring within it, as well as recommendations regarding its protection (Gajl 1932). Furthermore, there is a description of plant communities and flora, as well as their transformations

(Kobendza 1932), which is a condensed version of the earlier monograph (Kobendza 1929).

In the post-war period, in addition to research on the composition of the vegetation of Bielański Forest, the issue of understanding its transformations, distortions, and the need for its protection was increasingly developing. This was due to increasing anthropogenic pressure, especially since the establishment of the Culture Park in Bielany in 1950 and the intensification of related unfavorable impacts.

Between 1958 and 1962, comprehensive studies of the Bielański Forest were conducted, some of which were published in *Rocznik Warszawski* journal in the form of five articles forming a cohesive whole titled *Las Bielański w Warszawie*. They essentially served as a monograph of this site at the time, but above all, provided a scientific justification for its protection. The core of this series consists of three articles. The first dealt with the history of the Bielański Forest and was, at the time, an original and extensive study, as this issue had not been previously described in detail (Kosacka 1963). The second article characterised the physiography and utilisation of the Forest (Czechowicz 1963). In the physiographic part, the following issues were described: terrain relief, geology, water conditions, soils, and climate. In the section illustrated with photos dedicated to utilisation, changes that had occurred in plant communities in relation to the state described by Kobendza (1929) were shown. The author cites results from an unpublished typescript by Maria Borowik (1961) *Opracowanie fitosocjologiczne zbiorowisk roślinnych Lasu Bielańskiego*, which stated that the previously described typical alder forest, identified by Kobendza (1929), had disappeared, and its dried habitat was taken over by a riparian forest (formerly described as an alder-oak forest). In turn, the dried parts of the riparian forest transformed into a low hornbeam forest (previously described as a hornbeam and oak forest). The utilisation issue concludes with a review of factors causing environmental degradation. The third article is a report on studies of the recreational attendance and use of the Forest (Baum and Stasiak 1963). These three publications are preceded by an introduction, which presents the assumptions and objectives of the entire project (Baum 1963a). Finally, a brief, synthetic summary of the research results and their derived conclusions is included. The most significant conclusion was that: "The area of the Bielański Forest in Warsaw should be protected by law as a unique monument of nature and culture of both the capital and the country." (Baum 1963b). The study concludes with an appendix comprising eight historical maps of the Forest, ranging from the turn of the 18th and 19th centuries to 1880.

Bielański Forest was designated as a protected reserve after another 10 years in 1973 (Zarządzenie… 1973). The protected area covered 130.35 ha, which was nearly the entire forest area within its pre-1914 borders. In the following decade, a book-length monograph about the Bielański Forest and its reserve was published (Baum and Trojan 1982). The monograph, after introductory chapters, begins with a chapter on the history of the forest (Kosacka 1982), which is a somewhat shortened version of a previous study (Kosacka 1963). Issues related to forest protection, ongoing changes, and conservation proposals are discussed in a separate chapter (Baum et al. 1982). Another distinct chapter is dedicated to urban and social conditions for preserving the reserve (Baum 1982).

The most comprehensive and extensive work in this monograph of Baum and Trojan (1982) was a chapter dedicated to the plant cover (Sudnik-Wójcikowska 1982). The phytosociological study by Borowik (1961), cited by Czechowicz (1963), is also mentioned here as a manuscript in the sub-section on plant communities. Several more recent, also unpublished, manuscripts from the 1960s and 1970s on floristics, phytosociology, ecology, and forest habitats are also listed. Based on three of them, with certain additions and modifications, plant communities were described. In the forest area, under contemporary names, the elm-ash *Ficario-Ulmetum* and the oak-hornbeam *Tilio-Carpinetum* forests were described. The chapter also includes an introduction to the history of botanical research as well as, for the first time, a complete list of the flowering flora, comprising 414 species with descriptions of their distribution. This list was mainly developed based on three earlier works, along with the author's observations and supplements (Sudnik-Wójcikowska 1982). Data related to the history of research and the historical flora, some of which were partially missing from this study, have now been supplemented and expanded (Ciurzycki et al. 2025a, b).

Research on vegetation in the second half of the 20th century

During the last quarter of the 20th century, comprehensive studies of the vegetation of Warsaw, including Bielański Forest, were conducted by the staff of the Department of Phytosociology and Plant Ecology at the University of Warsaw. The results of the floristic studies were published in the monograph *Flora miasta Warszawy i jej przemiany w ciągu XIX i XX wieku* (Sudnik-Wójcikowska 1987). The complete list of Warsaw's plants included 1,416 species, with historical and contemporary data, as well as distribution maps. Field data were collected between 1977 and 1982. Bielany was not only within the spatial scope of this work but also specifically mentioned in descriptions of selected, usually rarer, species (Sudnik-Wójcikowska 1987). The results of the phytosociological studies were published in the monograph *Zróżnicowanie przestrzenne roślinności Warszawy* (Chojnacki 1991), which includes, among others, maps of actual and potential vegetation, based on field data collected from 1977 to 1982 and supplemented in 1984. A synthesis of the results, covering flora and vegetation, was published in a joint publication regarding the impact of urbanisation on Warsaw's plant cover (Chojnacki and Sudnik-Wójcikowska 1994).

In the 1980s and 1990s, comprehensive floristic, phytosociological, and ecological studies of the vegetation cover in the Bielański Forest were also conducted at the Department of Phytosociology and Plant Ecology, University of Warsaw. First, changes in vegetation caused by anthropogenic modifications of hydrological conditions (Chojnacki and Mróz 1984) were described. Several moisture variants were distinguished in the alluvial and oak-hornbeam forests present here. For the ash-elm forest *Ficario-Ulmetum*, these were moist, typical, and drier, and for the oak-hornbeam forest *Tilio-Carpinetum*: two moist (one with *Aegopodium podagraria* and the second with *Corydalis cava* and *C. solida*) and the typical and drier variants. Historical and current changes in the water network caused by human activity were presented. It was found that most of these changes resulted in a lowering of the groundwater table and a decrease in flow in the watercourses. However, it was noted that the separation of the Bielański Forest from the Vistula River by the construction of a flood levee and the Wisłostrada embankment hindered water outflow from the terraces and contributed to the swamping of the lowest terrace. Changes in vegetation were described in relation to the state outlined in Kobendza's (1929) work. It was established that the previously described *Alnetum typicum* now more accurately represented a waterlogged form of the *Ficario-Ulmetum* rather than an oak grove. This community, similar to the former *Alneto-Quercetum* (i.e., the typical and drier variant of *Ficario-Ulmetum*), as well as the oak-hornbeam forests, exhibits the same trend of change, that is, the replacement of more hygrophilous communities and variants by drier communities or variants. Although these processes are still ongoing, they are stabilising in a state corresponding to current habitat conditions.

The next issue addressed was a comprehensive assessment of anthropogenic distortions of the forest based on the analysis of the share and distribution of forest and non-forest species, as well as species representing natural, semi-natural, and synanthropic communities (Solińska-Górnicka and Symonides 1990). In these studies, a network of 378 squares with sides of 50 m was established, within which research plots were designated. A total of 286 vascular plant species were recorded, including 149 diagnostic species syntaxonically. Typically forest species, characteristic of alluvial and oak-hornbeam forests from the *Querco-Fagetea* class, had the highest share, exceeding 60%, in areas situated in the lowest part of the Forest. The area where such a high proportion was found covered only 20% of the studied region. The share of non-forest species (i.e., those of forest edges and clearings, meadows, dry grasslands, and synanthropic communities) summed up to 38% of all species. These mainly concentrated on the forest edges, along pathways, and on former playgrounds. The study also examined the distribution of 53 anthropophyte species, with the highest presence recorded in the southern and western parts of the Forest.

The continuation of the studies (with the same methodology, i.e., the network of points and plots for plant inventories) was an assessment of the threat level to rare and endangered species within the reserve (Solińska-Górnicka and Symonides 1991). The work determined the share of different species groups to the flora of the reserve, particularly native forest species. Nine native forest plant species were listed as being particularly endangered within the reserve. These were *Asarum europaeum, Brachypodium sylvaticum, Carex digitata, Carex remota, Chrysosplenium alternifolium,*

Hypericum montanum, Isopyrum thalictroides, Paris quadrifolia, and *Phyteuma spicatum*. A group of seven other species, threatened to a lesser extent, was also distinguished. The study also noted the disappearance of 11 rarer forest species and 3 non-forest species previously documented by Kobendza (1929) and Sudnik-Wójcikowska (1982). The prospects for the continued presence of the rarest forest species were considered quite negative due to the intensifying adverse changes affecting both flora and vegetation.

In later studies, the changes in the population structure of the species within the stand were analyzed using a network of 94 plots, spaced 100 m apart (Symonides and Solińska-Górnicka 1991). In the populations of trees on floodplain habitats, a clear regression of *Alnus glutinosa* and *Ulmus laevis* was observed, expressed by the absence of seedlings and juvenile individuals. The structure of *Ulmus campestris* populations was somewhat more favorable, but only locally within the reserve. The most advantageous population structure, characterized by a dominance of young trees, was observed in *Fraxinus excelsior*. The lack of regeneration of the main floodplain species, combined with the considerable growth of *Carpinus betulus* and *Quercus robur*, confirmed the decline of floodplain forests and their succession toward hornbeam woods. In hornbeam forests, abundant natural regeneration of *Acer platanoides*, *Carpinus betulus*, *Cerasus avium, Quercus robur*, *Q. petraea*, and *Tilia cordata* was observed. Moreover, the absence of regeneration of species previously introduced to the forest was noted, most notably *Pinus sylvestris* and a few other species foreign to the area. Among alien species, the spreading of *Acer negundo* posed a serious threat. Its older individuals were found on the reserve's edge, while the youngest were also present within it, including the best preserved patches of floodplain and hornbeam forests.

By the late 1990s, a comprehensive study was published that detailed the long-term dynamics of vegetation in Bielański Forest, framing it as the transformation of a relic ancient forest within an urban context (Solińska-Górnicka et al. 1997). This study was based on 141 phytosociological relevés collected between 1987 and 1989, along with 52 repeated ones from 1996. It included, among other elements, a modified map of the plant communities derived from Kobendza's work (1929), with descriptions and classifications updated to current standards. The study observed distinct community changes, including a transition from *Querco-Pinetum* to *Tilio-Carpinetum calamagrostosum* and from *Circaeo-Alnetum* to *Tilio-Carpinetum* with *Alnus glutinosa*. Additionally, the phytosociological classification of *Carpineto-Quercetum* was refined, splitting it into *T-C typicum* and *T-C corydaletosum*. These communities exhibited a decrease in native species and the emergence of anthropophytes. Only *Ficario-Ulmetum* maintained its specificity; however, alongside the typical variant, two additional variants: one featuring *Carpinus betulus* and one dominated by *Alnus glutinosa* were identified. The study further predicted that if the groundwater level continues to decline and eutrophication increases – primarily due to the mass presence of roosting rooks *Corvus frugilegus* – all communities will likely transform into the *Tilio-Carpinetum* typicum form, characterized by *Impatiens parviflora* and *Sambucus nigra*, except for the *Ficario-Ulmetum*, which would evolve into the *T-C corydaletosum* form. The document includes a large-scale (1:4000) map of the vegetation, showcasing the distribution of 19 plant communities at the association, sub-association, or other syntaxa levels. Among these, natural and degenerated forests, as well as substitute forest and grassland communities, are distinguished. The results are presented in six tables, featuring 139 phytosociological relevés. This compilation is significant for providing a rich source of material that is much more extensive and detailed than Kobendza's study from the interwar period (1929).

Recently, the flora and vegetation surveys have appeared as chapters in a popular science ecological monograph of the Bielany district (Luniak 2010). In the chapter on vascular plant flora, it was stated that the number of recorded species in the district exceeds 760, which constitutes 64% of the approximately 1200 species found in all of Warsaw. This study pointed out that the flora of Bielany is undergoing dynamic changes, particularly over the past 200 years. It is estimated that at least several dozen native plant species have been irrevocably lost. On the other hand, some new valuable rare species are still being found. The most interesting and rarest species recently found in the Bielański Forest is *Corydalis intermedia*, discovered and confirmed here at the beginning of the 21st century (Pawlikowski 2004). The issue of alien species was also discussed in the monograph, concluding that the proportion of an-

thropophytes in the flora of Bielany is lower than in the city as a whole (Sudnik-Wójcikowska 2010). The chapter on vegetation discussed natural, semi-natural, and synanthropic types of forest and non-forest communities and presented a map of their distribution (Chojnacki and Kozłowska 2010).

Research on bryoflora at the turn of the 20th and 21st centuries

Since the bryological research conducted in the 1970s by the team of bryologists from the University of Warsaw (I. Rejment-Grochowska, D. Sobotka, and J. Mickiewicz) was concluded, no exclusive studies in this field have been carried out later by Warsaw researchers. Partial information about the presence of bryophytes can be found in the work on the dynamics of vegetation in the Bielański Forest (Solińska-Górnicka et al. 1997). The data contained in the tables published there include 28 bryophytes species, including *Orthodicranum montanum* – a species currently quite common, but previously not recorded from the Bielański Forest. The work also provided valuable information about another species, the rare epiphytic *Anomodon longifolius*, which was found here for the first time since the 19th century (Steinhaus 1887; Ciurzycki 2018).

New data for the Bielany bryophyte flora – understood not as the Bielański Forest and its immediate surroundings, but the entire current district of the city – include a study on the bryophytes of Warsaw's parks and cemeteries (Fudali 2003). The work lists 36 moss species from the Wawrzyszewski and Northern cemeteries (around Wólka Węglowa) and Kaskada Park (Marymont), located in the Bielany area in their narrow, historical sense. From a historical perspective, an interesting site is Kaskada Park, situated in the same place where, at the end of the 17th century, a park was established near the manor house "Marie Mont". This is where H. C. Erndtel embarked on his initial botanical studies when the site was a hunting residence of King August II (Erndtel 1730; Hryniewiecki 1954), and a hundred years later, when the park belonged to the Institute of Agricultural and Forest Sciences, bryophytes were collected here by W. Jastrzębowski (Majewski 1876).

A short, popular science description of Bielany's bryoflora can also be found in a natural history monograph devoted to this district of Warsaw (Luniak 2010). The section on flora includes a chapter on bryophytes, which does not provide a total number of species but lists 40 sample taxa representing various habitats and plant communities (Fudali 2010). This study includes, among others, the now common epiphyte *Dicranoweisia cirrata*, previously not recorded throughout Bielany and the neighboring Kampinos Forest (Ciurzycki 2018). In the monograph, in the chapter summarizing the state of Bielany's nature and its conservation needs, it is stated with regard to bryophytes that "There occur probably about half a hundred species in Bielany, mainly mosses, but also several species of related to mosses liverworts – rarely found in the city." (Luniak and Kozłowska 2010). Detailed data on the occurrence of bryophytes from the earliest research to the present day were compiled in a study on the history of bryophyte research in the Kampinos Forest and its surroundings, including Bielany (Ciurzycki 2018).

Research on mycobiota

In the 20th century, reports of fungi identified in Bielany were scarce. In the work of Prof. Józef Trzebiński (1867–1941), a botanist and phytopathologist, lecturer at WULS-SGGW, the University of Warsaw, and Stefan Batory University in Vilnius, among others, *Phylloporia ribis* on gooseberry was mentioned (Trzebiński et al. 1916). Prof. Józef Kochman (1903–1995), head of the Department of Plant Pathology at WULS-SGGW, listed fungi parasitising cultivated and wild plants (mainly microfungi) from the area. In the monograph of smut fungi of Poland from this area, he named two species: *Microbotryum cordae* as *Ustilago cordai* and *Sphacelotheca hydropiperis* (Kochman 1936). However, the well-known and esteemed herbarium publication *Mycotheca Polonica* contains seven species found and identified by Kochman or by his students and collaborators from Bielany: *Camarosporidiella elongata* as *Cucurbitaria elongata*, *Coleosporium campanulae*, *Golovinomyces depressus* as *Erysiphe depressa*, *Leptosphaeria dumetorum, Microbotryum anomalum* as *Ustilago anomala*, *Puccinia helianthi-mollis* as *P. helianthi*, and *Puccinia menthae* (Kochman 1959, 1964). Henryk Orłoś (1896–1983), a graduate of forestry at the Warsaw University of Life Sciences, phytopathologist, and professor at the Forest Research Institute, presented a photograph of a barberry leaf from Bielany showing symptoms of infection by *Puccinia graminis*

– the causative agent of stem rust disease in cereals and grasses – in the 1951 guide to identifying tree diseases and wood decay (Orłoś 1951). In the second half of the 20th century, scattered mentions of a few macrofungal species from Bielany can be found in the works of Prof. Alina Skirgiełło (1911–2007), a mycologist at the University of Warsaw, founder and chair of the Mycological Section of the Polish Botanical Society (1956–2007), as well as founder and editor of the journal *Acta Mycologica*. In her monograph *Rodzaj Russula w Polsce i w krajach ościennych*, Skirgiełło (1951) listed five species – *Russula adusta*, *R. atropurpurea*, *R. densifolia*, *R. ochroleuca*, and *R. risigallina*, listed as *R. lutea* – found in the Bielański Forest during the summer and autumn of 1943, that is, during the German occupation of Poland.

None of the species listed by Skirgiełło was mentioned by Błoński and Chełchowski in their works from the late 19th century. In a series of six articles on the distribution of higher fungi in Europe (*Materials to knowledge of the geographical distribution of higher fungi in Europe*) published in *Acta Mycologica* between 1965 and 1984, Skirgiełło lists several species of fungi collected and/or identified by herself, originating from the Bielański Forest, such as *Armillaria mellea* sensu lato or *Suillus bovinus* (Skirgiełło 1972), *Climacodon septentrionalis* (Skirgiełło 1976), *Cyathus olla*, and *Kuehneromyces mutabilis* (Skirgiełło 1984). Information about two rare species (*Onygena corvina*, *Xerula pudens*) found in the Bielański Forest is included in a work by Dr. Wanda Rudnicka-Jezierska (Rudnicka 1960), a mycologist from the University of Warsaw. In the Bielański Forest, on wood, the presence of 13 species of dark-pigmented, conidial fungi characterised by darkly colored hyphae and spores (including *Chloridiopsiella preussii* as *Chloridium preussii*, *Chaetopsis grisea*) was confirmed by Assoc. Prof. Alicja Borowska, a mycologist and microbiologist from the University of Warsaw (Borowska 1986). In the early 1980s, Tomasz Oszako, a graduate of forestry at the Warsaw University of Life Sciences, phytopathologist, and later a professor at the Forest Research Institute, found, during his master's thesis research on the distribution of the bioindicator fungus *Rhytisma acerinum*, indicative of air pollution changes, its abundant occurrence in the Bielański Forest (Oszako 1985). Nine species of entomopathogenic fungi from the order *Laboulbeniales* (e.g., *Euzodiomyces lathrobii*, *Laboulbenia calathi*) from materials originating from Bielany were published by Prof. Tomasz Majewski (2008) from the Department of Plant Pathology at WULS-SGGW. Data on the mycobiota of Bielany can also be found in various unpublished materials, such as *Plan Ochrony rezerwatu Las Bielański* (Miścicki 1992) and in master's theses conducted at the Department of Forest Protection at WULS-SGGW (e.g., Sawicki 1981; Żółciak 1981; Kalinowska 2007).

The summary of the recognition of macrofungi was only provided in the 21st century. In the natural history monograph of Bielany (Luniak 2010), the chapter on fungi, Szczepkowski and Sierota (2010) reported that, based on both literature data and their own research, over 300 species of macrofungi have been identified within the district. They provided numerous examples of fungi and discussed their habitats. However, the popular science character of the publication did not permit the publication of a complete list of species. The data for the current Bielany district mainly come from the Bielański Forest and from Bielany in the historical sense. Among the given approximately 300 species, 57 (approximately 20%) are listed on the Red list of threatened macrofungi (Wojewoda and Ławrynowicz 2006). Two of them, *Hapalopilus croceus* and *Hericium erinaceus*, which are threatened in Europe, are under strict protection in Poland and have been included among the 33 species of fungi proposed for inclusion in Annex 1 of the Bern Convention (Kujawa et al. 2020b). There are also fungi here that are under partial protection: for example, *Fistulina hepatica*, *Grifola frondosa*, *Ganoderma lucidum*, and *Inonotus obliquus*, as well as species that were previously protected but now do not have such a status and are relatively common, such as *Calvatia gigantea*, *Geastrum triplex*, and *Sarcosypha austriaca*. The species included in the Red List of macrofungi of Poland (Wojewoda and Ławrynowicz 2006) include, among others, *Phleogena faginea*, *Sarcodontia spumea* (*Spongipellis spumeus*), *Volvariella bombycine*, and *Xylobolus frustulatus* (Szczepkowski et al. 2008; Szczepkowski and Piętka 2008; Szczepkowski and Sierota 2010; Szczepkowski et al. 2013; Szczepkowski and Kowalczuk 2020).

Within Warsaw, the greatest amount of data on mycobiota has been gathered from the Bielany area. This is largely due to the historical research conducted by Chełchowski (1888, 1898) and Błoński (1896) in the late

19th century. Both authors identified a total of approximately 223 species in Bielany (16 Ascomycota and 207 Basidiomycota), of which 15 belong to microfungi and 208 to macrofungi. Since the time of these researchers, over 130 years ago, systematic studies on mycobiota have not been carried out in the Bielański Forest. Modern data usually come from individual reports concerning selected species of fungi. The data collected by A. Szczepkowski from the late 20th century onward are the result of his observations during teaching sessions with WULS-SGGW students, field sessions of the Phytopathology Section of the WULS-SGGW Forestry Students' Scientific Association (Grzywacz and Szczepkowski 2023), private walks, and, more recently, mycological workshops organised by the Warsaw Municipal Forests, including in the Bielański Forest. Among the dozens of previously unpublished species from the Bielański Forest, some examples include *Amanita phalloides, Bolbitius titubans, Byssomerulius corium, Calycina citrina, Coniophora puteana, Daldinia petriniae, Fomitopsis pinicola, Fuscoporia ferruginosa, Gloeoporus pannocinctus, Gloeophyllum sepiarium, G. trabeum, Gymnopilus penetrans, Gymnopus fusipes, Gyroporus cyanescens, Hohenbuehelia atrocoerulea, Inocutis dryophila, Inonotus cuticularis, Lyomyces sambuci, Neonectria coccinea, Ossicaulis lignatilis, Otidea onotica, Pallidohirschioporus biformis, Phaeolus schweinitzii, Phallus impudicus, Peniophora rufomarginata, Phyllotopsis nidulans, Picipes badius, Pleurotus pulmonarius, Skeletocutis amorpha, Stereum gausapatum, Trametes gibbosa, T. trogii, Trametopsis cervina, Tricholoma populinum,* and *Xylodon flaviporus*.

More detailed discussion of the historical data from Chełchowski's (1888, 1898) and Błoński's (1896) works, including, separately for both authors, the number of species in various groups of fungi, has recently been summarised in a study dedicated to the research of the Bielański Forest in the 19th century (Ciurzycki et al. 2025b). This study found that, out of the 30 species recorded in the 19th century, only 6 species, now recognised as threatened and protected, were documented in the Bielański Forest at the turn of the 21st century. However, it is difficult to say whether this indicates a decline of 80% of the previously reported species. The analysis of the decline of fungal species is not directly comparable to that of vascular plants, for example, because historical data are relatively extensive, whereas contemporary data are fragmentary. Considering the immediate and wider surroundings of the Bielański Forest in Warsaw and the Kampinos National Park, current information is available for 19 of the 30 mentioned species. It can be assumed that conducting current detailed studies of mycobiota in the Bielański Forest would yield data on a greater number of species that have remained there since the end of the 19th century.

Just as in the case of bryophytes, even in fragmentary data, the proportion of species from threatened and protected groups is higher than among vascular plants, drawing attention. These differences mainly result from a large number of species in the red-listed fungi group. Comparing the lists of plant and fungi species in this respect, it is evident that, in the case of plants, species classified in this group are generally significantly rarer than in fungi. Such a conclusion is supported not only by partial data from Bielany but also by examples from other well-studied sites. For this reason, comparisons of different taxonomic groups regarding the conservation status of threatened and protected species are not entirely justified. To some extent, the inference about the condition of the Forest based on the occurrence, at least of some, of species from the red list of fungi (Wojewoda and Ławrynowicz 2006) also seems questionable. A more accurate measure of the forest's conservation status appears to be the presence of protected fungal species (Rozporządzenie… 2014).

Research on lichen biota

From the interwar period, only fragmentary data on the lichens of the Bielański Forest are available. They are included in Kobendza's study (1929), in which three epiphytic species were listed: *Hypogymnia physodes*, *Platismatia glauca*, and *Pseudevernia furfuracea*. In the 1970s, in a little-known study entitled *Porosty Warszawy jako biowskaźniki zaburzeń środowiska miejskiego* (Zimny and Kucińska 1974), 78 species of lichens from the Warsaw area were reported. From the zone rich in lichens, called "normal", 71 species were listed. This zone included, among others, the Bielański Forest and other larger green areas such as the Wilanowski, Łazienkowski, Ujazdowski, and Skaryszewski parks. In these areas, 32 species not found in the urban zone (divided into subzones: rocky and desert areas without lichens) were identified. Some species were undoubt-

edly collected in the Bielański Forest, but their exact locations were not specified in the species list. In the early 21st-century natural history monograph of Bielany, the chapter on lichens listed 36 species, noting that this was not a comprehensive list (Koziarska 2010). In this brief popular science publication, only a few examples were provided, mainly at the genus level.

The first comprehensive studies of the lichen biota of the Bielański Forest Reserve were conducted in 2009 (Kubiak et al. 2010a). At that time, 68 species of lichens were recorded, along with three species of lichenicolous fungi, including two relatively common ones: *Athelia arachnoidea*, *Lichenoconium lecanorae*, and the very rare *Sphinctrina anglica*, as well as one species of slime mold – *Licea parasitica*, traditionally classified as a lichenicolous fungus. The above data also included 14 species from a list published for Warsaw in the 1970s (Zimny and Kucińska 1974). Among the lichens, nine species protected in Poland (in accordance with the regulations of that time) were identified, for example, *Melanelixia fuliginosa, Parmelia saxatilis*, and *Platismatia glauca*. Fourteen threatened species listed on the red list were recorded, including two in the endangered category (EN): *Chaenotheca stemonea* and *Opegrapha vermicellifera*, six at risk of extinction (VU): *Bacidia rubella, Melanohalea elegantula, Parmelina tiliacea, Porina chlorotica, Thelocarpon intermediellum, Usnea hirta,* and five near threatened (NT) and one of lower concern (LC) (Cieśliński et al. 2006). In total, 19 species of protected and threatened taxa were documented. The study also included the area adjacent to the reserve, where in the forest stand with *Robinia pseudoacacia*, 11 lichen species were found that were also recorded within the reserve. In the discussed publication, Kubiak et al. (2010a) did not distinguish the category of relic forest species. However, one species from this group was listed: *Opegrapha vermicellifera* (Cieśliński et al. 1996).

The confirmed biota of lichens was recognised as moderately rich and diverse, considerably less numerous than on a comparable area in natural forest communities. However, it was also characterised as a relic. The recorded species, although not very numerous, can be considered as natural components of the forests. Additionally, the proportion of synanthropic lichens is minimal (Kubiak et al. 2010a). A significant achievement, described more precisely in a separate study, was the discovery of two interesting taxa: a very rare lichenicolous fungus, *Sphinctrina anglica*, and the lichen on which it was found, *Protoparmelia hypotremella* (Kubiak et al. 2010b). The Bielański Forest remains, thus a refuge for rare lichen biota species, not only for Warsaw and its surroundings but also across Poland.

Old and majestic trees in the Forest

In the Bielański Forest, attention was drawn to the magnificent trees and the necessity of their protection quite early on. This stemmed from a strong interest in safeguarding old trees or other natural peculiarities and their inventorying, initiated in the 19th century, as part of the conservation movement for nature protection. Already in the mid-19th century, Połujański (1854), describing the Bielański Forest, emphasised that it was the only forest subject to the Institute of Agronomy in Marymont to have a management plan, which also included the ages of the pines and oaks. The Bielański Forest was then divided into two management districts: in the first, covering the higher, sandy terraces, there was a mixture of pine and oak aged 100–150 years, while in the second, covering the fertile and moist terraces, the dominant species was a 200-year-old oak with some admixture of ancient pine trees.

From the interwar period, we learn about the oldest trees in the Bielański Forest and the measurements of some of them from Kobendza's works (1929, 1932). In the first monograph of Bielany, describing the alder-oak forest, the author drew attention to the oldest and largest oaks (Kobendza 1929). From the description, it appears that these trees were numbered at the time and their age was recorded. Kobendza thus used the existing inventory. He listed the six oldest oaks, giving their numbers and trunk circumferences. The largest had the "faded no." and a circumference of 5.5 m. The others were nos. 47 – 4.5 m; 21 – 4.45 m; 19 – 4.27 m; 51 – 3.73 m, and no. 20 – 3.50 m. He further wrote, "These are old trees, but their measurements cannot be taken as an indicator of longevity calculations. On moist sites, the oak grows quickly, producing annual increments of 1 to 1½ cm thick. Therefore, the age: 300, 350, or 400 years, given on the trees, should be regarded as questionable, as it may turn out that the oldest oak is just over 300 years, and the majority will be at most 200 years old." He then described the phenomenon of their dying, manifesting

as the drying of the tops of the crowns and noted that "The mighty oaks that we can still see among the alders are witnesses to former, more suitable edaphic conditions. There is not a year that one of these giants does not fall; currently, one of the thickest, oldest oaks is nearing the end of its life." This oak, with a circumference of 5.5 m, was depicted in a photograph, and the description included, among other things, that the crown is slowly drying out, with only the two lowest branches remaining alive (Kobendza 1929).

In the grove at the northern edge of the high terrace extending toward the Vistula, there was a uniform stand of *Quercus petraea* with specimens reaching approximately 2 m in circumference and 20–25 m in height. In another location within the hornbeam-oak forest, the thickest and likely the oldest pine in the Bielański Forest was described, with a circumference of 2.86 m and a height of up to 30 m. In turn, the description of the pine woodland mentioned several old pines, aged between 130 and 150 years, with a circumference exceeding 2 m and a height of over 30 m. Regarding the oldest oak and the thickest pine, as well as other trees, Kobendza wrote similarly three years later in a study on the Bielański Forest dedicated to their preservation needs (Kobendza 1932). Later, data from this work, referring to the entire monograph (Gajl and Kobendza 1932), appeared in an inventory of monument oaks in Poland. Item number 398 includes an information: "Bielany. Several old oaks, the thickest of which has a circumference of 5.50 m." (Środoń 1934).

The monograph *Bielany pod względem botanicznym* (Kobendza 1929) contains yet other valuable observations about trees. In his description of a pine forest, he noted that some pines had dense, intertwined branches, which he believed was caused by the presence of the fungus *Melampsorella caryophyllacearum*, now known as *Melampsorella elatina* (Alb. & Schwein.) Arthur. However, this was a misdiagnosis, as this fungus occurs only on fir, and the observed witch's broom symptom could have been caused by a phytoplasma. A little further on, he noted also: "On the tops of older pines, we often encounter narrow-leafed mistletoe (*Viscum angustifol*ium Wiesb.) in large, isolated clumps. This is the closest occurrence of mistletoe to the Warsaw area" – as Bielany was not a part of Warsaw at that time. In our work, we refer to mistletoe as *Viscum album* s.l. because it was first described from Bielany by Błoński (1892) under the name common mistletoe *Viscum album* L., who also recorded it in neighboring Babice. The taxon mentioned by Kobendza is currently a subspecies of common mistletoe *Viscum album* L. subsp. *austriacum* (Wiesb.) Vollm. The herbarium of the Faculty of Biology, University of Warsaw, contains 26 specimens of mistletoe *Viscum album* subsp. *austriacum* collected from *Pinus sylvestris* in the years 1868–1978 in various parts of Poland. One specimen with a preserved fragment of a pine branch comes from the Bielański Forest (Buraków), where it was collected in 1904 by Jan Muszyński (1884–1957), later a professor at the University of Vilnus and Łódź, a botanist, and pharmacist, with a host annotation on the envelope label – "on pines and poplars" (WA0000075394). This plant was not recorded in any subspecies in the 1980s, neither in the Bielański Forest itself nor in its immediate vicinity (Sudnik-Wójcikowska 1982, 1987). The above data indicate a relatively wide distribution, although initially a rare occurrence of *Viscum album* subsp. *austriacum* on pine in Poland since at least the mid-19th century, which may explain why it was not recorded in studies conducted in the 20th century. Only recent years have brought the expansion of this species, which negatively affects the growth and health of pine stands in Poland (Szmidla et al. 2019; Iszkuło et al. 2020). For several years, Szczepkowski (data unpublished) has been observing mistletoe on many pines in the Bielański Forest, both within the reserve (including sections 5, 10, 12, 13) and in its buffer zone on the side of Marymoncka Street. Based on the size of the largest mistletoe shrubs (diameter approximately 0.5 m), their age is estimated to be at least a dozen years, which indicates that their current presence in the Bielański Forest has been ongoing since at least the early 21st century.

In the 1950s, engineer Ryszard Zaręba (1924–1994), who later became a professor at the Faculty of Forestry at WULS-SGGW, drew attention to the old and majestic oaks in the Bielański Forest. He utilised the fact of felling dried-out trees to determine the age of seven specimens. Their ages ranged from 209 to 312 years (average 256), and the diameters of the trunks without bark at a height of 30–40 cm ranged from 92 to 120 cm. One of the causes of the decline of old oaks was attributed to drainage conducted during the interwar period, which lowered the groundwater level. The maladaptation of the venerable trees to the newly created conditions re-

sulted in the appearance of dry crowns, basidiomata of fungi such as *Fomes fomentarius* and *Phellinus* species, as well as insect feeding, including stag beetles *Lucanus cervus*, ultimately leading to the death of entire trees (Zaręba 1958). The results of these studies were, therefore, consistent with the estimations of the trees' ages and the diagnosis of their decline according to Kobendza (1929).

In the list of nature monuments of the then Warsaw Voivodeship as of 31 October 1985 (Łaszek and Sendzielska 1989), there was an oak with a trunk diameter of 6.6 m (?) and a height of 30 m, growing in section 5d of the Bielański Forest. The guidebook *Najstarsze drzewa w Polsce* (Pacyniak 1992) likely mentions the same monument oak, with a circumference of 541 cm, a breast diameter of 172 cm, and a height of 35 m, with an estimated age of 354 years and a health status classified as level 2 (i.e., a tree with partially dead, thinner branches in the upper parts of the crown and with the presence of pests and fungi in minor amounts). The author also notes the presence of not only old oaks but also black alders, elms, hornbeams, small-leaved limes, and a few maples growing in the floodplain and oak-hornbeam forests of the Bielański Forest reserve.

In the years 1996–1997, during inventory and assessment of the health status of oaks in the Bielański Forest, 1029 living specimens with a circumference greater than 250 cm, measured at a height of 1.3 m, were identified, including 516 specimens with a circumference over 300 cm and an average crown loss of approximately 35% (Łukaszuk 1997). In 2012, about 10% of the old oak trees, both living and dead, were found to have the basidiomata of *Fistulina hepatica* (Szczepkowski 2020).

Other recent geobotanical research

Due to its location within a large urban agglomeration, the forests of Warsaw are particularly susceptible to various forms of anthropogenic pressure. In 2012, on behalf of the Municipal Forest enterprise, employees of the Warsaw University of Life Sciences Department of Forest Sciences conducted comprehensive studies on the condition of 15 forest complexes in Warsaw. The Bielański Forest stands out positively in comparison to others in terms of the state of preservation of phytocoenoses among Warsaw's forest complexes (Ciurzycki and Marciszewska 2018). It was found to have nearly the highest proportion of natural and minimally disturbed forest areas. Only the Sobieski Forest was rated slightly better in this regard. The significantly lower disturbance in the Bielański Forest compared to other Warsaw forests primarily results from the fact that these are typically secondary forests, often established relatively recently, and frequently beeing forest substitute communities, influenced by regular forest management practices. Currently, the main factor distorting the phytocoenoses in the Bielański Forest is intense recreational use. It is also important to remember that part of the Bielański Forest (not protected as a reserve) was formed on post-agricultural lands as secondary communities. Nearly 12% of the forest area consists of forest substitute communities with *Robinia pseudoacacia* that originated about 100 years ago. As a result, neophytisation and pinetisation (sensu Olaczek 1974) are distinctly noticeable among the types of the Forest stand distortions. A significant proportion of stands with various mixed forms of distortions have also been here observed (Ciurzycki and Marciszewska 2018).

In terms of synanthropisation of the flora, out of 15 inventory-registered taxa in the Warsaw forests, 10 species were found in the Bielański Forest, that is, *Acer negundo, Fraxinus pennsylvanica, Impatiens parviflora, Parthenocissus quinquefolia, Prunus serotina, Quercus rubra, Reynoutria* sp., *Robinia pseudoacacia, Solidago* sp., and *Syringa vulgaris*. The most common species here were *Impatiens parviflora* (on over 70% of measurement plots) and *Acer negundo* (on approximately 37% of measurement plots). A total of 87% of the plots were colonised, with an average of 1.9 species per plot and an average cover of 31.5% on the plot. The study showed that within this range, the Bielański Forest is the third most extensively colonised urban forest complex in Warsaw by alien plant species (Obidziński et al. 2016).

In terms of the presence of dead wood, among the 15 surveyed forest complexes in Warsaw, the Bielański Forest has not only the highest amount of dead wood per ha – 33.5 m^3/ha – but also significantly more than the next in the ranking, Kabacki Forest (18.99 m^3/ha). In the remaining cases, this value ranges from a few to a dozen m^3/ha, with an average of 13.71 m^3/ha (Skwarek and Bijak 2015). The mycobiota of the Bielański Forest includes 65 species of epixylic fungi and two species on tree leaves, already known from

this site. The same number was found in Kabacki Forest. In the other complexes, the number of epixylic fungi observed varies from 18 to 49 taxa (J. Piętka 2012, unpublished data).

The issue of distortions also appears in other contemporary studies of the Bielański Forest, particularly those concerning the neophyte transformation of flora and the possibilities of counteracting this process. The presence of approximately 100-year-old spontaneously developing forests of *Robinia pseudoacacia* in the Bielański Forest allowed the testing of methods for their reconstruction. Between 1992 and 2007, *Robinia* was gradually removed from stands where the second layer was formed by common maple and sycamore. The procedures carried out proved to be an effective method of eliminating *Robinia* since it does not regenerate under the dense canopy of the maples (Gazda and Miścicki 2012). This treatment consequently increased the proportion of common maple and sycamore in all layers, contributing to the further naturalisation of the entire phytocoenosis. However, the reconstruction process could not be completed within the planned time because residents' protests in 1999 led to the suspension of the works (Miścicki and Wysocka-Fijorek 2021). The work was resumed in 2021.

The current transformations of the forest's vegetation are primarily due to recreational activity. The impact of this factor on changes in the forest floor has been described in the vicinity of paths in the dryer variant of oak-hornbeam habitats (Grutkowska 2010; Zdanowicz and Skłodowski 2013). From the mid-1980s to the end of the 20th century, the Bielański Forest also served as a winter roost for a population of corvids numbering over 100,000 individuals. This factor, which through eutrophication causes changes in communities, has been noted previously (Solińska-Górnicka et al. 1997). This issue was recently described in detail in a separate study. It was found that birds caused significant transformation of the vegetation. The intensity of changes varied across the different layers of the community: with the weakest among trees, moderate among shrubs, and the strongest in the forest floor. In the stand, this was seen as tree dieback, while in the shrub layer, the expansion of black elderberry *Sambucus nigra* indicated significant eutrophication. In the groundcover, the decline of rare native species and their replacement by alien species, neophytes, was observed (Maksym and Sławska 2011). Currently, a gradual regeneration of these phytocoenoses is taking place.

Discussion

In studies concerning the nature of Warsaw, the Bielański Forest is described as an extremely valuable object. It is also often referred to as a relic of the "Mazovian Forest". However, it is worth noting that the use of the term "Puszcza" (primeval forest) with a capital letter to describe the original forests of Mazovia could be questionable as a proper name. In older sources concerning the history of forests and forestry, the name "Puszcza Mazowiecka" was not used. These are primarily forests that largely no longer exist and are not clearly defined. Therefore, the name should not carry the character of, for example, the nearby Kampinos Forest (Heymanowski 1965, 1966, 1969; Zaręba 1986). Regardless of this, there is no doubt that the Bielański Forest is an "old forest" in the sense of a forested surface area that reaches back to the original primeval forest in Mazovia. This is a relatively rare situation within urban areas, including Warsaw. The remaining forest complexes in Warsaw are comparatively young, mostly originating from reforestation efforts, often on post-agricultural land, shaped under the influence of forest management, and characterized by a high proportion of substitute forest communities (Ciurzycki and Marciszewska 2018). In this context, the Bielański Forest can be considered close to natural (Symonides and Solińska-Górnicka 1990). However, the question remains as to what the current state of preservation is, how much of the former primeval forest remains, and what the current value of the Bielański Forest is, as well as what its conservation goal should currently be.

The Bielański Forest undoubtedly holds significant historical and cultural value, including for the history of botanical research. This stems from numerous studies conducted here over the past few centuries. It can be said that research on specific branches of botany originated here, and many distinguished botanists have worked in this area (Ciurzycki et al. 2025a, b). In this way, the Bielański Forest is among the top ten sites with the most historically documented botanical studies in Poland (Obidziński 2023). As noted in the most recent monograph on Bielany, it has been studied significant-

ly longer than the Białowieża Forest (Chojnacki et al. 2010). It is also worth remembering its importance not only for advancements in botanical research, including mycology, but also in zoological and non-living nature (Jakubowski et al. 2010).

Botanical research in the 20th century, as in the previous two centuries (Ciurzycki et al. 2025a, b), was most abundantly represented by studies of vascular plant flora. This was the starting point for research, and it is in this area that the greatest changes have occurred. Over 140 years ago, K. Łapczyński stated that "the Bielański Forest had until then been the capital of vegetation in the Warsaw area", adding that due to strong human pressure and the disappearance of species, this state would soon change (Łapczyński 1882). Unfortunately, recent analyses have fully confirmed this diagnosis. It is worth noting that the process of impoverishment of the Bielański Forest flora likely began in the 18th century. Of the species listed by Erndtel that have disappeared to this day (20), half (10) have not been recorded by any subsequent author. They were, therefore, not recorded not only in the 20th century but also throughout the 19th century, including the earliest comprehensive study from that period, by Szubert (1824), presenting the rich flora of the Warsaw area. Among the species that disappeared here were the rarest plants, not only from the Bielański Forest but also from Mazovia and Central Poland (Ciurzycki et al. 2025a).

The Bielański Forest, as a refuge for vascular flora, long ago lost its significance on a scale larger than the city. Therefore, its value today manifests itself primarily in its historical aspect, where it will forever remain significant. The data it provides, albeit fragmentary, reach back 300 years. This includes information on many species, now very rare in the region and in Poland. This enables the study of flora transformations, both in Warsaw and in Mazovia, as well as on individual species (Ciurzycki et al. 2025a, b). The data used here, as the final stage of the analyses, are also essentially historical, dating back three to four decades. Therefore, it needs updating. However, it is currently only marginally relevant for further analysis of the flora's decline. It appears that the most significant changes in this area have already taken place. It is likely that only species that are largely tolerant of human impact will remain. Current and future research should focus on the process of species arrival, including expansive apophytes, and especially anthropophytes, including invasive species. The Bielański Forest can serve as a model example of the transformation of flora in a former forest fragment under the long-term pressure of various factors related to its location within a large urbanised area (Symonides and Solińska-Górnicka 1990).

Data on bryophytes largely come from historical studies of varying degrees (Ciurzycki 2018). Recent scientific studies either focus on sites outside the Forest (Fudali 2003) or are derived from phytosociological studies (Solińska-Górnicka et al. 1997). The material contained in phytosociological relevés is likely quite comprehensive with respect to the forest floor. However, in accordance with the methodology, it does not include information on epiphytic and epixylic species, which are important for understanding the entire bryoflora of the forest. Due to the lack of comprehensive contemporary data, the summary of the number of species from this group that have occurred in the past and present is only approximate. However, similar trends are visible here, namely a decline in species richness overall, and most significantly in the groups of endangered and protected species, as well as relict species of primeval forests.

The species diversity of macrofungi in Bielany, encompassing a list of 300 species, including 57 threatened species, is not particularly large, considering it is a remnant forest. For comparison, for example, in the Strict Protection Area Przyćmień (109 ha) within Kampinos National Park, 303 macrofungal species have been recorded during just a few visits conducted during the Park's 3-year studies of its macromycobiota (Karasiński et al. 2015). And in the Osetno reserve (112.22 ha) located in the Szczecin Landscape Park Puszcza Bukowa, 20 years of research resulted in a list of almost 600 species of macrofungi (Domian et al. 2025). Even in anthropogenic environments, such as parks and botanical gardens in Poland, the number of species exceeds 200 (Szczepkowski 2016), with some locations reaching as many as 333 taxa, such as in the Palatial Park in Poznań-Radojewo, covering less than 22 ha (Kujawa et al. 2020a), which is much smaller than the Bielański Forest. In Warsaw's Skaryszewski Park, established in the early 20th century, over 130 species have been observed, including 19 listed on the Red List (Szczepkowski 2016, 2021). Of a selected group of 30 species of fungi recorded in the Bielański Forest in the second half

of the 19th century, now considered threatened and protected, only six species have been recorded here today (Ciurzycki et al. 2025b).

It is, however, difficult to say to what extent the comparison of species richness with other objects or the analysis of disappearance is comprehensive in the case of fungi. The quoted number of species (300) is approximate. This figure pertains to data from the entire Bielany area, and although most of it concerns the Forest itself (the reserve and buffer zone), the exact number is not precisely known. There is also quite extensive historical data available, along with relatively fragmentary contemporary data. For fungi as well, since it is the only among the discussed groups, no comprehensive list of species has ever been published. Such a task requires a separate study and exceeds the scope of this review work.

Despite the mentioned reservations, it seems that the Bielański Forest, as a refuge for rare species, currently has greater significance for fungi than for vascular plants and probably bryophytes. There are still species here regarded as indicators of well-preserved forests, which are threatened and proposed for protection throughout Europe (e.g., *Hapalopilus croceus* and *Hericium erinaceus*; A. Szczepkowski unpublished). Further detailed studies of fungi also increase the likelihood of discovering additional rare taxa compared to plants. The changes that have occurred in forests over the last century are diverse, not always of equal importance to plants and fungi. For a large group of lignicolous fungi, the beneficial factors are the venerable age of trees and the increasing amount of dead wood in forests compared to past decades. The Bielański Forest stands out positively compared to other urban forest complexes in Warsaw in terms of the amount of dead wood (Skwarek and Bijak 2015), which should result in greater diversity of epixylic species.

In the case of lichens, the situation regarding the completeness of data is the inverse of that of fungi. All historical data, starting from the oldest, are of an indicative nature. From the Bielany site, only single species were reported (Ciurzycki et al. 2025a, b). The relatively extensive materials published nowadays on the lichen biota of the Bielański Forest (Kubiak et al. 2010a, b) include only 72 species, with a negligible proportion of anthropogenic species, and here, very rare species are present, one forest species and a total of 19 protected and threatened species. For these reasons, the lichen biota (and lichenicolous fungi) are considered to be relic.

In terms of vegetation, the Bielański Forest had been studied almost from the beginning of phytosociology, as one of the first sites in Poland (Kobendza 1929). The results were published even before pioneering studies of the neighboring Kampinos Forest (Kobendza 1930). From today's perspective, the research conducted at that time was merely a phytosociological outline of the object. However, even from this outline, it is evident that the studies were initiated at a time when the Forest was already heavily transformed over a large area. On the other hand, an exceptional phenomenon here was the preservation within the city of patches of riparian elm-ash forest *Ficario-Ulmetum campestris* and the low oak-hornbeam grove *Tilio-Carpinetum corydaletosum*. Furthermore, more detailed studies revealed various directions of vegetation changes. Implemented protection measures allowed partial regeneration of the previously most altered sections of the Forest. However, the general trend of changes indicates that, as a result of the continuous lowering of groundwater levels, the former diversity of the Forest, which included communities from mixed forests through various types of groves to alder woodland, is becoming simplified and homogenised across the entire area into various types of groves (Solińska-Górnicka et al. 1997).

Halting this process appears to be impossible at this point. It would require the removal of undesirable species and the reintroduction of extinct ones, both of which are costly and uncertain (Symonides and Solińska-Górnicka 1990). Unforeseen problems may also arise; for instance, attempts to naturalise *Robinia* tree stands were suspended for two decades due to local community concerns (Gazda and Miścicki 2012; Miścicki and Wysocka-Fijorek 2021).

Deep transformations of the vascular flora and plant communities of the Bielański Forest have been ongoing for at least 100 years. This is evidenced by literature on the topic from the 1880s, including the first monograph of Bielany from the 1920s and detailed studies from the 1980s and 1990s. Later works mainly presented various aspects of vegetation distortions. It is noteworthy that both scientific and popular accounts of the Bielański Forest do not always maintain an appropriate balance between showcasing its still-preserved, valuable elements and the state of

its profound transformations and existing threats. It seems that future research on the plant cover of the Bielański Forest could reveal further continuation of the transformations shown in this and previous studies (Ciurzycki et al. 2025a, b), and due to its historical and extensive bibliography, the Bielański Forest could be regarded as a model object in this regard.

Conclusions

1. There are considerable differences in the completeness of data among various types of botanical research in the Bielański Forest. The assessment of the forest's condition, based on the analysis of the occurrence of specific plant or fungi groups, leads to valuable and somewhat different conclusions.
2. The identification of vascular flora and plant communities is relatively thorough and more comprehensive when compared to bryoflora and mycobiota, both in terms of historical and current data. The assessment of the condition of the forest, based on its vascular flora and plant communities, indicates that it now has a strong anthropogenic character. Currently, it can serve as a model for research into the processes of transformation and synanthropisation of the flora within a fragment of what was once a primary forest, now situated in a large city.
3. The identification of resources of bryophytes is comparable to that of vascular plants. However, there is more relic species for natural forests. Additionally, species classified as rare, endangered, or protected can be found among them. New and detailed studies of bryophyte flora would likely confirm the evidence of negative changes in the forest, but they may also uncover new and valuable species.
4. The study of mycobiota necessitates compiling, developing, and publishing existing data in the form of a list of species along with their data sources. The recognition of fungal species diversity is currently unsatisfactory, estimated within the macromycetes group at around 50% and practically unrecognised for micromycetes. It would be useful to thoroughly describe the contemporary fungal biota, which would allow for recognising its changes in relation to historical data. It is worthwhile to continue relatively recent studies of lichen biota.
5. Despite the differences between historical and contemporary data, analysing fungal and lichen biota offers insights into the relatively better preservation of the Forest. Further systematic research on mycobiota would enable the monitoring of the most valuable taxa and could lead to the discovery of species that represent remnants of the Forest's once-wild character. Due to the lack of research and data on the slime molds from Bielany in the 20th and 21st centuries, there is a need for contemporary recognition of this group of organisms.
6. The identification of resources and condition of old trees and dead wood in the Bielański Forest is fairly good. However, it would be beneficial to enhance this information, for example, by including maps that illustrate their distribution. Future studies focusing on bryophytes, fungi, slime molds, and lichens should pay special attention to these epiphytic and epixylic habitats.
7. The Bielański Forest also offers a wonderful opportunity for historical exploration. With records spanning nearly three centuries, one may examine the transformations shaped by environmental conditions. Sharing these insights can enhance community awareness about the significant effects of human actions on nature conditions.
8. The Bielański Forest serves a variety of important functions, including cultural, social, recreational, educational, protective, and scientific roles. It requires special attention from the authorities of Warsaw and should be actively protected through conservation measures to ensure its preservation.

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