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THE CONTRIBUTION AND IMPORTANCE OF RARE MACROFUNGI IN SELECTED PLOTS OF ENDANGERED XEROTHERMIC GRASSLANDS IN THE NIDA BASIN

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Abstract

Xerothermic habitats of protected sites in the Nida Basin are of special natural value. The richness of steppe plant species contributes to the biodiversity of grassland ecosystems and increases the floristic and landscape uniqueness of Ponidzie. A rich thermophilous biota of interesting steppe macromycetes (Basidiomycetes) develops in the xerothermic vegetation in the area.

As preliminary investigations into macrofungi in xerothermic communities in the Nida Basin have shown, many very rare and valuable species as well as species new to the Polish mycobiota occur in the study area. Several rare species of gasteroid fungi, such as *Geastrum minimum* and *G. schmidelii*, were found in patches of *Sisymbrio-Stipetum capillatae.* Many taxa are indicator species of these biocoenoses. Noteworthy are parasitic macrofungi infecting roots of the genus *Stipa*: *Gastrosporium simplex* and *Polyporus rhizophilus*. Localities of species of the genus *Tulostoma*: *T. brumale, T. kotlabae* and *T. melanocyclum*, *T. squamosum*, new to the Nida Basin, were recorded in patches of *Koelerio-Festucetum rupicolae* and *Festucetum pallentis.* The above fungi are very rare in Poland's mycobiota. They are strongly threatened and are classified as endangered (E). *Geastrum minimum* and the species of the genus *Tulostoma* are strictly protected.

Key words: xerothermic grasses, *Festuco-Brometea*, gasteromycetes, Basidiomycetes, Ponidzie, thermophilous fungi, threatened fungi, protected fungi.

INTRODUCTION

As plant communities, xerothermic grasslands occurring in Poland are differentiated from other grass ecosystems by a high diversity of species of steppe plants originating in warmer climatic zones of southern and south-eastern Europe. Eight plant associations represent the xerothermic vegetation cover of the Nida Basin (Łuszczyńska, 1992). *Sisymbrio-Stipetum capillatae* occurring in the "Skorocice", "Przęślin", "Skotniki Górne", "Góry Wschodnie" and "Winiary Zagojskie" reserves as well as in Wola Zagojska Górna are the best developed associations. The associations *Adonido-Brachypodietum pinnati* and *Thalictro-Salvietum pratensis* occur very commonly on limestone substrate (Łuszczyński and Łuszczyńska, 1992, 2009 a; Kostuch and Misztal, 2007). Highly interesting and floristically well-developed *Seslerio-Scorzoneretum purpureae* grasslands have developed on northern hill slopes near Zwierzyniec, Stawiany, Szaniec, Łagiewniki and Sułkowice. Steppe flower grasslands with *Inula ensifolia*, accompanied by rare species *Carlina onopordifolia*, *Cirsium pannonicum*, *Linum flavum* and *L. hirsutum*, develop on south, south-east and south-west facing slopes. The best-developed patches of *Inuletum ensifoliae* were observed near Pińczów, Szczaworyż, Sułkowice, Szaniec and Stawiany (Łuszczyński and Łuszczyńska, 2009 b; Łuszczyński et al. 1998).

The richness of xerothermic vegetation encourages the development of a very interesting biota of thermophilous steppe species of macrofungi (Basidiomycetes) closely associated with these phytocenoses. As preliminary research into the contribution of macrofungi in xerothermic associations of the Nida Basin and Chęciny District shows, many very rare species new to the Polish and European mycobiotas occur in the area (Łuszczyński and Łuszczyńska, 1991-1992; Łuszczyński, 2006; Jaworska et al. 2012). The results of these observations will be used in further studies on the occurrence of fungi in xerothermic habitats of the Nida Basin.

The objective of this research was:
- to identify the species diversity of macrofungi (Basidiomycetes) in xerothermic grasslands in the Nida Basin;
- to determine the ecological diversity of habitats occupied by macrofungi and the diversified xerothermic plant cover in the study area;
- to identify indicator species of fungi of these biocoenoses.

MATERIALS AND METHODS

Mycological investigations into macrofungi have been conducted since October 2010 until now and are planned to continue for the next three years. Xerothermic plant communities in protected areas such as Nature 2000 sites, nature reserves (e.g. "Skorocice", "Skowronno", "Skotniki Górne", and "Winiary Zagojskie" reserves) and landscape parks (Nadnidziański Landscape Park, Szaniecki Landscape Park, Kozubowski Landscape Park) in selected subregions of the Nida Basin were studied. Field studies were conducted using permanent research plots and were supplemented with the route method. Thirty research plots marked permanently were established in six xerothermic plant associations (five plots in each of the six plant communities). The plot size was determined by the size of a homogenous plant patch and is consistent with the standards of phytosociological relevés used in such communities (between 70 m^2 and 100 m^2). Research plots were set up in the following associations: *Adonido-Brachypodietum pinnati, Festucetum pallentis, Inuletum ensifoliae, Seslerio-Scorzoneretum purpureae, Sisymbrio-Stipetum capillatae,* and *Thalictro-Salvietum pratensis*. Phytosociological relevés were performed in all the plots.

Macrofungi of the class Basidiomycetes were collected during each mycological observation. The number of fruitbodies, the substrate and organoleptic features such as the odour and taste of individual fruitbodies were established at collection. An important element of the observations was to identify types of plant communities outside the research plots to examine relationships between fungi and types of xerothermic vegetation. Laboratory studies were carried out with a light microscope, scanning electron microscope and standard chemicals. Basidia, cistidia and spores, whose structure and size are important for taxonomic identification, were measured. The material was deposited in the herbarium of the Department of Botany, Institute of Biology, Jan Kochanowski University, Kielce.

The nomenclature of fungi follows Wojewoda (2003). Categories of threat follow Wojewoda and Ławrynowicz (2006).

RESULTS AND DISCUSSION

Nearly 50 species of macrofungi were recorded in the plots of xerothermic vegetation in the Nida Basin. Species new to the area, rare and threatened in Poland as well as species that can be described as indicator species of specific xerothermic associations are the most interesting fungi. Especially noteworthy are the following gasteroid fungi: *Bovista tomentosa, Gastrosporium simplex*, *Geastrum minimum, G. schmidelii, Tulostoma brumale*, *T. kotlabae T. melanocyclum,* and *T. squamosum*, as well as the following agaricoid fungi: *Entoloma incanum*, *Hygrocybe persistens* and *H. reae*.

Gastrosporium simplex was recorded three times in the *Sisymbrio-Stipetum capillatae* and *Seslerio-Scorzoneretum purpureae* associations at the locality in Wola Zagojska Górna (ATPOL square Fe 24) and in the *Sisymbrio-Stipetum capillatae* association at the locality in Krzyżanowice (ATPOL square Fe 14) (Fig. 1). Its fruitbodies develop hypogeously and are spherical. Basidiocarps are characteristically white and produce a white, long mycelium: rhizomorphs whose strands wrap around roots of grasses (Fig. 2). *Gastrosporium simplex* obligatorily parasitizes roots of grasses, mainly grasses of the genus *Stipa*. It has also been observed outside the study area among grasses of the genera *Brachypodium*, *Bromus*, *Festuca*, *Koeleria*, *Sesleria* (Pilát, 1958; Kreisel, 1987; Krieglsteiner, 1991).

It is interesting that the species was previously recorded in patches of *Sisymbrio-Stipetum capillatae* (Šmarda, 1957; Bujakiewicz, 1997; Łuszczyński and Łuszczyńska, 1991-1992) and *Potentillo-Stipetum capillatae* (Stasińska, 2002, 2003). These authors stress that the species is closely attached to xerothermic plant communities and argue that it is thermophilous, occurring in warm, sunny and dry places with temperatures often exceeding 39°C. However, in this study fruitbodies of *Gastrosporium simplex* were found in patches of *Seslerio-Scorzoneretum purpureae* under *Festuca rupicola* on a north-facing slope where thermal and humidity conditions are very different from south-facing slopes. If the locality is confirmed in subsequent years, this may considerably affect the information on its range and ecological requirements currently available. *Gastrosporium simplex* is very rare in the Polish mycobiota. In Poland it is included in the red list of Polish threatened macrofungi as an endangered (E) species (Wojewoda and Ławrynowicz, 2006).

Bovista tomentosa produced fruitbodies in the *Adonido-Brachypodietum pinnati* grassland. Its fruitbodies were collected in Zwierzyniec near Busko Zdrój (ATPOL square Fe 15). *B. tomentosa* is a thermophilous fungus, highly stenothermal and for this reason it is identified with xerothermic and psammophilous

habitats. To date, *B. tomentosa* has been recorded in *Festucetum pallentis* and *Origano-Brachypodietum* phytocenoses (W o j e w o d a , 2003).

Bovista tomentosa is classified as a vulnerable species on the red list of Polish threatened macrofungi (W o j e w o d a and Ł a w r y n o w i c z , 2006). It is included in the red list of the Góry Świętokrzyskie Mts as a rare species (Ł u s z c z y ń s k i , 2002; 2008).

Fruitbodies of macrofungi belonging to the genus *Geastrum*, *G. minimum* and *G. schmidelii* were found in a xerothermic grassland in patches of *Sisymbrio-Stipetum capillatae* in the "Krzyżanowice" reserve (ATPOL square Fe 14) (Figs 3 and 4). Both *G. minimum* and *G. schmidelii* are closely attached to the driest and warmest xerothermic grasslands. Further localities of these species were recorded in the *Festucetum pallentis* association in Gacki village (ATPOL square 24) and in patches of the *Sisymbrio-Stipetum capillatae* association in the Skorocice reserve (ATPOL square Fe 24). They are quite rare in Poland in comparison with other species of the genus *Geastrum* (W o j e w o d a , 2003). Both of these species are red-listed in Poland. *G. minimum* is classified as a vulnerable (V) species and *G. schmidelii* is an endangered (E) species (W o j e w o d a and Ł a w r y n o w i c z , 2006).

Species of the genus *Tulostoma*, which are represented only by five species in Poland (W o j e w o d a , 2003), are some of the most interesting fungi in the study area. Three species of the genus *Tulostoma* were recorded and future observations may provide further information on the number of localities of the species and the number of taxa of this genus. Species identified in this study include *Tulostoma kotlabae*, a very rare fungus in the Polish mycobiota. The only locality of the species was previously reported from the Kampinos National Park (R u d n i c k a - J e z i e r s k a , 1991). The fungus was found in thermophilous xerothermic grasslands in *Koelerio-Festucetum rupicolae* and *Festucetum pallentis* patches. Fruitbodies of *T. kotlabae* developed on shallow limestone (Figs 5 and 6). Its fruitbodies were recorded in Poland in Wola Zagojska Górna (ATPOL square Fe 24).

Similarly to *T. kotlabae*, *Tulostoma squamosum* is very rare in the fungal biota of Poland. It occurred quite numerously in the research plots and both the number of localities and the abundance of fruitbodies were high. Fruitbodies of *T. squamosum* were recorded at three localities. They were observed in *Festucetum pallentis* in Gacki village, in patches of *Sisymbrio-Stipetum capillatae* in the Skorocice reserve, and in *Festucetum pallentis* in Wola Zagojska (Figs 9 and 10).

Three new localities of *Tulostoma melanocyclum* were recorded in the study. Two sites were noted in phytocoenoses of the association *Sisymbrio-Stipetum capillatae* in the Skorocice and Krzyżanowice reserves (ATPOL Fe 14). The third locality was recorded in patches of *Festucetum pallentis* in Wola Zagojska (Figs 7 and 8).

Tulostoma brumale is relatively more common than the above species of this genus but it is also very rare. It has been observed in communities such as *Sisymbrio-Stipetum capillatae*, *Thalictro-Salvietum pratensis* and *Peucedano-Pinetum* (W o j e w o d a , 2003). It is also, however, a very rare species. Relatively large numbers of localities of *T. brumale* were recorded in this study. Its fruitbodies were found in Wola Zagojska Górna, where they grew in patches of *Sisymbrio-Stipetum capillatae* and *Koelerio-Festucetum rupicolae*. Further localities were found in Szaniec near Busko Zdrój (ATPOL square Fe 15), also in patches of *Koelerio-Festucetum rupicolae.*

All these species of the genus *Tulostoma* are very rare not only in Poland (W o j e w o d a and Ł a w r y n o w i c z , 2006; W o j e w o d a , 2003; Ł u s z c z y ń s k i , 2008) but also in Europe (H a n s e n and K n u d s e n , 1997; J ü l i c h , 1984; K r e i s e l et al. 1992; P i l á t , 1958; W r i g h t , 1987). In Poland these species are strictly protected and red-listed. *Tulostoma brumale* is classified as a rare (R) species (W o j e w o d a and Ł a w r y n o w i c z , 2006) and it is included as an endangered (E) species in the regional red list of the Góry Świętokrzyskie Mts (Ł u s z c z y ń s k i , 2002; 2008). *Tulostoma kotlabae* and *T. melanocyclum* are classified as endangered (E) species (W o j e w o d a and Ł a w r y n o w i c z , 2006).

The following rare species of the order Agaricales were collected: *Entoloma incanum*, *Hygrocybe persistens* and *H. reae*. *Entoloma incanum* was noted in patches of the *Inuletum ensifoliae* association near plantings of *Pinus sylvestris* in Pińczów (ATPOL square Fe 13) and in *Seslerio-Scorzoneretum purpureae* in the Krzyżanowice reserve.

Species of the genus *Hygrocybe*: *H. persistens* and *H. reae*, were collected in the community *Seslerio-Scorzoneretum purpureae* in the Krzyżanowice reserve. Both species are endangered and red-listed. *Hygrocybe persistens* is listed as endangered (E) and *H. reae* is listed as rare (R) (W o j e w o d a and Ł a w r y n o w i c z , 2006).

The above species were previously known from few localities (W o j e w o d a , 2003). Sites of *Entoloma incanum*, *Hygrocybe persistens* and *H. reae* were recently recorded in the Chęciny Region in xerothermic grasslands *Thalictro-Salvietum pratensis* and *Origano-Brachypodietum* (Ł u s z c z y ń s k i , 2010; J a w o r s k a et al. 2012). This confirms that these fungi are attached to grasslands of the *Cirsio-Brachypodion pinnati* alliance.

The occurrence of individual species in specific habitat types is given in Table 1.

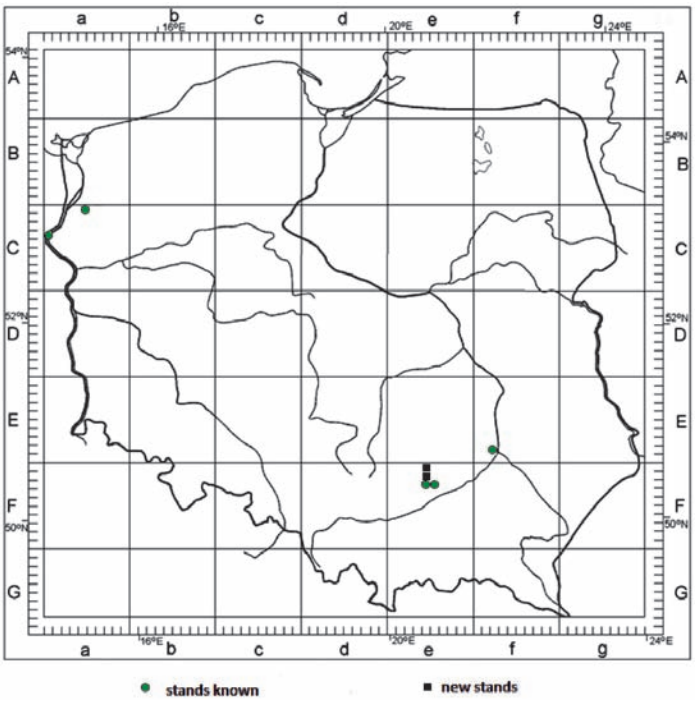

Fig. 1. Distribution of *Gastrosporium simplex* in Poland.

Fig. 2. Fruitbodies of *Gastrosporium simplex* at the locality in Wola Zagojska Górna (5 October 2010; photo by J. Łuszczyński).

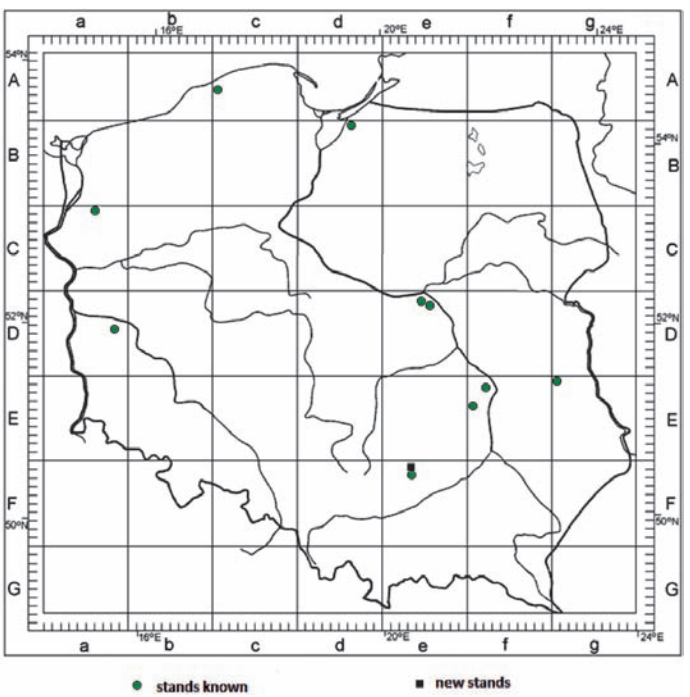

Fig. 3. Distribution of *Geastrum schmidelii* in Poland.

Fig. 4. Fruitbodies of *Geastrum schmidelii* at the locality in the Krzyżanowice reserve (15 October 2010; photo by A. Tomaszewska).

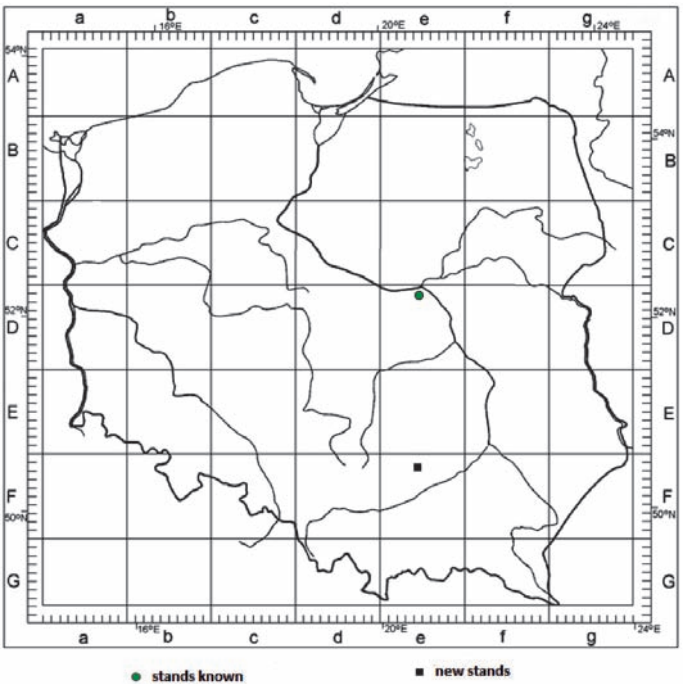

Fig. 5. Distribution of *Tulostoma kotlabae* in Poland.

Fig. 6. Fruitbodies of *Tulostoma kotlabae* at the locality in Wola Zagojska Górna (5 October 2010; photo by A. Tomaszewska).

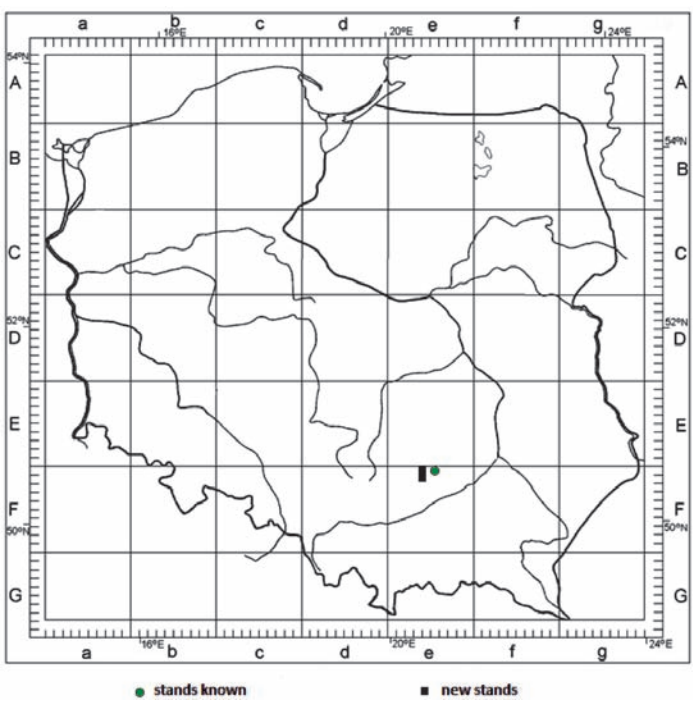

Fig. 7. Distribution of *Tulostoma melanocyclum* in Poland.

Fig. 8. Fruitbodies of *Tulostoma melanocyclum* at the locality in Wola Zagojska Górna (5 October 2010; photo by A. Tomaszewska).

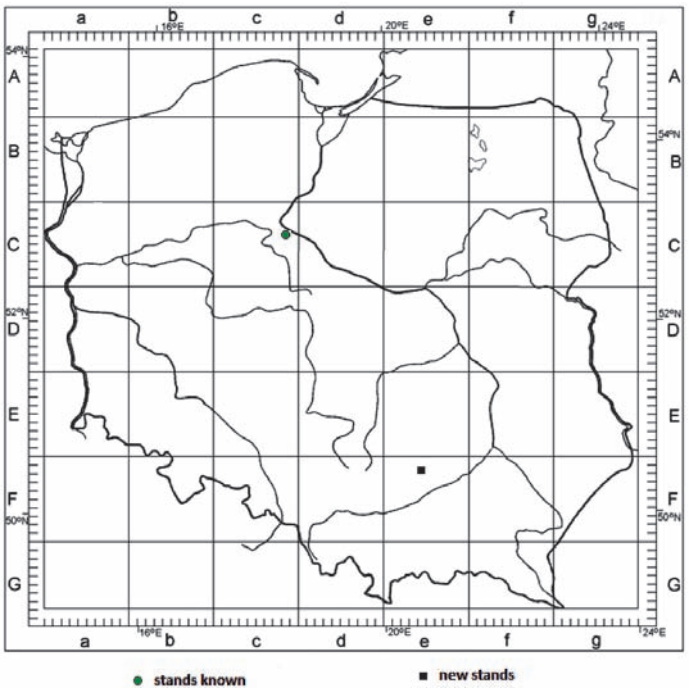

Fig. 9. Distribution of *Tulostoma squamosum* in Poland.

Fig. 10. Fruitbodies of *Tulostoma squamosum* at the locality in Wola Zagojska Górna (16 July 2011; photo by A. Tomaszewska).

Table 1.
A list of macrofungi recorded in xerothermic grasslands in the Nida Basin

Fungi species	Plant communities
Bovista tomentosa (Vittad.) Quél.	*Adonido-Brachypodietum pinnati*
Entoloma incanum (Fr.: Fr.) Hesler	*Inuletum ensifoliae, Seslerio-Scorzoneretum purpureae*
Gastrosporium simplex Mattir.	*Sisymbrio-Stipetum capillatae, Seslerio-Scorzoneretum purpureae*
Geastrum minimum Schwein.	*Festucetum pallentis, Sisymbrio-Stipetum capillatae*
Geastrum schmidelii Vittad.	*Festucetum pallentis, Sisymbrio-Stipetum capillatae*
Hygrocybe persistens (Britzelm.) Singer	*Seslerio-Scorzoneretum purpureae*
Hygrocybe reae (Maire) J. E. Lange	*Seslerio-Scorzoneretum purpureae*
Tulostoma brumale Pers.: Pers.	*Sisymbrio-Stipetum capillatae, Koelerio-Festucetum rupicolae*
Tulostoma kotlabae Pouzar	*Koelerio-Festucetum rupicolae, Festucetum pallentis*
Tulostoma melanocyclum Bres.	*Sisymbrio-Stipetum capillatae, Festucetum pallentis*
Tulostoma squamosum (Gmelin in L.): Pers.	*Festucetum pallentis, Sisymbrio-Stipetum capillatae*

CONCLUSIONS

Xerothermic habitats occurring in Poland are often the most mycologically under-explored and poorly recognized plant communities. The list of species of macrofungi in phytocenoses of the class *Festuco-Brometea* comprises approximately 40 species (S t a s i ń s k a , 2008). They are mostly very rare, endangered and threatened (W o j e w o d a and Ł a w r y n o w i c z , 2006).

Preliminary research into macrofungi in xerothermic grasslands in the Nida Basin shows that many very rare and valuable species and species new to the Polish mycobiota occur in the area. The majority of fungi were closely attached to specific communities of xerothermic vegetation and did not occur elsewhere. Indicator species of extremely thermophilous and dry grasslands of the alliances *Festuco-Stipion* and *Seslerio-Festucion duriusculae* are: *Gastrosporium simplex*, *Polyporus rhizophilus*, *Geastrum minimum*, *G. schmidelii*, *Tulostoma brumale, T. melanocyclum, T. kotlabae* and *T. squamosum*. *Entoloma incanum, Hygrocybe persistens* and *H. reae* seem to be closely attached to grasslands of the alliance *Cirsio-Brachypodion pinnati*.

Bovista tomentosa was recorded only in *Adonido-Brachypodietum pinnati,* but it can be treated only as locally differentiating due to its broader ecological scale.

Thermophilous steppe species of macromycetes are rarely recorded in Poland due to the uniqueness of xerothermic associations. General climatic conditions in Poland are not conducive to the development of these macrofungi. Progressive processes of natural succession not only pose a threat to xerothermic vegetation but also cause a drop in the number of localities of macrofungi. Systematic pasturage and cutting of ligneous vegetation by local users are economically important factors which help to protect xerothermic grasslands from overgrowing and to conserve the biota of steppe species of macrofungi. New artificial plantings affect the species composition of fungi and mycorrhizal partners of pine and birch were recorded in pine and birch woodlands in the study area. Those included *Leccinum scabrum*, *Lactarius torminosus* under birches and *Rhizopogon obtextus* and *Suillus collinitus* under pines.

The following conclusions can be based on our investigations:

Many rare and threatened species of macrofungi were recorded in preliminary mycological studies in xerothermic grasslands.

Further investigations in the area are needed to fully assess the diversity of the fungal biota and ecological requirements of macrofungi.

Complex protection of xerothermic biocoenoses is not possible unless the role and contribution of fungi occurring in them are known. Some fungal species are closely attached to specific types of xerothermic habitats. Their natural habitats must be jointly protected to ensure the persistence of both.

The rare occurrence of the fungi recorded in our study is caused by the uniqueness of xerothermic grasslands in Poland. Some of the taxa are indicator species of these biocoenoses.

It is recommended to use fungi associated with xerothermic grasslands to assess threats and transformations taking place due to the disappearance of this type of plant communities in Poland.

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Udział i znaczenie rzadkich grzybów wielkoowocowych w wybranych powierzchniach zagrożonych muraw kserotermicznych w Niecce Nidziańskiej

Streszczenie

Siedliska kserotermiczne obszarów naturowych Niecki Nidziańskiej to jedne z najcenniejszych elementów przyrody w Polsce. Ze względu na bogactwo gatunków roślin stepowych przyczyniają się nie tylko do powiększenia różnorodności gatunkowej ekosystemów murawowych ale także niebywale podnoszą walory florystyczne i krajobrazowe Ponidzia. Występowanie roślinności kserotermicznej na omawianym terenie niesie ze sobą pojawienie się bogatej bioty termofilnych, stepowych gatunków grzybów wielkoowocnikowych Basidiomycetes mających na tym obszarze szczególne znaczenie.

Wstępne badania macromycetes w zespołach kserotermicznych Ostoi Nidziańskiej wykazały istnienie wielu bardzo rzadkich, cennych a także nowych dla mikobioty Polski gatunków. W płatach zespołu *Sisymbrio-Stipetum capillatae* zanotowano obecność rzadkich gatunków grzybów gasteroidalnych m.in: *Geastrum minimum* i *G. schmidelii*. Wiele zanotowanych taksonów to gatunki wskaźnikowe dla tych biocenoz. Na szczególną uwagę zasługują grzyby wielkoowocnikowe pasożytujące na korzeniach traw z rodzaju *Stipa* – *Gastrosporium simplex* oraz *Polyporus rhizophilus*. W płatach zespołów *Koelerio-Festucetum rupicolae* oraz *Festucetum pallentis* zanotowano całkiem nowe dla Niecki Nidziańskiej stanowiska gatunków z rodzaju *Tulostoma – T. brumale, T. kotlabae, T. melanocyclum* oraz *T. squamosum*. Przedstawione powyżej gatunki zaliczane są do bardzo rzadkich elementów mikobioty naszego kraju. Wszystkie należą do grzybów silnie zagrożonych, którym nadano kategorie zagrożenia E – wymierające, a *Geastrum minimum* i *G. schmidelii* oraz wymienione gatunki *Tulostoma* objęte są ścisłą ochroną gatunkową.