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# Characteristics of the vascular plant flora in the Olkusz Ore-bearing Region

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## Introduction

From both scientific and practical points of view it is important to monitor the changes caused by human activity in the natural environment over time and space, as well as the consequences of these changes. Areas affected by industrial activities especially merit such continuous observation. Waste heaps created by industry over the course of decades can become sites of fascinating botanical research, a true natural laboratory (Wierzbicka 2002; Baker *et al*. 2010; Řehounková *et al*. 2011). The area in the Silesia-Cracow Upland between Olkusz and Sławków, called the Olkusz Ore-bearing Region, is one such laboratory, as a major centre for mining and processing of zinc and lead ores in Poland. The specificity of the local vegetation was already observed by researchers in the late 19th and early 20th centuries (Zalewski 1886; Wóycicki 1913). Many floristic studies of this area were published in the second half of the 20th century and the first decade of the 21st century (e.g. Dobrzańska 1955; Kwiatkowska 1957; Wika and Szczypek 1990; Bernacki and Nowak 1994; Nowak 1997, 1999; Grodzińska *et al.* 2000; Drobnik 2003; Drobnik and Stebel 2003; Babczyńska-Sendek 2005; Szarek-Łukaszewska and Grodzińska 2007, 2008). They provided a wealth of new and interesting data. Due to differences in methods of data collection and differences in the level of detail in area exploration, it has not been possible to compare the results and identify the changes that have occurred in the flora of this industrialised region.

The cartogram method, by which the species growing in a grid of squares demarcated in an area are inventoried, is the most useful method of tracking changes in an area's flora during a given period. Nowak (1999) used this method to characterise the vascular plant flora of the eastern part of the Garb Tarnogórski mesoregion, which includes the entire Olkusz Ore-bearing Region. More than a dozen years have passed since that study was done, during

which time the landscape has undergone visible changes. To update the floristic data, not long ago we repeated that work, employing the same method and covering the same areas (squares) used in the earlier study. The result was a monograph entitled *The vascular plants of the Olkusz Ore-bearing Region* (Nowak *et al.* 2011) – and this chapter.

## The study area

The research area was an 8 × 6 km rectangle extending from Międzygórze in the east to Stary Olkusz in the west and from Laski in the north to the Pustynia Starczynowska desert and the Sztoła river valley in the south (see Fig. 1 in Holeksa *et al.* – Chapter 7, this volume). The morphology, geological structure, soil and hydrology of the area is highly diverse. Its character is determined mostly by the presence of zinc and lead ore, sand and dolomite. Mining and processing of these materials led to the formation of vast excavations, heaps and mine waste areas, and heavy metal pollution of the environment, mainly the soil. Another consequence of mining was lowering of the water table and the formation of artificial canals draining water from underground excavations. Large areas of the OOR were occupied by infrastructure associated with mines and zinc smelters. Rail and road transport routes connecting nearby urban centres were rapidly built. The flora also changed significantly. Presently it is represented mainly by grassland of different types, fallows and cultivated areas.


Fig. 1. Study area shown on the ATPOL grid. Grid of 2 × 2 km squares bolded; grid of 1 × 1 km squares not bolded

Ryc. 1. Badany obszar na tle siatki kwadratów ATPOL. Linią pogrubioną zaznaczono sieć kwadratów o boku 2 km, linią cieńszą sieć kwadratów o boku 1 km

More information about the study area is provided in Chapter 2 (Godzik, this volume), and about its flora in Chapter 7 (Holeksa *et al*., this volume).

## Methods of the study

The floristic composition of the 48 km$^2$ area was studied using the cartogram method in 2008–2009. The basic study plot was a 1 km$^2$ square demarcated according to the ATPOL method used for the *Atlas of distribution of vascular plants in Poland* (*ATPOL*) (Zając 1978). The mapped squares were within two 100 km$^2$ ATPOL squares (DF36, DF46) and in twelve 4 km$^2$ squares from Nowak's 1999 study (Fig. 1). A locality was defined according to the occurrence of particular species in the square. Species nomenclature follows Mirek *et al*. (2002). The data on the recorded species include frequency of occurrence, and classification in geographical and historical groups (Mirek *et al*. 2002; Tokarska-Guzik 2005; Tokarska-Guzik *et al*. 2012) and in phytosociological groups (Matuszkiewicz 2008; Zarzycki *et al*. 2002). Species are also categorised as legally protected (Anonymous 2004), endangered in Poland (Zarzycki and Szeląg 2006), mountain species (Zając 1996) and high-altitude elements interesting from a phytogeographical point of view.

## Results and discussion

The vascular plant flora of the Olkusz Ore-bearing Region (OOR) comprises 736 species. Almost half of them (47.0%) are rare and very rare species. Least often noted were species considered very frequent (8.6%) and common (10.3%) (Fig. 2).

The recorded species belong to 102 families and 372 genera; 706 of them are angiosperms (Magnoliophyta), 7 are gymnosperms

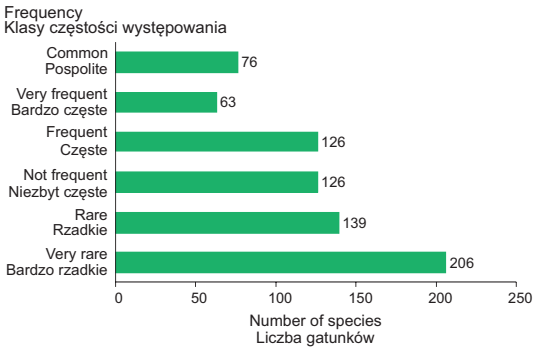


Fig. 2. Number of species in each frequency class in the OOR flora. Classes of frequency: very rare, 1–2 localities; rare, 3–5 localities; not frequent, 6–10 localities; frequent, 11–20 localities; very frequent, 21–30 localities; common, 31–48 localities

Ryc. 2. Liczba gatunków w poszczególnych klasach częstości we florze OOR. Klasa częstości: bardzo rzadki – 1–2 stanowiska; rzadki – 3–5 stanowisk; niezbyt częsty – 6–10 stanowisk; częsty – 11–20 stanowisk; bardzo częsty – 21–30 stanowisk; pospolity – 31–48 stanowisk

(Pinophyta), and 23 species are cryptogams (Lycopodiophyta, Equisetophyta, Polypodiophyta). Among the angiosperms the most numerously represented families are Asteraceae (88 species), Poaceae (67), Rosaceae (48), Fabaceae (43), Brassicaceae (31), Cyperaceae (30), Lamiaceae (30) and Caryophyllaceae (27). The most numerously represented genera are *Carex* (23 species), *Salix* (13), *Vicia* (10) and, with 8 species each, *Galium*, *Veronica*, *Rumex*, *Trifolium* and *Viola*. Gymnosperms are represented by 2 families (Pinaceae, Cupressaceae). The most frequent cryptogamic plants are Equisetophyta and Polypodiophyta.

Of the 736 species recorded, 547 (74.3%) are native species, 179 (24.3%) are of foreign origin (anthropophytes) and 10 (1.4%) are of uncertain status in the flora of Poland (Fig. 3). The majority of the anthropophytes are established species (132 species, 17.9%), including 59 (8%) early established species (archaeophytes) and 73 (9.9%) late established species (kenophytes) (Appendices 1, 2). In the flora of

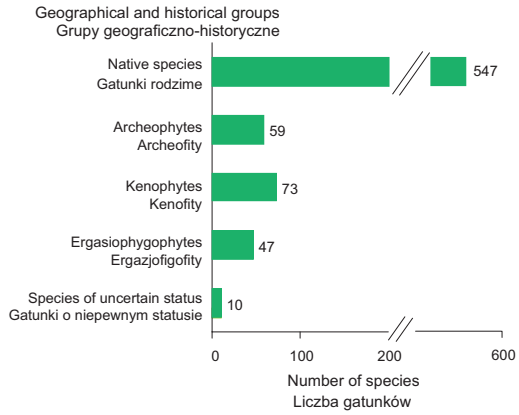


Fig. 3. Number of species classified in different geographical and historical groups in the OOR flora

Ryc. 3. Liczba gatunków należących do różnych grup geograficzno-historycznych we florze OOR

the OOR there are 47 (6.4%) not established species (ergasiophygophytes) (Fig. 3).

On the basis of published information about species in Poland (Tokarska-Guzik 2005; Tokarska-Guzik *et al*. 2012) we analysed the species composition of established anthropophytes in terms of their invasiveness or receding tendency. As stable elements of the flora they can considerably influence processes of synantrophisation of the vegetation. Among them the archaeophytes are above all associated with cultivation areas, and kenophytes with many types of habitats. In the group of archaeophytes only 4 (*Avena fatua*, *Echinochloa crus-galli*, *Setaria pumila* – Fig. 4, *Setaria viridis*) were included in the group of invasive weeds (Appendix 1). Some species in this group of anthropophytes show a receding tendency (*Agrostemma githago*, *Lathyrus tuberosus*, *Neslia paniculata*, *Stachys annua* – Fig. 5, *Veronica agrestis*). Archaeophytes occur in ruderal habitats (e.g. *Lathyrus tuberosus*, Fig. 6) as a result of abandonment of arable fields in the OOR. As many as 38 of the 73 recorded kenophytes are classified as invasive in Poland (Appendix 2). Six of them are invasive weeds (*Amaranthus retroflexus*, *Conyza canadensis* – Fig. 7, *Galinsoga ciliata*, *Galinsoga parviflora*, *Oxalis fontana* – Fig. 8, *Veronica persica*). In the OOR the strongly invasive species are *Aster novi-belgii* (Fig. 9) and *Heracleum sosnowskyi* which "wanders" along a drainage canal (Fig. 10). *Reynoutria sachalinensis* (Fig. 11) still occurs in one habitat and is in its initial phase of invasion. One habitat of a species presently classified as potentially invasive, *Typha laxmanni*, was recorded.

Figure 12 shows the shares of geographical and historical groups in the floras of particular squares. Anthropophytes occur in all squares. The share of established anthropophytes, both kenophytes and archaeophytes, is highest in the northeast of the OOR, which is largely built-up; its fields are presently fallows. This area has the highest share of invasive species of the kenophyte group. The share of established anthropophytes is lowest in the southeast of the OOR, where pine forests dominate. Unstable elements of the flora, ergasiophygophytes, are observed especially in reclaimed former mining areas and also in built-up areas. They do not occur in the east of the study area. Established anthropophytes occur in plant communities representing 24 phytosociological classes. The most common ones are meadow species of the Molinio-Arrhenatheretea class (143) and field weed species of the Stellarietea mediae class (97). Less established anthropophytes are observed in forest communities of the Querco-Fagetea class (72), ruderal communities of the Artemisietea vulgaris class (69) and xerothermic grasslands of the Festuco-Brometea class (68). The classes Asteretea and Littorelletea uniflorae are only represented by single species. Meadow species of the Molinio-Arrhenatheretea class are the ones most commonly distributed in the study area; they were observed in all squares, between 3 and 91 species per square (Fig. 13). Their distribution is

Fig. 4. *Setaria pumila*, an archaeophyte of the invasive weeds group (photo T. Nowak)

Ryc. 4. *Setaria pumila* – archeofit z grupy chwastów inwazyjnych (fot. T. Nowak)

Fig. 5. *Stachys annua*, a receding archaeophyte in a follow field (photo T. Nowak)

Ryc. 5. *Stachys annua* – ustępujący archeofit na odłogu (fot. T. Nowak)

Fig. 6. *Lathyrus tuberosus*, a receding archaeophyte in a ruderal habitat (photo T. Nowak)

Ryc. 6. *Lathyrus tuberosus* – ustępujący archeofit na siedlisku ruderalnym (fot. T. Nowak)

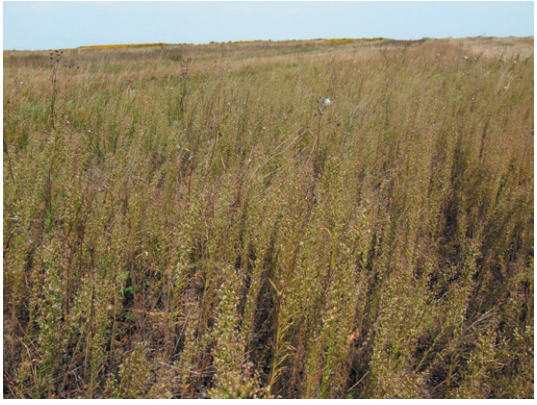

Fig. 7. *Conyza canadensis*, a kenophyte of the invasive weeds group in a fallow field (photo T. Nowak)

Ryc. 7. *Conyza canadensis* – kenofit z grupy chwastów inwazyjnych na odłogowanych polach (fot. T. Nowak)

Fig. 8. *Oxalis fontana*, a kenophyte of the invasive weeds group in a stubble field (photo T. Nowak)

Ryc. 8. *Oxalis fontana* – kenofit z grupy chwastów inwazyjnych na ściernisku (fot. T. Nowak)

Fig. 9. *Aster novi-belgii*, an invasive kenophyte transforming mainly meadow communities (photo M. Jędrzejczyk-Korycińska)

Ryc. 9. *Aster novi-belgii* – inwazyjny kenofit przekształcający głównie zbiorowiska łąkowe (fot. M. Jędrzejczyk-Korycińska)

Fig. 10. *Heracleum sosnovskyi*, an invasive kenophyte spreading along a drainage canal (photo T. Nowak)

Ryc. 10. *Heracleum sosnowskyi* – inwazyjny kenofit wzdłuż kanału odwadniającego (fot. T. Nowak)

Fig. 11. *Reynoutria sachalinensis*, an invasive kenophyte (photo T. Nowak)

Ryc. 11. *Reynoutria sachalinensis* – inwazyjny kenofit (fot. T. Nowak)

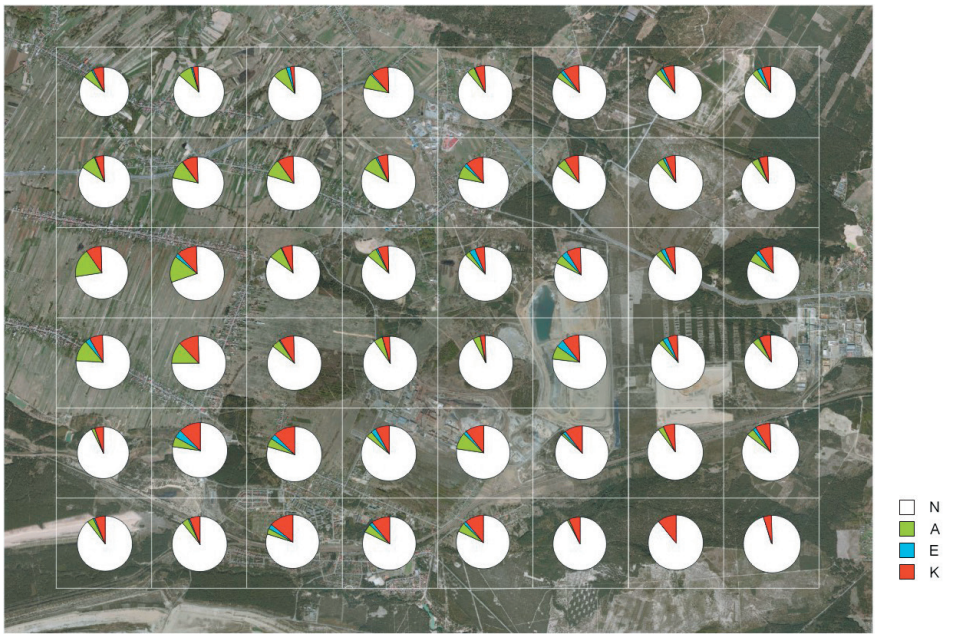


Fig. 12. Shares of geographical and historical groups to the composition of the flora of individual study squares. Explanation of pie chart colours: native species (N), archaeophytes (A), ergasiophygophytes (E), kenophytes (K)

Ryc. 12. Udział grup geograficzno-historycznych w składzie flory poszczególnych kwadratów badawczych. Objaśnienia kolorów kół na diagramie: gatunki rodzime (N), archeofity (A), ergazjofigofity (E), kenofity (K)

even except for the southeastern margin, where they are least numerous. The pattern of distribution confirms the broad ecological range of species of this group. The concentrations of species of woodland and scrub margins, xerothermic grassland of the classes Trifolio-Geranietea sanguinei and Festuco-Brometea, as well as psammophilous grassland of the Koelerio glaucae-Corynephoretea canescentis class, reflect above all the pattern of geological substrates. Woodland and scrub margin species as well as xerothermic grassland species are represented by 2 to 45 species per square (Fig. 14). They occur most frequently in areas with dolomite outcrops, including post-mining areas where the terrain has been altered to various extents, and are most numerous along a diagonal strip from the southwest to northeast. Psammophilous grassland species, numbering between 1 and 20 species per square, are associated above all with substrate formed on post-glacial deposits (Fig. 15). The largest number of them are in large sandy areas and they also occur on smaller sites in different parts of the post-mining area. Species of deciduous and mixed forest of the classes Querco-Fagetea, Alnetea glutinosae and Querco robori-petraeae number between 2 and 35 per square (Fig. 16) and are concentrated in different parts of the study area. These are degraded remnants of forest communities containing remnants of forest herb layer species.

In the OOR the mountain element is represented by 23 species (3.1%) classified in three altitudinal groups (Table 1, Fig. 17). The localities of the mountain species concentrate in the forest communities (Fig. 18). Interestingly, some of these species occur in anthropogenic

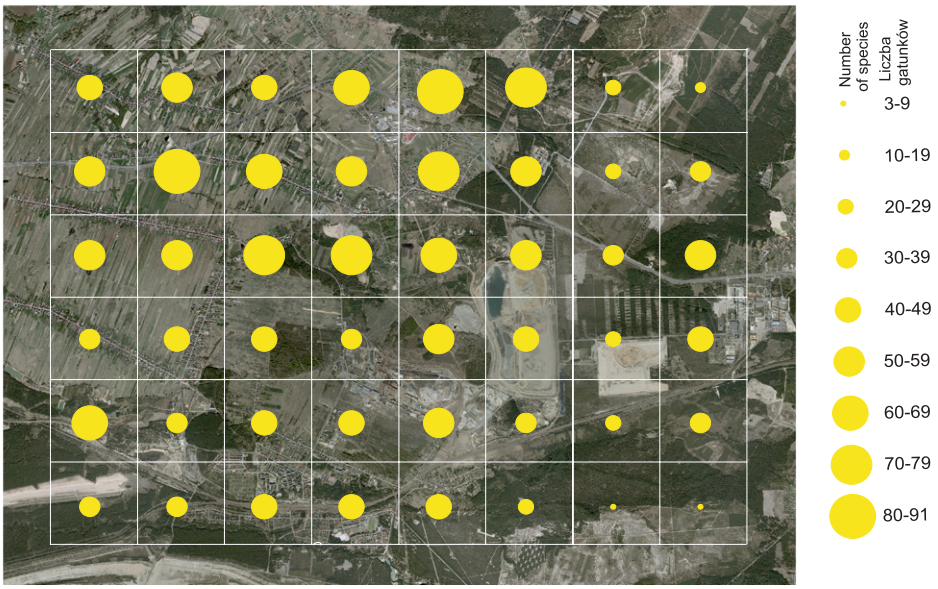


Fig. 13. Number of meadow species (Molinio-Arrhenatheretea class) in individual study squares

Ryc. 13. Liczba gatunków łąkowych (klasa Molinio-Arrhenatheretea) w poszczególnych kwadratach badawczych

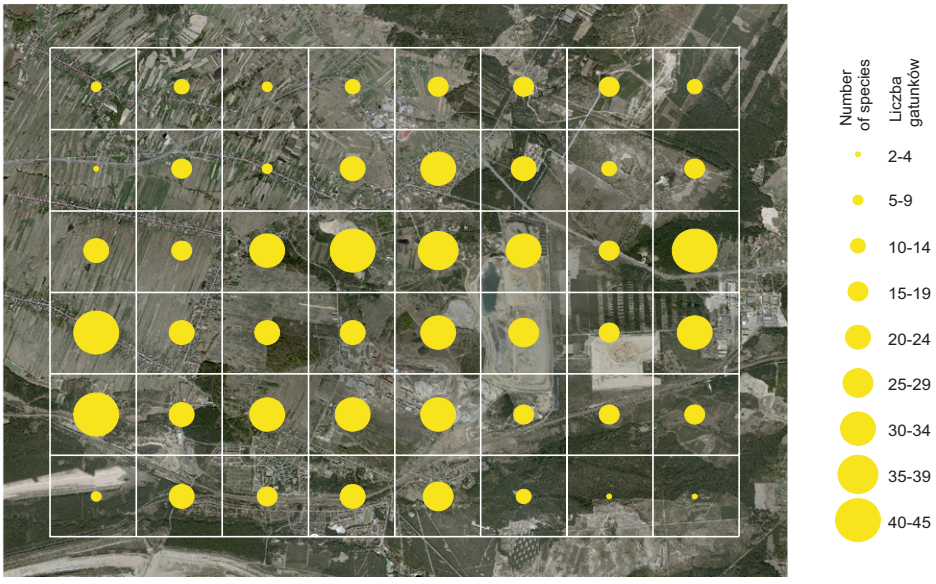


Fig. 14. Number of species of xerothermic grassland and woodland and scrub margins (Festuco-Brometea and Trifolio-Geranietea sanquinei classes) in individual study squares

Ryc. 14. Liczba gatunków muraw kserotermicznych i okrajków (klasy: Festuco-Brometea, Trifolio-Geranietea sanguinei) w poszczególnych kwadratach badawczych

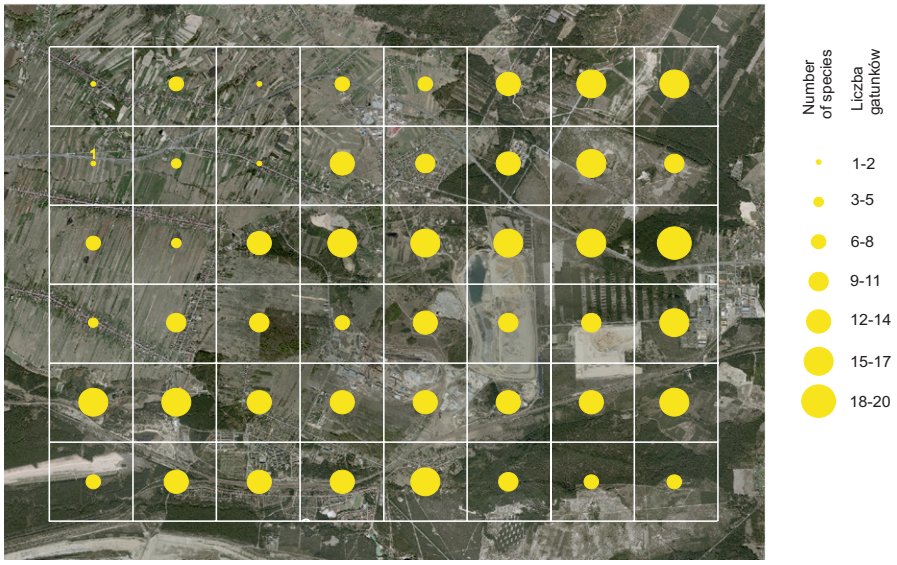


Fig. 15. Number of species of psammophilous grassland (Koelerio glaucae-Corynephoretea canescentis class) in individual study squares

Ryc. 15. Liczba gatunków muraw psammofilnych (klasa Koelerio glaucae-Corynephoretea canescentis) w poszczególnych kwadratach badawczych

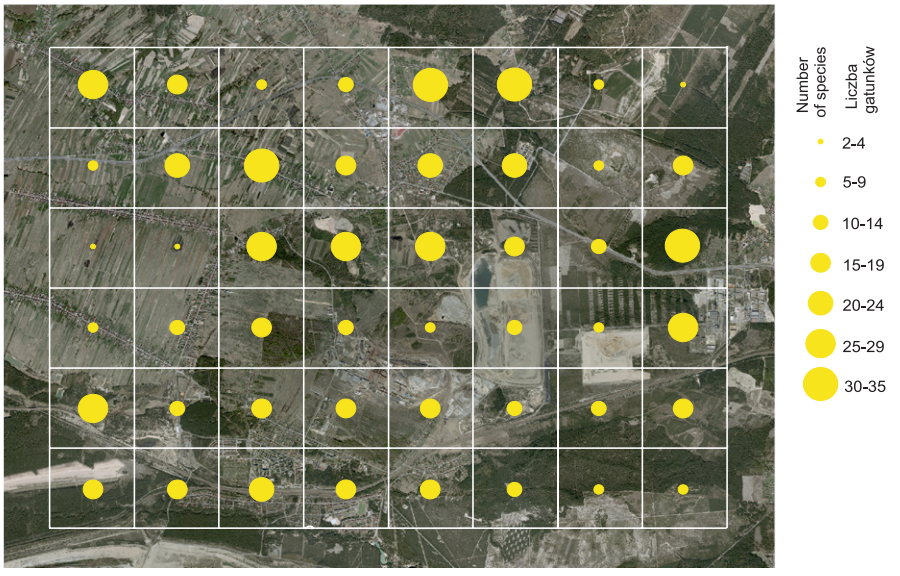


Fig. 16. Number of species of deciduous and mixed forest (Querco-Fagetea, Alnetea and Qercetea robori-petraeae classes) in individual study squares

Ryc. 16. Liczba gatunków lasów liściastych i mieszanych (klasy: Querco-Fagetea, Alnetea glutinosae, Qercetea robori--petraeae) w poszczególnych kwadratach badawczych

Fig. 17. *Biscutella laevigata*, a multizonal species on a post-mining wasteland (photo M. Jędrzejczyk-Korycińska)

Ryc. 17. *Biscutella laevigata* – gatunek ogólnogórski na nieużytkach pogórniczych (fot. M. Jędrzejczyk-Korycińska)

Fig. 19. *Chamaenerion palustre*, a montane species recorded exclusively in railway habitats (photo T. Nowak)

Ryc. 19. *Chamaenerion palustre* – gatunek reglowy notowany wyłącznie na siedliskach kolejowych (fot. T. Nowak)

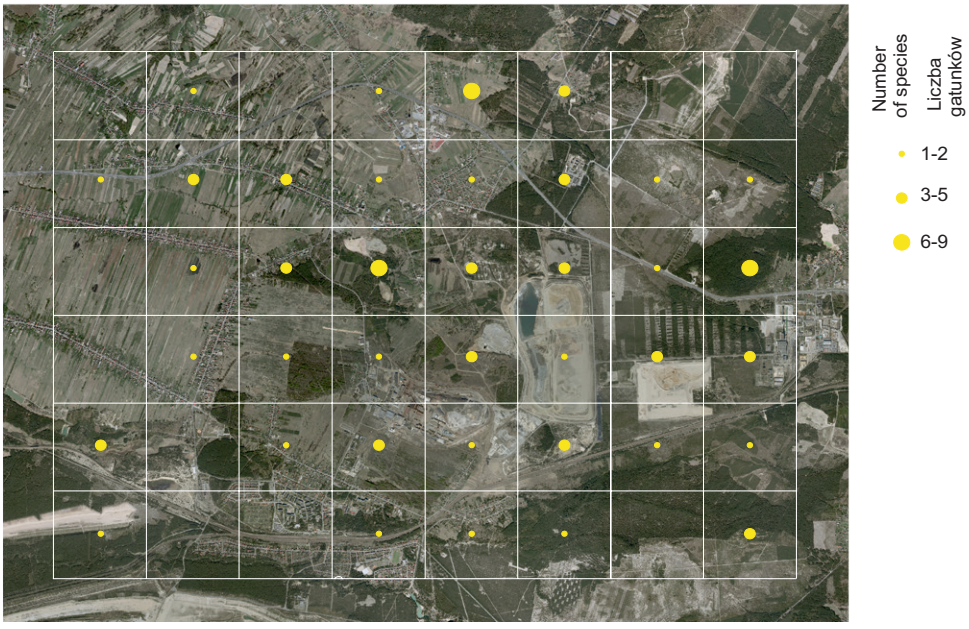


Fig. 18. Number of mountain species in individual study squares

Ryc. 18. Liczba gatunków górskich w poszczególnych kwadratach badawczych

Table 1. Mountain species in the flora of the OOR
Tabela 1. Gatunki górskie we florze OOR

| Multizonal species<br>Gatunki ogólnogórskie | Montane species<br>Gatunki reglowe | Submontane species<br>Gatunki podgórskie |
|---|---|---|
| *Alchemilla crinita* | *Centaurea oxylepis* | *Equisetum telmateia* |
| *Alchemilla glabra* | *Chamaenerion palustre* | |
| *Asplenium viride* | *Equisetum variegatum* | |
| *Biscutella laevigata* | *Gentianella germanica* | |
| *Calamagrostis villosa* | *Malaxis monophyllos* | |
| *Cardaminopsis halleri* subsp. *halleri* | *Polygonatum verticillatum* | |
| *Chaerophyllum hirsutum* | *Rosa pendulina* | |
| *Goodyera repens* | *Sambucus racemosa* | |
| *Gymnadenia conopsea* subsp. *conopsea* | | |
| *Huperzia selago* | | |
| *Melampyrum sylvaticum* | | |
| *Ranunculus serpens* subsp. *nemorosus* | | |
| *Thesium alpinum* | | |
| *Veratrum lobelianum* | | |

habitats substituting for their original habitat. One example is *Chamaenerion palustre* growing on dolomite rubble on railway land (Fig. 19).

In the study area, 46 (6.1%) of the species are protected by law, 39 of them under strict and 7 under partial protection (Table 2, Figs 20, 21). Twenty protected species occur in forest communities (10 species of Vaccinio-Piceetea class, 10 of Querco-Fagetea class), 24 occur in the non-forest communities (7 species of Molinio-Arrhenatheretea, 8 of Festuco-Brometea, 5 of Scheuchzerio-Caricetea nigrae, 2 of Potametea, 1 of Nardo-Callunetea, 1 of Epilobietea angustifolii) and 1 species occurs in a shrubby community (Rhamno-Prunetea).

The strictly protected species include 11 species of the Orchidaceae family, most of them rare or very rare, such as *Dactylorhiza majalis* (Fig. 22). The frequently occurring species under strict protection include taxa of the genus *Epipactis* (*Epipactis atrorubens*, *E. helleborine*) (Figs 23, 24, Table 1). Strictly protected species have localities in all except one of the OOR squares (Fig. 25). Most of them grow in small enclaves of the least transformed vegetation, in meadow complexes on soil of different levels of moisture, but species of this group are relatively common in degraded areas as well. These areas are substitute habitats for them.

Twelve species recorded in the OOR are considered endangered in Poland (Table 3). They represent 1.6% of its flora. Most of them are also protected by law (Table 2), including *Epipactis palustris* (Fig. 26). Apart from the native species, this group also includes one established anthropophyte of the archaeophyte group, *Bromus secalinus*.

The presence and spatial distribution of strictly protected species, floristically the most valuable ones, contribute to the high natural value of the study area. Here we draw attention especially to the Orchidaceae, including the genus *Epipactis* (Table 2) and *Malaxis monophyllos*, which is a fixed component of the

Fig. 20. *Ophioglossum vulgatum*, a meadow species, the rarest fern of the OOR (photo M. Jędrzejczyk-Korycińska)

Ryc. 20. *Ophioglossum vulgatum* – zaliczany do paproci chroniony przedstawiciel gatunków łąkowych (fot. M. Jędrzejczyk-Korycińska)

Fig. 21. *Orobanche lutea*, a protected species of xerothermic grassland (photo M. Jędrzejczyk-Korycińska)

Ryc. 21. *Orobanche lutea* – chroniony przedstawiciel gatunków muraw kserotermicznych (fot. M. Jędrzejczyk-Korycińska)

Fig. 22. *Dactylorhiza majalis*, a protected species of wet meadows (photo M. Jędrzejczyk-Korycińska)

Ryc. 22. *Dactylorhiza majalis* – chroniony przedstawiciel podmokłych łąk (fot. M. Jędrzejczyk-Korycińska)

Fig. 23. *Epipactis atrorubens*, one of the most frequently recorded Orchidaceae (photo T. Nowak)

Ryc. 23. *Epipactis atrorubens* – jeden z najczęściej notowanych storczykowatych (fot. T. Nowak)

Fig. 24. *Epipactis helleborine*, one of the most frequently recorded Orchidaceae (photo M. Jędrzejczyk-Korycińska)

Ryc. 24. *Epipactis helleborine* – jeden z najczęściej notowanych storczykowatych (fot. M. Jędrzejczyk-Korycińska)

Fig. 26. *Epipactis palustris*, a protected and endangered species of low-sedge bog-springs, growing extensively in a meadow overgrown by *Aster novi-belgii* (photo T. Nowak)

Fot. 26. *Epipactis palustris* – chroniony i zagrożony przedstawiciel mlak niskoturzycowych, masowo na łące zarastanej przez astra nowobelgijskiego *Aster novi-belgii* (fot. T. Nowak)

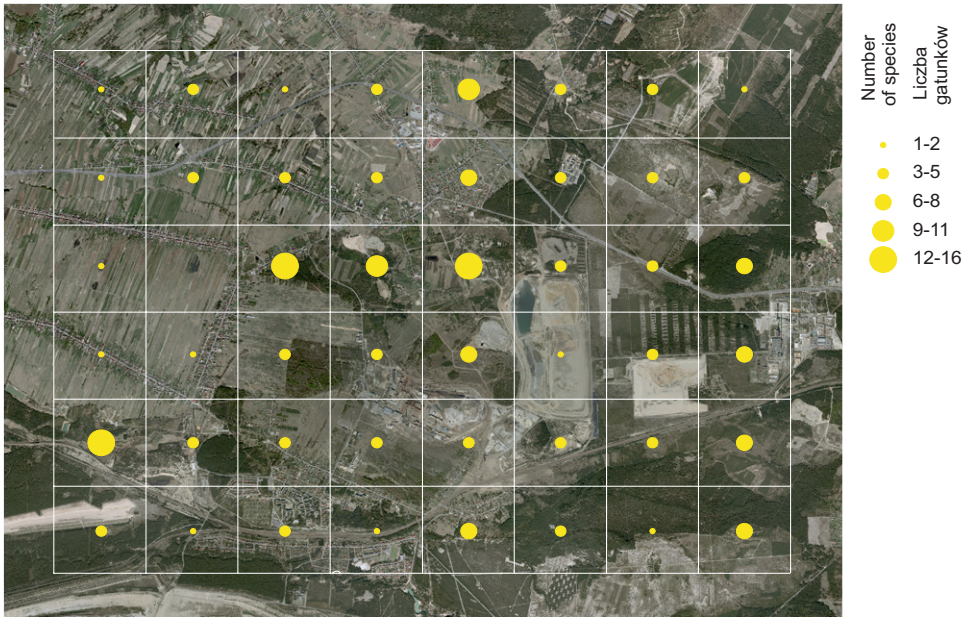


Fig. 25. Number of strictly protected species in individual study squares in the OOR

Rys. 25. Liczba gatunków ściśle chronionych w poszczególnych kwadratach badawczych w OOR

Table 2. Species protected by law in the flora of the OOR
Tabela 2. Gatunki prawnie chronione we florze OOR

| Species<br>Gatunek | Frequency<br>Klasa częstości | Phytosociological classification<br>Klasyfikacja fitosocjologiczna | Family<br>Rodzina |
|---|---|---|---|
| | Strict protection<br>Ochrona ścisła | | |
| *Aguilegia vulgaris* | rare | Que. Fag. | Ranunculaceae |
| *Batrachium fluitans* | very rare | Potam. | Ranunculaceae |
| *Batrachium trichophyllum* | very rare | Potam. | Ranunculaceae |
| ***Botrychium lunaria* | very rare | Nar. Cal. | Ophioglossaceae |
| *Carlina acaulis* | frequent | Fes. Bro. | Asteraceae |
| *Centaurium erythraea* subsp. *erythraea* | frequent | Epi. ang. | Gentianaceae |
| *Chimaphila umbellata* | frequent | Vac. Pic. | Pyrolaceae |
| *Colchicum autumnale* | not frequent | Mol. Arr. | Colchicaceae |
| *Dactylorhiza incarnata* subsp. *incarnata* | very rare | Sch. Car. | Orchidaceae |
| *Dactylorhiza majalis* | rare | Sch. Car. | Orchidaceae |
| *Dactylorhiza ×aschersoniana* | very rare | Sch. Car. | Orchidaceae |
| *Diphasiastrum complanatum* | very rare | Vac. Pic. | Lycopodiaceae |
| *Epipactis atrorubens* | frequent | Que. Fag. | Orchidaceae |
| *Epipactis helleborine* | frequent | Que. Fag. | Orchidaceae |
| ***Epipactis palustris* | not frequent | Sch. Car. | Orchidaceae |
| *Epipactis ×schmalhausenii* | rare | Que. Fag. | Orchidaceae |
| *Equisetum telmateia* | very rare | Que. Fag. | Equisetaceae |
| *Equisetum variegatum* | rare | Sch. Car. | Equisetaceae |
| ***Gentiana pneumonanthe* | very rare | Mol. Arr. | Gentianaceae |
| *Gentianella ciliata* | rare | Fes. Bro. | Gentianaceae |
| *Gentianella germanica* | rare | Fes. Bro. | Gentianaceae |
| *Gladiolus imbricatus* | very rare | Mol. Arr. | Iridaceae |
| ***Goodyera repens* | very rare | Vac. Pic. | Orchidaceae |
| *Gymnadenia conopsea* subsp. *conopsea* | very rare | Mol. Arr. | Orchidaceae |
| *Hepatica nobilis* | very rare | Que. Fag. | Ranunculaceae |
| ***Huperzia selago* | very rare | Vac. Pic. | Huperziaceae |
| ***Iris sibirica* | very rare | Mol. Arr. | Iridaceae |
| *Jovibarba sobolifera* | very rare | Vac. Pic. | Crassulaceae |
| *Lathyrus latifolius* | very rare | Fes. Bro. | Fabaceae |
| *Ledum palustre* | very rare | Vac. Pic. | Ericaceae |
| *Lilium martagon* | very rare | Que. Fag. | Liliaceae |
| *Listera ovata* | rare | Mol. Arr. | Orchidaceae |
| *Lycopodium annotinum* | very rare | Vac. Pic. | Lycopodiaceae |
| *Lycopodium clavatum* | very rare | Vac. Pic. | Lycopodiaceae |
| ***Malaxis monophyllos* | frequent | Vac. Pic. | Orchidaceae |
| ***Ophioglossum vulgatum* | very rare | Mol. Arr. | Ophioglossaceae |
| *Ornithogalum umbellatum* | very rare | Mol. Arr. | Hyacinthaceae |

Table 2. Continued – Tabela 2. Kontynuacja

| Species<br>Gatunek | Frequency<br>Klasa częstości | Phytosociological classification<br>Klasyfikacja fitosocjologiczna | Family<br>Rodzina |
|---|---|---|---|
| *Orobanche lutea* | not frequent | Fes. Bro. | Orobanchaceae |
| *Veratrum lobelianum* | very rare | Que. Fag. | Melanthiaceae |
| | Partial protection<br>Ochrona częściowa | | |
| *Convallaria majalis* | frequent | Vac. Pic. | Convallariaceae |
| *Frangula alnus* | frequent | Que. Fag. | Rhamnaceae |
| *Galium odoratum* | very rare | Que. Fag. | Rubiaceae |
| *Ononis arvensis* | not frequent | Fes. Bro. | Fabaceae |
| *Ononis spinosa* | not frequent | Fes. Bro. | Fabaceae |
| *Primula veris* | very rare | Fes. Bro. | Primulaceae |
| *Viburnum opulus* | not frequent | Rha.Pru. | Caprifoliaceae |

Frequency – see Fig. 2.

*Phytosociological classification: Epi. ang. – Epilobietea angustifolii; Fes. Bro. – Festuco-Brometea; Mol. Arr. – Molinio-Arrhenatheretea; Nar. Cal. – Nardo-Callunetea; Potam. – Potametea; Que.Fag. – Querco-Fagetea; Rha.Pru. – Rhamno-Prunetea; Sch. Car. – Scheuchzerio-Caricetea nigrae; Vac. Pic. – Vaccinio-Piceetea;

**Species classed as endangered in Poland (see Table 3).

Klasa częstości – patrz Ryc. 2.

*Klasa fitosocjologiczna: Epi. ang. – Epilobietea angustifolii; Fes. Bro. – Festuco-Brometea; Mol. Arr. – Molinio-Arrhenatheretea; Nar. Cal. – Nardo-Callunetea; Potam. – Potametea; Que.Fag. – Querco-Fagetea; Rha.Pru. – Rhamno-Prunetea; Sch. Car. – Scheuchzerio-Caricetea nigrae; Vac. Pic. – Vaccinio-Piceetea;

**Gatunki zaklasyfikowane jako zagrożone w Polsce (por. Tabela 3).

forest communities developed in post-mining areas. *Malaxis monophyllos* is estimated to number several thousand plants in the OOR. There are also several protected forest species, members of the classes Querco-Fagetea and Vaccinio-Piceetea, including *Hepatica nobilis*, *Lilium martagon* and *Chimaphila umbellata* (Table 2). Their presence reflects the previous existence of deciduous and mixed forests in the OOR. A unique phenomenon of the forests in the southern part of the OOR is the presence of 4 Lycopodiaceae species: *Lycopodium annotinum*, *L. clavatum*, *Diphasiastrum complanatum* and *Huperzia selago* (Table 2). The Olkusz Ore-bearing Region is also a refuge for species endangered in Poland such as *Biscutella laevigata*, whose localities in the OOR are outside the main range, as well as *Goodyera repens*, *Thesium alpinum* and *Huperzia selago* (Table 2). The presence of these plants makes the OOR a highly important platform for conservation of the most valuable elements of the Polish flora.

The contemporary flora of vascular plants in the OOR comprises 736 species, about 100 species more found than in the earlier study (Nowak 1999). This number becomes significant when compared with the floras of larger areas. The flora of the eastern part of the Garb Tarnogórski mesoregion, with an area of ca. 600 km$^2$, comprises 1033 species (Nowak 1999), the flora of the southeastern

Table 3. Species endangered in Poland and recorded in the OOR
Tabela 3. Gatunki zagrożone w Polsce odnotowane w OOR

| Species<br>Gatunek | Threat category<br>Kategoria zagrożenia |
|---|---|
| *Allium angulosum* | V |
| *Biscutella laevigata* | [V] |
| *Botrychium lunaria* | V |
| *Bromus secalinus* | V |
| *Epipactis palustris* | V |
| *Gentiana pneumonanthe* | V |
| *Goodyera repens* | [E] |
| *Huperzia selago* | [V] |
| *Iris sibirica* | V |
| *Malaxis monophyllos* | V |
| *Ophioglossum vulgatum* | V |
| *Thesium alpinum* | [E] |

V, [V] – vulnerable and vulnerable at isolated localities situated outside the main area of occurrence; [E] – declining – endangered; species on the verge of extinction at isolated localities outside the main area of occurrence.

V, [V] – narażone i narażone poza głównym zasięgiem występowania; [E] – wymierające, krytycznie zagrożone, poza głównym obszarem występowania.

part of the Katowice Upland (280 km$^2$) comprises 904 species (Urbisz 2001), and the flora of the Kraków-Częstochowa Upland (2615 km$^2$) comprises 1431 species (Urbisz 2008). As seen from our report, the number of vascular plant species in the OOR, which is 12 to more than 50 times smaller than those three areas, is equal to 70%, 73% and 51% of the number of species in their flora. Those figures state the case for the biodiversity of the OOR. The ratios of the analysed groups of species in the OOR are similar to those in the compared regions. In particular, the contribution of anthropophytes does not indicate any exceptional transformation of the OOR flora as might be expected for this industrial area. The presence of a large number of protected species should be emphasised. They represent more than half of all the protected species recorded in the eastern part of the Garb Tarnogórski mesoregion (Nowak 1999) and number 13 more than in the southwestern part of the Katowice Upland (Urbisz 2001). We grant that the OOR has 129 fewer vascular plant species than the much larger and topographically more diverse Kraków-Częstochowa Upland (Urbisz 2008).

## Conclusions

• The vascular plant flora of the OOR is rich and diversified. Alteration of the terrain and changes in its exploitation resulted in the formation of a mosaic of habitats and the presence of species of different phytosociological and ecological groups. They represent mainly local resources. As a result, diversity is greater in mining areas than in less transformed areas.

• The vascular plant flora of the OOR comprises 736 species: 547 native species, and 179 species of foreign origin – anthropophytes and 10 species of uncertain status in the flora. Some anthropophytes are invasive and pose a threat to native vegetation.

• The OOR vascular plant flora contains 46 species protected by law, including 8 endangered species, and 4 other endangered species not protected by law. Usually they grow in the least transformed vegetation enclaves and rarely also in ruderal habitats, which are substitute habitats for them.

• The OOR vascular plant flora includes 23 mountain species often having limited and sometimes having isolated ranges. This component adds another phytogeographic dimension to the OOR.

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**Appendix 1**. Alphabetical list of archaeophytes recorded in 2008–2009 in the OOR

**Załącznik 1**. Alfabetyczny wykaz archeofitów odnotowanych w latach 2008–2009 w OOR

*1. *Agrostemma githago*
2. *Anagallis arvensis*
3. *Anthemis arvensis*
4. *Apera spica-venti*
5. *Armoracia rusticana*
6. *Artemisia absinthium*
**7. *Avena fatua*
8. *Ballota nigra* subsp. *nigra*
9. *Bromus secalinus*
10. *Bromus tectorum*
11. *Camelina microcarpa* subsp. *sylvestris*
12. *Capsella bursa–pastoris*
13. *Centaurea cyanus*
14. *Cichorium intybus* subsp. *intybus*
15. *Consolida regalis*
16. *Descurainia sophia*
**17. *Echinochloa crus-galli*
18. *Euphorbia helioscopia*
19. *Euphorbia peplus*
20. *Fallopia convolvulus*
21. *Fumaria officinalis* subsp. *officinalis*
22. *Geranium pusillum*
23. *Lactuca seriola*
24. *Lamium album*
25. *Lamium amplexicaule*
26. *Lamium purpureum*
*27. *Lathyrus tuberosus*
28. *Leonurus cardiaca*
29. *Lepidium campestre*
30. *Lepidium ruderale*
31. *Lithospermum arvense*
32. *Malva alce*
33. *Malva neglecta*
34. *Malva sylvestris*
35. *Matricaria maritima* subsp. *indora*
36. *Myosotis arvensis*
*37. *Neslia paniculata*
38. *Papaver dubium*
39. *Papaver rhoeas*
40. *Pastinaca sativa* s.str.
41. *Raphanus raphanistrum*
42. *Scleranthus annuus*
43. *Senecio vulgaris*
**44. *Setaria pumila*
**45. *Setaria viridis*
46. *Sinapis arvensis*
47. *Sisymbrium officinale*
48. *Solanum nigrum*
49. *Sonchus asper*
50. *Sonchus oleraceus*
51. *Spergula arvensis* subsp. *arvensis*
*52. *Stachys annua*
53. *Thlaspi arvense*
54. *Urtica urens*
*55. *Veronica agrestis*
56. *Vicia hirsuta*
57. *Vicia tetrasperma*
58. *Vicia villosa*
59. *Viola arvensis*

* receding (VU); ** invasive weed

* ustępujący (VU); ** inwazyjny chwast

**Appendix 2**. List of kenophytes recorded in 2008–2009 in the OOR

**Załącznik 2**. Wykaz kenofitów odnotowanych w latach 2008–2009 w OOR

*1. *Acer negundo*
2. *Aesculus hippocastanum*
**3. *Amaranthus retroflexus*
*4. *Aster ×salignus*
*5. *Aster novi-belgii*
*6. *Bidens frondosa*
*7. *Bromus carinatus*
*8. *Bunias orientalis*
9. *Cerasus vulgaris*
10. *Chamomilla suaveolens*
**11. *Conyza canadensis*
12. *Cornus alba*
13. *Datura stramonium*
*14. *Echinocystis lobata*
15. *Echinops sphaerocephalus*
16. *Eragrostis minor*
*17. *Erigeron annuus*
18. *Erigeron ramosus*
*19. *Fraxinus pennsylvanica*
20. *Galeopsis angustifolia*
**21. *Galinsoga ciliata*
**22. *Galinsoga parviflora*
23. *Geranium pyrenaicum*
*24. *Helianthus tuberosus*
*25. *Heracleum sosnowskyi*
*26. *Impatiens glandulifera*
*27. *Impatiens parviflora*
*28. *Juglans regia*
*29. *Juncus tenuis*
30. *Lepidium densiflorum*
*31. *Lolium multiflorum*
*32. *Lupinus polyphyllus*
*33. *Lycium barbatum*
34. *Malus domestica*
35. *Medicago sativa*
36. *Medicago ×varia*
37. *Oenothera depressa*
38. *Oenothera paradoxa*
39. *Oenothera royfraseri*
**40. *Oxalis fontana*
*41. *Padus serotina*
*42. *Parthenocissus inserta*
43. *Physalis alkekengi*
44. *Populus* 'NE 42'
45. *Pinus nigra*
46. *Populus ×berolinensis*
47. *Populus ×canadensis*
48. *Populus nigra* „Italica"
49. *Prunus domestica* subsp. *domestica*
50. *Pyrus communis*
*51. *Quercus rubra*
*52. *Reynoutria japonica*
*53. *Reynoutria sachalinensis*
*54. *Rhus typhina*
55. *Ribes rubrum*
*56. *Robinia pseudoacacia*
*57. *Rosa rugosa*
*58. *Rudbeckia laciniata*
*59. *Rumex confertus*
60. *Salix acutifolia*
61. *Sedum spurium*
62. *Senecio vernalis*
/*/69. *Typha laxmannii*
70. *Veronica arvensis*
**71. *Veronica persica*
72. *Vicia dasycarpa*
*73. *Vicia grandiflora*

* invasive; ** invasive weed; /*/ potentially invasive

* inwazyjny; ** inwazyjny chwast; /*/ potencjalnie inwazyjny