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Alien plant species in the protected landscape area of the Odra river meanders: habitat preferences and threats

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Abstract. The protected landscape area of "The Odra River Meanders" is located in the south-west part of the province of Silesia, along the Odra river, on the border with the Czech Republic. This meandering fragment of the Odra river is one of the few places in Europe where natural geomorphological processes are still preserved. During botanical investigations, the occurrence of 363 vascular plant species was confirmed, including 95 species of alien origin. The participation of archaeophytes was 12%, kenophytes 10% and diaphytes 4%. A high participation of these groups of species was noted in habitats transformed by human activities, such as fields, roadsides and hedges, as well as in natural ones, such as steep escarpments and gravel sandbanks which have been shaped by the dynamic flow of the river. The first group of habitats was characterised by the highest proportion of archaeophytes, whereas in more natural habitats, the ascendancy of kenophytes (= neophytes) over older adventives was noted, e.g. the most common and widespread in this area were species from the *Reynoutria* (*Fallopia*) genus. The number of alien species in each habitat type was quite high and ranged from 1 to 62.

Key words: alien plant species, riverside habitats, biological invasions, nature conservation, Odra River Meanders

1. Introduction

In the south-east part of the province of Silesia, the Odra river flows through the commune of Krzyżanowice. Its 8-kilometres long border section, situated between Poland and the Czech Republic, is preserved in its natural state. This meandering fragment of the Odra river is one of the few places in Europe where the natural geomorphological processes are still preserved. As defined by the Act on Nature Protection of 16 April 2004, it is designated as the protected landscape area (Obrdlík 2003; Nieznański 2006). In September 2006, this area was notified to the European Ecological Natura 2000 Network (2008).

In the light of the high natural value of "The Odra River Meanders", the spread of species of alien origin is one of the most important threats to the area. Plants which penetrate patches of natural vegetation, such as the Asiatic species of the genus *Reynoutria* (= *Fallopia*) which are widespread in this terrain, should be given particular consideration. At present, eradication of these plants is carried out across large areas of riparian forests.

No legal grounds exist yet in Poland for combating alien invasive species. Although it is forbidden to introduce IAS (Invasive Alien Species) to Poland, it is still allowed to plant them in domestic gardens and to use them in landscaping and forestry.

The aim of undertaking the present study was to determine the level of participation of alien species in the flora of the area studied, as well as to estimate the type and scope of the threat posed by alien plant species with regard to the native biological diversity. A list of the most invasive plants was also compiled.

2. Materials and methods

2.1. Study site

The studied section of the Odra river represents a unique fragment of a dynamic river system (Fig. 1, 5). "The Odra River Meanders" are an example of a river-bed natural development. This is shown by the movement of river bends, which can fragment naturally leading to the formation of old river-beds. Also, in this section of the Odra river, the dynamic flow of the river contributes to the rise of steep escarpments which are

Fig. 1. The location of "The Odra River Meanders" area

the result of the undermining of the banks. In addition, islands and gravel or muddy sandbanks are created and destroyed. The processes shaping the river have created rich mosaics of microhabitats, providing refuges to many valuable and rare plant and animal species (Obrdlík 2003; Nieznański 2006; Tokarska-Guzik *et al*. 2007). On both sides of the river, seven types of natural habitats were identified which were described in the Annex I of Council Directive (92/43/EEC) as important for the European Community. Five of them are present on the territory of both Poland and the Czech Republic. They are: lowland rivers and mountain foot with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation, rivers with muddy banks with *Chenopodion rubri* p.p. as well as *Bidention* p.p. vegetation, riverside forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*), riverside forests with *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia* and hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (Obrdlík 2003).

The dynamic processes which in natural ways shape the trough of the river have, on both sides of the Polish – Czech border, contributed to the development of a heterogeneous mosaic of microhabitats. These phenomena create conditions for the occurrence of valuable species of animals in this area (Rast *et al*. 2000; Nieznański 2006).

At the same time, this is the area most threatened by alien plant invasions. Since 2005, a programme for combating knotweeds (*Reynoutria* spp.) has been running there. It is one of the first attempts undertaken in Poland. This programme constitutes an integral part of the project "Protection of the natural value of meanders of the river Odra on the Polish-Czech border as a model solution for other state border watercourses in Europe", executed with the participation of non-governmental organisations: Worldwide Wildlife Fund – WWF Poland and Green League, the local government authority of the Krzyżanowice commune (southern Poland), and the Department of Botany in the Faculty of Biology and Environment Protection at the University of Silesia. It is aimed at the preservation of the unique character of the meanders of the Odra river and, in many sections of the area, the restoration ("re-creation") of the natural values disturbed in the course of invasion by plants of alien origin (predominantly knotweeds: *Reynoutria japonica* and *R.* ×*bohemica*). One of the project tasks is to initiate a programme for the control of knotweeds in order to permit natural succession of vegetation and to monitor the changes which occur in the plant cover.

Sporadic species: *Quercus palustris* [Er] (PSP 2, RF 1), *Lycopersicon esculentum* [Kn] (GS 3, RI 2), *Lolium multiflorum* [Kn] (LM 3, RF 2), *Petroselinum crispum* [Er] (FM 2, RF● 2), *Acer negundo* [Kn] (FL 2, RF 1), *Chenopodium bonus-henricus* [Ar] (RS 2, GS 2), *Chenopodium urbicum* [Ar] (RS 2, GS 2), *Malva neglecta* [Ar] (RS 1, BOR 1), *Abutilon theophrasti* [Ef] (FL 2, BS 2), *Vicia hirsuta* [Ar] (RS 2, LM 3), *Centaurea cyanus* [Ar] (RS 3, FL 3), *Avena sativa* [Er] (PFP 2, RS 2), *Cichorium intybus* [Ar] (PFP 1, RS 2), *Parthenocissus inserta* [Kn] (RF 4), *Fraxinus pennsylvanica* [Kn] (RF 3), *Aster* x *salignus* [Kn] (RF 2), *Fraxinus angustifolia* subsp. *oxycarpa* [Er] (RF 2), *Lamium amplexicaule* [Ar] (RF● 2), *Narcissus poëticus* [Er] (PSP 2), *Atriplex prostrata* subsp. *prostata* [Kn] (RI 3), *Rudbeckia hirta* [Kn] (RI 1), *Calendula officinalis* [Er] (GS 1), *Cucurbita pepo* [Er] (GS 1), *Tagetes patula* [Er] (GS 1), *Elodea canadensis* [Kn] (OR 5), *Tilia tomentosa* [Er] (BOR 1), *Juglans regia* [Kn] (FS 1), *Ranunculus arvensis* [Ar] (LM 2), *Veronica arvensis* [Ar] (LM 2), *Phacelia tanacetifolia* [Ef] (LM 1), *Rapistrum rugosum* [Ef] (LM 1), *Barbarea intermedia* [Kn] (FM 2), *Cornus sericea* [Er] (FM 1), *Verbena officinalis* [Ar] (FM 1), *Reynoutria sachalinensis* [Kn] (RS 2), *Muscari neglectum* [Er] (RS 2), *Avena fatua* [Ar] (RS 2), *Bromus sterilis* [Ar] (RS 2), *Lathyrus tuberosus* [Ar] (RS 2)

Explanations:

Scale of abundance of species: 1 – single specimen; 2 – small cluster; 3 – medium cluster; 4 – large cluster; 5 – field; I – number of habitats in which the species was recorded, II – geographical-historical groups, Ar – Archaeophytes, Kn – Kenophytes, Ef – Ephemerophytes (=casuals), Er – Ergasiophygophytes (species which escaped from cultivation), „?" – uncertain status of species, ● – species noted only on plots where control methods for *Reynoutria* were implemented

Type of habitat: ORB – old river-beds, BORB – banks of old river-beds, RB – banks of the Bełk river, RO – banks of the Odra river, RE – river escarpments, GS – gravel sandbanks, RI – river island, WS – willow scrub, RF – riparian forests, PSP – poplar-spruce plantation, BS – border of shrub, FS – mid-field shrub, LM – lowland hay meadow, FM – fallow meadow, FL – fields, RS – roadsides, PFP – public footpaths

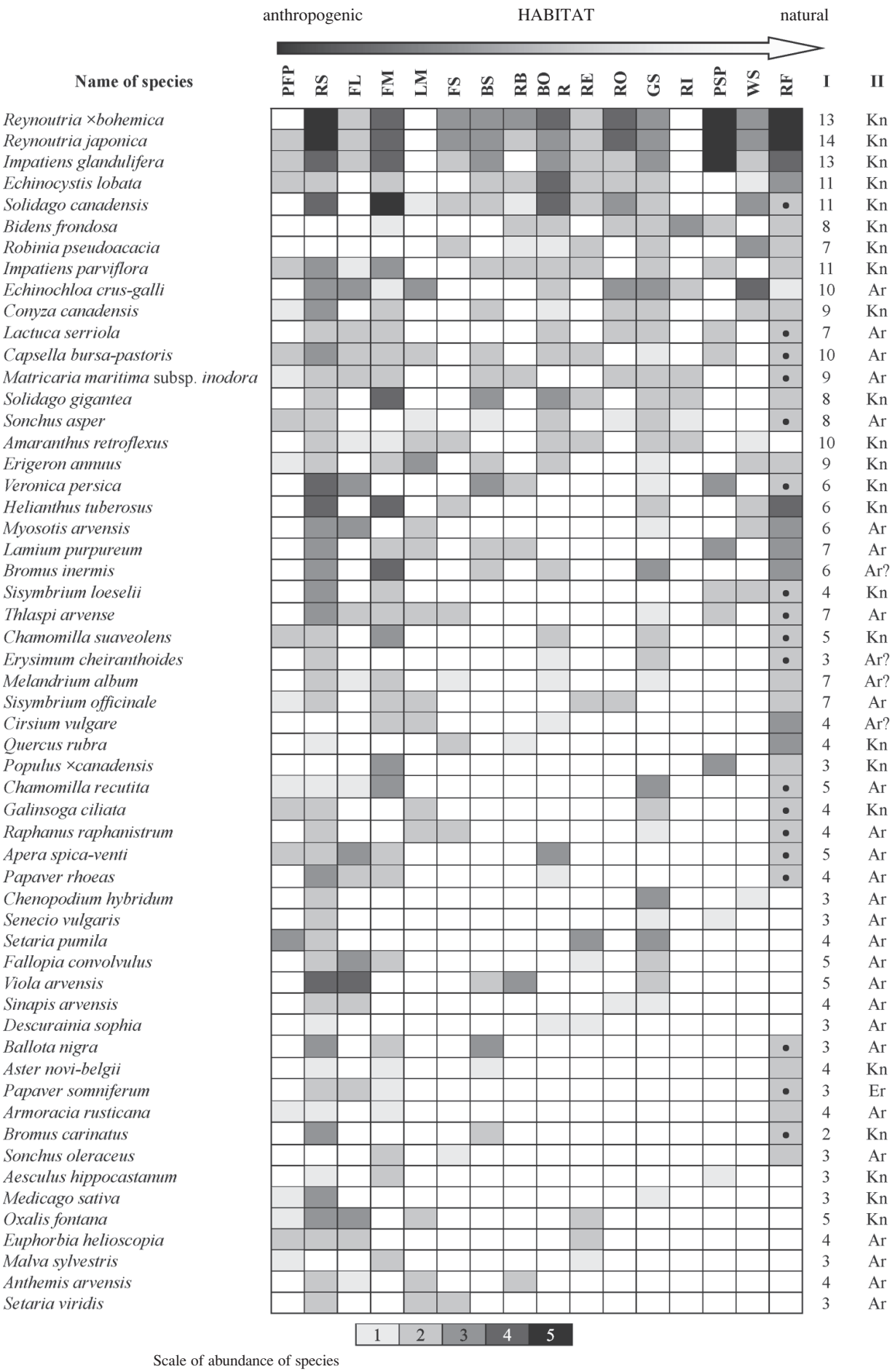

Fig. 2. Habitat preferences, frequency and status of alien plant species in the flora of "The Odra River Meanders"

2.2. Field investigations

Although the area is recognised as a unique example of a natural river section, there was still a lack of detailed information about its flora. Studies on the vascular plant flora diversity of "The Odra River Meanders" were carried out during the growing seasons of 2005-2008. They were conducted in the different periods of the growing season (Tokarska-Guzik *et al*. 2007; Koszela 2008).

The detailed lists of species were prepared for the habitats identified. The habitats were classified into seventeen main types. The abundance in each particular habitat-type was recorded for each species (see explanations below Fig. 2). The frequency of occurrence was also assessed: the species was considered 'sporadic' if present in 1-2 habitat types, 'moderate' if present in 3-4 habitat types, 'frequent' if present in 5-8 and 'abundant' if present in more than 9 habitat-types. The species were referred to the geographical-historical groups which were adopted according to the classification of Kornaś (1968). The referrals were made on the basis of data contained in the studies by Mirek *et al*. (2002) and Tokarska-Guzik (2005a). The analysis comprised 95 species of alien origin, including archaeophytes, the older-arrival synanthropic species, kenophytes (=neophytes), the recent-arrival synanthropic plants which have arrived since the 15th century and diaphytes-species considered not to be naturalised in Poland.

2.3. Data analysis

Alien plants species identified in the investigated area were listed in the Fig. 2. The figure was prepared on the basis of the number and character of habitats in which a given species appear as well as its abundance there. The more often and abundantly the species occurred in the habitats classified as more natural, the higher is its position in the Fig. 2.

Statistical analyses were conducted using the software STATISTICA 8.0. The Principal Component Analysis (PCA) was performed to identify those species which pose the greatest threat to the preservation of natural state of "The Odra River Meanders". The matrix was prepared on the basis of the figure and took into consideration only those alien species, which appeared in six or more habitats.

3. Results

During the botanical investigations, the occurrence of 363 vascular plant species was confirmed, including 95 species of alien origin (Fig. 2). In the flora of "The Odra River Meanders" the participation of archaeophytes was 12%, kenophytes 10% and diaphytes (casual plant species and garden escapees) 4%. A high participation of these groups of species was noted in habitats transformed by human activities, such as fields, roadsides and hedges, as well as in more natural ones, like steep escarpments and gravel sandbanks which have been shaped by the dynamic flow of the river (Fig. 3). The first type of habitats was characterised by the highest proportion of archaeophytes, e.g. *Capsella bursa-pastoris*, *Euphorbia helioscopia* and *Lactuca serriola*, whereas in more natural habitats, the ascendancy of

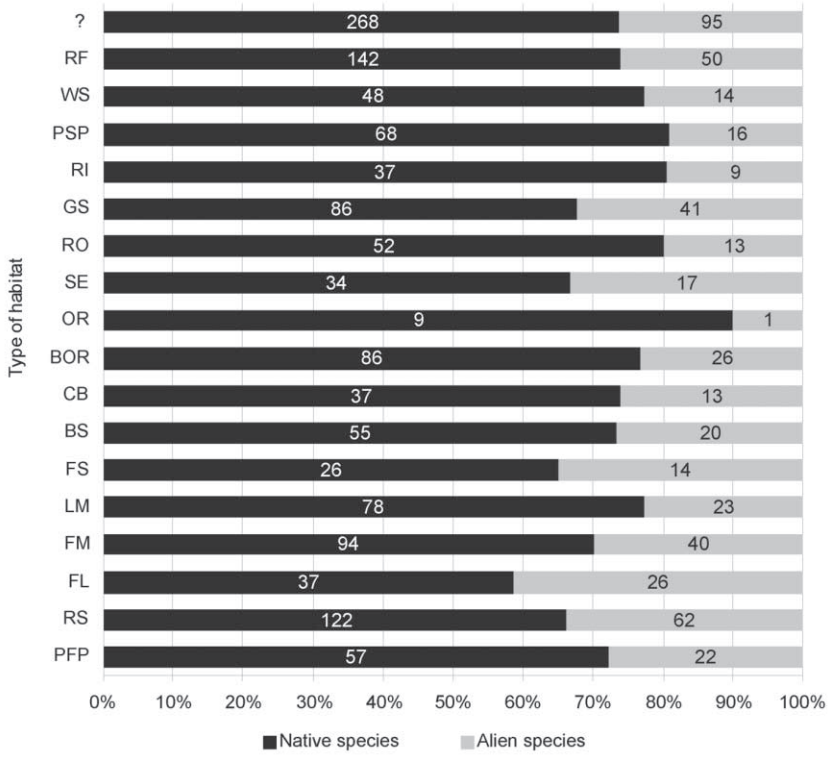

Fig. 3. Participation of alien plant species in the flora of the area investigated with respect to the type of habitat

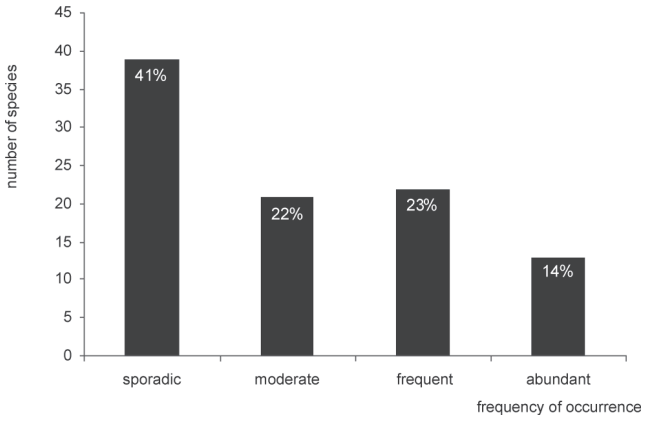

Fig. 4. The ecological amplitude of alien plant species against a background of seventeen main types of habitats in "The Odra River Meanders"

kenophytes over older newcomers was noted, e.g. *Reynoutria japonica, R.* ×*bohemica* or *Impatiens glandulifera*. These species are characterised by the widest ecological amplitude. They were noted in the largest number of habitats and were classified to the group 'abundant' (Fig. 4). 'Sporadic' species, which were found in 1 or 2 habitats, made the greatest contribution to the flora of „The Odra River Meanders" (41%). *Reynoutria japonica* and *R.* ×*bohemica* were widely spread on this terrain. *Reynoutria* plants formed dense and large monospecific stands at roadsides, in poplar-spruce plantations and in patches of riparian forests. Besides, smaller stands were recorded on fields and also along public footpaths (Fig. 5).

The number of alien species per particular habitat type identified ranged from 1 to 62. The highest number of alien species (62) was noted at roadsides. Other habitats which are susceptible to penetration by alien plant species are meadows and gravel sandbanks. A high participation of these groups of plants was confirmed in riparian forests (50). Nevertheless, in this habitat, 20 alien species (e.g. *Solidago canadensis*, *Chamomilla recutita* and *Veronica persica*) were noted only on the plots where the control methods for *Reynoutria* had been implemented. The lowest number of alien species was noted in old river beds and within water courses. In old river beds, only one alien species, *Elodea canadensis,* was recorded. In the flora of this area the participation of ephemerophytes (= casuals) is low (1%) and includes three species: *Abutilon theophrasti,* which was noted on fields and also on the borders of scrub, and *Phacelia tanacetifolia* and *Rapistrum rugosum*, which were both recorded in lowland hay meadows (Fig. 6).

The PCA analysis which was conducted for alien

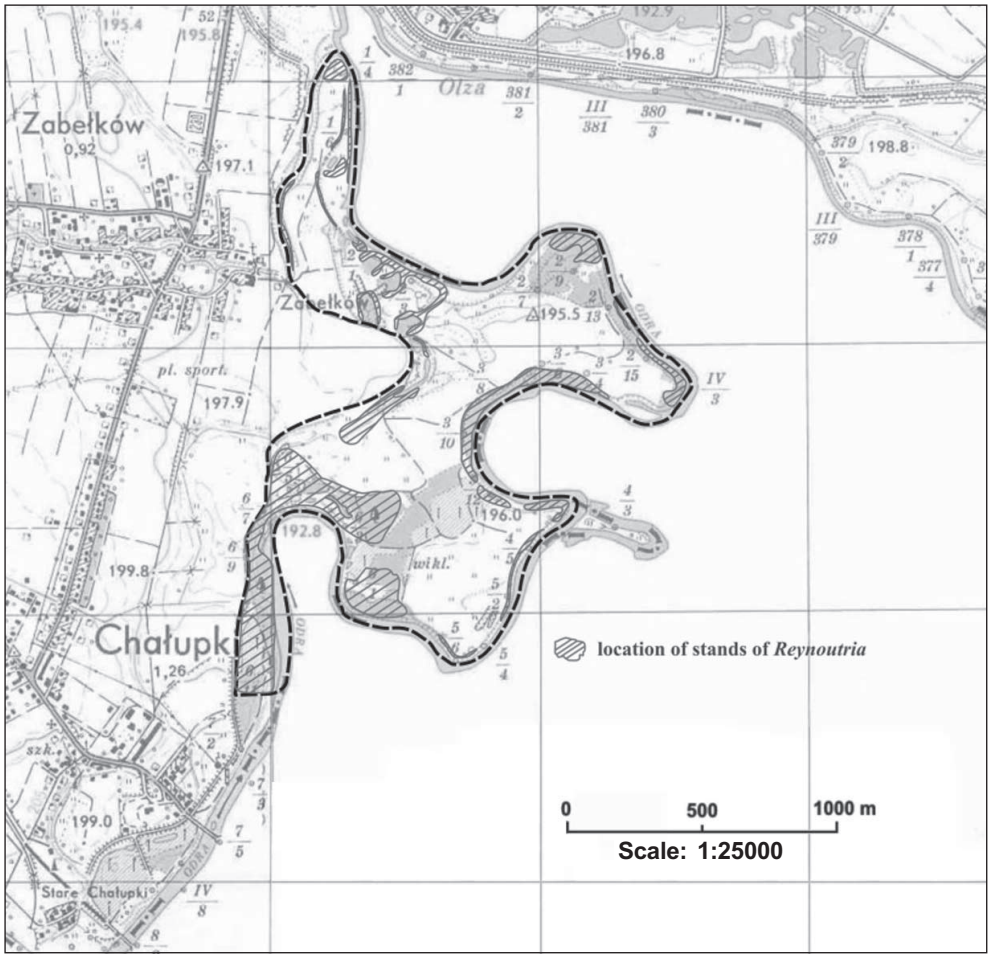

Fig. 5. The location of *Reynoutria* stands

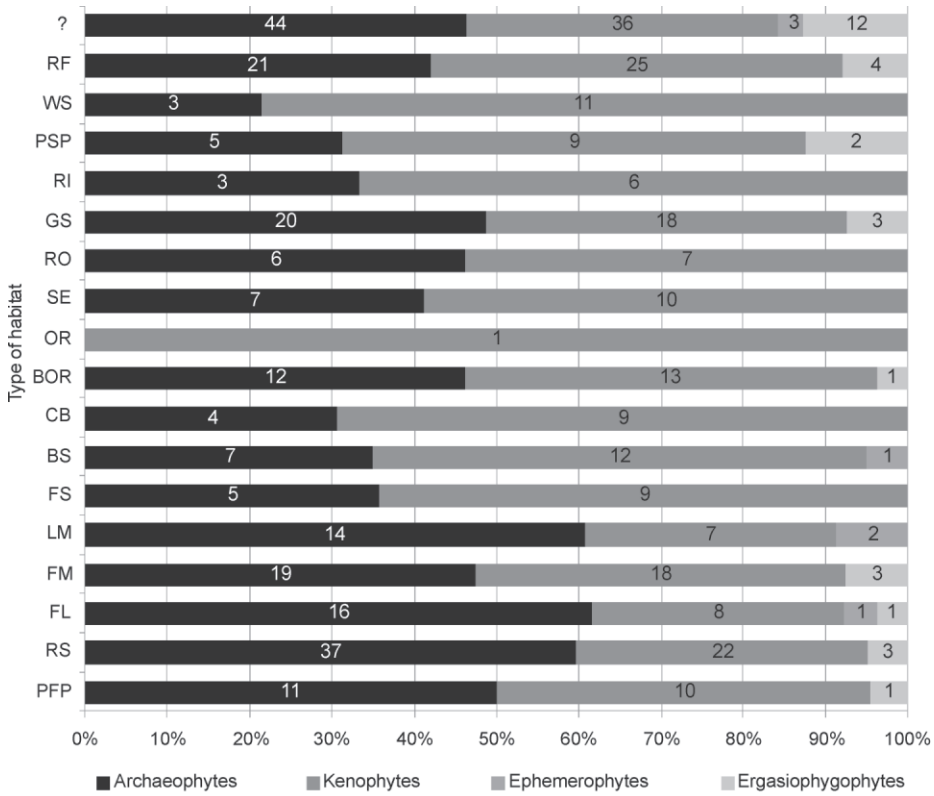

Fig. 6. Participation of the geographical-historical groups of alien species in the flora of the investigated area with respect to the habitat type
Explanations: see Fig. 2

species demonstrated that two species of *Reynoutria* – *R. japonica* and *R.* ×*bohemica* – stand out clearly in this group (Fig. 7). These species were confirmed in the similar number and type of habitats. They appear also in similar abundance. *Impatiens glandulifera, Echinocystis lobata, Solidago gigantea* and *Solidago canadensis* also diverge from the group of kenophytes and archaeophytes. They were found in at least 10 types of habitats. These species may justly be considered as ‚dangerous' from the point of view of the threat they pose to the native flora and vegetation of "The Odra River Meanders".

4. Discussion

Alien species which were noted in the study area account for 26% of the entire flora of "The Odra River Meanders". This number is lower than that ascribed to the flora of Poland (28.6%, Tokarska-Guzik 2005a). Alien plant species do not affect all habitats equally (Schnitzler *et al*. 2007). "Particular habitats such as watersides are the most endangered ones and are most easily invaded by alien invasive plants and then play a role as a transmitter into other habitats such as scrub and woodland" (Tokarska-Guzik 2003). Invasive kenophytes which occupy these types of habitats, often on a massive scale, include *Solidago canadensis* and *Solidago serotina* (these species also massively encroach on fallow fields), as well as *Reynoutria*, *Impatiens glandulifera*, *Rudbeckia laciniata* or *Heracleum mantegazzianum* (Tokarska-Guzik 2005b).

There are some habitats in the study area in which the participation of alien plant species exceeds 32%. These are gravel sandbanks and steep escarpments shaped by the dynamic flow of the river. The riverside habitats are considered as exceptionally susceptible to penetration by species of alien origin (e.g. Jankowski & Świerkosz 1995; Faliński 2000, 2004; Kucharczyk 2003; Rejmánek *et al*. 2005; Tokarska-Guzik 2005a; Richardson *et al*. 2007). This phenomenon is connected chiefly with the natural flow of the river and its frequent floods. As a result of these processes propagules of many species, including alien plants have the chance to move considerable distances (Faliński 2000; Richardson *et al*. 2007). The habitats like the carved banks of rivers, the river islands or the edges of valleys are additionally vulnerable because of their pioneer character. Such areas are often used by those species as bridge-heads, from which they spread further, for example, deep inland (Faliński 2000). Furthermore, according to the current and previous results (Tokarska-Guzik *et al*. 2006; Schnitzler *et al*. 2007 and literature cited therein), willow- poplar communities appear most vulnerable to the invasion of alien plant species. The canopy of these communities is typically more open and allows moderate levels of light to reach the forest floor, which can facilitate establishment.

Many species of kenophytes broaden their range by spreading along river valleys. The Odra and other rivers

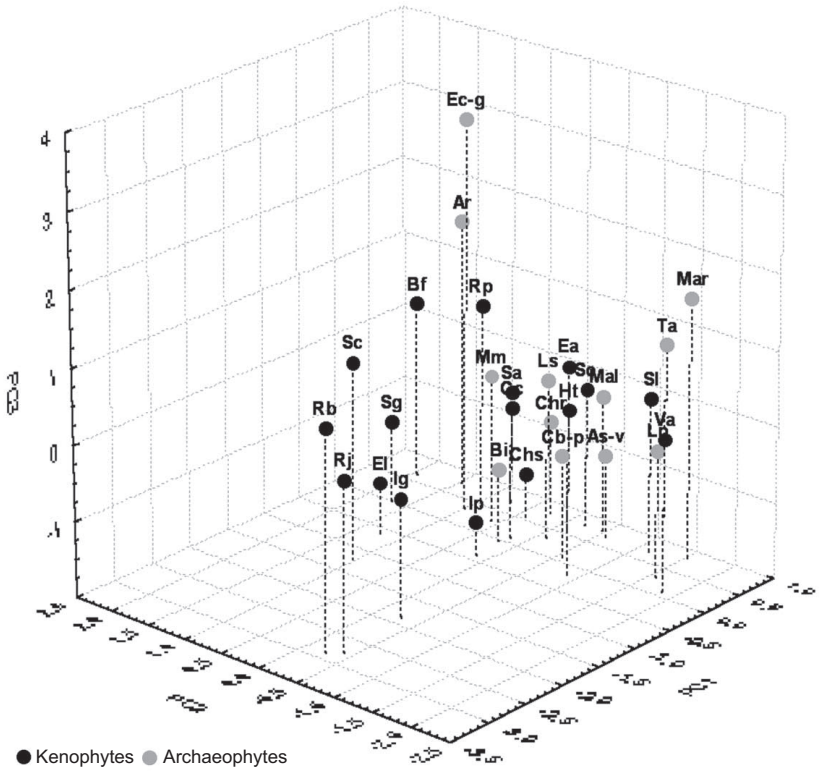

Fig. 7. Results of the Principal Component Analysis (PCA) applied to the correlation matrix of data (habitat preferences, frequency and abundance) for the species given below

Explanations: Ar – *Amaranthus retroflexus*, As-v – *Apera spica-venti*, Bf – *Bidens frondosa,* Bi – *Bromus inermis,* Cb – *Capsella bursa-pastoris,* Cc – *Conyza canadensis,* Chr – *Chamomilla recutita,* Chs – *Chamomilla suaveolens,* Ea – *Erigeron annuus,* Ec-g – *Echinochloa crus-galli,* El – *Echinocystis lobata,* Ht – *Helianthus tuberosus,* Ig – *Impatiens glandulifera,* Ip – *Impatiens parviflora,* Lp – *Lamium purpureum,* Ls – *Lactuca serriola,* Mal – *Melandrium album,* Mar – *Myosotis arvensis,* Mm – *Matricaria maritima* subsp. *inodora,* Rb – *Reynoutria* ×*bohemica,* Rj – *Reynoutria japonica,* Rp – *Robinia pseudoacacia,* Sa – *Sonchus asper,* Sc – *Solidago canadensis,* Sg – *Solidago gigantea,* Sl – *Sisymbrium loeselii,* So – *Sisymbrium officinale,* Ta – *Thlaspi arvense,* Vp – *Veronica persica*

are used in this way for example by *Helianthus tuberosus, Solidago canadensis, Solidago gigantea, Impatiens glandulifera* and *Rubus americanus* (Jankowski & Świerkosz 1995; Faliński 2000). The first four species are present in large numbers in "The Odra River Meanders". Kucharczyk (2003) considers *Eragrostis albensis, Oenothera hoelscheri, Oenothera depressa and Xanthium albinum* as plants which are connected with the valleys of large rivers, in particular, the Vistula (Wisła) and the Bug, but they also occur throughout the lower Oder (Odra) area. *Rumex confertus, Bunias orientalis, Mimulus guttatus, Bidens frondosa* and *Echinocystis lobata* spread in the same way (Tokarska-Guzik 2005; Tokarska-Guzik & Dajdok 2004; Tokarska-Guzik *et al.* 2008). The two last species of kenophytes are also present in the study area.

Two taxa of *Reynoutria* – *R. japonica* and *R.* ×*bohemica* are widespread and abundant in different habitats in "The Odra River Meanders" area. They were noted in 14 of the 17 habitats distinguished. These plants are considered as one of the threats to riverside habitats, in particular, to riparian forests (Bailey & Schnitzler 2003; Tokarska-Guzik *et al.* 2006; Schnitzler *et al.* 2007).

The species of archaeophytes account for a considerable percentage of the flora in this section of the Odra river. This is most probably the result of presence of fields and roads – habitats with which these plants are connected (Kornaś & Medwecka-Kornaś 2002).

5. Conclusions

- The participation of alien plant species in the entire flora of "The Odra River Meanders" area comprises 26%.
- Disturbed habitats which are the result of human activity or the dynamic flow of the river are more susceptible to penetration by alien plant species.
- Archaeophytes prefer the more anthropogenic habitats e.g. fields and roadsides, whereas kenophytes (neophytes) were noted in more natural habitats, e.g. old river beds and scrub.
- Large areas of open and disturbed habitats in riparian forests are susceptible to penetration by alien plant species.

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