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# Occurrence of anthropophytes along streams of the Sowie Mountains and Dzierżoniów Basin (South-Western Poland) in dependence on land use

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**Abstract:** Habitat disturbances and adjacent home gardens (with alien plants cultivated for decorative purposes) favor invasions of anthropophytes, which eliminate native plants and create new plant communities along streams. Research carried out in the Sowie Mountains and Dzierżoniów Basin (Kotlina Dzierżoniowska), showed dependence between the occurrence of anthropophytes and type of land use (forest, agricultural, or built-up area). Plant communities dominated by alien species usually form 2 types of stands: small patches in built-up areas (within the stream-bed protected by stone or concrete walls), and large linear patches in sections of streams flowing along agricultural areas. Occurrence of anthropophytes was researched also in relation to distance from the stream-bed. Some anthropophytes are related to the interior (riparian) sub-zone (*Impatiens glandulifera*, *Rudbeckia laciniata*), while others can occur in different sub-zones (*Solidago gigantea*, *Reynoutria japonica*, *R. sachalinensis, Echinocystis lobata*). Forest communities, despite their degeneration, are the least invaded. Only *Impatiens parviflora* occurs along streams in forests (its average Braun-Blanquet cover-abundance in forest sections is 2.7, while 0.5 in agricultural, and 0.4 in built-up sections). *Impatiens glandulifera* forms denser stands in stream sections in built-up areas than in agricultural areas, while other species show an inverse relation.

**Key words:** invasive plants, river banks, stream, land use type, Sowie Mountains

## 1. Introduction

According to the geographical and historical classification of synanthropic plants (Kornaś 1977), most of invasive species are kenophytes. Invasive plant species spread intensively, abundantly, and repeatably, either spontaneously or due to human activity (Faliński 1972). Their negative effect is manifested in elimination of native species and transformation of plant communities in invaded places. Kenophytes associated with river banks are considered to be a special threat. Due to habitat disturbances and water flow, they effectively spread in river valleys, which are ecological corridors (Pyšek & Prach 1993).

Although research on invasive plants has many aspects, it has recently focused on habitat effects (Chytrý *et al*. 2008a, 2008b). The type of land use determines the nature of the habitat and the degree of human impact. Forest communities in river valleys are increasingly fragmented due to felling, agriculture, urban development, or improvement of rivers. Plant communities found there are usually devastated or greatly altered, which allows invasive plant species to become established (Olaczek 2000).

The vegetation zone adjacent to a watercourse fulfills an important function. It provides habitats for both animals and plants, and facilitates migration and diffusion. It filters polluted runoff and stabilizes stream banks, thereby reducing erosion. It also forms a buffer zone between the stream and the nearby agricultural land (Haycock *et al*. 1996).

The vegetation along streams that flow through agricultural areas, often consists of a mosaic of various plant communities, dominated by marsh plants, shrubs, low trees, and species that grow best in edge communities (Dajdok & Wuczyński 2005). These habitats support the growth and development of interesting plant species and valuable plant communities. When invaded by alien species, the habitats become less diverse.

The main goal of this study was to analyze the relations between the distribution of selected alien species in plant communities near watercourses and the type of land use in the area. The habitat preferences of particular species of invasive plants were also determined.

## 3. Material and methods

The study was carried out in 2006 in the Sowie Mountains and the Dzierżoniów Basin (Kotlina Dzierżoniowska) in the central part of the Sudety Mountains and Sudety Foothills, near the border between Poland and the Czech Republic. The study area comprises ATPOL map squares BE-85, BE-86 and BE-95 (Zając 1978).

The examined plant communities were adjacent to the following streams: Brzęczek, Kamionka-Pieszycki Potok, Kłomnica, and Miła. All of these streams are 10-15 km long, and flow down the slopes of the Sowie Mountains into the Piława river near the town of Dzierżoniów (Fig. 1). They flow through various types of landscape, which, for the purposes of this study, can generally be classified as forest, agricultural or built-up (low housing), in accordance with the system described by Kistowski (1997). Other types of landscape were not found in the study area. The forests were either degraded communities of the class *Querco-Fagetea* or spruce plantations. The stream sections within agricultural areas were dredged, straightened and banked. In built-up areas, the banks were stabilized using stone or concrete.

The distribution of the following alien species was studied: *Echinocystis lobata*, *Impatiens glandulifera*, *I. parviflora*, *Reynoutria japonica*, *R. sachalinensis*, *Rudbeckia laciniata*, and *Solidago gigantea*. For the purposes of this study, a stand of a given species was defined as an area of at least one square meter covered by the species, surrounded by an area in which the species was not found. Isolated single specimens of a given species were not taken into account. Stands were categorized as small or large. Small stands were defined as dense up to 10 meters long, or diffuse up to 100 meters long. Large stands were defined as dense over 10 meters long, or diffuse over 100 meters long.

Each side of the stream was analyzed separately and divided into sections according to the dominating type of land use in the adjacent area: forest, agricultural or built-up. Vegetation zones on each side of a stream were divided into interior, middle and exterior sub-zones, with the interior sub-zones directly adjacent to the stream. In places where the banks were reinforced with stone or concrete, all sub-zones were treated as one (Fig. 2). In vegetation patches containing invasive species, 128 phytosociological relevés were made in accordance to the Braun-Blanquet method (Braun-Blanquet 1964). In the following text, the number of relevés used when describing the results, was marked as N. Data was analyzed with STATISTICA, using the Kruskall-Wallis test. The database included 128 samples, characterized by land use type (marked with numbers 1-3) and Braun-Blanquet cover-abundance of the 7 studied anthropophytes (r was changed into 0.1, while + into 0.5). The independent variable was land use type, while dependent variables were cover-abundance values of the anthropophytes.

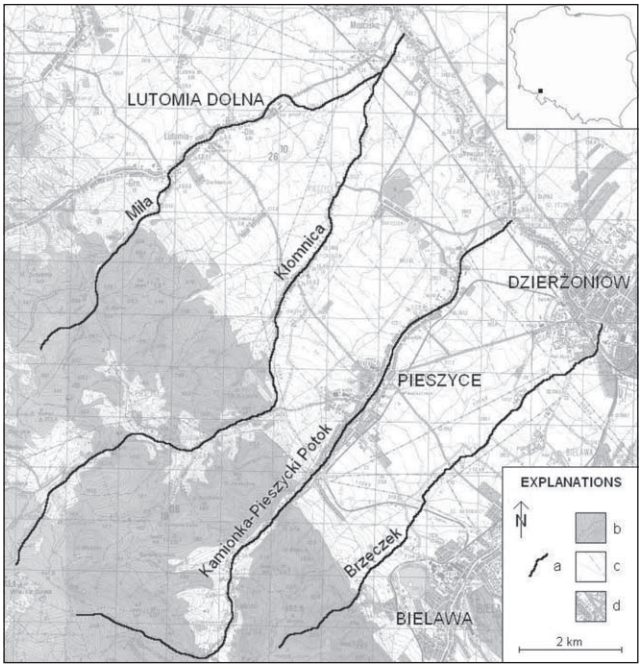


**Fig. 1.** Map of the study area
Explanations: a – stream, b – forests, c – agricultural areas, d – built-up areas

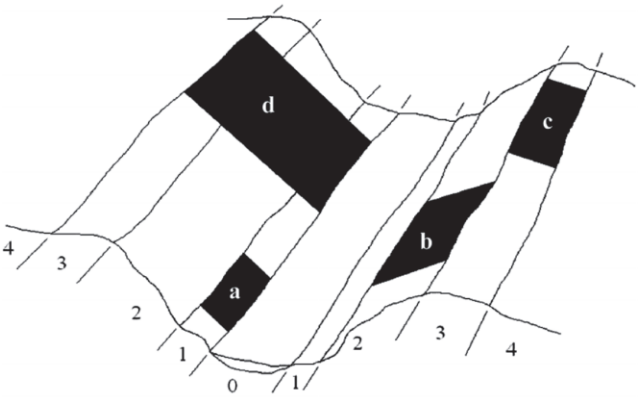


**Fig. 2.** Location of relevés in the stream buffer zone
Explanations: 0 – stream bed, 1 – interior sub-zone, 2 – middle sub-zone, 3 – exterior sub-zone, 4 – forest or agricultural communities, a, b, c – relevés in particular sub-zones, d – relevé covering all sub-zones (modified from Dajdok & Wuczyński 2005)

Plant species nomenclature used in this report followed Mirek *et al*. (2002). Plant communities were identified using the classification system proposed by Brzeg (1989).

## 4. Results

The 3 main types of land use distinguished differ significantly in number of stands of invasive species. In forests, only 13 patches of alien species were found, and all of them were stands of *Impatiens parviflora*. By contrast, 159 stands were found in agricultural areas, and mainly consisted of dense communities formed by invasive species, less commonly of isolated patches. In built-up areas, 135 stands were found, but invasive species generally occurred in small stands scattered along the whole length of the section. Of these, 69 were stands of *I. glandulifera*. In total, 307 stands of invasive species were found (Table 1).

and built-up areas. There were therefore no barriers to their spread between these 2 types of habitat. In relevés made in sections flowing through agricultural areas, invasive species occurred at a rate of 1.5 per relevé, with a maximum of 4 (N=68). The species with the highest cover-abundance were *Reynoutria japonica* and *R. sachalinensis*. The mean value was 4.2 (on the Braun-Blanquet scale) for *R. japonica*, and 4.0 for *R. sachalinensis*. The species with the lowest coverage was *I. parviflora*, with a mean value of 0.5. In relevés made in sections flowing through built-up areas, invasive species occurred at a rate of 1.9 per relevé, with a maximum of 4 (N=50). The species with the highest cover-abundance was *I. glandulifera*, with a mean value of 3.8. In comparison, its mean value in agricultural areas was 2.5. The species with the lowest value there was *I. parviflora*, with a mean of 0.4 (Fig. 3).

**Table 1.** Number of sites along the studied streams in relation to land use type

| Species | Stand type | Stream | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Brzęczek | | Kamionka-Pieszycki Potok | | Kłomnica | | Miła | |
| | | N-U | U | N-U | U | N-U | U | N-U | U |
| *Echinocystis lobata* | L | 0 | 0 | 0 | 0 | 7 | 0 | 3 | 0 |
| | S | 1 | 0 | 0 | 0 | 4 | 0 | 0 | 1 |
| *Impatiens glandulifera* | L | 0 | 0 | 2 | 0 | 17 | 6 | 5 | 1 |
| | S | 0 | 0 | 7 | 28 | 6 | 25 | 0 | 9 |
| *Impatiens parviflora* | L | 37(5*) | 2 | 9(3*) | 1 | 0 | 1 | 5(2*) | 0 |
| | S | 13 | 4 | 4 | 13 | 0 | 4 | 9(3*) | 0 |
| *Reynoutria japonica* | L | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 |
| | S | 0 | 0 | 1 | 7 | 6 | 2 | 0 | 0 |
| *Reynoutria sachalinensis* | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | S | 0 | 4 | 2 | 2 | 0 | 0 | 0 | 0 |
| *Rudbeckia laciniata* | L | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| | S | 0 | 0 | 0 | 0 | 8 | 16 | 0 | 0 |
| *Solidago gigantea* | L | 0 | 2 | 0 | 0 | 5 | 0 | 0 | 1 |
| | S | 8 | 1 | 0 | 1 | 2 | 1 | 0 | 3 |

**Explanations:** N-U – non-built-up area (*forest), U – built-up area, L – large stands, S – small stands

In built-up areas, the flora of the stream-bed itself was dominated by *I. glandulifera*. This is because the stream-beds in built-up areas in mountainous regions are banked and paved with stone or concrete. This impedes the growth of native species, and only some of them (such as *Urtica dioica* and *Phalaris arundinacea*) grow to any appreciable height. Even these species are largely displaced by the more competitive species *I. glandulifera* and, in some places, *Reynoutria japonica* or *R. sachalinensis*.

Very few patches of native plants were found in the stream-beds. Mountain streams are periodically dredged for flood control, which further promotes the spread of invasive species. The exposed stream-bed is quickly colonized by invasive species, especially *I. glandulifera*, which can grow in the cracks and crevices of stream-beds lined with stone or even concrete.

In forests, invasive species occurred with a rate of 1.0 species per relevé (N=9). The only alien species found there was *I. parviflora*. By contrast, all of the invasive species examined were found in both agricultural

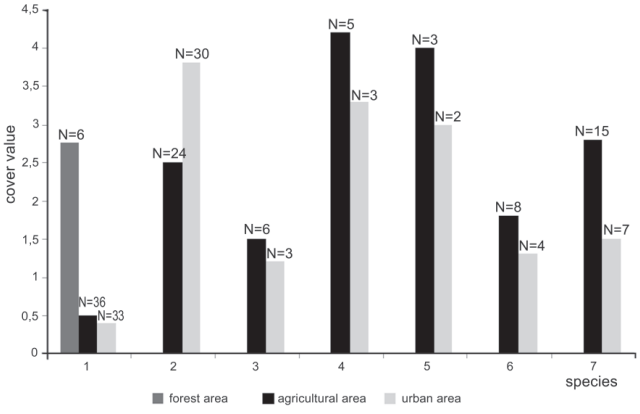


**Fig. 3.** Cover-abundance of anthropophytes in dependence on land use type

Explanations: N – number of phytosociological relevés with the species, 1 – *Impatiens parviflora*, 2 – *Impatiens glandulifera*, 3 – *Echinocystis lobata*, 4 – *Reynoutria japonica*, 5 – *Reynoutria sachalinensis*, 6 – *Rudbeckia laciniata*, 7 – *Solidago gigantea*

**Table 2.** Results of the Kruskall-Wallis test

| Dependent variable | Land use | N | Sum of ranks | Kruskall-Wallis test |
|---|---|---|---|---|
| *Echinocystis lobata* | 1 | 10 | 600.0 | H (2. N=128) |
| | 2 | 68 | 4525.0 | =2.4552 |
| | 3 | 50 | 3131.0 | p=0.2930 |
| *Impatiens glandulifera* | 1 | 10 | 360.0 | H (2. N=128) |
| | 2 | 68 | 3421.0 | =46.9214 |
| | 3 | 50 | 4475.0 | **p=0.000** |
| *Impatiens parviflora* | 1 | 10 | 952.5 | H (2. N=128) |
| | 2 | 68 | 5063.5 | =26.8558 |
| | 3 | 50 | 2240.0 | **p=0.000** |
| *Reynoutria japonica* | 1 | 10 | 600.0 | H (2. N=128) |
| | 2 | 68 | 4467.5 | =1.2090 |
| | 3 | 50 | 3188.5 | p=0.5463 |
| *Reynoutria sachalinensis* | 1 | 10 | 620.0 | H (2. N=128) |
| | 2 | 68 | 4347.0 | =1.0759 |
| | 3 | 50 | 3289.0 | p=0.5839 |
| *Rudbeckia laciniata* | 1 | 10 | 585.0 | H (2. N=128) |
| | 2 | 68 | 4163.0 | =7.6570 |
| | 3 | 50 | 3508.0 | **p=0.0218** |
| *Solidago gigantea* | 1 | 10 | 550.0 | H (2. N=128) |
| | 2 | 68 | 4449.5 | =1.8660 |
| | 3 | 50 | 3256.5 | p=0.3934 |

Explanations: 1 – forests, 2 – agricultural areas, 3 – built-up areas, N – number of relevés

Differences in occurrence of invasive species between various types of land use were statistically significant for *I. parviflora*, *I. glandulifera*, and *Rudbeckia laciniata* (Table 2). Box plot diagrams for those species are shown in Fig. 4. In the interior sub-zone, the most common invasive species were *I. glandulifera* and *Rudbeckia laciniata*. *Impatiens glandulifera* was found in 75% of relevés from this sub-zone (N=54), and *R. laciniata* was found in 70% (N=12). The other invasive species were found in only 10 to 20% of the relevés from this sub-zone. In the middle sub-zone, the most common invasive species was *Solidago gigantea*, which was found in 48% of the relevés (N=23). In the exterior sub-zone, the most common invasive species was *Echinocystis lobata*, which was found in 38% of the relevés (N=9). Those 2 species were relatively common in all sub-zones. *Reynoutria japonica* and *R. sachalinensis* were also found in all 3 sub-zones, but usually formed extensive thickets that covered the entire buffer zone (N=13).

In both agricultural and built-up areas, the plant communities along streams were dominated by alien species

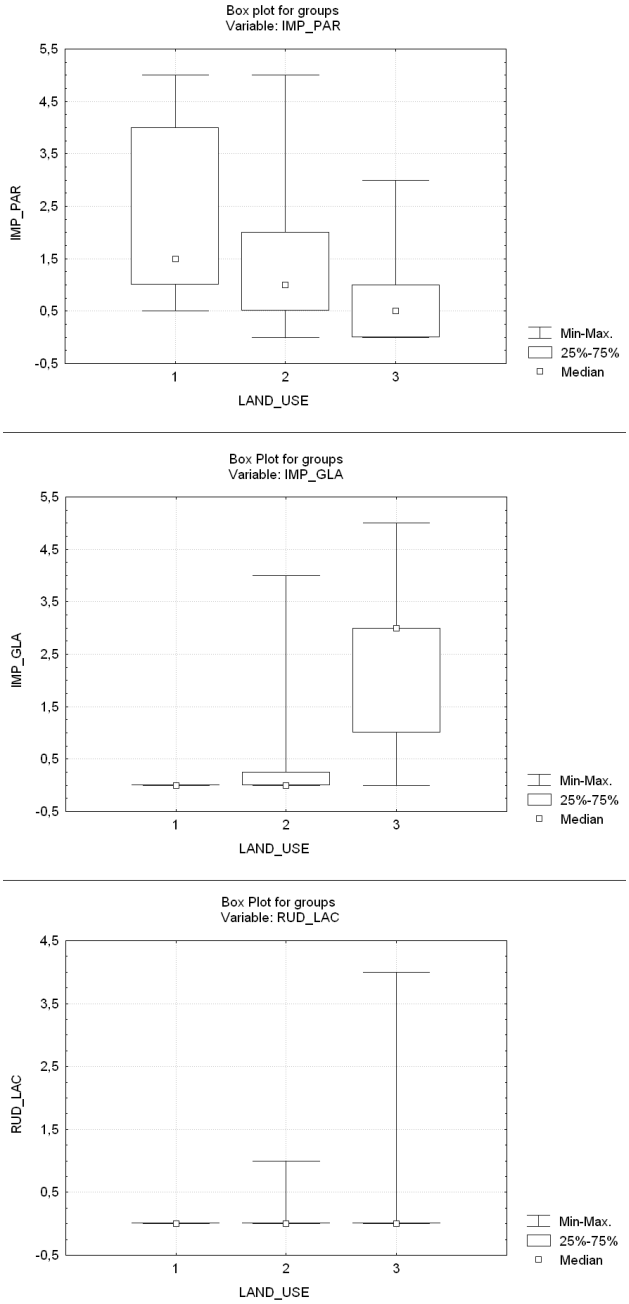


**Fig. 4.** Cover-abundance of *Impatiens parviflora*, *I. glandulifera*, and *Rudbeckia laciniata* in various areas
Explanations: 1 – forests, 2 – agricultural areas, 3 – built-up areas

(Fig. 5). These patches were classified as belonging to the associations *Impatienti-Calystegietum sepium* (Moor 1958) Soó 1971 and *Rudbeckio-Solidaginteum*

**Table 3.** Distribution of invasive species in sub-zones along the stream-bed

| Sub-zone | Percentage of relevés with species (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Echinocystis lobata* | *Impatiens glandulifera* | *Impatiens parviflora* | *Reynoutria japonica* | *Reynoutria sachalinensis* | *Rudbeckia laciniata* | *Solidago gigantea* |
| Interior | 50.0 | 75.0 | 39.5 | | | 70.0 | 28.5 |
| Middle | 12.5 | 15.0 | 44.0 | 100* | 100* | 20.0 | 47.5 |
| Exterior | 37.5 | 10.0 | 16.5 | | | 10.0 | 24.0 |

Explanations: *covering all sub-zones

**Table 4.** *Impatienti-Calystegietum sepium* (Moor 1958) Soó 1971 (1-5), *Rudbeckio-Solidaginetum* R. Tx. et Raabe 1950 (6-10) and community with *Reynoutria* sp. (11-15)

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day (June 2006) | 11 | 12 | 31 | 31 | 12 | 28 | 28 | 31 | 28 | 6 | 28 | 12 | 28 | 6 | 6 |
| Stream | KPP | KPP | KPP | M | KPP | K | K | M | K | B | K | KPP | K | B | B |
| Relevé area (m²) | 15 | 15 | 10 | 20 | 10 | 20 | 30 | 5 | 5 | 15 | 20 | 10 | 10 | 20 | 50 |
| Cover of tree layer (%) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cover of shrub layer (%) | 0 | 0 | 15 | 0 | 15 | 5 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 20 | 0 |
| Cover of herb layer (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 65 | 50 | 100 | 85 | 100 | 100 | 100 | 100 |
| Part of stream buffer zone | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| **Ch. Ass. *Impatienti-Calystegietum*** | | | | | | | | | | | | | | | |
| *Impatiens glandulifera* | 4 | 4 | 3 | 3 | 4 | 2 | 1 | . | . | . | 1 | + | . | . | . |
| **Ch. Ass. *Rudbeckio-Solidaginetum*** | | | | | | | | | | | | | | | |
| *Solidago gigantea* | . | . | 1 | . | . | 3 | 4 | 3 | 1 | 4 | . | . | . | . | . |
| *Rudbeckia laciniata* | . | . | . | . | . | 1 | + | + | 3 | . | . | . | . | . | . |
| **Ch. of community with *Reynoutria* sp.** | | | | | | | | | | | | | | | |
| *Reynoutria japonica* | . | . | . | . | . | . | . | . | . | . | 4 | 4 | 5 | . | . |
| *Reynoutria sachalinensis* | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | 5 |
| **Ch. All. *Convolvuletalia sepium* et *Glechometalia hederaceae**** | | | | | | | | | | | | | | | |
| *Impatiens parviflora** | 1 | 1 | r | + | . | . | . | r | . | + | + | . | r | + | . |
| *Calystegia sepium* | + | . | . | + | . | + | + | . | . | . | . | . | . | . | . |
| *Glechoma hederacea** | + | + | . | . | . | . | . | . | . | . | + | . | . | . | . |
| *Veronica chamaedrys** | . | . | . | + | . | . | . | . | + | . | + | . | . | . | . |
| Sporadic species: *Cuscuta europaea* 8(+). *Petasites hybridus** 13(1) | | | | | | | | | | | | | | | |
| **Ch. Cl. *Artemisietea vulgaris*** | | | | | | | | | | | | | | | |
| *Urtica dioica* | 2 | 2 | 2 | 2 | + | + | + | 2 | . | . | + | + | + | 2 | . |
| *Artemisia vulgaris* | . | . | + | . | . | . | 2 | . | 1 | + | . | . | . | . | . |
| *Epilobium hirsutum* | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . | 1 | . |
| *Galium aparine* | + | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 |
| *Cirsium arvense* | . | . | . | . | . | + | 1 | . | . | . | . | . | . | . | . |
| *Rubus caesius* | . | . | . | . | . | + | . | . | . | + | . | . | . | . | . |
| Sporadic species: *Echinocystis lobata* 5(2). *Tanacetum vulgare* 6(+) | | | | | | | | | | | | | | | |
| **Accompanying species** | | | | | | | | | | | | | | | |
| *Phalaris arundinacea* | 1 | + | + | . | 2 | + | 1 | 1 | . | 2 | . | . | . | 1 | . |
| *Poa trivialis* | . | + | + | . | . | . | . | . | . | + | . | . | r | + | + |
| *Aegopodium podagraria* | . | . | . | . | . | . | . | . | . | + | + | + | + | . | + |
| *Poa pratensis* | . | . | . | . | . | . | + | + | + | . | . | + | . | . | . |
| *Poa palustris* | + | 1 | . | . | . | . | . | . | . | + | . | . | . | . | . |
| *Dactylis glomerata* | . | . | . | . | . | . | + | r | . | . | . | + | . | . | . |
| *Salix alba* (b) | . | . | . | . | 2 | . | . | . | . | . | . | . | . | 2 | . |
| *Impatiens noli-tangere* | + | . | . | + | . | . | . | . | . | . | . | . | . | . | . |
| *Alchemilla* sp. | . | + | r | . | . | . | . | . | . | . | . | . | . | . | . |
| *Geranium pratense* | . | . | . | . | . | . | + | . | . | . | . | . | . | r | . |
| Sporadic species: *Acer platanoides* c 8(+), *Alnus glutinosa* b 10(1), *Daucus carota* 8(+), *Equisetum* arvense 8(+), *Festuca rubra* 10(1), *Lysimachia vulgaris* 10(+), *Lythrum salicaria* 10(+), *Phleum pratense* 10(+), *Salix fragilis* b 10(1), *Sambucus nigra* b 3(2), *Scrophularia nodosa* 8(+), *Valeriana officinalis* 10(+), *Vicia cracca* 12(r) | | | | | | | | | | | | | | | |

Explanations: B – Brzęczek, KPP – Kamionka-Pieszycki Potok, K – Kłomnica, M – Miła

**Fig. 5.** *Echinocystis lobata*, *Impatiens glandulifera*, *Rudbeckia laciniata*, and *Solidago gigantea* at Kłomnica – invasive plants have taken over the natural vegetation

R. Tx. et Raabe 1950. Communities dominated by *Reynoutria* sp. were also distinguished (Table 4).

## 5. Discussion

The spread of invasive species along a stream can cause great changes in the ecosystem of the stream valley. Native species are displaced by alien plants that are able to adapt better to the local conditions. This reduces species diversity and promotes the formations of plant communities that are uniformly dominated by alien species. Watercourses are migration corridors of kenophytes (especially *Impatiens glandulifera*), and built-up areas perform a role of „footholds" for alien plant species (Tokarska-Guzik 2005).

Numerous types of ecological complexes were distinguished by Jackowiak (1990) when describing vegetation in relation to land use types in Poznań. The

region analyzed here is more homogenous, so only 3 types of land use were recognized. However, different numbers of invasive plants in vegetation patches related to various types of land use (the lowest in forests, medium in agricultural, and the highest in built-up areas) still correspond to different stages of land transformation. They can be classified as different degrees of hemeroby (Chmiel 1993, after Sukopp 1972), considering forests as oligohemerobic, agricultural areas as mesohemerobic, and built-up areas as euhemerobic.

Habitats in built-up areas are most altered by human activity. They are also most susceptible to invasion by alien species. The main factors that contribute to the degradation of stream habitats in built-up areas are: stream improvement, wrong management of riverside areas, and the presence of large pools of alien species in the form of decorative plants, growing in gardens adjacent to streams. River valleys are most transformed in built-up areas. Native flora is retreating, while alien plants are appearing there. Riverside vegetation shows a high contribution of synanthropic plants of the class *Artemisietea*; this differs them from natural communities, not changed by human impact (Brzeg & Ratyńska 1983). River improvement in mountains can also decrease the number of mountain species, while increase the number of lowland and synanthropic species (Koczur 1999). This research has revealed a high contribution of invasive plants in built-up areas, which is comparable with results of Kucharczyk (2003) from the Middle Vistula valley.

For the streams included in the presented study, the sections adjacent to forests seem to be resistant to invasion by alien species. However, if forest is improperly managed, it becomes more susceptible to invasion by alien species, especially trees and bushes (Křivánek & Pyšek 2008). Some invasive species can be abundant along paths and in clearings in forests in Lower Silesia. These include *Impatiens parviflora*, *I. glandulifera*, and *Solidago gigantea* (Tokarska-Guzik & Dajdok 2004). Another species encountered in that region is *Spiraea tomentosa*, which is considered to be an invasive species in the Lower Silesian and Niemodlin Forests (Dajdok & Śliwiński 2007).

Alien species had difficulty spreading along the course of the Brzęczek, probably because it does not flow through built-up areas. The only settlement of any size that it passes through is Dzierżoniów, and the length of this segment of the stream is only about one kilometer long. The Brzęczek stream-bed has not been improved. There are no gardens near the stream, so they cannot serve as sources of propagules of alien species. This suggests that the valleys of watercourses flowing through seminatural areas may be somewhat more resistant to invasion by alien species. Kucharczyk (2003) also has observed a low number of kenophytes in agricultural areas (with scattered rural housing and small towns). Human activity does, however, greatly change the landscape of river valleys. Especially important in this respect are: forest clearance, water pollution, stream improvement, and dike building (Kasprzak 2002). The effects are more drastic in agricultural areas than in built-up areas. Along the Brzęczek, only *Impatiens parviflora* was often abundant. However, this species is commonly found all over Poland, and is treated by some researchers as a naturalized species. In fact, it is considered as one of characteristic species for the alliance *Alliarion,* which includes native communities (Matuszkiewicz 2005). Some authors even distinguish an autonomous association called *Impatientetum parviflorae* (Fal. 1966) Brzeg 1989. It was often encountered in the Odra (Oder) river valley in the province of Lower Silesia (Świerkosz 1993; Macicka-Pawlik & Wilczyńska 1996; Anioł-Kwiatkowska *et al.* 1998).

Under favorable conditions, every cultivated species can potentially escape and become naturalized (Mirek *et al.* 2002). This is the way in which invasive species first become established in a given area. Even when they are no longer cultivated, they can effectively spread upstream and downstream on their own, gradually increasing their range (Faliński 2000). According to observations and the reports of the local inhabitants, all of the invasive species found along the streams studied had escaped from gardens. *Impatiens glandulifera*, *Solidago gigantea* and *Rudbeckia laciniata* had been planted as ornamentals. *Reynoutria japonica* had been used as a hedge plant, and *Echinocystis lobata* was used to improve the appearance of wire-mesh fences. *Impatiens glandulifera* for the first time was observed outside cultivation in the Sowie Mountains in the 1970s (Pender 1975). No information is available on when the other species escaped, nor when plant communities dominated by alien species first started to appear.

There are different opinions on how *Impatiens glandulifera* affects plant communities along streams. In one study, the number of species in plant communities invaded by *Impatiens glandulifera* fell by 4 to 15 species (Hulme & Bremner 2006). In another study, however, the number of species was not affected (Hejda & Pyšek 2006). In relevés presented in Table 3, besides the dominating anthropophyte, only 4 to 8 other species can be found. The low numbers suggest a negative impact of invasive plants. The fact that *Impatiens glandulifera* grows well on islets of deposited sediment in banked and paved stream-bed is not surprising. This species is particularly able to adapt to various habitats, such as ruderal sites, edge communities, and marshes (Anioł-Kwiatkowska 1974; Dajdok *et al.* 1998; Tokarska-Guzik & Dajdok 2004), and even potato and grain fields (Andrzej Wuczyński pers. comm.; Zygmunt Dajdok pers. comm.). Small stands of *Impatiens glandulifera* found in built-up areas may represent an early stage

in the formation of the larger stands found in agricultural areas.

*Reynoutria japonica* and *R. sachalinensis* in some places completely dominated the vegetation zone adjacent to the stream, markedly decreasing species diversity (Tokarska-Guzik *et al*. 2006). Furthermore, when thickets of these species die off due to frost, for example, the surface of the soil is left bare, which increases the risk of erosion and mudslides. This can block the stream and increase the risk of spring flooding (Tschiedel 2006).

The extensive plant communities dominated by alien species that are found in agricultural areas can be treated either as aggregations of kenophytes (Matuszkiewicz 2005), or as self-sustaining communities of alien species (Faliński 1998). For example, patches of the association *Impatienti-Calystegietum sepium* (Moor 1958) Soó 1971 have been identified in the Odra river valley (Dajdok & Anioł-Kwiatkowska 1998; Dajdok *et al*. 1998, 2003). The species composition of these stands has been found to be stable over time (Dajdok *et al*. 2003).

## 6. Conclusions

As a result of this research, some dependences between occurrence of invasive plants along stream sections and type of land use in the area are noticeable. In agricultural areas, plant communities dominated by invasive species build usually large stands, which are stretched out along the course of the stream. In built-up areas with banked and paved stream-beds, communities dominated by invasive species usually consisted of scattered, smaller, but dense patches, growing on islets of sediment on the stream-bed. Although the conditions there were not favorable for the growth of most of the invasive species included in the study, the coverage of *Impatiens glandulifera* was very high. The number of invasive species in patches of riparian vegetation was related to neighboring land use types. The lowest was observed in forest sections, while the highest, in built-up sections.

Invasive plants were more common in the interior and middle sub-zones. Nevertheless, the distribution patterns of the invasive species included in this study indicate that they took advantage of the available space to dominate quickly the vegetation zone adjacent to the streams. In agricultural and built-up areas, invasive species sometimes entirely dominated the flora of the stream valley, forming new types of plant communities.

Although forest communities in the Sowie Mountains have been degraded, the alien species included in this study did not spread effectively along the parts of the streams flowing through that area.

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