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Management of invasive plant species in the valley of the River Ślepiotka in Katowice – the example of the REURIS project

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ABSTRACT

In recent years, programmes aimed at improving environmental conditions in river valleys within urban spaces have been initiated in many of the European Community countries. An example is the project "Revitalization of Urban River Spaces – REURIS" which was implemented in 2009-2012. Its main aim was to revitalize a part of the valley of the River Ślepiotka in Katowice. One of the tasks of the project was a comprehensive treatment to combat invasive plant species occurring in this area, carried out by using a combination of chemical and mechanical methods. Chemical treatment involved the application of herbicide mixtures, and mechanical treatment included, among others, mowing and/or removal of the undesirable plants. The work focused primarily on reducing the spread of two species of the *Impatiens* genus: *I. glandulifera* and *I. parviflora,* and the species *Padus serotina*, *Reynoutria japonica* and *Solidago canadensis.* Currently, the maintenance works on this section of the river are performed by the Urban Greenery Department in Katowice, which continues the elimination of invasive plants, according to the objectives of the REURIS program. In 2012 the Department of Botany and Nature Protection at the Faculty of Biology and Environmental Protection started to monitor the implementation and the effects of the implemented actions for elimination and participated in the action of removal of selected invasive plant species: *Impatiens parviflora* and *Reynoutria japonica* within specific areas. These actions led to a reduction in the area occupied by invasive plants and a weakening of their growth rate and ability to reproduce.

KEY WORDS: revitalization, control treatments, alien plants, urban river

1. Introduction

1.1. Invasive alien species – basic concepts, threats and management

Invasive alien species (IAS) are species of foreign origin, whose introduction and/or spread is a threat to biodiversity and/or to the functioning of ecosystems (CBD/IUCN; SOURCE INT. 1). This threat is manifested in the displacement of native flora and fauna due to effective reproduction at a considerable distance from the parent plants and the colonization of new, large areas (HEYWOOD & BRUNEL, 2008).

Invasive alien plant species are nowadays one of the greatest threats to the environment and economy, and in many cases also to the health of humans and animals. This phenomenon is compounded by the rapid development of trade, transport and tourism, which facilitates overcoming geographical barriers and the uncontrolled spread of plants beyond their natural range (PYŠEK ET AL., 2002; PYŠEK & RICHARDSON, 2010; TOKARSKA-GUZIK ET AL., 2012). The intensive development of invasive plant populations may limit opportunities for growth and rooting of native plant species, e.g. mass colonization by *Solidago gigantea*, which creates compact associations and hinders the development of co-occurring plants (JACOBS ET AL., 2004). The mass spread of many invasive plant species, which often leads to the domination of extensive surfaces, consequently requires high financial outlay spent on the fight against them or the development of effective programmes to eliminate them (HEYWOOD & BRUNEL, 2008; LARSEN, 2013). The excessive spread of these plants often

affects the reduction or loss of land value, as well as causing damage to infrastructure (HEYWOOD & BRUNEL, 2008; LARSEN, 2013). In Europe the costs associated with invasive species are estimated at about 12 billion euro a year (TOKARSKA-GUZIK ET AL., 2012).

In Poland different kinds of actions aimed at reducing the spread of invasive plant species are undertaken more and more often. They also result from the legal regulations introduced at international and local level. The basic document of European interest is the Convention on the Conservation of European Wildlife and Natural Habitats (DZ. U. 1996) signed in 1979 in Bern (Switzerland), which obliges the signatories to undertake the strict control of the introduction of alien species. Following this document, the European Strategy on Invasive Alien Species was developed in 2003 (GENOVESI & SHINE, 2004). This strategy indicates, among others, the need to collect information about the spread of invasive species, to introduce regulations at national level and to develop methods for early detection and monitoring of new alien species (GENOVESI & SHINE, 2004). Another important document at international level is the Convention on Biological Diversity (DZ. U. 2002), signed in 1992 at the conference "Environment and Development" in Rio de Janeiro (Brazil). This document obliges the ratifying countries to prevent and control the spread of alien species which threaten ecosystems, habitats and native species (DZ. U. 2002). In Polish law, the problem of invasive alien species has been signaled in the Act on the Protection of Nature of the 16th April 2004 (DZ. U. 2004). Article 120 of this Act prohibits the introduction of alien species and their movement in the environment. However, there are exceptions from these prohibitions for the establishment of tree stands outside forests and areas covered by any forms of nature conservation and for the use of alien plants within the scope of rational agriculture and forestry (DZ. U. 2004). In 2011, the Minister for the Environment issued the Regulation on the list of alien plants and animals which can threaten native species, or natural habitats, if released into the environment (DZ. U. 2011), in which the list of plant and animal species being such a threat was published. In the case of plants, the list comprises, among others, *Heracleum mantegazzianum, H. sosnovskyi, Impatiens glandulifera* and *Reynoutria japonica* (DZ. U. 2011). The introduction of these species into natural environments has been prohibited. All cases of introduction, storage, breeding and reproduction must be preceded by the consent of the General Director for Environmental Protection (DZ. U. 2004).

1.2. River valleys as migration corridors for alien species

The effectiveness of colonization of new areas by invasive plants is conditioned by the presence of a specialized mechanism for the spread of diaspores and the use of different transport vectors. For this purpose the species use, among others, watercourses (hydrochory), which serve as migration corridors (FALIŃSKI, 2000; ZAJĄC ET AL., 2011). The main reason for this phenomenon is water flow, allowing for the movement of their propagules down the river (KOWARIK & SÄUMEL, 2003; ZAJĄC ET AL., 2011). Rivers do not constitute ecological or geographical barriers, which facilitates the movement of plants and their settlement both in river channels and in ox-bow lakes, on the banks of river channels, as well as in the whole river valleys and in adjacent areas (FALIŃSKI, 2000). This way of spreading, using fragments of plants (shoots, rhizomes), is seen in *Reynoutria japonica, Elodea canadensis, Echinocystis lobata*, and, using seeds and/or fruits, in *Impatiens glandulifera*, *I. parviflora, Xanthium albinum, Bidens frondosa* and *Echinocystis lobata* (FALIŃSKI, 2000; TOKARSKA-GUZIK, 2005; DAJDOK & TOKARSKA-GUZIK, 2009; ZAJĄC ET AL., 2011).

Another way of spreading diaspores, and one of the most effective methods, is one which uses air currents, known as anemochory (SOONS, 2006; TOKARSKA-GUZIK ET AL., 2012). This mechanism is clearly visible along large river valleys, which intensify this process (DAJDOK & TOKARSKA-GUZIK, 2009). The fruits of plants capable of anemochory are equipped with aerial apparatuses, enabling these structures to flow on the air and be transferred over long distances. Spreading disapores through the wind is characteristic for many species of the Asteraceae family, for example *Solidago canadensis* or *Rudbeckia laciniata* (TOKARSKA-GUZIK ET AL., 2012).

Another effective way to spread seeds is by ballochory, which uses ballistic mechanisms. Species which use ballochory have fruits, which rapidly crack with a small touch, spreading diaspores relatively large distances. The seeds which are released in this way can reach the vicinity of a watercourse and be moved to a greater distance by the water. Ballochory is characteristic for species of the *Impatiens* genus: *I. glandulifera* and *I. parviflora* (PODBIELKOWSKI, 1995; TOKARSKA-GUZIK ET AL., 2012).

1.3. The natural, economic and social importance of river valleys

From the ecological point of view, the river valley is one of the key elements of the environment responsible for the functioning of related habitat types and constitutes a separate, specific ecological system connecting aquatic and terrestrial ecosystems (ŚWIERKOSZ ET AL., 2004; RICHARDSON ET AL., 2007). It fulfills a number of tasks for the inhabiting organisms; among others it provides access to nutrients, creates a convenient microclimate and acts as a filter for deposited sediments (RICHARDSON ET AL., 2007). Any interference in this system not only affects individual ecosystems, but may also disturb the conditions of the entire fragment of the river (OLACZEK, 2000). Riverside areas are characterized by the occurrence of many valuable natural habitats and are linear ecological corridors for many rare and endangered species of plants and animals (ŚWIERKOSZ ET AL., 2004; DAJDOK & TOKARSKA-GUZIK, 2009). Moreover, the river has been an integral part of human life since Neolithic times (OLACZEK, 2000). Due to high productivity and biodiversity of the watercourse, river valleys were the areas used for agriculture and livestock production and additionally they hosted the first human settlements (OLACZEK, 2000; MARSZAŁEK, 2010). Rivers also had a significant impact on the economic and commercial development of countries. The presence of a watercourse strengthened the political, demographic and social relationships of towns situated in its vicinity (PANCEWICZ, 2004; MARSZAŁEK, 2010). The communication routes formed along rivers contributed to the development of trade and maritime transport, as well as inland shipping (PANCEWICZ, 2004; BERKOVICH, 2009; ŁEPEK, 2009; MARSZAŁEK, 2010), and the continuous trade and communication exchange helped the cultural and social development of towns situated in the vicinity of watercourses (PANCEWICZ, 2004).

The intensive use of river valleys for agricultural and industrial applications led to the transformation of their natural vegetation (OLACZEK, 2000). The results of improper use of the riverside areas due to human activity include a decrease of habitat diversity, progressing the depletion of flora and fauna, as well as opening up new routes for invasive alien plants to be introduced (FALIŃSKI, 2000; OLACZEK, 2000). On Polish territory, such species include: *Echinocystis lobata, Impatiens glandulifera* and *Reynoutria japonica* which spread along the drainage basins of the Oder, Vistula and Carpathian streams (TOKARSKA-GUZIK, 2005; TOKARSKA-GUZIK ET AL., 2007; ZAJĄC ET AL., 2011; SOURCE INT. 2).

The problem of the spread of invasive plants in river valleys and their elimination is a subject of increasing interest among local governments around the world. Nowadays, more and more programmes are initiated aimed at improving the ecological conditions of riverside areas and one of their tasks comprises the removal of invasive plants. The examples of such projects in Europe include: "*Preservation of alluvial forest habitats in Morávka river basin*" project, implemented in the Czech Republic, "*My favourite river*" project, implemented on the river Neckar in Germany or "*URSULA*" project aimed at revitalization of the river Don and its tributaries in Great Britain (BARTÁK ET AL., 2010; SOURCE INT. 3, 4). Such projects have also been started in Poland. These include: „*Revitalization of Urban River Spaces (REURIS)*" project, under which a fragment of the Ślepiotka river valley in Katowice was revitalized, "*Clean river Szarlejka – revitalization of land for environmental purposes*", aimed at the improvement of the environmental condition of the Szarlejka river in Radzionkówand the revitalization of a fragment of the Vistula river in Warsaw within the project "*Warsaw Water and Bicycle Node bike & sail*" (SOURCE INT. 5, 6, 7).

1.4. The "Revitalization of Urban River Spaces" project as an example of actions at regional and local levels

The project "*Revitalization of Urban River Spaces (REURIS*)", implemented under the Central Europe programme, was focused on the adoption of strategies and actions aimed at the revitalization of urban river spaces and the rational use of revitalized space by organizing a number of pilot actions (SOURCE INT. 8). The project was fully financed by the European Regional Development Fund, and involved 8 partners from 6 regions of three different countries: Poland (Katowice, Bydgoszcz), the Czech Republic (Brno, Pilsen) and Germany (Stuttgart, Leipzig). The works relating to the implementation of the project lasted from September 2009 till the end of August 2012. Its total cost exceeded 3.4 million euros (SOURCE INT. 8). One of the pilot actions performed was the revitalization of the River Ślepiotka in Katowice. The partners within the REURIS project assumed the restoration of the natural environmental and landscape qualities, and the functioning of natural spaces and proper water retention within the river valley, as well as the restoration of recreational areas for the local

community (SOURCE INT. 6). One of the main tasks completed in the Ślepiotka river valley was the fight against invasive plant species. The total cost of the treatments performed was nearly 80,000 PLN, with the largest financial expenditure being incurred for the chemical control of *Reynoutria japonica* knotweed (ZZM, 2011).

The aim of the present study was to assess the effectiveness of the treatments undertaken to eliminate the invasive alien plant species, performed within the framework of the REURIS project and continued by the Urban Greenery Department in Katowice and students of the University of Silesia, after completion of the project.

2. Study area

The study area is situated in southern Poland, in Silesia voivodeship, in the Ochojec district of Katowice (Fig. 1). In terms of physiography, the area belongs to the province of the Polish Uplands, the sub-province of the Silesian-Cracow Upland, the macroregion of the Silesian Upland and the region of the Katowice Upland (KONDRACKI, 2001).

Ślepiotka is the western tributary of the Kłodnica, which belongs to the catchment area of the Oder, with a length of about 8 km. The total catchment area of the river is approximately 14 km^2 and is entirely located within the city of Katowice (TRZĄSKI, 2000). The major part of the river valley is covered by forests, and only its middle section is situated within the area of city structures. The fragment of the valley covered by the REURIS program is characterized by the natural occurrence of podzolic soils, stagnosols, brown soils and alluvial soils (BARCIAK ET AL., 2012).

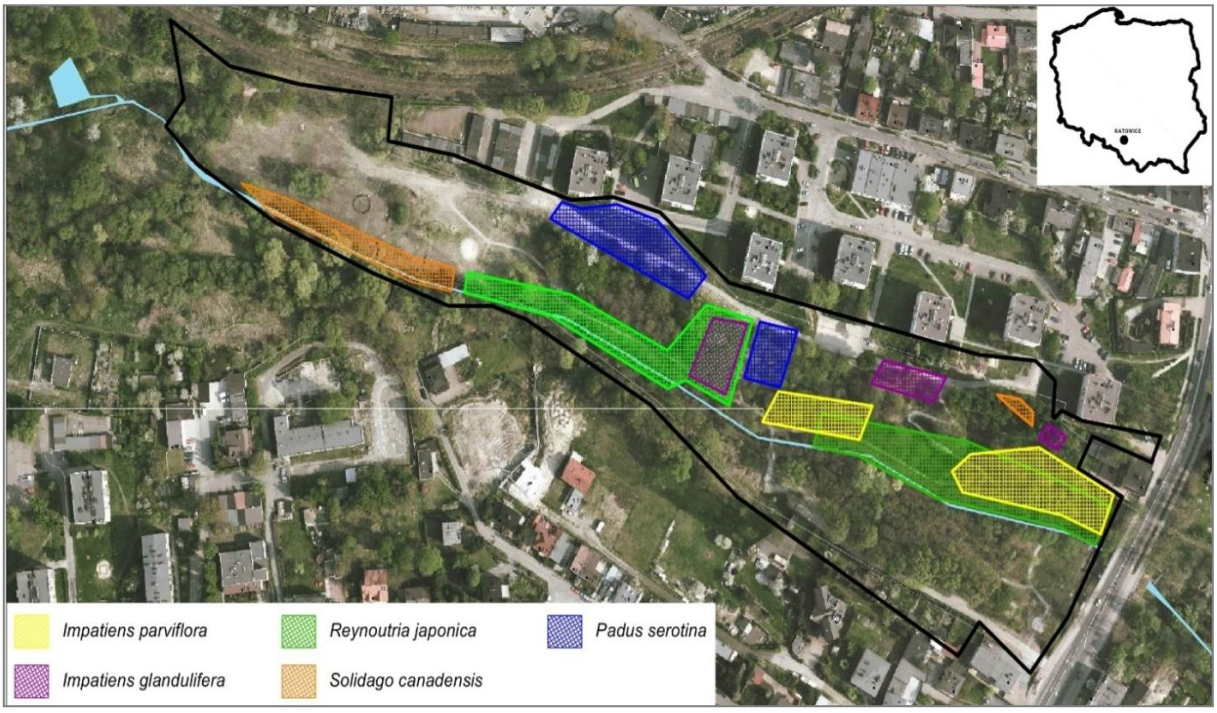

Fig. 1. Location of the study area, including the area of elimination of invasive plant species in the Ślepiotka river valley in Katowice

The actions planned under the project "*Revitalization of Urban River Spaces (REURIS)*" were carried out in a part of the River Ślepiotka valley with an area of approximately 4.13 ha, located in a densely built-up and populated area of the city of Katowice. The choice of location for this investment was determined by: the Katowice Urban Development Plan for the valley, ecological factors and social conditions (LANGE & NISSEN, 2012; SOURCE INT. 6).

Prior to the planned technical works, in the discussed section of the River Ślepiotka, a total of 160 species of vascular plants, including 5 invasive alien species, were inventoried (SZENDERA, 2009). They included: *Impatiens glandulifera* (Fig. 2), *I. parviflora* (Fig. 3), *Padus serotina*, *Reynoutria japonica* and *Solidago canadensis* (Fig. 4).

Impatiens glandulifera and *I. parviflora* are herbaceous annual plants, which belong to the Balsaminaceae family. The primary range of occurrence of both species covers Asia. The fruits of balsams are capsules, which crack with a light touch and release seeds to a distance of up to 6 m from the parent plant (DAJDOK, 2009). The reproduction of

these plants is only generative, by seeds. A single plant is able to produce over 4,000 seeds, as a result of which up to 32,000 diaspores can be spread over each 7 m^2 annually (HELMISAARI, 2010). Apart from the above mentioned autochory, these plants can also spread by allochory, using wind, animals or water (TOKARSKA-GUZIK, 2005; DAJDOK, 2009). The most likely way they were transferred to the area of Ślepiotka valley is from the nearby allotment gardens.

Padus serotina is a woody species, which belongs to the Rosaceae family. Original locations of its occurrence are areas of North and Central America. This plant is used in forestry as a supplement of wood stands. Its reproduction is generative by seeds and less often vegetative by developing root suckers (STARFINGER, 2010). One tree produces an average of approx. 6,000 seeds, which have a high germination capacity (CLOSSET-KOPP ET AL., 2007). *Padus serotina* spreads by endozoochory - seed dispersal via ingestion by vertebrates (TOKARSKA-GUZIK, 2005). Most likely, the seeds of this bird cherry were brought to the Ślepiotka valley area by birds feeding on the fleshy fruits.

Fig. 2. *Impatiens glandulifera* in the Ślepiotka valley (*K. Bzdęga*, 2012)

Fig. 3. A patch of *Impatiens parviflora* on the bottom of the Ślepiotka valley (*M. Frelich*, 2012)

Fig. 4. A patch of *Solidago canadensis* on the bank of the Ślepiotka River (*M. Frelich*, 2012)

Reynoutria japonica is an impressive perennial plant of the Polygonaceae family. Its shoots grow to a height of 2-3 m, while its rhizomes with long underground stolons reach a length of 10-20 m and grow up to 2 m deep (CHILD & WADE, 2000). It was brought from Asia to Europe as an ornamental plant. The reproduction of Japanese knotweed is mostly vegetative by expanding rhizomes or less often generative (TOKARSKA-GUZIK, 2005; LARSEN, 2013). The plant is characterized by strong regenerative abilities. Even a fragment of a rhizome weighing 0.7 g can grow into a new plant (ALBERTERNST & BÖHMER, 2011). The occurrence of *R. japonica* in the Ślepiotka valley can be attributed to the close vicinity of allotment gardens, where this plant could have been grown previously, and by its being brought into the valley area subsequently as fragments of its rhizomes transported within soil during adjustment works and/or carried by the flow of the river.

Solidago canadensis is a perennial plant of the Asteraceae family, which originates from North America. A special quality of this species is its ability to rapidly expand into new areas. Its reproduction

is generative by seeds and vegetative due to rhizomes (KABUCE & PRIEDE, 2010). One plant can produce up to 10,000 seeds (KABUCE & PRIEDE, 2010), which spread by anemochory (SZYMURA & SZYMURA, 2011). Presumably seeds of this species, equipped with aerial apparatuses, entered the valley on the wind.

3. Materials and methods

The starting point for assessing the effectiveness of the methods used to control invasive plant species in the Ślepiotka river valley in Katowice was an analysis of the project documentation, including photographs from the period before and after implementation of the project, as well as local site inspections. Additionally, the opinions of the residents were collected and used. The first inspection was carried out after completion of the project in July 2012. Subsequently, in the following years: 2013 and 2014, observations were continued and inspections were performed three times during each growing season, in spring (April), summer (July) and autumn (October). This evaluation covered the following species: *Impatiens glandulifera, I. parviflora, Padus serotina, Reynoutria japonica* and *Solidago canadensis*. During these works the locations of the plants in the study area were monitored, the size of each stand and the height of the plants were measured and the time of flowering and fruiting phases were recorded. These activities were used to compare the "initial" state – before the performed treatments and after the completed elimination under the REURIS project and works continued by the Urban Greenery Department in Katowice and students from the University of Silesia.

3.1. Range of treatments related to the elimination of invasive plants (based on project documentation)

Project documentation and time tables were completed by December 2009, while the execution of major works took place in 2010. Preliminary steps related to the fight against invasive plants were performed in autumn 2010. They comprised mowing of shoots of goldenrod, balsam species and knotweed (Fig. 1), and a subsequent deposition of the collected biomass to the urban composter (MANA & SZENDERA, 2009). In winter 2010 the employees of the Urban Greenery Department in Katowice, responsible for the subsequent fight against invasive plants, were familiarized with the procedures and planned dates of chemical and mechanical treatments, as were also trained to distinguish the undesirable plants from protected plants also occurring within the area (MANA & SZENDERA, 2009).

In spring 2011 activities related to the maintenance of green areas in the revitalized fragment of the Ślepiotka valley were undertaken by the Urban Greenery Department in Katowice (LANGE & NISSEN, 2012). The assigned duties included the fight against invasive plant species according to the guidelines contained in the "*Instructions for land maintenance and development*…" (TRZĄSKI & SZENDERA, 2011). It was assumed that treatments limiting the growth of invasive plant populations would be conducted regularly every 2-3 weeks during the growing season (from April to October) for a period of at least 3 years. They involved the use of a combination of mechanical and chemical methods tailored to target specific invasive plant species (TRZĄSKI & SZENDERA, 2011).

3.2. Knotweed control

Knotweed control was based on the use of two kinds of methods, chemical and mechanical, to eliminate invasive plants. The first step of the work involved a treatment of these plants with mixtures of herbicides. To make the treatments fully effective, two types of mixtures were developed. The first supplement contained 75% glyphosate, 25% of (4-chloro-2-methylphenoxy) acetic sodium salt and an addition of lime saltpeter (TRZĄSKI & SZENDERA, 2011). It was applied on the surface and served for the temporary control of knotweed plants (Tab. 1). The second supplement was prepared in two different versions: version A, containing 75% of fluazifop-P-butyl, 25% of linuron and a chelating agent, and version B, composed of soil disinfectant – dazomet and a small addition of urea (TRZĄSKI & SZENDERA, 2011). The former supplement (version A) was applied to the surface, while the latter (version B) was applied internally, using a probe (to a depth of 2 m). Both versions of the applied mixture were aimed at sustaining the effects of the previous control (Tab. 1)(TRZĄSKI & SZENDERA, 2011).

After the treatment with herbicides, the treated surfaces were covered with black sunlight-proof foil for a period of one month, in order to starve the rhizomes of knotweed (TRZĄSKI & SZENDERA, 2011). In locations where chemical treatment had not given satisfactory results, the rhizomes were additionally unearthed (Tab. 1). The biomass obtained in this way was disposed of at the urban compost facility (TRZĄSKI & SZENDERA, 2011).

Table 1. Characteristics and an assessment of the effectiveness of the methods used to control invasive plant species in the Ślepiotka river valley in Katowice (methods taken from the REURIS project documentation)

<table>
<tr><th rowspan="2">Species</th><th colspan="2">The proposed control methods</th><th rowspan="2">The frequency and time of application</th><th rowspan="2">The evaluation of used method</th><th rowspan="2">The effectiveness of applied treatments according to the scale*</th></tr>
<tr><th>Type</th><th>Details</th></tr>
<tr><td colspan="6">during the REURIS project</td></tr>
<tr><td rowspan="4">Reynoutria japonica</td><td>chemical</td><td>application of herbicides</td><td>6×painting on of glyphosate and 3×spraying of herbicides per 0.5 ha</td><td rowspan="4">reduction of growth and weakening the condition of shoots</td><td rowspan="4">2</td></tr>
<tr><td rowspan="3">mechanical</td><td>mowing</td><td>before start of the main works</td></tr>
<tr><td>application of black sunlight - proof foil</td><td>for a period of one month (3× per 0.5 ha surface)</td></tr>
<tr><td>excavation of rhizomes</td><td>was performed after the chemical treatments in places where satisfactory results were not observed</td></tr>
<tr><td>Impatiens glandulifera</td><td rowspan="4">mechanical</td><td rowspan="4">Manual or mechanical removal</td><td rowspan="4">5× per 0.93 ha surface</td><td rowspan="2">reduction of the number of plants</td><td>3</td></tr>
<tr><td>Impatiens parviflora</td><td>2</td></tr>
<tr><td>Padus serotina</td><td rowspan="2">limiting the spread by inhibition</td><td>1</td></tr>
<tr><td>Solidago canadensis</td><td>1</td></tr>
<tr><td colspan="6">after the REURIS project (continuation by students)</td></tr>
<tr><td>Reynoutria japonica</td><td rowspan="3">mechanical</td><td rowspan="3">Manual removal</td><td rowspan="2">1× a year (spring)</td><td>a reduction and/or the lack of increase in the area</td><td>2</td></tr>
<tr><td>Impatiens glandulifera</td><td rowspan="2">reduction of the number of plants</td><td>2</td></tr>
<tr><td>Impatiens parviflora</td><td>2× a year in different phases of plants growing</td><td>3</td></tr>
</table>

* The assessment of the effectiveness of the methods used to control invasive plant species according to the scale:
0 - increase, 1 – stable, 2 – discernable decrease, 3 – circa 50% decrease, 4 – circa 75% decrease, 5 – completely elimination

3.3. Control of other invasive plant species

In the case of other invasive species, such as: *Impatiens glandulifera*, *I. parviflora, Padus serotina* and *Solidago canadensis* (Fig. 1), an elimination procedure, which consisted of manual or mechanical removal of plants, was applied (Tab. 1). The obtained biomass was transported out of the valley and subjected to utilization procedures (TRZĄSKI & SZENDERA, 2011).

In the case of *Impatiens glandulifera* and *I. parviflora*, as well as seedlings and undergrowth of *Padus serotina*, the control consisted of manual removal of whole plants at the time of their appearance in spring (Tab. 1) (TRZĄSKI & SZENDERA, 2011). Patches of vegetation with a dominant share of *Solidago canadensis* were mowed mechanically. A control was conducted in places where there was no risk of destruction of native plant species (Tab. 1). The procedure was performed before the production of seeds (TRZĄSKI & SZENDERA, 2011).

After completion of the REURIS project, control action of the invasive plants was also undertaken by local residents and the Department of Botany and Nature Protection at the Faculty of Biology and Environmental Protection of the University of Silesia in Katowice, as well as the Urban Greenery Department in Katowice. Students are still actively involved in the manual removal of knotweed and balsam shoots (Tab. 1) in the section of the valley which had been covered by the REURIS program (Fig. 5), within academic courses on "*Hazards of civilization and sustainable development*" and "*Sustainable development of urban and industrial areas*".

Fig. 5. Removal of *Reynoutria japonica* shoots (A) and securing the collected biomass for utilization(B) by students from the Faculty of Biology and Environmental Protection of the University of Silesia, as part of field work in the Ślepiotka valley (*K. Bzdęga*, 2013)

4. Results

Based on the analysis of project documentation, including photographs and results of field inspections, it was found that the treatments aimed to control: *Impatiens glandulifera*, *I. parviflora, Padus serotina, Reynoutria japonica* and *Solidago canadensis*, conducted under the REURIS project, contributed to a reduction and/or lack of increase in the area occupied by invasive species, although their complete elimination was not achieved (Tab. 1). A similar outcome was obtained as a result of elimination of two invasive species: *Reynoutria japonica* and *Impatiens parviflora* continued by students from the Faculty of Biology and Environmental Protection of the University of Silesia after the completion of the project (Tab. 1).

In the case of *Impatiens glandulifera* and *I. parviflora* a reduction of the number of plants of these species occurring in the valley was achieved. As a result of the annual removal of balsam species, the number of plants in each new generation in each successive year was reduced and the large number of seedlings appearing despite this was a result of the mobilization of the seed reserves from the soil seed bank. In turn, the action of the removal of *Padus serotina* and *Solidago canadensis* undergrowth contributed effectively to limiting their spread by their inhibition (Tab. 1). The growth of knotweed was reduced and the condition of its shoots was weakened, which was a result of regular mechanical and chemical control (Tab. 1) (during the duration of the REURIS project). Currently, the height of individual shoots of this perennial does not exceed 40 cm (Fig. 6). They are weaker and thinner than the shoots of those plants, which grow outside the study area the Ślepiotka valley, and not covered by the control. The regular repeated treatments led to the inhibition of generative reproduction: the plants were not allowed to produce flowers and seeds.

Fig. 6. A patch of *Reynoutria japonica* after application of the combined controls on the following areas: A – by a swamp, B – by a serpentine descent down the slope to the bottom of the valley (*M. Frelich*, 2012)

5. Discussion

The result of the activities conducted to eliminate invasive plant species in the Ślepiotka river valley is in most cases a reduction of the area occupied by these plants and a decrease in their health condition. A similar result was obtained during the control of knotweed in another region of the Silesia province: in the Natura 2000 protected area "The Border Meanders of the Oder River" (TOKARSKA-GUZIK ET AL., 2007; TOKARSKA-GUZIK & KOSZELA, 2009). In this case a similar combined (mixed) mechanical and chemical method was used. Initially the plants were mowed (autumn 2005), and subsequently during the next two growing seasons (2006 and 2007) mowing was repeated and spraying with herbicide at different concentrations was applied (TOKARSKA-GUZIK ET AL., 2007; TOKARSKA-GUZIK & KOSZELA, 2009). Another example of activities conducted to eliminate invasive knotweed species was in the project "*Preservation of Alluvial Forest Habitats in the Morávka River Basin*" in the Czech Republic (BARTÁK ET AL., 2010). Within this project two methods of chemical control of species belonging to the *Reynoutria* genus were used. The first of these consisted of the foliar application of herbicide, while the second one was based on injection of glyphosate into plant stems (BARTÁK ET AL., 2010). These treatments were carried out several times during the growing season over the successive few years. The final result of this control was comparable with the results of the elimination conducted in the Ślepiotka valley in Katowice. The result of these activities was a reduction in the number of knotweed shoots in areas covered by the control, and a reduction of their size and a weakening of their condition (BARTÁK ET AL., 2010). Further elimination of these plants, in subsequent years was based on the use of mechanical methods (clearance and excavating of rhizomes), due to the small size of knotweed shoots, which prevented the application of herbicide into the stem by injection (BARTÁK ET AL., 2010). Similar results have also been achieved in the control of *Reynoutria japonica* in Great Britain. As a result of mechanical (mowing) and chemical (spraying herbicides) treatments, it was possible to reduce the density of knotweed shoots, which ranged between 60-95% of all shoots, in six localities (FORD, 2004). Different results were achieved during the tests of controls of *R. japonica* in the Ojcowski National Park. Mowing plants and unearthing their rhizomes during one growing season has not led to a reduction of the occupied area, but only resulted in weakening their vigour (SOŁTYS-LELEK & BARABASZ-KRASNY, 2009). The differences in the obtained results should be associated with the methods used for elimination procedures, and especially with the length of the treatment periods. The results obtained in the Ojcowski National Park suggest that the exclusive use of mechanical methods is not effective for the control of knotweed (SOŁTYS-LELEK & BARABASZ-KRASNY, 2009). It seems that the use of mixed methods, applied over several growing seasons, is an important requirement for achieving the desired results; in such localities knotweed regenerates more slowly. Abandonment of the systematic removal of knotweed, in a situation when all shoots of this plant have not been eliminated, may eventually result in a reversion back to the situation in the area prior to starting the control (TOKARSKA-GUZIK ET AL., 2007). This happened in the case of the above cited example of the area Natura 2000 "The Border Meanders of the Oder River", which required the development of a new programme of protective action. Furthermore, in view of its totipotency, *Reynoutria* biomass should be treated as hazardous waste in disposal and not composted.

Some studies suggest that the best method for elimination of *Impatiens parviflora* is the removal of individual plants or mowing the area occupied by these plants for at least two years (KUSZEWSKA, 2007). However, the period of combating these plants depends on the level of viability of seeds, which in the case of balsam is estimated to be 18 months (KUSZEWSKA, 2007). It is also planned to use this method to reduce the population of *Impatiens glandulifera* in the area of Wigry National Park within the project: Effective protection of endangered species and habitats in the area Natura 2000 "Refuge of Wigry" (ZACKIEWICZ, 2013). These actions are being implemented in the years 2013-2017 and will cover the area along the River Czarna Hańcza, around lake Czarne and by lake Wigry (ZACKIEWICZ, 2013). The expected outcome of the planned works is a reduction of the size of the Himalayan balsam population by 80%-90% in the area covered by the programme (ZACKIEWICZ, 2013). The control of *Impatiens glandulifera* was also conducted in the area of the Ojcowski National Park. These treatments consisted of mowing patches of balsam, which were conducted for several growing seasons (SOŁTYS-LELEK & BARABASZ-KRASNY, 2009). However, the applied methods of elimination did not produce a satisfactory result due to the fact that the treatments were applied too late and they were not precise (SOŁTYS-LELEK & BARABASZ-KRASNY, 2009). In turn, an analogous procedure of manual removal of *Impatiens parviflora*

in the area of the Bory Tucholskie National Park contributed to a reduction in the occurrence of plants and weakening of their condition, as well as a reduction in their growth (SOURCE INT. 9). The method has been successful due to the regularity of its execution – three times during the growing season, as well as its precision – all plants were removed before their flowering stage (SOURCE INT. 9).

A comprehensive evaluation of the eradication of invasive plants species in the valley of the Ślepiotka river in Katowice during the REURIS Project is not possible, due to the lack of complete project documentation. In Poland, more and more similar programmes are occurring, but there is still a deficit of legal regulations concerning invasive plants management, in comparison with legislation of Western European countries. The important problem is the lack of appropriate instructions concerning so called "good practice" in the Polish language, which could be a guide for companies involved in this type of actions. Such publications could help to increase the awareness of invasive plants management and contribute to enhancing the effectiveness of using methods.

6. Conclusions

The complete elimination of invasive plant species in a specific area is extremely difficult and expensive, and in some cases even impossible. Most of the conducted treatments resulted only ina reduction in the area occupied by the invasive plants. To make the work related to the control and to result in the weakening of the condition of the invasive plants in order to produce the best possible results, it is necessary to choose the appropriate method, which is adapted to the biology and ecology of the plant species, as well as to the characteristics of the specific area. It seems that the use of mixed methods was effective for knotweed control and lead to the reduction in the density of shoots, in the area of occurrence and a weakening of their vigour. The actions of manual or mechanical removal of other invasive species, such as: *Impatiens glandulifera*, *I. parviflora, Padus serotina* and *Solidago canadensis* contributed effectively to limiting their spread by inhibiting the process of increasing the area occupied by them. Therefore, all control treatments should be performed regularly and continued for at least several growing seasons (for annuals – in accordance with the persistence of the seed bank and their viability) and more (for perennials plants spreading by vegetative and depending on the occupied area). However, an accurate evaluation of the control of invasive plants species, during the REURIS project has been considerable impeded. The cause of this is the lack of detailed description of the "initial" state occurring before the performed treatments and a vague projects document. Although the projects document expressed the belief of the undertakers that the methods to be used would be highly effective, it did not completely achieve the desired effect. Based on our own observations and studies conducted after the completion of the REURIS Projectit is recommended to use these control treatments to cover all plants at all stages of development (including seedlings) and prevent them from producing fruits.

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