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INVASIVE ALIEN PLANTS IN PROTECTED AREAS WITHIN CITY BORDERS, ŁÓDŹ, (POLAND)

BOMANOWSKA ANNA, REWICZ AGNIESZKA*, WOLSKI GRZEGORZ J. AND KATARZYNA KRASOŃ

Department of Geobotany and Plant Ecology, Faculty of Biology and Environmental Protection, University of Łódź, Banacha Str. 12/16, 90-237 Łódź, Poland
**Corresponding author's email: stefa@biol.uni.lodz.pl*

Abstract

The aim of the study was to present the occurrence of invasive alien plant species in two forest reserves: "Las Łagiewnicki" and "Polesie Konstantynowskie", located within the city of Łódź (Central Poland). Currently, five vascular plants (*Impatiens parviflora, Juncus tenuis, Padus serotina, Quercus rubra, Robinia pseudoacacia*) and one moss (*Orthodontium lineare*) considered as invasive were found in the studied reserves. Invasive plant species accounted for a small percentage of the flora in the studied reserves, and their sites were mainly concentrated in areas transformed by human activity. The most common species were*Impatiens parviflora* and *Padus serotina*. Due to the location of the reserves within city borders and the proven negative effect of the found species on ecological systems, their sites should be monitored.

Key words: Forest reserve, Invasive species, Poland, Vascular plants, Bryophytes.

Introduction

Biological invasions have become an important issue in ecology and recently received global attention (Pyšek *et al*., 2012). The introduction and establishment of invasive alien plants have a negative influence on diversity patterns and dynamics of ecological systems, and also threaten human health and the economy (Mack *et al.,* 2000; Hejda *et al*., 2009; Pyšek *et al.,* 2012). The translocation of plant species beyond their native biogeographical regions is closely related to human activity, e.g., the development of global trade, transport and tourism, and marking out new routes, which makes the migration of numerous species possible (Levine & D'Antonio, 2003; Christen & Matlack, 2006). However, an increasing number of reports refer to the penetration of alien and invasive plant species into non-harmful habitats located in protected areas (McKinney, 2002; Pyšek *et al*., 2003; Pauchard & Alaback, 2004; Foxcroft *et al.,* 2013). This is even more pronounced in protected areas located within city borders.

It has been repeatedly documented that urban environments promote introductions of alien species (Pyšek, 1998, Celesti-Grapow *et al*., 2001, 2006, Pyšek *et al.,* 2004; Witosławski, 2006; LaSorte *et al*., 2007, 2008; Stešević & Jovanović, 2008; Ricotta *et al*., 2009; Jarošík *et al*., 2011b; Lososová *et al*., 2012; van Ham *et al*., 2013). Urban habitats are heavily transformed and characterised by great habitat heterogeneity, with mosaics of different habitats, many of them strongly disturbed and frequently enriched in nutrients, which facilitates invasion by alien plants (Chocholoušková & Pyšek, 2003; Celesti-Grapow *et al*., 2006; Botham *et al.,* 2009; Kowarik, 2011; Zisenis, 2015). Furthermore, urban habitats are exposed to a high propagule pressure from alien plants, as many ornamental plants are grown in urban gardens, parks and residential areas, and some of them may eventually escape from cultivation and naturalise (Pyšek, 1998; Jarošík *et al*., 2011a).

Obviously, as in other protected areas, the conservation focus in nature reserves in urban areas is on the diversity of native species but conservation efforts in these protected areas are complicated by fragmentation of populations of native plants and high proportions of alien species (Jarošík *et al*., 2011b, Kantsaa *et al*., 2013; Jaszczak & Wajchman, 2014). Unlike the protected areas located outside urban habitats, remnants of natural habitats remain restricted to small and isolated patches and generally have no buffer zone limiting the invasion of alien species and protecting them against intensive use for tourism and recreational purposes (Borgström *et al.,* 2012; Jarošík *et al*., 2011a; Jaszczak *et al*., 2014; Dyderski *et al*., 2015).

Maintaining biological biodiversity in urban landscapes has recently become a conservation priority and protecting natural remnants within cities is increasingly viewed as important (Breuste, 2004; Alvey, 2006). Consequently, non-native species, particularly invasive in flora of urban ecosystems in Europe (Lososová *et al*., 2012; Pyšek, 1998), have recently come into focus as a threat to urban biodiversity throughout Europe (van Ham *et al*., 2013).

Łódź, the capital of Łódzkie Province, with a population of 767 600 inhabitants and a total area of 294 km^2, is the biggest city in Central Poland and dominates the region due to its metropolitan functions (Witosławski, 2006). Due to the spatial development, the administrative borders of the city now include areas of considerable value in terms of nature, which are refuges of wild nature in the urbanised land (Witosławski, 2006 Kurowski & Witosławski, 2009). These include two forest reserves, a landscape park on the north border of the city, and over a dozen areas of lower regime protection, e.g.: protected landscape areas, nature-landscape complexes and areas of ecological utility. Together, they were named "The Green Treasures of Łódź" (Kurowski & Witosławski, 2009). The nature reserves "Las Łagiewnicki" and "Polesie Konstantynowskie" were established to protect multi-species deciduous forests that are a remnant of the now-gone Puszcza Łódzka (Kurowski & Witosławski, 2009). Urban development in Łódź has led to the situation when the investigated reserves previously situated on the city's outskirts are now in the city centre, in the vicinity of busy streets and residential buildings, so they are directly exposed to strong pressure from the surrounding environment.

The objective of the study was to present the floristic composition of invasive plant species occurring in the two nature reserves in Łódź.

Material and Methods

The study area: The occurrence of invasive plant species in protected areas of Łódź was analysed with regard to the two most valuable objects: the "Las Łagiewnicki" reserve and the "Polesie Konstantynowskie" reserve (Fig. 1).

The "Polesie Konstantynowskie" nature reserve (N 51 45'30.24, E 19 25'06.68), covering 9.8 ha and established in 1930, is one of the oldest reserves in Poland, and the first ever established within the administrative city borders (Olaczek & Sowa, 1980). It is located in the western part of Łódź, neighbouring two busy streets, the Zoological Garden and residential buildings. It is a part of the largest city park in Łódź, Józef Piłsudski Park. The reserve was established to protect the site of the European silver fir *Abies alba* at the northern limit of its geographical range, and to protect the well-preserved phytocenoses of oak-hornbeam forest (*Tilio-Carpinetum*), swamp alder forest (*Ribeso nigri-Alnetum*), and alluvial ash-alder forest (F*raxino-Alnetum*; Kurowski & Witosławski, 2009). In the reserve, 150 vascular plant species have been identified (Olaczek & Sowa, 1980). Visitors have no access to the "Polesie Konstantynowskie" reserve, which is separated from the public part of the park by metal fencing.

The "Las Łagiewnicki" nature reserve (N 51 49'52.57 E 19 28'38.63), covering 69.84 ha, was established in 1996 in the northern part of the city. It is a part of a large (1200 ha) forest complex of the same name, located within the city borders, which is a popular recreation venue for residents of Łódź. The "Las Łagiewnicki" is a forest reserve established to protect the well-preserved phytocenoses of oak-hornbeam forest (*Tilio-Carpinetum*) and Euro-Siberian steppic woods with *Quercus* spp. (*Potentillo albae-Quercetum*), as well as sites of protected and rare plant species in the region (Kurowski & Witosławski, 2009). In the reserve, 279 vascular plant species have been identified (Witosławski *et al.*, 2000). Visitors have access to the reserve for educational and tourism purposes, but require permission from the Regional Director for Environmental Protection in Łódź.

Data collections and analysis: Data on the occurrence of invasive plant species in the "Polesie Konstantynowskie" reserve were gathered during the botanical research carried out in 2010-2011. Alien flora was studied by the cartogram method in a grid of equal-sized study plots – basic squares measuring 125 m × 125 m based on the ATPOL grid used for mapping the distribution of vascular plant species in Poland (Zając & Zając, 2001). The reserve area was divided into 12 basic squares. Each basic square was equivalent to a site (Fig. 2). Data were collected as floristic lists with data on the abundance of particular species. The dispersion for each invasive species was determined on a conventional 3-degree scale: sporadic (1) – species spotted over 1-2 squares, rare (2) – spotted over 3-7 squares, common (3) – spotted over 7 squares (dispersed more or less evenly throughout the whole reserve). The list of invasive plant species occurring in the "Las Łagiewnicki" reserve was prepared based on literature data (Witosławski *et al.*, 2000). The methodology of floristic studies used by Witosławski *et al.* (2000) was comparable to that used in the authors' own research.

Invasive plant species were distinguished after Tokarska-Guzik *et al.* (2012) and after Söderström (1992). Categories of invasiveness of vascular plants were adopted from Tokarska-Guzik *et al.* (2012). Plant names were taken from Mirek *et al.* (2002) and Ochyra *et al.* (2003).

For each invasive species, its relative frequency of occurrence was estimated (Brower & Zar, 1984). Frequency (Fi) was calculated according to the formula: Fi = (ji/ k) × 100 %, where: j – the number of reserves, in which species 'i' was recorded, and k – the total number of reserves.

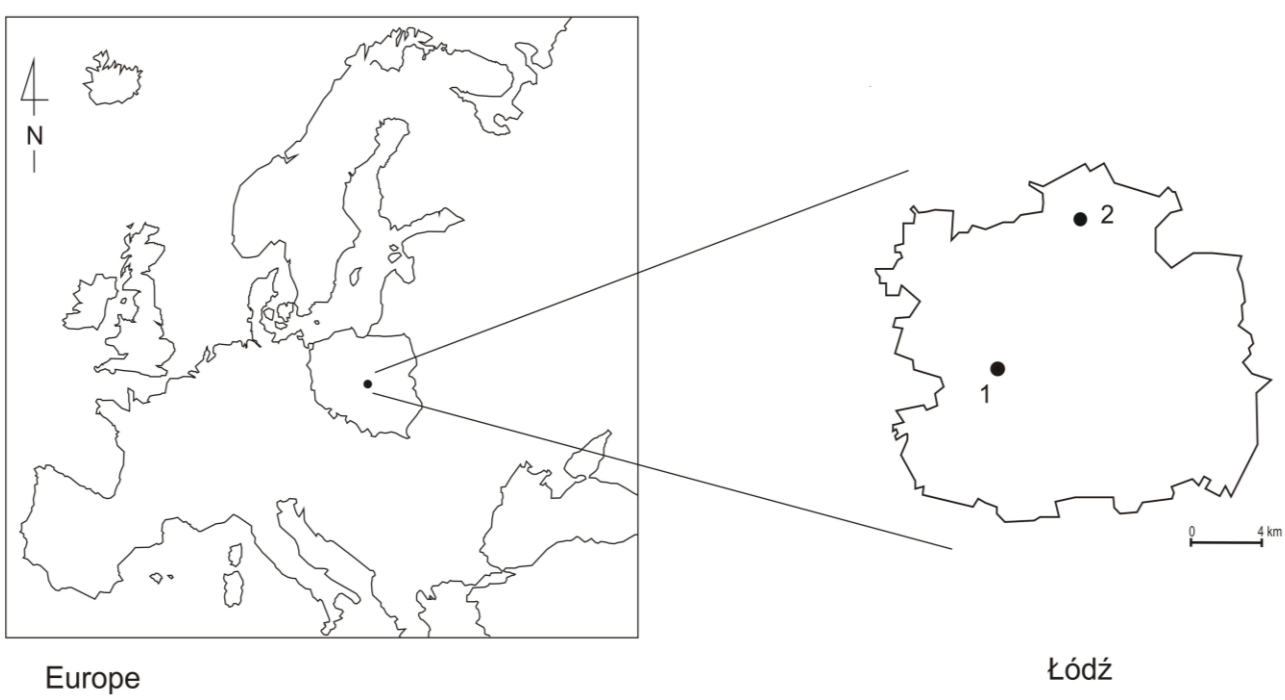

Fig. 1. Location of the reserves taken under study. Explanations: 1 – the "Polesie Konstantynowskie" reserve, 2 – the "Las Łagiewnicki" reserve.

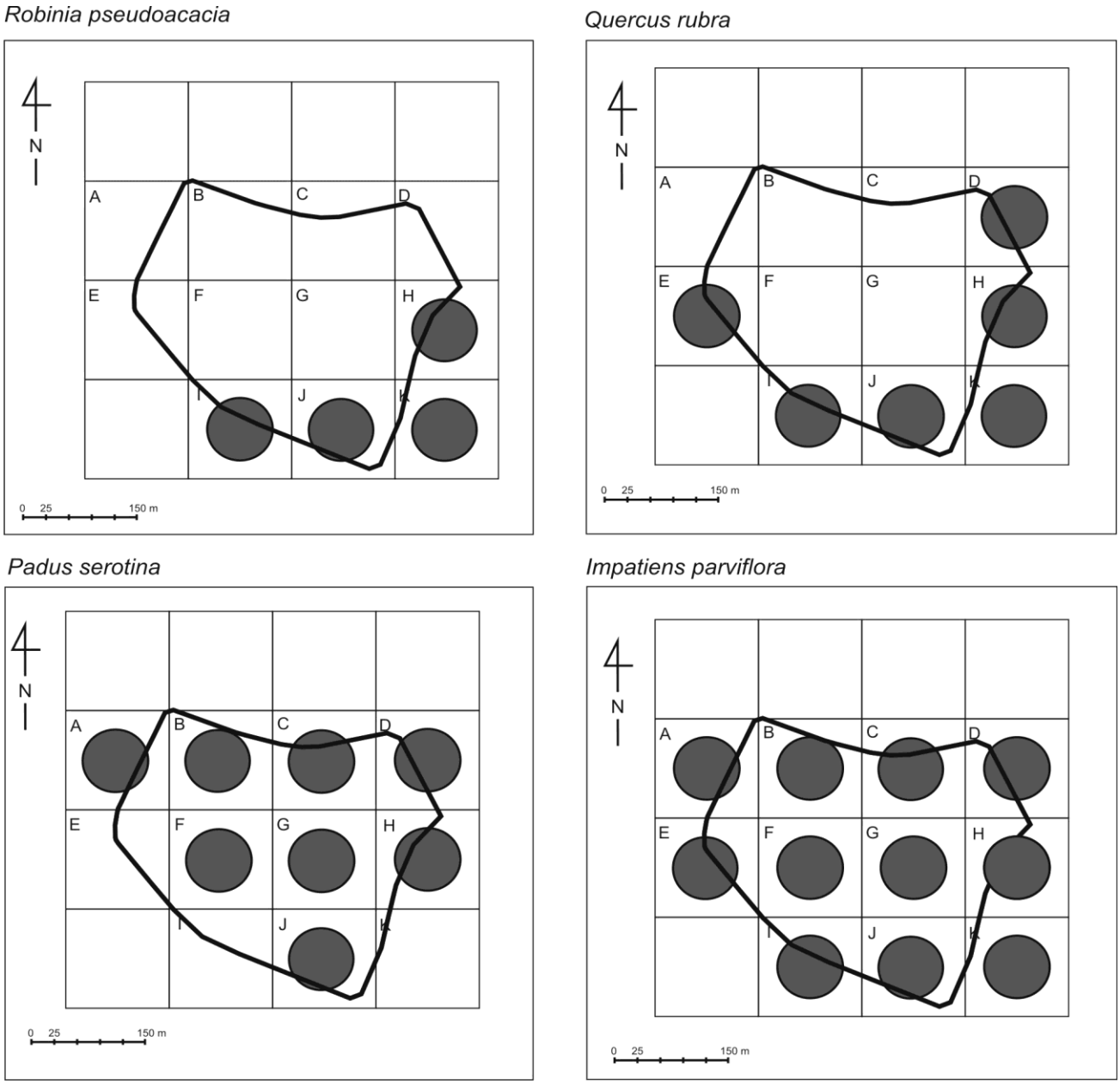

Fig. 2. Distribution of invasive alien species in the Polesie Konstantynowskie reserve.

Results

In the studied nature reserves, only five invasive plant species were recorded in total, including four vascular plants and one moss. In the "Polesie Konstantynowskie" reserve, four vascular plant species and one moss were recorded, and four invasive vascular plant species in the "Las Łagiewnicki" reserve (Table 1). Three invasive species (*Impatiens parviflora*, *Quercus rubra*,*Padus serotina*) were found in both reserves, and another three (*Juncus tenis*, *Orthodonthium lineare*, *Robinia pseudoacacia*,) were found in only one reserve (Table 1).

The most common species in the studied nature reserves were *Impatiens parviflora*, frequently recorded in both reserves, and *Padus serotina*, dispersed evenly throughout the whole of the "Polesie Konstantynowskie" reserve, but slightly less frequently in the "Las Łagiewnicki" reserve (Table 1). *Quercus rubra* and *Robinia pseudoacacia* were recorded with a low frequency, and their sites were concentrated in the southern part of both reserves (Fig. 2; Witosławski *et al.*, 2000). The lowest frequency was found for *Juncus tenuis*, recorded occasionally on forest roads in the "Las Łagiewnicki" reserve, and for *Orthodontium lineare*, recorded only once on a pine stump in the southern part (J square) of the "Polesie Konstantynowskie" reserve.

Alien invasive plants, except *Juncus tenuis*, were recorded both inside forest communities and in places transformed by human activity, e.g.: near forest roads, demarcation lines, and the borders of the reserves.

Almost all the recorded species belong to the highest (IV) category of invasiveness, including the most dangerous plants, which invade natural habitats and form large populations, and are also expansive (Tokarska-Guzik *et al.*, 2012). Only *Juncus tenuis* belongs to category I, which includes weeds persisting on anthropogenic habitats (Table 1).

Table 1. List of invasive vascular plant species recorded in the studied nature reserves.

Species	Family	Occurence in particular reserves		Fi (%)	Category of invasiveness
		Polesie Konstantynowskie	Las Łagiewnicki		
Vascular plants					
Impatiens parviflora DC.	Balsaminaceae	3	3	100	IV
*Juncus tenuis*Willd.	Juncaceae	-	1	50	I
Padus serotina(Ehrh.) Borkh.	Rosaceae	3	2	100	IV
Quercus rubra L.	Fagaceae	2	2	100	IV
Robinia pseudoacacia L.	Fabaceae	2	-	50	IV
Mosses					
Orthodontium lineare Schwägr.	Orthodontiaceae	1	-	50	-

Explanations: 1, 2, 3 – abundance scale, I, IV – categories of invasiveness (according to Tokarska-Guzik *et al*., 2012): I - weeds, mainly in anthropogenic habitats, IV – the most dangerous invasive plants, the significance of the presence of those species in Poland is fundamental

Discussion

The recorded invasive vascular plants are the most common alien species in the area of the city of Łódź, settled in the urban flora in the last century (Witosławski, 2006). However, the invasive moss is a new species to the city's flora, and its two sites within the city borders were identified not earlier than in the 21st century (Wolski, 2011).

The study shows that invasive plants account for a small percentage of the flora of the urban reserves located within the borders of Łódź. In the "Polesie Kostantynowskie" reserve, they account for only 2.7% (Olaczek & Sowa, 1980), and in the "Las Łagiewnicki" reserve for only 1.4% of all the plants (Witosławski *et al.*, 2000). In total, this is ca. 10% of all the invasive vascular plants found in the area of Łódź (Witosławski, 2006). Our results support previously raised findings that nature reserves and protected areas possess some resistance against invasions (Pyšek *et al*., 2003; Foxcroft *et al*., 2011; Jarošík *et al*., 2011b).

The small share of invasive species in the flora of the studied habitats, despite their location near the city centre, probably results from the limited penetration of humans and the shortage of anthropogenically transformed habitats, e.g.: tramped or cleared sites, and roads which are most exposed to the risk of invasion by alien plant species. The "Polesie Konstantynowskie" reserve is fenced, unavailable for public use, and has no road network, while the "Las Łagiewnicki" reserve, despite having a network of forest roads and demarcation lines, is located deep inside a forest complex, and tourism traffic there occurs only along the reserve's borders. Studies have demonstrated that linear landscape structures, such as roads and tracks,and the number of visitors are, apart from the size of a protected area, its habitat diversity and abundance of native flora, the most important factors responsible for the spread of invasive alien species (McKinney, 2002; Pyšek *et al.,* 2003; Pauchard & Alaback, 2004; Christen & Matlack, 2006).

Although the number of recorded invasive species is low, it is worrisome that among the invasive species are noxious invaders of the Polish flora, species that often exert a high impact on vegetation and species diversity of invaded communities as they rapidly transform habitats and natural plant communities and compete with native plant species (Tokarska-Guzik *et al.,* 2012), such as *Impatiens parviflora*, *Padus serotina*, *Quercus rubra* and *Robinia pseudoacaccia*. Similar results from protected areas located in other big cities, e.g.: Prague, Warsaw, and Poznań support the generalisation that those species seem to be better adapted to severely changed conditions (Jarošík *et al*., 2011b; Ciurzycki *et al*., 2015; Dyderski *et al*., 2015).

The greatest threat to the native flora of the studied reserves is posed by *Impatiens parviflora*, which, due to its wide ecological amplitude, is found in almost all the habitats in the studied reserves, and is abundant in many sites, forming large compact patches. Small balsam competes with native plant species, and its presence is an indicator of habitat degradation (Hejda, 2012; Ciurzycki *et al*., 2015).

Invasive trees (*Padus serotina*, *Quercus rubra*, *Robinia pseudoacacia*) are among the most common alien species introduced to forest areas in Poland (Tokarska-Guzik *et al.,* 2012). They are usually most frequently recorded in protected forest areas in cities (Jarošík *et al*., 2011b, Ciurzycki *et al*., 2015). In the studied reserves, their presence also results from intentional planting (Olaczek & Sowa, 1980; Witosławski *et al.,* 2000). Among the invasive trees, the greatest threat to forest vegetation is *Padus serotina*.American black cherry, which was planted to improve habitat grading, has spread at an alarming rate, causing the elimination of native species and degeneration of forest phytocenoses (Starfinger, 1997). The threat posed by *Quercus rubra* results from the limiting of species diversity in the patches of vegetation which it invades, mainly because the fallen leaves of Northern red oak decompose very slowly, disabling the growth of other plants (Woziwoda *et al.,* 2014). Another species, *Robinia pseudoacacia*, is a very popular tree planted in urban green areas – in parks, gardens and along roadsides, and it also easily colonises disturbed forest habitats (Tokarska-Guzik *et al.,* 2012). Once introduced in an area, Black Locust expands rapidly, creating dense clones of shaded islands with little ground vegetation. As a nitrogen-fixing species *Robinia pseudoacacia* can achieve early dominance on open sites where nitrogen is limiting to other species (Rice *et al.,* 2004).

The analysis of the distribution of a single invasive moss in the "Polesie Konstantynowskie" reserve confirmed the observations made by other authors (Söderström, 1992; Fudali *et al.*, 2009), who found this species on decaying wood, an optimum habitat observed for this moss in Poland (Fudali *et al.*, 2009).

Due to the proven negative effect of most of the discussed alien plant species on natural communities, measures should be taken to limit their spread in the studied reserves.

Considering that none of the investigated reserves was free of invasive alien species, our results suggest that in Łódź nature reserves there is a warning potential for future invasions unless appropriate control measures are imposed by nature conservation authorities. The best results in controlling invasive species can be achieved with combined methods, i.e. mechanical and chemical control (Mack *et al.*, 2000; Tokarska-Guzik *et al.*, 2012). However, the current regulations in Poland on the use of chemicals to control invasive species forbid their use in protected areas (Nature Conservation Act, Polish Journal of Laws of 2004, No. 92, item 880, as amended). Invasive plants can only be removed mechanically (by outrooting, cutting down or digging out, etc.). Unfortunately, such methods are labour-intensive, often expensive, and effective only at the initial stages of species penetration in a given area (Tokarska-Guzik *et al.*, 2012). An obstacle in the efficient mechanical control of invasive plant species is their considerably wide distribution in the studied reserves. Due to this fact, all actions taken should be at first targeted at the monitoring of the sites of their occurrence, and next at limiting the population size of invasive plant species.

To make targeted practical recommendations specific to particular reserves with distinct environmental and vegetation settings, studies on the current status of individual invasive species and their dynamics over time are needed, ideally initiated by municipal administration.

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