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Article

You can't see the woods for the trees: Invasive *Acer negundo* L. in urban riparian forests harms biodiversity and limits recreation activity

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Abstract: Public access to high quality green environments has become a key issue for city managers and a matter of environmental justice. Remnants of natural ecosystems allow citizens a direct contact with nature, but conversely the presence of people contributes further to the existing disturbances. Urban pressures on ecosystem remnants may act to favour the expansion of some invasive species in cities. Whilst the negative impacts of invasive species on ecosystem function is well documented little is known how invasive species influence the use of green spaces by people. Here, we examined one of the few remnants of urban riparian forests in Europe, the Vistula river valley in Warsaw which has recently become an attractive recreation site. Despite their high ecological value, the poplar and willow forests have been increasingly taken over by the invasive tree species *Acer negundo*. We examined the status of the invasion process and the relationship between recreational ecosystem services and the characteristics of the tree stands – tree species, tree density and age and NDVI values. We found the willow forest to be more susceptible to invasion by *A. negundo* than the poplar forest, which was revealed in significantly higher share of the maple individuals and their greater volume per unit area. Presence of *A. negundo* affected biodiversity resulting in decreased undergrowth density and number of species. The use intensity by the public, assessed on the basis of trampling intensity and the density of existing informal tracks, were negatively correlated to the presence of *A. negundo*. This study highlights the need to integrate invasive species management into green infrastructure planning and management.

Keywords: blue-green infrastructure, nature-based solutions, urban green spaces, invasive trees, trampling, forest remnants

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1. Introduction

The increasing urban population of cities worldwide combined with anxiety over the life quality of residents has resulted in an increasing interest in the benefits to be derived from city green areas [1, 2, 3, 4, 5, 6; 7]. Many cities were established on the banks of rivers and frequently the remnants of former riparian forests constitute an important part of the green systems of the city [8, 9]. Despite remaining under strong anthropogenic pressure, including land-use change, pollution, lack of cyclic flooding, human trampling or the introduction of non-indigenous organisms [10]. Those ecosystems generate multiple important services for the city residents [11, 12]. Natural riparian forests are recognized for their positive contribution to nutrient removal, carbon capture, air purification, pollination, noise buffering and water cleaning [13, 14, 15, 16, 17]. The few examples of riparian forests which were preserved in cities play an additional important role by contributing recreation opportunities to citizens and allowing them to interact with nature. The role of recreation in city green spaces in improving citizen health and well-being has been widely recognized and is regarded as one of the most important ecosystem services urban green spaces offer [18, 19, 20, 21, 22, 23, 24]. More and more studies also reveal an increasing demand from city residents for “less ordered” green areas providing the possibility to experience nature more directly than the traditional urban green spaces such as parks can offer [25, 26].

Physical disturbances to nature in cities, such as pollution, drought or drainage lead to irreversible changes in the existing ecosystems. Preserving high biodiversity in urban environments faces major difficulties, and river valleys are additionally highly susceptible to other negative changes, including a high risk of biological invasions [27]. Invasive plant species (IAS) not only severely alter the biodiversity of the areas they colonize but can also alter the ecosystem services provisioning by those areas [28]. The negative effects of various IAS on ecosystem services provisioning were recognized for multiple services [29], as affecting pollination [30], water supply [32], carbon sequestration or erosion control [32]. Yet little is known about the impact of IAS on the recreational potential of an area, and still less about ecosystem services in riparian forests due to their scarcity and difficulties in RES assessment [33].

Nature preservation in cities is strongly driven by social approval and a participatory approach to spatial urban planning has become good practise [34]. Consequently, it is crucial to recognize if IAS in urban areas, riparian forests in particular, affect the perception of urban green areas and result in a decline of ecosystem service provisioning [29]. Invasive tree species are common in urban forests, and likely to remain so due to low effectiveness of removal actions [29], yet little is known concerning their perception as a component of natural vegetation remnants or regenerating forms. The presence of invasive tree species affects the ecosystem function [35, 36, 37, 38, 39], but also changes in their visual appearance which can affect how people use the space [39, 40]. Invasive plant species can be therefore perceived negatively by the public and be associated with their environmental impact, but still a significant share of society might have no negative attitude towards the presence of invasive species [41]. Many plants, now declared as invasive species, were deliberately introduced to urban recreational areas due to their aesthetic values, hence the public may be positive towards IAS. Despite any ecosystem services lost, other services such as use in medicine or biofuels may occur [29]. The public may perceive IAS similarly to native trees, and IAS management thus receives low priority [42, 43]. The dispersal process of invasive plant species and

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their negative effects on the ecosystems still require further examination [36], but it is also predicted that climate change and human actions will escalate of the process [55, 56].

Ash-leaved maple (*Acer negundo*), a native of North America was commonly planted in Europe due to high tolerance to heat and water stress and has become one of the most invasive plant species occurring in riparian forests in Europe. Due to intensive seed production and easy dispersal by wind and water it has spread throughout Poland, and other parts of Europe, being most successful in urbanized regions along rivers [44, 45]. In this study we investigated the process of invasion in riparian forests by *A. negundo* and evaluate how it affects the structure of the riparian forests preserved in Vistula river in Warsaw and the effect of *A. negundo* on recreational ecosystem services of this area. We address the following questions: 1) What are the forest stand characteristics of riparian forest invaded to various extent by *A. negundo* - habitat type, tree density and age; 2) What is the effect of *A. negundo* on the biodiversity and NDVI, as indirect measure of biomass and quality of the riparian forest stands; 3) How are the recreational ecosystem services, expressed in intensity of penetration by visitors, linked to the presence of *A. negundo* and the forest characteristics.

2. Materials and Methods

2.1. Study area

The investigation was conducted in Warsaw, Poland's capital city, which covers an area of 517 square kilometres and is inhabited by over 1.76 million citizens (GUS, 2018). The city is characterized by high greenness, with the green infrastructure, including agricultural areas, accounting for nearly 50% of the city's area, along with over 14% forested lands [46]. The urban green space of Warsaw consists of 201 parks and forests, and 12 nature reserves. The unique element of Warsaw's green system is the strip of natural riparian forest which developed along the Vistula river (Fig 1) in between the embankments. The case of Warsaw is a unique example of a natural riparian forest formed within a narrow strip between the river and the embankments which is also located in the strict city centre. Today the area is covered by the 50-year old riparian forests *Populetum albae* and *Salicion albae* – 91E0 (Interpretation Manual - EUR28 2013), accompanied by the oxbow lakes represented by the *Potamion* and *Nymphaeion* plant communities (code 3150-2) and muddy banks with *Chenopodion rubri* p.p *Bidention* p.p. vegetation (code 3270), all being Natura 2000 habitat types, temporarily appearing between the groyenes. Despite the high ecological value, revealed in number of species the area is subjected to various pressures and the negative changes can be revealed in the presence of the invasive tree species such as *A. negundo* which has been noted in substantial numbers in the forest stand, both in the canopy and undergrowth [47].

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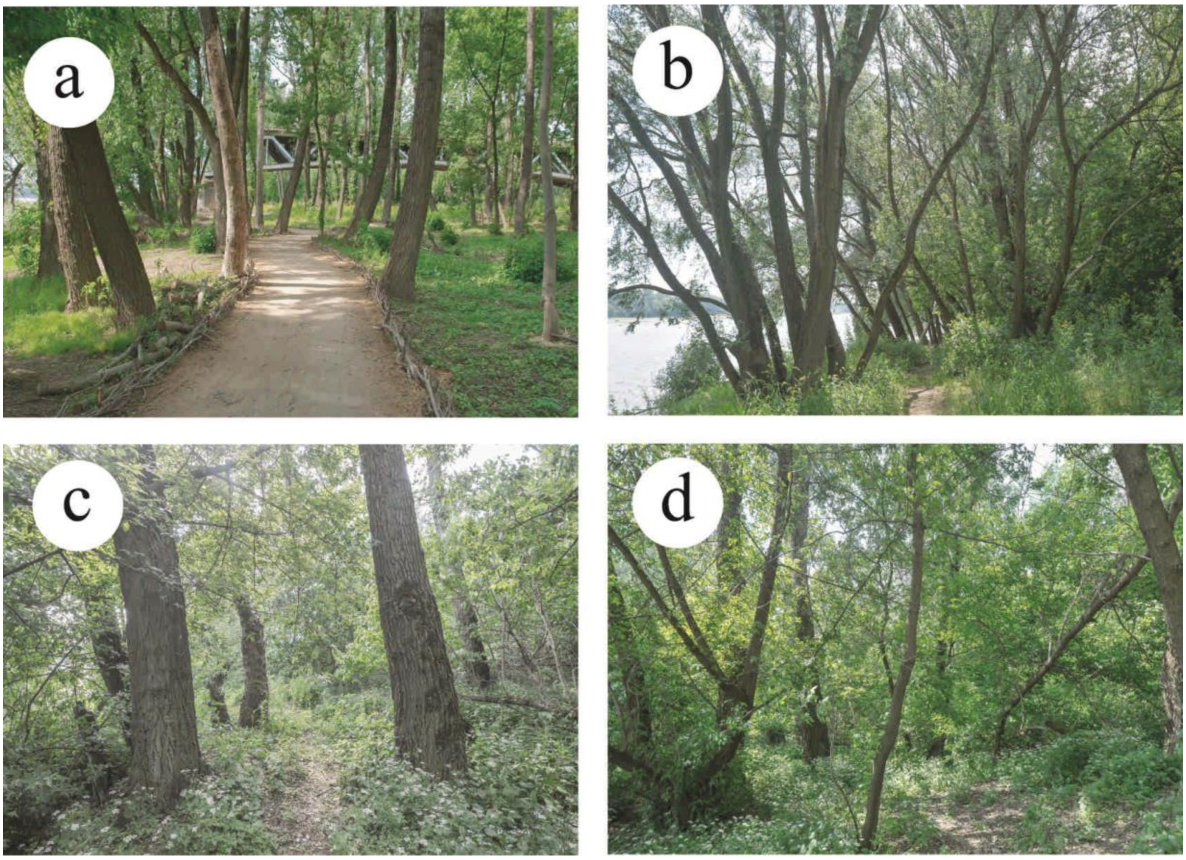

Figure 1. Main formal route along the riparian forest (formal trail) (a), informal trails in poplar riparian forest *Populetum albae* (b), willow riparian forest with *Populus x canescens* (c) and willow riparian forest heavily invaded by *A. negundo* (d)

Since the 70's the area of riparian forests received little attention from the city's managers, due to the cyclic floods and associated lack of installed permanent infrastructure and remained unmanaged. In 2007 the Municipality of Warsaw made the area accessible to the public by creating a "nature track" along the river in the forest. The track was an approximately 20 km section of a sandy route parallel to the river course designated for walking and cycling, which remains periodically flooded along with the temporary infrastructure. Since that time the number of visitors has grown substantially. In years 2014-2018 the yearly number of cyclists recorded has grown to over 140 000 (source: http://rowery.um.warszawa.pl). The track along the natural shore of the river, accompanied by cultural and educational events remains one of the most popular places in Warsaw [47] offering the citizens a wide range of ecosystem services and the possibility to experience nature in the middle of a major city. Apart from the main formal trail along the forest a growing interest of the citizens in nature-seeking has resulted in increased activity of the visitors off the main track and led to multiple off-trail routes throughout the forests.

2.2. Canopy tree inventory

In the years 2015-2017 a detailed tree canopy inventory was held in the 20 km riparian forest strip (Figure 1). We identified all tree individuals and recorded the species, the area was divided into homogenous forest patches in terms of tree age, species (Figure 2) and habitat. A detailed vector map of the forest stand patches was created based on field maps and ortophotomap from year 2017. The patches varied from 0.01 to 1.63 ha. Within each distinguished patch every single tree trunk of breast height diameter larger than 4 cm was recorded. All tree species were identified, including the hybrids between *Populus* sp. and *Salix* sp. We also estimated the age of the forest stand patches on the basis of rectified RGB orthophotomaps from years (1945, 1975, 1977, 1982, 1987, 1994, 2001, 2005, 2008, 2010, 2011 and 2012 retrieved from the Warsaw Municipality Office).

The forest stand patches were categorized based on the dominant tree species in the canopy and vegetation composition as two habitat types - poplar or willow riparian forests and further analysed separately, due to the differences in habitat characteristics. The willow forests patches were located closer to the river and were of approximately 50 m width, the undergrowth was dominated by the species characteristic of the *Salicetum albo-fragilis* type the content of sand in soil was >50% and cyclic flooding took place every 2-10 years [48]. The poplar forest stand patches were located further from the water course and stretched further to the embankment. The habitat was less frequently flooded and the vegetation composition was characteristic for the *Populetum albae* type [49].

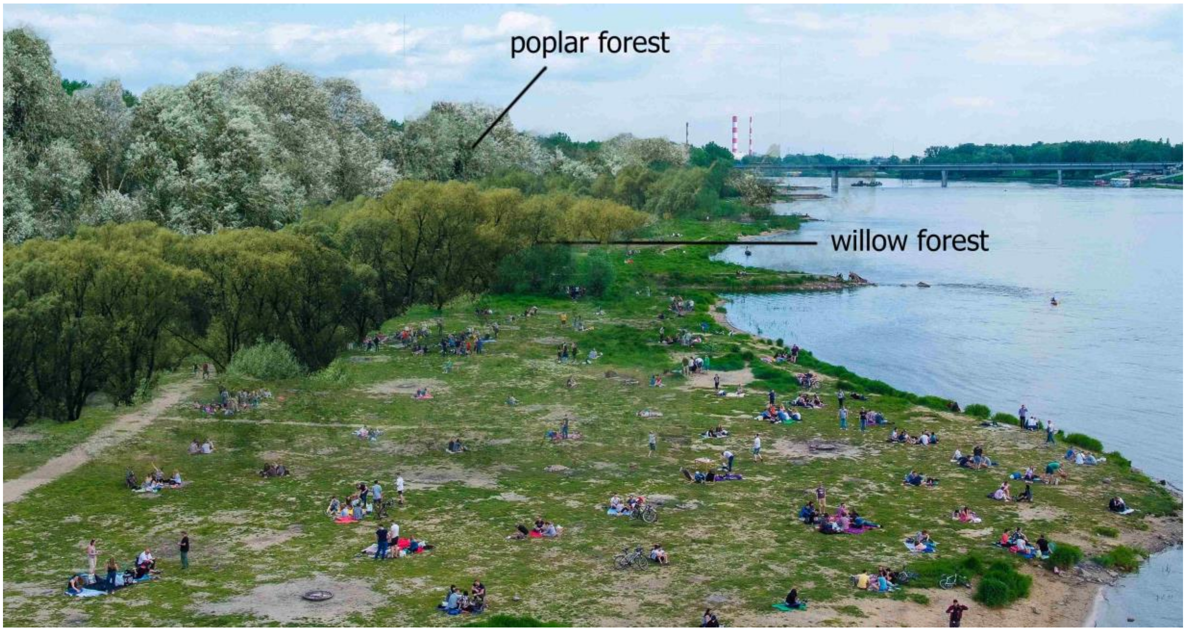

Figure 2. Photograph presenting the investigated riparian habitats – typical willow and poplar forests used for recreation in Warsaw

2.3. The effect of *A. negundo* on biodiversity

The distribution dynamics and effects of invasive *A. negundo* presence on the riparian forests structure was investigated in detail. Vegetation was recorded in 83 representative 20×20 m plots in homogenous areas to a various level invaded by *A. negundo*. In each plot the percentage of *A. negundo*, number of species in the canopy and undergrowth, and percentage cover of each of the layers - trees, shrubs, and undergrowth cover was recorded.

Vegetation quality assessment was performed by calculating average Normalized Difference Vegetation Index (NDVI) for each of the previously identified forest patches from Sentinel 2

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multispectral images. NDVI is frequently used to quantitatively assess urban vegetation, and values vary from -1 to 1, where maximum values correspond to highest coverage of vegetation. We used a cloudless scene obtained during the vegetation season (6.08.2017) to calculate NDVI using a software addendum (Quality Assurance Tools) (van Leeuwen, TBRS, Tucson, Arizona) applied to ENVI software. Normalized difference vegetation index was calculated using red and NIR reflectance as: NDVI = [(NIR - Red)/(NIR + Red) [50].

2.4. Off trail activity as an indicator of recreational ecosystem services of riparian forests

We assumed the intensity of visits to be an indirect measure of user preference and willingness to spend time in this area. We inventoried the "traces" of user activity beyond the main walking track by mapping informal trails in the riparian forest, identified as linear damages in vegetation and soil being the effect of off-trail activity [51]. We used two indicators: 1) off trail density per patch, which better indicates the tendency of visitors to spatially penetrate the area and cause damage to the vegetation and 2) off trails soil compaction, which more describes the intensity of visits and can be related to the number of visitors who had used the trail. Mapping of informal trails was performed in years 2016 and 2017 in May-August in the field using a GPS device along the whole 20 km river section in the willow and forest stands. Linear tracks with visible vegetation losses and bare ground were inventoried. The density of tracks was presented as density in m/ha. In the central part of each inventoried trail section in the representative part soil compaction was measured using a penetrometer Eijkelkamp 06.01.SA and presented in kN/cm^2. The measurement was performed in all patches at least 5 repetitions and the score averaged. Previous studies revealed that the main walking trail was visited by 136 to 687 people per day over the weekend and from 69 to 343 during weekdays [47]. A small proportion of the visitors, 1.1-11.5% walk off the main trail which equates to around three thousand people/year who spend time beyond the main track within the natural riparian forest, most walk off the track only for a short period of time [47].

One-way ANOVA/MANOVA were used, followed by Tukey to test differences in forest type and vegetation parameters – tree stand composition and NDVI values. Pearson correlation was used to assess the relationship between the presence of *A. negundo* and the total vegetation cover at various heights and recreational ecosystem services expressed in the length and density of informal tracks. Statically significant differences were at $p<0.05$. All statistical analyses were performed in SPSS 13 software.

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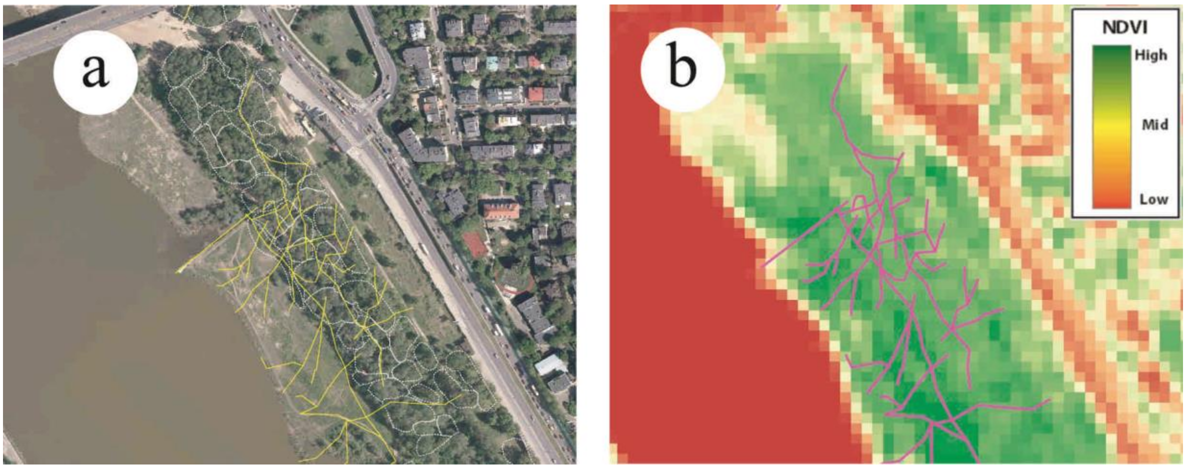

Figure 3. Example of the results of tree stand mapping – white lines represent distinguished homogenous tree patches (left), results of the informal tracks inventory (right) and NDVI values calculated from SENTINEL.

3. Results

3.1. Invasion intensity into different forest types

The forest stands in the investigated area were to a various level invaded by *A. negundo* and the intensity of invasion significantly differed between the two investigated forest stand types. Apart from the obvious difference in the share of indigenous species, the forests differed in in terms of both volume and number of individuals of the invasive maple (Table 1). The maple was significantly more abundant in the willow forest than in the poplar, both in terms of number of individuals and the tree volume. In the willow forests, more frequently subject to flooding, on average 165 individuals per patch were noted, while in the more distant poplar stands on average 96 maple individuals were found. This constituted nearly half of the total number of individuals (47.8%) in the willow forest and over one third (33.5%) in the poplar forest. The differences between the two forest and the maple occurrence were also significant in terms of the volume of the trees expressed in their basal area. While the average basal area of maples per patch was twice as big in the willow forests (245.9) to poplar forests (157.1) it no longer prevailed in any of the stands in terms of volume as its share in the total tree basal area was minimal and only accounted for 4.3% and 2% respectively. (Table 1). Tree stand of poplar forests, to a lesser extend invaded were characterized by higher NDVI values, associated with larger biomass and vegetation fitness. NDVI also increased with the forest age, but the increase was found to be significant only in the willow forest (Table 1).

Table. 1. Differences in tree canopy structure, tree density and NDVI values between the willow and poplar forest stand and between the forests stands of different age, differences between the groups using ANOVA and post-hoc Tukey test at $p<0.05$. Different letters and with * indicate at significant differences.

	Number of trunks per patch				Total tree basal area [cm²/ha]				
Type forest and average age of	maples	poplars	willows	maple % in total number of trunks	maples	poplars	willows	maple % in total basal area	NDVI

trees [years]									
willow	165.0	17.8	162.3	47.8	245.9	877.6	4649.8	4.3	0.55
poplar	96.8	163.9	28.3	33.5	157.1	6907.9	836.3	2.0	0.60
p-value	**0.09***	**0.00***	**0.00***		**0.01***	**0.00***	**0.00***		**0.00***
willow									
<10	633.1a	3.9a	223.6	73.6	454.5a	79.0a	2606.3a	14.5	0.50a
10-20	150.1b	5.3ab	149.3	49.3	209.9b	164.7a	3898.6ab	4.9	0.52ab
20-30	77.4b	25.3b	160.2	29.4	194.9b	949.9ab	3838.0ab	3.9	0.55ab
>30	102.9b	22.1ab	152.7	37.1	239.4b	1361.6b	6082.1b	3.1	0.57b
p-value	**0.00***	**0.01***	0.71		**0.00***	**0.00***	**0.01***		**0.01***
poplar									
<10	240.5a	59.2	30.1a	72.9	309.5a	3402.7	1030.4	6.5	0.59
10-20	200.4ab	125.1	25.1a	57.2	229.0ab	6341.2	524.5	3.2	0.58
20-30	81.4bc	175.3	50.5b	26.5	101.2b	7260.5	1247.7	1.2	0.60
>30	61.8c	177.2	15.7c	24.3	158.0ab	7132.9	664.4	2.0	0.61
p-value	**0.00***	0.31	**0.00***		**0.03***	0.44	0.40		0.72

The structure of the forests stands strongly depends on their age. Young stands are significantly more highly invaded (73.6 %) than younger stands (37.1%), the number of individuals being 14.5% and 3.1% in terms of volume, respectively. Whereas the native tree species show both increased numbers and volume in older stands (Table 1). In both willow and poplar forest stands at the age up to 20 years the maple is always the dominating tree species, while the older stands from 20 to 40 years showed only a small fraction of this species in terms of the basal area of trunks, which is at least 5 times lower than of the native trees. In willow stands a significant increase in numbers of poplars is noted in older stands when compared to younger ones, while both, poplar and willows increase in volume. In poplar forests, the increase in numbers is not significant, while the willows decrease in numbers, the increase in volume is not homogenous (table 1).

3.2. The effect of A. negundo on biodiversity

We found that the presence of *A. negundo* strongly modifies the structure of the forest stand at many levels. *A. negundo* is a main component of the shrub layer (2-5 m height) along with *Sambucus nigra* and *Populus nigra* and *Salix alba* seedlings, hence the high correlation obtained (r^2=0.775; Table 2). The presence of *A. negundo* contributes to lower density of the canopy (r^2=-0.338) and high density of *A. negundo* is associated with a decline of the plant density of the undergrowth (r^2=-0.584). The development of the species in the canopy is also followed by a continuous decline of total number of plant species in undergrowth (r^2=-0.378).

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Table. 2. The relationship between the presence of *A. negundo* and the total vegetation cover at various heights. Perason correlation coefficients. significant values shown in bold at p<0.05

	Tree layer	**Shrubs**	**Undergrowth**	**Number of species**
Share of *A. negundo* in layer (p-value)	**-0.338***	**0.775***	**-0.584***	**-0.378***

3.3. Effect of A. negundo on Recreation Ecosystem Services

By linking Recreational Ecosystem Services (RES) to indicators describing visitor activity throughout the area them walking off the main track we found that the relation between the maple density and off–trail activity strongly depends on the habitat type. In the willow forest the relation between the maple coverage and visitor activity is statistically significant and as the coverage of the maple increases the soil compaction decreases (p=-0.212; table 3). The soil compaction decreases which allows us to conclude that the presence of *A. negundo* results in reduced off-trail activity of the visitors. This relationship with the density of *A. negundo* was not observed in the poplar forest.

A clear positive relationship between the abundance of maple, expressed in the average tree basal area were found with the penetration intensity by visitors expressed in path soil compaction and path density (p=0.276 and p=0.652; table 3). While the number of trees *per se* (highest in youngest stands. table 1) was not related to the visitor activity or was negatively correlated (Table 3). In the case of the poplar forest a negative relation between the presence of *A. negundo* and the trail density was found (p=-0.345; table 3). Other indicators and tree species cover were unequivocally related to off-trail activity.

Table. 3. Pearson's correlation coefficients for the recreational ecosystem services indicators (off trail density and off-trail soil compaction) relation with the tree canopy structure in willow and poplar riparian forests. Significant differences were shown in bold

Poplar forest

	maple		poplar		willow		all trees	
	no	b.area	no	b.area	no	b.area	no	b.area
Off trail	-	-0,179*	0,192	0,173*	0,048	0,128	0,133	0,652*
Off trail	-	-0,406*	0,098	0,081	-	-0,017	-	0,276*

Poplar forest

	maple		poplar		willow		all trees	
	num ber	basal area	num ber	basal area	num ber	basal area	num ber	basal area
Off trail	-	-0,060	0,096	0,099	-	-0,093	-	0,073
Off trail	0,052	-0,039	-	-0,078	0,033	0,022	0,005	-0,071

no – number, b.area – basal area

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4. Discussion

This study revealed significant alterations of the structure and biodiversity of riparian forests when invaded by *A. negundo* from the herbaceous layer up to the canopy. The maple always prevailed as the dominating species in younger stands, both in terms of number of individuals and the volume in both willow and poplar tree stands, while in tree stands of 30-40 years the indigenous tree species were present in higher densities. The presence of maple was associated with a selective negative impact on the patterns of how people move across the area, revealed in informal track density and soil compaction. We found the willow forests where the share of maple was higher to be less frequently visited while in poplar forests this relationship was less visible. The study showed the major effect of the invasive maple on both the biodiversity and recreation, indicating at accurate management implications for this species to optimize nature conservation and recreation in such valuable areas.

With an increased demand from city residents for direct contact with nature [52], natural ecosystems such as riparian forests, will become more frequently visited and gain more importance as places for recreation. Here, we found that willow stands invaded by *A. negundo* maple were less visited by people, while a reduction in visitation was not evident for poplar tree stands with a high maple density. *A. negundo* is perceived no differently to other trees by the public and is treated as an accepted component of the green space, more attractive than the view of the built-up areas [53]. Yet we found reduced usage of willow stands with a high maple content. The effect was more visible in the willow forests located closer to the water where the density of the trails and their compaction were negatively correlated to both number and volume of maple. The use of poplar stands was less affected, the track density was only found to be smaller in sites where the number of individual maples was high. In the willow stands with high *A. negundo* the activity of visitors on informal tracks was reduced by over one third. These areas are of a high importance to the visitors as the presence of water in the recreational area has a great influence on the aesthetical judgment [54]. For many visitors the presence or absence of invasive species may have little impact on recreation, a previous study found that many users accept spontaneous vegetation on grasslands providing it remains green [26] and many citizens may not recognize a species as invasive. Our measurements were based on the "traces" of the visitors and may be affected by the soil difference between the two habitats or by proximity to water and user preferences for areas close to water. Also, differences in the "visibility' and easiness of penetration and herbaceous vegetation density which might have affected the distribution of the informal tracks over the area.

In this study, *A. negundo* proved to be a widespread component of the riparian forest flora of Warsaw. The riparian forests in cities are reported to have 10-40% of invasive tree species [36, 55] and over the last 100 years an increase of IAS in urban floras has been noted [57]. The invasion alters the composition of the forests, affecting for instance mineralization processes leading to replacement of the riparian native species [58]. In extreme cases in the riparian zones the invasion can lead to the development of homogenous communities of novel ecosystems little resembling the former riparian forests [59]. Our study showed widespread invasion of *A. negundo* in riparian forests but restricted to the young forests stands. We also found major differences between the willow forests situated close to the river course and the poplar forests located further from the river. The willow forest may be more susceptible to invasion by *A. negundo*, where the density of shoots of the native willow was larger than analogically poplars in the neighbouring habitat (Table 2). The river catchments are in general at risk of being subject to biological invasions [60], but the sites which are being regularly flooded are also more frequently subject to establishment of the seedlings from the seeds carried by water [61]. The correlation between the risk of invasion with the distance to the river course is previously recognized [62]. The willow forests compared to poplar forests, despite higher invasion rate, were characterized by lower NDVI, indicating at higher biomass values in contrast to a study from Bulgaria where it was the more invaded sites in the riparian zones which had the highest canopy cover [63].

None of the patches distinguished was bereft of *A. negundo* , and the oldest stands did not reveal trends of this species disappearing. Young tree stands up to the age of 20 years were characterized by numerous maple shoots of small basal area. In the older forest patches of age 20-40 years the share of maple is lower while the indigenous trees prevail both in terms of number of shoots and their basal area (Table 2). This development stage of the regenerating riparian forest is for *A. negundo* a moment of entering the survival phase, as its shoots grow in volume and develop under the canopy of other trees but do not increase in numbers. *A. negundo* encounters biotic resistance in an intermediate successional niche when the indigenous species grow more rapidly [64]. The maple in older stands indicate *A. negundo* does stabilize at a low level showing little need to undertake removal actions for this species. Removal of trees results in creating gaps which would be quickly filled by the maple as it reproduces effectively from both shoots and rhyzomes [65]. The seedlings of maple are characterized by high tolerance and quick growth rate in the gaps [66].

The presence of *A. negundo* strongly affects the structure of the tree stand and the herbaceous vegetation were noted. Woodlands with *A. negundo* had less dense canopy and more developed shrub layer with floristically poor herb layer which relates to loss of ecological value [37, 56, 67]. The examined sites which were partially artificially created by river regulation and further developed due to natural processes (accumulation, succession). Increased penetration intensity by invasive species and degradation of indigenous plant communities is expected to be intensified by increasing pressure from recreational activities [68], and the future may be bleak for the remnants of natural forest in urban environments.

High demand for green areas and outdoor recreation in cites results in riparian areas being incorporated into the city's green system, both the ones of high ecological value and the degraded ones [69]. In Warsaw, similarly to other European cities, the residents seek direct contact with nature, it especially to the most valuable components of nature [7, 70]. Areas along rivers, overgrown with dense vegetation of riparian forests and plentiful shore vegetation are highly attractive to visitors [71], and the characters destroyed patches are repaired [65, 72]. Such natural ecosystems are exposed to high numbers of visitors and serve as recreation areas, but they are also subject to increased trampling and biodiversity loss [69, 73, 74). The preservation of biodiversity may then contradict the ability of residents to freely and actively use the space. It is not known how to manage degraded areas still having traces of naturalness but with high share of invasive species. Should they be protected as remnants of natural vegetation or a rather more flexible approach should be used, eg. to apply no removal of invasive species, despite them posing a threat to biodiversity and to make it available to the public because of their contribution to recreation. Invasive species impede biodiversity, but also

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offer a multitude of other services to the residents [29, 75], therefore their removal in cities, where they were introduced in the first place as ornamental plants requires understanding of both, the ecological process and taking into account the preferences of the public.

This study showed that recreation can be affected by the presence of the invasive *A. negundo.* However, if removal actions were to be undertaken it is more desirable in the areas which are more intensively visited, therefore the willow forests close to the water. Removal of high numbers of the maple could result in a rapid decline of aesthetics and social approval of the more valuable areas by the water, as the public perceives the maple better than areas bereft of vegetation [41]. Recreational activity in such areas should rather be supported by creating additional infrastructure, as in protected areas, which could limit the pressure and boost indigenous riparian vegetation regeneration. From the point of the biodiversity preservation the maples should be removed [72] but taking into account the costs and constantly occurring disturbances in the area it is expected that the maple will become an inseparable component of the city's green spaces. The maple can be treated more gently, the risk of invasion expansion should be taken into account but so should its role in contribution to recreation and ecosystem services provisioning [29]. If removal of *A. negundo* is necessary it should be carefully considered and if occurring should be spread over a longer period (over 30 years) allowing the indigenous plant communities to regenerate and eliminate the maple through natural abiotic pressure [66].

5. Conclusions

1. *A. negundo* is a permanent and abundant component of the urban riparian forests in Vistula river valley in Warsaw, it was found to be more abundant in willow forests stands than in poplar forests.
2. The abundance of *A. negundo* was found to be significantly higher in younger stands than in older ones, the differences were manifested in both number of stems and their volume.
3. Occurrence of *A. negundo* in riparian forests negatively affects biodiversity, shrub layer and herbaceous vegetation, the more invaded stands were poorer in species.
4. Increased share of *A. negundo* were found to be related to decreased activity of visitors in the forest, but the effect was stronger in the willow forests, the poplar forests were less affected Presence of *A. negundo* can play an important role in providing recreation possibilities for the city dwellers.

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