# THE SPREAD OF INVASIVE NEOPHYTES IN THE RIPARIAN VEGETATION OF THE TICHÁ ORLICE

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***Abstract***
**The spread of invasive neophytes in the riparian vegetation of the Tichá Orlice**
This article summarises the observations and findings gained during the field survey of invasive neophytes in riparian vegetation of the river of Tichá Orlice in the Czech Republic. Seventeen taxa that could significantly load the riparian vegetation of the given area were chosen. A methodology of mapping and surveying which was designed by Matějček (2009) was applied. Using this methodology, neophytes were recorded in segments (500 m long parts of the river channel). The occurrence was expressed by the means of a logarithmic scale. Final data were evaluated with the aid of indexes for individual segments or groups of segments. As more parts of the river channel network of the Czech Republic have been mapped and surveyed this way, it is possible to compare the final data and results.
In the riparian vegetation of the Tichá Orlice following plants were registered most frequently: Himalayan Balsam (*Impatiens glandulifera),* Small Balsam (*Impatiens parviflora)* and Reynoutria *(Reynoutria sp. div.)* The mapped part of the Tichá Orlice is, in comparison to other watercourses, belongs to the watercourses that are loaded with the invasive kinds of plants more than average.

***Key words***
Invasive plants, neophytes, the river of Tichá Orlice, mapping, riverbank

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## 1. Introduction

The invasive ecology belongs to the most dynamically developing branches of ecology (Williamson, 1996). Biological invasions of non-native species are obviously connected with human-mediated changes of the environment and the gravest of them burden the economy and change the operation of the ecosystems invaded (Williamson 1996, Mack et al. 2000, Mooney a Hobbs 2000).

Surroundings of the rivercourses belong to the areas that have been touched by invasive species most significantly and, at the same time, to the most diverse dynamic habitat on the mainland (Naiman et al. 1993). Riparian vegetation is found on the fringe between the water habitat and dryland habitat (Gregory et al. 1991, Naiman et al. 1993) and thus is important for spreading species into bordering countryside (*Heracleum mantegazzianum*, *Reynoutria sp., Impatiens glandulifera* in the Czech Republic; Pyšek a Prach 1993). Watercourses serve as corridors for the transfer of dispersions and nutrients (Gregory et al. 1991, Richardson et al. 2007). The range and extend of the invasion touch is influenced by three factors: the amount of propagules invading the environment (propagule pressure), characteristics of the non-native species, and the liability of the environment to the invasions of the new species (invasibility) (Lonsdale 1999). Thus, with the increasing input of propagules, the riparian zones of the watercourses are very invasible to non-native plant species. Due to more favourable conditions, the riparian zones of temperate areas towards the south are invaded more significantly than subartic areas (Naiman and Décamps 1997).

The weakening of the natural functions is supported by human-mediated activities. Logically, any interference with the hydrological regime also changes the composition of the river habitat and can enable the spreading of non-native plants. When building a hydro-engineering plant, the natural water overflows are purposely suppressed and the flow regulation is provided (Décamps et al. 1995; Jansson et al. 2000). Human activities usually increase the input of nutrients and decrease the light passage through the water column and the plant cover that stabilises the bank and prevents erosion (Gregory et al. 1991). All over the world, the expansion of non-native plants increases due to the disturbances and the input of non-native dispersions. All these disturbances of the regime can influence the species diversity and convenience the non-original species (Richardson et al. 2007). The invasion of the non-native plants so called transformers than continue changing the river ecosystem.

The root system often influences the humidity conditions of the soil profile (Burgess et al. 2001), plant invasion along the river decreases the speed of the flowing water and thus local floods eventuate, the plants can influence the composition of the soil (salinity, organic matters, presence of C:N). According to Davis et al. (2000) the theory of the resource fluctuation is one of the serious reasons of the acceleration of the invasion into the disturbed ecosystems. The significant alternations of nutrients, water, and light, or fluctuations in time lower competitiveness and prioritize the growth of non-native invasive plant species.

Serious changes of the original ecosystem are caused by several invasive species that are called transformers (Richardson et al. 2000). Among these we can find e.g. *Accacia mearnsii, Eukalyptus, Tamarix* (LeMaitre et al. 2002; Zavaleta et al. 2001). For instance, bushes *Sesbania punicea* in South America and *Tamarix ramisissima* in

North America recapture sediments, increase roughness and cause the clogging of the watercourse (Hoffmann and Moran 1988, Zavaleta 2000).

In the Czech Republic the river banks are often uncultivated and no management that could reduce the spread of dangerous neophytes is done. These places are more likely to be invaded (Pyšek and Prach 1993, Richardson et al. 2007). The spreading of propagules through the river streem is in the Czech Republic significant especially with the species of *Impatiens glandulifera*, whose occurrence is limited by the humidity conditions, and the species of *Reynoutria*, sp. div. (Pyšek and Prach 1993).

The spread of neophytes in the Czech Republic has been published in many works (Nováková and Rydlo 1980; Slavík 1996; Mihulka 1997; Višňák 1997; Rydlo 1999; Trenčianská 2000; Köppl 2002; Blažková 2003; Vymyslický 2004; Buček 2006, Matějček 2009). The mapping of invasive species in riparian woodland of selected south-Moravian rivers was done by Vymyslický (2004) and Řepka et al. (2007). In a work by Mihulka (1997) a survey of mapping in the surroundings of České Budějovice in South Bohemia is given. Trenčianská (2000) mapped non-native species in the riparian vegetation of the rivers of Labe and Úpa, Buček (2006) mapped the situation around the upper stream of the river of Morava. Višňák (1997) evaluated the occurrence of the invasive neophytes in the northern part of the Czech Republic. Rydlo (1999) maps *Impatiens glandulifera* along the river of Berounka. Pyšek, P. and Pyšek, A. (1995) mapped the spread of the species of *Heracleum mantegazzia*num. In a work by Matějček (2009), the information on 1693 segments of riparian vegetation along watercourses in Bohemia and Moravia (nearly 850 km of riparian vegetation) which were mapped between 2006 and 2008 is given. Similar situation of the occurrence of invasive plant species is dealt with in another work by Matějček (2010).

Non-native species are often mapped in the Czech Republic and detailed information on their spread and on the dynamics of their population is available (Pyšek et al., 2002). The spread of invasive species has been dealt with by e.g. Weber (1997). Chytrý et al. (2009) mapped the neophyte load in a large scale in Europe. The level of invasion was evaluated according to the habitat character and the propagules pressure. Europe is considered to be a more resistant continent than the others. It is given by historical aspects (Drake, 1989). One of the latest common projects focused on the occurrence of non-native plant species in Europe was elaborated by Lambdon et al. (2008).

## 2. Methods

The terms used in the text follow the terminology suggested by Richardson et al. (2000). Thus the term “invasive species” means non-native species, which has been spread in the new area intentionally or unintentionally due to human-mediated activities. Its population is stable and independent from human interventions and it produces a large numbers of offspring which spread into a considerable distance from the parent plants and have a potential ability of further spreading. Invasive plants according to Moravcová et al., (2010) which spread reproductively have seeds distinctively adapted for spreading by the means of water or wind. Invasive plants usually produce large amounts of light round seeds that are able to sprout in following years.

The term "neophytes" is understood as non-native species that spread in the given area after the discovery of America (approx. 1500 AD). This term says nothing about the fact that the species is invasive, so called transformer, or just non-native species dependent on the human care (Richardson et al. 2000, Pyšek et al. 2002, Pyšek et al. 2004).

For mapping, a method designed for the project VaV SM/2/57/05 "Long-term changes in riparian ecosystems in floodplains along watercourses hit by extreme floods" was exploited. The spread of invasive neophytes belonged to the parameters mapped in the project (Langhammer et al. 2005). After the realization of the project, the method evaluating the presence of invasive species in the riparian vegetation proved good as an entirely independent procedure when mapping species in floodplains along rivers. The advantage of this method is the possibility to compare the neophyte load along all watercourses mapped.

## 2.1 Characteristic of the area surveyed

The mapping was being done from July to August 2009, which is in the time when a extensive cover of invasive neophytes bloom. For these purposes the middle stream area of the river of Tichá Orlice was chosen ($27^{th}$ – $67.5^{th}$ river kilometre) situated in eastern Bohemia.

The river springs in the mountains of Jeseníky, flows through folds, where it crosses the lowered spine of the Orlické Mountains. In valleys, it flows through meadows along its partly straightened river channel. In its middle part, the river creates a deep valley where it already looks like a river flowing in protracted bends. The downstream is flanked with fluvial terraces. The river here is rather deep and forms sharp bends with gently flowing water. The part of the Tichá Orlice mapped belongs to temperate area of the foothills character. Local climate is influenced by deeper valley notches of the rivers of Divoká Orlice and Tichá Orlice (Culek 1996).

The potential native vegetation of the northern part of the bioregion is represented by acidophilic oak woods. On the steep marl hills there are isles of calciphile beechwoods or scree woods. Nowadays, the woods are of the secondary species composition predominant spruce fir vegetation and pine monocultures. Oak woods in the valley notches are also typical (Culek 1996). In the lower part of the watercourse surveyed, there is a floodplain forest biotope with periodical flooding (Neuhauslová-Novotná 1998). The part of the river surveyed flows through several towns and smaller villages. Regional roads and international railway network Berlin – Prague – Vienna lead through the river valley. Neighbouring meadows are agriculturally exploited.

## 2.2 Characteristic of invasive species

From the catalogue of non-native species in the Czech Republic we chose seventeen most significant species that occur in the riparian vegetation of rivers flowing through urban areas as well as through semi-natural areas (Pyšek et al. 2002). Although the chosen species influence their surroundings into a different extent, all of them are classified as invasive. According to Richardson et al., (2000) about 10% of invasive species are so called transformers influencing the biodiversity and the state economy. This term is not applied with any of the chosen species (Pyšek et al. 2002). It is not supposed that all chosen taxa will occur along the chosen

watercourses. Some of them are spread throughout the whole area, some of them are expected only in certain parts of the area.

2.3 Description of the method

The riparian vegetation is understood as a belt of vegetation along the watercourse which is flooded approximately once a year and its width is given by the water surface on one side and by the bank range on the other side (Novák et al. 1986).

The presence of neophytes was recorded in so called segments, which are 500 m sections of the riparian vegetation. The results then were presented in relation to segments or to a series (a set of segments). The number of neophytes was expressed by the means of a algorithmic scale (1-9 species recorded was expressed as 1, 10 – 99 belonged to number 2, 100 – 999 species to number 3, 1000 – 9999 to 4, etc.) A great range of values was chosen intentionally so that the error in the neophyte number estimation would be reduced. For the analysis of the results the median of this algorithmic scale was used (5, 50, 500, …).

Kindred species were – to make the mapping easier - recorded without the interspecific differentiation (*Galinsoga parviflora* and *G. ciliata, Solidago gigantea* and *S. canadensis, Parthenocissus quinquefolia* and *P. inserta, Reynoutria japonica, R. sachalinensis* and *R. bohemica*).

In the case of the species of *Reynoutria* sp., the distinguishing between individual plants is complicated due to its rhizome system. Every footstalk is thus considered to be an individual plant (Matějček 2009).

For each segment several factors were used (number of taxa NT, number of individuals NI, simple index of neophyte load Is and weighted index of the neophyte load Iw). Through these indexes we characterised the neophyte load.

The simple index, Is = log NI + NT, expresses the total neophyte load in the given segment of the riparian vegetation where the number of the present neophyte species as well as the present number of individuals is taken into consideration.

The weighted index, $Iw = \log (\sum NI_x \cdot k_x)$, makes provision for several actuating factors (size of the invasive species, potential dangerousness for natural communities and interests of inhabitants, strategy of growth and reproduction), which are within each species evaluated with taxon coefficient $_x$, $k_x$ (Tab.1). Symbol $NI_x$ means the number of individuals of the taxon $_x$ and $k_x$ is the coefficient of the taxon $_x$.

Tab.1: The coefficients of individual monitored taxa used for the weighted index of the neophyte load determination. Classification of the average size of the plant: 3 = wood species over 5 m, 2 = fully grown herbs (herbaceous plants) usually reaching more than one meter, 1 = small herbs; classification of perenniality (life history): 0 = annuals, 1 = biennials and perennials; classification of the potential dangerousness: 1 = species classified as dangerous invasive species, 2 = species classified usually as the most dangerous, 0 = species without significant infuence.

| | Plant size | Danger | Life history | Coefficient (k) |
|---|---|---|---|---|
| *Acer negundo* | 3 | 1 | 1 | 5 |
| *Ailanthus altissima* | 3 | 1 | 1 | 5 |
| *Conyza canadensis* | 1 | 1 | 0 | 2 |
| *Erigeron annuus* | 1 | 0 | 0 | 1 |
| *Galinsoga sp.* | 1 | 0 | 0 | 1 |
| *Helianthus tuberosus* | 2 | 1 | 1 | 4 |
| *Heracleum mantegazzianum* | 2 | 2 | 1 | 5 |
| *Impatiens glandulifera* | 2 | 2 | 0 | 4 |
| *Impatiens parviflora* | 1 | 1 | 0 | 2 |
| *Lupinus polyphyllus* | 1 | 1 | 1 | 3 |
| *Lycium barbarum* | 2 | 1 | 1 | 4 |
| *Parthenocissus sp.* | 2 | 0 | 1 | 3 |
| *Quercus rubra* | 3 | 1 | 1 | 5 |
| *Reynoutria sp.* | 2 | 2 | 1 | 5 |
| *Robinia pseudacacia* | 3 | 1 | 1 | 5 |
| *Rudbeckia laciniata* | 2 | 1 | 1 | 4 |
| *Solidago sp.* | 2 | 1 | 1 | 4 |

## 3. Results

We mapped 162 segments, which makes 81 kilometers along each side of the river channel. Eighteen series were created, each of which contained 9 segments. These followed one another.

Out of seventeen mapped taxa eleven were recorded in the riparian vegetation. As far as the species of *Acer negundo, Ailanthus altissima, Heracleum mantegazzianum, Lupinus polyphyllus, Lyceum barbarum, Rudbeckia laciniata* are concerned, their presence was not proved and recorded.

In average, each segment (loaded as well as without load) contained two invasive neophytes. Within the whole area mapped there were only three segments without the neophyte load. The maximum of taxa recorded in one segment was six. A series (nine neighbouring segments) contained in average five taxa. The most frequently recorded species were *Impatiens glandulifera* and *I. parviflora* (Fig.1). They were

accompanied by the species of *Helianthus tuberosus*, *Reynoutria sp*. and *Solidago sp.*

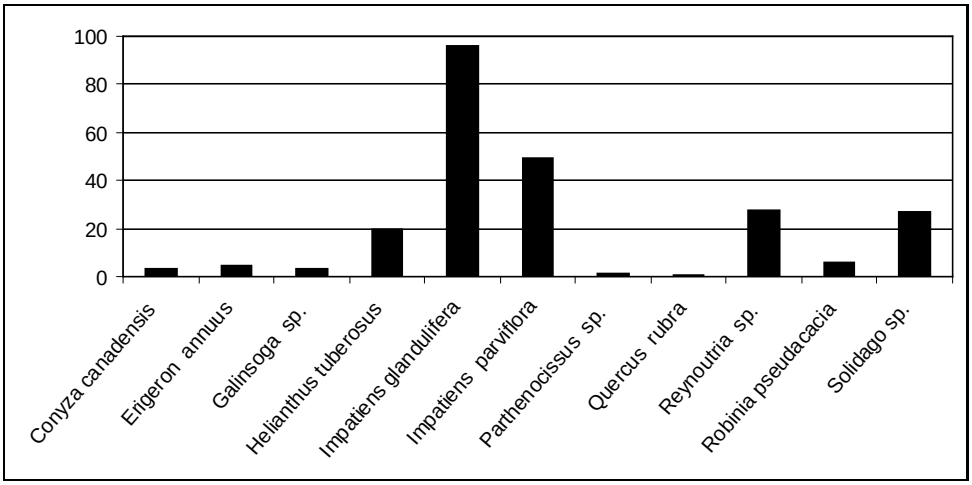


Fig.1: The abundance of invasive species in the riparian vegetation of the river of Tichá Orlice in %.

The most frequent species in the riparian vegetation was *Impatiens glandulifera*, nearly 1700 individuals in each segment of the area mapped (Fig.2). The number of individuals of the species of *Impatiens parviflora, Reynoutria sp.* and *Solidago* sp. was about 100 individuals per segment.

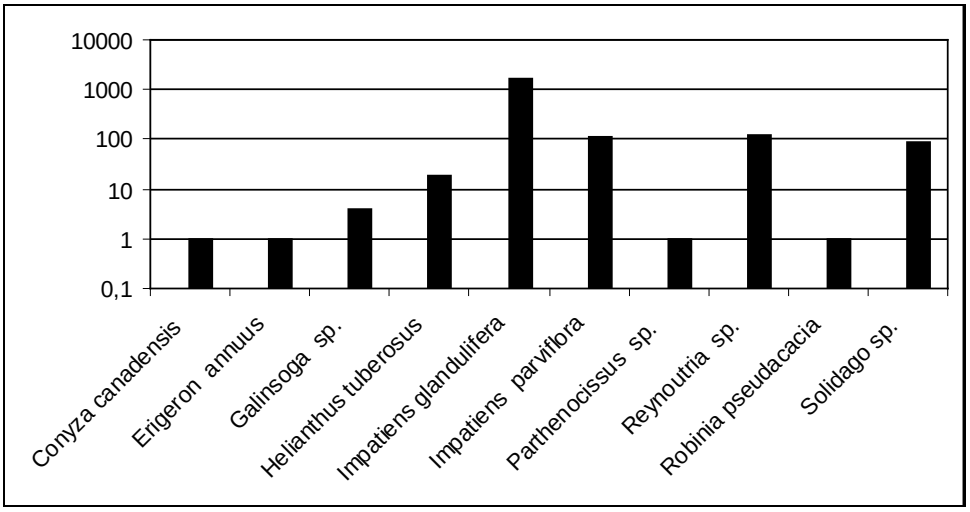


Fig.2: Average amount of individuals in a segment.

The value of the simple index (Is) of the load depends to great extend on the number of taxa in the segment. Thus the greatest load is always recorded where five and six taxa are present in a segment. This also was the greatest number of taxa in one mapped section. In series 5, 6 and 8 on the right side of the riverbank

(Fig.3, 5), in average as many as three invasive plant species were recorded. The average index of load in a segment is 5.

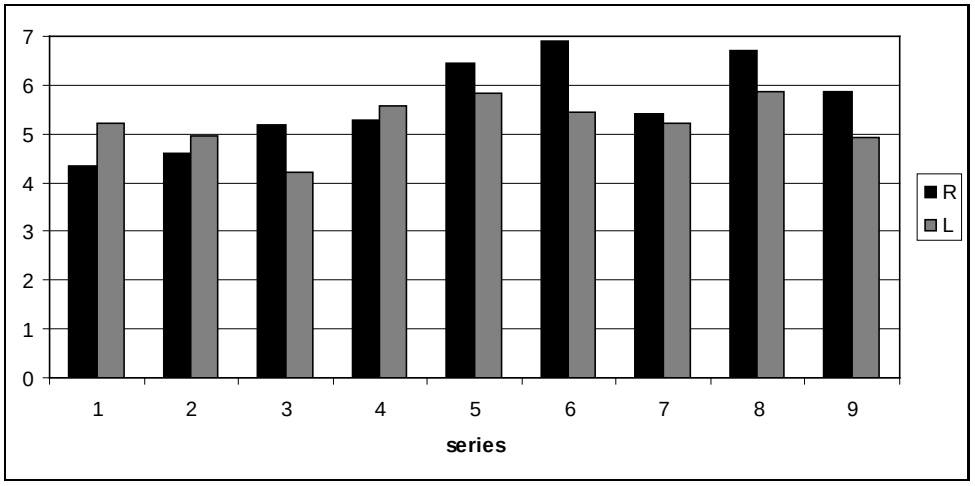


Fig.3: Average simple index of neophyte load in series. R – right riverbank, L – left riverbank.

The average weighted index of the neophyte load (Iw) ranges between 2.87 and 4.16. This marker more concisely expresses the neophyte load of the given segment (Fig.4, 6). The coefficient $k_x$ expresses the size, persistence and dangerousness of each taxon. Chosen invasive species are evaluated within a scale from 1 to 5, where 1 means that the species influences its surroundings very little, and 5 means that the species is aggressive towards its surroundings. According to the table (Tab.1) above, the following taxa reached the highest values - *Helianthus tuberosus, Impatiens glandulifera, Quercus rubra, Reynoutria sp.* and *Solidago sp*. Their enhanced occurrence thus meant a higher neophyte load of the given segment. We don´t evaluate tree *Quercus rubra* as dangerous invasive plant. The coeficient increased thank its size.

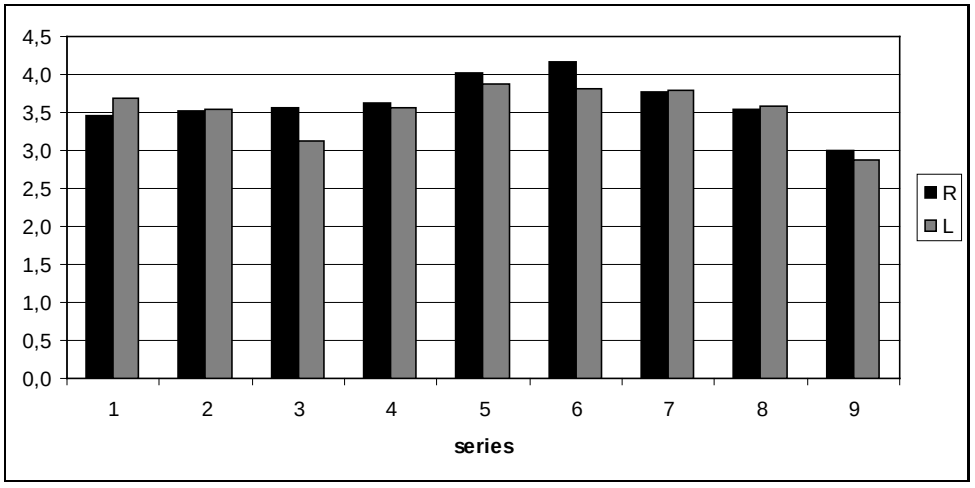

Fig. 4: Average weighted index of the neophyte load Iv in series, R – right riverbank, L – left riverbank.

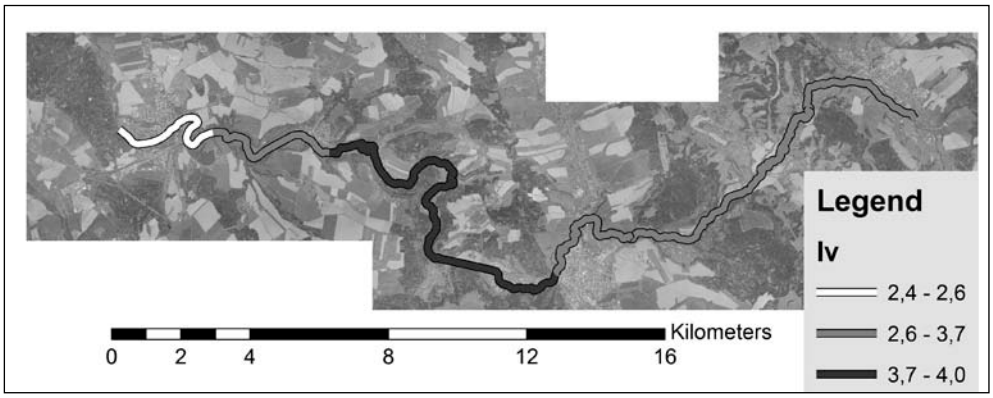


Fig. 5: Average simple index (Is, Ip) of neophyte load in series

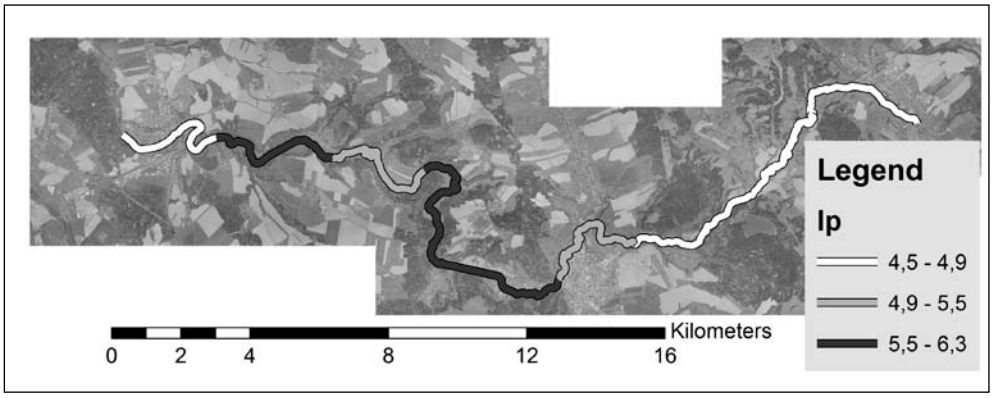


Fig. 6: Average weighted index (Iw, Iv) of the neophyte load i series

## 4. Discussion

Himalayan Balsam (*Impatiens glandulifera)* was the most numerous invasive species present in the area mapped. The species of Reynoutrias (*Reynoutria sp.*), Goldenrod (*Solidago sp.*), Jerusalem Artichoke (*Helianthus tuberosus* ) and Small Balsam (*Impatiens parviflora* ) were also often present. The river banks are an ideal background for the spreading of these invasive neophytes. Thus it is possible to expect the increase in their numbers in the future. *Reynoutria sp.* together with s *Heracleum mantegazzianum* are in the Czech Republic considered to be the species that can change the conditions in the area invaded to the greatest extent, as they are able to cover the affected area with their biomass (Hejda et al. 2009).

*Impatiens glandulifera* not only intensively covers the surroundings of the watercourse, but also uses it for the seed transport (Pyšek and Prach 1993). Most often it was recorded outside rocky hillsides and forest scrubs in any riparian vegetation. Its spreading into the surroundings was only restricted by the

management of the mowing of the nearby meadows. In urban areas its presence was restricted by mowing up to the range of the river channel. The species of *Reynoutria* sp., *Helianthus tuberosus* and *Solidago* sp. were restricted in the same way. The species of *Impatiens parviflora* most frequently occurred in the herb level of forest scrubs along the water course.

Less frequent occurrence or absence of other neophytes can be influenced by the ecology of a given species (Pyšek et al. 2008). Limited spread can be caused by thermophily of the species (*Ailanthus altissima, Acer negundo*, *Robinia pseudacacia, Lycium barbarum*) or by the fact that the species has not spread in the area yet (*Rudbeckia laciniata, Heracleum mantegazzianum, Conyza canadensis, Lupinus polyphyllus*) or it does not mean any serious danger (*Parthenocissus sp, Quercus rubra, Erigeron annuus, Galinsoga* sp.).

The method of the neophyte mapping was created following the purpose of the easy use in the field. For this reason the number of neophytes is given in estimated numbers in a logarithmic scale. The number of neophytes can be burdened by inaccurate estimation of each mapper. However, the use of the logarithmic scale enables to minimise these errors.

This type of mapping did not take into consideration the type of biotope where the neophytes occurred or, vice versa, where they were absent. The method was not designed this way. However, a certain trend determining the presence or the absence of a species was obvious. The whole area mapped is located in cultural landscape. Therefore, it is possible to presume a greater supply of nutrients which supports the growth of the neophytes. The more frequent occurrence of invasive plants was distinct in ruderal areas and in riparian vegetation without management. Contrariwise, the occurrence of most of the species was significantly lower on rocky hillsides and in forest vegetation sloping towards the river channel.

### 4.1 Mapping comparison

The most similar watercourses (considering the length, the area of river-basin and the flow) which were also mapped (Tab.2) are: the Cidlina, the Chrudimka, the Malše, the Střela and the Ploučnice (Matějček, 2009). The neophyte load of none of the watercourses was as great as the neophyte load of the part of Tichá Orlice mapped. A very similar situation with the neophyte load was recorded at the downriver of the Tichá Orlice (Matějček, 2009), which borders with the mapped area. As far as the neophyte load is concerned the Tichá Orlice most significantly approaches the values recorded in the riparian vegetation of a much larger river of the Ohře (average PT = 3,18 and average PJ = 1930).

Comparing the results of the watercourses mapped (Matějček 2009) the Tichá Orlice belongs to the watercourses with the above-average neophyte load. The average number of taxa (NT= 2) and the average number of individuals in segments (NI= 2040) belongs to above-average values in comparison with the other watercourses. The average weighted index Iw= 3,59 can also be evaluated as above-average. The number of neophytes in the riparian vegetation can be caused by a great supply of dispersions, as the river also flows through urban areas and roads and railways go through the valley (Chytrý et al. 2009). The cultural landscape is also to a different extent used for farming. Anyway, it is difficult to decide if the high share of invasive plants in anthropogenic surroundings is caused by the increased number of

propagules, frequent disturbances, fragmentation of landscape or the increased supply of nutrients (Chytrý et al. 2005). It is probable that these factors will interact to a different extent synergistically.

Tab.2: Mapping comparison.

| River | NI | NT | Is | Iw | Dominant neophyte |
|---|---|---|---|---|---|
| Cidlina | 6 | 0,2 | 0,39 | 0,32 | - |
| Chrudimka | 173 | 3,2 | 5,03 | 2,38 | - |
| Malše | 794 | 2,7 | 5,17 | 3,12 | Reynoutria sp., I. parviflora, Robinia pseudacacia |
| Ploučnice | 372 | 2,4 | 4,63 | 2,82 | I. glandulifera, I. parviflora |
| Střela | 191 | 0,9 | 1,30 | 1,22 | I. parviflora |
| Tichá Orlice | 2040 | 2,0 | 5,35 | 3,53 | I. glandulifera |
| downriver of the Tichá Orlice | 1443 | 2,0 | 4,58 | 3,18 | Reynoutria sp., I. glandulifera |

## 5. Conclusion

The Tichá Orlice belongs to the watercourses with the above-average neophyty load. The most frequently recorded species were *Impatiens glandulifera* and *I. parviflora*. They were accompanied by the species of *Helianthus tuberosus*, *Reynoutria sp*. and *Solidago sp*. The part of the river surveyed flows through a cultural landscape and the river banks are with no management that could reduce the spread of neophytes.

Invasive plants were recorded in any riparian vegetation, in surroundings of meadows, in ruderal areas and in urban areas. Human activities support the presence of invasive plants in a large scale. So we suppose the most extensive invasive plants will spread in future.

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***Summary***

**THE SPREAD OF INVASIVE NEOPHYTES IN THE RIPARIAN VEGETATION OF THE TICHÁ ORLICE**

This article is hinting about one of the problems the furutre landscape. Non-native plants occurred in Czech Republic last 150 years and some of them become invasive. They are able compete with protected species or farm crops, speed up erosion or complicated overflooding.

With using methodic of complex mapping stream and alluvium it was mapped a chosen part of riverbank Tichá Orlice. There were located chosen neophytes where we supposed they will be occured in riverbank vegetation. The methodic afford information about presence and abundance chosen neophytes.

Most offten were occured this plants – *Impatiens glandulifera, Reynoutria sp., Helianthus tuberosus* and *Solidago sp*. They are herbaceous plants usually reaching more than one meter. The high density these plants prevents full access to the place of occurrence. In comparison with other similar rivers (similar through flow, river-basin and longitude of river), the river Tichá Orlice belongs to on above-average burden watercourse.

Mapping of riverbanks demonstrated that invasive plants are part of vegetation. Invasive plants are regular destroyed only in protected areas. Except these areas plants can spread without some restriction. That is why plants can expand unlimited.