Research Article

# *Telekia speciosa* (Schreb.) Baumg. in human made environment: spread and persistence, two sides of the same coin

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## Abstract

For proper management of invasive alien species (IAS), it is needed to know species persistence and spread capacity as ignoring them may significantly bias the estimates of species presence. We compared 50 years old historical and current distribution of *Telekia speciosa* to assess its population change in a restricted area of a chateau park. The aim of this study is to analyse factors that may have shaped the persistence on previous sites, as well as, the spread of the species from historical sites by using repeated sampling. We found that after 50 years *Telekia speciosa* persisted at 67% sites and has spread to another 381 new sites. Such a level of persistence and rate of spread over a fifty year period goes exceedingly beyond any known records for other IAS.

**Key words:** Czech Republic, Heartleaf, horticulture, invasive species, land-use, repeated sampling

## Introduction

Understanding the patterns of species dynamics (i.e. survival, persistence, spread, and extinctions) is a key ecological question relevant to management of rare or invasive species. The dynamics of spread and persistence of individuals or species populations in the landscape are affected by several factors including habitat characteristics as well as characteristics linked to meta-population dynamics (Crawley 1997). The habitat attributes comprise the availability of resources, disturbance regimes and changes in land use (Chytrý 2012). The meta-population characteristics are mostly affected by the size of populations especially when small isolated populations are highly threatened by stochastic environmental and demographic processes (Silvertown and Charlesworth 2001) or decreased population fitness (Brassil 2001; Dennis 2002). In addition, the most important factor that affects invasive species persistence and spread is management actions (i.e. eradication or suppression; Pyšek et al. 2001; Pergl et al. 2012; Pluess et al. 2012).

To understand the patterns of survival and spread of any species, we mostly rely on estimates of past distributions and specific locality description

using herbarium records and distribution maps (Delisle et al. 2003; Aikio et al. 2010; Wild et al. 2019). Recently, the analyses of aerial photographs have become available for some species, however, systematical documentation of new introductions by aerial photographs is a matter of the last decades (Müllerová et al. 2005). Such studies allow for the assessment of the role of individual habitats for species persistence and spread. Since the focus of studies on species distribution is biased towards native and especially rare species, there is a continuous increase of studies on IAS (invasive alien species) (Pyšek et al. 2008). The most recent trend comprises IAS detection from high resolution imagery obtained by unmanned aircrafts (Müllerová et al. 2017).

The lack of proper knowledge of individual species persistence and spread limits our understanding of the factors that may play a role in shaping species distribution (Wilson et al. 2009; Pergl et al. 2011). Ignoring species persistence may significantly bias the estimates of species presence when using cumulative data (Pergl et al. 2012; Skálová et al. 2017; Kaplan et al. 2018). Therefore, for an accurate assessment of species dynamics we need to analyse persistence and spread (i.e. both sides of the coin).

Heartleaf or Yellow Oxeye (*Telekia speciosa*) was recorded in detail between 1965–1967 within the 250 ha chateau park (Jehlík and Lhotská 1970) in Průhonice. In this study, we focus on population dynamics of the species over 50 years by comparing the distribution pattern in the 1960s with the current distribution mapped during 2017–2018. The aim of this study is to analyse factors that may have shaped the persistence on previous sites, as well as, the spread of the species from historical sites by using the comparative approach.

## Materials and methods

### *Species description*

*Telekia speciosa* (Schreb.) Baumg., belonging to Asteraceae family, is a perennial, herbaceous plant. The plant is characterized by the flowering stem which can reach a height up to 2 m (usually 1 m), broad leaves (ca 10–40 cm long), and yellow flowers up to 2–5 cm in diameter (Kaplan 2004). The species is native to south-eastern Europe and western Asia. Invaded distribution range includes the rest of Europe (DAISIE 2009). *Telekia* was introduced mainly as an ornamental decorative plant but now occurs in a wide range of habitats including disturbed land (e.g. waste land, abandoned meadows and their borders), forest edges, pastures and neighbourhoods of former plantations in gardens and parks (e.g. road edges) (Brandes 2010). The species prefers moist and nitrogen rich soils (www.pladias.cz/en/taxon/overview/Telekia%20speciosa; www.alienplantsbelgium.be/content/telekia-speciosa). Flowering in Central Europe occurs between June and August.

The species is classified as invasive in many European countries with various levels of invasiveness (Belgium: www.alienplantsbelgium.be/content/telekia-speciosa; Verloove 2002, 2006; Austria and Germany: Jäger 1976; Essl et al. 2011; Nehring et al. 2013; Poland: Zając and Zając 2009; Czech Rep.: Pergl et al. 2016a). In the Czech Republic, the species is distributed in several isolated areas (Orlické Mts., Krušné Mts., Beskydy, Šumava) and in several chateau parks (Kopecký 1977; Dostálek 1998; Smolová et al. 2010; Kubů 2016; AOPK ČR 2019). The species was introduced to the Czech Republic in ca 1820 and shortly after it escaped into the wild (Pyšek et al. 2012). It is widely used as an ornamental plant in private gardens (Pergl et al. 2016b) that serve as sources for the further spread from cultivation into the landscape along rivers and moist verges.

### *Study area*

The study area is located in a 250 ha chateau/dendrological park of chateau Průhonice which is registered on the UNESCO World Heritage List. The Průhonice chateau and/or dendrological park (further referred as *park*) is located at the south-eastern border of Prague (WGS 84: 50.000N; 14.557E) with mild warm climate. The natural park was founded in 1885 in the watershed area of the stream Botič and its tributaries, the Dobřejovický and Zdiměřický streams. The park consists of a mixture of composition with open and forested areas. There are groups of trees and bushes with meadows, ponds, streams and their dead meanders. The park is also valuable from the dendrological point of view with its collection of about 1,600 species of local and exotic woody taxa and over 500 species of indigenous origin, 8% of which are on the Red List of the Czech Republic and are associated with the most valuable riparian and water-influenced habitats (www.pruhonickypark.cz).

Management within the park involves cutting meadows for hay, selected clearing in the forest, fishing in ponds and occasional usage of herbicides in rockeries and alongside pathways including suppression of invasions of *Fallopia* spp. *Telekia speciosa* is not managed in the park as it is decorative and positively valued by the visitors (J. Šmída *pers. comm.*).

The first report on the cultivation of *T. speciosa* in the Průhonice park is from The Registry Book of the Dendrological Society (in Czech: Matriční kniha Dendrologické společnosti, Jehlík and Lhotská 1970). The species is listed as cultivated in the inventory of the Alpinum from 1936–1940 (Tyller 1990). Later it was mentioned as escaped from the Alpinum by Karel Domin (1943) and also in the wider neighbourhood (Lhotská 1988). The species was also intentionally spread by seeding to the neighbouring villages (e.g. in 1958 to the valley of brook in Dobřejovice; Tyller 1990).

### *Species distribution and land use*

Data on *Telekia speciosa* presence between 1965–1967 (further referred to as *historical records*) are based on mapping in the park and its surroundings

by Vladimír Jehlík. The historical observations on *Telekia* distribution were digitized in ArcGIS 10.1 (ESRI 2012) from the publication Jehlík and Lhotská (1970). *Telekia* current distribution mapping (further referred to as *recent records*) was carried out in 2017–2018. The mapping was done via Collector for ArcGIS (ESRI 2017) on iPad and iPhone using GPS position and aerial orthophoto as a base map. During the recent data inventory of *Telekia* occurrences, we recorded additional information on the abundance, number of flowering individuals per site, reproduction status (i.e. sterile *vs.* flowering individuals) and site characteristics (i.e. managed/unmanaged and open site/canopy growth). Isolated individuals (maximal extent of the site ca 4 $m^2$ with sparse abundance up to ca one individual per $m^2$) were mapped individually as points. Larger stands were recorded as polygons with information of abundance/coverage.

The recent land use and landscape structures within the park were taken from maps of the park managers and online map resources at https://geoportal.gov.cz. The map of land use, forest distribution and location of houses related to historical records was extracted from a classified 1953 orthophoto obtained from CENIA (https://kontaminace.cenia.cz).

### *Data analyses and recent records*

To overcome the issue of setting artificial discrimination lines for individuals and large populations and the problems of calculation of density data on recent distributions, we transformed the distribution records to points taking the centroid of polygons. Then the centroids were used to calculate historical and recent data layers of Kernel density (cell size 10 m, radius 100 m). From maps of land use and land structure presence in buffer zones 10 m around each *Telekia* presence of water, road (asphalt), silk road and path, building, forest canopy and meadow occurrence was determined. For each site, we calculated the distances to the nearest neighbour sites; using the historical and recent censuses. We also calculated density values for historical and recent layers.

Data on persistence using historical distributions were analysed by classification trees with the following explanatory variables: presence of road, pathway, forest, meadow, water, building in 10 m buffer, distance to the nearest neighbour, density value of historical layer. As persisted site were classified those that were found in recent inventory closer than 20 m from any historical *Telekia* site. The distance for the classification of persisting sites was taken to cover the uncertainty bias in mapping in the history and digitalization of the printed map, in which 20 m represents 1 mm in the physical map.

Recent distributions were analysed using regression trees, with density of recent distributions as the dependent variable. The density assessed visually in percentage cover was used in order to correctly weight between the single individuals and large populations ranging up to 10 $m^2$. Explanatory

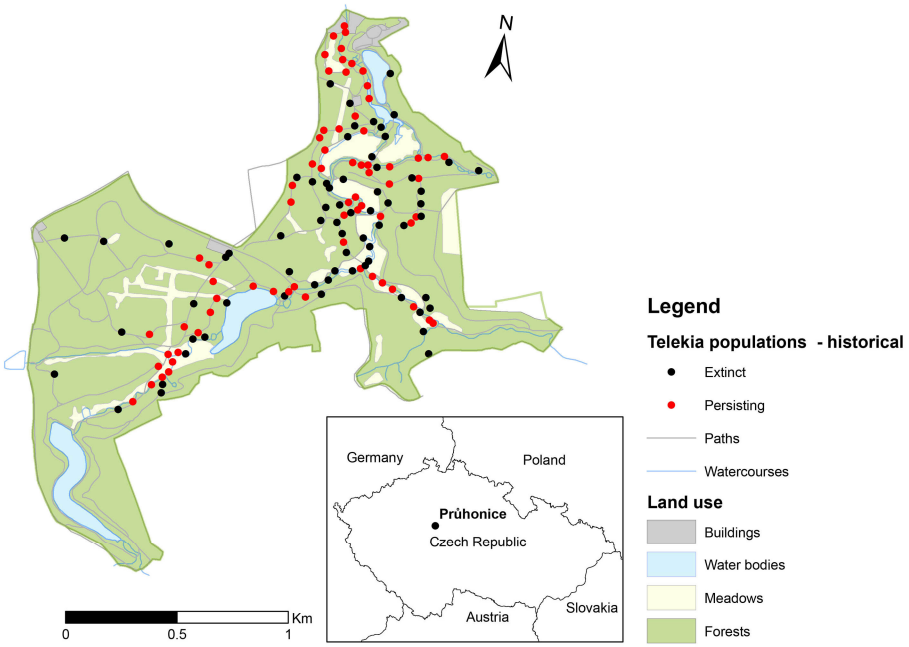


**Figure 1.** Distribution of *Telekia* at historical sites (Jehlík and Lhotská 1970) with indication of persistence until 2017–2018. The recent land use categories are shown at the background. As persisting sites were classified those sites that were found in recent inventory (2017–2018) closer than 20 m from any historical *Telekia* site. Georeferenced data are available in Supplementary material Table S1.

variables were the same as in the previous analysis with density of historical records, density to historical closest population, and distance to historical land use (i.e. road, houses, forest and water).

Regression and classification trees were constructed using binary recursive partitioning, with the default Gini index impurity measure used as the splitting index (Breiman et al. 1984; Steinberg and Colla 1995). The trees are suitable to analyse data with many collinear explanatory variables (Breiman et al. 1984; De'ath and Fabricius 2000). Ten-fold cross-validation was used to obtain estimates of cross-validated relative errors for these trees. The calculations were done in CART 8.0 and in R 3.0.2 (R Development Core Team 2017).

## Results

Distribution of *Telekia* in historical maps covered 136 sites (Figure 1). Of these, 45 were classified as extinct and 91 as persisting. The final classification tree (Figure 2) has five terminal nodes. The variables included in the tree are distance to the nearest neighbour, presence of forest within the 10 m buffer zone and density. Occurrences that are isolated (> 123.5 m) and are not in close distance to forest have a higher probability of becoming extinct (e.g. nodes 1 and 5), than at sites where the density is high or distance to neighbours is medium (e.g. nodes 3 and 4). Occurrences of *Telekia* that are characterized both by low density and are close to other populations tend to extinct. No effect of landscape structures such as water or road presence was found to be significant.

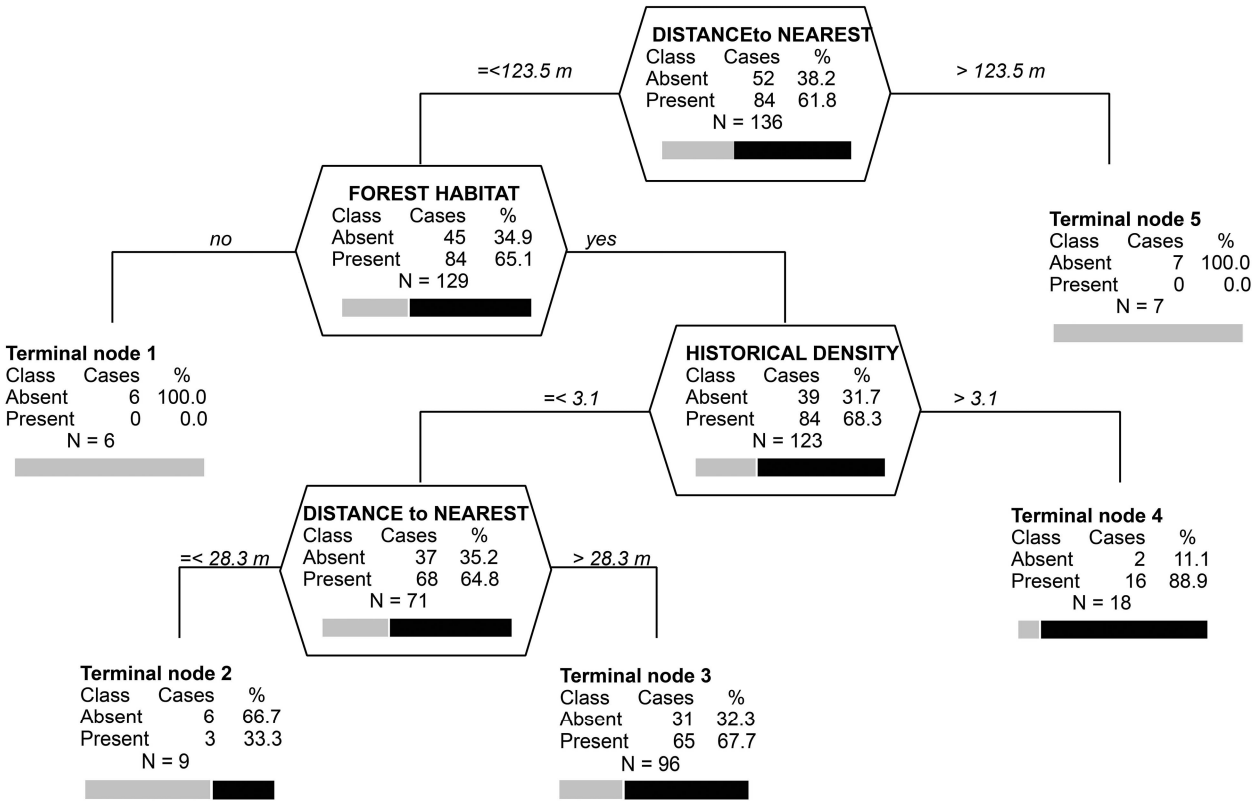


**Figure 2.** Classification tree for the persistence of historical populations. A population is classified as persisting (present) if *Telekia* was recorded during recent sampling in a distance up to 20 m. Forest habitat refers to the type of land use and covers all sites which are located to 10 m from any forested area, and historical density refers to values of the Kernel density (cell size 10 m, radius 100 m). Grey bars represent extinct and black bars persisting sites.

In the recent inventory, there were 549 isolated occurrences of *Telekia* that were mapped (Figure 3) and 381 that were located outside the range of 20 m buffer from historical occurrences. The size of the occurrences ranged from single individual to 10 $m^2$. We mapped 252 sites as individual plant records and 216 sites as those with flowering individuals. The abundance at sites mapped as polygons included 83 sites with abundance of *Telekia* to 20% and 21 sites with abundance higher than 75%. The regression tree (Figure 4) showed that the density of *Telekia* in the recent dataset was negatively associated with the distance to historical occurrences (i.e. node 6, mean 471.9 m). In sites close to historical occurrences the recent distribution was high in the neighbourhood of ponds or in meadows (i.e. terminal nodes 4 and 5, means 1241.9 m and 963.3 m). Terminal nodes 1, 2 and node 5 indicate the interaction between the distance to source populations and their density, when populations close to historical occurrences show in average lower recent density.

## Discussion

In this study, we found that after 50 years *Telekia speciosa* persisted at 67% sites and has spread to another 381 new sites. Such a level of persistence and rate of spread over a fifty year period goes exceedingly beyond any known records for other IAS. For *Heracleum mantegazzianum*, it was shown

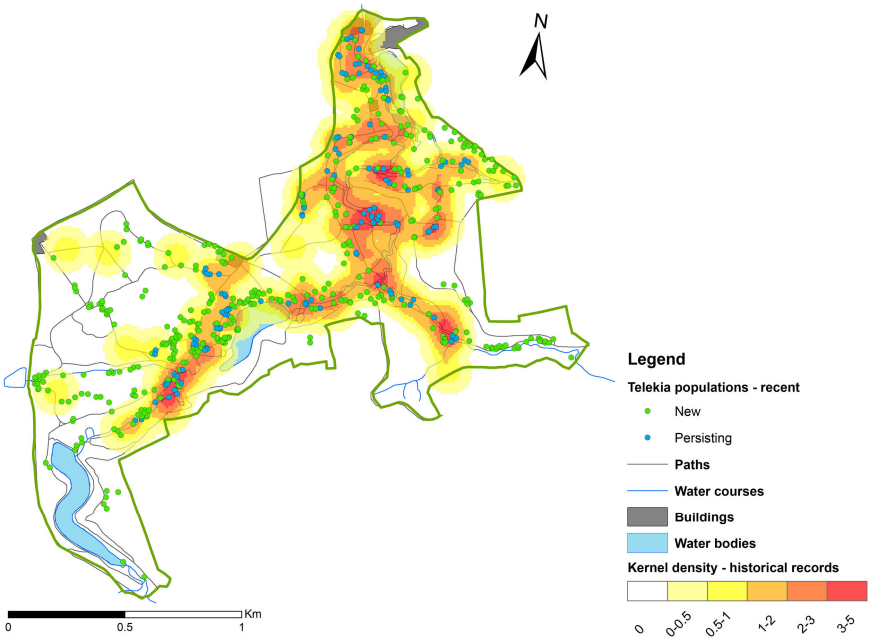


**Figure 3.** Map of the recent distribution of *Telekia speciosa* in the Průhonice park. The map shows a combination of persisting and newly recorded populations. The Kernel density calculated from all historical records is shown in the background. Georeferenced data are available in Supplementary material Table S2.

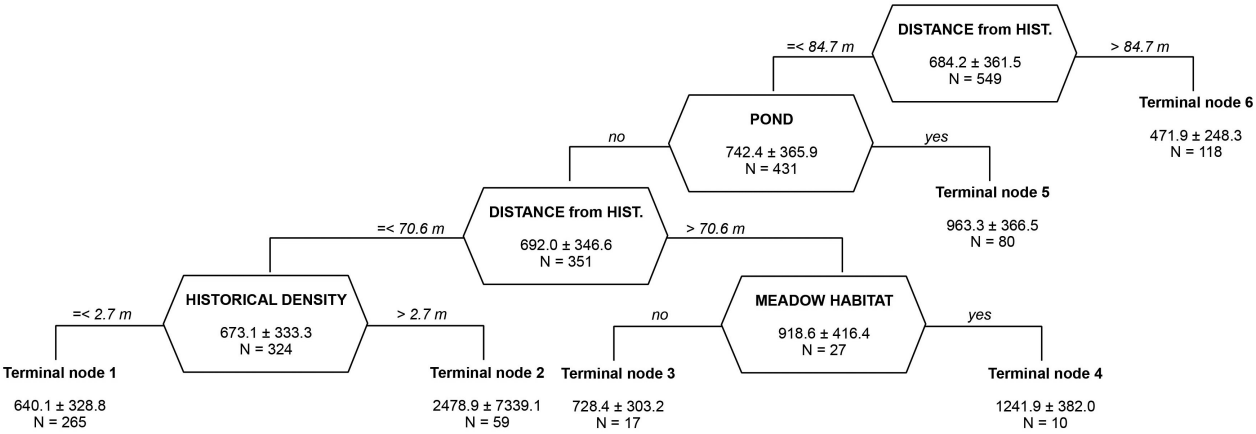


**Figure 4.** Regression tree for density of newly recorded occurrences of *Telekia speciosa* in the Průhonice park. Distance from historical site refers to the distance between the recent and closest historical site. Pond refers to occurrence of pond within the 10 m buffer around a site, meadow habitat refers to open type of land use and covers all sites which are located to 10 m from any meadow, and historical density refers to values of the Kernel density (cell size 10 m, radius 100 m).

that it disappeared from 55% to 76% of the sites (Wade et al. 1997; Pergl et al. 2012). Given that it is a problematic species (Nielsen et al. 2005; Pyšek et al. 2007; Pergl et al. 2016a, c), *Telekia* is not target of awareness and complex eradication campaigns. On the contrary, the spread of *Telekia* in the studied area was tolerated by management via selective mowing.

In a comparable study using similar species, *Rudbeckia laciniata* (i.e. a tall representative in Asteraceae family planted as ornamental) showed larger scale persistence of 77% (Pyšek et al. 2001). Both species are reproducing by seeds and *R. laciniata* has a stronger potential to spread vegetatively, highlighting a higher potential to persist. The same pattern

was found for other clonal species such as *Fallopia* (syn. *Reynoutria*) *japonica* (86% persistence) and *F. sachalinensis* (75%) (Pyšek et al. 2001). *Telekia* takes advantage of suitable life history in the studied environment (seed dispersal, good regeneration, efficient spread) and the current management, when large sites of *Telekia* are protected from mowing to be kept as visual dominants in the park. Considering the habitats invaded, the pattern found for *R. laciniata* showed that it persists better in riparian and transport habitats (ca 81%) while in undisturbed habitats the persistence is only 70% (Pyšek et al. 2001). Although there were no clear effects of landscape structures found in our study (by analysing the historical sites only and both historical and recent data) and only effects of neighbouring populations was confirmed, the distribution of *Telekia* in the park is restricted to paths; ca 90% of occurrences is within 50 m distance from the path and only four sites (from the total of 549) are located further than 100 m from the path.

The pattern of persistence of *Telekia* historical populations shows the significant role of distance to neighbouring populations, but with no clear linear relationship. From the data it seems that largely isolated plants or individual plants have a higher probability to be vanished. On the other hand, plants occurring in larger groups which can't be overlooked are not usually mowed and are kept for ornamental purposes. Compared to patterns found in the open landscape outside the parks, e.g. *Heracleum mantegazzianum* had high persistence in meadow and forest margins and lesser in road verges, parks and similar habitats that reflect increased eradication efforts at sites located close to human settlements where the species is highly visible and attracts the attention of stakeholders, managers and local authorities bearing in mind its toxicity (Pergl et al. 2012). *Telekia* does not pose any serious health problems and is highly ornamental, therefore its management is highly selective. Such attitude and management strategy is in contrast to many invasive species that are eradicated for biodiversity conservation (Pluess et al. 2012; Pyšek et al. 2013; Vítková et al. 2017).

Jehlík and Lhotská (1970) and later Lhotská (1988) found in their survey *Telekia* also outside the park mostly along the Botič stream as a result of natural spread. *Telekia* was recorded in their survey in several places, but only as small occurrences of a few plants. Other invasive species like *Fallopia sachalinensis*, *Solidago canadensis* and *Galega officinalis* were rarely recorded. This is quite surprising as the park serves as a large source of propagules. Our recent survey did not confirm the rapid spread outside the park, but *Telekia* was found persisting on all of the eight previously recorded sites. As we recorded *Telekia* only on four new sites along the Botič stream, we assign this pattern with the highly intensive management along the stream or dense overstorey of riverine vegetation unsuitable for growth of this semi-heliophilous species.

Although the species was not found to spread widely outside the park nowadays, our observations from the park clearly shows a high invasion potential of *Telekia* under combination of medium level disturbances, high propagule pressure and open sunny habitats which is also observed in other areas where the species was introduced (Kopecký 1977; Dostálek 1998; Smolová et al. 2010; Kubů 2016). Unfortunately there are not yet robust data on the impact of *Telekia* on biodiversity and soil. However our data (Pergl et al. *unpublished*) indicate that in sites of high dominance of *Telekia* other species richness is significantly lower to comparable uninvaded plots. Parks and ornamental plantations can thus be a suitable source of further invasions to the open landscape (van Kleunen et al. 2018), especially for species with a good spreading ability (Moravcová et al. 2010) or species that will gain from future climate change (Haeuser et al. 2018). The highest risk is from the perennial plantations since the species are selected to reproduce independently and are planted outside urban areas (Kutlvašr et al. 2019).

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## Declarations of interest: none

## Authors' Contribution

PP and RF collected the field data. JB and MA did the GIS analyses. JP did the statistical methods and outlined the manuscript. All authors edited and commented the manuscript.

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**Supplementary material**

The following supplementary material is available for this article:

**Table S1.** Distribution data of historical data of *Telekia speciosa* in the Průhonice park.

**Table S2.** Distribution of *Telekia speciosa* in the Průhonice park in the years 2017–2018.

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