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Non-native woody plant species in urban forests of Frankfurt/Main (Germany)

Neophytische Gehölzarten in urbanen Wäldern von Frankfurt am Main

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Abstract

In 23 survey areas with woodland vegetation or woodland succession in Frankfurt/Main with a total size of 134 hectares, woody species were surveyed (excluding species only occurring as planted individuals). We found 149 woody taxa; 42% of them indigenous, and 58% non-native. Out of the 86 non-native taxa, 49 were naturalized in Frankfurt while 37 were considered as casual. Among non-native taxa, East Asian taxa formed the largest phytogeographic group. We found taxa originating from horticulture (cultigens) to be an important part of the woody flora of Frankfurt/Main. The most common taxa were *Acer pseudoplatanus*, *A. platanoides*, *Betula pendula*, and *Sambucus nigra*; the two *Acer* species were regarded as naturalized. Non-native woody species were generally common (with percentages ranging from 24% to 79% in individual areas).

Keywords: cultigens, introduction pathways, non-native plants, urban forests, woody species

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

In Central European cities many non-native woody plants which are offered in increasing number by nurseries (KŘIVÁNEK & PYŠEK 2008, HALFORD et al. 2011) are planted in private gardens and public green spaces. Many of these ornamental plants produce an abundant supply of propagules. Such high propagule pressure combined with suitable habitat conditions offers ample possibilities for the naturalization of ornamental woody species in cities, especially in remnant forests, urban wasteland, abandoned orchards, and marginal strips of railroad lines and highways (WITTIG 1991, SUKOPP & WITTIG 1998, REICHARD & WHITE 2001, WITTIG 2002a, DEHNEN-SCHMUTZ et al. 2007, KŘIVÁNEK & PYŠEK 2008, BUCHAROVA & VAN KLEUNEN 2009, RICHARDSON & REJMÁNEK 2011, LOEB 2012, REJMÁNEK & RICHARDSON 2013, ČEPLOVÁ et al. 2017). Specific ecological conditions – warmer and at times dryer local climate compared to the surrounding landscape as well as high frequencies and

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intensities of disturbances – augment habitat diversity in cities, creating niches for the naturalization of non-native plants (LANDSBERG 1981, REBELE 1994, TAHA 1997, HILL et al. 2002, WITTIG 2002a, OKE 2011, NIEMELÄ 2013, WILLIAMS et al. 2015).

Invasions by non-native woody plants are rapidly increasing in importance around the world (RICHARDSON & REJMÁNEK 2011, REJMÁNEK 2014, RICHARDSON et al. 2014). Various authors analyzed non-native woody plants in smaller parts of Central Europe, also emphasizing their temporal expansion dynamics (e.g., HETZEL 2006, Upper Franconia; HETZEL 2012, Ruhr area/Germany; KUNICK 1987, Germany; PILSL et al. 2008, Salzburg/Austria; SCHMID 2005, Stuttgart/Germany; KOWARIK 1995, KOWARIK et al. 2013, Berlin/Brandenburg). GREGOR et al. (2012) reported a large number of non-native woody plants for Frankfurt/Main but specific surveys on the importance of this group for Frankfurt/Main are still missing.

With regard to non-native woody species in near-natural and anthropogenic forests of Frankfurt/Main we asked: (1) What is the number of non-native woody species and which species are most common? (2) What is the origin of the non-native woody species? (3) Do frequency distributions differ between indigenous, naturalized and casual taxa? (4) To which proportion do non-native woody species contribute to the total richness of woody species in the analyzed forests? (5) Is the occurrence of non-native woody species positively connected to massive soil disturbance?

2. Methods

Within the political borders of the city of Frankfurt/Main, the fifth-largest city of Germany, there are approximated 1743 patches of wooded areas with altogether 350.7 ha scattered throughout the city (unpublished data from the Habitat Mapping Scheme of the City of Frankfurt/Main). In 23 wooded areas with a total size of 134 hectares we surveyed all spontaneously occurring woody species (excluding species only occurring as planted individuals) during the vegetation periods 2011 through 2016. The surveyed areas were selected to represent different types of urban forest; by this we mean both forest-like areas in which spontaneously growing trees and shrubs occur and areas which are in succession towards such forest-like stands. A further criterion for selection was accessibility, since many potentially relevant areas were fenced-in or otherwise inaccessible. Each survey covered the total area of each forest and was continued until no new species were found. Each survey lasted mostly between 100 and 180 minutes depending on size and homogeneity of the survey area. The location, size and vegetation type of the surveyed areas are summarized in Table 1; their spatial distribution is shown in Figure 1. We classified the study areas in two groups: Areas that apparently showed strongly modified soils due to excavation or deposition of earth or debris vs. areas apparently without massive changes of the soil surface.

We considered trees, shrubs and woody lianas with mean height exceeding 0.5 m as woody species. We did not consider taxa with only short-lived or weakly lignified stems (*Rubus* spp.) as woody species. The classification of shrubs versus dwarf-shrubs (not considered) like *Vaccinium* spp. followed JÄGER (2011). For each area we recorded if planted trees and shrubs were present (including an estimate of their overall cover) and estimated the abundance of non-planted species with five semiquantitative classes: (1) very rare: less than 5 specimens – very low coverage, (2) rare: 5–10 specimens – very low coverage, (3) scattered: > 10 specimens – coverage 2–5%, (4) frequent: > 10 specimens – coverage 5–25%, (5) dominant: > 10 specimens – covering > 25%.

For taxonomic identification we used JÄGER (2011), MEYER et al. (2002), ROLOFF & BÄRTELS (2006) and DICKORÉ & KASPEREK (2010). We included *Lonicera nitida* E.H. Wilson into *L. pileata* Oliv. Identification problems remained in *Malus*, *Ulmus*, and *Tilia*; particularly for young plants we sometimes had to restrict our identification to the genus level. Specimens of taxa remarkable for the flora of Frankfurt, as well as taxa involving identification problems were collected and deposited in the Herbarium Senckenbergianum (FR).

Table 1. Investigation areas. Actual or former use: A = agriculture; F = Forest; H = Housing; I = Industry; M = Military; R = Railroad, Highway; C = Cemetry; P = Park.
Tabelle 1. Untersuchungsgebiete. Aktuell oder frühere Nutzung: A = Landwirtschaft; F = Wald; H = Gebäude; I = Industrie; M = Militär; R = Eisenbahn, Autobahn; C = Friedhof; P = Park.

Name	Date of survey(s)	Coordinates, center of survey area (in decimal degrees)	Size (approx.) in hectares	Actual (former) use	Coverage of planted shrubs and trees (%)	Soil apparently strongly modified	Woody vegetation
Forest area "Niedwald"	2011-09-14	50.1102; 8.5901	40	F	50		broad-leaved forest
Forest area "Riederwald"	2012-10-16	50.1255; 8.7332	30	F	40		broad-leaved forest
Forest area "Goldstein"	2013-07-23	50.0748; 8.6095	8	F	80		broad-leaved forest
Forest area "Rebstockwäldchen"	2011-06-15	50.1148; 8.6234	3.2	F	40		broad-leaved forest
Forest area "Rodsee"	2013-08-05	50.0736; 8.5500	2.5	F	20		broad-leaved forest
Schwanheim, sand dunes	2013-08-27	50.0879; 8.5596	3	(A)			dune area
Agricultural fallow land Oberrad	2012-10-09	50.1039; 8.7404	6	(A)			succession on former agricultural land
Former orchard west of Campus Riedberg	2013-06-05	50.1703; 8.6274	3	(A)	40		succession on former agricultural land
Sinai park	2013-09-25	50.1447; 8.6753	1.5	(A) P			succession on former agricultural land
Bank of river Main near Western harbour	2012-07-10	50.0988; 8.6614	1	(I) P	30	×	bank of channelized river
Bank of river Main near Schwanheim	2012-09-19	50.0944; 8.5685	1	P	30	×	bank of channelized river
Bank of river Main near Osthafen	2013-09-10	50.1086; 8.7223	0.75	–	40	×	bank of channelized river
US Army Depot Rödelheim	2016-10-18	50.1264; 8.5942	17.4	(M)	5	×	succession on formerly built-up area or industrial land
Former airfield Bonames	2011-08-23 & 2012-10-01	50.1768; 8.6546	5.6	(M) P		×	succession on formerly built-up area or industrial land
Railway station Frankfurt East	2011-10-25	50.1146; 8.7110	3	(R)		×	succession on formerly built-up area or industrial land
Urban fallow Grusonstraße/Ostbahnhofstraße	2011-10-25	50.1125; 8.7048	1	(H)		×	succession on formerly built-up area or industrial land
Railway station Mainkur	2012-09-11	50.1354; 8.7703	1	(R)		×	succession on formerly built-up area or industrial land
Urban fallow Niederrad	2012-09-24	50.0839; 8.6322	1	(I)		×	succession on formerly built-up area or industrial land
Urban fallow Lise-Meitner-Straße	2011-06-07	50.1160; 8.6397	0.6	(I)		×	succession on formerly built-up area or industrial land
Embankment of highway 5 near Griesheim	2012-06-27	50.0973; 8.6147	2	R	60	×	other
Northern embankment of former freight station	2011-09-28	50.1072; 8.6160	1	(R)	10	×	other
Southern embankment of former freight station	2011-09-28	50.1063; 8.6146	1	(R)	10	×	other
Schwanheim, deposit area	2013-08-27	50.0879; 8.5596	1	–	5	×	other

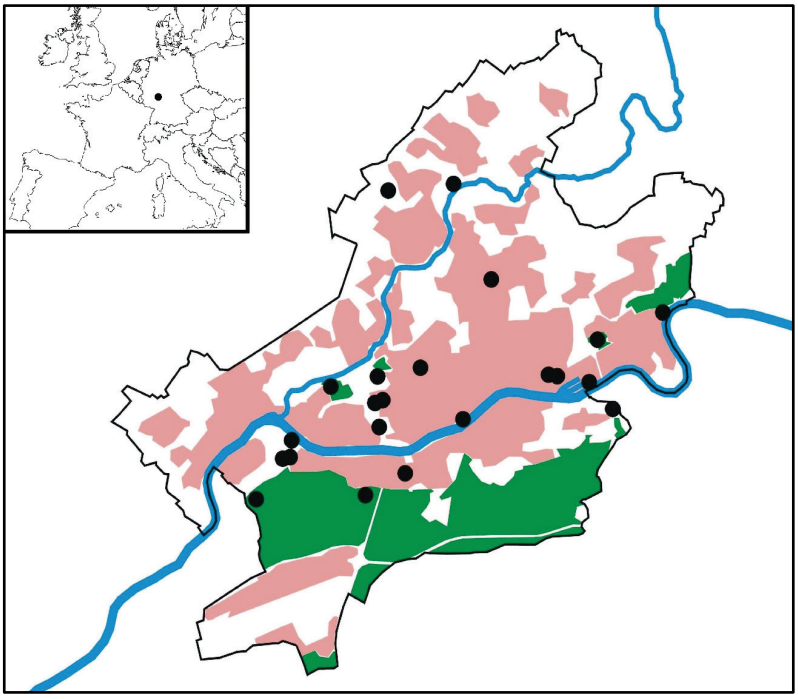

Fig. 1. Distribution of examined plots (black dots) within the political borders of Frankfurt (forest areas shown in green, built-up areas in red, rivers in blue).

Abb. 1. Lage der Untersuchungsgebiete (schwarze Punkte) in Frankfurt am Main (grün: Wälder, rot: bebaute Gebiete, blau: Flüsse).

We treated all taxa as non-native to Frankfurt/Main if they were not mentioned for the present area of Frankfurt/Main in the regional floras of REICHARD (1772/1778), BECKER (1827), or FRESENIUS (1832/1833). Additionally, we considered *Pinus sylvestris* to be non-native to Frankfurt, according to IMMEL (1933). Non-native or alien taxa were classified as casual or naturalized according to the criteria given by RICHARDSON et al. (2000) and PYŠEK et al. (2004): Casual alien plants flourish and sometimes even reproduce occasionally in an area, but do not form self-sustaining populations, and rely on repeated introductions for their persistence. Naturalized plants reproduce consistently and sustain populations over many life cycles without a need for direct intervention by humans. Nomenclature of plants follows the online list of vascular plants of Germany (BUTTLER et al. 2018) except for the non-included *Malus prunifolia* (Willd.) Borkh.

We used the Mann-Whitney-U test for differences between mean values of percentage of non-native taxa vs. indigenous taxa in areas with or without strongly modified soils. Statistics were calculated in R version 3.5.0 (R CORE TEAM 2018).

3. Results

The results of the survey are given in Supplement S1. Altogether, we found 149 spontaneously occurring woody taxa in our survey areas, 63 (42%) of them indigenous, 49 (33%) naturalized non-native and 37 (25%) considered as casual non-native taxa. On average, 32.5 spontaneously occurring woody taxa were found per area.

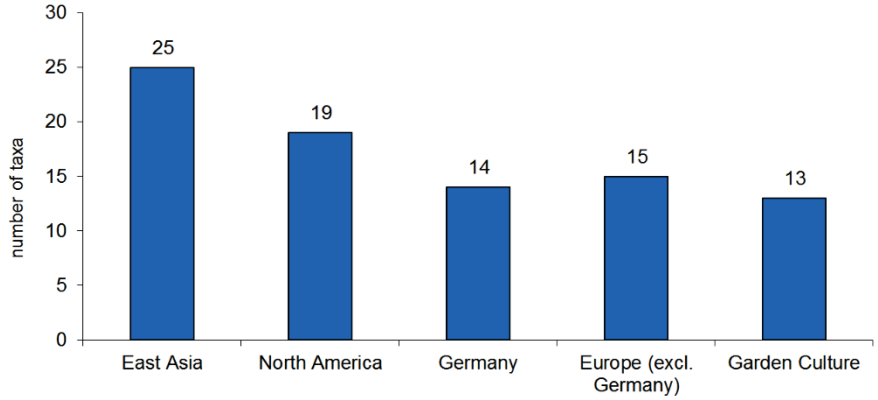

Fig. 2. Origin of non-native woody species recorded in 23 survey areas in Frankfurt/Main.

Abb. 2. Herkunft der nicht-indigenen Gehölze, die in den 23 Untersuchungsflächen in Frankfurt am Main vorkamen.

The 25 most common woody taxa comprised 11 non-native taxa. *Acer pseudoplatanus* occurred in 22 out of 23 sites and was the most common of all woody taxa, its congener *A. platanoides*, also regarded as non-native, ranged as second (20/23). *Cornus sanguinea* subsp. *australis* and *C. s.* subsp. *hungarica* were the next most common non-native taxa (both at rank 9, with occurrences in 16 survey areas). Next in the list of the most common non-native taxa were: *Robinia pseudoacacia* (15/23), *Parthenocissus inserta* (14/23), *Ailanthus altissima* (13/23), *Juglans regia* (13/23), *Prunus serotina* (11/23), *Acer negundo* (11/23), and *Buddleja davidii* (11/23). The most common indigenous taxa were *Betula pendula* (20/23), *Sambucus nigra* (19/23) and *Acer campestre*, *Fraxinus excelsior*, *Quercus robur*, and *Rosa canina* (all four: 17/23).

Figure 2 shows the origin of the non-native woody species found in our study. Non-native taxa of East Asian origin were the largest group, followed by taxa from North America. The group of taxa which originated in garden culture (by plant breeding and/or hybridization) comprised 13 taxa.

Figure 3 shows the frequency distributions of indigenous, naturalized non-native, and casual non-native taxa in the 23 survey areas. Indigenous and naturalized non-native taxa had a similar distribution: most taxa were rare. Distributions were clearly left-sided. This was even more pronounced in casual non-native taxa: none of these had more than 6 occurrences, while 25 casual taxa were only found once.

Between the surveyed areas the percentage of non-native taxa – naturalized or casual – varied from 24% (Niedwald) to 79% (highway embankment Griesheim; Supplement S1). The percentage of naturalized non-native taxa varied from 20% (forest Rodsee) to 71% (highway embankment Griesheim). The mean percentage of the number of non-native taxa was 50% (SD ± 12).

In areas with strongly modified soils we found a higher percentage of non-native taxa vs. indigenous taxa than in areas without strongly modified soils (Fig. 4). For the proportion of non-native taxa, the median was 53% on strongly modified soils (maximum: 79%) but only 46% on unmodified soils (maximum 54%). For indigenous taxa the values were reciprocal. However, these differences were not statistically significant (Mann-Whitney-U test).

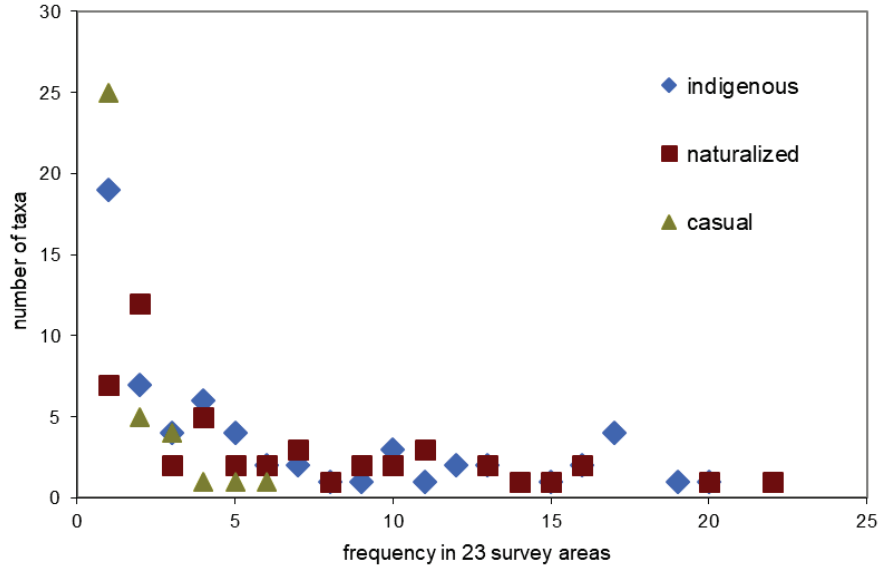

Fig. 3. Frequency of indigenous and naturalized or casual non-native woody species in 23 survey areas.

Abb. 3. Häufigkeit von einheimischen, eingebürgerten neophytischen und unbeständigen neophytischen Gehölzen in den 23 Probeflächen.

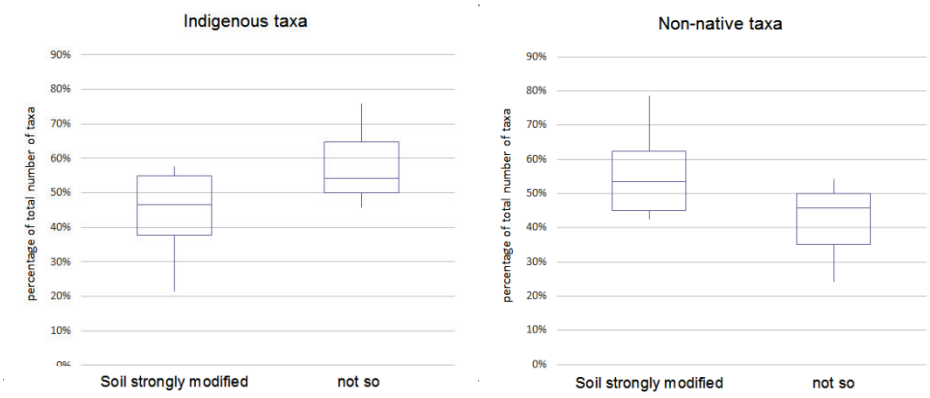

Fig. 4. Percentage of indigenous (left) and non-native (right) spontaneous woody plants regarding their share of the total number of taxa in areas with or without strongly modified soils.

Abb. 4. Prozentanteile von einheimischen (links) und neophytischen (rechts) spontanen Gehölzen an der Artenzahl von Gehölzen in Gebieten mit oder ohne stark veränderten Böden.

4. Discussion

In urban fallows of Berlin, KOWARIK (1992a) found that *Robinia pseudoacacia* was the most important species. At railway stations in the Rhine-Ruhr-area (Northrhine-Westphalia), WITTIG (2008) found *Buddleja davidii*, *Robinia pseudoacacia* and *Ailanthus altissima*

among the 7 most common spontaneous woody species. At railway stations in the Rhine-Ruhr area and the Rhine-Main area in Hesse and Rhineland-Palatinate, *Buddleja davidii* was the most common spontaneous woody species (WITTIG 2002b, 2008). These three species were also among the more common species in Frankfurt/Main (found in more than 45% of the survey areas).

Species indigenous in other parts of Germany dominated among the 11 most common non-native woody species: *Acer pseudoplatanus* (1.), *A. platanoides* (2.), *Cornus sanguinea* subsp. *hungarica* (3.). Species originating from North America were *Robinia pseudoacacia* (5.), *Parthenocissus inserta* (6.), *Acer negundo* (9.) and *Prunus serotina* (9). *Ailanthus altissima* (7., Fig. 5) and *Buddleja davidii* (9.) originated from East Asia and *Cornus sanguinea* subsp. *australis* (3.) and *Juglans regia* (7.) from Europe outside Germany.

We found a considerable proportion of non-native woody taxa originating from garden culture, differing taxonomically from their wild ancestors: There were 13 taxa in the woody flora of Frankfurt (out of 86 non-native taxa, and 149 taxa in total) which originated from horticultural selection or hybridization. These taxa can be termed cultigens (for a definition see SPENCER & CROSS 2007; for the broader term anecophytes compare SCHOLZ 2007). There are a few examples of earlier studies from Central European cities which explicitly quantified the relative importance of woody cultigens. A value of ca. 5% for woody taxa originating from horticultural selection or hybridization given by KOWARIK (1992b) related only to taxa introduced until the year 1916. For residential areas of Berlin, MAURER (2002) found that 4 out of 61 spontaneous woody taxa (ca. 7%) originated from horticultural selection or hybridization, while for residential areas of Hamburg RINGENBERG (1995) stated that 13% of spontaneous woody taxa belonged to this group. Our results from Frankfurt fall

Fig. 5. Former logistic center of the American Forces at Frankfurt-Rödelheim. *Ailanthus altissima* growing in pavement cracks (Photo: G. Kasperek, 17.09.2016).

Abb. 5. Ehemaliges Logistikzentrum der amerikanischen Armee in Frankfurt-Rödelheim. *Ailanthus altissima* wächst in Pflasterritzen (Foto: G. Kasperek, 17.09.2016).

within this range. In order to take account of their growing importance (SPENCER & CROSS 2017), cultigens could be considered a phytogeographical group of its own in future studies on non-native plants.

Non-native woody species were a major component of all surveyed urban forests in the city of Frankfurt/Main. Any comparison of percentages given in studies of different authors should be made with caution since methodologies vary. In particular, uncertainties arise from four aspects:

(a) definition of non-native or alien plants/neophytes (the latter being a term used in Central Europe for non-native plants introduced after the rediscovery of the Americas),
(b) inclusion vs. non-inclusion of casual taxa,
(c) broad vs. narrow delimitation of the investigated "urban" area, and
(d) accuracy of taxonomic identification.

Our approach to the first aspect (a) is in line with Central European tradition, but uses a regional concept of classification: We regard *Acer pseudoplatanus* and *A. platanoides* as non-native. They are non-native in Frankfurt/Main but indigenous in the Taunus Mountain just 15 km to the north. Such a regional approach towards status determination is rarely followed and many surveys would consider these two species as indigenous. With the widest possible inclusion of casual taxa (b), we also follow a Central European tradition. Our delimitation of "urban" (c) includes some agricultural and forested areas at the edge of the city, but we did not sample patches in rural settings. We aim at the greatest possible taxonomic accuracy (d). In many studies *Cornus sanguinea* subsp. *australis* (in 16 of /23) and *Cornus sanguinea* subsp. *hungarica* are not distinguished taxonomically, or are not identified as non-native, as they are morphologically similar to the indigenous *Cornus sanguinea* subsp. *sanguinea.* With these four aspects in mind, we have strived to select studies with similar approaches for comparison with our results.

KUNICK (1987) reported high percentages of non-native woody plant species in central European cities, i.e. mostly ranging from 25 to 50% of woody plant species, and reaching > 50% in Vienna. KOWARIK (1992a) listed percentages of non-native woody species for the vegetation of five urban fallows in Berlin of 5–72% (mean 45%). WITTIG (2008) found that 73% of all individuals belonged to neophytic species at railway stations in the Rhine-Ruhr-area (Northrhine-Westphalia). A thorough analysis of the role of non-native woody species for Berlin was performed by KOWARIK et al. (2013). Our results were similar to those of the authors mentioned above. KOWARIK et al. (2013) found 181 non-native woody species (57 of them naturalized) and 89 indigenous woody species; the percentage of neophytic woody taxa in Berlin was about 65%. In our 23 survey areas we found 63 indigenous and 86 non-native woody species (49 of them naturalized), the percentage of neophytic woody taxa being 58%. For the whole city of Frankfurt 83 indigenous and 129 non-native woody species are known, the percentage of non-native woody taxa being 61% (56 of them naturalized) (unpublished data of Habitat Mapping Scheme Frankfurt/Main). The frequency of non-native woody species in Berlin was higher in disturbed urban habitats and wastelands than in forests. All non-native woody species occurring in Berlin with a frequency of more than 10% also occurred in Frankfurt/Main.

When focusing on urban floras without regard to life form, percentages of non-native taxa rarely surpassed 50%, at least in Central Europe (KOWARIK 2008). The high percentages found for woody taxa indicate that non-native trees and shrubs might be a particularly rewarding focus for studies on the dynamics of urban floras.

From a global perspective, woody plant species account for 32.1% of all naturalized plant species but they only account for 11.6% of the 200 most widely distributed naturalized plants (PYŠEK et al. 2017). Of these top 200 species, *Robinia pseudoacacia* is the only woody species that occurred in Frankfurt. Very rare species are numerous among naturalized woody species. This reflects a possibility that the widespread cultivation of large numbers of winter-hardy woody plants might result in the naturalization of many of them.

One of our starting points was the question whether areas with strongly modified soils have higher percentages of non-native woody species in Frankfurt/Main than areas without strongly modified soils. Our surveys found a tendency for this. But the effect was not strong and failed to pass a significance test. The general propagule pressure on suitable areas of the city seemed to overlock effects caused by soil disturbance.

At the beginning of the 19th century only very few non-native woody species were mentioned as naturalized in Frankfurt (REICHARD 1772/1778, BECKER 1827, FRESENIUS 1832/1833): *Lonicera caprifolium* (not found in our survey), *Lycium barbarum* (not found in our survey), *Populus alba*, *Prunus cerasus*, and *P. domestica*. Probably, the naturalization of *Acer pseudoplatanus* and *A. platanoides* had already begun at that time, as BECKER (1827) and FRESENIUS (1832/1833) mentioned them as planted along country roads. For the year 1900, no further woody species were mentioned as naturalized by GREGOR et al. (2012). *Ailanthus altissima* was first mentioned as a garden plant in Frankfurt by BLUM & JÄNNICKE (1892). In 1947 many young *Ailanthus* plants grew in the destroyed inner city (ESEBECK according to KRAMER 1995). The rapid spread of *Ailanthus altissima* and many other non-native woody species in Frankfurt occurred only within the last decades. In Frankfurt/Main, some frost sensitive non-native woody species occasionally found in the Ruhr area (HETZEL 2012) with its distinctly milder climate were missing (e.g., *Buxus sempervirens*, *Pachysandra terminalis*, *Lonicera henryi*) or very rare (e.g., *Euonymus fortunei*, *Prunus laurocerasus*, *Aucuba japonica*).

Nevertheless, non-native woody plant species have become a substantial part of the dendroflora of Frankfurt/Main, outnumbering indigenous trees and shrubs in many places.

Erweiterte deutsche Zusammenfassung

Einleitung – Mitteleuropäische Städte bieten zahlreiche Standorte, die die Verwilderung von Gehölzen ermöglichen; zugleich sind infolge von Anpflanzungen Diasporen zahlreicher nichteinheimischer Gehölze präsent (BUCHAROVA & VAN KLEUNEN 2009, ČEPLOVÁ et al. 2017). Eine weltweit festzustellende Ausbreitung neophytischer Gehölze wird immer stärker zum Gegenstand von Untersuchungen (RICHARDSON & REJMÁNEK 2011, REJMÁNEK 2014, RICHARDSON et al. 2014), wobei vermehrt auch die Gehölzflora kleinerer Gebiete analysiert wird (z. B. HETZEL 2006, PILSL et al. 2008). Die vorliegende Studie untersucht anhand von Gehölzbeständen in Frankfurt am Main folgende Fragen: (1) Welches sind die häufigsten neophytischen Gehölze? (2) Welche Herkunft haben die neophytischen Gehölze? (3) Unterscheiden sich die Häufigkeitsverteilungen innerhalb verschiedener Gruppen von Gehölzen? (4) Wie hoch ist der Anteil neophytischer Gehölze an der Gesamtzahl der Gehölzarten? (5) Besteht ein Zusammenhang zwischen dem Vorkommen neophytischer Gehölze und massiven Bodenstörungen?

Methoden und Untersuchungsgebiet – Im Zeitraum von 2011 bis 2016 wurden innerhalb der administrativen Grenzen der Stadt Frankfurt am Main 23 urbane Wälder (Wälder im engeren Sinne sowie zumindest teilweise mit spontanen Gehölzen bestandene Flächen) in Hinblick auf ihre Gehölzflora untersucht (vgl. Tab. 1). In jeder Fläche wurden alle wildwachsenden Gehölzsippen unter Verwendung einer semiquantitativen fünfstufigen Häufigkeitsskala erfasst. Zudem wurden die Gesamthäufigkeit gepflanzter Gehölze erfasst sowie die Bodenverhältnisse als weitgehend natürlich oder als

anthropogen stark gestört klassifiziert. Alle Taxa, die in den Regionalfloren von REICHARD (1772/1778), BECKER (1827) oder FRESENIUS (1832/1833) nicht aufgeführt waren, wurden als neophytisch eingestuft; sie wurden für das Stadtgebiet Frankfurt als unbeständig oder eingebürgert klassifiziert (nach den Kriterien von RICHARDSON et al. [2000] und PYŠEK et al. [2002, 2004]). Die Nomenklatur folgt BUTTLER et al. (2018). Statistische Berechnungen wurden mit R, Version 3.5.0, durchgeführt.

Ergebnisse – In den untersuchten Gehölzbeständen wurden 149 Gehölzsippen nachgewiesen (Beilage S1), von denen 63 Sippen (42 %) als einheimisch, 49 Sippen (33 %) als eingebürgerte Neophyten und 37 Sippen (25 %) als unbeständige Neophyten einzustufen sind. In den 23 untersuchten Flächen kamen durchschnittlich 32,5 Gehölzsippen vor. Der Anteil eingebürgerter neophytischer Gehölzsippen in den Flächen variierte von 20–71 %. Neophytische Gehölzsippen insgesamt (d. h. einschließlich der Unbeständigen) machten 24–79 % der Arten aus, mit einem Mittelwert von 50 % (SD ± 12).

Eine Analyse der neophytischen Gehölze nach phytogeographischen Gruppen ergab, dass die 25 Taxa ostasiatischer Herkunft die größte Gruppe bildeten (Abb. 2). Die Gruppe der Taxa, die erst in Kultur entstanden sind (Cultigene), umfasste 13 Sippen (8,7 %). Daher liegt es nahe, in zukünftigen Untersuchungen diese Taxa als eine eigene phytogeographische Gruppe zu behandeln.

Acer pseudoplatanus, in Frankfurt als Neophyt betrachtet, kam in 22 von 23 Flächen vor und war damit die häufigste Gehölzsippe. Die häufigste einheimische Art war *Betula pendula* (20/23). 25 unbeständige neophytische Gehölze wurden jeweils nur einmal gefunden.

In Gehölzbeständen mit anthropogen stark veränderten Bodenverhältnissen waren die Anteile einheimischer Arten gegenüber Neophyten reduziert, jedoch waren die Unterschiede nicht signifikant.

Diskussion – Nichteinheimische Gehölze waren eine wesentliche Komponente in allen untersuchten urbanen Wäldern von Frankfurt am Main. Ein Vergleich mit Angaben von KUNICK (1987), KOWARIK (1992a) und KOWARIK et al. (2013) ergab die übereinstimmende Tendenz, dass neophytische Gehölzsippen häufig zwischen 25 und 50 % erreichen, nicht selten aber auch Werte im Bereich 50 bis 75 % aller Gehölzsippen. Kumuliert über die gesamte Stadt erreichten nichteinheimische Gehölze in Berlin einen Anteil von etwa 65 % an der Gehölzflora; für Frankfurt ergab sich ein Anteil von etwa 60 %.

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Author contribution statement

T. Gregor and G. Kasperek conceived the study together, conducted all the research together and wrote the manuscript together.

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Supplements

Supplement S1. Frequency of woody taxa per survey area.

Beilage S1. Häufigkeiten der Gehölz-Taxa pro Untersuchungsfläche.

References

BECKER, J. (1827, „1828“): Flora der Gegend um Frankfurt am Main. Erste Abtheilung. Phanerogamie. – Ludwig Reinherz, Frankfurt a. M.: 509 pp.

BLUM, J. & JÄNNICKE, W. (1892): Botanischer Führer durch die städtischen Anlagen in Frankfurt am Main. – Mahlau und Waldschmidt, Frankfurt am Main: 188 pp.

BUCHAROVA, A. & VAN KLEUNEN, M. (2009): Introduction history and species characteristics partly explain naturalization success of North American woody species in Europe. – J. Ecol. 97: 230–238.

BUTTLER, K.P., THIEME, M. et al. (2018): Florenliste von Deutschland - Gefäßpflanzen. Version 10 (August 2018). – URL: http://www.kp-buttler.de/florenliste [accessed 2019-05-04].

ČEPLOVÁ, N., LOSOSOVÁ, Z. & KALUSOVÁ, V. (2017): Urban ornamental trees: a source of current invaders; a case study from a European city. – Urban Ecosyst. 20: 1135–1140.

DEHNEN-SCHMUTZ, K., TOUZA, J., PERRINGS, C. & WILLIAMSON, M. (2007): The horticultural trade and ornamental plant invasions in Britain. – Conserv. Biol. 21: 224–231.

DICKORÉ, W.B. & KASPEREK, G. (2010): Species of *Cotoneaster* (*Rosaceae*, *Maloideae*) indigenous to, naturalising or commonly cultivated in Central Europe. – Willdenowia 40: 13–45.

FRESENIUS, G. (1832/1833): Taschenbuch zum Gebrauche auf botanischen Excursionen in der Umgegend von Frankfurt a. M., enthaltend eine Aufzählung der wildwachsenden Phanerogamen, mit Erläuterungen und kritischen Bemerkungen im Anhange. – Heinr. Ludw. Brönner, Frankfurt am Main: VI, 1–332, 337–621 pp.

GREGOR, T., BÖNSEL, D., STARKE-OTTICH, I. & ZIZKA, G. (2012): Drivers of floristic change in large cities. A case study of Frankfurt/Main (Germany). – Landsc. Urban Plan. 104: 230–237.

HALFORD, M., HEEMERS, L., MATHYS, C., VANDERHOEVEN, S. & MAHY, G. (2011): Socio-economic survey on invasive ornamental plants in Belgium. – Final report February 2011. – URL: http://www.alterias.be/images/stories/downloads/socio_economic_survey_en.pdf [accessed 2019-05-04].

HETZEL, G. (2006): Die Neophyten Oberfrankens. Floristik, Standortcharakteristik, Vergesellschaftung, Verbreitung, Dynamik. – PHD Thesis. Julius-Maximilian-Universität (Würzburg). – URL: https://opus.bibliothek.uni-wuerzburg.de/opus4-wuerzburg/frontdoor/deliver/index/docId/1573/file/komplett.pdf [accessed 2019-05-04].

HETZEL, I. (2012): Ausbreitung klimasensitiver ergasiophygophytischer Gehölzsippen in urbanen Wäldern im Ruhrgebiet. – Diss. Bot. 411: 1–205, CD-ROM.

HILL, M.O., ROY, D.B. & THOMPSON, K. (2002): Hemeroby, urbanity and ruderality: bioindicators of disturbance and human impact. – J. Appl. Ecol. 39: 708–720.

IMMEL, R. (1933): Beiträge zur Frühgeschichte der Nadelholzkultur und der Holzartenverbreitung in Hessen. – Allg. Forst- Jagdzeit. 109: 173–186, 219–230.

JÄGER, E.J. (Ed.) (2011): Rothmaler. Exkursionsflora von Deutschland. Gefäßpflanzen: Grundband. 20. Aufl. – Spektrum, Heidelberg: 930 pp.

KOWARIK, I. (1992a): Zur Rolle nichteinheimischer Arten bei der Waldbildung auf innerstädtischen Standorten in Berlin. – Verh. Ges. Ökol. 21: 207–213.

KOWARIK, I. (1992b): Einführung und Ausbreitung nichteinheimischer Gehölzarten in Berlin und Brandenburg und ihre Folgen für Flora und Vegetation. Ein Modell für die Freisetzung gentechnisch veränderter Organismen. – Verh. Bot. Ver. Berlin Brandenbg., Beih. 3: 1–180.

KOWARIK, I. (1995): Time lags in biological invasions with regard to the success and failure of alien species. – In: PYŠEK, P., PRACH, K., REJMÁNEK, M. & WADE, M. (Eds.): Plant invasions - general aspects and special problems: 15–38. SPB Academic Publishing (The Hague).

KOWARIK, I. (2008): On the role of alien species in urban flora and vegetation. – In: MARZLUFF, J., SHULENBERGER, E., ENDLICHER, W., ALBERTI, M., BRADLEY, G., RYAN, C., SIMON, U. & ZUMBRUNNEN, C. (Eds.) Urban ecology. An international perspective on the interaction between humans and nature: 321–338. Springer, New York.

KOWARIK, I., VON DER LIPPE, M. & CIERJACKS, A. (2013): Prevalence of alien versus native species of woody plants in Berlin differs between habitats and at different scales. – Preslia 85: 113–132.

KRAMER, H. (1995): Über den Götterbaum. – Natur Mus. 125: 101–121.

KŘIVÁNEK, M. & PYŠEK, P. (2008): Forestry and horticulture as pathways of plant invasions: a database of alien woody plants in the Czech Republic. – In TOKARSKA-GUZIK, B., BROCK, J.H., BRUNDU, G., CHILD, L., DAEHLER, C.C. & PYŠEK, P. (Eds.): Plant Invasions: Human perception, ecological impacts and management: 21–38. Backhuys Publishers, Leiden.

KUNICK, W. (1987): Woody vegetation in settlements. – Landsc. Plan. 14: 57–78.
LANDSBERG, E.H. (1981): The urban climate. – Academic Press, New York: 275 pp.
LOEB, R.E. (2012): Arboricultural introductions and long-term changes for invasive woody plants in remnant urban forests. – Forests 2012: 745–763.
MAURER, U. (2002): Pflanzenverwendung und Pflanzenbestand in den Wohnsiedlungen der 1920er und 1930er Jahre in Berlin. Ein Beitrag zur historischen Pflanzenverwendung. – Diss. Bot. 353: 1–221.
MEYER, F.H., HECKER, U., HÖSTER, H.R. & SCHROEDER, F.-G. (2002): Jost Fitschen, Gehölzflora. Ein Buch zum Bestimmen der in Mitteleuropa wildwachsenden und angepflanzten Bäume und Sträucher. Mit Knospen- und Früchteschlüssel. 11. Aufl. – Quelle & Meyer, Wiebelsheim: 902 pp.
NIEMELÄ, J. (Ed.) (2013): Urban ecology. Patterns, processes, and applications. (Reprint with corrections.) – Oxford, University Press: 374 pp.
OKE, T.R. (2011): Urban heat islands. – In DOUGLAS, I., GOODE, D., HOUCK, M. & WANG, R. (Eds.): The Routledge Handbook of urban ecology: 120–131. Routledge, London.
PILSL, P., SCHRÖCK, C., KAISER, R., GEWOLF, S., NOWOTNY, G. & STÖHR, O. (2008): Neophytenflora der Stadt Salzburg (Österreich). – Sauteria 17: 1–597.
PYŠEK, P., PERGL, J., ESSL, F. … VAN KLEUNEN, M. (2017): Naturalized alien flora of the world: species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. – Preslia 89: 203–274.
PYŠEK, P., RICHARDSON, D.M., REJMÁNEK, M., WEBSTER, G., WILLIAMSON, M. & KIRSCHNER, J. (2004): Alien plants in checklists and floras: Towards better communication between taxonomists and ecologists. – Taxon 53: 131–143.
PYŠEK, P., SÁDLO, J. & MANDÁK, B. (2002) Catalogue of alien plants of the Czech Republic. – Preslia 74: 97–184.
R CORE TEAM (2018): R: A language and environment for statistical computing. – R Foundation for Statistical Computing. – Vienna, Austria. URL: https://www.R-project.org/.
REBELE, F. (1994): Urban ecology and special features of urban ecosystems. – Glob. Ecol. Biogeogr. Lett. 4(6): 173–187.
REICHARD, J.J. (1772/1778): Flora Moeno-francofurtana enumerans stirpes circa Francofurtum ad Moenum crescentes secundum methodum sexualem (Flora of Frankfurt/Main containing plants growing near Frankfurt/Main following the sexual method) [in Latin]. – Henricus Ludovicus Broenner, Francofurtum ad Moenum: [10], 112 & [4] pp.; [8], 196 & [10] pp.
REICHARD, S.H. & WHITE, P. (2001): Horticulture as a pathway of invasive plant introductions in the United States. – BioScience 51: 103–113.
REJMÁNEK, M. (2014): Invasive trees and shrubs: where do they come from and what we should expect in the future? – Biol. Invasions 16: 483–498.
REJMÁNEK, M. & RICHARDSON, D.M. (2013): Trees and shrubs as invasive alien species – 2013 update of the global database. – Divers. Distrib. 10: 1093–1095.
RICHARDSON, D.M., HUI, C., NUNEZ, M.A. & PAUCHARD, A. (2014): Tree invasions: patterns, processes, challenges and opportunities. – Biol. Invasions 16: 473–481.
RICHARDSON, D.M., PYŠEK, P., REJMÁNEK, M., BARBOUR, M.G., PANETTA, F.D., WEST, C.J. (2000): Naturalization and invasion of alien plants: Concepts and definitions. – Divers. Distrib. 6: 93–107.
RICHARDSON, D.M. & REJMÁNEK, M. (2011): Trees and shrubs as invasive alien species – a global review. – Divers. Distrib. 17: 788–809.
RINGENBERG, J. (1995): Kultivierte und spontane Gehölze in der städtischen Wohnbebauung. – Schriftenr. Vegetationskd. 27: 193–199.
ROLOFF, A. & BÄRTELS, A. (2006): Flora der Gehölze. Bestimmung, Eigenschaften und Verwendung. Mit einem Winterschlüssel von B. Schulz. 2. Aufl. – Ulmer, Stuttgart: 844 pp.
SCHMID, M. (2005): Untersuchungen zur neophytischen Gehölzflora im Stuttgarter Stadtgebiet. – Jahresh. Ges. Naturkd. Württemberg 161: 187–258.
SCHOLZ, H. (2007): Questions about indigenous plants and anecophytes. – Taxon 56: 1255–1260.
SPENCER, R.D. & CROSS, R.G. (2007): The International Code of Botanical Nomenclature (ICBN), the International Code of Nomenclature for Cultivated Plants (ICNCP), and the cultigen. – Taxon 56: 938–940.
SPENCER, R.D. & CROSS, R.G. (2017): The origins of botanic gardens and their relation to plant science, with special reference to horticultural botany and cultivated plant taxonomy. – Muelleria 35: 43–93.

SUKOPP, H. & WITTIG, R. (1998): Stadtökologie. Ein Fachbuch für Studium und Praxis. 2. Aufl. – Gustav Fischer, Stuttgart: 474 pp.
TAHA, H. (1997): Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. – Energy Build. 25: 99–103.
WILLIAMS, N.S.G., HAHS, A.K. & VESK, P.A. (2015): Urbanisation, plant traits and the composition of urban floras. – Perspect. Pl. Ecol., Evol. Syst. 17: 78–86.
WITTIG, R. (1991): Ökologie der Großstadtflora. – Gustav Fischer, Stuttgart: 261 pp.
WITTIG, R. (2002a): Siedlungsvegetation. (Reihe Ökosysteme Mitteleuropas aus geobotanischer Sicht). – Ulmer, Stuttgart: 252 pp.
WITTIG, R. (2002b): *Buddleja davidii* Franch. (*Buddlejaceae*), das erfolgreichste Pioniergehölz großstädtischer Bahnhöfe im Rhein-Main-Gebiet. – Schriftenr. Umweltamt Wissenschaftsstadt Darmstadt 17(1): 28–31.
WITTIG, R. (2008): Die häufigsten spontanen Gehölzarten von Bahnhöfen des Ballungsraumes Rhein-Ruhr. – Decheniana 161: 7–10.

Supplement S1. Frequency of woody taxa per survey area.
Abundance classes: 1) very rare: less than 5 specimens – very low coverage, (2) rare: 5–10 specimens – very low coverage, (3) scattered: > 10 specimens – coverage 2–5%, (4) frequent: > 10 specimens – coverage 5–25%, (5) dominant: > 10 specimens – covering > 25%. Status: I = indigenous taxon, nat = naturalized non-native taxon, cas = casual non-native taxon.

Beilage S1. Häufigkeiten der Gehölz-Taxa pro Untersuchungsfläche.
Häufigkeitsklassen: 1) sehr selten: weniger als 5 Pflanzen – sehr geringe Deckung, (2) selten: 5–10 Pflanzen – sehr geringe Decking, (3) zerstreut: > 10 Pflanzen – Deckung 2–5%, (4) häufig: > 10 Pflanzen – Deckung 5–25%, (5) dominant: > 10 specimens – Deckung > 25%. Status: I = indigene Sippe, nat = eingebürgerte neophytische Sippe, cas = unbeständige neophytische Sippe.

	Status in Frankfurt	Origin	Frequency	US Army Depot Roedelheim	Former airfield Bonames	Forest area "Riederwald"	Bank of river Main near Osthafen	Railway station Mainkur	Bank of river Main near Schwanheim	Urban fallow Lise-Meitner-Straße	Forest area "Rebstockwäldchen"	Agricultural fallow land Oberrad	Urban fallow Niederrad	Forest area "Goldstein"	Railway station Frankfurt East	Northern embankment of former freight station	Forest area "Niedwald"	Bank of river Main near Western harbour	Schwanheim, deposit area	Former orchard west of Campus Riedberg	Sinai park	Southern embankment of former freight station	Urban fallow Grünostraße/Ostbahnhofs	Schwanheim, sand dunes	City forest "Rodsee"	Embankment of highway 5 near Griesheim
Latitude				50.1264	50.177	50.126	50.109	50.135	50.094	50.116	50.115	50.104	50.084	50.0748	50.115	50.107	50.11	50.099	50.088	50.1703	50.145	50.106	50.113	50.0879	50.0736	50.0973
Longitude				8.5942	8.6546	8.7332	8.7223	8.7703	8.5685	8.6397	8.6234	8.7404	8.6322	8.6095	8.7110	8.6160	8.5901	8.661	8.5596	8.6274	8.6753	8.6146	8.7048	8.5596	8.5500	8.6147
sum of taxa			**57**	**56**	**51**	**42**	**40**	**38**	**37**	**37**	**37**	**36**	**35**	**35**	**34**	**34**	**29**	**28**	**26**	**24**	**24**	**22**	**18**	**15**	**15**	**14**
Acer campestre L.	I	.	17	3	1	3	1	3	1	2	1	2	2	1	2	1	4	1		1				1		
Acer ginnala Maxim.	cas	E As	1										1													
Acer negundo L.	nat	N Am	11	2	1	1	2		4		2				3	1		3			3		1			
Acer platanoides L.	nat	D	20	1	1	5	1	4	3	3	2	1	2		1	2	5		2	1	1	2	1		1	2
Acer pseudoplatanus L.	nat	D	22	1	1	3	1	2	3	2	4	2	2	2	2	3	5	2	2	4	3	3		1	5	1
Acer saccharinum L.	nat	N Am	2						2		1															
Aesculus hippocastanum L.	nat	Eu	6	1			1							1			1		1							1
Ailanthus altissima (Mill.) Swingle	nat	E As	13	3		2	3	2	1	2			3		4	3		3				2	2			2
Alnus glutinosa (L.) Gaertn.	I	.	5		2		3										1	4							3	
Alnus glutinosa (L.) Gaertn. × incana (L.) Moench	I	.	1		1																					
Alnus incana (L.) Moench	cas	D	1		1																					
Amelanchier lamarckii F.G.Schroed.	nat	N Am	4	1						1			1	3												
Betula pendula Roth	I	.	20	4	4	1	1	4		3	2	1	3	2	2	2	1	2	4		2	3	2	2		1
Buddleja davidii Franch.	nat	E As	11	2	1			4		4	2		4		5	3		2				2	5			
Carpinus betulus L.	I	.	11	1		3		2	1		2		1	2			5				3			1	2	
Castanea sativa Mill.	cas	Eu	1																					1		
Catalpa bignonioides Walt.	nat	N Am	2	1	1																					
Catalpa ovata G.Don	nat	E As	1					2																		
Celastrus orbiculatus Thunb.	nat	E As	1	2																						
Clematis vitalba L.	I	.	12	3			3		2	2		1			1	3	1	2		1	4	2				
Colutea arborescens L.	nat	Eu	2			1								1												
Cornus sanguinea L. subsp. australis (C.A.Meyer) Soó	nat	Eu	16	4	5	3	2	3	2	2	1		1		1	2	1			3	4	3				2
Cornus sanguinea L. subsp. hungarica (Kárpáti) Soó	nat	D	16		1		3	2	2	2	2	2	1		3	3		1	1	1	2	2	1			
Cornus sanguinea L. subsp. sanguinea	I	.	15	1	2	1	2	2		2	3	5	1		2		2	3	2	1		1				
Cornus sericea L.	nat	N Am	2	1									1													
Corylus avellana L.	I	.	9	1		2		2	2			1		1			2				2				3	
Cotoneaster ×wateri Exell	cas	E As	1							1																
Cotoneaster cf. ambiguus Rehder & E.H.Wilson	cas	E As	1			1																				
Cotoneaster dammeri Schneider	cas	E As	1													1										
Cotoneaster dielsianus É. Pritz.	nat	E As	3	2									1	1												
Cotoneaster divaricatus Rehder & E.H.Wilson	nat	E As	4											1	2	1						2				
Cotoneaster salicifolius Franch.	cas	E As	3				1			3			1													
Crataegus calycina Peterm.	I	.	1			1																				
Crataegus laevigata (Poir.) DC.	I	.	3								1						4								2	
Crataegus macrocarpa Hegetschw. / C. calycina Peterm.	I	.	3			1												2						1		
Crataegus media Bechst.	I	.	1							1																
Crataegus monogyna Jacq.	I	.	13	4	2	3	4	2	3		2	4		1		3			3		3		3			
Crataegus subsphaerica Gandoger	I	.	4		3	1	1													1						
Cytisus scoparius (L.) Link	I	.	3	1				1								2										
Euonymus alatus (Thunb.) Siebold	cas	E As	1			1																				
Euonymus europaea L.	I	.	10		1	2		2	2		1	1		1			1		1		1					
Fagus sylvatica L.	I	.	4			2								2			2								1	
Fallopia baldschuanica (Regel) Holub	cas	E As	1									1														
Ficus carica L.	cas	Eu	1	1																						
Forsythia intermedia Zabel	cas	GK	1	1																						
Frangula alnus Mill.	I	.	2											2											2	
Fraxinus excelsior L.	I	.	17	2		2	3	3	5	2	4	1	1		2	3	3	2	2	2					4	1
Hedera helix L.	I	.	10			4	1	1		1			1		1		4			1	2				2	
Hypericum calycinum L.	cas	Eu	1															4								
Ilex aquifolium L.	nat	D	2			3								2												
Juglans regia L.	nat	Eu	13	2	2	3	2		3				2		2	1	2		2	3	3					2
Juniperus sabina L.	cas	D	1													1										
Laburnum anagyroides Medik.	nat	Eu	1										1													
Ligustrum ovalifolium Hassk.	cas	E As	1														2									
Ligustrum vulgare L.	I	.	13	2	2	2	3	2	2	3	1	2	2		2					1	1					
Lonicera periclymenum L.	I	.	1											1												
Lonicera pileata Oliv.	nat	E As	4												2			2	1				1			
Lonicera xylosteum L.	I	.	6			1		1		2		1			2							1				
Mahonia aquifolium (Pursh) Nutt.	nat	N Am	10	2		1	1		1	2				2	1	1						1	2			
Malus domestica Borckh.	nat	GK	9	1	1		3			2		3			1	1				1						2
Malus prunifolia (Willd.) Borkh.	cas	E As	1													1										
Morus alba L.	cas	E As	2	1				1																		
Parthenocissus inserta (Kern.) Fritsch	nat	N Am	14	1	1	3	1	2	1			2	4		1	3		1	4			3				2
Parthenocissus tricuspidata (Siebold & Zucc.) Planch.	cas	E As	1																					1		
Paulownia tomentosa (Thunb.) Steud.	nat	E As	2	1	1																					
Philadelphus coronarius L.	nat	Eu	2							1									1							
Picea abies (L.) H.Karst.	cas	D	1											1												
Pinus strobus L.	nat	N Am	2					1						2												
Pinus sylvestris L.	nat	D	9	1		2		1		1			1	2					2					4		1
Platanus hispanica Muenchh.	nat	GK	6	1			1		1						1		1						2			
Populus ×canescens (Aiton) Sm.	I	.	6		2	1					1		1		3								4			
Populus alba L.	nat	D	7	1	2						1	2					3				1		1			
Populus balsamifera L.	nat	N Am	2								2								1							
Populus canadensis Moench	nat	GK	10	1	2			3	3	4	3	1	4			1		3								
Populus nigra L.	I	.	1						1																	
Populus tremula L.	I	.	5		3			2			2			2								1				
Populus trichocarpa Hook.	nat	N Am	7	2	3			4	1			1			3					1						
Prunus avium (L.) L.	I	.	16	3	1	3	3	1	3	2	3		1	2		1	3	1	3	3			2			
Prunus cerasifera Ehrh.	nat	Eu	8		2		4		1	2	2				2					5			2			
Prunus domestica L. subsp. domestica	nat	GK	2									2								2						
Prunus domestica L. subsp. insititia (L.) Bonnier & Layens	nat	GK	1		1																					
Prunus fruticans Weihe	nat	GK	5		1		2													2	2	2				
Prunus laurocerasus L.	nat	Eu	4		1	1								1							1					
Prunus mahaleb L.	nat	D	7	3			1			2		2			1	2					2					
Prunus padus L. subsp. padus	I	.	7		1	2					1		1				1				3			3		
Prunus persica (L.) Batsch	cas	E As	4	1		1				1					1											
Prunus serotina Ehrh.	nat	N Am	11		1	2	1	1					1	4		1	1				1			2	2	
Prunus spinosa L.	I	.	7		2	2		1	1		2						2					2				
Prunus virginiana L.	cas	N Am	1		1																					
Pseudotsuga menziesii (Mirb.) Franco	cas	N Am	3	1							1			2												
Pyracantha coccinea M.J.Roem.	cas	Eu	5					1		2		1	1											1		
Pyrus communis L.	nat	GK	2				1		1																	
Quercus petraea (Mattuschka) Liebl.	I	.	1					1																		
Quercus robur L.	I	.	17	1	1	4	2	2	2		3	3		2	1	2	5		3	3	2			3	3	
Quercus rubra L.	nat	N Am	4			1						1		5		2										
Rhamnus cathartica L.	I	.	1	2																						
Rhus typhina L.	nat	N Am	1	3																						
Ribes rubrum L.	nat	GK	1			2																				
Ribes uva-crispa L.	nat	GK	2			2								1												
Robinia pseudoacacia L.	nat	N Am	15	2		2	3			5		3	3	3	3	2		1	4			2	5	3		1
Rosa canina L. (incl. R. canina agg.)	I	.	17	3	2	2		2	2	3	1	3	3		1	2	1	2		3	2	1		1		
Rosa corymbifera Borkh.	I	.	3	1								1														
Rosa elliptica Tausch	I	.	1					1																		
Rosa glauca Pourr.	cas	D	3	1	1					1																
Rosa gremlii (H.Christ) Gremli	I	.	2		1				1																	
Rosa inodora Fr.	I	.	1		1																					
Rosa micrantha Sm.	I	.	1																1							
Rosa multiflora Thunb.	cas	E As	1	1																						
Rosa rubiginosa L.	I	.	1					2																		
Rosa spinosissima L.	cas	D	1																							2
Rosa subcanina (Christ) Vuk.	I	.	10	1	1		3			1	3	1				4			1	3		3				
Rosa subcollina (Christ) Vuk.	I	.	2				1								1											
Rosa tomentosa Sm.	I	.	1							1																
Salix alba L.	I	.	12	1	4		4	1	1	1	2	2	1					3	3				1			
Salix caprea L.	I	.	16	3	3			4		2	2	4	2	1	1	2		1	1	1	2	2	1			
Salix caprea L. × cinerea L.	I	.	1		2																					
Salix caprea L. × viminalis L.	I	.	2		2							3														
Salix cf. alba L. × purpurea L.	I	.	1		2																					
Salix cinerea L.	I	.	5		3		2				1							3	1							
Salix matsudana Koltz. "tortuosa"	cas	E As	2		1							2														
Salix multinervis Döll	I	.	2		4														1							
Salix purpurea L.	I	.	2		1		1																			
Salix rubens Schrank	I	.	4		1				4								1	2								
Salix sepulcralis Simonk.	cas	E As	1						1																	
Salix triandra L.	I	.	1						1																	
Salix triandra L. × viminalis L.	I	.	1						1																	
Salix viminalis L.	I	.	4		2		1	1	2																	
Sambucus nigra L.	I	.	19	3	1	3	3	3	2		3		1	1	2	3	3	1	2	3	4	3	1			1
Sambucus racemosa L.	I	.	1											1												
Sorbaria sorbifolia (L.) A.Braun	cas	E As	1															1								
Sorbus aucuparia L. subsp. aucuparia	I	.	8	1	1	2				1				3							3			1	2	
Sorbus intermedia (Ehrh.) Pers.	cas	D	2					1								2										
Spiraea billardii Hérincq	cas	GK	1									1														
Symphoricarpos ×chenaultii Rehder	cas	GK	3	1		1						1														
Symphoricarpos albus (L.) S.F.Blake	nat	N Am	3		1								1						1							
Syringa vulgaris L.	nat	Eu	1	2																						
Taxus baccata L.	nat	D	5	1		2					1			2			1									
Tilia cordata Mill.	I	.	5			1	2		1		1						2									
Tilia europaea L.	cas	GK	6			1		1	1			1		2											3	
Tilia platyphyllos Scop.	I	.	1				1																			
Tilia tomentosa Moench	cas	Eu	2			1									1											
Tsuga heterophylla (Raf.) Sarg.	cas	N Am	1											1												
Ulmus glabra Huds.	I	.	4			2	1				3							3								
Ulmus laevis Pall.	I	.	2								3						2									
Ulmus minor Mill.	I	.	4	2		2						3						3								
Viburnum rhytidophyllum Hemsl.	cas	E As	2			1				1																
Vinca major L.	cas	Eu	1																				1			
Viscum laxum Boiss. & Reut.	I	.	1																					3		
Vitis ×novae-angliae Fernald	cas	N Am	1	1																						
sum indigenous taxa	63		21	32	25	24	23	21	16	24	18	14	16	14	12	22	15	14	14	13	11	6	8	11	3
sum naturalized non-native taxa	49		27	20	19	17	13	15	15	12	12	18	15	18	17	7	11	12	10	11	11	10	5	3	10
sum casual non-native taxa	37		9	4	7	1	4	2	6	1	6	3	4	2	5	0	2	0	0	0	0	2	2	1	1
sum non-native taxa	86		36	24	26	18	17	17	21	13	18	21	19	20	22	7	13	12	10	11	11	12	7	4	11
sum all taxa	149		57	56	51	42	40	38	37	37	36	35	35	34	34	29	28	26	24	24	22	18	15	15	14
indigenous taxa / all taxa			0.37	0.57	0.49	0.57	0.58	0.55	0.43	0.65	0.50	0.40	0.46	0.41	0.35	0.76	0.54	0.54	0.58	0.54	0.50	0.33	0.53	0.73	0.21
naturalized non-native taxa / all taxa			0.47	0.36	0.37	0.40	0.33	0.39	0.41	0.32	0.33	0.51	0.43	0.53	0.50	0.24	0.39	0.46	0.42	0.46	0.50	0.56	0.33	0.20	0.71
casual non-native taxa / all taxa			0.16	0.07	0.14	0.02	0.10	0.05	0.16	0.03	0.17	0.09	0.11	0.06	0.15	0.00	0.07	0.00	0.00	0.00	0.00	0.11	0.13	0.07	0.07
non-native taxa / all taxa			0.63	0.43	0.51	0.43	0.43	0.45	0.57	0.35	0.50	0.60	0.54	0.59	0.65	0.24	0.46	0.46	0.42	0.46	0.50	0.67	0.47	0.27	0.79