Identification of pathways of introduction in Latvia for 66 invasive alien species of European Union concern

Linda Gerra-Inohosa, Digna Pilāte, Zane Lībiete and Iluta Dauškane, Ēriks Aleksejevs, Dmitrijs Boiko, Andris Čeirāns, Māris Plikšs

Latvian State Forest Research Institute “Silava”

2021

Summary

The list of invasive alien species of the European Union concern includes 66 species, from which 30 are animal species and 36 - plant species. The aim of this study was to develop the methodology for identifying pathways of introduction for invasive alien species of the EU concern in Latvia and to asses and prioritize these pathways. The results showed that according to environmental impact aasesment of invasive alien species two high risk plant species (*Heracleum sosnowskyi* and *Impatiens glandulifera)* and nine low or moderate risk animal species (*Alopochen aegyptiacus, Eriocheir sinensis, Myocastor coypus, Nyctereutes procyonoides, Ondatra zibethicus, Orconectes limosus, Pacifastacus leniusculus, Perccottus glenii* and *Trachemys scripta*) occur in Latvia. The animal species were introduced unintentionally while both invasive alien plant species in Latvia have been introduced intentionally. The remaining 55 species have not been recorded in the wild in Latvia. Four of these plant species (*Elodea nuttallii, Heracleum mantegazzianum, Asclepia syriaca, Heracleum persicum*) and six of the animal species (*Arthurdendyus triangulates, Eriocheir sinensis, Orconectes limosus, Pacifastacus leniusculus, Perccottus glenii, Procyon lotor*) have high establishment potential in Latvia. The results showed that the main pathways of introduction for plant species are *Horticulture, Secondary introduction* and *Aquarium* for aquatic plant species, but for the animal species the most significant pathways of introduction are *Secondary introduction* and *Escape*. Both the plant and animal species from the EU list are using all modes of entry for introduction and spread. The number of possible pathways of introduction and modes of entry varies among the studied species.

This study is developed within the Interreg Europe 2014-2020 programme project "Protecting European Biodiversity from Invasive Alien Species" (INVALIS, PGI05271).

Contents

Introduction

Today, with the rapid global increase in trade, travel, transport and tourism, preventive measures are the most effective defense against invasive alien species. The most common approach is to target individual species. For this purpose, the assessment of species' pathways has been identified as a very important element to prevent the species from entering the country. This method identifies the route and mechanisms of the introduction and spread of invasive alien species (Wittenberg et al., 2005). Richardson et al. (2011) defined pathways as "a suite of process that result in the introduction of an alien species from one geographical location to another" and vectors as "dispersal mechanisms and means of introduction". The vectors could be also described as subcategories of pathways of introduction, which describe the pathways in more details. At the same time the mode of entry is used to provide a broad and general pathways description (Hulme et al., 2008; Madsen et al. 2014).

The documentation of information on current and potential pathways is seen as critical for managing the threat posed by alien species. Also precise, reliable and detailed information on pathways is important for the development of alien species risk assessments, management, monitoring, and surveillance (Harrower et al., 2018).

Latvia as a European Union (EU) member state is required to act in accordance with Regulation (EU) 1143/2014 on invasive alien species (the IAS regulation) and to perform all necessary measures to prevent intentional and unintentional introduction and distribution of the invasive alien species. Today, there are approximately 797 alien species recorded in the territory of Latvia (Priede, 2014). Only a small part of these species is defined as invasive. Moreover, from the list of invasive species of the EU List, which includes 66 invasive alien species, only 11 species have been found in the wild in Latvia, namely two plant species – *Heracleum sosnowskyi* and *Impatiens glandulifera*, - and nine animal species - *Alopochen aegyptiacus, Eriocheir sinensis, Myocastor coypus, Nyctereutes procyonoides, Ondatra zibethicus, Orconectes limosus, Pacifastacus leniusculus, Perccottus glenii, Trachemys scripta*.

The introduction of the raccoon dog (*Nyctereutes procyonoides*) in Latvia started in 1948, the muskrat (*Ondatra zibethicus*) spread from the neighboring countries in the middle of 20th century (Tauriņš, 1982). During 60-80 years these species have spread in all territory of Latvia and occupied their ecological niche (Zorenko, 2008; State Forest Service, 2020). Nutrias (*Myocastor coypus*) were often kept in rural farms in the second half of the 20th century. During this time they were often spotted in the wild after escaping. Due to climatic conditions these animals have not established in the wild (Zorenko, 2008), but if the winters will grow warmer it will be possible. Keeping of nutrias in rural farms becomes popular again, and there is a trade of these animals (Klovāne, 2018). In the beginning of 20th century, the introduction of *Eriocheir sinensis* started (Nature Conservation Agency, 2021). Crayfish (*Orconectes limosus, Pacifastacus leniusculus*) and *Perccottus glenii* are more recent incomers. *Pacifastacus leniusculus* was released in the wild intentionally in 1983, but in the end of 1990s *Orconectes limosus* it has been found in Latvia. The entry of the spiny cheek crayfish into Latvia is unclear. It can also be found in Lithuania, from where it may possibly have migrated to Latvian territory (Aleksejevs and Birzaks, 2020).Further spread of these species is facilitated by unsanctioned transporting and release in waterbodies. *Perccottus glenii* was identified in the wild in 1974 (Pupiņa et al., 2015). Two new invasive species have been identified during the last ten years – since 2006 observations of *Trachemys scripta* are being reported (Čeirāns et al., 2019) and in 2015 some specimens of *Alopochen aegyptiacus* were observed for the first time (www.putni.lv). Part of the animal species that do not occur in the wild in Latvia are being kept in zoos, private collections, used in aquacultures, some of these are being kept in aquariums or as pets.

The plant species *Heracleum sosnowskyi* is native to the north of Caucasus and was introduced in Latvia in 1948. It was cultivated as a perspective forage plant species. Later it was also grown for ornamental purposes and beekeeping. Since then, it has spread in almost all territory of Latvia and nowadays is one of the most dangerous invasive alien species in the country. The second plant species *Impatiens glandulifera* originates from the western part of the Himalayas. First record of this species in Latvia is dated with 1898, but a massive naturalization of this species started in the middle of 20th century. It was introduced as decorative plant species in the Baltic countries. Today it is included in the

"Black list" of invasive species (Gudžinskas et al., 2014). Part of the species (eight plant species) of the EU List is offered for sale in different nurseries (Latvijas stādi, 2021; Ozoli, 2021; Stādīsim.lv, 2021) and some aquatic plant species are also provided through aquarium clubs. According to literature the EU concern species *Heracleum mantegazzianum* has been mentioned in flora of Latvia (Gavrilova and Šulcs, 1999) but has not been recently found in the wild. Situation is similar with the species *Ailanthus altissima* that has been included in the atlas of Latvian woody plants, but at the same time has only four records (Laiviņš et al., 2009).

In Latvia, transport is the most often occurring pathway for alien species' introduction. For many alien species the pathways of introduction are unknown, however, transport, agriculture, horticulture and landscaping are considered to be the main pathways of introduction of invasive alien plant species in Latvia (NOBANIS, 2015; NOBANIS, 2021).

The purpose of this study was to conduct a pathway analysis. It includes the development of methodology for identifying pathways of introduction for invasive alien species of the EU List in Latvia. This study also presents example of the first steps in prioritizing the pathways of invasive alien species of EU concern in Latvia. Additionally, the prioritization of vectors is also performed.

Material and methods

Environmental impact assesment and analysis of the pathways of introduction has been carried out for 66 alien species (Table 1), which are invasive and included in the Commission Implementing Regulations (EU) 2016/1141**,** (EU) 2017/1263 un (EU) 2019/1262 of the Regulation (EU) No 1143/2014 on invasive alien species of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species.

The species are divided into two groups:

- Species occurring in the wild in Latvia and/or form populations in the wild;
- Species not occurring in the wild in Latvia and/or occur only as records of individual escaped specimens. There are reports of capture of some individuals (Balvos iemaldās Ķīnas ūdensbriedis mundžaks, 2010).

According to this division, collecting and analysis of data was carried out. The analysis of pathways, vectors and modes of entry of species occurring in Latvia was performed, based on information sources and studies available for the territory of Latvia. Analysis of the rest of the species was carried out based on the information about these species in other countries and was not referred to situation of Latvia. For information and environmental impact assessment we used mainly NOBANIS and CABI data bases of invasive species (https://www.nobanis.org, https://www.cabi.org), as well as the results of analysis of IAS of EU concern in the context of Denmark (Grousset et al., 2018) and Belgium (Pathways of unintentional introduction and spread of IAS of Union concern in Belgium, 2018). For additional information we used studies and risk assessments of the species for which they are available. For some mammal species we used information from Baiwy et al., 2015, Canova and Rossi, 2008, Delibes et al., 2004 for birds - from Keller et al., 2020, for reptiles and amphibians - from Banha et al., 2017**,** Ficetola et al., 2007a,b, for fish - from Arbačiauskas et al., 2012, Galanidi et al., 2019, Gozlan et al., 2010, Grabowska et al., 2010, Timm et al., 2009, Zięba et al., 2020, for arthropods - from Arbačiauskas et al., 2012, Husemann et al., 2020, Kouba et al., 2014, Ojaveer et al., 2007. For the plant species information for characteristics of individual species was obtained for numerous

publicitations, including the exiting and possible species distribution (Grīnberga and Priede, 2010; Balalaikins and Kantāne, 2020; Romanceviča, 2019; Priede, 2008; Donald and Mehrhoff, 1999; OEPP, EPPO, 2017, 2019; EPPO, 2021; Fried et al., 2016; Coetzee et al., 2017; Balogh and Dancza, 2017; Wheeler and Ding, 2014; Lozano et al., 2020; Kowarik and Säumel, 2007). Also additional information from the following webpages were used: Invasive species in Belgium, 2021, Invasive species Ireland, 2021, Global Biodiversity Information Facility, 2021 (https://www.gbif.org/), State Plant Protection Service of the Republic of Latvia, 2021, Nature Conservation Agency, 2021, Ministry of Environmental Protection and Regional Development of the Republic of Latvia, 2021.

Table 1
The studied species of EU List

	Group/ Acronym	**Species**	**Latvian name**	**Introduction year in Latvia (with reference)**
Mammals				
1.	Nyct proc	*Nyctereutes procyonoides*	Usūrijas Jenotsuns	1948 (Tauriņš, 1982)
2.	Onda zibe	*Ondatra zibethicus*	Ziemeļamerikas ondatra	1961 (Tauriņš, 1982)
3.	Myoc coyp	*Myocastor coypus*	Dienvidamerikas bebružurka jeb nutrija	1970s (Zorenko, 2008)
4.	Proc loto	*Procyon lotor*	Parastais jenots	
5.	Call eryt	*Callosciurus erythraeus*	Sarkanvēdera krāšņvāvere	
6.	Sciu caro	*Sciurus carolinensis*	Pelēkā vāvere	
7.	Sciu nige	*Sciurus niger*	Melnā vāvere	
8.	Tami sibi	*Tamias sibiricus*	Sibīrijas burunduks	
9.	Herp java	*Herpestes javanicus*	Mazais Indijas mangusts	
10.	Nasu nasu	*Nasua nasu eta*	Dienvidamerikas degunlācītis	
11.	Munt reev	*Muntiacus reevesi*	Ķīnas mundžaks	
Birds				
12.	Acri tris	*Acridotheres tristis*	Parastā maina	

	Group/ Acronym	Species	Latvian name	Introduction year in Latvia (with reference)
13.	Alop aegy	*Alopochen aegyptiacus*	Nīlas jeb Ēģiptes zoss	2015 (www.putni.lv)
14.	Corv sple	*Corvus splendens Viellot*	Indijas vārna	
15.	Oxyu jama	*Oxyura jamaicensis*	Jamaikas zilknābis	
16.	Thre aeth	*Threskiornis aethiopicus*	Svētais ibiss	
Reptiles				
17.	Trac scri	*Trachemys scripta*	Sarkanausu bruņurupucis	2006 (Čeirāns et al., 2019)
Amphibians				
18.	Lith cate	*Lithobates (Rana) catesbeianus*	Amerikas vēršvarde	
Fish				
19.	Lepo gibb	*Lepomis gibbosus*		
20.	Perc glen	*Perccottus glenii*	Rotans	1974 (Pupiņa et al., 2015)
21.	Plot line	*Plotosus lineatus*	Svītrainais zušu sams	
22.	Pseu parv	*Pseudorasbora parva*	Amūras čebačeks	
Arthropods				
23.	Erio sine	*Eriocheir sinensis*	Ķīnas cimdiņkrabis	1930s
24.	Orco limo	*Orconectes limosus*	Dzeloņvaigu vēzis	2005 (Aleksejevs and Birzaks, 2020)
25.	Orco viri	*Orconectes virilis*		
26.	Paci leni	*Pacifastacus leniusculus*	Amerikas signālvēzis	1983 (Aleksejevs and Birzaks, 2020)
27.	Proc clar	*Procambarus clarkii*	Sarkanais purva vēzis	
28.	Proc fall	*Procambarus fallax*	Marmorvēzis	
29.	Vesp velu	*Vespa velutina nigrithorax*	Āzijas sirsenis	
Worms				
30.	Arth tria	*Arthurdendyus triangulatus*	Jaunzēlandes plakantārps	
Angiosperms				
31.	Elod nutt	*Elodea nuttallii*		
32.	Alte phil	*Alternanthera philoxeroides*		
33.	Cabo caro	*Cabomba caroliniana*		
34.	Hydr ranu	*Hydrocotyle ranunculoides*		

	Group/ Acronym	Species	Latvian name	Introduction year in Latvia (with reference)
35.	Gymn spil	*Gymnocoronis spilanthoides*		
36.	Laga majo	*Lagarosiphon major*	Āfrikas elodeja	
37.	Ludw pepl	*Ludwigia peploides*		
38.	Lysi amer	*Lysichiton americanus*	Amerikas lizihitons	
39.	Myri aqua	*Myriophyllum aquaticum*		
40.	Eich cras	*Eichhornia crassipes*	Resnkātu ūdenshiacinte	
41.	Ludw gran	*Ludwigia grandiflora*		
42.	Myri hete	*Myriophyllum heterophyllum*		
43.	Salv mole	*Salvinia molesta*		
44.	Hera sosn	*Heracleum sosnowskyi*	Sosnovska latvānis	1948 (Gudžinskas et al., 2014)
45.	Impa glan	*Impatiens glandulifera*	Puķu sprigane	1898; in the middle of 20th century (Gudžinskas et al., 2014)
46.	Acac sali	*Acacia saligna*		
47.	Aila alti	*Ailanthus altissima*	Augstais ailants	
48.	Bacc hali	*Baccharis halimifolia*		
49.	Card gran	*Cardiospermum grandiflorum*		
50.	Cort juba	*Cortaderia jubata*		
51.	Gunn tinc	*Gunnera tinctoria*	Krāsu gunnera	
52.	Hera mant	*Heracleum mantegazzianum*	Mantegaca latvānis	
53.	Lesp cune	*Lespedeza cuneata*		
54.	Lygo japo	*Lygodium japonicum*		
55.	Andr virg	*Andropogon virginicus*		
56.	Ascl syri	*Asclepias syriaca*	Sīrijas asklēpija	
57.	Ehrh caly	*Ehrharta calycina*		
58.	Hera pers	*Heracleum persicum*	Persijas latvānis	
59.	Humu scan	*Humulus scandens*		
60	Micr vimi	*Microstegium vimineum*		
61.	Part hyst	*Parthenium hysterophorus*		

	Group/ Acronym	Species	Latvian name	Introduction year in Latvia (with reference)
62.	Penn seta	*Pennisetum setaceum*	Purpurvioletā sarzāle	
63.	Pers perf	*Persicaria perfoliata*		
64.	Pros juli	*Prosopis juliflora*		
65.	Puer mont	*Pueraria montana*		
66.	Tria sebi	*Triadica sebifera*		

The environmental impact assessment of the invasive alien species

The development of criteria and evaluation method for invasive species' environmental assessment was performed following Madsen et al. (2014), with some modifications. The scores' descriptions and explanations are according to Vanderhoeven et al. (2015). Supplemental information was added to some scores to adapt the system to the situation in Latvia. In total, four different variables of impact are used for invasive species' environmental assessment: dispersal potential and invasiveness, colonization of high conservation value habitats, adverse impacts on native species, and alteration of ecosystem functions (Table 2). Each variable is divided in semi-quantitate scores from 0 to 3 according to the magnitude of impact. Thus, the maximum score for one invasive species may reach 12. In result, according to the obtained score value, the analysed species may be divided into four risk groups: unknown risk species (total score 0); low risk species (total score 1-6); medium risk species (total score 7-9) and high risk species (total score 10-12).

Table 2

Methodology of environmental impact assessment

I Dispersion potential or invasiveness	
0	Deficient data, no score.
1	Invasions have not been documented (there is only opinion of expert or observation in nature) or it is very low: the species does not spread in the environment because of poor dispersal capacities and low reproduction potential; the species is common in all territory of Latvia, the species has found its ecological niche and does not show its invasiveness.

2	Moderate dispersion potential has been documented; dispersion potential is low, except when assisted by humans. The fecundity is medium or high. The species does not colonise remote places, except with human assistance. Natural dispersal rarely exceeds more than 1 km per year. The species can become locally invasive because of strong reproduction potential.
3	High dispersion and fecundity potential has been documented (high invasiveness); the species is highly fecund, can easily disperse through active or passive means over distances > 1 km per year and initiate new populations. Here the plant species that take advantage of anemochory, hydrochory and zoochory are to be considered.
II Colonisation of high conservation value habitats of EU	
0	Deficient data, no score
1	The parameter has not been documented (there is only opinion of expert or observation in nature); the species does not spread in the environment or its reproduction potential is very low: colonisation is happening/the species colonise only man-made habitats.
2	Moderate colonisation has been documented; the colonisation is happening in habitats with low or medium conservation value and may occasionally colonise high conservation value habitats.
3	High colonisation has been documented; the species often colonises high conservation value habitats (most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and therefore poses a potential threat for red-listed species.
III Adverse impacts on native species	
0	Deficient data, no score
1	The parameter has not been documented (there is only opinion of expert or observation in nature), the impact is low; the impact to native species is negligible; data from invasion histories suggest that the negative impact on native populations is negligible.
2	Moderate impact has been documented; the species is known to cause local changes, but effect is usually considered as reversible. It has been demonstrated that non-native species are known to cause local changes (<80%) in population abundance, growth or distribution of one or several native species, especially among common and ruderal species.
3	High impact has been documented; the species cause important local changes that mostly are irreversible; the development of the non-native species often cause local severe (>80%) population declines and the reduction of species diversity. At the regional scale the development of high risk species can be considered as a factor precipitating species' decline, including rare species' decline. Those alien species form long-standing populations and their impacts on native biodiversity are considered as hardly reversible.

IV Alteration of ecosystem functions	
0	Deficient data, no score
1	The changes have not been documented (there is only opinion of expert or observation in nature) or the changes are small. The impact on ecosystem processes and structures is considered as negligible.
2	Moderate changes have been documented; the impact on ecosystem processes and structures is moderate and considered as easily reversible.
3	Large changes have been documented. The impact on ecosystem processes and structures is strong and difficult to reverse.

Assessment of species' establishment or potential for establishment in Latvia

The assessment of establishment was carried out for all IAS according to Pathways of unintentional introduction and spread of IAS of Union concern in Belgium (2018) with climate-related modifications and adaptations to Latvian conditions. We used 5-score assessment, based on information sources about the natural range of the species, size of their populations, abundance and survival in Latvia and similar climatic conditions in other European countries (Table 3). The highest value (5) was assigned to species introduced and occurring in the wild in Latvia for more than 50 years and forming stable and vital populations in the wild.

The climatic division encompasses equatorial, subequatorial, tropical, subtropical, temperate, subarctic and subantarctic, arctic and antarctic climate zones. The establishment assessment considered the location of the species' natural range in the climatic zones. High establishment value (4) was assigned to the species with their natural range in the same climatic zone as Latvia, regardless of the exact location.

Table 3
The criteria for the likelyhood of species' establishment in Latvia

Score value	Explanation
1	Very low likelyhood – tropical species; subequatorial species; subtropical species with no definite information about wild populations in Europe; able to form stable populations only in the Southern Europe.
2	Low likelyhood – individual specimens of the species have been observed in other Southern and Central European countries or species that form few

Score value	Explanation
	and isolated populations in other European countries; their natural range is located only in tropical or subtropical climatic zone.
3	Medium likelyhood – species that have been recorded in the wild in Latvia but have not established due to climatic conditions, however, they can establish themselves in the result of the climate change; species with a broad natural range encompassing subtropical and temperate climatic zones; species that have established themselves in other European countries but do not occur in the neighbouring countries of Latvia.
4	High likelyhood – species that occur in the wild in other European countries for more than 50 years; the closest wild populations are located in the neighbouring countries and other close locations and may spread to Latvia in the result of the climate change; species with their natural range in the temperate climatic zone; species occurring in the wild in Latvia but not propogating; species that occur seldom in Latvia and maybe propogate but are with uneven distribution.
5	Very high likelyhood – species that occur in the wild in Latvia for more than 50 years; species that occur in the whole territory in Latvia and have formed stable long-term wild populations.

Assessment of modes of entry, pathways of introduction and vectors of invasive alien species

The modes of entry, pathways of introduction and vectors are defined according to Madsen et al. (2014) (Table 4), having as a basis division and pathway definition developed by NOBANIS. Individual pathways and vectors have been supplemented. Pathways of introduction and vectors are, to the extent possible, determined for all IAS of the EU list, regardless of the fact that the primary introduction may have been intentional, considering the fact that further dispersion of the species is unintentional process. Example: many angiosperms have been introduced intentionally as ornamental garden plants, from where they could escape in the wild. Under the pathways of introduction we understand also the spread of already established species.

Two types of introduction have been defined:

- Intentionally – indicates intentional introduction (conscious introduction with human assistance);
- Unintentionally – indicates unintentional (unconscious) introduction.

Table 4

The pathways of introduction, associated modes of entry and vectors of the IAS

Pathway of introduction (short description)	**Associated modes of entry**	**Vectors**
Agriculture Plants for production of food for human and animal consumption, including crops.	Escape, Contaminant	Cuttings, Fruits and vegetables, Bird Seeds, Grain, Plants with roots, Seeds, Stored products (Other than grain), Other
Angling/Sport Live bait or dispersal via fishing gear and/or boats or as a consequence of aqua sports.	Release, Escape, Contaminant, Stowaway	Fishing material
Animal husbandry Animals for production of food for humans, including the pest species introduced via the animal hosts.	Contaminant	
Aquaculture Fish/crayfish/algae/plants/shellfish/seafood farming, or consequences of stocking of species (pest species) –including marine cultures, animals escaping from aquaculture.	Escape, Contaminant	
Aquaria Aquariums	Escape, Contaminant	
Ballast water and sediments	Stowaway	

Pathway of introduction (short description)	**Associated modes of entry**	**Vectors**
Ballast water and sediments in tanks, as well as solid ballast, includind also the dispersal via shipping in general.		
Biological Control Introduced as a putative bio control agent/pest of another species.	Release	
Escape Fur farming, pet-animals escapes from captivity, laboratory animals, animal escapes, pet trade, plant escapes.	Escape	Botanical gardens, Breeding farms, Confinement, Farms, Pets, Research, Zoo, Other
Forestry Timber and tree production, including the pest species introduced via tree hosts or products.	Escape, Contaminant	Bark and wood chips, Plants with roots (including pot plants), Sawn wood (processed), Seeds, Timber (round wood), Wood packaging material, Other
Horticulture Plants used for ornamental purpose, gardening, garden ponds.	Escape, Contaminant	Cut flowers and branches, Cuttings, Plants with roots (including pot plants), Seeds, Other
Hull fouling	Stowaway	
Hunting (Released as hunting quarry or prey)		
Landscaping The use of plants in the landscape (such as hedge plantings, binding of soil, erosion control).	Release, Contaminant	Cuttings, Plants with roots (including pot plants), Seeds, Erosion control/Dune stabilisation, Other

Pathway of introduction (short description)	**Associated modes of entry**	**Vectors**
Medicinal Plants or animals used for this purpose.	Release, Escape	Plants with roots (including pot plants), Seeds, Other
Reintroduction Re-introduction of species that have previously died out in the country.		
Secondary introduction Introduced species where populations have been introduced from a nearby country/sea area – which are not the natural distribution area.	Corridor, Unaided	
Transport Infrastructure, translocation of machinery, transportation along roads and rails, planes, package material etc.	Stowaway	Agricultural/ Aquacultural machinery, Aircraft/cur/truck/train/ship/leisure boat, Military, Packaging material (except wood packaging material), Peoples baggage, Clothes, footwear, Other
Other – Contaminant (soil, man-made goods, ornamental fish)	Release, Escape, Contaminant, Stowaway	Soil
Not known		

The prioritization of pathways of introduction and vectors of invasive alien species.

The analysis of the frequency of introduction pathways and vectors has been carried out according to Pathways of unintentional introduction and spread of IAS of Union concern in Belgium (2018).

The values used to characterize the introduction pathways have been determined according to the literature data about the frequency with which species use a specific pathway of vector:

- 0.33 – low likelyhood of use – the species uses the pathway/vector seldom or not at all; it is unlikely but still possible that the pathway/vector refers to the specific species. Very low number of cases is described in the literature. Very low number of observations of the species exist in this pathway/vector.
- 0.66 – medium likelyhood of use – the species uses the pathway/vector regularly. Several cases are described in the literature. Regular, though not frequent observations of the species exist in this pathway/vector.
- 1 – high likelyhood of use – the species usually uses this pathway/vector, and it is the main pathway/vector for its introduction. Most of the published literature refer to this pathway/vector. There are frequent observations of the species in this pathway/vector. The ability of the species to spread naturally is evaluated with score 1.

The frequency of introduction pathways and vectors has been evaluated for every IAS. For the IAS occuring in Latvia we used the information about the introduction pathways and vectors of these species in the territory of Latvia. For other species, considering the principle of precaution, we took into consideration all potential introduction pathways and vectors mentioned in the literature.

The assessments are used in the prioritization analysis of introduction pathways and vectors (Table 5). The basis for the prioritization are:

1. The number of IAS (n) using the specific pathway or vector (Table 5);
2. The value of the pathway is based on the impact of species and the frequency of the introduction per pathway. The pathways were ranked based on summary (∑) that takes into acount number of species in the pathway, multiplication between the relative ecological impact score (I) (corrected with establishment potential (E)) and the frequency score (V). The formula is defined in Table 5.

Table 5
Calculation of prioritization of the pathways and vectors

Species	**Impact of species (I/10)**	**Frequency of use of the pathway (V)**	**Establishment potential (E)**	**I*V*E**
Species 1	0,9	0,33	2	0,594
Species 2	0,1	1	5	0,5
Species 3	1,2	0,66	4	3,168
Species 4	1,1	0,33	3	1,089

n=4 $\sum = 5,351$

Assessment of mode of entry

Mode of entry was determined for all IAS. For the characterization of the modes of entry we used the modes of entry defined by Madsen et al. (2014) (Table 6).

Table 6
Summary of the mode of entries

Mode of entry	**Explanation**	**Example**
Release in nature	Intentional introduction as a commodity with release into natural, semi-natural environment.	Agents of biocontrol, game animals, plants for controlling erosion
Escape	Intentional introduction as a commodity to be kept in confined/managed situation but escapes unintentionaly.	Cultivated edible plants, farm and breeding farm animals, plants used in forestry, pets, garden plants, live bait
Contaminant	Unintentional introduction with a specific commodity, being ecologically associated with the organisms or goods transported.	Parasites, pests, commensal organisms from traded plants and animals
Stowaway	Unintentional introduction (transportation) via the movement of other organisms or goods, not being ecologically associated.	Organisms from the water transport hulls, ballast waters, soil, sediment, dispersed by marine transport, land transport, aviation

Mode of entry	Explanation	Example
Corridor	Unintentional introduction via antropogenic corridors linking previously unconnected regions, the species disperse under its own power.	Lessepsian migrants (Eritrean invasion), alien species of Ponto-Caspian region in the Baltics
Unaided	Unintentional introduction through natural dispersal of alien species across political borders, not using antropogenic corridors.	Potentially all alien species and taxons that can disperse
Not known	No information about mode of entries.	

Results

Species of the EU list

The present study covers 66 species of the "List of invasive alien species of Union concern". Appendix 1 provides the list of all studied species and their taxonomic group. Altogether, the EU List Nr.1143/2014 contains 30 animal and 36 plant species representing eight taxonomic groups. Most species are angiosperms (36 species) and mammals (11 species) (Figure 1). Some taxonomic groups include only one species such as reptiles (*Trachemys scripta*), amphibians (*Lithohates (Rana) catesbeianus*) and worms (*Arthurdendyus triangulatus*) (Appendix 1).

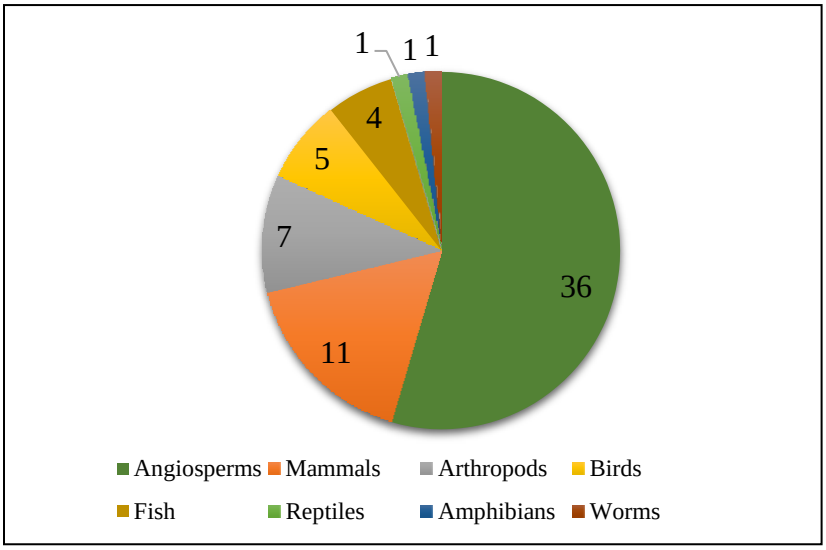

Figure 1. The 66 species of the EU List by taxonomic group.

Establishment or potential for establishment in Latvia

Whether the species is already established in Latvia or could be expected or is not to be expected to establish, could influence the importance of individual pathways and their prioritization according to the chosen method. The information about each species establishment or potential for establishment was determined mostly based on species native origin, preferred climate, and its distribution in Europe.

There are two plant (*Heracleum sosnowskyi, Impatiens glandulifera*) and three animal species (*Myocastor coypus, Nyctereutes procyonoides, Ondatra zibethicus*) which are documented in the wild in Latvia, as well as one bird species (*Alopochen aegyptiacus*), one turtle species (*Trachemys scripta*), one fish species (*Perccottus glenii*), one crab species (*Eriocheir sinensis*) and two crayfish species (*Orconectes limosus, Pacifastacus leniusculus*). Three of these species *Alopochen aegyptiacus*, *Myocastor coypus* un *Trachemys scripta* currently do not propagate in the wild in Latvia (Zorenko, 2008; www.putni.lv; Čeirāns et al., 2019). The situation with *Eriocheir sinensis* is unclear (Nature Conservation Agency, 2020).

Animals

Two invasive alien species of mammals correspond to very high establishment category (Figure 2): *Nyctereutes procyonoides* and *Ondatra zibethicus*. *N.procyonoides* was introduced in Latvia during 1940s, while the establishment of *O. zibethicus* in Latvia is dated with 1961. Nowadays these species occur in the whole area of the country, they have occupied their ecological niche, created stable populations and do not exhibit significant signs of invasiveness; the number of animals does not increase (Tauriņš 1982, State Forest Service, 2020).

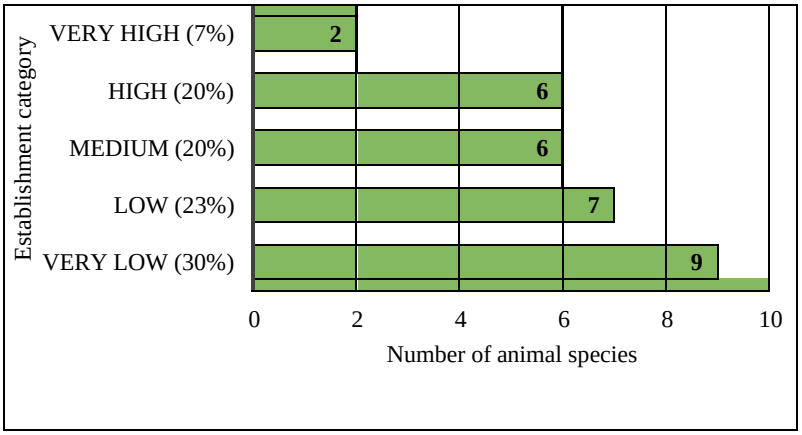

Figure 2. Establishment categories of the invasive alien animal species of EU List in Latvia.

Six species correspond to high establishment category (*Arthurdendyus triangulates, Eriocheir sinensis, Orconectes limosus, Pacifastacus leniusculus, Perccottus*

glenii, Procyon lotor) (Figure 2). These are the species with their natural range in the temperate climatic location or those who in many European countries occur in the wild at least for 60 years, with closest wild populations in neighbouring countries or countries located close. One mammal species, *Procyon lotor*, has not yet been observed in the wild in Latvia, but there is concern for its potential establishment, as it has been observed in the wild in Lithuania, Belarus and Russia (Canova and Rossi, 2008). In Latvia this animal is kept as a pet and in private zoos. This category also includes four alien species occurring in Latvia (*Eriocheir sinensis, Orconectes limosus, Pacifastacus leniusculus, Perccottus glenii*). *E. sinensis* occurs seldom and it is considered that the species does not reproduce in the Baltic Sea. However, in the southern part of the Baltic Sea (including Latvia) some female *E. sinensis* with eggs have been found. The rest three species have appeared in Latvia relatively recently – in the end of the 20th century or in the beginning of 21st century, they occur comparatively seldom, and their distribution is uneven (Aleksejevs and Birzaks, 2020; Čeirāns et al., 2019; Nature Conservation Agency, 2020).

Six animal species fall into medium establishment category (*Alopochen aegyptiacus, Lithobates (Rana) catesbeianus, Myocastor coypus, Sciurus carolinensis, Tamias sibiricus, Trachemys scripta*) (Figure 2). These are species with wide natural range encompassing subtropical and temperate climatic zones and have established in other European countries but have not formed stable populations in the neighbouring countries. There are three species among these that occasionally occur in the wild in Latvia but have not established themselves due to climatic conditions (*Alopochen aegyptiacus*, *Myocastor coypus*, *Trachemys scripta*). Climate change may facilitate their establishment.

Climate conditions in Latvia are not suitable for tropical and subtropical species, therefore nine animal species fall in the category of very low establishment (*Acridotheres tristis, Herpestes javanicus, Nasua nasua, Orconectes virilise, Oxyura jamaicensis, Plotosus lineatus, Procambarus clarkia, Procambarus fallax, Threskiornis aethiopicus*) (Figure 2). Seven IAS of animals correspond to low establishment (*Callosciurus erythraeus, Corvus splendens Viellot, Lepomis gibbosus, Muntiacus reevesi, Pseudorasbora parva, Sciurus niger, Vespa velutina nigrithorax*). These are species with their natural range in the subtropical climatic zone; several specimens have been observed in Southern European and Central European countries, and in some of the European

countries there are minor isolated populations. In Latvia there is information about observations of escaped single specimens of *Muntiacus reevesi* and *Myocastor coypus* in the wild, but these mammals have not formed wild populations (Zorenko, 2008; Balvos iemaldās Ķīnas ūdensbriedis mundžaks, 2010).

Plants

The results showed that two invasive plant species were already established (included in very high establishment category) in Latvia - *Heracleum sosnowskyi, Impatiens glandulifera* (Figure 3). The species *Heracleum sosnowskyi* has been included in the official list of invasive species in Latvia (Regulations of the Cabinet of Ministers No 468, 2008). The second species *Impatiens glandulifera* is included in the so called "Black list" with priority to be monitored (Evarts-Bunders and Evarte-Bundere 2020). Both species are forming stable and vital populations in the country.

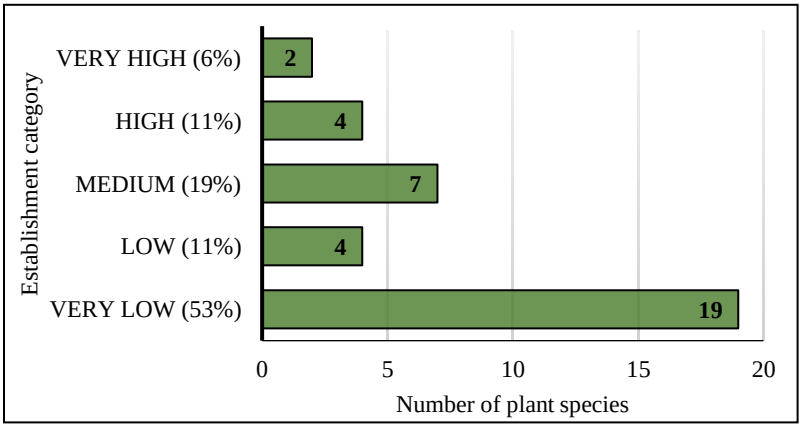

Figure 3. Establishment categories of the invasive alien plant species of EU List in Latvia.

Four of the studied species - *Elodea nuttallii*, *Heracleum mantegazzianum*, *Asclepias syriaca*, *Heracleum persicum* have high potential to be established in Latvia (included in high establishment category) (Figure 3). All these species have been found in the wild in one of the neighbouring countries located in the same boreal biogeographical region. The species *Heracleum mantegazzianum* also has been included in this category. It has been mentioned in the flora of Latvia as species with characteristics of invasiveness (Gavrilova and Šulcs, 1999), but recently it has not been found in the wild. One of the species in the list (*Asclepias syriaca*) is available for purchase (commercial trade).

Seven plant species - *Cabomba caroliniana, Hydrocotyle ranunculoides, Lysichiton americanus, Myriophyllum heterophyllum, Ailanthus altissima, Humulus scandens, Baccharis halimifolia* - have been identified as potentially able to establish themselves in Latvia (included in medium establishment category) (Figure 3). Four species are already found in commercial trade in the market of Latvia. Even though one of these species (*Ailanthus altissima*) has been recorded in the territory of Latvia (4 records) by Laiviņš et al. (2009), there is no evidence about its wider distribution in the wild. In addition, *Alianthus altissima* is a typical species for meridional – temperate climate.

From the 34 plant species that are not recorded in the country 23 are not considered to be able to establish themselves at this moment. During the research four species have been included in the low establishment category and 19 species – in the very low establishment category (Figure 3). Mostly these species are native to South America, Asia, and Southern Africa and are characterized as tropical or sub-tropical climate species. Most of these species occur in the southern part of Europe. At the same time four species are offered in the market in Latvia (*Eichhornia crassipes, Andropogon virginicus, Pennisetum setaceum, Gunnera tinctoria*) and one is common in Botanical garden (*Lygodium japonicum*).

The environmental impact assessment of the invasive alien species

Animals

The environmental impact assessment for the species occurring in the wild in Latvia is based on the evaluation of actual situation. Nearly all IAS of animals that are found in the wild in Latvia are low risk and medium risk species (Appendix 1). Medium risk species are *Nyctereutes procyonoides* and *Trachemys scripta*. The rest are low risk species (Appendix 1).

The environmental impact assessment of the species that have not been recorded in Latvia is based on the risk assessment performed in the countries where these species occur. More than half of these species are high risk species, five are medium risk species and three – low risk species.

Plants

According to the results, two plant species (*Heracleum sosnowskyi, Impatiens glandulifera*) are widespread in the wild in Latvia and are high risk species with total score 12 each. Both are characterized with high dispersion potential; they are colonizing high conservation value habitats, having adverse impacts of native species as well as altering ecosystem functions.

The remaining 34 plant species which were not considered to be common in the wild of Latvia are also high risk species according to the risk assessment in other countries (Denmark, Belgium) and to the available general information about species' biology and ecology. These 34 plant species were not evaluated with specific regard to the territory of Latvia, because of lack of source information.

Analysis of type of introduction, pathways and vectors and mode of entry

The present analysis applies to Latvia only with regarding to species which are common in the wild in Latvia – two plant species and nine animal species. For the rest of the species the types of introduction, modes of entry and pathways/vectors correspond to the types of introduction, pathways, vectors and mode of entry of these species determined in other countries. Consequently, information about invasive alien species that are not considered to be established in the wild in Latvia is compiled from various available sources in other countries.

Animals

Type of introduction

Almost all IAS, except two animal species, correspond to unintentional type of introduction. Animal species correspond merely to unintentional type of introduction (Appendix 2). More than half of 30 IAS correspond to intentional type of introduction (Figure 4). Two species (*Herpestes javanicus* and *Trachemys scripta*) correspond merely

to intentional type of introduction. The rest are introduced both intentionally and unintentionally.

In Latvia one half of occurring IAS of animals (5 species) are introduced both intentionally and unintentionally (*Alopochen aegyptiacus*, *Nyctereutes procyonoides*, *Orconectes limosus*, *Pacifastacus leniusculus*, *Perccottus glenii*). Three species are introduced unintentionally (*Eriocheir sinensis*, *Myocastor coypus* and *Ondatra zibethicus*). One species has been introduced intentionally (*Trachemys scripta*).

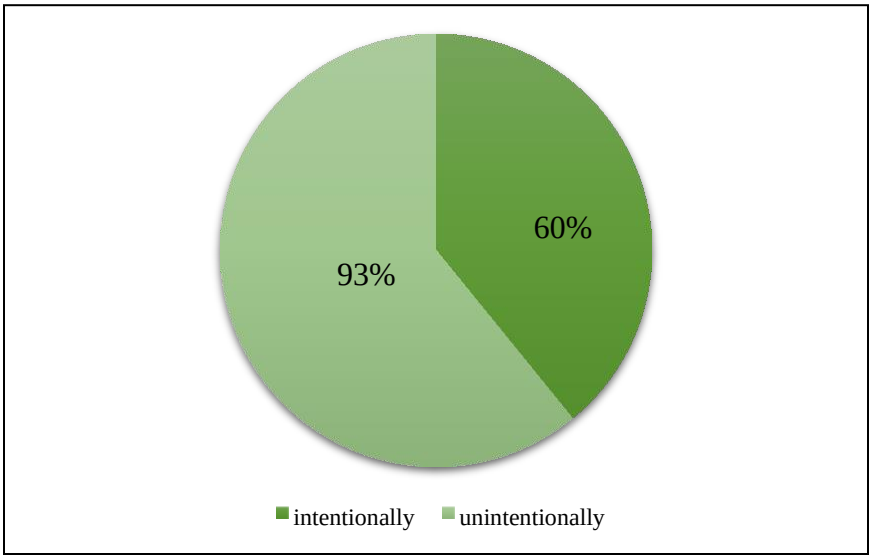

Figure 4. Introduction types of IAS of animals.

Pathways of introduction and vectors

For animals, 17 pathways of introduction have been identified (Table 7). Most of the species (42%) are introduced by means of *Escape*, the same number of species – by means of *Secondary introduction*. The prioritization of pathways of introduction has demonstrated that *Escape*, followed by *Secondary introduction*, were the main pathways. Most rarely occurring pathways of introduction are *Forestry*, *Animal husbandry*, *Landscaping* and *Biological Control*.

Table 7.
IAS of animal's pathways of introduction and frequency

Pathway of introduction	**Number of IAS (n)**	**∑ (Species Impacts I/10* Species Frequency V * Species Establishment E)**
Secondary introduction	12	23,642
Escape	12	17,655
Other (ornamental)	7	12,893
Aquaculture	5	10.1
Aquaria	6	7,7
Hunting	3	5,755
Transport	3	4,264
Angling/Sport	3	4.21
Horticulture	2	4
Ballast water and sediments	2	3,8
Commodity contaminants	2	3,592
Agriculture	1	2,8
Not known	1	2,4
Biological Control	2	1,463
Landscaping	1	0,924
Animal husbandry	1	0,924
Forestry	1	0,396

Half of the IAS (50%) is introduced by means of one pathway (Figure 5). The rest of the species are introduced via two or more pathways. One insect species (*Vespa velutina nigrithorax*) is introduced via six pathways, and one flatworm species (*Arthurdendyus triangulates*) can be introduced via seven pathways (Appendix 2). One species may use several pathways of introduction with the same frequency or some of them more and some – less frequently.

IAS of animals occurring in Latvia are introduced using one or two pathways, and they are *Escape*, *Secondary introduction*, *Aquaculture*, *Hunting*, *Angling/Sport*, *Aquaria* and *Ballast water and sediments*. The unintentional introduction pathway of *Orconectes limosus* remains unknown. This species belongs to the *intentionally/unintentionally* type of introduction.

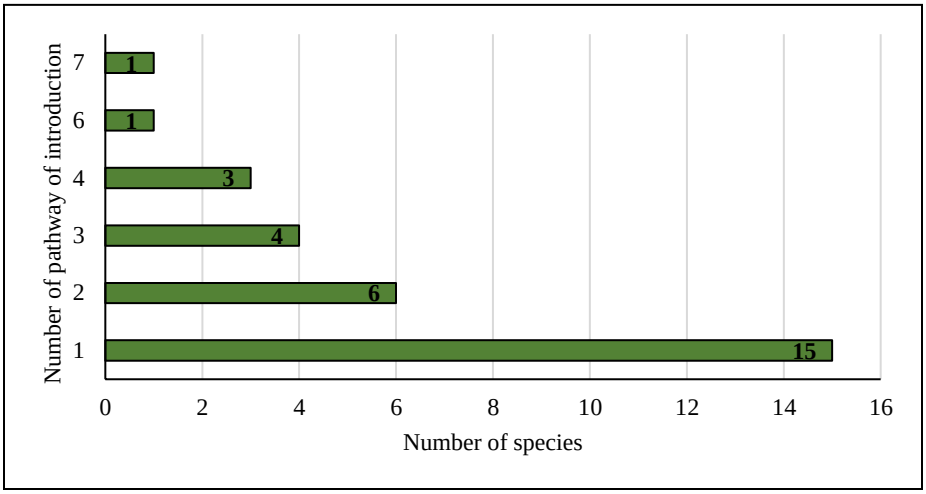

Figure 5. The number of pathways of introduction used by the IAS of animals.

Table 8
IAS of animals' introduction vectors and frequency

Vectors	**Number of IAS (n)**	**∑ (Species Impacts I/10* Species Frequency V * Species Establishment E)**
Pets	9	15,817
Zoo	9	14,226
Breeding farms	4	10,491
Farms	2	4,6
Fishing material	3	4,1
Plants with roots (Incl. Pot plants) (Horticulture)	1	4
Agricultural machinery	2	3,592
Fruits and vegetables	1	2,8
Plants with roots (Agriculture)	1	2,8
Other (Agriculture)	1	2,8
Cut flowers and branches	1	2,8
Confinement	2	2,763
Aircraft/car/truck/train/ship/leisure boat	3	2,188
Packaging material (Except wood packaging material)	1	1,2
Research	2	1,056
Plants with roots (Incl. Pot plants) (Horticulture)	2	0,924
Timber (Round wood)	1	0,396
Wood packaging material	1	0,396

Vectors	Number of IAS (n)	∑ (Species Impacts I/10* Species Frequency V * Species Establishment E)
Other (Horticulture)	1	0,396
Soil	1	0,396

There are 20 vectors of introduction identified for animals (Table 8). For 30% of all 30 invasive animal species, the vectors of introduction are *pets* and *zoo*. For 13% of the species the vector of introduction is *breeding farms*. The prioritization of the vectors of introduction has demonstrated that these three vectors are the most frequent for the introduction of animals. Similarly to pathways of introduction, there may be several vectors for the same species, and the same species may use them with varying frequency (Appendix 3). Two species of invertebrates are using the largest number of vectors - *Arthurdendyus triangulates* (8 vectors) and *Vespa velutina nigrithorax* (8 vectors). For example, the most frequent vectors of introduction for *V. velutina nigrithorax* are *Packaging material (Except wood packaging material*), *Plants with roots (Incl. Pot plants*) and *Aircraft/car/truck/train/ship/leisure boat*, the species also uses *Wood packaging material*, *Timber (Round wood)*, *Agricultural machinery* or *Other* with less frequency.

The introduction vectors for the animal species in Latvia are *Pets*, *Breeding farms*, *Zoo* and *Fishing materials*.

Mode of entry

IAS of animals spread in the wild using all defined modes of entry (Figure 6). For most of the species (67%) the mode of entry in the wild is *Escape*, for 42% of the species it is *Release*, but for 26% of the species - *Unaided*. Three species use one mode of entry – *Contaminant* for *Arthurdendyus triangulates*, *Corridor* for *Plotosus lineatus*, *Not known* for *Orconectes limosus*. Species may have one or several modes of entry (Appendix 4). One mode of entry is used by 14 species, two modes of entry are used by 13 species, but three modes of entry are used by three species (*Herpestes javanicus*, *Lithobates (Rana) catesbeianus* and *Plotosus lineatus*).

IAS of animals occurring in Latvia have been spreading and continue to spread via four modes of entry: *Escape* (*Alopochen aegyptiacus*, *Myocastor coypus*, *Perccottus glenii*, *Trachemys scripta*), *Release* (*Alopochen aegyptiacus*, *Nyctereutes procyonoides*, *Pacifastacus leniusculus*), *Unaided* (, *N. procyonoides, Ondatra zibethicus, T. scripta*), *Stowawaey* (*Eriocheir sinensis*), *Not known* (*Orconectes limosus*).

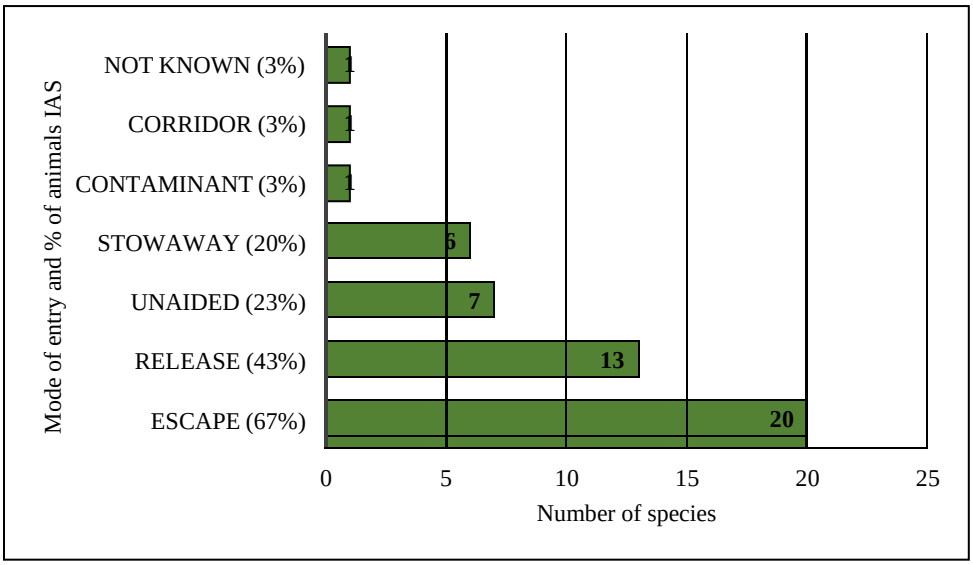

Figure 6. Modes of entry, number of species and percentage of the IAS of animals.

Plants

Type of introduction

In this study we considered that intentional and unintentional collection, transport and release of propagules or live individuals are extensive processes that transition into each other. Consequently, the introduction could be a continuum from intentional to unintentional processes. Therefore, the species that were primary introduced intentionally may correspond also to the introduction pathway 'intentionally/unintentionally' (Essl et al., 2018). The introduction type could also be specific to the country. Because the most part of EU list plant species (34 of 36 species) have not been recorded in Latvia, the documented information about type of introduction was mostly based on possible introduction types of species in Europe and our own expert opinion, and as such should be considered.

According to the available informational about species' type of introduction in the other European countries, all aquatic plants (13 species) may be introduced intentionally or by a combination of intentional and unintentional introduction. None of the aquatic plants is being introduced only unintentionally. As none of EU list aquatic plants has been recorded in Latvia in the wild, we assume that they all have been introduced intentionally as well as by intentional/unintentional introduction type (Appendix 5).

For terrestrial plant species (23 species), largest part of the species may have been introduced primarily intentionally (78 % of all terrestrial species), or by a combination of intentional/unintentional introduction. The exception is five plant species (22 %) – *Andropogon virginicus, Ehrharta calycina, Microstegium vimineum, Parthenium hysterophorus, Prosopis juliflora* – these species may have been introduced primarily unintentionally (Figure 7).

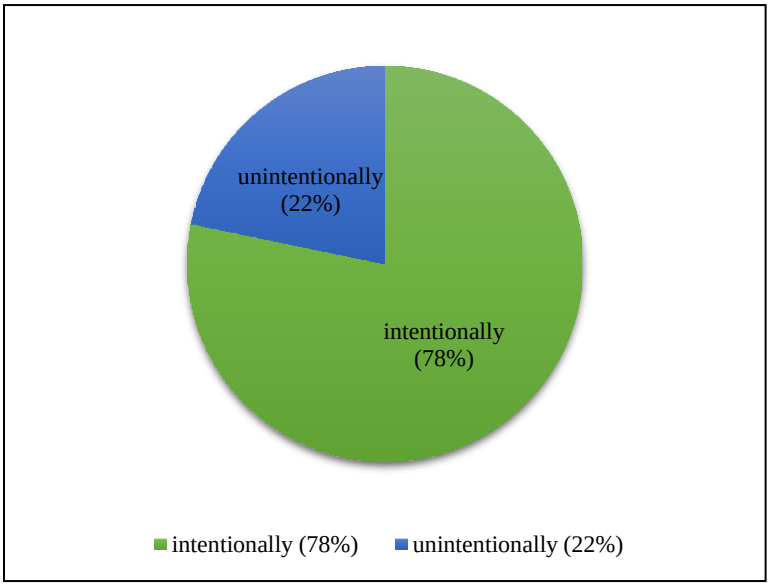

Figure 7. Introduction types of IAS of terrestrial plants.

In Latvia both alien invasive plant species of EU list *Heracleum sosnowskyi* and *Impatiens glandulifera* have been introduced intentionally (Appendix 5).

Pathways of introduction and vectors

We gathered all available information about all possible pathways for each EU list species. The pathways of aquatic (13 species) and terrestrial plants (23 species) were analyzed separately.

Aquatic plants

In the result, 12 possible pathways were identified for aquatic plant species (Table 9). The pathways *Horticulture* and *Secondary introduction* were most common and applicable to all analyzed aquatic species (13 species). The prioritization of pathways of introduction has demonstrated that *Horticulture*, followed by *Aquaria*, were the main pathways. Most rarely occurring pathways of introduction are *Ballast water and sediments*, *Agriculture* and *Medicinal*. Finally, one species could be transported in pathway *Others*, which was soil (Table 9). The pathways and vectors of introduction for each species have been summarized in Appendices 5 and 6.

Table 9.
IAS of aquatic plants' pathways of introduction (and spread of established species) and frequency.

PATHWAY OF INTRODUCTION	**NUMBER OF IAS (n)**	**∑ (species Impacts I/10 * Species Frequency V* Species Establishment E)**
Horticulture	13	14.1
Aquaria	10	10.526
Secondary introduction	13	10.46
Transport	12	9.36
Angling/Sport	10	6.468
Aquaculture	7	5.016
Escape	6	4.62
Landscaping	2	1.76

PATHWAY OF INTRODUCTION	NUMBER OF IAS (n)	∑ (species Impacts I/10 * Species Frequency V* Species Establishment E)
Ballast water and sediments	1	1
Others	1	0.33
Medicinal	1	0.33
Agriculture	1	0.33

More than half of the species were introduced by six or more pathways (Figure 8). One species *Alternanthera philoxeroides* could be introduced via nine pathways (Appendix 5). The rest of the four species were introduced via four or five pathways (Figure 8).

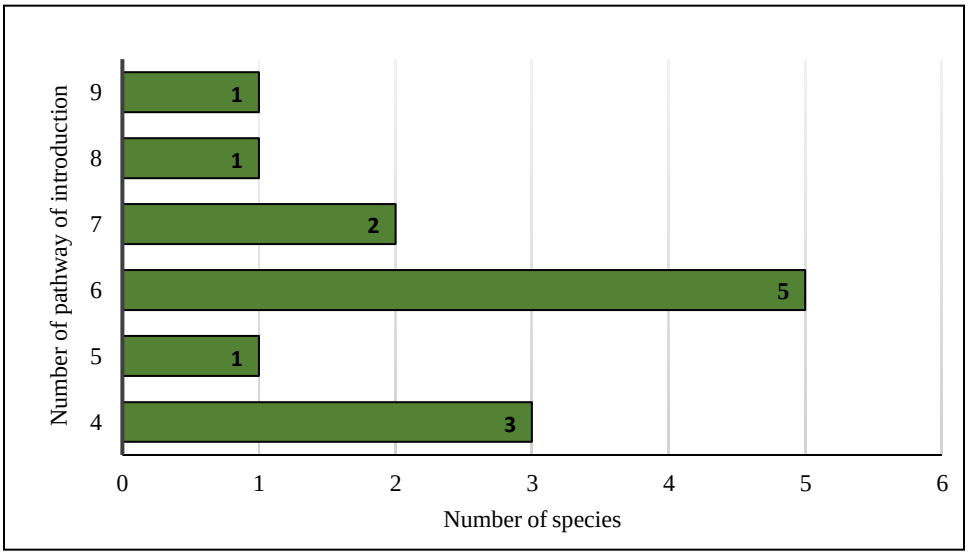

Figure 8. The number of pathways of introduction used by the IAS of aquatic plants.

During the study, it was possible to identify seven vectors for aquatic plant species. The available information about species introduction vectors in different countries is very broad, sometimes there are difficulties in identifying specific vectors for a specific pathway. Consequently, the presented results of the analysed vectors offer only an insight into this study part. It must be developed further in the future considering specific pathways regarding Latvia. (Table 10).

In our study we could mostly divide vectors according to Transport pathways - two of them (*Agriculture/Aquaculture machinery* and *Aircraft/ship/leisure boat*) (Table 10). These vectors had the highest frequency as well. Related to pathways Angling/Sport was *Fishing equipment* as one of the potential introduction vectors for IAS. Six species were attributed to the vector *Escape* from *Botanical gardens.* The species *Ludwigia peploides* was the one using the largest number of identified vectors (7 vectors) (Appendix 6).

Table 10.
IAS of aquatic plants introduction vectors and frequency

VECTORS	**NUMBER OF IAS (n)**	**∑ (species Impacts I/10* species Frequency V* Species Establishment E)**
Other (Horticulture)	13	29.4
Aircraft/ship/leisure boat	12	18.512
Agriculture/Aquaculture machinery	12	17.424
Fishing equipments	10	12.606
Plants with roots (Horticulture)	3	8.5
Botanical gardens, Aquarim, Zoo (Escape)	6	4.62
Clothes, footwear	4	3.234

Terrestrial plants

For terrestrial plant species 10 pathways of introduction have been identified (Table 11). Most of the species have been and/or could be introduced by *Secondary introduction*, *Horticulture* and *Transport*. Also the pathways' prioritization demonstrated similar results. Most rarely occurring pathways of introduction were *Medicinal* and *Ballast water and sediments*. There may be several pathways for the same species, and the same species may use them with varying frequency (Appendix 5).

IAS of plants occurring in Latvia are *Heracleum sosnowskyi* and *Impatiens glandulifera*. The species *Heracleum sosnowskyi* was introduced in Latvia using five pathways, from which the pathways *Agriculture* and *Secondary introduction* were associated with the highest frequency (Appendix 5). The other plant species *Impatiens glandulifera* has also been introduced in Latvia by five pathways: *Escape, Horticulture, Transport, Secondary introduction* and *Others (Soil Contaminant)*.

The terrestrial plant species could be introduced by means of at least three pathways (Figure 9). The most part of studied species were introduced via four or six pathways (Figure 9). There may be several pathways for the same species, and the same species may use them with varying frequency (Appendix 5).

Table 11.
IAS of terrestrial plants' pathways of introduction (and spread of established species) and frequency

PATHWAY OF INTRODUCTION	**NUMBER OF IAS (n)**	**∑ (species Impacts I/10 * Species Frequency V * Establishment E)**
Secondary introduction	23	46.778
Horticulture	20	42.698
Transport	14	23.298
Escape	12	18.002
Agriculture	11	17.945
Ohters (Contaminant Soil)	10	16.104
Landscaping	12	11.582
Forestry	7	7.567
Medicinal	3	1.815
Ballast water and sediments	1	1

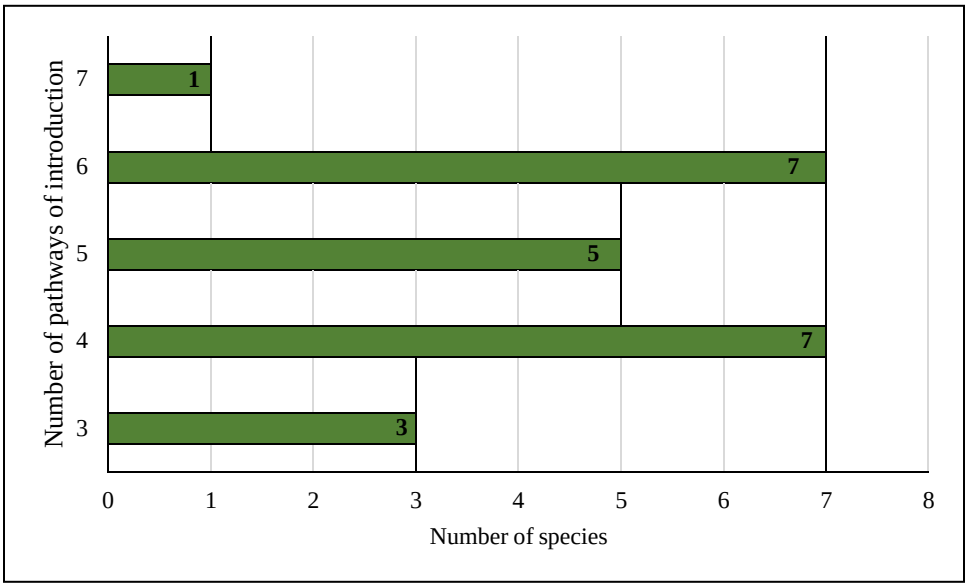

Figure 9. The number of pathways of introduction used by the IAS of terrestrial plants.

There are 18 vectors of introduction identified for terrestrial plants, part of which has not been identified under specific introduction of pathway (Table 12). However, for most species (17 species) it was not possible to identify vectors under pathway *Horticulture*. It was not possible also for seven species for pathway *Agriculture* and for four species for pathway *Ladscaping*. For 48 % of all 23 terrestrial plant species, the vectors of introduction were *Aircraft/car/truck/train/ship/leisure boat* and for 30 % of all studied species the vector *Clothes, footwear* was important during the introduction. The prioritization of the vectors of introduction demonstrated that vectors *Aircraft/car/truck/train/ship/leisure boat*, *Soil*, *Seeds (Horticulture)* and *Botanical gardens (Escape)* were the most frequent for the introduction of terrestrial plants. Similarly to pathways of introduction, there may be several vectors for the same species, and the same species may use them with varying frequency (Appendix 6).

One species *Parthenium hysterophorus* was characterized with the largest number of identified introduction vectors – six vectors (Appendix 6). However, no vectors were identified for four species (not including vectors *Others*) - *Gunnera tinctoria, Asclepias syriaca, Persicaria perfoliata, Pueraria montana.*

Table 12
IAS of terrestrial plants' introduction vectors and frequency.

VECTORS	**NUMBER OF IAS (n)**	**∑ (species Impacts I/10 x species Frequency V * Species Establishment E)**
Other (Horticulture)	17	33.678
Aircraft/car/truck/train /ship/leisure boat	11	21.243
Soil	10	16.104
Seeds (Horticulture)	5	13.42
Botanical gardens (Escape)	5	10.435
Other (Agriculture)	7	9.756
Clothes, footwear	7	9.504
Erosion Control/ dune stabilization	8	8.216
Seeds (Agriculture)	2	7.1
Other (Landscaping)	4	3.366
Plants with roots (Incl. Pot plants)	1	3.3
Agriculture/Aquaculture machinery	4	2.915
Military (Transport)	2	2.046
Peoples baggage	1	1.452
Packaging material	2	1.089
Grain	1	0.726
Stored products (Other than grain)	1	0.363
Research (Escape)	1	0.363

The introduction vectors for the terrestrial plant species in Latvia were *Seeds, Aircraft/car/truck/train/ship/leisure boat, Clothes, footwear* and *Soil* for species *Heracleum sosnowskyi*. Species *Impatiens glandulifera* was using similar vectors - *Botanical gardens, Aquarim, Zoo (Escape), Seeds, Aircraft/car/truck/train/ship/leisure boat, Clothes, footwear* and *Soil* (Appendix 6).

Mode of entry

Aquatic species

IAS of aquatic plants spread in the wild using almost all defined modes of entry, almost each of the studied species was using all identified modes of entry (Figure 10). The exception was the species *Lysichiton americanus* which did not correspond to the mode of entry *Stowaway* and the species *Eichhornia crassipes* which did not correspond to the mode of entry *Contaminant* (Appendix 4). There was no evidence in the literature that some of aquatic species has been using *Release in Nature* – mode of entry.

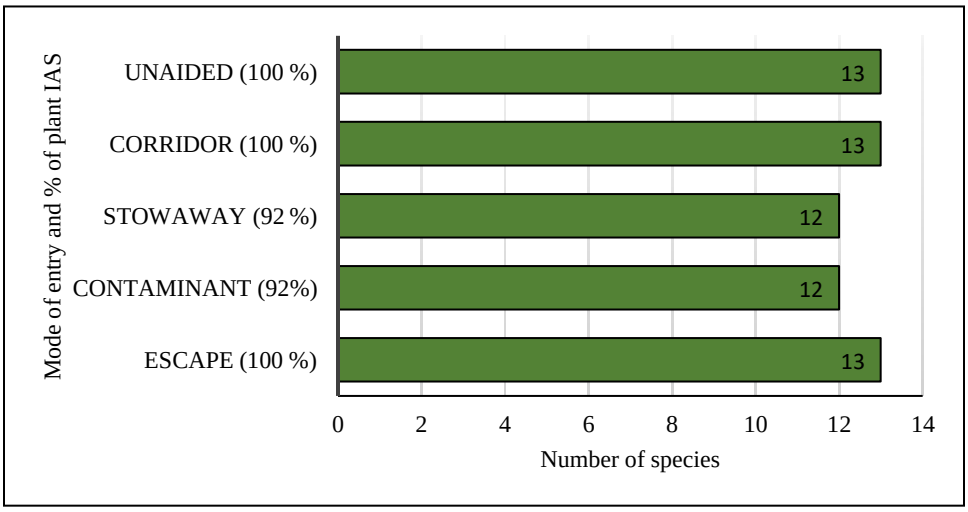

Figure 10. Modes of entry, number of species and percentage of the IAS of aquatic plants.

Terrestrial species

IAS of terrestrial plants spread in the wild using all defined modes of entry (Figure 11). For most of the species (91 %) the mode of entry was *Unaided*, but for 87 % of all studied terrestrial species it was *Escape* (Figure 11). For three species it was documented that mode of entry could be *Not known*. As in previous occasions, the species may have several modes of entry (Appendix 4).

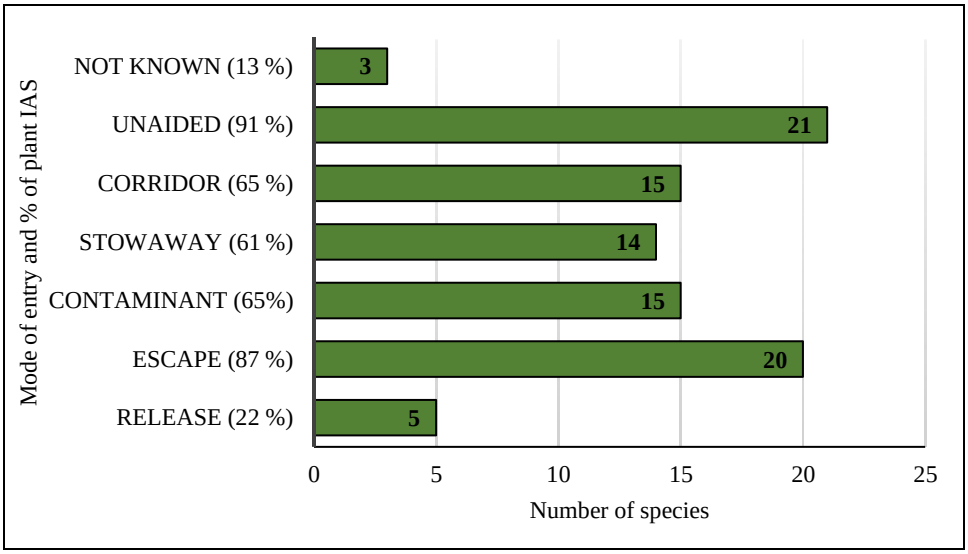

Figure 10. Modes of entry, number of species and percentage of the IAS of terrestrial plants.

IAS of terrestrial plant *Heracleum sosnowskyi* in Latvia has been spreading and via all identified modes of entry: *Release, Escape, Contaminant, Stowaway, Corridor, Unaided.* The species *Impatiens glandulifera* was using following modes of entry – *Release, Escape, Contaminant, Stowaway, Corridor, Unaided* (Appendix 4).

Conclusions

All 9 animal ISS found in the wild in Latvia are low or medium risk species. Medium-risk species are *Nyctereutes procyonoides* and *Trachemys scripta*. The others are low-risk species. The environmental impact assessment for wild species in Latvia is based on an assessment of the actual situation. The results are showing that a common species distributed throughout the territory of Latvia with a stable number of individuals may be of low or medium risk (*Nyctereutes procyonoides, Ondatra zibethicus*). A low or medium risk species may be a currently rare species that does not survive and / or reproduce in the wild (*Alopochen aegyptiacus, Eriocheir sinensis, Myocastor coypus, Trachemys scripta*); species with local distribution and relatively low invasiveness (*Orconectes limosus, Pacifastacus leniusculus, Perccottus glenii*). However, as environmental conditions can change, the degree of risk to the species may change too.

More than half of 21 species that do not occur in Latvia are high risk species, five are medium risk species and three are low risk species. This environmental impact assessment is theoretical and, according to the principle of precaution, based on the risk assessment in the countries where the species occur or on studies concerning the species.

High risk of introduction in the whole territory of Latvia is associated with those IAS of animals whose natural range are located in the temperate zone and/or they occur in the wild in many European countries for more than 60 years, and the closest wild populations are located in the neighbouring countries. The probability of introduction is increased by the fact that these animals are kept as pets, for example, *Procyon lotor*.

Medium risk of introduction is associated with the species with wide natural range encompassing subtropical and temperate zones that have already established themselves in other European countries, for example, *Lithobates (Rana) catesbeianus*, *Tamias sibiricus*. Some of these species are detected in the wild in Latvia but have not yet established themselves due to climatic conditions (e.g., *Myocastor coypus*, *Trachemys scripta*). Climate change may facilitate their establishment and survival in the wild.

Climatic conditions in Latvia are not suitable for species of tropical and subtropical zones.

All IAS, except *Herpestes javanicus* and *Trachemys scripta*, correspond to the unintentional type of introduction. More than half of the species introduced unintentionally correspond also to the intentional type of introduction. This means that initially the species may be introduced intentionally, and after acclimatization and naturalization in the new environment the animals may spread to new areas unintentionally.

Typical IAS of unintentional introduction type are those who are introduced via *Ballast water and sediments*, *Stowaway*, or *Escape*.

IAS use 17 pathways of introduction. The main pathway of introduction is *Secondary introduction*, followed by escape *Escape* and *Ornamental*. The least frequent pathways of introduction are *Forestry*, *Animal husbandry*, *Landscaping* and *Biological Control*.

Animals may use only one, or two or more pathway of introduction. More primitive terrestrial organisms use higher number of pathways. One species may use several pathways of introduction with similar or varying frequency.

IAS of animals in Latvia are introduced via one or two pathways of introduction, and they are *Escape*, *Secondary introduction*, *Hunting*, *Aquaria* un *Ballast water and sediments*. The unintentional pathway of introduction of *Orconectes limosus* in Latvia is unknown.

There are 20 vectors of introduction of IAS of animals. The most frequently used vectors are *Pets* uand *Zoo*. Similarly to pathways of introduction, also vectors for one species may be several, and the same species may use several vectors with similar or varying frequency. The highest number of vectors is used by terrestrial invertebrates.

IAS of animals spread in the wild via all defined modes of entry. Most species spread via *Escape*, slightly less than half of the species spread via *Release*. A species may use one or several modes of entry.

The IAS of animals occurring in Latvia have been introduced and continue to spread via four modes of entry: *Escape*, *Relese*, *Unaided*, *Stowaway* and *Not known*.

In Latvia two high-risk invasive alien plant species of EU list - *Heracleum sosnowskyi* and *Impatiens glandulifera* - have been naturalized. Acoording to literature, the rest 34 invasive plant species of EU concern are high-risk species, but none of them has been found in the wild in Latvia so far. However, additional 11 species from the EU list may are cultivated in gardens or in other indoor and outdoor spaces.

In the future special attention should be paid to possible introduction of following species - *Elodea nuttallii, Heracleum mantegazzianum, Asclepias syriaca, Heracleum persicum*, because these species have been recorded in the neighbouring countries, and the climate conditions in Latvia is similar to countries where these species already occur.

The most part of EU concern invasive alien plant species are not occuring in Latvia and/or have low or very low establishment potential. These species originate from South Africa, Asia, South America with tropical or subtropical climate. Mostly these species are found in the southern part of Europe.

Both invasive alien plant species of EU list that occur in the wild in Latvia (*Heracleum sosnowskyi, Impatiens glandulifera*) have been introduced intentionally and later have spread unintentionally, using all modes of entry. Both species were introduced and still are spreading to new habitats via at least five pathways of introduction. These pathways are *Agriculture, Secondary introduction, Horticulture, Transport, Escape* and *Contaminant of Soil*.

The results of the study showed that invasive alien plant species of EU concern may use 12 pathways of introduction for aquatic species and 10 for terrestrial plant species. Most significant introduction pathways of invasive alien plant species of EU list are *Horticulture* (including ornamental gardening), *Secondary introduction*, as well as one additional pathway of introduction for aquatic plant species - *Aquaria*.

This study identified possible vectors of introduction for invasive plant species. According to literature, the vectors under the pathway of introduction *Transport* were the most frequently mentioned and described, however, it is possible that other vectors (for example, under pathway of introduction *Horticulture*) may be more significant for invasive alien plant species, but it was not recorded in this study, becauce of the lack of information. Therefore, the methodology should be improved in the future according to specific situation in Latvia.

Current prioritization of pathways of introduction and vectors, as well as the spread of invasive alien species of EU list allowed to identify the most important pathways of introduction relevant for Latvia only for species which are found in the wild in Latvia. Although the main pathways in the EU are similar, it has been mentioned that they may vary among regions or countries. Therefore in the future possible pathways of introduction and vectors for all invasive alien species of EU list relevant to Latvia should be analysed.

Literature

Aleksejevs Ē. 2015. Latvijas ezeri un to zivis, Latvijas zivsaimniecības gadagrāmata 2015 19. gads, pp. 58-69.

Aleksejevs Ē. 2019. Latvijas ezeru un ūdenskrātuvju zivju maksimālie izmēri. Latvijas zivsaimniecības gadagrāmata 2019 23. gads, pp. 57-64.

Aleksejevs Ē., Birzaks J. 2020. Distribution of freshwater crayfish in Latvia, Acta Biol. Univ. Daugavp., 20 (1), pp. 1-11.

Arbačiauskas K., Višinskiene G., Smilgevičiene S., Rakauskas V. 2012. Non-indigenous macroinvertebrate species in Lithuanian fresh waters, Part 1: Distributions, dispersal and future. Knowl Manag Aquat Ecosyst, 402, pp. 1-18.

Baiwy, E.,Schockert, V., Branquart, E. 2015. Risk analysis of the Fox squirrel, Sciurus niger, Risk analysis report of non-native organisms in Belgium. Cellule interdépartementale sur les Espèces invasives (CiEi), DGO3, SPW / Editions, updated version, 34 pp.

Balalaikins M., Kantāne J. 2020. Puķu spriganes sastopamība, izplatīšanās koridori un izplatības karstie punkti meža ainavā Latvijā. Pārskats par Lauku atbalsta dienesta finansēto pētījumu, Daugavpils, 55 pp.

Balogh L., Dancza I. 2017. *Humulus japonicas*, an emerging invader in Hungary, Plant Invasions: Human perception, ecological impacts and management, pp. 73-91.

Banha F., Gama M., Anastacio P.M. 2017. The effect of reproductive occurrences and human descriptors on invasive pet distribution modelling: *Trachemys scripta elegans* in the Iberian Peninsula // Ecological Modelling 360, pp 45-52.

Britton R.J. 2010. Pan-continental invasion of Pseudorasbora parva: towards a better understanding of freshwater fish invasions, Fish and Fisheries, 11 (4), pp. 315-340, DOI:10.1111/j.1467-2979.2010.00361.x.

Canova L., Rossi S. 2008. First records of the northern raccoon Procyon lotor in Italy. - Hystrix, The Italian Journal of Mammalogy, 19 (2), DOI: https://doi.org/10.4404/hystrix-19.2-4428

Cardiospermum grandiflorum. 2017. Bulletin OEPP/EPPO, 47 (3), pp. 526-530.

Čeirāns A., Pupiņš M. 2019. Sešu īpaši aizsargājamo abinieku sugu un purva bruņurupuča populāciju izzušanas riska novērtējum saistībā ar invazīvo sugu – rotana un sarkanausu bruņurupuča ietekmi. Darba dokuments LVAFA finansēta projekta Nr. 1-08/189/2018 „Invazīvo sugu – rotana (*Perccottus glenii*) un sarkanausu bruņurupuča (*Trachemys scripta*

elegans) ietekmes novērtēšana un mazināšana uz reto abinieku un rāpuļu sugu populācijām" uzdevumu veikšanai, 33 pp.

Čeirāns A., Pupiņš M., Pupiņa A., Škute A. 2018. Vadlīnijas invazīvo organismu –rotana (*Perccottus glenii*) un abinieku patogēnu Batrachochytrium spp.,ierobežošanas pasākumu veikšanai Daugavpils, Ilūkstes un Krāslavas novados, Daugavpils Universitāte, 48 pp.

Čeirāns A., Pupiņš M., Škute A. 2019. Vadlīnijas invazīvo sugu –rotana (Perccottus glenii) un sarkanausu bruņurupuča (*Trachemys scripta elegans*) apkarošanai apdraudētākajās abinieku un rāpuļu populācijās Latvijā, DaugavpilsUniversitāte, 43 pp.

Coetzee J.A., Hillb M.P., Ruiz-Téllezc T., Starfingerd U., Brunele S. 2017. Monographs on invasive plants in Europe $N^0$2: *Eichhornia crassipes* (Mart.) Solms, Botany Letters, 164 (4), pp. 303-326.

Delibes M., Clavero M., Prenda J., del Carmen Blázquez M. and Ferreras P. 2004. Potential impact of an exotic mammal on rocky intertidal communities of northwestern Spain Biological Invasions, 6, pp. 213-219.

Donald H.L., Mehrhoff L.J. 1999. Introduction of nonindigenous aquatic vascular plants in southern New England: a historical perspective, Biological Invasions, 1, pp. 281-300.

Ehrharta calycina Sm. 2019. Bulletin OEPP/EPPO, 49 (1), pp. 55-60.

Essl F., Bacher S., Genovesi P., Hulme P.E., Jeschke J.M., Katsanevakis S , Kowarik I., Kühn I, Pyšek P., Rabitsch W., Schindler S., Kleunen van M., Vilà M., Wilson M. R. U., Richardson D.M. 2018. Which Taxa Are Alien? Criteria, Applications, and Uncertainties, BioScience, 68, pp. 496–509.

Ficetola G.F., Coïc C., Detaint M., Berroneau M., Lorvelec O., Miaud C. 2007 a. Pattern of distribution of the American bullfrog Rana catesbeiana in Europe, Biological Invasions, 9 (7), pp. 767-772.

Ficetola G.F., Thuiller W., Miaud C. 2007 b. Prediction and validation of the potential global distribution of a problematic alien invasive species — the American bullfrog, Div Distr, 13 (4), pp. 476-485.

Fried G., Caño L., Brunel S., Beteta E., Charpentier A., Herrera M., Starfinger U., Panetta F.D., 2016. Monographs on invasive plants in Europe: *Baccharis halimifolia* L., Botany Letter, DOI: 10.1080/23818107.2016.1168315.

Galanidi, M., Turan, C., Öztürk, B. and Zenetos, A., 2019. Europen Union (EU) Risk Assessment of Plotosus lineatus (Thunberg, 1787); a summary and information update., J. Black Sea/Mediterranean Environment, 25 (2), pp. 210-231.

Gavrilova Ģ. Šulcs V. 1999. Latvijas vaskulāro augu flora: Taksonu saraksts, Rīga, Latvijas Akadēmiskā bibliotēka, 136 pp.

Gozlan, R.E., Andreou D., Asaeda T., Beyer K., Bouhadad R., Burnard D., Caiola N., Cakic P., Djikanovic V., Esmaeili H.R., Falka I., Golicher D., Harka A., Jeney G., Grabowska, J., Kotusz, J. Witkowski, A. 2010. Alien invasive fish species in Polish waters: an overview, Folia Zoologica, 59 (1), pp. 73-85, DOI:10.25225/fozo.v59.i1.a1.2010.

Grīnberga L., Priede A. 2010. *Elodea canadensis* Michx. in Latvia, Acta Biologic Universitatis Daugavpiliensis, 10 (1), pp. 43-50.

Grousset F., Johannsen V.K., Ravn H.P. 2018. Identification and evaluation of pathways to Denmark for the 49 invasive alien species of Union concern under Regulation 1143/2014, Frederiksberg, University of Copenhagen, 70 pp.

Gudžinskas Z., Kazlauskas M., Pilāte D., Balalaikins M., Pilāts M., Šaulys A., Šaulienė I., Šukienė L. 2014. Lietuvos ir Latvijos pasienio regiono invaziniai organizmai. Lietuvas un Latvijas pierobežas invazīvie organsmi, Vilnius, BMK Leidykla, 184 pp.

Harrower, C.A., Scalera R., Pagad S., Schönrogge K., Roy, H.E. 2018. Guidance for interpretation of CBD categories on introduction pathways, Convention on Biological Diversity, https://www.cbd.int/doc/c/9d85/3bc5/d640f059d03acd717602cd76/sbstta-22-inf-09-en.pdf, (accessed 12 December 2020).

Hulme P.E., Bacher S., Kenis M., Klotz S., Kühn I., Minchin D., Nentwig W., Olenin S., Panov V., Pergl J., Pyŝek P., Roques A., Sol D., Solarz W., Vilà M. 2008. Grasping at the routes of biological invasions: a framework for integrating pathways into policy, Journal of Applied Ecology, 45, pp. 403-414.

Husemann M, Sterr A, Maack S, Abraham R. 2020. The northernmost record of the Asian hornet Vespa velutina nigrithorax (Hymenoptera, Vespidae). Evolutionary Systematics, 4 (1), pp. 1-4, https://doi.org/10.3897/evolsyst.4.47358.

Invasive Alien Species of Union concern. 2017. European Union, 34 pp, https://ec.europa.eu/environment/nature/pdf/IAS_brochure_species.pdf.

Jakubāne I., Pilāte D., Dreijers E., Zolovs M. 2016. Distribution of "Spanish slug" *Arion lusitanicus* auct. non Mabille 1868 (or *Arion vulgaris* Moquin-Tandon, 1855) (Gastropoda: Arionidae) in Latvia, Acta Biol. Univ. Daugavp., 16 (2), pp. 175-180.

Keller, V., Herrando, S., Voříšek, P., Franch, M., Kipson, M., Milanesi, P., Martí, D., Anton, M., Klvaňová, A., Kalyakin, M. V., Bauer, H.-G. & Foppen, R. P. B. 2020. European Breeding Bird Atlas 2: Distribution, Abundance and Change, European Bird Census Council & Lynx Edicions, Barcelona, 98, 136, 137, 252, 708 pp.

Kikillus K.H., Hare K.M., Hartley S. 2010. Minimizing false-negatives when predicting the potential distribution of an invasive species: a bioclimatic envelope for the red-eared slider at global and regional scales, Animal Conservation, 13 (s1), pp. 5-15.

Knospiņa E., Putnis I. 2014. Apaļais jūrasgrundulis – arvien biežāks viesis Latvijas piekrastē, Latvijas zivsaimniecības gadagrāmata 2014. 18. gads. pp. 46-51.

Kornobis F.W., Domaradzki K., Jakubska-Busse A., Jurová J., Homolová, Z. 2019. How does an invasive *Heracleum sosnowskyi* affect soil nematode communities in natural conditions?, Nematology, 21, pp. 71-89.

Kouba A., Petrusek A., Kozák P. 2014. Continental-wide distribution of crayfish species in Europe: update and maps, Knowl Manag Aquat Ecosyst, 413, pp. 1-31.

Kowarik I., Säumel I. 2007. Biological flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle, Perspectives in Plant Ecology, Evolution and Systematics, 8, pp. 207-237.

Laiviņš M., Bice M., Krampis I., Knape Dz., Šmite D., Šulcs V. 2009. Rīga, SIA Apgāds Mantojums, 606 pp.

Lapiņa I. 1966. Jenotsuns. Rīga: Zinātne, 59 pp.

Lozano V., Marzialetti F., Carranza M.L., Chapman D., Branquart E., Dološ K., Große-Stoltenberg A., Fiori M., Brundu G., Capece P. 2020. Modelling *Acacia saligna* invasion in a large Mediterranean island using PAB factors: A tool for implementing the European legislation on invasive species, Ecological Indicators, 116, pp. 1-8.

Madsen C.L., Dahl C.M., Thirslund K.B., Grousset F., Johannsen V.K., Ravn H.P. 2014. Pathways for non-native species in Denmark. Department of Geosciences and Natural Resource Management, University of Copenhagen, Frederiksberg. 131 pp.

Matthews J., Beringen R., Lamers L.P.M., Odé B., Pot R., van der Velde G., van Valkenburg J.L.C.H., Verbrugge L.N.H., Leuven R.S.E.W. 2013. Knowledge document for risk analysis of the non-native Fanwort (*Cabomba caroliniana*) in the Netherlands, Reports Environmental Science 443, Nijmegen, the Netherlands, Radboud University, 46 pp.

NOBANIS. 2015. Invasive Alien Species, Pathway analysis and horizon scanning for countries in Northern Europe, Denmark, Rosendahls-Schultz Grafisk, 229 pp.

Ojaveer, H., Gollasch S., Jaanus A., Kotta J., Laine A.O., Minde A., Normant M., Panov V.E. 2007. Chinese mitten crab Eriocheir sinensis in the Baltic Sea—a supply-side invader?, Biological Invasions, 9 (4), pp. 409-418, DOI:10.1007/s10530-006-9047-z.

Opermanis O., Mednis A., Bauga I. 2001. Duck nests and predators: interaction, specialisation and possible management, Wildlife Biology, 7, pp. 87-96.

Ozolinš J.,Pilāts V. 1995. Distribution and status of small and medium-sized carnivores in Latvia. - Ann. Zool. Fennici, 32,pp. 21-29.

Pathways of unintentional introduction and spread of IAS of Union concern in Belgium, Report 1. Identification and prioritization. 2018. https://purews.inbo.be/ws/portalfiles/portal/17315610/Report_Prioritization_Pathways_Belgium.pdf, (accessed 12 December 2020).

Priede A. 2008. Distribution of invasive non-native plant species in Latvia, Latvijas Veģetācija, 17, 158 pp.

Priede A. 2014. Latvijas svešzemju sugu saraksts, Invasive species, http://biodiv.daba.gov.lv/cooperation/invaz, (accessed 12 December 2020).

Pupina A., Pupins M., Skute A., Pupina Ag., Karklins A. 2015. The distribution of the invasive fish amur sleeper, rotan Perccottus glenii Dybowski, 1877 (Osteichthyes, Odontobutidae), in Latvia, Acta Biol. Univ. Daugavp., 15 (2), pp. 329-341.

Pupins M. 2007. First report on recording of the invasive species Trachemys scripta elegans, a potential competitor of Emys orbicularis in Latvia, Acta Universitatis Latviensis, Biology, 723, pp. 37-46.

Pupins M., Pupina A. 2011. First records of 5 allochthonous species and subspecies of Turtles (Trachemys scripta troostii, Mauremys caspica, Mauremys rivulata, Pelodiscus sinensis, Testudo horsfieldii) and new records of subspecies Trachemys scripta elegans in Latvia, Manag. Biolog. Invasions, 2, pp. 69-81.

Regulation List of invasive plant species. 2008. Cabinet Regulation No. 468.

Richardson D.M, Pyšek P., Carlton J.T. 2011. A compendium of essential concepts and terminology in biological invasions, In: D.M. Richardson (ed.), Fifty Years of Invasion Ecology: The Legacy of Charles Elton, Oxford, Blackwell Publishing, pp. 409–420.

Romanceviča N. 2019. Izplatītāko invazīvo sugu ierobežošana Cēsu novadā. Metodiskais materiāls, Priekuļi, 90 lpp.

Tauriņš E. 1982. Latvijas zīdītājdzīvnieki, Rīga, Zvaigzne, 256 pp.

Timm U., Pilats V., Balciauskas L. 1998. Mammals of the East Baltic, Proceedings of the Latvian Academy of Sciences. Section B,52, No. 1/2 (594/595), pp.1- 9.

Timm, H., Olšauskytė V., Druvietis I., Spriņģe G., Aleksandrov J. V., Łapińska M., Skorupskas R., Gavrilova Ģ., Gaumiga R., Zalewski M., Briede A., Parele E., Melnik M.M. 2009. Baltic and Eastern Continental Rivers, Rivers of Europe, pp. 607-642, DOI:10.1016/bF978-0-12-369449-2.00016-3.

Wheeler G.S., J. Ding J. 2014. Is Chinese tallowtree, *Triadica sebifera*, appropriate target for biological control in the United States?, Invasive Plant Science and Management, 7, pp. 345-359.

Vanderhoeven S., Adriaens T., D'hondt B., Van Gossum B., Vandegehuchte M., Verreycken H.,Cigar J., Branquart E. 2015. A science-based approach to tackle invasive alien species in Belgium – the role of the ISEIA protocol and the Harmonia information system as decisions upporttool, Management of Biological Invasions, 6 (2), pp. 197-208.

Wittenberg R., Cock M.J.W. 2005. Best practices for the prevention and management of invasive alien species. In H.A. Mooney et al. (ed.), Invasive alien species: A new synthesis, Island Press, pp. 209-232.

Zięba G., Vilizzi, L. and Copp, G.H., 2020. How likely is Lepomis gibbosus to become invasive In Poland under conditions of climate warming?, Acta Ichthyologica Et Piscatoria, 50 (1), pp. 37–51, DOI: 10.3750/AIEP/02390

Zolovs M., Jakubāne I., Kirilova J., Kivleniece I., Moisejevs R., Koļesnikova J., Pilāte D. 2020. The potential antifeedant activity of lichen-forming fungal extracts against the invasive Spanish slug (*Arion vulgaris*), Canadian Journal of Zoology, 98 (4), pp. 195-201.

Zorenko T. 2008. Latvijas zīdītāju noteicējs, Rīga, Gandrs, 95 pp.

Websites

Balvos iemaldās Ķīnas ūdensbriedis mundžaks. 2010. [website], https://www.delfi.lv/archive/balvos-iemaldas-kinas-udensbriedis-mundzaks.d?id=34714367, (accessed 15 January 2021).

Bandīts melnajā maskā jeb Kad mājdzīvnieks ir jenots. 2016. [website], https://www.delfi.lv/mansdraugs/zveru-dzive/47554129_bandits-melnaja-maska-jeb-kad-majdzivnieks-ir-jenots ,(accessed 15 January 2021).

CABI, [website], https://www.cabi.org/, (accessed 9 January 2021).

EPPO, [website], https://www.eppo.int/index, (accessed 9 January 2021).

Global Biodiversity Information Facility, [website], https://www.gbif.org/, (accessed 9 January 2021).

Invasive species in Belgium, [website], https://ias.biodiversity.be/, (accessed 9 January 2021).

Invasive species Ireland, [website], https://invasivespeciesireland.com/, (accessed 9 January 2021).

Klovāne I. 2018. Atkal modē. Viss par nutriju audzēšanu un kopšanu. [website], https://www.la.lv/nutriju-atgriesanas, (accessed 15 January 2021).

Latvijas Stādi, [website], http://latvijasstadi.lv/lv, (accessed 9 January 2021).

Mājās turēts jenots - virtuozs svešu mantu iegūšanā. 2018. [website], https://www.lsm.lv/raksts/dzive--stils/vide-un-dzivnieki/majas-turets-jenots-virtuozs-svesu-mantu-iegusana.a270068/, (accessed 15 January 2021).

Nature Conservation Agency, [website], https://www.daba.gov.lv/lv, (accessed 9 January 2021).

NOBANIS, [website], https://www.nobanis.org/, (accessed 9 January 2021).

Ozoli stādaudzētava, [website], www.ozolistadaudzetava.lv, (accessed 9 January 2021).

Putni.lv, [website], http://www.putni.lv/, (accessed 15 January 2021).

Stādīsim.lv, [website], http://stadisim.lv/, (accessed 9 January 2021).

State Forest Service, [website], https://www.vmd.gov.lv/, (accessed 15 January 2021).

State Plant Protection Service of the Republic of Latvia, [website], https://www.vaad.gov.lv/, (accessed 9 January 2021).

The Ministry of Environmental Protection and Regional Development of the Republic of Latvia, [website], https://www.varam.gov.lv/lv, (accessed 9 January 2021).

Ziņkārīgais draugs jenots. 2012. [website], https://www.la.lv/zinkarigais-draugs-jenots%E2%80%A9-2, (accessed 15 January 2021).

Appendix 1

Species of the EU List. The impact value, occurrence in the wild and establishment of invasive alien species in Latvia. Abbreviations: low risk species (total score 1-6; white); medium risk species (7-9; grey) and high risk species (10-12; dark grey).

Group	Species	Dispersion potential	Colonization of high conservation value habitats	Adverse impacts on native species	Alteration of ecosystem functions	Impact value	Registered in Latvia	Establishment in Latvia
Mammals	*Nyctereutes procyonoides*	1	3	2	1	7	1	5
	Ondatra zibethicus	1	3	1	1	6	1	5
	Myocastor coypus	2	0	0	0	2	1	3
	Procyon lotor	3	3	3	2	11	0	4
	Callosciurus erythraeus	3	3	3	2	11	0	2
	Sciurus carolinensis	3	3	3	2	11	0	3
	Sciurus niger	3	3	3	2	11	0	2
	Tamias sibiricus	2	3	2	2	9	0	3
	Herpestes javanicus	3	3	3	2	11	0	1
	Nasua nasua	3	3	3	2	11	0	1
	Muntiacus reevesi	3	3	3	3	12	0	2
Birds	*Acridotheres tristis*	2	1	1	1	5	0	1
	Alopochen aegyptiacus	3	0	0	0	3	1	3
	Corvus splendens Viellot	1	1	1	1	4	0	2
	Oxyura jamaicensis	3	2	3	2	10	0	1
	Threskiornis aethiopicus	3	3	3	2	11	0	1
Reptiles	*Trachemys scripta*	2	2	2	1	7	1	3
Amphibians	*Lithobates (Rana) catesbeianus*	3	2	3	2	10	0	3
Fish	*Lepomis gibbosus*	2	2	3	2	9	0	2
	Perccottus glenii	1	1	2	2	6	1	4
	Plotosus lineatus	2	2	2	2	8	0	1
	Pseudorasbora parva	3	2	3	2	10	0	2
Arthropods	*Eriocheir sinensis*	1	2	1	1	5	1	4
	Orconectes limosus	2	2	2	0	6	1	4
	Orconectes virilis	3	3	3	1	10	0	1
	Pacifastacus leniusculus	1	2	2	0	5	1	4
	Procambarus clarkii	3	3	3	2	11	0	1

	Procambarus fallax	3	1	2	1	7	0	1
	Vespa velutina nigrithorax	3	0	3	0	6	0	2
Group	Species	Dispersion potential	Colonization of high conservation value habitats	Adverse impacts on native species	Alteration of ecosystem functions	Impact value	Registered in Latvia	Establishment in Latvia
Worms	*Arthurdendyus triangulatus*	3	0	2	2	7	0	4
Angiosperms/ Aquatic species	*Elodea nuttallii*	3	3	3	3	12	0	4
	Alternanthera philoxeroides	2	2	3	3	10	0	1
	Cabomba caroliniana	3	2	3	2	10	0	3
	Hydrocotyle ranunculoides	3	2	3	3	11	0	3
	Gymnocoronis spilanthoides	3	2	3	3	11	0	1
	Lagarosiphon major	3	2	3	3	11	0	2
	Ludwigia peploides	3	2	3	3	11	0	2
	Lysichiton americanus	2	2	3	3	10	0	3
	Myriophyllum aquaticum	3	2	3	3	11	0	1
	Eichhornia crassipes	3	2	3	3	11	0	1
	Ludwigia grandiflora	3	2	3	3	11	0	2
	Myriophyllum heterophyllum	3	2	3	3	11	0	3
	Salvinia molesta	3	2	3	3	11	0	1
Angiosperms/ Terrestrial species	*Heracleum sosnowskyi*	3	3	3	3	12	1	5
	Impatiens glandulifera	3	3	3	3	12	1	5
	Acacia saligna	3	2	3	2	10	0	1
	Ailanthus altissima	3	2	3	3	11	0	3
	Baccharis halimifolia	3	2	3	3	11	0	3
	Cardiospermum grandiflorum	3	2	3	3	11	0	1
	Cortaderia jubata	3	2	3	3	11	0	1
	Gunnera tinctoria	3	2	3	3	11	0	2
	Heracleum mantegazzianum	3	2	3	3	11	0	4
	Lespedeza cuneata	3	2	3	3	11	0	1
	Lygodium japonicum	3	2	3	3	11	0	1
	Andropogon virginicus	3	2	3	3	11	0	1
	Asclepias syriaca	3	2	3	3	11	0	4
	Ehrharta calycina	3	2	3	3	11	0	1
	Heracleum persicum	3	1	3	3	10	0	4
	Humulus scandens	3	3	3	3	12	0	3
	Microstegium vimineum	3	2	3	3	11	0	1

	Parthenium hysterophorus	3	2	3	3	11	0	1
Group	Species	Dispersion potential	Colonization of high conservation value habitats	Adverse impacts on native species	Alteration of ecosystem functions	Impact value	Registered in Latvia	Establishment in Latvia
	Pennisetum setaceum	3	2	3	3	11	0	1
	Persicaria perfoliata	2	2	3	3	10	0	1
	Prosopis juliflora	3	2	3	3	11	0	1
	Pueraria montana	2	2	3	3	10	0	1
	Triadica sebifera	3	2	3	3	11	0	1

Appendix 2

Type of introduction, pathway of introduction and frequency of IAS of animals. The species that are registered in the wild in Latvia are shown in the bold.

Species/ Terrestrial species	**Nyct pro**	**Onda zib**	**Myoc coy**	Proc lot	Call ery	Sciu car	Sciu nig	Tami sib	Herp jav	Nasu nas	Munt ree	Acri tri	**Alop aeg**	Corv spl	Oxyu jam	Thre aet	Vesp vel	Arth tri
Type of introduction																		
Intentionally									1									
Unintentionally		1	1	1								1		1		1	1	1
Intentionally/ unitentionally	1				1	1	1	1		1	1		1		1			
Pathway of introduction																		
Agriculture																		1
Angling/Sport																		
Animal husbandry																		0,33
Biological Control									1									
Escape			1	1	1	0,33	0,66	1		0,33	1	0,33	1		0,66	0,66		
Forestry																	0,33	
Horticulture																	1	1
Hunting	0,33						1				1							
Landscaping																		0,33
Secondary introduction	1	1			0,33	1	1	1		1	1						0,66	
Transport																	1	1
Other (soil, ornamental purposes)						1	1	1	0,33								1	1
Commodity contaminants																	0,66	1
Not known																		

Species/ Aquatic species	**Trac scr**	Lith cat	Lepo gib	**Perc gle**	Plot lin	Pseu par	**Erio sin**	**Orco lim**	Orco vir	**Paci len**	Proc cla	Proc fal
Type of introduction												
Intentionally	1											
Unintentionally			1		1	1	1					
Intentionally/ unitentionally		1		1				1	1	1	1	1
Pathway of introduction												
Angling/Sport				1					1		1	
Aquaculture		1		1		1				1	1	
Aquaria	1			1	1				1		1	1
Ballast water and sediments			1				1					
Biological Control											0,33	
Secondary introduction		1		0,33	0,33							
Other (soil, ornamental purposes)									0,33			

Appendix 3

Vectors of introduction and frequency of IAS of animals for species for which vectors has been defined. The species that are registered in the wild in Latvia are shown in the bold.

Species	**Myoc coy**	Proc lot	Call ery	Sciu car	Sciu nig	Tami sib	Nasu nas	Munt ree	Acri tri	**Alop aeg**	Corv spl	**Trac scr**	Lith cat	**Perc glen**	Vesp vel	Arth tri	Orco vir	Proc cla
Fruits and vegetables																1		
Plants with roots (Agriculture)																1		
Other (Agriculture)																1		
Fishing material														1			1	1
Breeding farms						0,33				1			1	1				
Confinement							0,33	1										
Farms	1																	
Pets	1	1	1	0,33	1	1	0,33		0,33			1						
Research					0,33												0,33	
Zoo		1	1	0,33	0,33	0,33	0,33	0,33	0,33	1								
Timber (Round wood) Forestry															0,33			
Wood packaging material Forestry															0,33			
Cut flowers and branches Horticulture																1		
Plants with roots (Incl. Pot plants) Horticulture															1	1		
Other Horticulture															0,33			
Plants with roots (Incl. Pot plants) Landscaping																0,33		
Agricultural machinery															0,66	1		
Aircraft/cur/truck/train/ship/leisure boat											0,33				1	0,33		
Packaging material (Except wood packaging material)															1			
Soil																1		

Appendix 4

Mode of entry of IAS of animals and plants. The species that are registered in the wild in Latvia are shown in the bold.

Group	Species	**Mode of Entry**						
		Release	Escape	Contaminant	Stowaway	Corridor	Unaided	Not known
Mammals	***Nyctereutes procyonoides***	1					1	
	Ondatra zibethicus						1	
	Myocastor coypus		1					
	Procyon lotor		1					
	Callosciurus erythraeus		1					
	Sciurus carolinensis	1	1					
	Sciurus niger	1	1					
	Tamias sibiricus	1	1					
	Herpestes javanicus	1			1		1	
	Nasua nasua	1	1					
	Muntiacus reevesi	1	1					
Birds	*Acridotheres tristis*		1					
	Alopochen aegyptiacus	1	1					
	Corvus splendens Viellot				1			
	Oxyura jamaicensis	1	1					
	Threskiornis aethiopicus		1					
Reptiles	***Trachemys scripta***		1				1	
Amphibians	*Lithobates (Rana) catesbeianus*	1	1				1	
Fish	*Lepomis gibbosus*				1			
	Perccottus glenii		1					
	Plotosus lineatus		1			1	1	
	Pseudorasbora parva		1					
Arthropods	***Eriocheir sinensis***				1			
	Orconectes limosus							1
	Orconectes virilis	1	1					
	Pacifastacus leniusculus	1						
	Procambarus clarkii	1	1					
	Procambarus fallax		1					
	Vespa velutina nigrithorax				1		1	
Worms	*Arthurdendyus triangulatus*			1	1			

Angiosperms/ Aquatic	*Species*	**Mode of Entry**						
		Release	Escape	Contaminant	Stowaway	Corridor	Unaided	Not known
	Elodea nuttallii		1	1	1	1	1	
	Alternanthera philoxeroides		1	1	1	1	1	
	Cabomba caroliniana		1	1	1	1	1	
	Hydrocotyle ranunculoides		1	1	1	1	1	
	Gymnocoronis spilanthoides		1	1	1	1	1	
	Lagarosiphon major		1	1	1	1	1	
	Ludwigia peploides		1	1	1	1	1	
	Lysichiton americanus		1	1		1	1	
	Myriophyllum aquaticum		1	1	1	1	1	
	Eichhornia crassipes		1		1	1	1	
	Ludwigia grandiflora		1	1	1	1	1	
	Myriophyllum heterophyllum		1	1	1	1	1	
	Salvinia molesta		1	1	1	1	1	
Angiosperms/ Terrestrial species	***Heracleum sosnowskyi***	1	1	1	1	1	1	
	Impatiens glandulifera	1	1	1	1	1	1	
	Acacia saligna	1	1	1		1	1	
	Ailanthus altissima	1	1		1	1	1	
	Baccharis halimifolia	1	1	1	1	1	1	
	Cardiospermum grandiflorum		1	1			1	
	Cortaderia jubata		1		1	1	1	
	Gunnera tinctoria		1	1		1	1	
	Heracleum mantegazzianum		1	1	1	1	1	
	Lespedeza cuneata		1			1	1	
	Lygodium japonicum		1	1	1		1	
	Andropogon virginicus		1	1	1	1	1	
	Asclepias syriaca		1					1
	Ehrharta calycina		1		1	1	1	
	Heracleum persicum		1	1	1	1	1	
	Humulus scandens		1			1	1	
	Microstegium vimineum			1	1	1		
	Parthenium hysterophorus			1	1		1	
	Pennisetum setaceum		1	1	1	1	1	
	Persicaria perfoliata			1	1		1	
	Prosopis juliflora		1	1			1	1
	Pueraria montana		1				1	
	Triadica sebifera		1				1	1

Appendix 5

Type of introduction, pathway of introduction and frequency of IAS of plants. The species that are registered in the wild in Latvia are shown in the bold.

Species/Aquatic plants	Elod nutt	Alte phil	Cabo caro	Hydr ranu	Gymn spil	Laga majo	Ludw pepl	Lysi amer	Myri aqua	Eich cras	Ludw gran	Myri hete	Salv mole
Type of introduction													
intentionally	1	1	1	1	1	1	1	1	1	1	1	1	1
unintentionally	1	1	1	1	1	1	1	1	1	1	1	1	1
Pathway of introduction													
Agriculture		0,33											
Angling/Sport	0,33	0,33	0,66			0,66	0,66		0,66	0,66	0,66	0,66	0,66
Aquaculture			0,66			0,66	0,66		0,66		0,66	0,66	0,66
Aquaria, domestic	1	1	1	1	1	1	0,66		1			1	1
Ballast water and sediments		1											
Escape							0,33	0,33		0,33	0,33	0,33	0,66
Horticulture	1	1	1	1	1	1	1	1	1	1	1	1	1
Landscaping								0,66				1	
Medicinal		0,33											
Transport	0,66	1	0,66	0,66	0,66	1	0,66		0,66	0,66	0,66	0,66	0,66
Secondary introduction	0,66	1	0,66	0,66	0,66	1	1	0,66	1	0,66	0,66	1	1
Ohters (Soil contaminant)		0,33											

Species/ Terrestrilal plants	**Hera sosn**	**Impa glan**	Acac sali	Aila alti	Bacc hali	Card gran	Cort juba	Gunn tinc	Hera mant	Lesp cune	Lygo japo	Andr virg	Ascl syri	Ehrh caly	Hera pers	Humu scan	Micr vimi	Part hyst	Penn seta	Pers perf	Pros juli	Puer mont	Tria sebi
Type of introduction																							
intentionally	1	1	1	1	1	1	1	1	1	1	1		1		1	1			1	1		1	1
unintentionally												1	1	1	1	1	1	1	1	1	1		1
Pathway of introduction																							
Agriculture	1						0.33		1	0.66		0.66	0.33	1			0.66	0.66			0.66	1	
Ballast water and sediments																				1			
Escape		0.33	1	1			0.33		0.66		0.66	0.66			1	0.33	0.33				0.66		0.66
Forestry			1	1							0.66	0.66					0.33				0.66		0.66
Horticulture	0.66	0.66	1	1	1	1	1	1	1		1		1		1	1	0.33	0.33	1	1	0.66	1	0.66
Landscaping			1	0.66	0.33		1			1		0.33		0.66		0.33			0.66		0.66	0.66	0.66
Medicinal				0.33							0.33							0.33					
Transport	0.66	0.66		0.66	0.33	0.33	0.66		0.66		1	0.66		0.66	0.66		0.66	1	1				
Secondary introduction	1	1	0.66	1	1	1	1	1	1	1	1	1	0.33	1	1	0.66	1	1	1	0.66	1	0.33	1
Others (Contaminant Soil)	0.66	0.33	0.66		0.33	0.66		0.66	0.66						0.66		0.33			0.33			

Appendix 6

Vectors of introduction and frequency of IAS of plants. The species that are registered in the wild in Latvia are shown in the bold.

Species/ Aquatic plants	Elod nutt	Alte phil	Cabo caro	Hydr ranu	Gymn spil	Laga majo	Ludw pepl	Lysi amer	Myri aqua	Eich cras	Ludw gran	Myri hete	Salv mole
Fishing equipments	0,33	0,33	0,66			0,66	0,66		0,66	0,66	0,66	0,66	0,66
Botanical gardens, Aquarim, Zoo (Escape)							0,33	0,33		0,33	0,33	0,33	0,66
Other (Horticulture)	1	1	1	1	1	1	1	1	1	1	1	1	1
Plants with roots (Horticulture)				1			1	1					
Agriculture/Aquaculture machinery	0,66	0,66	0,66	0,66	0,66	0,66	0,66		0,66	0,66	0,66	0,66	0,66
Aircraft/ship/leisure boat	0,66	1	0,66	0,66	0,66	1	0,66		0,66	0,66	0,66	0,66	0,66
Clothes, footwear		0,33					0,66					0,33	0,33

Species/ Terrestrial plants	**Hera sosn**	**Impa glan**	Acac sali	Aila alti	Bacc hali	Card gran	Cort juba	Gunn tinc	Hera mant	Lesp cune	Lygo japo	Andr virg	Ascl syri	Ehrh caly	Hera pers
Grain															
Seeds (Agriculture)	1													1	
Stored products (Other than grain)							0,33								
Other (Agriculture)									1	0,66		0,66	0,33		
Botanical gardens, Aquarim, Zoo (Escape)		0,33					0,33		0,66						1
Research (Escape)															
Plants with roots (Incl, Pot plants)					1										
Seeds (Horticulture)	0,66	0,66			1	1									
Other (Horticulture)			1	1	1	1	1	1	1		1		1		1
Erosion Control/ dune stabilization			1	0,66			1			1				0,66	
Other (Landscaping)					0,33							0,33			
Agriculture/Aquaculture machinery														0,66	
Aircraft/car/truck/train/ship/leisure boat	0,66	0,66		0,66	0,33		0,66		0,66		1	0,66			0,6
Military												0,66			0,33
Packaging material (Except wood packaging material)															
Peoples baggage									0,33						
Clothes, footwear	0,33	0,33				0,33			0,33			0,66			0,66
Soil	0,66	0,33	0,66		0,33	0,66		0,66	0,66						0,66

Species/ Terrestrial plants	Humu scan	Micr vimi	Part hyst	Penn seta	Pers perf	Pros juli	Puer mont	Tria sebi
Grain			0,66					
Seeds (Agriculture)								
Stored products (Other than grain)								
Other (Agriculture)		0,66				0,66	1	
Botanical gardens, Aquarim, Zoo (Escape)	0,33							
Research (Escape)						0,33		
Plants with roots (Incl, Pot plants)								
Seeds (Horticulture)				1				
Other (Horticulture)	1	0,33	0,33		1	0,66	1	0,66
Erosion Control/ dune stabilization				0,66			0,66	0,66
Other (Landscaping)	0,33					0,66		
Agriculture/Aquaculture machinery		0,66	1	0,33				
Aircraft/car/truck/train/ship/leisure boat			1	1				
Military								
Packaging material (Except wood packaging material)		0,66	0,33					
Peoples baggage								
Clothes, footwear			0,33					
Soil		0,33			0,33			