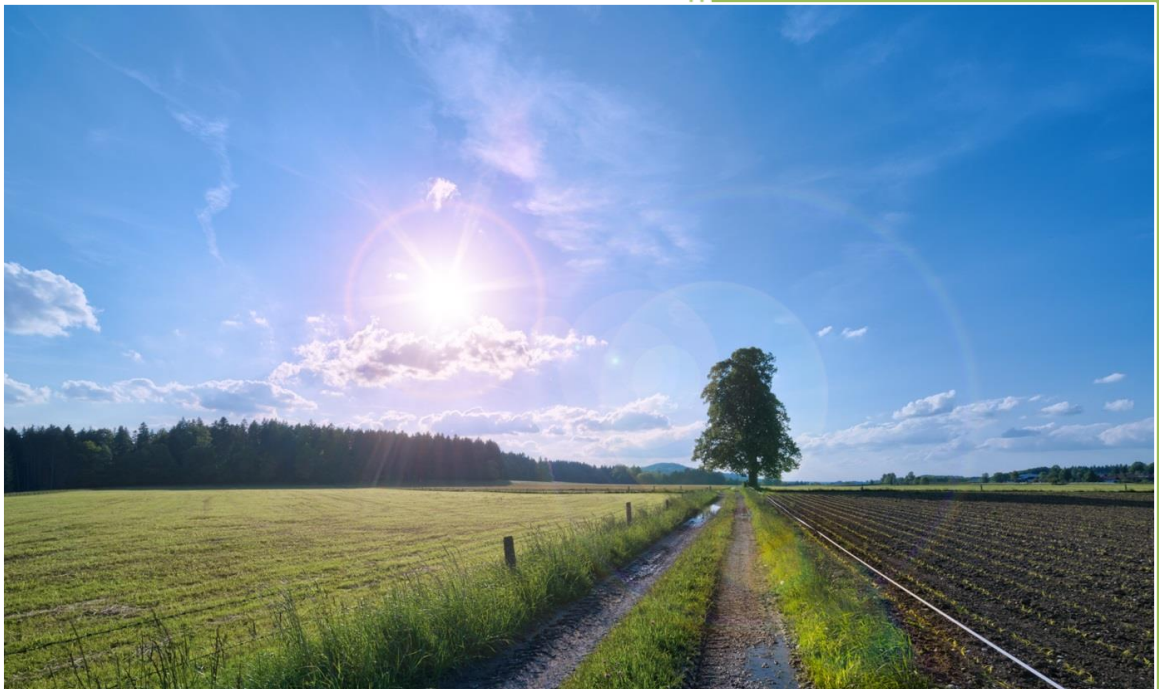


# 2014

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21<sup>st</sup> May 2014

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Commissioned by  
Office for Risk Assessment and Research  
(Invasive Alien Species Team)  
Netherlands Food and Consumer Product Safety Authority  
Ministry of Economic Affairs



Radboud University Nijmegen



# Series of Reports on Environmental Science

The series of reports on Environmental Science are edited and published by the Department of Environmental Science, Institute for Water and Wetland Research, Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands (tel. secretariat: + 31 (0)24 365 32 81).

## Reports Environmental Science nr. 461

Title: Horizonscanning for new invasive non-native species in the Netherlands  
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Cover photo: After the rain (Andreas Krappweis)

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Project number: 62001981  
Client: Netherlands Food and Consumer Product Safety Authority, P.O. Box 43006, 3540 AA Utrecht

Reference client: NVWA, order nr. 60001903, d.d. November 22, 2013

Orders: Secretariat of the Department of Environmental Science, Faculty of Science, Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, the Netherlands, e-mail: secre@science.ru.nl, mentioning Reports Environmental Science nr. 461

Key words: Ecological effects, dispersal, exotic species, pathways, risk assessment, vectors, risk management.

Printed on environmentally friendly paper

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# Contents

- 1. Introduction ..... 7
  - 1.1 Background and problem statement..... 7
  - 1.2 Research goals..... 7
  - 1.3 Outline and coherence of research ..... 8
- 2. Methods ..... 9
  - 2.1 Contributing experts ..... 9
  - 2.2 Compilation of risk prioritised species lists that fulfil the horizonscan criteria ..... 9
    - 2.2.1 Identification of non-native species fulfilling criteria 1, 2 and 3 of the horizonscan .....11
    - 2.2.2 Compilation of the list of (opportunistic) species with ecological risk scores from climatically similar countries.....14
    - 2.2.3 Combining of list one and two species .....21
    - 2.2.4 Species risk prioritisation .....21
    - 2.2.5 List of potentially invasive species for the Netherlands .....22
  - 2.3 Compilation of the horizonscan database ..... 23
    - 2.3.1 Scientific name .....23
    - 2.3.2 Species group .....23
    - 2.3.3 Taxonomic group .....23
    - 2.3.4 Synonyms.....24
    - 2.3.5 Common English names.....24
    - 2.3.6 Dutch common name .....24
    - 2.3.7 Naturalis non-native species classification .....24
    - 2.3.8 General group .....24
    - 2.3.9 Occurrence in the Netherlands .....25
    - 2.3.10 Native range .....25
    - 2.3.11 Non-native range .....25
    - 2.3.12 Preferred EUNIS habitat type .....25
    - 2.3.13 (Other) habitat types .....26
    - 2.3.14 Most risky areas of origin .....26
    - 2.3.15 Pathways.....26
    - 2.3.16 Vectors.....27
    - 2.3.17 Primary hotspots.....27
    - 2.3.18 Secondary hotspots .....27
    - 2.3.19 Potential socio-economic and ecological impacts.....28

2.3.20	Risk score.....	28
2.3.21	Key references .....	28
2.4	Metadata analysis.....	28
2.4.1	Pathways.....	29
2.4.2	Impacts .....	29
2.4.3	Species origin.....	29
3.	Results.....	30
3.1	Summary of species meeting the horizonscan criteria.....	30
3.2	Metadata analysis.....	31
3.2.1	Overview of potentially invasive and ecologically harmful species in the Netherlands .	31
3.2.2	Geographical origins of most concern.....	33
3.2.3	Pathways of most concern .....	34
3.2.4	Ecological impacts of most concern .....	39
4.	Discussion .....	43
4.1	Gaps in knowledge and uncertainties .....	43
4.2	Geographical origins of most concern .....	46
4.3	Pathways of most concern .....	46
4.4	Ecological impacts of most concern .....	50
4.5	Options for prevention .....	52
4.5.1	Relevant pathways.....	52
4.5.2	Prevention .....	53
5.	Conclusions and recommendations .....	56
6.	Acknowledgements .....	58
7.	References .....	59
8.	Glossary.....	66
	Appendix 1. Overview of information sources .....	67
	Appendix 2. List of non-native bird species present in the Netherlands in 2004-2013 based on waarneming.nl.....	68
	Appendix 3. Pathway definitions.....	80
	Appendix 4. Species selected by contributing experts fulfilling the horizonscan criteria .....	95
	Appendix 5. List of potentially invasive species in the Netherlands .....	110
	Appendix 6. Eradication through monitoring and early intervention.....	113

# Summary

## *Introduction*

According to the Dutch species register there are 2011 non-native species present in the Netherlands. Moreover, a number of non-native species that are established in climatically similar countries may be transported to and potentially colonise the Netherlands. A number of these species are invasive. In 2013, the European Commission published a policy proposal for the prevention and management of invasive alien species introduction and spread. The document proposes three intervention types: prevention, early warning and rapid response, and management.

To allow the effective prioritisation of preventative measures and early eradication of potentially invasive - non-native species in the Netherlands, insight is required into the species that can access the Netherlands via relevant pathways and establish here. Therefore, the Dutch Office of Risk Assessment and Research Planning of the Netherlands Food and Consumer Product Safety Authority (NVWA) requires that a horizonscanning project is carried out. The horizonscan identifies potential invasive non-native species in the Netherlands and assesses the relative risk posed by each species, including information about their origin, vectors and pathways. In addition, an overview is given of potentially effective approaches for prevention that address the most commonly occurring dispersal pathways and vectors.

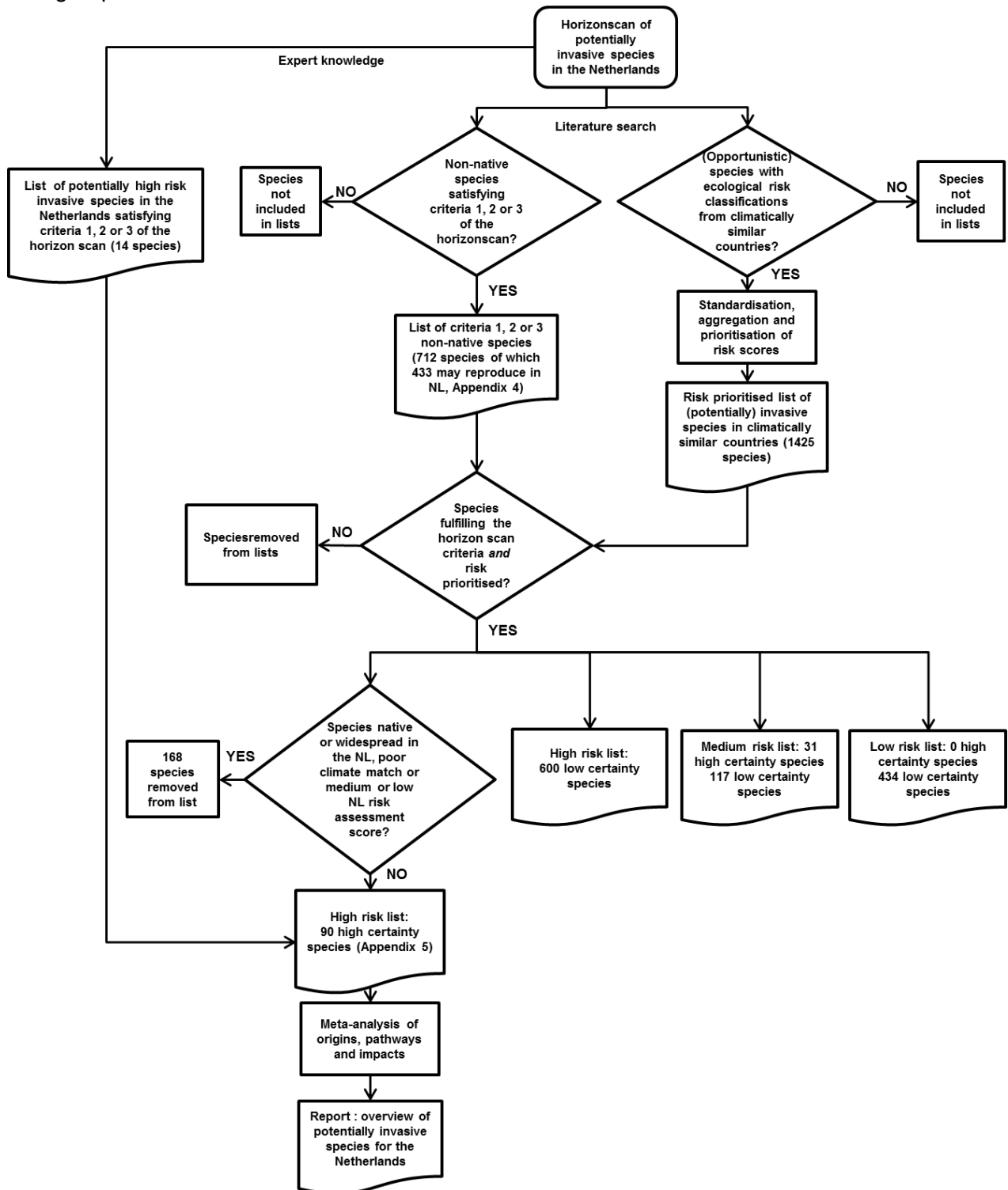
## *Materials and methods*

The horizonscan was carried out by compiling two separate species lists which were subsequently combined (Figure S.1). List one was comprised of non-native species that fulfilled the following three criteria:

- 1) The non-native species has, to date, not been recorded in the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.
- 2) The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.
- 3) The non-native species shows a limited distribution in Dutch nature that make it amenable to eradication.

List two was comprised of species assigned ecological risk classifications in countries with similar climates to the Netherlands and opportunistic species. Individual risk classifications were collected on invasive species present on national lists and horizonscans from Germany, Belgium, Northern France, Denmark, the United Kingdom and Ireland. An additional list was obtained for the Great Lakes of North America, a potential source of non-native species in the Netherlands. The risk classifications attributed to each of these species were then given a standardised score to allow comparisons between scores of the same species. Scores ranged from one (low risk) to three (high risk). The standardised scores were then aggregated by calculating the average score for each species. The average risk score was assumed to represent the risk that the species posed if it were to establish in the Netherlands. Average risk scores were then ranked (prioritised) from high to low and accorded a measure of certainty.

Certainty was defined according to the number of individual risk classifications used to calculate the average risk score. Species assigned medium and high average risk scores were given a high certainty rating if two or more individual risk classifications were used to calculate the average score. Species assigned a low average risk score were given a high certainty rating if four or more individual risk classifications were used to calculate the average score. All other species were assigned to the low certainty group.



**Figure S.1:** Flowchart describing the compilation of the risk prioritised non-native species lists for the Netherlands.

Lists one and two were then compared and combined to produce a single list of species with risk scores classified according to the horizonscan criteria. Species not occurring on both lists were therefore removed. The combined list was then divided into six sub lists according to species average risk score and certainty ranking (high risk, high certainty; high risk, low certainty; medium risk, high certainty; medium risk, low certainty; low risk, high certainty and low risk, low certainty). High risk, high certainty species that, according to expert judgement, did not fulfil the horizonscan criteria and were considered unlikely to successfully establish in the Netherlands because of a poor climate match were subsequently removed. However, not all species fulfilling the horizonscan criteria and posing a potentially high ecological risk to the Netherlands are included in foreign horizonscans and lists. Therefore, a number of species known, according to expert knowledge, to pose a high potential ecological risk to the Netherlands and fulfilling the criteria of the horizonscan were also added to the high risk, high certainty list. A review of Dutch risk assessments provided additional species classified as high risk that were added to the list if they satisfied the horizonscan criteria. Moreover, species already present on the high risk, high certainty list but receiving a low or medium risk score in a Dutch risk assessment were either removed, or additional justification for their presence was sought from experts. The resulting high risk, high certainty list includes species that are potentially invasive in the Netherlands.

The species contained on the list of potentially invasive species in the Netherlands were then examined by querying a number of invasive species databases (Appendix 1) and reviewing available literature including Dutch, English and Belgian risk assessments. The origins, pathways, impacts and primary and secondary hotspots associated with each species were reviewed and inserted in a database. Information within the database was then analysed in a meta-analysis to determine the most important origins, pathways, impacts and primary and secondary hotspots. Finally, a discussion of potentially effective measures for prevention with reference to the most important pathways for list species is presented.

### *Results*

In total 712 species met the horizonscan criteria prior to the assessment of ecological risk (list one). Of these, 433 species were considered able to reproduce in the Netherlands. 23 species could possibly fulfil the horizonscan criteria but a lack of information meant that this could not be stated with certainty. The likelihood of these species establishing in the Netherlands is lower.

1425 species were risk prioritised according to species potentially invasive in countries with similar climates to the Netherlands and opportunistic species (list two).

Following the removal of species not fulfilling the criteria of the horizonscan and a review of Dutch risk assessments, 76 species were prioritised as high risk, high certainty. 14 additional non-native species were suggested for addition to the list by the contributing experts. The horizonscan list of potentially invasive species for the Netherlands therefore contains a total of 90 species that fulfil the criteria of the horizonscan and may cause significant ecological damage in the Netherlands (Appendix 5).



600 species were allocated to the high risk, low certainty list; 31 species were allocated to the medium risk, high certainty list; 117 species were allocated to the medium risk, low certainty list; 0 species were allocated to the low risk, high certainty list and 434 species were allocated to the low risk, low certainty list. Due to space limitations, these lists are presented in a separate excel file.

#### *Conclusions and recommendations*

The results from the meta-analyses highlight the importance of the intentional trading as a pathway for the introduction of non-native animal and plant species to the Netherlands. For species groups listed as potentially invasive species for the Netherlands, the most frequently occurring pathways are the pet and aquarium trade, ornamental pathway, horticulture and the botanical/garden/zoo/aquaria pathway. Considering species listed and currently absent from the Netherlands (criterion 1), the most likely pathways include hitchhiking on a ship or boat, utilising interconnected waterways/basins/seas, intentional release or escape from botanical gardens, zoos or aquaria or transport with habitat material. The pet and aquarium, ornamental and botanical garden/zoo/aquaria pathways were related to the highest number of ecological impacts recorded in available literature. Freshwater animals were associated with the highest number of impacts of high risk species followed by terrestrial animals and terrestrial plants.

The geographical origins of most concern for non-native species present on the list of potentially invasive species for the Netherlands are Asia and North America. Asia is likely to supply the most terrestrial animal and plant species, while North America will probably be the source of most freshwater and marine animals.

A number of recommendations are made. Comparing international risk classifications is hindered by the different methods used by separate nations. It is recommended that non-native species risk assessments are standardised to allow for direct comparisons between national risk classifications. Globally, there is a constant flow of new data describing the characteristics of non-native species and their potential invasiveness. It is recommended that the horizonscan is updated on a regular basis to take into account future assessments of ecological risk, particularly in the case of species where, to date, no assessment has been undertaken. During the course of the horizonscan, it was difficult to establish where the impacts of species' occurred in their non-native range. It is recommended that research undertaken regarding the impacts of invasive species also considers the geographical location where impacts occur. Finally, because of a lack of data, it is recommended that non-native species that breed incidentally and whose possible impacts feature a high degree of uncertainty are monitored alongside non-native species identified as high risk.

# 1. Introduction

## 1.1 Background and problem statement

According to the Dutch species register there are 2011 non-native species present in the Netherlands (Naturalis Biodiversity Center, 2014). Moreover, a number of non-native species that are established in climatically similar countries may be transported to and potentially colonise the Netherlands. A number of these species are invasive. For the purpose of this study the term invasive encompasses species that cause negative ecological impacts in a non-native range. This definition has been applied by a number of authors and forms the basis of European legislation to address invasive alien species and protect biodiversity (Molnar et al., 2008; Hellmann et al., 2008; European Commission, 2013). Measures against the establishment of non-native species have been found to be most effective at preventing negative impacts (Leung et al., 2002; Finnoff et al., 2007; Coetzee et al., 2009). If the prevention of establishment of invasive species is not possible, then the early identification and eradication of small populations is preferable to prevent negative impacts from occurring (early detection and rapid response). The European Commission has published a policy proposal for the prevention and management of invasive alien species introduction and spread. The document proposes three intervention types: prevention, early warning and rapid response, and management (European Commission, 2013).

To allow the effective prioritisation of preventative measures and early eradication, insight is required into the potentially invasive - non-native species that can access the Netherlands via relevant pathways and establish here. Therefore, the Dutch Office of Risk Assessment and Research Planning of the Netherlands Food and Consumer Product Safety Authority (NVWA) requires that a horizonscanning project is carried out. The horizonscan identifies potential new invasive non-native species in the Netherlands and assesses the relative risk posed by each species, including information about their origin, vectors and pathways. The horizonscan is particularly relevant for EU discussions concerning the European Commission's proposal for the regulation of non-native species.

## 1.2 Research goals

The research goals of this project are:

- To provide an overview of standardised aggregated risk scores, possible pathways for introduction to the Netherlands and potential ecological impacts of non-native species that (1) are invasive in other countries in the world that are climatologically similar to the Netherlands or (2) are invasive and known to establish in different climate zones and habitats (tolerant opportunist species). Selected species have to fulfil one of the following criteria:

- 1) The non-native species has, to date, not been recorded in the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.
  - 2) The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.
  - 3) The non-native species shows a limited distribution in Dutch nature that make it amenable to eradication.
- To identify non-native species that fulfil criteria 1, 2 and 3 and pose high potential risk for native species and ecosystems in the Netherlands.
  - To produce a database for potential new invasive species that pose a high potential risk including detailed information on taxonomy, occurrence in the Netherlands and surrounding countries, habitat preference, native and non-native ranges, potential origins, pathways and ecological and socio-economic impacts.
  - To undertake a meta-analysis that will rank the most common origins, dispersal pathways, vectors, hotspots for introduction, and potential ecological impacts of potential new invasive species contained in the database. This will facilitate species prioritisation of management interventions.
  - To provide an overview of possible preventive management interventions that address the most commonly occurring dispersal pathways and vectors identified during the meta-analysis.

### **1.3 Outline and coherence of research**

The problem statement, goals and research questions relevant to a horizonscan of non-native species in the Netherlands are described above. This section describes the outline of the report and coherence of various research activities for the horizonscan. Chapter 2 describes (1) the methodological framework of the project, (2) the different experts and organisations involved in the horizonscan, (3) the compilation of the risk prioritised species lists that fulfil the horizonscan criteria and the list of potentially invasive species for the Netherlands, (4) the compilation of the horizonscan database. Chapter 3 gives an overview of species that fulfil the criteria of the horizonscan, the results of the meta-analysis containing an overview of species assigned the highest aggregated risk scores, pathways and vectors of most concern, impacts of most concern, origins of high risk species, and analysis of weighted versus average aggregated risk scores. Chapter 4 discusses gaps in knowledge and uncertainties, and the most important dispersal pathways and impacts of high risk species. Chapter 5 draws conclusions and gives recommendations for further research. An appendix contains background information on the standardisation of risk classifications and the risk assessment and prioritisation protocols analysed, definitions of dispersal pathways, details of individual species that satisfy the criteria of the horizonscan and a non-exhaustive list of suggestions for possible management interventions to curb invasive species in the Netherlands.

## 2. Methods

### 2.1 Contributing experts

A group of experts from participating organisations in the Netherlands Centre of Expertise on Exotic Species (NEC-E) was brought together to provide expert advice during the project (Table 2.1). These organisations consist of a number of specialist nature consultancy organisations (Bargerveen Foundation, Natuurbalans-Limes Divergens), organisations specialising in field surveys and data compilation, utilizing a network of volunteers (Bureau van de Zoogdierverseniging, RAVON, SOVON, FLORON) and the Radboud University Nijmegen. Based on their expertise, each organisation was assigned to a species group featured within the horizonscan. Throughout the duration of the project, the experts were responsible for assisting with the compilation of species lists, for providing advice on and filling knowledge gaps in the dataset and contributed to the present report.

**Table 2.1:** Organisations providing expert knowledge during the Horizonscan project.

Organisation name	Weblink	Speciality
SOVON	<a href="http://www.sovon.nl">www.sovon.nl</a>	Birds
RAVON	<a href="http://www.ravon.nl">www.ravon.nl</a>	Reptiles, amphibians
Stichting Bargerveen	<a href="http://www.stichtingbargerveen.nl">www.stichtingbargerveen.nl</a>	Invertebrates
Bureau van de Zoogdierverseniging	<a href="http://www.zoogdierverseniging.nl">www.zoogdierverseniging.nl</a>	Mammals
Natuurbalans-Limes Divergens	<a href="http://www.natuurbalans.nl">www.natuurbalans.nl</a>	Fish
FLORON	<a href="http://www.FLORON.nl">www.FLORON.nl</a>	Plants
Radboud University Nijmegen, IWWR	<a href="http://www.ru.nl/iwvr/">www.ru.nl/iwvr/</a>	Freshwater and marine species, project management

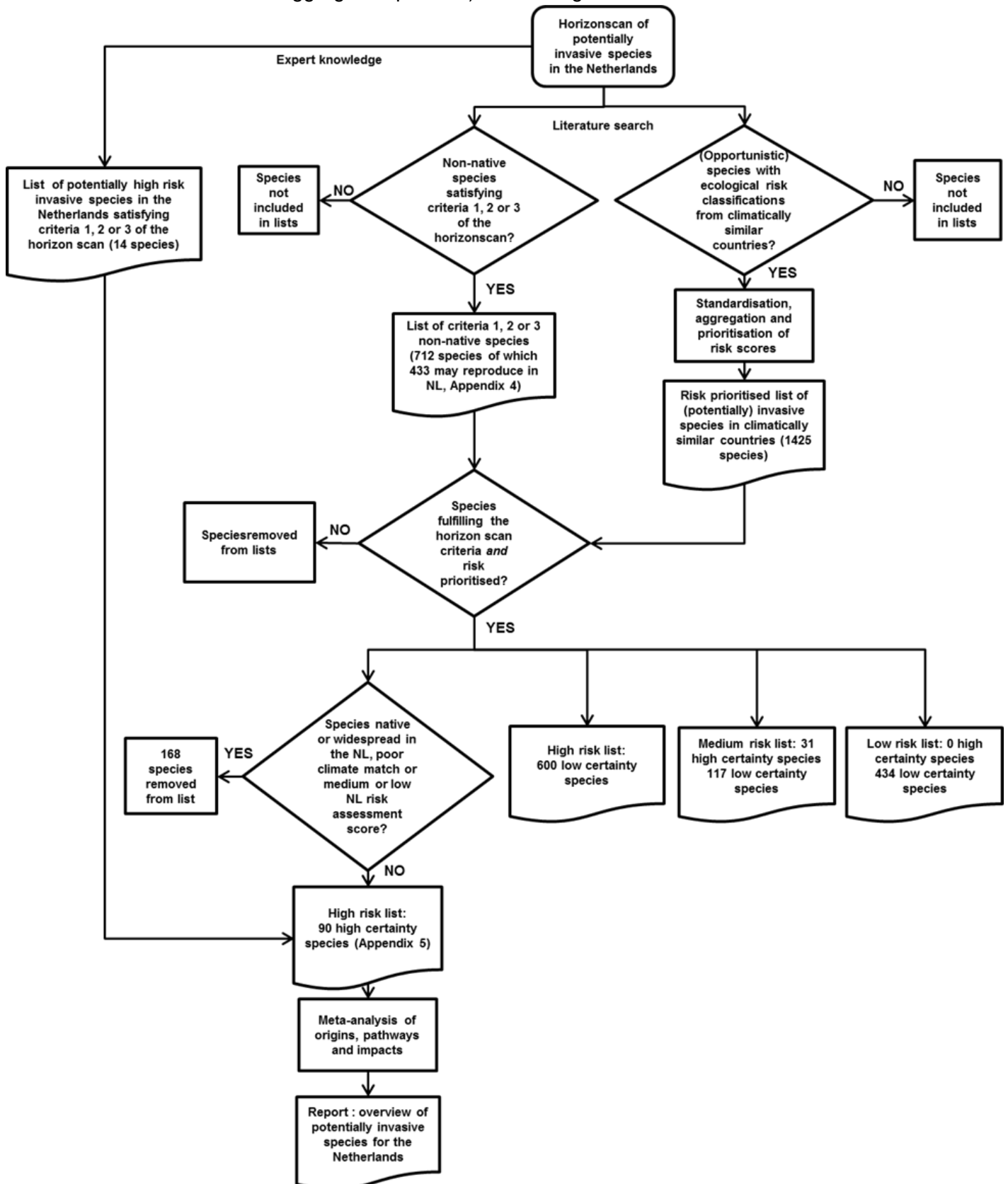
### 2.2 Compilation of risk prioritised species lists that fulfil the horizonscan criteria

The compilation of risk prioritised species lists that fulfil the horizonscan criteria was carried out by comparing two lists derived from a literature search (Figure 2.1). List one comprised non-native species that fulfilled the following three criteria:

- 1) The non-native species has, to date, not been recorded in the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.
- 2) The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.
- 3) The non-native species shows a limited distribution in Dutch nature that make it amenable to eradication.

List two comprised (opportunistic) species with ecological risk classifications from climatically similar countries. Individual risk classifications within this list were standardised in order to allow aggregation of risk scores. Species without a high

aggregated risk score (>2) and a high certainty score (2 or more standardised risk scores used in the aggregation process) were categorised as medium and low risk.



**Figure 2.1:** Flowchart describing the compilation of the risk prioritised non-native species lists for the Netherlands.

Lists one and two were then compared and combined to form a single list. Species not present on both lists, i.e. species not fulfilling criteria 1, 2 or 3 of the horizonscan and risk prioritised, were removed from the combined list. The combined list was then divided into six sub lists ranked according to species risk score and certainty. Sub lists were defined according to (1) high risk, high certainty; (2) high risk, low certainty; (3) medium risk, high certainty; (4) medium risk, low certainty; (5) low risk, high certainty and (6) low risk, low certainty.

The high risk, high certainty list was then screened by the expert contributors and species that are native, considered unable to establish or present in more than one or two populations in the Netherlands were removed. Moreover, a number of species not appearing on lists one and two but known, according to expert knowledge, to pose a high potential ecological risk to the Netherlands and fulfilling the criteria of the horizonscan were added. Species that are considered high risk according to a Dutch risk analysis and that fulfilled the criteria for inclusion in the horizonscan were automatically added to the high risk, high certainty list. Moreover, species already present on the high risk, high certainty list but scoring low or medium risk in a Dutch risk assessment were either removed or additional justification for their presence was sought for their high risk classification from the expert contributors. Therefore, the resulting high risk, high certainty list only includes species that are potentially invasive in the Netherlands.

### 2.2.1 Identification of non-native species fulfilling criteria 1, 2 and 3 of the horizonscan

The expert contributors applied different methods to compile the list one species according to the information at their disposal and the characteristics of the species group concerned. The most important methodological difference lay in the interpretation of limited populations for each species group (criterion 3 of the horizonscan). The methods used by different expert contributors are described in the following paragraphs.

#### *Birds*

Two different approaches were taken to compose a gross list of bird species that met criteria 1 to 3 of the horizonscan as a starting point for further assessment of the possible ecological impact.

Firstly a gross list of species was compiled based on records from waarneming.nl. A selection from the data on waarneming.nl showed that in the last ten years (2004-2013), more than 250 non-native species were recorded in the Netherlands (validated and unvalidated records). This dataset mainly consists of casual records of location, date and number of birds. There is no correction for “observer bias” and only very little information on breeding status. When a selection was made according to breeding status, only 11 species remained including three species with populations too large to meet criterion 3. The 250 species including some hybrids all meet criteria 1 & 2, but the data do not allow a good selection of species that also meet criterion 3 (limited number of populations in the Netherlands). In order to estimate which species are present only in a limited number of populations, the number of 1x1 km squares in which a species was seen in a particular year and the maximum number of 1x1 km squares in which a species was seen in one month of that same year was calculated. We excluded the species where the monthly maximum number of records was more than ten. The list of

remaining 240 species can be found in appendix 2. No further check on the exact number of locations or populations for each species or on possible breeding pairs was done. The table is sorted according to the number of 1x1 km squares (high to low) and the year. This list was not used for the selection of species likely to cause ecological damage. The list may be useful as a reference for non-native species that have been recorded in small numbers in the period 2004-2013.

In order to select species that meet criteria 1 to 3 and are also potentially invasive and likely to cause ecological damage it was decided not to start from the initial wide selection of birds as described above. This selection was only used as an additional data source to cross check information if required. Instead, available horizon scans, risk analyses, existing databases on (potentially) invasive species, additional literature and expert judgement was used to assess which species are likely to reach the Netherlands, have the potential to become invasive and are likely to have a negative impact. Two very useful publications were Lensink et al. (2013a & 2013b) and an unpublished database with information on bird species non-native to the Netherlands (G. Ottens, unpublished data). This database contains non-native bird species that (1) have been breeding in the Netherlands or (2) have been breeding in Germany, Great Britain, Belgium or France and are probably able to reach the Netherlands. This selection was narrowed down by removing species with more than 10 breeding pairs which was seen as a proxy for limited distribution (criterion 3 of the horizon scan). We did not check the actual number of locations or local populations of these species. The breeding bird atlas was used as a reference point, (SOVON, 2002). Species with breeding records established before the period reviewed by the atlas (1998-2000) were left out. The result of this exercise can be found in appendix 4 including an estimation based on expert judgement of the likelihood that the species will have a negative ecological impact in the Netherlands.

For birds, it is important to be aware that apparently “non-native” species may also be rare, wild, migratory birds or species expanding their native range (breeding, wintering or stopping over) because of environmental changes as a result of land use or climate change. This is the case for three species in appendix 4: (1) the lesser white-fronted goose (*Anser erythropus*), this species was native to Sweden and has been reintroduced to the wild in Sweden costing significant effort; (2) the red breasted goose (*Branta ruficollis*), this is an occasional migratory bird from south eastern Europe; (3) the flamingo (*Phoenicopterus roseus*), this species may originate from the Mediterranean.

### *Mammals*

To select the mammal species for the horizon scan database, two approaches were used:

- 1) A selection of relevant mammal species from the national lists of England, Germany, Belgium and the, at the time of writing, draft Dutch 'positive-list' (Koene et al., 2013). This list includes species that are suitable to be kept domestically in the Netherlands.
- 2) An analysis of data from the non-native mammal species in the NDFF-database (<https://ndff-ecogrid.nl/>) and [www.waarneming.nl](http://www.waarneming.nl), which gave an overview of (validated) records of non-native mammal species in the Netherlands. This was done because some species that occur in the Netherlands are not yet listed in other

countries. Information from the available Dutch risk analyses on non-native mammals (NVWA - Ministry of Economic Affairs) was used to inform the analysis.

A draft-list of non-native mammal species in the Netherlands was compiled from these two approaches. Some species, such as brown rat (*Rattus norvegicus*), black rat (*Rattus rattus*), muskrat (*Ondatra zibethicus*) and coypu (*Myocastor coypus*) are already established and controlled. The American mink (*Neovison vison*) is not established and probably does not reproduce in the Netherlands, but is controlled. Therefore, these species were not included. Only species with a maximum of one or two populations in the Netherlands were selected. Most non-native mammal species are not yet established and do not reproduce in the Netherlands.

The final list of mammals comprised 18 species. In total, 12 were selected due to their occurrence on foreign lists and six were added as a result of expert judgement.

#### *Reptiles and amphibians*

Risk assessments of amphibians and reptiles in adjacent countries are rare; these species are present but often insufficiently studied. Therefore, literature such as species atlases and group assessments (e.g. tortoises and snakes) was mainly used to collect data. In this way 13 amphibians and 30 reptile species were selected which are either found in the Netherlands or in adjacent countries outside of their natural range.

Many species on this initial list could be eliminated because of the high (subtropical) temperature ranges required for successful reproduction, especially among reptiles. Moreover, some Dutch invasive reptile and amphibian species are native in neighbouring countries, but their natural dispersal capacity is low. Some of these species are native to Germany and France and have not been risk assessed, in these cases expert judgment was relied upon. Three reptiles (species or species group) and three amphibians were incorporated into the list of potentially invasive species for the Netherlands.

#### *Invertebrates*

In addition to the information sources already mentioned (Appendix 1), two additional sources were used to derive an overview of recently introduced species:

- 1) The macrofauna newsmail. In this regularly produced newsletter, specialists of aquatic macroinvertebrates share records of interesting, rare and invasive species. Many of these specialists are involved in extensive monitoring projects and thus provide a fast and trustworthy source of distributional data. All newsletters for the last three years were scanned for newly established species.
- 2) The minutes of the yearly meetings of the working group on invasive species of the Dutch and Flemish ecological society. A large number of taxonomical specialists are active in this group. During their yearly meeting, these specialists provide lists of newly encountered non-native species.



### *Plants*

Non-native plant species with a limited distribution within the Netherlands and fulfilling criterion 3 of the horizonscan were obtained from three sources (1) the site [waarneming.nl](http://waarneming.nl), (2) the National Databank Flora & Fauna (NDFF) and (3) herbarium specimens from the National Herbarium presented during the 2013 FLORON-day (Duistermaat, 2013).

All species with a limited distribution within one or two provinces in the Netherlands were obtained from [waarneming.nl](http://waarneming.nl). Unverified observations were discarded. From this list the indigenous species, present on the official list of Tamis et al., 2004, were removed. The remaining non-native species were judged on whether their establishment was the result of deliberate planting or sowing, or more or less spontaneous spread. Species recorded in one or two 5x5 km squares with apparent spontaneous establishment were listed as non-native plant species with a limited distribution. In some cases one or two adjacent 5x5 km squares were regarded as a single area of occurrence. This list was completed with non-native species with a limited distribution who were only present in the NDFF but absent from [waarneming.nl](http://waarneming.nl). Also a few new non-native species (six species) recently delivered as herbarium specimens to the National Herbarium were added to the list.

The non-native species added to the list of non-native plant species with a limited distribution can apparently establish themselves in the Netherlands and are potentially able to disperse from these new locations.

### *Fish*

In addition to the species selection criteria of the horizonscan and the resources mentioned in appendix 1, the following steps were used to complete the horizonscan fish species list:

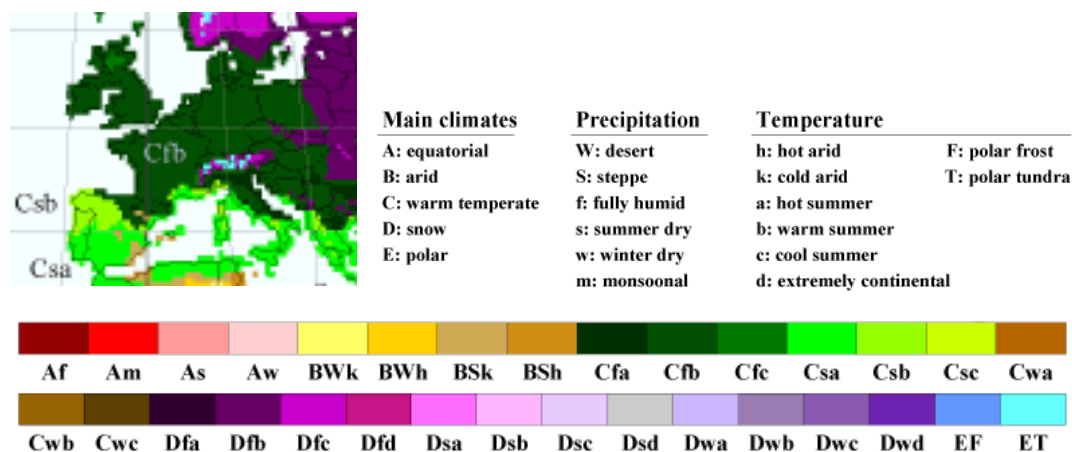
- 1) An analysis of the data of non-native fish species in the NDFF and RAVON-database, [www.waarneming.nl](http://www.waarneming.nl) and [www.vangstenregistratie.nl](http://www.vangstenregistratie.nl), which gave an overview of (validated) records of (new) non-native fish species in the Netherlands.
- 2) A selection of relevant fish species from the national lists of England, Germany, Belgium and from Dutch risk analyses.
- 3) A Google search to find fish species of which records are not yet available in the mentioned databases, reports and websites and to obtain information about species in the pet trade which may become invasive when introduced into the wild.

#### **2.2.2** Compilation of the list of (opportunistic) species with ecological risk scores from climatically similar countries

##### *Literature search and climate match*

A literature search was carried out to compile list two, comprising non-native species that are (1) invasive in countries climatologically similar to the Netherlands, or (2) invasive and known to establish in different climate zones and habitats (opportunist species). To compile a species list that satisfied these criteria, all available horizonscans, black lists and priority lists of invasive species from climatically comparable countries to the Netherlands were collected. Countries identified as climatically similar according to the Koppen-Geiger climate classification, were the neighbouring countries of Belgium,

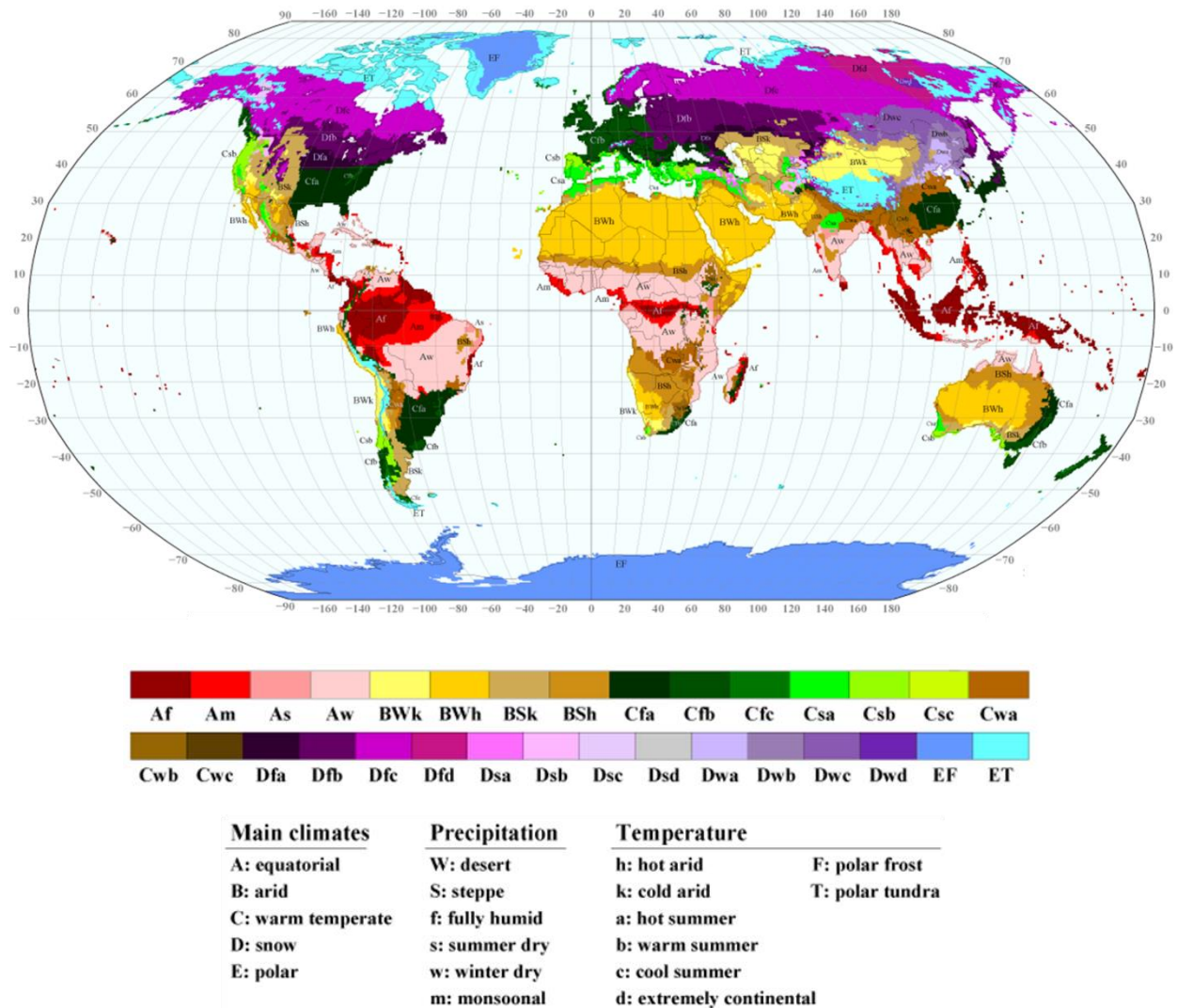
northern France, Germany, Denmark, Luxembourg, the United Kingdom and Ireland (Rubel & Kottek, 2010; <http://koeppen-geiger.vu-wien.ac.at/>, figure 2.2). The Koppen-Geiger climate classification bases its climate maps on recent data sets from the Global Precipitation Climatology Centre (GPCC) at the German Weather Service and the Climatic Research Unit (CRU) of the University of East Anglia in the United Kingdom (Rubel & Kottek, 2010).



**Figure 2.2:** European regions climate matched to the Netherlands (region Cfb). Adapted from Kottek et al. (2006).

There are locations outside Europe that share a climate match with the Netherlands, for example parts of south eastern Australia and South America (Figure 2.3). However, it was assumed that the data obtained from foreign horizonscans and lists derived from the regions in figure 2.2 include species from these locations. Potentially invasive species native to climate matched regions outside Europe are therefore indirectly included in the analysis.

Only the species with records in the northern half of France were included in the horizonscan as southern France is climatically dissimilar to the Netherlands. The North American Great Lakes and St. Lawrence river basin were also included in the literature study as this region is a possible source for the introduction of aquatic non-native species to the Netherlands via ballast water. The invasive species in this region are regarded as representative for other eastern American regions (such as the Hudson, Chesapeake bay river basins). The literature search was largely internet based with use of a university library. Various academic and non-academic search engines and websites were used in a systematic search. An overview of all web based resources is given in appendix 1.



**Figure 2.3:** Global regions climate matched to the Netherlands (region Cfb). Adapted from Kottek et al. (2006).

#### *Standardisation of individual risk classifications*

Risk classifications obtained from individual horizon scans and national lists are categorised using different classification systems and therefore required standardisation to allow them to be compared and aggregated. The different classification systems are described in table 2.2. Individual risk classifications were standardised by according a number between one (low risk) to three (high risk) to each classification to produce a standardised risk score. Numbers were allocated to each classification according to the scheme in table 2.2.

It should be noted that species included in horizon scans are present in low numbers or absent from the country where the study has been carried out. There is often limited or no evidence of ecological damage, and authors rely on data from climatically similar regions where the species is more abundant. Therefore, a number of species are classified according to their potential ecological risk (for example the Danish list system and Irish amber lists). In these cases the precautionary principle was applied and a high risk score was allocated to species on these lists. The precautionary principle should be applied when an activity raises threats of harm to the environment, even if some cause

and effect relationships are not fully established scientifically (Raffensperger & Tickner, 1999). Species classified as high risk were later screened and removed by expert contributors if it was certain that a high risk classification was not justified for the Netherlands.

**Table 2.2:** Definition and standardisation of individual risk classifications.

Classification system / protocol		Category			Reference / website
ISEIA		Watch list (Moderate risk)	Black list (High risk)	Alert list (High risk)	Branquart (2007); Parrott et al. (2009); <a href="http://ias.biodiversity.be/">http://ias.biodiversity.be/</a>
FISK	Low	Medium	High		Copp et al. (2009); Cefas (2010)
Danish list system			Black list	Observation list	<a href="http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Arter/Sortlisten/">http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Arter/Sortlisten/</a>
German- Austrian black list information System (GABLIS)	White list			Black list, Grey list	Rabitsch et al. (2013); Nehring et al. (2010); Essl et al. (2011)
UK-adapted Australian Weed Risk Assessment	Low risk	Moderate risk	Urgent, critical		Thomas (2010)
RINSE meta-list			Black list	Alert list	Gallardo et al. (2013)
North American Great lakes (NOAA Great lakes aquatic nonindigenous species information system - GLANDIS)			Non-indigenous*	Watch list*	<a href="http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html">http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html</a>
Irish risk classification system			Priority list (most unwanted, amber)*	Watch list (most unwanted, amber)*	Kelly et al. (2013)
Invasive species list			Listed*		Muséum national d'Histoire naturelle [Ed]. 2003-2013. Inventaire national du Patrimoine naturel, <a href="http://inpn.mnhn.fr">http://inpn.mnhn.fr</a>
Standardised risk classification	1	2	3	3	

\*Species classified as high risk according to the precautionary principle (Raffensperger & Tickner, 1999).

*ISEIA*: the Belgian Biodiversity Platform developed the first version of the Invasive Species Environmental Impact Assessment (*ISEIA*) protocol. The protocol assesses environmental impact only and can be applied to all taxonomic groups. The assessment consists of four sections matching the last steps of the invasion process: the potential for spread (1), establishment (2), adverse impacts on native species (3) and ecosystems (4). Scores for each section are based on the species impact history in neighbouring areas and their ecological profiles. Risk prioritisation carried out using the *ISEIA* protocol are classified as (1) uncategorised: all present and absent species featuring a low ecological risk and all absent species with a moderate ecological risk; (2) watch list: all present species with a moderate ecological risk; (3) alert list: all absent species with a

high ecological risk; (4) black list: all present species with a high ecological risk (Branquart, 2007).

*FISK*: this is a risk prioritisation procedure carried out using the Freshwater Invasiveness Scoring Kit (FISK). The FISK protocol is applied using a questionnaire that classifies species as low, medium or high risk (Cefas, 2010; Copp et al., 2009). FISK is an adaptation of the Australian weed risk assessment (WRA) and decision tree approach known as 'fish profiling' (Copp et al., 2005). Only FISK scores relevant to fish were used during this analysis.

*Danish list system*: this system is based on expert knowledge. It defines invasive species as plants and animals that may be moved from one part of the world to another facilitated by human vectors resulting in negative effects on native species (Danish Ministry of Environment, 2014). Only invasive species present in Denmark are present on the Danish black list. Other species that are either absent from Denmark but may establish in future and have shown invasive characteristics in comparable regions; or species that have already been introduced to Denmark, are present in limited numbers and showing invasive features are placed on an observation list.

(<http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Arter/Sortlisten/>).

*The German- Austrian black list information system (GABLIS)*: This is a recently developed risk assessment tool for use in Germany and Austria. GABLIS is applied to species that are currently absent from Germany and assesses only ecological impacts. Species are classified as (1) black list: species that can become invasive based on information from climatologically similar countries; (2) grey list: non-native species that on the basis of expert knowledge can become invasive; (3) white list: non-native species that do not become invasive based on information from climatologically similar countries (Essl et al., 2011).

*The UK-adapted Australian weed risk assessment*: this assessment is a method of risk prioritisation of plant species that are either present in England but not yet established or absent. Categories are defined as (1) low risk: no further assessment required at this time; (2) moderate risk: more detailed risk assessment recommended; (3) urgent: more detailed risk assessment strongly recommended; (4) critical: more detailed risk assessment is a priority (Thomas, 2010).

*The RINSE meta-lists*: the RINSE project (Reducing the Impacts of Non-native Species in Europe) comprised a horizonscan of potentially invasive species for a number of European countries. Locations within the RINSE region are southern England, northern France, Belgium and the Netherlands. While the Netherlands is included in the RINSE region, the results of the RINSE project are generic for the entire region and not specific to the Netherlands. The RINSE meta-lists include a black list of invasive species present in the RINSE region and an alert list of invasive species absent from the RINSE region. The alert list is ordered on the basis of ecological impact, invasive potential, possible economic impact and amenability to management intervention. The black list is ordered on the basis of expert knowledge of the most problematic non-native species in the RINSE region (Gallardo et al., 2013).



*GLANSIS*: the GLANSIS (Great Lakes non-indigenous species) information system categorises species that may cause ecological damage as a result of increasing abundance on the basis of presence (non-indigenous list) and absence (watch list) from the North American Great Lakes

(<http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html>).

*The Irish risk classification system*: this system comprises a risk assessment based on questions relating to invasion history, vectors and pathways, suitability of habitats, propagule pressure, establishment success, spread potential and assesses ecological, economic impacts and impacts on human and animal health. Species categorised in the Irish risk classification system feature on a priority list of species already established in Ireland and a watch list of species that are not currently known to occur in Ireland. These categories contain two sub lists: a list of most-unwanted invasive species and an amber list of invasive species. The most unwanted list comprises potential and established non-native species that pose the highest ecological risk to Irish nature. Amber list species may become invasive in Ireland and need to be monitored, they are potentially invasive species. Amber list species could represent a significant impact on native species or habitats causing significant decline or loss; or could impact either/both Natura 2000 sites and the goals of the EU Water Framework Directive (Kelly et al., 2013).

*Inventaire national du Patrimoine naturel*: the French inventory comprises a list of invasive species without further classification. Species on the French list have already been recorded and are probably present in the northern part of France (<http://inpn.mnhn.fr>).

#### *Aggregation and weighting of standardised risk scores*

The minimum, maximum and average (aggregated) scores were calculated for all standardised risk scores per species. It was assumed that the aggregated risk score reflects the potential ecological risk to native species and ecosystem functioning in the Netherlands.

Subsequently, a weighting was assigned to gain insight into the relative contribution of standardised risk scores derived from a full risk assessment methodology to the overall aggregated risk score. Classification methods may be divided into two types. Risk identification tools are used to initially prioritise species in terms of ecological risk after which a separate, more detailed analysis of the highest risk species is carried out. A full risk assessment comprises both of these elements. It was assumed that standardised risk scores obtained from full risk assessments have a greater certainty than risk scores obtained from methodologies used purely for risk identification. Therefore, aggregated risk scores calculated with a higher number of standardised risk scores derived from full risk assessments were assigned a higher weighting. Table 2.3 gives an overview of the differences in methodological approach of the classification methods included in this study.

**Table 2.3:** Differences in methodological approach in classification methods used to calculate aggregated risk scores.

Protocol	Methodology
ISEIA	risk identification
FISK	risk identification
GABLIS	risk identification
Lists based on expert judgement	risk identification
The UK-adapted Australian weed risk assessment	risk identification
Irish scheme	full risk assessment

Standardised risk scores derived from a risk identification methodology were assigned a lower weighting than risk scores derived from an official risk assessment methodology using the following formula:

$$\text{Weighted risk score} = (a - b) \times 1 + b \times 2$$

Where  $a$  = the number of standardised risk scores and  $b$  = the number of standardised risk scores obtained from an official risk assessment methodology.

A linear regression was carried out to ascertain whether the weighted risk score was statistically different from the aggregated risk score using the statistical software package SPSS 17.0 (IBM, 2008). If the linear regression is found to be significant, then the weighted risk score does not reveal more information about the contribution of full risk assessments compared to the aggregated risk score and maybe removed from the results of the horizonscan. In linear regression a regression line is derived that describes the linear relationship between the  $X$  (average aggregated risk score) and  $Y$  (weighted risk score) variables. The linear regression is estimated with the help of the following equation:

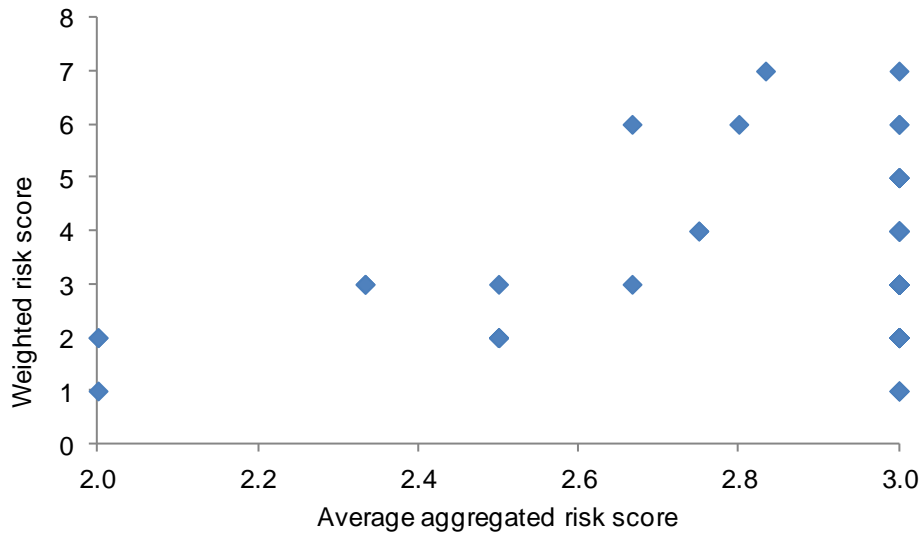
$$Y = a + b \times X + \epsilon$$

$Y$  is the dependent variable;  $X$  is the independent variable; and ' $a$ ' and ' $b$ ' are the regression coefficients that represent the distance between the data points and the regression line. An  $R^2$  is calculated in combination with a linear regression. The size of the  $R^2$  value indicates how closely  $X$  (average aggregated risk score) and  $Y$  (weighted risk score) are related.  $R^2$  varies between zero (the regression line explains 0% of the variation around the average value) and one (the regression line explains 100% of the variation around the average value). If the  $R^2$  approaches one, then all data points lie close to the regression line and it can be concluded that the average aggregated risk score predicts the weighted risk score well. In this case, the weighted risk score does not distinguish aggregated risk scores calculated with a higher number of standardised risk scores derived from full risk assessments.

Linear regression also includes a calculation of significance where a  $p$  value is generated. If the  $p$  value is less than 0.05 then it can be concluded that  $X$  (average aggregated risk score) and  $Y$  (weighted risk score) are significantly correlated.

The regression analysis (Figure 2.4) indicates that the aggregated average risk score and weighted risk score are not significantly correlated ( $p = 0.089$ ). The explained variance is very low (coefficient  $R^2 = 0.0374$ ) indicating that the weighted risk score is

different from the aggregated risk score. The weighted risk score was therefore used in the horizonscan to explain the contribution that full risk assessments made to the calculation of the aggregated risk score.



**Figure 2.4:** Analysis of aggregated average risk scores and weighted risk scores.

### 2.2.3 Combining of list one and two species

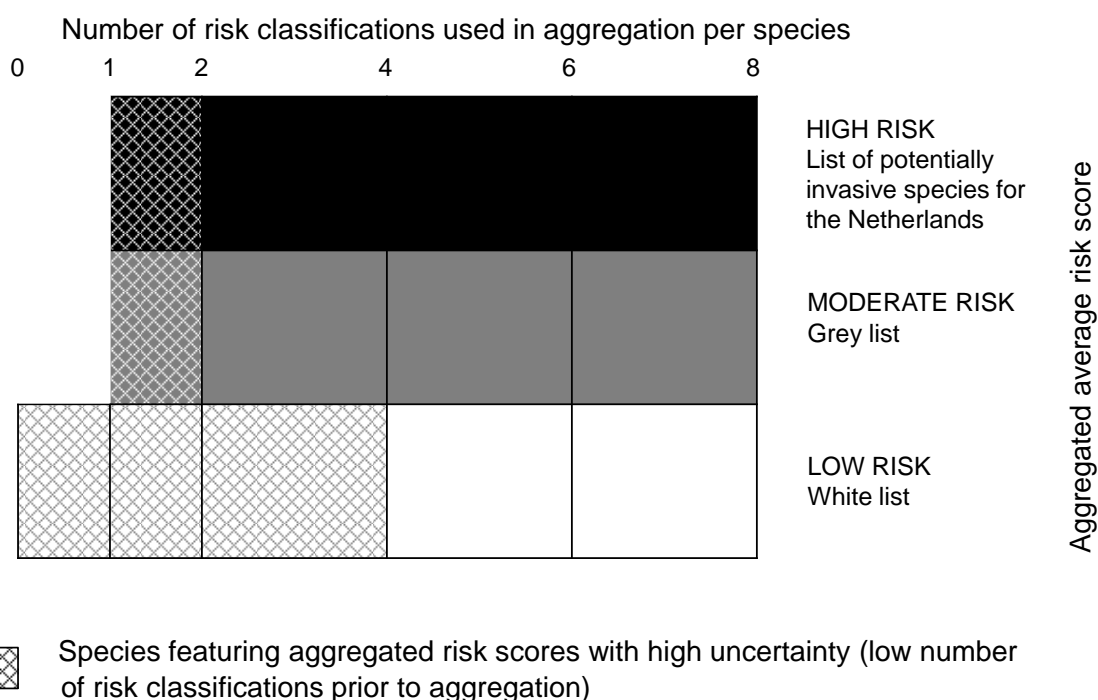
The lists generated from the methods described in sections 2.2.2 and 2.2.3 were then combined to produce a single list of species with risk scores classified according to the horizonscan criteria.

### 2.2.4 Species risk prioritisation

The combined species list was then risk prioritised. The aggregated risk scores range from zero (low risk) to three (high risk). Following aggregation of standardised risk scores, the non-native species were prioritised according to their aggregated risk score and the number of standardised risk scores available prior to aggregation (Figure 2.5). This led to the production of six sub lists defined by risk and certainty. Species with an aggregated risk score of more than two that was derived from two or more standardised risk scores were allocated to a list of potentially invasive species for the Netherlands with high certainty (non-native species that are certain to cause a high level of ecological damage in countries that are climatically similar to the Netherlands). Species with an aggregated risk score of more than two but derived from only one standardised risk score were allocated to a list of potentially invasive species for the Netherlands with high uncertainty (non-native species that may cause a high level of ecological damage in countries that are climatically similar to the Netherlands). Species with an aggregated risk score of more than one and equal or less than two and derived from two or more standardised risk scores were allocated to a grey list with high certainty (non-native species that are certain to cause a moderate level of ecological damage in countries that are climatically similar to the Netherlands). Species with an aggregated risk score of more than one and equal or less than two but derived from only one standardised risk



score were allocated to a grey list with high uncertainty (non-native species that may cause a moderate level of ecological damage in countries that are climatically similar to the Netherlands). Species with an aggregated risk score of zero to one but derived from four or more standardised risk scores were allocated to a white list with high certainty (non-native species that are certain to cause a low level of ecological damage in countries that are climatically similar to the Netherlands). Species with an aggregated risk score of zero to one but derived from less than four standardised risk score were allocated to a white list with high uncertainty (non-native species that may cause a low level of ecological damage in countries that are climatically similar to the Netherlands). The stricter classification of certainty for white list species results from the uncertainty relating to the measurement of ecological impacts and the possibility that negative impacts have occurred but have not been observed in the countries concerned.



**Figure 2.5:** Species prioritisation matrix.

### 2.2.5 List of potentially invasive species for the Netherlands

The high risk, high certainty species list was then screened by the expert contributors. Species that, according to expert judgement, did not fulfil the horizonscan criteria and were considered unlikely to successfully establish in the Netherlands because of a poor climate match were removed. However, not all species fulfilling the horizonscan criteria and posing a potentially high ecological risk to the Netherlands are included in foreign horizonscans and lists. Therefore, a number of species known, according to expert knowledge, to pose a high potential ecological risk to the Netherlands and fulfilling the criteria of the horizonscan were also added to the high risk, high certainty list. A review of species already risk assessed as high risk during a Dutch risk assessment, and also fulfilling the horizonscan criteria, provided additional species for the list. Moreover, species already present on the high risk, high certainty list but scoring low or medium risk in a Dutch risk assessment were either removed, or additional justification for their

presence on the list was sought from the expert contributors. The resulting high risk, high certainty species form a list of potentially invasive species for the Netherlands.

## **2.3 Compilation of the horizonscan database**

The species list of potentially invasive species for the Netherlands formed the basis for the horizonscan database. The horizonscan database includes information on species names and (taxonomic) group, habitat preferences, native and non-native range, pathways and vectors, hotspots for entry, impacts and (aggregated) risk scores. To supplement information already obtained from national invasive species priority lists and horizonscans, a detailed search of national, European and international databases was carried out using the official scientific names of the species (Appendix 1). These data were supplemented by information found in all available Dutch, Belgian and English individual risk assessments carried out for these species. The information taken from these individual risk assessments is supplementary to the information taken from foreign horizonscans and lists, used to prioritise species for ecological risk (section 2.2.2). Subsequently, the database was circulated to the expert contributors for the addition of any other information that could be derived from expert knowledge. All information sources were referenced within the horizonscan database and in the references section of this report. The following sections include the methodology used to select the required information for each species.

### **2.3.1 Scientific name**

The scientific species names were analysed for synonyms and misspellings using expert knowledge and the official taxonomic register of the Netherlands, the Dutch species register (Naturalis Biodiversity Center, 2014) and the Integrated Taxonomic System (ITIS) <http://www.itis.gov>. Occasionally, it was impossible to determine a species name due to taxonomic uncertainty. In these cases the genus was entered instead of a complete species name.

### **2.3.2 Species group**

The species group was derived from information obtained during the compilation of the initial species list using horizonscans and national priority lists, supplemented during the systematic search of non-native species databases and then standardised according to expert knowledge. Species were classified as crustaceans, birds, fish, amphibians, mammals, molluscs, plants, insects, sea stars, bryozoans, hydroids, worms or reptiles.

### **2.3.3 Taxonomic group**

The taxonomic order of each species was obtained using the official taxonomic register of the Netherlands, the Dutch species register (Naturalis Biodiversity Center, 2014). If the species was not listed in the database then the information was derived from the North American Integrated Taxonomic System (ITIS) <http://www.itis.gov>.

#### 2.3.4 Synonyms

Synonyms were identified during the systematic search of species databases and supplemented using expert knowledge and the Dutch species register (Naturalis Biodiversity Center, 2014).

#### 2.3.5 Common English names

Common English names were derived from information obtained during the compilation of the initial species list using horizonscans and national priority lists, and supplemented during the systematic search of non-native species databases.

#### 2.3.6 Dutch common name

Dutch common names were obtained from the official list of non-native species in the Netherlands contained within the Dutch species register and from expert knowledge.

#### 2.3.7 Naturalis non-native species classification

The non-native species included in the list of potentially invasive species for the Netherlands are classified according to the non-native species project of the Dutch species register (Naturalis Biodiversity Center, 2014). The information contained within the project is collected by Dutch flora and fauna specialists of the Dutch 'Particuliere Gegevensbeherende Organisaties' (PGOs). The classification refers to the length of time that the species has been present in the Netherlands and is described in table 2.4.

**Table 2.4:** Classification of non-native species in the Netherlands (Naturalis Biodiversity Center, 2014).

Code	Status in the Netherlands
2	Precise status unknown
2a	Reproducing independently for at least 100 years
2b	Reproducing independently for between 10 and 100 years
2c	Reproducing independently for less than 10 years
2d	Incidental import, no reproduction

Although it is not currently included in this classification, the addition of a category for incidental reproduction would be useful for some species groups. Reproduction may also be facilitated domestically for pet species. It should be noted that only species classifications contained within the Dutch species register are included in the horizonscan database. However, this does not mean that other species do not fall within one of these categories.

#### 2.3.8 General group

The general group was defined according to whether the species is a terrestrial, freshwater or marine animal or plant. A number of ambiguous species types were classified as follows. Firstly, estuarine species were classified under marine animals or

plants. Secondly, waterfowl were classified under terrestrial animals. Finally, floodplain plants were classified under terrestrial species.

### 2.3.9 Occurrence in the Netherlands

The contributing experts were consulted regarding the current distribution in the Netherlands of non-native species with an aggregated risk score of more than 2 (High risk). Species present in the Netherlands with more than a limited distribution that would be difficult to eradicate through management intervention were removed from the database. The other species were classified as either absent, present only in private / public collections, present in limited populations or present as a limited number of individuals. Species classified under a limited number of individuals are unable to reproduce in the Netherlands and therefore do not constitute a population.

### 2.3.10 Native range

The native range of the species was derived from the invasive species compendium (<http://www.cabi.org/isc/>) which featured the most extensive information on species' native and non-native distribution of all sources examined. Native range outside Europe was described on the continental scale. Locations within Europe were defined as southern, eastern, western and northern Europe. If a species originated from the Ponto-Caspian region, then this was specifically stated as this is an important area of origin for aquatic non-native species found in the Netherlands. Finally, a number of hybrid species have been created for the plant and animal trade. These hybrid species were considered not to have a native range and 'not applicable' was entered under these circumstances.

### 2.3.11 Non-native range

The non-native range of the species was derived from the invasive species compendium (<http://www.cabi.org/isc/>) which features an extensive description of species native and non-native distribution throughout the world. Non-native range outside Europe was described on the continental scale. Native range within Europe was defined on a per country basis. If the species was not recorded in the invasive species compendium, then the NOBANIS (<http://www.nobanis.org/>) and DAISIE (<http://www.europe-aliens.org/>) non-native species databases were used to determine the non-native range. For the purpose of this study, species that extend their natural range into the Netherlands from adjacent countries are not included in the definition of non-native. However, species that are introduced to adjacent countries and then disperse to the Netherlands are considered non-native.

### 2.3.12 Preferred EUNIS habitat type

The preferred habitats of the species were defined using the highest aggregation of the habitat types defined within the European Nature Information System (EUNIS) <http://eunis.eea.europa.eu/>. This is an online database maintained by the European Topic Centre on Biological Diversity for the European Environment Agency and the European Environmental Information Observation Network (European Environment Agency, 2014).

### 2.3.13 (Other) habitat types

Species may be found in more than one habitat and additional suitable habitats were listed under his column heading. Often the preferred species habitat type could not be identified or classified easily under the EUNIS system. In these cases 'not specified' was entered into the preferred EUNIS habitat type column and a complete list of habitats where the species may be found was entered under the '(other) habitat types' column heading.

### 2.3.14 Most risky areas of origin

The most risky areas of origin of the non-native species are defined as:

- 1) The location(s) from which the species is most likely to be introduced to the Netherlands (if not currently present in the Netherlands).
- 2) The location(s) where the species is present in the Netherlands and is able to spread from.

In many cases the species concerned is currently not present in the Netherlands and specific information about locations where the species would originate from if it were to enter the Netherlands was unavailable. In this situation, the most risky area of origin for the species was estimated using species specific pathway and vector information and the native and non-native range of the species. The expert contributors were then asked to examine and verify the information entered. If the species is already present in the Netherlands in limited abundance then the most risky area of origin for spread to other regions may be within the Netherlands itself. Therefore, the Netherlands was also considered for entry under this column heading.

#### *Certainty*

A measure from one (low certainty) to three (high certainty) was entered to give an indication of the certainty of the information entered under most risky areas of origin. For example if information was based solely on expert knowledge then a one (low certainty) was entered into this column. If the information was based on evidence from literature directly pertaining to the Netherlands then a three (high certainty) was entered. This approach is an adaptation of the methodology applied by Standards Australia and Standards New Zealand non-governmental standards organisations and the UK risk assessment scheme for all non-native species (Baker et al., 2008).

### 2.3.15 Pathways

Pathways are the means by which non-native species move to locations outside their native range. Natural pathways could include means such as wind or water currents. Other pathways can be enhanced by, or even entirely created through human activity. The horizonscan database focuses primarily on human facilitated pathways. Pathway information is classified according to the draft scheme that has been developed by the International Union for Conservation of Nature Invasive Species Specialist Group (UNEP, 2014). The classification system will be applied nationally in the Netherlands within the non-native species sections of the Dutch species register (Naturalis

Biodiversity Center, 2014). The pathway definitions are given in appendix 3. Pathways are defined under a number of categories: release in nature (10 pathways), escape from confinement (13 pathways), transport contaminant (nine pathways), transport stowaway (11 pathways), corridor (one pathway) and other (two pathways). A cross is entered if the non-native species has utilized the pathway to access locations outside of its native range. Extra information relevant to the spread of the non-native species including region specific information was added under the column 'additional information'.

### **2.3.16 Vectors**

The vector definitions were taken from the European DAISIE project, an online resource that provides an inventory of invasive species that threaten European terrestrial, fresh-water and marine environments and is funded by the European Commission (DAISIE, 2014). Vectors are defined as intentional and unintentional releases, dispersal, transport or escape. Often, multiple vectors were applicable and these were all entered into this column.

### **2.3.17 Primary hotspots**

A primary hotspot is defined as the location or locations where the non-native species will probably first appear or has first appeared in the Netherlands. Information on primary hotspots should therefore be analysed in combination with information about the occurrence of the species in the Netherlands (Section 2.3.9). For example, the harbours of Rotterdam and Amsterdam and the large rivers are locations where an aquatic non-native species may first appear in the Netherlands. The detail with which a primary hotspot may be described may vary according to the manner in which the species is introduced. For example, a non-native species that is sold by retailers for ornamental use and has a wide environmental tolerance may escape or be released and establish at many locations close to where the species is kept. On the other hand, if a species is known to travel in ballast water, then it is likely that it will first appear at major sea ports and then disperse via the major waterways. Species that are present in neighbouring countries such as Germany and Belgium may, through natural dispersal, cross the border into the Netherlands. In this case the border with the relevant country is defined as the primary hotspot.

### **2.3.18 Secondary hotspots**

A non-native species can disperse without the additional intervention of people from primary hotspots to other areas. If these other areas can be defined as specific locations then they are defined as secondary hotspots. For example, a non-native species that first appears at an international seaport (primary hotspot), may then hitchhike on the hull of inland shipping and establish at inland harbours within the Netherlands (secondary hotspot).

#### *Certainty*

A measure from one (low certainty) to three (high certainty) was entered to give an indication of the certainty of information entered under primary and secondary hotspots. For example, if information was based solely on expert knowledge then a one (low

certainty) was entered into this column. If the information was based on evidence from literature directly pertaining to the Netherlands then a three (high certainty) was entered. This approach is an adaptation of the methodology applied by Standards Australia and Standards New Zealand non-governmental standards organisations and the UK risk assessment scheme for all non-native species (Baker et al., 2008).

### **2.3.19 Potential socio-economic and ecological impacts**

This section indicates the potential societal, economic and ecological impacts that may occur in the Netherlands. The extra information column adds information that is relevant to the risk that the non-native species poses. As the species present in the horizonscan database are present in only limited populations or absent for the Netherlands, evidence for impacts specific for the Netherlands is for the overwhelming majority of species unavailable. The described impacts are relevant to other (climatically similar) countries where the species is present. If an impact is assigned to a particular country then the name of the country is given in the extra information section. If the impact is described without spatial information then no reference to a country could be given. Therefore, the potential impacts recorded may only occur if the species were to achieve high densities in Dutch nature.

### **2.3.20 Risk score**

The risk score sections describe the minimum and maximum risk scores attained for the species during the review of horizonscans and international species lists following standardisation (Section 2.2.2). Additionally, the average aggregated risk score is given for all the available horizonscans and international species lists per individual species. The number of risk scores used to determine the minimum, maximum and aggregated risk score is given followed by the number of official risk assessments that make up this total. Finally the result of the calculation for weighted risk score is given.

### **2.3.21 Key references**

A number of key citations are given which contain a more complete overview of the species contained in the database and were used to make additions to the database. The full reference for the citations and any other additional references used to complete the assessment are included in the references section of this report.

## **2.4 Metadata analysis**

A metadata analysis was carried out to analyse the data contained within the horizonscan database. The metadata analysis assessed the distribution of the species in the Netherlands and the frequency of pathways, impacts and origin of the species contained in the horizonscan database.

### **2.4.1 Pathways**

The pathways utilised by the non-native species in the horizonscan database were ranked according to their frequency of occurrence. This analysis aimed to identify the most frequent routes of entry for the non-native species posing a high potential ecological risk in the Netherlands. Pathway type and frequency was analysed separately for species featured on the list of potentially invasive species for the Netherlands (high aggregated risk score) but absent from the Netherlands and for all species present on the list of potentially invasive species for the Netherlands.

### **2.4.2 Impacts**

The potential impacts resulting from the non-native species in the horizonscan database were ranked according to frequency of occurrence. The ranking procedure aimed to identify the most frequently occurring potential ecological impacts of species with a high potential ecological risk in the Netherlands. The species groups and general groups responsible for the greatest number of impacts were highlighted by totalling the number of impacts relating to each. This provided information regarding the absolute number of impacts per species group and general group. The number of impacts per species group and general group was then standardised by dividing the number of impacts by the number of individual species from which the impact information was obtained. This allowed comparisons of impact frequency between species groups and general groups.

### **2.4.3 Species origin**

The origins of the non-native species contained in the horizonscan database were defined according to their continental native range. The number of species was calculated per continent of origin for all species and per general group.



## 3. Results

### 3.1 Summary of species meeting the horizonscan criteria

#### *Non-native species fulfilling criteria 1, 2 and 3 of the horizonscan*

In total 712 species met the horizonscan criteria (list 1). Table 3.1 gives an overview of the number of species selected by the contributing experts that fulfil the criteria of the horizonscan. A complete overview of all the individual species meeting the horizonscan criteria is contained in appendix 4. A number of species fulfilled the criteria but were considered unable to reproduce in the Netherlands the numbers of which are given in table 3.1. There were also a number of species that could possibly fulfil the horizonscan criteria but a lack of information meant that this could not be stated with certainty. These species are allocated to a separate column in the table and appendix. The likelihood of these species establishing in the Netherlands is lower.

**Table 3.1:** Number of species fulfilling the horizonscan criteria per species group and selection criterion.

Species group	Horizonscan criteria*	Species fulfilling criteria (n)	Species fulfilling criteria and able to reproduce in the Netherlands	Species possibly fulfilling criteria (n)
Amphibians	1	0	0	0
	2	19	5	0
	3	9	6	0
Birds	1	240	?	0
	2	2	0	0
	3	52	36	0
Fish	1	12	12	0
	2	4	3	2
	3	20	20	0
Macroinvertebrates / insects / worms	1	13	13	0
	2	1	1	0
	3	5	5	21
Mammals	1	5	5	0
	2	43	43	0
	3	29	27	0
Plants	1	13	13	0
	2	13	13	0
	3	216	216	0
Reptiles	1	0	0	0
	2	14	14	0
	3	2	1	0
<b>TOTAL</b>		<b>712</b>	<b>433</b>	<b>23</b>

\***Criterion 1:** The non-native species has, to date, not reached the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.

**Criterion 2:** The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.

**Criterion 3:** The non-native species occurs in a limited distribution in Dutch nature that makes it amenable to eradication.

#### *Species prioritisation*

76 species were prioritised as high risk, high certainty species. 14 other non-native species were suggested for addition to the list by the contributing experts that were not prioritised in the initial assessment. This was because they did not appear frequently

enough in the analysed foreign horizonscans and national lists as high risk species or have not been risk assessed in the Netherlands. However, according to expert knowledge these extra species satisfied the horizonscan criteria and may also become invasive and cause significant ecological damage in the Netherlands. The horizonscan list of potentially invasive species for the Netherlands contains a total of 90 species that fulfil the criteria of the horizonscan and may cause significant ecological damage in the Netherlands (high risk) (Appendix 5).

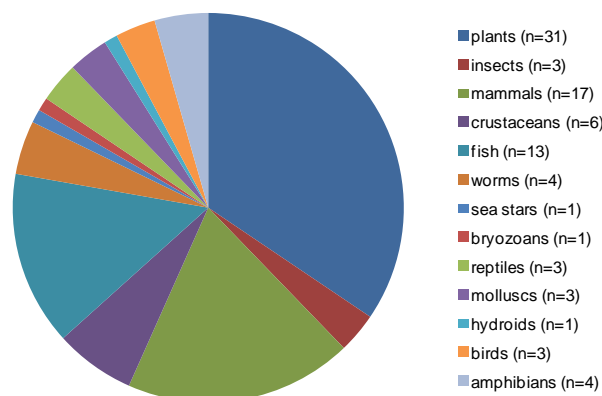
600 species were allocated to the high risk, low certainty list; 31 species were allocated to the medium risk, high certainty list; 117 species were allocated to the medium risk, low certainty list; zero species were allocated to the low risk, high certainty list and 434 species were allocated to the low risk, low certainty list. These lists are contained in a separate Microsoft Excel file.

### 3.2 Metadata analysis

The following sections describe the results of a meta-analysis of the 90 high risk, high certainty species (list of potentially invasive species for the Netherlands) with special emphasis placed on pathways, potential impacts and origins. High risk, low certainty and lower risk species are not included in the analysis. It should be noted that certain species groups contain more individual species than others and therefore pathways, potential impacts and origins appear in greater numbers for the analysed variables. To facilitate the prioritisation of management interventions for species groups appearing on the list of potentially invasive species for the Netherlands, the absolute as well as the relative numbers of species per species group and general group are analysed.

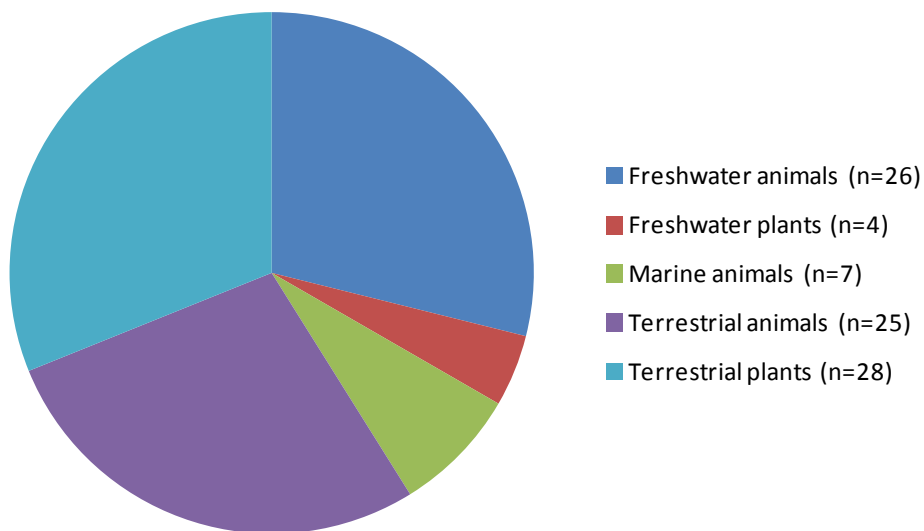
#### 3.2.1 Overview of potentially invasive and ecologically harmful species in the Netherlands

Figure 3.1 gives an overview of the relative contribution of different species groups to the horizonscan list of potentially invasive species for the Netherlands. The largest species group present on the list are plant species (n=31), followed by mammals (n=17) and fish (n=13). In spite of large numbers of non-native marine species in the Netherlands and surrounding countries, marine species are represented in relatively small numbers (bryozoans, sea stars and hydroids).



**Figure 3.1:** Relative contribution of species groups to the list of potentially invasive species for the Netherlands.

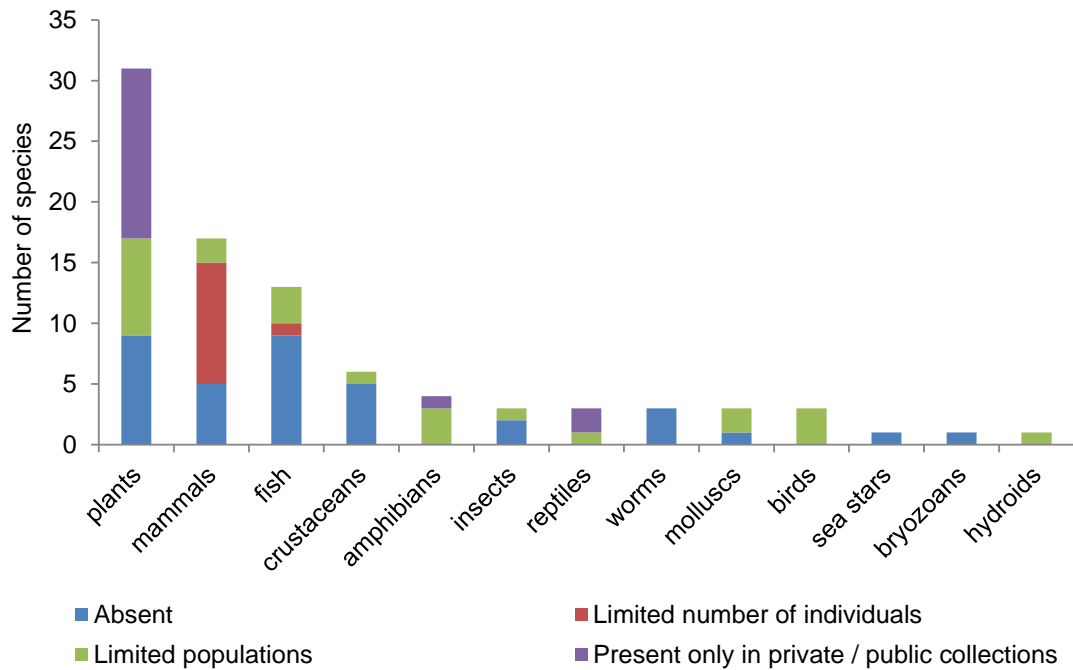
The relative contribution of general groups to the list of potentially invasive species for the Netherlands is shown in figure 3.2. Freshwater and terrestrial animals and terrestrial plants appear most frequently on the list followed by marine animals and freshwater plants.



**Figure 3.2:** Relative contribution of general groups to the list of potentially invasive species for the Netherlands.

The occurrence of potentially invasive species in the Netherlands classified per species group is described in figure 3.3. Occurrence is defined according to the horizon scan criteria: absent from the Netherlands (n=36); present only in a limited number of populations that will allow the species to be eradicated (n=25); present only as a limited number of individuals, unable to reproduce and therefore not constituting populations, that will allow the species to be eradicated (n=11); present only in private / public collections (n=17).

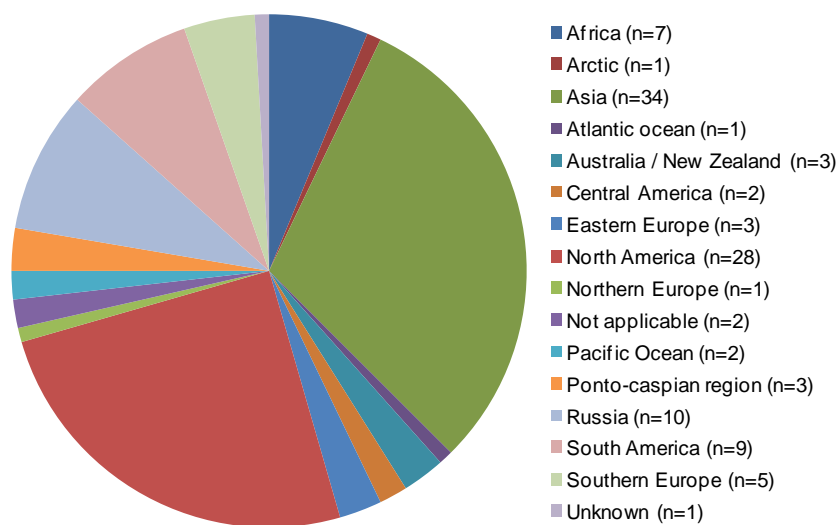
Plants occur most frequently in Dutch private and public collections only, followed by reptiles and amphibians. No other species listed are present in private and public collections only. It should be emphasised that species only appear in this category if they are not present in Dutch nature. Species present in Dutch nature are categorised under limited number of individuals or limited populations but may also be present in private and public collections. For example, the grey squirrel (*Sciurus carolinensis*) is frequently kept as a pet but is categorised as a species present as a limited number of individuals in Dutch nature. Plants occur most frequently in limited populations that may be amenable to eradication followed by fish, birds and amphibians. Only two high risk species groups are present as a limited number of individuals in the Netherlands: mammals and fish. Mammal species occur most frequently as a limited number of individuals followed by fish species. Fish species are the most frequently absent high risk species followed by plants and crustaceans.



**Figure 3.3:** Occurrence of potentially invasive species in the Netherlands per species group.

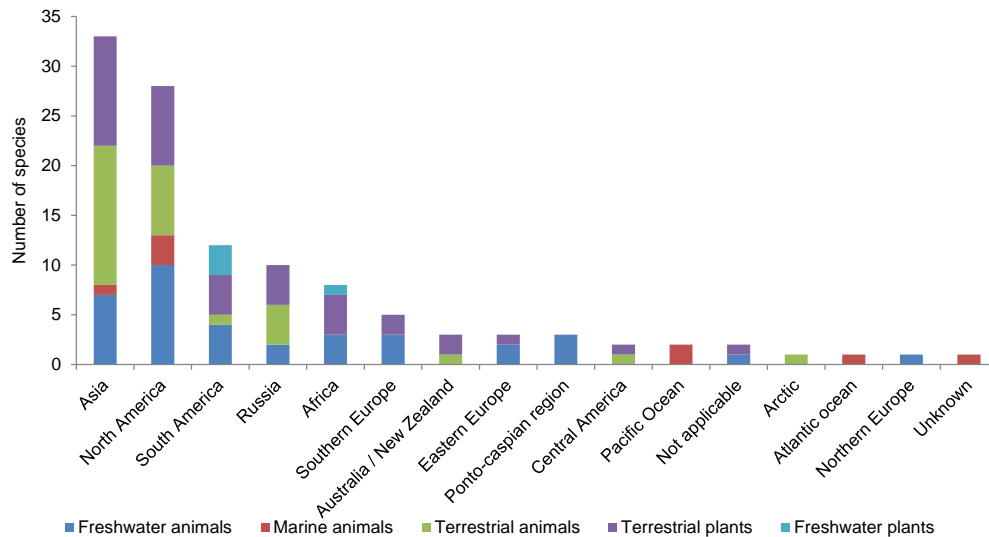
### 3.2.2 Geographical origins of most concern

Figure 3.4 gives an overview of the most frequently listed geographical origins of the non-native species occurring on the list of potentially invasive species for the Netherlands defined by their native range. Asia and North America are the most frequently listed geographical origin of most concern, followed by Russia, South America, Africa and southern Europe. Hybrid species were considered not to have a native range (not applicable), while one species' geographical origin remained unknown because of taxonomic confusion with other related species.



**Figure 3.4:** Geographical origin of species present on the list of potentially invasive species for the Netherlands.

Figure 3.5 displays the geographical origin of the non-native species featured on the list of potentially invasive species for the Netherlands per species group. Asia supplies the most species of terrestrial animals and plants while North America is the main source of freshwater and marine animals.



**Figure 3.5:** Geographical origin of species per general group.

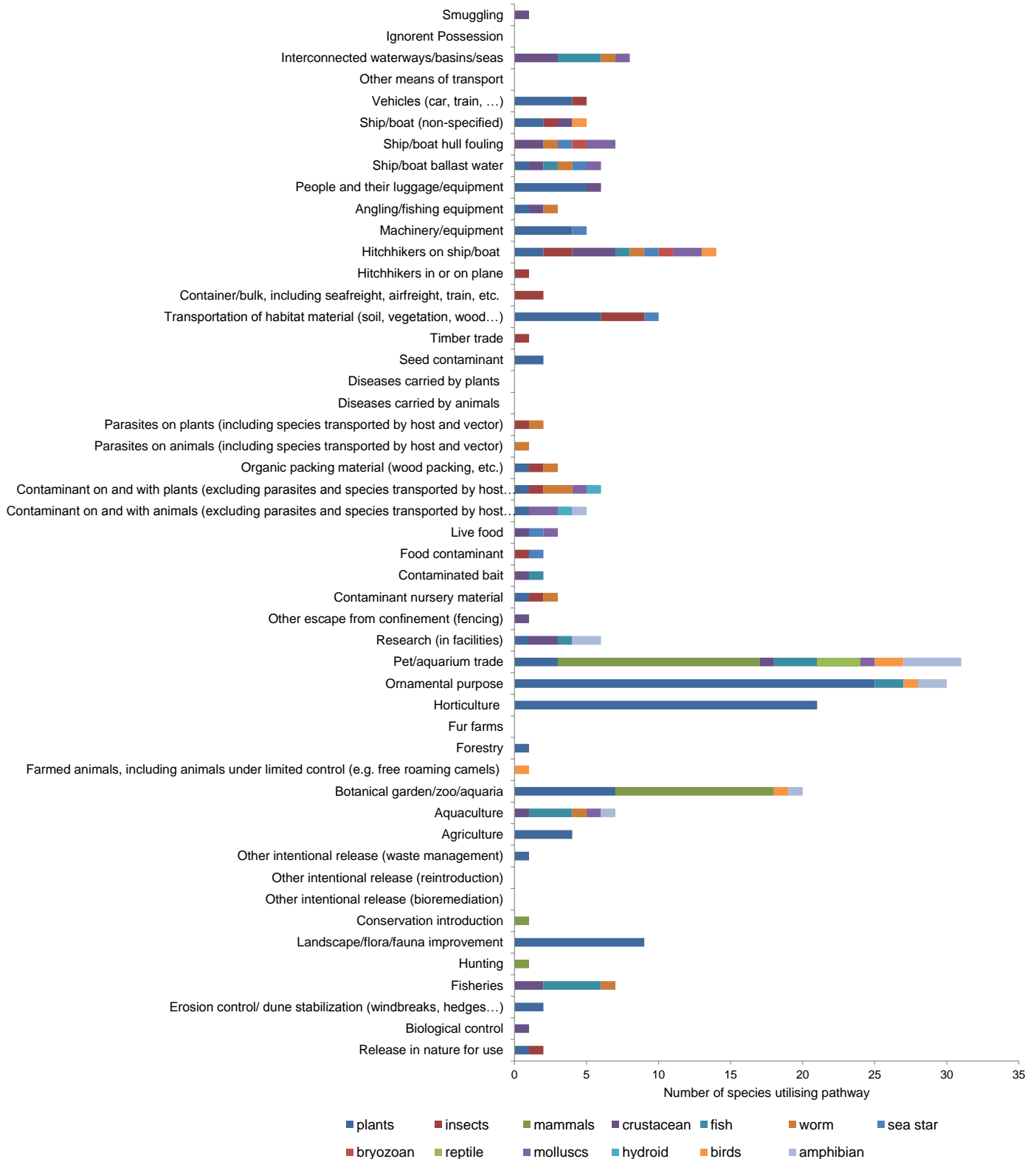
### 3.2.3 Pathways of most concern

Pathway definitions are given in appendix 3. Many of the species in the horizonscan database do not occur in the Netherlands and pathway information is frequently not presented in a way that is region specific. Therefore, information on pathways of most concern should be treated as potential pathways with which a non-native species can extend its range into the Netherlands. Pathway information is most relevant for species that are absent from the Netherlands. Species present only in public / private collections are likely to enter nature as a result of release or escape. In contrast, species that are absent may utilise a diverse number of different pathways that may lead to establishment outside their native range. Pathway analyses were conducted for all species per species group and per general group and for species that are currently absent from the Netherlands per species group.

#### *Analysis of pathways for all species per species group*

The utilisation frequencies of dispersal pathways for all species present on the list of potentially invasive species for the Netherlands are displayed per species group in figure 3.6. The most frequently listed pathways are the pet and aquarium trade, utilised by a wide range of species groups (plants, mammals, crustaceans, fish, reptiles, molluscs, birds and amphibians) and the ornamental pathway which is dominated by plant species. However, the ornamental pathway is also utilised by small numbers of fish, birds and amphibians. Other frequently occurring pathways are horticulture, utilised only by plant species and the botanical/garden/zoo/aquaria pathway, utilised mainly by plants and mammals but also by birds and amphibians in small numbers. A number of pathways were not registered for species on the list of potentially invasive species for the Netherlands. These were ignorant possession, other means of transport, diseases

carried by animals and plants, fur farms, farmed animals including free roaming animals under limited control and other intentional release (reintroduction, bioremediation). Moreover, certain species groups dominate certain pathways. For example plants dominate the ornamental, horticultural and landscape, floral and faunal improvement pathways.



**Figure 3.6:** Possible introduction pathways for all species present on the list of potentially invasive species for the Netherlands per species group.

#### *Analysis of pathways per general group*

The utilisation frequencies of dispersal pathways for all species present on the list of potentially invasive species for the Netherlands are displayed per general group in figure 3.7. The pathways that occur most frequently are the pet/aquarium trade, ornamental purpose, horticulture and botanical/garden/zoo/aquaria. Freshwater and terrestrial animals dominate one of the most frequently occurring pathways, the pet/aquarium trade. Terrestrial plants dominate the other most occurring pathway, ornamental purpose. Freshwater animals and freshwater plants are represented less frequently. The horticulture pathway is dominated by terrestrial plants, while the botanical/garden/zoo/aquaria pathway is utilised mainly by terrestrial plants and animals. The relatively limited occurrence of aquatic plants and marine animals can be attributed to their low frequency of occurrence on the list of potentially invasive species for the Netherlands (Figure 3.2, section 3.2.1).

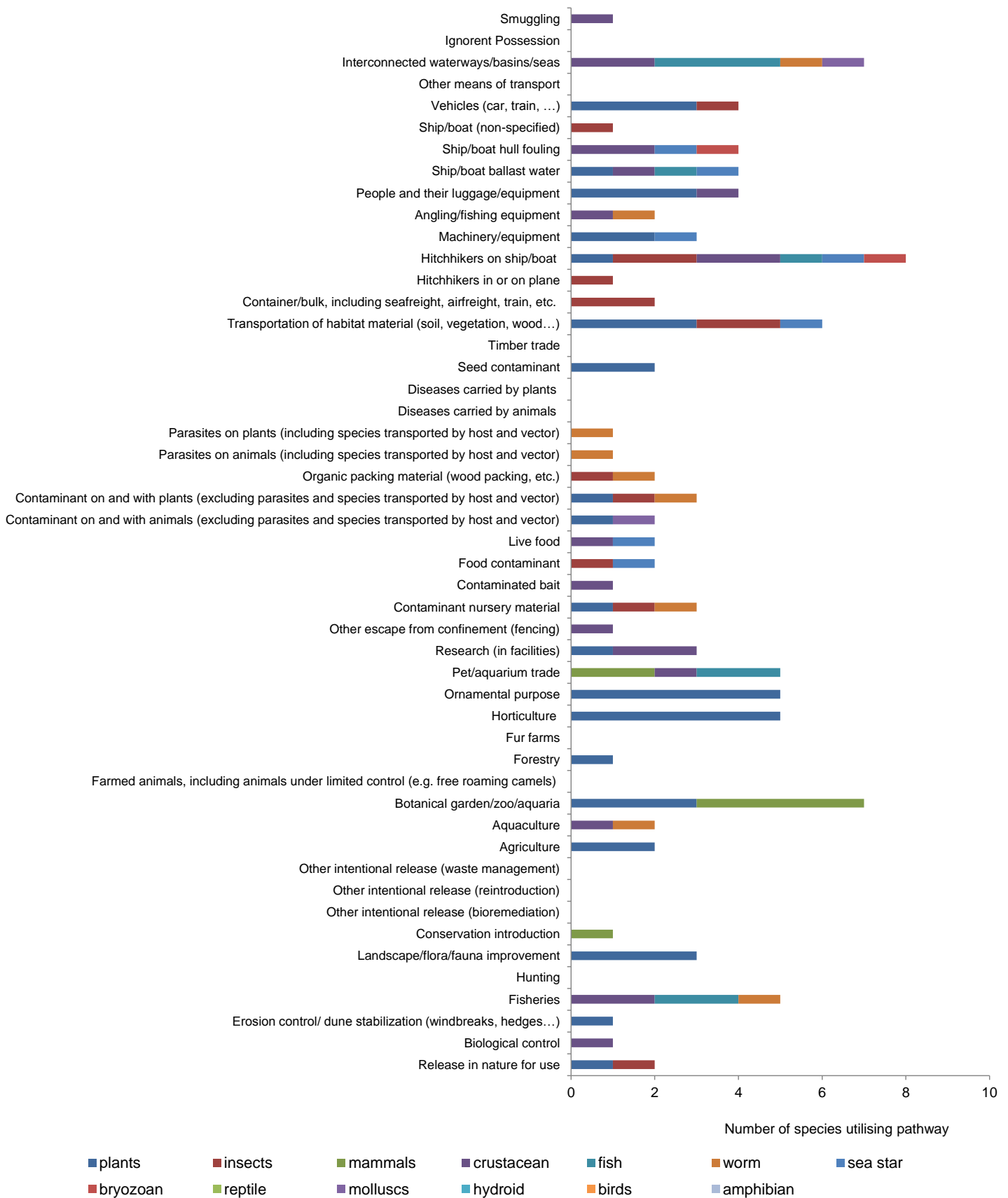
#### *Analysis of pathways for species absent from the Netherlands per species group*

The known pathways of species absent from the Netherlands per species group are illustrated in figure 3.8. The most frequently listed pathway for species absent from the Netherlands is hitchhiking on a ship or boat. This pathway is utilised by plant, insect, crustacean, fish, sea star and bryozoan species groups. However, the relative contribution of the hitchhiking on ships and boats pathway is far smaller when all species are examined for pathway utilisation (Figure 3.6). The second and third most frequently used pathways are related to interconnected waterways, basins or seas (utilised by crustaceans, fish, worms and molluscs) and (botanical) gardens, zoos and aquaria (utilised by plants and mammals). Finally, the fourth most frequently listed pathways are the transportation of habitat material utilised by plants, insects and sea stars and the ornamental pathway. A number of pathways in the classification were found to be irrelevant for the species on the list. These were ignorant possession, other means of transport, timber trade, diseases carried by animals and plants, fur farms, farmed animals including free roaming animals under limited control, other intentional release (waste management, reintroduction, and bioremediation) and hunting. Moreover, certain species groups dominate certain pathways. For example only plants utilise the ornamental, horticultural and landscape, floral and faunal improvement, agriculture, seed contaminant, forestry, erosion control / dune stabilisation and release in nature for use pathways.



**Figure 3.7:** Possible introduction pathways for all species present on the list of potentially invasive species for the Netherlands per general group.

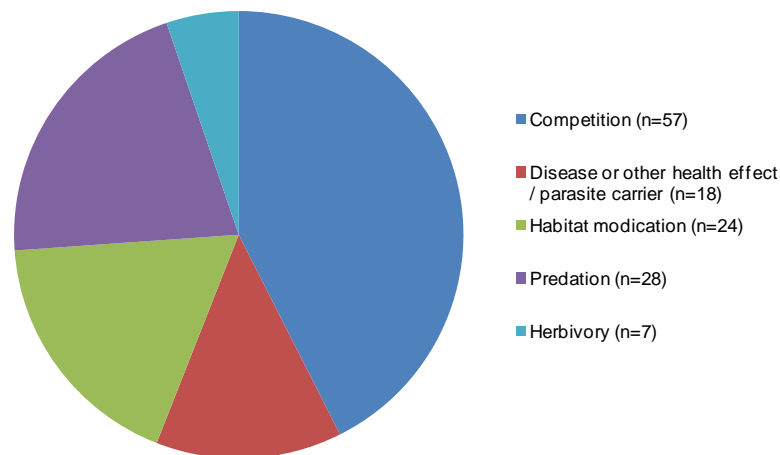




**Figure 3.8:** Possible introduction pathways for species absent from the Netherlands per species group.

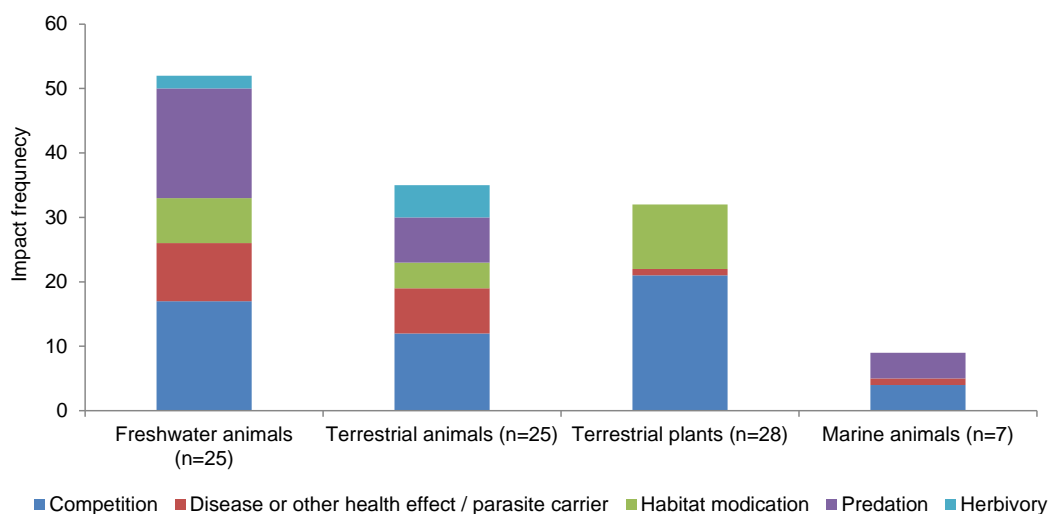
### 3.2.4 Ecological impacts of most concern

The relative contribution of the different potential ecological impact categories to the species listed as potentially invasive species for the Netherlands are presented in figure 3.9. Competition with native species forms the largest impact group followed by predation, habitat modification, and disease or other health effect / parasite carrier. Impacts related to herbivory occur less frequently than the other impact groups.



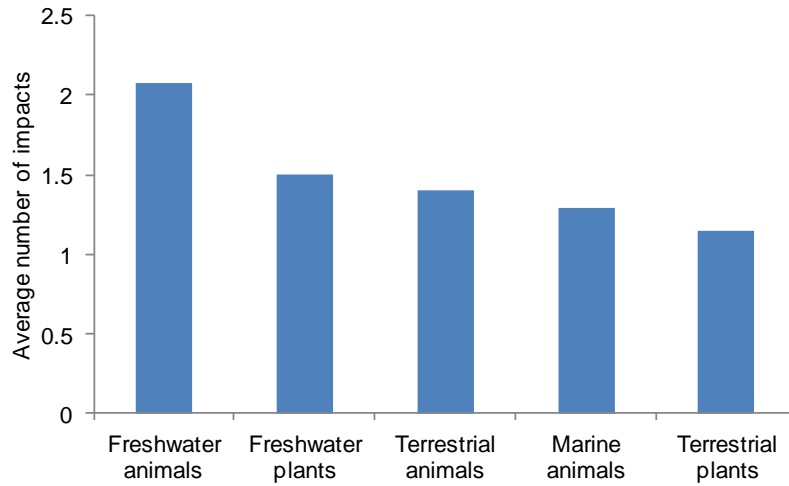
**Figure 3.9:** Relative contribution of impacts related to species present on the list of potentially invasive species for the Netherlands.

The potential ecological impacts of species per general group are displayed in figure 3.10. Freshwater animals exhibit the greatest number of impacts followed by terrestrial animals and terrestrial plants. Competition occurs most frequently within the terrestrial plants group, followed by freshwater animals and terrestrial animals. Predation occurs most frequently in the freshwater animals group compared to terrestrial animals and marine animals. Habitat modification impacts are most frequently connected with terrestrial plants, followed by freshwater animals and freshwater plants. It should be noted that the frequency of impacts is heavily influenced by the number of individual species within each general group appearing on the list.



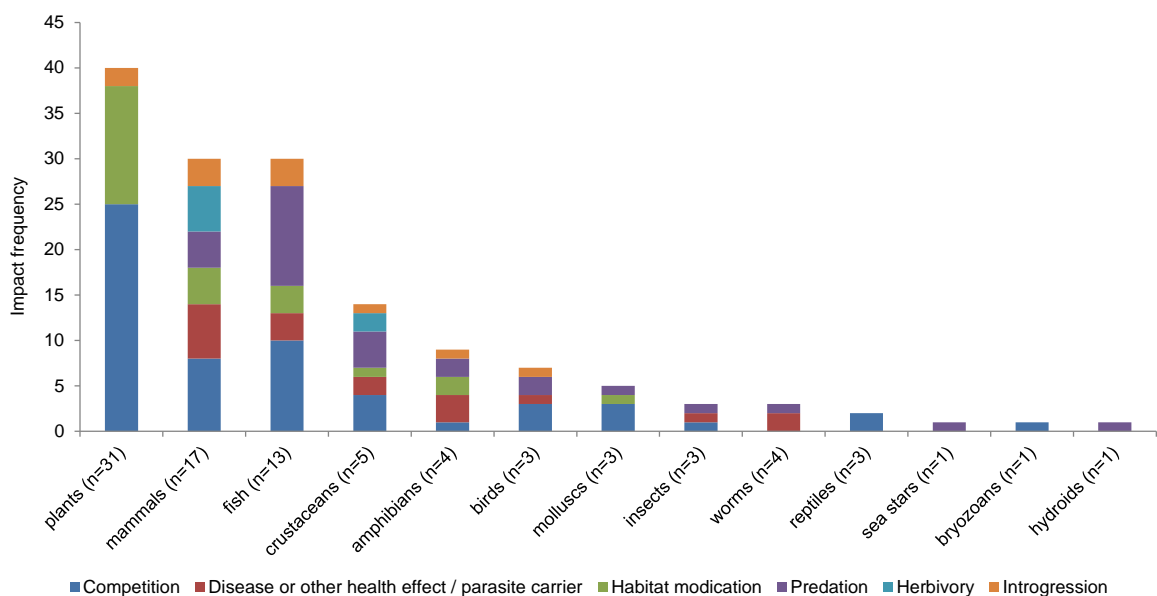
**Figure 3.10:** Potential ecological impact type recorded per general group.

Figure 3.11 shows the average number of impacts recorded per individual species within each general group. Freshwater animals and plants have the largest number of impacts per individual species followed by terrestrial animals, marine animals and terrestrial plants.



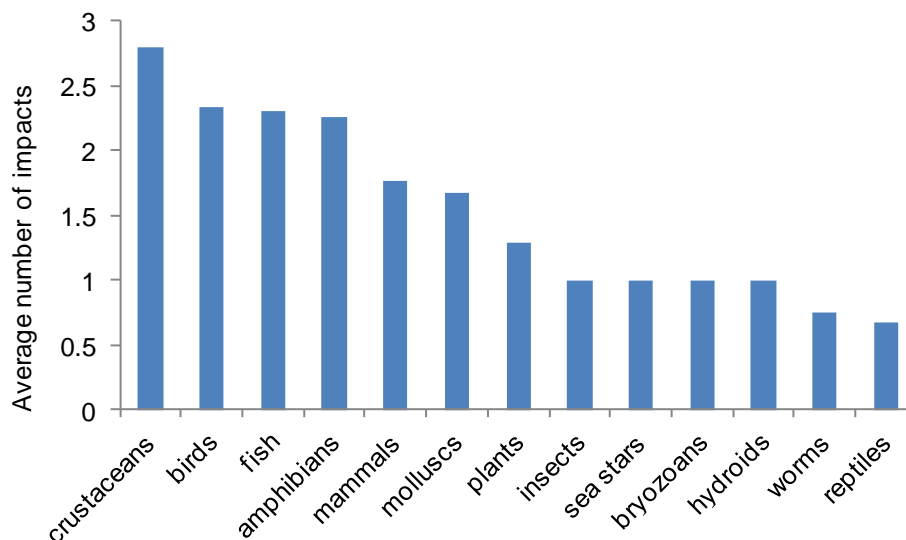
**Figure 3.11:** Average number of potential impacts per individual species per general group.

The potential ecological impacts per species group are displayed in figure 3.12. Plants feature the greatest overall number of ecological impacts, followed by mammals and fish. Ecological impacts of plants relate primarily to competition and habitat modification. Ecological impacts of mammals are more evenly spread across all impact categories. Competition, disease and other health effects / parasite carrier and herbivory related impacts occur most frequently within the mammal species group. Fish ecological impacts relate primarily to competition with and predation of native species. It should be noted that the frequency of impacts is heavily influenced by the number of individual species within each species group appearing on the list.



**Figure 3.12:** Impact type per species group present on the list of potentially invasive species for the Netherlands.

Figure 3.13 shows the average number of impacts recorded per individual within each species group. Freshwater animals, birds and mammals feature the highest number of recorded impacts of all species groups.



**Figure 3.13:** Average number of impacts per individual per species group.

Figure 3.14 indicates the type and frequency of potential ecological impacts that are assigned to different dispersal pathways of the species featured on the list of potentially invasive species for the Netherlands. Pathway definitions are listed in appendix 3. The pet and aquarium, ornamental, and botanical garden/zoo/aquaria pathways were related with the highest number of ecological impacts. The most frequently occurring impacts connected to these pathways is competition with native species, followed by habitat modification and disease or other health effect / parasite carrier. Four out of five pathways relating to the most frequently occurring ecological impacts occur as a result of the international trade in plants and animals. The only pathway not connected with the trade in live plants and animals is related to the unintentional transport of species via ships and boats (hitchhiking). However, it is expected that international trade features highly within this last group in the Netherlands due to the high frequency of commercial ship passages that occur via the major Dutch waterways.

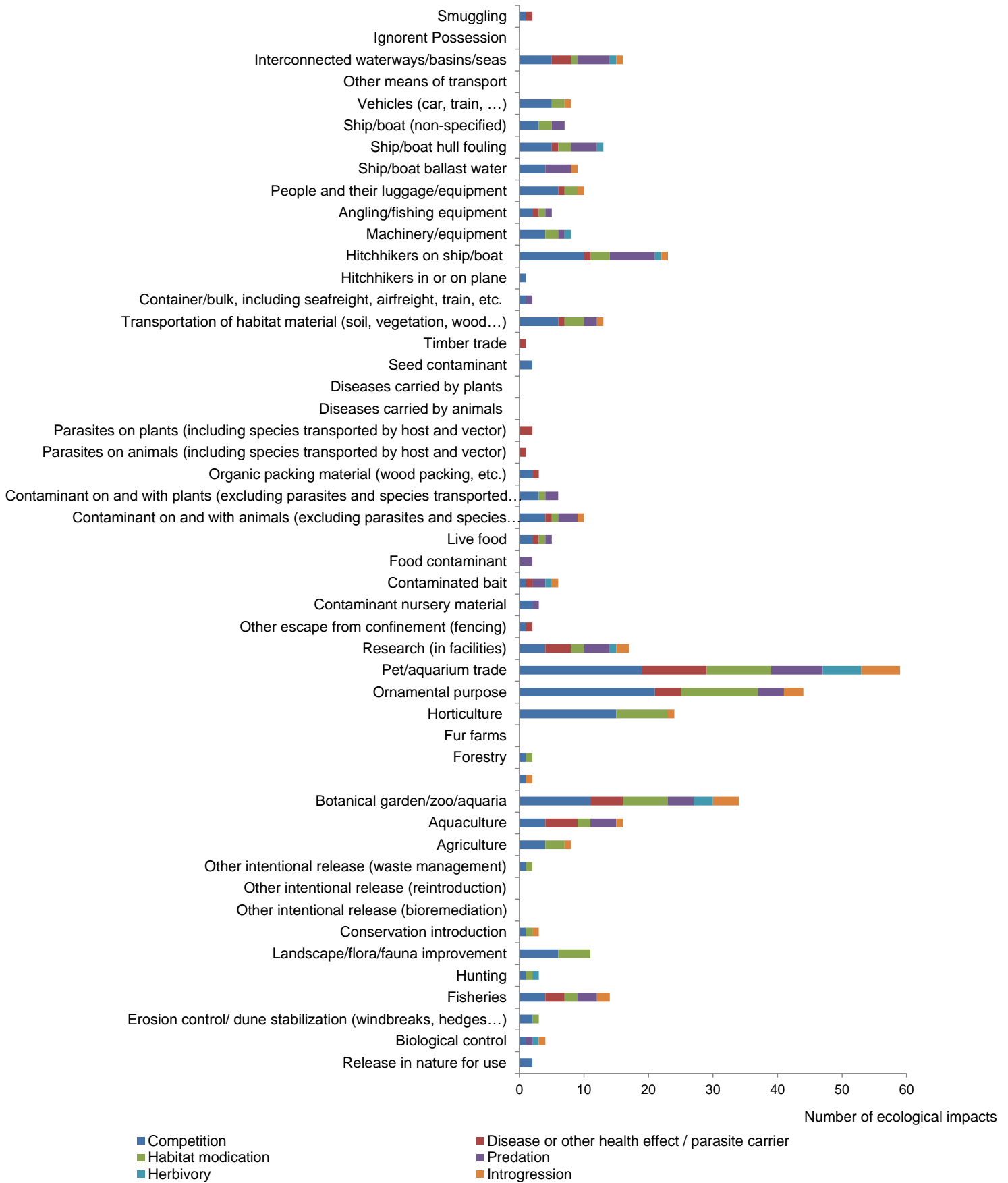


Figure 3.14: Number of ecological impacts per introduction pathway.

## 4. Discussion

The results from the pathway analyses highlight the importance of intentional trading as a pathway for the introduction of non-native animal and plant species to the Netherlands. For species groups listed as potentially invasive species for the Netherlands, the most frequently occurring pathways are the pet and aquarium trade, ornamental pathway, horticulture and the botanical/garden/zoo/aquaria pathway. A relatively large number of plant species present in limited distributions in the Netherlands have established in locations in urban areas. In most cases these are the offspring of planted ornamental species (R. Beringen, pers. comm.). Considering species listed and currently absent from the Netherlands, the most likely pathways include hitchhiking on a ship or boat, utilising interconnected waterways/basins/seas, intentional release or escape from botanical gardens, zoos or aquaria or transport with habitat material. The pet and aquarium, ornamental and botanical garden/zoo/aquaria pathways were related with the highest number of ecological impacts recorded in available literature. Freshwater animals were associated with the highest number of impacts of high risk species followed by terrestrial animals and terrestrial plants. These species groups contained similar numbers of species. A number of these results are supported in literature. Corridors are most often associated with aquatic rather than terrestrial species emphasising the importance of artificial waterways in the movement of non-native species (Hulme et al., 2008; Leuven et al., 2009). However, when corridors are excluded, the main mechanism for aquatic and terrestrial vertebrate species is release and/or escape from captivity (Hulme et al., 2008). Moreover, active release or escape is emphasised as an important introductory pathway for non-native plants (Kaye & Hoyle, 2001).

The geographical origins of most concern for non-native species present on the list of potentially invasive species for the Netherlands are Asia and North America. Asia is likely to supply the most species of terrestrial animals and plants while North America will probably be the source of most freshwater and marine animals.

The following sections contain a description of gaps in knowledge and uncertainties that were discovered while performing the horizonscan for the Netherlands. Following this, a discussion of the origins, most frequently occurring pathways and ecological impacts relating to new, potentially invasive species for the Netherlands is undertaken. Finally, relevant and potentially effective management measures relating to the most important pathways are discussed.

### 4.1 Gaps in knowledge and uncertainties

#### *Methodological difference*

The aggregation of standardised risk scores applied as part of the horizonscan is dependent on a number of differing methodologies to judge risk from studies carried out by different organisations and different expert groups from different countries. Differences in European risk assessment protocols include differences in scope,

weighting, scoring and classification methods, assessment criteria and uncertainty analysis (Dahlstrom et al., 2011; Heikkila, 2011; Verbrugge et al., 2012). Methodological approaches (quantitative statistical, semi-quantitative and qualitative expert judgement) differ in the weighting they give to the probabilities of introduction, establishment, dispersal, economic and environmental impact, and management (Hulme, 2011).

Moreover, several methods only go as far as identifying risk (e.g. ISEIA and FISK) rather than performing a complete risk assessment (Table 2.3, section 2.2.2). Risk assessment methods require a more detailed assessment. For example, the GB risk assessment contains 51 questions and therefore needs more data input than other methods. In the initial steps of the GB risk assessment, pre-screening tools such as FISK can be used. On the other hand, risk identification methods such as FISK were designed to examine the risk of certain species groups, for example freshwater fish and invertebrates, and may be more accurate at identifying risk than other methods.

#### *Data reliability*

The aggregation of data from national horizonscans and national lists raises issues of the reliability of observational data and the criteria used for the inclusion of certain impacts in the analyses. Often, the methods used to derive data for individual species are not included in horizonscans or reported with national black lists. Therefore, it is difficult to assess the reliability of data. For example, Strubbe et al. (2011) recently showed that evidence of impacts of invasive birds are generally not based on scientific research but on anecdotal observations relating to small areas only. Moreover, it was noticed during the literature review that some horizonscans contain a small number of errors in the case of some species. However, this was an infrequent occurrence.

#### *Lack of data and use of expert judgement*

In qualitative assessments of risk, lack of data is a frequently occurring problem. Of the more than 10,000 European alien species registered in the DAISIE database, ecological impacts are only documented for 1094 species (11%) and economic impacts for only 1347 species (13%) (Vilà et al., 2010; Hulme, 2012). This may well be due to a lack of observations rather than a lack of impact in species with no information. Moreover, the step between introduction and establishment is a critically important filter in biological invasions and one for which we have little information (Puth & Post, 2005; Hulme, 2012). Incomplete data input often results in a heavy reliance on expert judgement (Maguire, 2004; Strubbe et al., 2011; Verbrugge et al., 2012). Expert knowledge may not always be objective, accurate, consistent or reproducible (Hulme, 2012). Experts may interpret the same information differently depending on how the information is presented. The use of value laden words such as 'invasive' or 'aggressive' may influence the objective judgement of some assessors (Hulme, 2012). Species factsheets often include the most dramatic impacts and experts may focus on such information allowing an initially formed opinion to influence further judgement, even in the presence of contradictory information (Hastie & Dawes, 2010; Hulme, 2012). Moreover, experts may look for evidence that confirms their initial preconceptions about a species (confirmation bias) (Hulme, 2012).

There was a lack of country specific information regarding the most risky areas of origin, primary and secondary hotspots and impacts in the Netherlands for many of the species included in the horizonscan. In these categories there was a heavy reliance on expert

knowledge and the interpretation of pathway information. Impacts relating to other countries were often taken as a proxy to potential impacts in the Netherlands. However, the use of a single expert per species group increased the likelihood of consistency in situations where expert judgement was applied.

#### *Variation between European risk classifications*

In a study examining different risk identification and assessment methods applied in Europe, it was found that risk classifications for aquatic species showed dissimilarities for 18 of the 25 species examined when compared between countries (Verbrugge et al., 2012). Reasons given for these dissimilarities in risk classifications were differences between national assessment protocols, species environment matches in different biogeographical regions and the trade-off between data availability and expert judgement. Moreover, ecological impacts depend on region-specific habitat characteristics and conservation aims (Verbrugge et al., 2012).

As the horizonscan only included species absent or present in a limited distribution in the Netherlands, there is a lack of Dutch specific data. Therefore, the horizonscan methodology used data on risk classifications from surrounding countries and it was assumed that risk classifications in these countries are also relevant for the Dutch situation due to climatic similarity. The only variable consistently correlated with invasiveness in one region is invasiveness elsewhere (Wittenberg & Cock, 2001). However, the observation of differences between the classifications of neighbouring countries, sometimes including both low and high risk classifications for a species is worrisome in this respect (Verbrugge et al., 2012). Differences in species risk classification between climatically similar regions suggests that other unknown factors are influencing the results which increases the uncertainty of the aggregated risk score.

#### *Economic impacts*

It should be noted that the horizonscan did not take into account the cost of management of invasive species in its assessment of economic impact. This was because management costs will vary from country to country dependent on invasion stage and the type of management methods applied. In Europe, most expenses generated by invaders are in the form of management costs (Colautti et al., 2006; Vilà et al., 2010; Sinden et al., 2011). Therefore care should be taken in the interpretation of information given with regard to economic impact.

#### *Variations in habitat quality and quantity*

The horizonscan only considered similarities in climate between neighbouring countries and the Netherlands. However, the quality and quantity of suitable habitat will vary between locations and will have an additional large bearing on the likelihood of non-native species establishment.

#### *Approaches taken to reduce uncertainty*

To account for possible differences between national risk scores, only species that received a high risk rating in two or more of the surrounding countries were included in the horizonscan list of potentially invasive species for the Netherlands (high risk of ecological impacts). Moreover, the use of risk classifications only from countries in immediate proximity to the Netherlands, the United Kingdom and Ireland and locations



linking the Netherlands with an obvious pathway that has been shown to be utilised by non-native species is expected to increase the validity of the results. The inclusion of a weighting factor to assess the contribution of formal risk assessments to the aggregated risk score may help to reduce uncertainty in relation to the inclusion of different assessment methods, and highlights species that have been assessed more extensively.

In categories where there was a heavy reliance on expert knowledge to classify species within the horizonscan database, a qualitative assessment was made to provide an indication of the certainty of the information (score one: low certainty, score two: medium certainty, score three: high certainty). If an impact was described for a particular country and the name of the country given, this information was included in the horizonscan database along with the impact type.

## **4.2 Geographical origins of most concern**

The most frequent geographical origin of aquatic animals on the list of potentially invasive species for the Netherlands is North America. This observation is supported by Welcomme (1991), Vilà et al. (2010) and García-Berthou et al. (2005) who state that in contrast to other taxa such as plants and terrestrial vertebrates, freshwater species introduced to Europe come mostly from North America and enter through mid-latitude countries in western Europe (France, the UK, and Germany). France and Italy have been shown to be mostly responsible for introductions to European marine systems through aquaculture (Nunes et al., 2014).

## **4.3 Pathways of most concern**

The following sections describe the pathways that were highlighted to be the most frequently utilised by non-native species present on the list of potentially invasive species for the Netherlands. Firstly, the active movement of species via the trade in non-native species and the role of e-commerce and secondly, the passive movement of species via the artificial connections of river basins is discussed.

### *The trade in non-native species*

The most frequently employed pathways for the introduction of non-native species to the Netherlands involved the trade in non-native species. This result is reflected in the literature examining trends in non-native species introductions. The expansion of world trade has been implicated in the sharp increase in the number and frequency of non-native species introductions generally. In a multiple regression analysis of pathways contained within the global invasive species database, merchandise imports was the most important explanatory variable in most cases (Westphal et al., 2008). The greater the degree of international trade, the higher the number of invasive species. The increase in global trade may be seen as a proxy to an increase in propagule pressure which may be more important than the intrinsic properties of the native biota, measured at the national scale (Westphal et al., 2008).

For example, the introduction of non-native garden pond macrophytes into a country is almost certainly the result of the trade in live aquarium plants, legal or otherwise (Bowmer et al., 1995; Matthews et al., 2013). Brunel (2009) undertook a survey examining the importation of non-native aquatic plants to 10 countries in Europe. The Netherlands imported circa five million units of aquatic plants in 2006 and was the largest importer, coming top of a list of countries constituting France, the Czech Republic, Germany, Hungary, Switzerland, Austria, Latvia, Turkey and Estonia. Approximately 50,000 plant species are for sale in the Netherlands and Belgium, the Dutch wild flora consists of about 1,500 species (R. Beringen, pers. comm.). This high level of imports of aquatic species reflects what is seen in Europe in general. For example, one third of the aquatic species listed in the Invasive Species Specialist Group's top 100 worst invasive species of the International Union for the Conservation of Nature (IUCN) have been introduced via the aquarium trade or through ornamental release (Padilla & Williams, 2004; Martin & Coetzee, 2011). The trade in animals as pets is also a major concern. The frequent keeping of the non-native grey squirrel (*Sciurus carolinensis*) as a pet in the Netherlands, that may threaten native species if released, represents a high-risk pathway for a new invasive introduction (Bertolino et al., 2014; Dijkstra & Dekker, 2008). The introduction of squirrels increases in developed countries and proportionate to the volume of imported mammals (Bertolino et al., 2014). The Netherlands is in the process of introducing a positive list of pet species that may be successfully kept domestically. The list considers criteria such as zoonosis, ease of care and animal welfare, however potential invasiveness is not considered (Koene et al., 2013).

Trade is also implicated as the main mode of introduction for ornamental garden plants, a pathway that is utilised often by potentially invasive species that are absent from the Netherlands. In a study examining the introduction of non-native plant species to Europe, 39.9% of introductions were related to the trade in ornamental plants, 17.5% to horticulture and 9.9% arrived as a stowaway (Gooier et al., 2010). This pattern is also observed in other parts of the world. For example in Australia, about 80% of noxious weeds stem from ornamental plants used in gardening (Virtue, Bennett & Randall, 2004; Hulme, 2012). However, compared with other major introduction pathways, garden ornamentals have the lowest probability either of naturalising or becoming noxious weeds (Hulme, 2012).

The pet trade has also been implicated in non-native fish releases in Europe. A relationship was noticed between frequency of occurrence of aquarium fish in shops and the likelihood of introduction in nature (Duggan et al., 2006). Moreover, the most frequently introduced aquatic species' in Europe are freshwater fish (García-Berthou et al., 2005).

#### *The influence of e-commerce and the internet*

The ease with which international retailers can access customers from other countries increases the risk that species will be transported across international borders. Further growth in the volume of trade increases the frequency with which introductions are repeated and increases the possibility that a species will become established (Perrings et al., 2005; Randall & Marinelli, 1996; Kay & Hoyle, 2001). The dramatic increase in hobbyist, domestic and foreign commercial websites that discuss the beauty and

qualities of invasive aquatic plants is concerning (Kay & Hoyle, 2001). In recent risk analyses of two non-native and potentially invasive aquatic plant species, curly waterweed (*Lagarosiphon major*) and fanwort (*Cabomba caroliniana*), both plants were found to be available to the public from online retailers in the Netherlands (Matthews et al., 2012; Matthews et al., 2013). Also, the most probable pathway of entry for the striped skunk (*Mephitis mephitis*) to the Netherlands is via the trade in animals due to the lively internet trade and various hobbyist websites relevant to the Netherlands and neighbouring countries of Belgium and Germany (van Belle & Schut, 2011). Moreover, the internet trade in non-native squirrel species is of major concern (Dijkstra, 2014).

#### *Deliberate freeing versus escape*

Many introductions of non-native species begin with the trade in a species followed by its deliberate freeing or escape and subsequent dispersal in the environment. In our survey it was difficult to distinguish whether the freeing of non-native species was deliberate or accidental. However, there is evidence in the literature that shows that a high number of introductions are a result of deliberate acts. For example, only about 13% of aquatic plant and animal introductions in Europe are accidental (Welcomme, 1992; García-Berthou et al., 2005) and the act of discarding unwanted species into drains or waterways has been recorded in many examples worldwide (Fuller, 2003; Rixon et al., 2005; Martin & Coetzee, 2011). Moreover, the results of a recent survey examining the behaviour of aquarium and water garden owners in the Netherlands showed that 2.9% (n = 7) of the 239 respondents had disposed of aquatic plants in open water (Verbrugge et al., 2013). Further proof of deliberate introductions is provided by the occasional occurrence of common garden pond plants and animals in Dutch waters with examples of pumpkinseed sunfish (*Lepomis gibbosus*) (van Kleef et al., 2008). This fish species was introduced to the Netherlands in 1902 as an aquarium and garden pond fish. Deliberate freeing from confinement (e.g. aquaria) is one of the top five avenues for introduction of non-native invasive aquatic species, but has received relatively little attention from both scientists and policy makers (Padilla & Williams, 2004; Martin & Coetzee, 2011). Moreover, the first and second most important vectors of bird and mammal introductions into Europe are deliberate freeing and escape (Hulme et al., 2008; Bertolino et al., 2014). However, other authors argue that most bird introductions tend to be accidental, mostly as a result of pet escapes (Carrete & Tella, 2008). Squirrels are often introduced deliberately, while escape from captivity occurs less frequently (Bertolino et al., 2014).

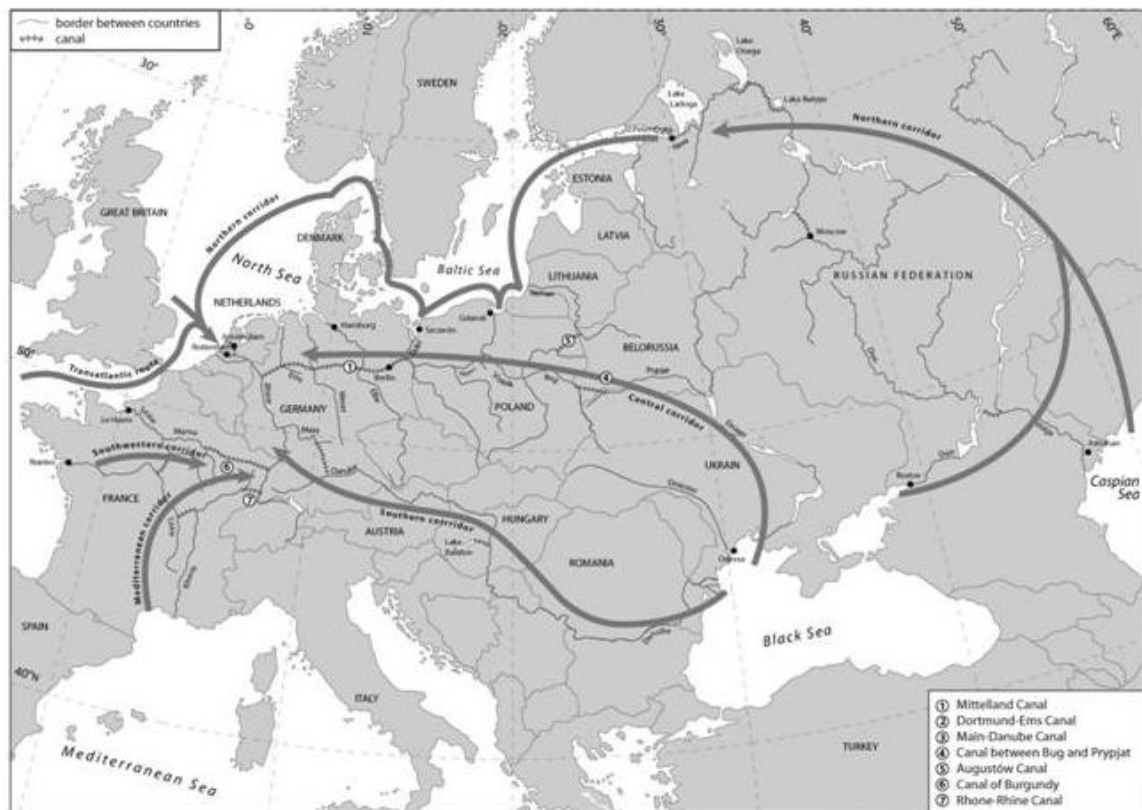
Some non-native species may disperse naturally to the Netherlands from non-native ranges in Belgium and Germany without the aid of humans. Example mammal species of particular concern are the muntjac (*Muntiacus reevesi*), raccoon (*Procyon lotor*) and also the raccoon dog (*Nyctereutes procyonoides*) and coypu (*Myocastor coypus*). When populations of non-native species in neighbouring countries grow, the risk of introduction via this pathway also increases, not only for these species, but possibly for other mammal species such as squirrels (H. Hollander, pers. comm.).

#### *Pathways related to international shipping and the artificial connection of river basins*

Two of the most important identified routes for the introduction of high risk species that are absent from the Netherlands are hitchhiking on ships or boats and the interconnected waterways, basins and seas pathway. This and the high number of

impacts associated with aquatic species (see section 4.4) emphasises the importance of these pathways. The network of artificial waterways that cross Europe connecting river basins has been implicated in the introduction of a number of freshwater species in the Netherlands. Over the last two centuries, the total surface area of river catchments connected to the river Rhine via artificially constructed waterways has increased by a factor of 21.6 and the cumulative number of non-indigenous species in time is significantly correlated with this increase in total surface area (Leuven et al., 2009).

A total of six anthropogenic pathways linking the Netherland's freshwater system to other regions were described by Leuven et al. (2009), (Figure 4.1). (1) The Northern corridor, connecting the catchments of the Black, Azov and Caspian seas via the Volga–Don Canal, and the Baltic and White seas via the Volga-Baltic Canal and White Sea–Baltic Sea Canal and the river Rhine via sea shipping; (2) The Central corridor, connecting the Black Sea basin with the Baltic Sea region via the Dnieper and Bug-Pripyat Canal and with the North Sea basin via an extensive network of waterways; (3) The Southern corridor, linking the Black Sea basin with the North Sea basin via the Danube-Main-Rhine waterway; (4) The South-western corridor, linking the rivers Loire and Seine; (5) The Mediterranean corridor, linking the Mediterranean basin with the North Sea basin via the Rhone and the Rhine-Rhone Canal; (6) The transatlantic and North Sea shipping routes to various sea harbours in the Rhine delta.



**Figure 4.1:** Principal dispersal corridors for aquatic invasive species to the river Rhine. Source: Leuven et al. (2009).

The sea going corridors, including the Northern corridor, have been effective in the transfer of non-native species for many centuries. However, increased trade and the introduction of ballast water in the 20<sup>th</sup> Century has led to increased risk of non-native

species introduction via these corridors. It has been estimated that many thousand species of freshwater, brackish water, and marine protists, plants and animals are transported at any moment in the ballast water of ships (Carlton & Geller, 1993; García-Berthou et al., 2005). Shipping has been found to be the most important pathway of introduction in European seas, with a wide ranging geographic pattern of initial introductions, particularly near large ports (Nunes et al., 2014). Moreover, marine systems are often the first point of contact for trade shipments arriving in a country, and so may be more vulnerable to invasion than terrestrial systems (Puth & Post, 2005). However, the lack of marine species present on the list of potential invasive species in the Netherlands appears to contradict this. The importance of ports is illustrated in figure 4.1 where sea going corridors terminate at port locations such as the ports of Rotterdam and Amsterdam.

The construction of inland canals connecting river basins, the most recent of which completed the Southern corridor after the building of the Main-Danube canal in 1992, has resulted in a number of aquatic non-native species introductions to the Netherlands (Leuven et al., 2009; Gooijer et al., 2010). The importance of this pathway to aquatic species was emphasised by García-Berthou et al. (2005) whose analysis of all aquatic species introductions to the Netherlands of known origin revealed that Germany was the dominant donor country, responsible for seven out of 28 introductions. In this study, that incorporates the southern and central corridors, Germany was highlighted as the only important donor of aquatic species to the Netherlands. Certain high risk aquatic species such as the racer goby (*Neogobius gymnotrachelus*), fish-hook waterflea (*Cercopagis pengoi*) and scud (*Obesogammarus obesus*), may be introduced via the corridors linking the Ponto-Caspian region (Black sea basin) with the Netherlands.

#### **4.4 Ecological impacts of most concern**

The following sections discuss the most frequently occurring impacts and species groups that are associated with the highest number of impacts of potentially invasive species for the Netherlands.

##### *Most frequently occurring impacts*

From the analysis of potential ecological impacts it was concluded that competition with native species results in the largest number of impacts followed by predation, habitat modification, and disease or other health effect / parasite carrier. However, this does not tell the whole story with regard to ecological and socio-economic impact. A simple analysis of impact occurrence or non-occurrence does not highlight the importance of scale. For example, a single plant species, Japanese knotweed (*Fallopia japonica*), accounts for a third of the total annual non-native plant management costs in Great Britain at 165,609,000 pounds (Williams et al., 2010). According to Hulme (2012), the next most costly non-native plant species in the UK are the wild oat (*Avena fatua*), which accounts for more than 58 million pounds of management costs per year and the common field-speedwell (*Veronica persica*) that accounts for more than 36 million pounds per year. All these plants compete with native species, but the associated impacts vary dramatically in scale. Simply counting the number of individual impacts that

are associated with a particular invasive species may not give an adequate picture of the scale of those impacts.

#### *Impacts per species group*

In general, after loss of habitat, invasive species are the second leading cause of global biodiversity loss (Moyle et al., 1986; Vitousek et al., 1997; García-Berthou et al., 2005). Results from the horizonscan indicate that freshwater species are related to the largest number of impacts per individual species followed by terrestrial animals. In a recent review of the ecological and economic impacts of non-native species in Europe, terrestrial vertebrates and freshwater organisms were shown to be of particular concern (Vilà et al., 2010). The authors reported that more than one-third of registered terrestrial vertebrates and freshwater organisms are known to cause impacts. This statement is further supported by Hulme (2012) who states that garden ornamentals have the lowest probability either of naturalising or becoming noxious weeds and by García-Berthou et al. (2005) who state that biodiversity loss as a result of invasive species was especially predominant in aquatic ecosystems. Aquatic invasive species also exhibit a high number of different impact types per species. For example nine impact types have been reported for brook trout (*Salvelinus fontinalis*) (Vilà et al., 2010). However, this may be partly caused by the enormous amount of attention that this species has received (H. van Kleef, pers. comm.). Many aquatic systems are quite isolated and feature many native species (Puth & Post, 2005). In isolated aquatic ecosystems, similarly to islands, the effect of non-native species results in high extinction rates of native species (Lodge, 1993; Puth & Post, 2005). Moreover, freshwater ecosystems demonstrate a higher vulnerability to introduced predators than terrestrial and marine ecosystems because native species generally feature fewer defence mechanisms and greater naïveté toward novel predators (Vilà et al., 2010).

The taxonomic groups with impacts documented across the greatest number of regions in Europe are terrestrial vertebrates and terrestrial invertebrates. The raccoon dog (*Nyctereutes procyonoides*) is known to cause problems in more than 50 European regions (Vilà et al., 2010). Moreover, the introduction of vertebrate predators has been the most important reason for extinctions globally, particularly on islands (Blackburn et al., 2004).

#### *Aquatic species and the tens rule*

The tens rule states that one in 10 species introduced become established, and that one in 10 of those established becomes a pest (Williamson & Fitter, 1996). However, care should be taken over the definitions applied within the tens rule, for example introduced means located outside control or captivity as a potentially self-sustaining population (Williamson & Fitter, 1996). Moreover, the tens rule has been mostly verified using terrestrial plants, birds, and biocontrol insects (Kolar & Lodge, 2001; Lockwood et al., 2001; García-Berthou et al., 2005) and infrequently for aquatic species (Ricciardi & Kipp, 2008). In an assessment of 123 aquatic species introduced into six contrasting European countries using the Food and Agriculture Organization's Database of Invasive Aquatic Species, the average percentage established was found to be 63% (García-Berthou et al., 2005). This suggests that aquatic species may carry an increased risk of becoming invasive outside of their native range relative to other species groups. The importance of aquatic pathways to list species that are currently absent from the

Netherlands together with the high number of impacts associated with this species group emphasises the potential for aquatic non-native species to cause ecological damage in the Netherlands.

## **4.5 Options for prevention**

The following sections discuss the most relevant pathways for the introduction of potentially invasive species and potentially effective options for the prevention of potentially invasive species for the Netherlands. Prevention of introductions is normally more cost efficient than post introduction eradication or control (Leung et al., 2002; Coetzee et al., 2009). Moreover, impacts related to eradication measures may be greater for native species than non-native species and even if eradication is successful, invasive species may have already caused long-term alterations in community structure and ecosystem function (Zavaleta et al., 2001; Smith et al., 2006; Carrete & Tella, 2008). Additionally, if eradication is successful but preventative measures are not undertaken then the potential for re-introduction of the species remains. Therefore, prevention targeting the most important pathways of introduction should be prioritised.

During the course of this project we came across several management options for the effective eradication of invasive alien species. Although an assessment of management options for eradication and control lay outside the scope of this project, these recommendations are included in appendix 6 since we feel that this is valuable information.

### **4.5.1 Relevant pathways**

In order to identify options for the prevention of potentially invasive species, the most important pathways of introduction should be identified. The analysis of the high risk non-native species listed in the horizonscan database demonstrates that non-native plants most frequently occur on the list. Moreover, literature highlights the risk of ecological impacts posed by non-native terrestrial vertebrates and aquatic species. The trade in live animals and plants is the most frequently occurring potential anthropogenic pathway of entry to the Netherlands of these species groups (Section 3.2.3, figure 3.8). For example, the introduction and establishment of non-native species in the natural environment via the aquarium trade is related to the number of organisms that are sold to the general public. The higher number of sales, the greater the chances of escape, and, ultimately, the greater the chance of establishment (Cohen et al., 2007; Martin & Coetzee, 2011). Therefore, options for the prevention of entry of these species should focus on the control of the trade in live animals and plants.

The increase in global trade may be seen as a proxy to an increase in propagule pressure which may be more important to the establishment of non-native species than the intrinsic properties of the native species, measured at the national scale (Westphal et al., 2008). Because the establishment transition is less crucial to the invasion process than the introduction one, it is essential to avoid the introduction of new species (García-Berthou et al., 2005). Moreover, because introductions to new countries within a continent are difficult to avoid, legislation and its implementation should be coordinated

internationally (García-Berthou et al., 2005; Westphal et al., 2008). The cross border trade in non-native species has been spurred on particularly by the increasing use of the internet and e-commerce as part of the globalization of trade. For example, the selling of non-native aquatic plants over the internet in the Netherlands is common (Matthews et al., 2012; Matthews et al., 2013). The increasing influence of e-commerce on introductory pathways has been mainly ignored by researchers and policy makers (Derraik & Phillips, 2010; Martin & Coetzee, 2011).

#### 4.5.2 Prevention

##### *Prevention through trade regulation*

A number of authors emphasise the potential effectiveness of limitations on the trade of potentially invasive species in preventing the expansion of species' non-native range and related ecological and socio-economic impacts (Carrete & Tella, 2008; Van Kleef et al., 2008; Bertoloni & Genovesi, 2005; Bertolino et al., 2014). For example, the international treaty CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) significantly reduced the volume of (legal) trade in non-native species following its introduction (Rivalan, 2007). However, blanket bans will likely meet with resistance from an industry that depends on the movement of non-native species for its livelihood.

Worldwide, a number of voluntary and mandatory regulations have been put in place to prevent the spread of non-native species. For example, in the United States the use of live bait by anglers is restricted, and boaters are required to remove vegetation from boats and trailers to prevent the spread of potentially invasive species (Puth & Post, 2005). In a further example, the banning of the non-native fanwort (*Cabomba caroliniana*) from sale in the Netherlands may have a significant economic impact on the aquatic plant trade. *C. caroliniana* is one of the most frequently imported aquatic plant species to the Netherlands and is a popular aquarium plant (Matthews et al., 2013). Attempts at banning the plant in the Netherlands may be opposed and will have to be considered in consultation with the retail sector (Verbrugge et al., 2013).

The above measures, when implemented alone, target relatively obvious vectors of non-native species, but may miss the more obscure or diffuse sources of invasion (Kay & Hoyle, 2001; Chapman et al., 2003; Puth & Post, 2005). A more wide ranging and additional method for the prevention of introductions via trade pathways may be the introduction of trade policy instruments that incorporate invasive non-native species, such as tariffs (Margolis et al., 2005; Westphal et al., 2008; Perrings et al., 2005) or tradable risk permits (Horan & Lupi, 2005; Westphal et al., 2008). Tariffs are defined as a tax levied by a government on imports or occasionally exports for purposes of protection, support of the balance of payments, or the raising of revenue. Tradable risk permits involve the selling of permits the price of which reflects the potential risk of non-native species introduction based on measures taken to lower those risks (Horan & Lupi, 2005).

The costs of invasive species impacts are often seen as an externality (an unintended side effect) of international trade. Externalities are best addressed through internalization. Internalization occurs when a cost is shifted so that it is included in the



price paid by the user (Perrings et al., 2005). Internalization results in those who harm society meeting the cost of negative impacts, an example of the 'polluter pays principle'. The polluter pays principle may be applied to encourage the import of species unlikely to pose ecological risks. However, a disadvantage of the polluter pays principle is that collateral damage to native species may still occur even if the cost of eradication of already present invasive species is met. Additionally, there is currently no effective mechanism within the World Trade Organization (WTO) and the international agreement regulating international trade, the General Agreement on Tariffs and Trade (GATT) that allows the internalization of the invasion externalities of international trade (Perrings et al., 2005). Moreover, it has been argued that limiting the trade in non-native species would increase poverty, remove economic incentives that protect habitats and restrict conservation efforts in developing countries (Cooney & Jepson, 2006; CITES, 2007; Carrete & Tella, 2008). To help mitigate these impacts, alternative income streams and incentives could be generated from innovative schemes such as ecotourism (Carrete & Tella, 2008).

#### *Prevention through education*

Education to promote knowledge of the negative impacts of invasive species and to increase the successful identification of potentially invasive plants within hobbyist groups, trade and regulatory bodies may reduce the risk of invasive species introductions. For example, plants are often misidentified and not recognised as invasive by hobbyists and plant dealers alike. Moreover, a lack of knowledge regarding the negative implications of invasive plant introduction results in less care given in the prevention of pond flooding or plant disposal, which are often discarded into ponds, ditches, streams and rivers (Duggan, 2010; Martin & Coetzee, 2011; Kay & Hoyle, 2001; Verbrugge et al., 2013). Awareness leaflets, press releases, calendars, notifications at potential hotspots and information websites, warning of the environmental, economic and social hazards posed by potentially invasive species will contribute to public awareness (Caffrey & O'Callaghan, 2007).

In a recent survey of Dutch consumers, the most frequent reason given for disposing of aquarium plants in waterways was that respondents thought it was a shame to destroy a living plant or that they wanted to make water-bodies as beautiful as garden ponds, highlighting a lack of knowledge with regard to the risks of non-native species (Verbrugge et al., 2013). Moreover, regulators may be unfamiliar with and may overlook invasive aquatic species, especially if they are present in small quantities and mixed with other plants (Carrete & Tella, 2008). A recent campaign in the Netherlands to highlight the risks associated with invasive non-native species in garden centres was partly successful at increasing retailer knowledge regarding impacts, however less successful at informing the wider public. A leaflet with information regarding invasive waterplants was offered to the public in 70% of the garden centres and pet shops included in the survey (Communicatiebureau de Lynx, 2010). More than six months following the introduction of the leaflets, only 4% of consumers in the included garden centres and pet shops were aware of invasive plants (Verbrugge et al., 2011; 2013). However, after two years, 16% of survey respondents said that they were familiar with the campaign (Verbrugge et al., 2013).

The scope of public and trade compliance has been questioned by authors who suggest that some hobbyists and others either may not look at educational websites and/or ignore them entirely and that within trade, similarly-appearing species may occasionally intentionally be misrepresented as other, non-invasive species (Carrete & Tella, 2008; Kay & Hoyle, 2001). In these cases, education alone will not be enough to prevent the introduction of potentially invasive species.

*Schemes for prevention of non-native species export from donor countries*

A lack of bio-security measures in donor countries further increases the risk of non-native species export. Innovative local schemes and larger scale interventions in donor countries may help to reduce the export of potentially invasive, non-native species. For example, an approach for protecting birds and their habitat could be nest sponsorship, demonstrated in a program involving parrots in Argentina (Parrot People, 2007; Carrete & Tella, 2008), which serves as an alternative to the removal of parrot chicks for the pet trade (Gilardi, 2006; Carrete & Tella, 2008). Ecotourism programs may provide an alternative source of income which might help to make the preservation of habitats and otherwise traded species economically attractive (Carrete & Tella, 2008). On a larger scale, international aid could be used to protect recipient countries against the inability of some donor countries to take effective biosecurity measures (Perrings et al., 2005). Schemes targeting specific regions should take into account that the implementation of measures in current donor regions may lead to the development of new donor regions for the import of potentially invasive species.

*Prevention of impacts through species selection*

The selection of certain species for trade that are unlikely to become invasive in temperate climates may reduce the risk of potential invasions in recipient countries featuring these climates. For example, a study in Spain showed that the most common caged bird species, such as the Australian budgerigar (*Melopsittacus undulatus*) are not the most successful invaders (Carrete & Tella, 2008). The authors of this study state that the most successful invaders are bird species that are caught in the wild and traded on the pet market such as the Argentinean monk parakeet (*Myiopsitta monachus*). Captive-bred species appear to have lost the ability to survive independently. However, many non-native species introduced via trade are selected because of the ease with which they reproduce and are often highly invasive species (H. van Kleef, pers. comm.). Therefore, the identification of species that are suitable for domestication but will not become invasive may be challenging.

## 5. Conclusions and recommendations

### *Metadata analysis*

- In total 712 species were identified that fulfilled the criteria of the horizonscan. A further 23 species possibly fulfil the criteria. Of these species, 433 species were considered able to reproduce in the Netherlands.
- 90 species were considered to pose a potentially high ecological risk to the Netherlands and placed on the Dutch list of potentially invasive species. 28 of these species are terrestrial plants, 26 are freshwater animals, 25 are terrestrial animals, seven are marine animals and four are freshwater plants.

The following conclusions are derived from the analyses of the horizonscan database.

### *Pathways of most concern*

- Intentional trading of non-native animal and plant species is the most important pathway for the dispersal of species present on the Dutch list of potentially invasive species.
- For all species appearing on the list of potentially invasive species for the Netherlands (criteria 1, 2 and 3 of the horizonscan), the most frequently occurring pathways associated with the trade in animals and plant species are the pet and aquarium trade, ornamental pathway, horticulture and the botanical/garden/zoo/aquaria pathway.
- Potentially invasive species absent from the Netherlands (criterion 1 of the horizonscan only) are most likely to hitchhike on a ship or boat, utilise interconnected waterways/basins/seas, be released or escape from botanical gardens, zoos or aquaria or be transported with habitat material.
- The pet and aquarium, ornamental and botanical garden/zoo/aquaria pathways were related with the highest number of ecological impacts recorded for potentially invasive species for the Netherlands. This reflects the high number of plant species present on the list of potentially invasive species for the Netherlands.

### *Impacts of most concern*

- Freshwater animals were associated with the highest absolute number of impacts of high risk species followed by terrestrial animals and terrestrial plants.
- When the number of impacts was averaged per general group, freshwater animals and plants were found to feature the highest number of impacts of all general groups.

### *Origins of most concern*

- The origins of most concern for non-native species present on the list of potentially invasive species for the Netherlands are Asia and North America.
- Asia supplies the most species of terrestrial animals and plants while North America is the source of most freshwater and marine animals.

#### *Recommendations for further research*

- It is recommended that non-native species risk assessments are standardised to allow for direct comparisons between national risk classifications.
- Globally, there is a constant flow of new data describing the characteristics of non-native species and their potential invasiveness. It is recommended that the horizon scan is updated on a regular basis to take into account future assessments of ecological risk, particularly in the case of species where, to date, no assessment has been undertaken.
- It is recommended that research undertaken regarding the impacts of invasive species also considers the geographical location where these impacts occur.

#### *Monitoring*

- Because of a lack of data, it is recommended that species that breed incidentally and whose possible impact features a high degree of uncertainty are monitored alongside high risk species.

## 6. Acknowledgements

We would like to thank the Netherlands Food and Consumer Product Safety Authority, Invasive Alien Species Team (NVWA-TIE) of the Dutch Ministry of Economic Affairs for financially supporting this study (order number: 60001903, d.d. November 22, 2013). We would also like to thank Ir. W. Lammers (NVWA-TIE) for constructive comments on an earlier draft of this report and for relevant information, Gert Ottens of Vogelbescherming Nederland who allowed us to use his database on avian non-native species and Melanie Gillings and Polly Bryant of the RINSE project for the supply of data and information that contributed to the horizonscan.

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## 8. Glossary

**Invasive species:** species that are initially transported through human action outside of their natural range across ecological barriers, and that then survive, reproduce and spread and that have negative impacts on the ecology of their new location as well as serious economic and social consequences (European Commission, 2013).

**Established:** a non-native species that has spread into the wild and whose reproduction is sufficient to maintain its population.

**Limited populations:** the non-native species occurs in a limited distribution in Dutch nature that makes it amenable to eradication.

**Naturalized:** a non-native species that has spread into the wild and whose reproduction is sufficient to maintain its population.

**Non-native:** animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found. For the purpose of this study, species that extend their natural range into the Netherlands from adjacent countries are not included in the definition of non-native. However, species that are introduced from other biogeographical areas to adjacent countries and then disperse to the Netherlands are considered non-native.

**Population:** a summation of all the organisms of the same species, who live in the same geographical area, and have the capability of interbreeding.

**Primary hotspot:** the location or locations where the non-native species will probably first appear or has first appeared in the Netherlands.

**Secondary hotspot:** A defined location where a non-native species can disperse to from a primary hotspot without additional intervention by people.

## Appendix 1. Overview of information sources

Organisation / database	Web address
Netherlands Food and Consumer Product Safety Authority (NVWA)	<a href="https://www.vwa.nl/onderwerpen/ongewenste-uitheemse-planten/dossier/invasieve-exoten/risicobeoordelingen-reactieperiode/risicobeoordelingsrapporten">https://www.vwa.nl/onderwerpen/ongewenste-uitheemse-planten/dossier/invasieve-exoten/risicobeoordelingen-reactieperiode/risicobeoordelingsrapporten</a>
Invasive species in Belgium	<a href="http://ias.biodiversity.be/species/all">http://ias.biodiversity.be/species/all</a>
Global invasive species database	<a href="http://www.issg.org/database/welcome/">www.issg.org/database/welcome/</a>
Werkgroep Exoten	<a href="http://www.werkgroepexoten.nl">http://www.werkgroepexoten.nl</a>
Nederlands soortenregister	<a href="http://www.nederlandsesoorten.nl">www.nederlandsesoorten.nl</a>
Great Lakes aquatic nonindigenous species information system (GLANSIS)	<a href="http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html">http://www.glerl.noaa.gov/res/Programs/glansis/glansis.html</a>
DAISIE (European alien species information)	<a href="http://www.europe-aliens.org/">www.europe-aliens.org/</a>
Invasive Species Compendium	<a href="http://www.cabi.org/isc/">http://www.cabi.org/isc/</a>
European and Mediterranean plant protection agency (EPPO)	<a href="http://www.eppo.int/INVASIVE_PLANTS/ias_plants.htm">http://www.eppo.int/INVASIVE_PLANTS/ias_plants.htm</a>
Global invasive species database	<a href="http://www.issg.org/database/welcome/">http://www.issg.org/database/welcome/</a>
NOBANIS	<a href="http://www.nobanis.org/">http://www.nobanis.org/</a>
Fishbase	<a href="http://www.fishbase.org">www.fishbase.org</a>
GB non-native species secretariat	<a href="http://www.nonnativespecies.org/home/index.cfm">http://www.nonnativespecies.org/home/index.cfm</a>
Web of science	<a href="http://apps.isiknowledge.com">http://apps.isiknowledge.com</a>
Google	<a href="http://www.google.com">www.google.com</a>
French Museum of natural history	<a href="http://inpn.mnhn.fr">http://inpn.mnhn.fr</a>
Danish nature agency	<a href="http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Arter/Sortlisten/">http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Arter/Sortlisten/</a>
Macrofauna newsletter	<a href="http://www.helpdeskwater.nl/onderwerpen/monitoring/ecologie/macrofaunanieuws/">http://www.helpdeskwater.nl/onderwerpen/monitoring/ecologie/macrofaunanieuws/</a>
Integrated taxonomic information system (ITIS)	<a href="http://www.itis.gov/">http://www.itis.gov/</a>
National databank of flora and fauna	<a href="https://ndff-ecogrid.nl/">https://ndff-ecogrid.nl/</a>
Dutch Register of catches of sports fish	<a href="http://www.vangstenregistratie.nl">www.vangstenregistratie.nl</a>
Waarneming.nl	<a href="http://www.waarneming.nl">www.waarneming.nl</a>

## Appendix 2. List of non-native bird species present in the Netherlands in 2004-2013 based on waarneming.nl

Latin name	Common Dutch name	Number of 1x1 km atlas squares over the entire year									
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Acridotheres cristatellus</i>	Kuifmaina							1	1		2
<i>Acridotheres tristis</i>	Treurmaina	1	1	3			1	1	2	4	2
<i>Agapornis fischeri</i>	Fischers Agapornis							1	1	4	5
<i>Agapornis personatus</i>	Zwartmaskeragapornis						1	1	4	2	1
<i>Agapornis roseicollis</i>	Perzikkopagapornis	2	2	5	4	4	8	6	12	6	10
<i>Aix sponsa x Aix galericulata</i>	Hybride Carolina-eend x Mandarijneend										1
<i>Alectoris rufa</i>	Rode Patrijs	1	1	3			1	0	1	3	1
<i>Alisterus scapularis</i>	Australische Koningsparkiet						1	1			
<i>Alopochen aegyptiacus x Cairina moschata</i>	Hybride Nijlgans x Muskuseend										1
<i>Amazona aestiva</i>	Blauwvoorhoofdamazonen			2					1	1	
<i>Amazona amazonica</i>	Oranjevleugelamazonen	1	2	1							
<i>Amazona oratrix</i>	Geelkopamazonen						1				
<i>Amazonetta brasiliensis</i>	Amazonetaling					1		1		1	
<i>Amblyramphus holosericeus</i>	Roodkoptroepiaal			3	2	1					
<i>Anas bahamensis</i>	Bahamapijlstaart	8	16	16	16	19	23	17	21	13	18
<i>Anas capensis</i>	Kaapse Taling	2	1	1	1	2	1	1		1	
<i>Anas castanea</i>	Kastanjetailing		1								
<i>Anas cyanoptera</i>	Kaneeltaling	4	5	4	6	12		2	3	5	1
<i>Anas cyanoptera orinomus</i>	Andes Kaneeltaling										1
<i>Anas falcata</i>	Bronskopeend			1			1				
<i>Anas flavirostris</i>	Chileense Taling				1	4	3	5	2	1	
<i>Anas formosa</i>	Siberische Taling			1	1						1
<i>Anas georgica</i>	Bruine Pijlstaart						2	2	2		
<i>Anas hottentota</i>	Hottentottaling		2		2	2	3	2		8	4
<i>Anas hottentota x Anas versicolor</i>	Hybride Hottentottaling x Zilvertaling	1			1						
<i>Anas laysanensis</i>	Laysantaling			1						1	
<i>Anas luzonica</i>	Filippijnse Eend		1			1				1	
<i>Anas poecilorhyncha</i>	Vlekbekeend			1				1	1		1
<i>Anas puna</i>	Punataling				1	1				1	1
<i>Anas rhynchotis</i>	Australische Slobeend	1	1			1	2			2	1
<i>Anas sibilatrix</i>	Chileense Smient	9	13	9	21	28	25	26	36	27	18
<i>Anas sibilatrix x Anas acuta</i>	Hybride Chileense Smient x Pijlstaart										2
<i>Anas sparsa</i>	Afrikaanse Zwarte Eend								1		
<i>Anas undulata</i>	Geelsnaveleend							1			2
<i>Anas versicolor</i>	Zilvertaling	1			1	3	2	4		3	
<i>Anas wyvilliana</i>	Hawaiieend						1				
<i>Anser anser x Anser indicus</i>	Hybride Grauwe Gans x Indische Gans	1	2				3	1	3	4	
<i>Anser cygnoides</i>	Afrikaanse Knobbeltgans					2	11	5	5	3	10

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.



Latin name	Common Dutch name	Number of 1x1 km atlas squares over the entire year										
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
<i>Anser indicus x Anser anser forma domesticus</i>	Hybride Indische gans x Soepgans								4	7	6	5
<i>Ara ararauna</i>	Blauwgele Ara				1	7	1			2	3	1
<i>Ara macao</i>	Geelvleugelara	1	1	1	1	1	2	3	3	4	4	2
<i>Aramides ypecaha</i>	Reuzenbosral				1	1					1	
<i>Aratinga nenday</i>	Nandayparkiet				1					1		
<i>Aythya australis</i>	Australische Witoogeend									1		
<i>Aythya valisineria</i>	Grote Tafeleend			1		1					1	
<i>Balearica regulorum</i>	Kroonkraanvogel	1		3		6	1	2	7	1	3	
<i>Bombycilla japonica</i>	Japanse Pestvogel		2								1	
<i>Bostrychia hagedash</i>	Hadada-ibis		1									
<i>Branta leucopsis x Anser indicus</i>	Hybride Brandgans x Indische Gans			4	1		2	2	1			2
<i>Branta sandvicensis</i>	Hawaiigans	1	2	1	1	6	1	6	4	2	2	
<i>Bubo africanus</i>	Afrikaanse Oehoe										3	1
<i>Bubo virginianus</i>	Amerikaanse Oehoe					3						
<i>Bucephala albeola</i>	Buffelkopeend			2	3	2	5	5	6	4	4	
<i>Bucorvus leadbeateri</i>	Zuidelijke Hoornraaf				1		1					
<i>Buteo jamaicensis</i>	Roodstaartbuizerd						1		3	2	1	
<i>Buteo swainsoni</i>	Prairiebuizerd										1	
<i>Buteogallus anthracinus</i>	Zwarte Buizerd											2
<i>Cacatua galerita</i>	Grote Geelkuifkaketoe							1				
<i>Cacatua goffiniana</i>	Goffins Kaketoe								1			
<i>Callipepla californica</i>	Californische Kuifkwartel			1			1	1	1	4	1	
<i>Callonetta leucophrys</i>	Roodschoudertaling	1	1	10	16	12	10	15	20	16	7	
<i>Caracara cheriway/plancus</i>	Kuifcaracara	2	4		1	2	1		5	3	7	
<i>Cardinalis cardinalis</i>	Rode Kardinaal						1	3	1	1	1	
<i>Carduelis spinoides</i>	Himalayagroenling				1							
<i>Carpodacus sibiricus</i>	Langstaartroodmus	1										
<i>Cathartes aura</i>	Roodkopgier				1	1	2	1				
<i>Cereopsis novaehollandiae</i>	Hoendergans				3	3	5	7	5			
<i>Ceryle rudis</i>	Bonte IJsvogel											1
<i>Chen rossii</i>	Ross' Gans	6	11	4	1		3	4	1	1	2	
<i>Chenonetta jubata</i>	Manengans	7	8	15	16	26	27	17	5	12	12	
<i>Chloephaga melanoptera</i>	Andesgans							6	1		1	
<i>Chloephaga picta</i>	Magelhaengans	9	10	8	15	15	13	17	12	10	4	
<i>Chloephaga poliocephala</i>	Grijskopgans											1
<i>Chloephaga rubidiceps</i>	Roodkopgans					1						
<i>Chrysolophus amherstiae</i>	Lady-Amherstfazant			1	2	2	2	5	4	2	3	
<i>Chrysolophus amherstiae X Chrysolophus pictus</i>	Lady-Amherstfazant X Goudfazant			1	1	1	1	2	1	1	2	
<i>Chrysolophus pictus</i>	Goudfazant	2	6	3	8	7	9	8	7	3	6	
<i>Chrysomus icterocephalus</i>	Geelkaptroepiaal				2	2						
<i>Ciconia abdimii</i>	Abdims Ooievaar					2						1

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.



Latin name	Common Dutch name	Number of 1x1 km atlas squares over the entire year										
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
<i>Colinus virginianus</i>	Boomkwartel											1
<i>Corvus albicollis</i>	Witnekraaf		3		1							1
<i>Coracias abyssinicus</i>	Sahelscharrelaar		2									
<i>Coracias caudatus</i>	Vorkstaartscharrelaar			1								3
<i>Corvus albus</i>	Schildraaf				1							1
<i>Corvus splendens</i>	Huiskraai	5	4	1	3	4	5	5	4	6	8	
<i>Coscoroba coscoroba</i>	Coscorobazwaan					2		2	2	1		
<i>Coturnix japonica</i>	Japane Kwartel							1	1			
<i>Crithagra mozambica</i>	Mozambiquesijs	1	6	4			1			1		
<i>Cyanochen cyanoptera</i>	Blauwvleugelgans	2	1		4	6	2	2	1	2	3	
<i>Cyanopica cooki</i>	Blauwe Ekster							8	1			1
<i>Cyanoramphus novaezelandiae</i>	Roodvoorhoofdkekari		1				1					
<i>Cygnus buccinator</i>	Trompetzwaan					1						
<i>Cygnus melancoryphus</i>	Zwarthalszwaan	2	3		2	12	10	11	19	10	13	
<i>Dendrocygna arborea</i>	Cubaanse Fluiteend						1	1				
<i>Dendrocygna autumnalis</i>	Zwartbuikfluiteend				1	2			2	2	3	
<i>Dendrocygna bicolor</i>	Rosse Fluiteend	2	1	3	4	6	5	14	11	5	1	
<i>Dendrocygna guttata</i>	Gevlekte Fluiteend							1				
<i>Dendrocygna viduata</i>	Witwangfluiteend	1	2	1	3	4	5	2	3	1		
<i>Dromaius novaehollandiae</i>	Emoe							1	1			
<i>Emberiza sahari</i>	Huisgors					1						1
<i>Eolophus roseicapilla</i>	Roze Kaketoe						1		2			
<i>Eophona migratoria</i>	Witvleugeldikbek	1	1	4	4	2						
<i>Erythrura gouldiae</i>	Goulds Amandine						1			1		
<i>Estrilda astrild</i>	Sint-Helenafazantje			1		1	4	1	1	2	2	
<i>Eudocimus albus</i>	Witte Ibis		1		1		1		1	2	5	
<i>Eudocimus ruber</i>	Rode Ibis		3	1	3	3			10	1		
<i>Euodice malabarica</i>	Loodbekje											1
<i>Euplectes afer</i>	Napoleonwever	2				1		5	3	3	3	
<i>Euplectes franciscanus</i>	Oranje Wever			1							2	
<i>Euplectes hordeaceus</i>	Roodvoorhoofdwever						1		1			
<i>Euplectes macrourus</i>	Geelrugwidavink							1		1	1	
<i>Euplectes progne</i>	Hanenstaartwida				1							
<i>Excalfactoria chinensis</i>	Chinese Dwergkwartel		2			2			1		3	
<i>Garrulax albogularis</i>	Witkeellijstergaai								1			
<i>Garrulax cineraceus</i>	Baardlijstergaai			1								
<i>Garrulax elliotii</i>	Elliot's Lijstergaai					1						
<i>Garrulax poecilorhynchus</i>	Rosse Lijstergaai			1		1						
<i>Geopelia cuneata</i>	Diamantduif				1	8	7	6	8	6	2	
<i>Geronticus eremita</i>	Heremietibis											2
<i>Grus japonensis</i>	Chinese Kraanvogel				2		1	4		5	12	
<i>Grus vipio</i>	Witnekkraanvogel			2								
<i>Grus virgo</i>	Jufferkraanvogel		1									

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.

Latin name	Common Dutch name	Number of 1x1 km atlas squares over the entire year										
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	
<i>Gyps rueppelli</i>	Ruppells Gier	10										
<i>Haemorrhous mexicanus</i>	Mexicaanse Roodmus			1		2	2	2	3	4	6	
<i>Haliaeetus leucocephalus</i>	Amerikaanse Zeearend								2	1	5	
<i>Haliaeetus pelagicus</i>	Stellers Zeearend						3					
<i>Himantopus mexicanus</i>	Amerikaanse Steltkluut				6		1					
<i>Lamprotornis caudatus</i>	Groene Langstaartglansspreeuw		1	1	1			1				
<i>Lamprotornis chalybaeus</i>	Groenstaartglansspreeuw			1	1				1			
<i>Lamprotornis nitens</i>	Roodschouderglansspreeuw							1				
<i>Lamprotornis purpureus</i>	Purperglansspreeuw			3	2		2					
<i>Lamprotornis splendidus</i>	Prachtglansspreeuw					1						
<i>Lamprotornis superbus</i>	Driekleurige Glansspreeuw		2		2		2	1				1
<i>Leiothrix lutea</i>	Japanse Nachtegaal		1		2	3	1	1	3	4	2	
<i>Leptoptilos crumenifer</i>	Afrikaanse Maraboe		7	2				1				
<i>Leucopsar rothschildi</i>	Balispreeuw						2					
<i>Lonchura oryzivora</i>	Rijstvogel						1		1			1
<i>Lonchura striata domestica</i>	Japanse Meeuw										2	1
<i>Lophodytes cucullatus</i>	Kokardezaagbek	1	2	2	4	5	3	1		1		
<i>Lophodytes cucullatus x Mergellus albellus</i>	Hybride Kokardezaagbek x Nonnetje	1									2	
<i>Lophura ignita</i>	Gekuifde Vuurrugfazant								1			
<i>Lophura nycthemera</i>	Zilverfazant				3		3		1			2
<i>Lophura swinhoii</i>	Swinhoes Fazant							1	1			1
<i>Malacorhynchus membranaceus</i>	Lepelbekeend							2	1	2		
<i>Marmaronetta angustirostris</i>	Marmereend			1	2	1		1				
<i>Meleagris gallopavo</i>	Kalkoen				4	4	1		6	4	6	
<i>Melopsittacus undulatus</i>	Grasparkiet	4	7	14	17	25	20	23	28	30	37	
<i>Merops bullockoides</i>	Witkapbijeneter								2			
<i>Milvago chimango</i>	Chimango								1			
<i>Minla ignotincta</i>	Roodstaartminla				1					1	1	
<i>Mycteria ibis</i>	Afrikaanse Nimmerzat		1				1	1				
<i>Myiopsitta monachus</i>	Monniksparkiet	5	8	13	11	11	12	12	13	13	12	
<i>Necrosyrtes monachus</i>	Kapgier							1				
<i>Neochmia ruficauda</i>	Binsenastrild									1		
<i>Neophema elegans</i>	Prachtparkiet											1
<i>Neophema pulchella</i>	Turkooisparkiet							1		2	1	
<i>Netta peposaca</i>	Peposaka-Eend		2	5	5	3	10	3	3	5	3	
<i>Nettapus auritus</i>	Afrikaanse Dwergeend									1	1	
<i>Numida meleagris</i>	Helmparelhoen		2	2	11	11	11	16	10	11	12	
<i>Ocyphaps lophotes</i>	Australische Kuifduif					1		3		1		
<i>Oena capensis</i>	Maskerduif		1									
<i>Onychognathus tristratii</i>	Tristrams Spreeuw		1				1	1	1			
<i>Oriolus auratus</i>	Afrikaanse Wielewaal				1	1						
<i>Oxyura vittata</i>	Argentijnse Stekelstaart				1	1		1				

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.

Latin name	Common Dutch name	Number of 1x1 km atlas squares over the entire year									
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Parabuteo unicinctus</i>	Woestijnbuizerd	1	1	2	1	2	3	3	10	7	3
<i>Paradoxornis webbianus</i>	Bruinkopdiksnavelmees							1	2	2	3
<i>Paroaria coronata</i>	Roodkuifkardinaal					1				1	
<i>Passer iagoensis</i>	Kaapverdische Mus										1
<i>Passer luteus</i>	Soedanese Goudmus							1			
<i>Pavo cristatus</i>	Blauwe Pauw		6	12	14	25	33	23	36	29	23
<i>Pelecanus onocrotalus</i>	Roze Pelikaan		1					3	2		
<i>Pelecanus rufescens</i>	Kleine Pelikaan				1	6	1	1		1	
<i>Phasianus colchicus x Chrysolophus pictus</i>	Hybride Fazant x Goudfazant										1
<i>Phoeniconaias minor</i>	Kleine Flamingo	10	6	8	5	14	13	5	11	10	10
<i>Phoenicopterus roseus</i>	Flamingo	10	10	12	8	8	5	9	4	7	8
<i>Phoenicopterus ruber ruber</i>	Caribische Flamingo	3	8	6	5	6	9	11	13	13	10
<i>Phoenicopterus spec.</i>	Flamingo spec.	8	14	14	7	8	8	6	8	6	2
<i>Pitangus sulphuratus</i>	Grote Kiskadie		1								
<i>Platalea alba</i>	Afrikaanse Lepelaar	1								6	2
<i>Platycercus adscitus</i>	Bleekkoprosella					1					1
<i>Platycercus caledonicus</i>	Geelbuikrosella										1
<i>Platycercus elegans</i>	Pennant rosella		1	1	5	6	2	4	7	5	1
<i>Platycercus eximius</i>	Prachtrosella					4	1	3	10	5	
<i>Plectropterus gambensis</i>	Spoorwiekgans		1			2	1	1			
<i>Ploceus baglafaecht</i>	Baglafaechtwever								1	1	
<i>Ploceus cucullatus</i>	Grote Textorwever	1		1	1	1			1	1	2
<i>Poicephalus senegalus</i>	Senegalpapegaai		1	2	2	2	3	2	1	5	4
<i>Poicephalus senegalus mesotypu</i>	Oranjebuik Senegalpapegaai									1	1
<i>Polytelis anthopeplus</i>	Regentparkiet						1				
<i>Polytelis swainsonii</i>	Barrabandparkiet										1
<i>Pomatorhinus ruficollis</i>	Roodkeelkruiplijster						1				
<i>Porphyrio poliocephalus</i>	Grijskoppurperkoet						2				
<i>Porphyrio porphyrio</i>	Purperkoet				2			0		0	1
<i>Psephotus haematonotus</i>	Roodrugparkiet				5	2	3	6	1	1	1
<i>Psittacara erythrogenys</i>	Ecuadoraratinga								1		
<i>Psittacula cyanocephala</i>	Pruimenkopparkiet		1				1	1		1	1
<i>Psittacula derbiana</i>	Lord Derby's Parkiet	1	1				1	1	1	1	1
<i>Psittacula eupatria</i>	Grote Alexanderparkiet	3	3	8	7	8	12	10	14	20	15
<i>Psittacula himalayana</i>	Grijskopparkiet							1			
<i>Psittacus erithacus</i>	Grijze Roodstaartpapegaai		1		2		2	2		1	2
<i>Pycnonotus aurigaster</i>	Roetkopbuulbuul	1	2	2				1	1		
<i>Pycnonotus barbatus</i>	Grauwe Buulbuul				1					2	
<i>Pycnonotus cafer</i>	Roodbuikbuulbuul	1		2			1				

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.

Latin name	Common Dutch name	Number of 1x1 km atlas squares over the entire year									
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Pycnonotus jocosus</i>	Roodoorbuulbuul		1	1				1			
<i>Pycnonotus leucotis</i>	Witoorbuulbuul							1	2		1
<i>Pycnonotus sinensis</i>	Chinese Buulbuul								1		
<i>Pyrrhura frontalis</i>	Bruinoorparkiet						1				
<i>Pyrrhura molinae</i>	Groenwangparkiet						1				1
<i>Quelea quelea</i>	Roodbekwever		1						1		
<i>Rhea americana</i>	Nandoe			1		1	2			1	3
<i>Rhodospiza obsoleta</i>	Vale Woestijnvink			1							
<i>Sarkidiornis melanotos</i>	Knobbeleend				1						
<i>Scopus umbretta</i>	Hamerkop	3			3	1					
<i>Spilopelia senegalensis</i>	Palmtortel		1		2	1		2	2	2	4
<i>Streptopelia roseogrisea</i>	Lachduif	1	2	4	2	4	8	4	6	4	2
<i>Streptopelia tranquebarica</i>	Rode Tortel			1					1		
<i>Tadorna cana</i>	Kaapse Casarca	1	7		1	8	10	10	12	23	24
<i>Tadorna radjah</i>	Radjaheend	2	2	2	1	1					
<i>Tadorna tadornoides</i>	Australische Casarca	1	2	2	2	1	3	3	5	2	4
<i>Tadorna variegata</i>	Paradijscarca	1			3	2	4	3	6	1	1
<i>Taeniopygia guttata</i>	Zebravink	2	1	6	7	4	9	16	16	13	11
<i>Tauraco persa</i>	Groene Toerako			1						1	1
<i>Thectocercus acuticaudatus</i>	Blauwkoparatinga								1		
<i>Thraupis episcopus</i>	Bisschopstangare						1				
<i>Threskiornis melanocephalus</i>	Zwartkopibis						1	9	14	3	
<i>Trachyphonus erythrocephalus</i>	Vuurkruiubaardvogel									1	
<i>Tragopan temminckii</i>	Temmincks Saterhoen									1	
<i>Turdus dissimilis</i>	Zwartborstlijster								1		
<i>Urocissa erythroryncha</i>	Roodsnavelkitta		3								
<i>Vanellus armatus</i>	Smidsplevier				4						
<i>Vidua macroura</i>	Dominicanerwida			1		1				1	1
<i>Vidua obtusa</i>	Breedstaartparadijswida		1								
<i>Yuhina diademata</i>	Diadeemmeestimalia			3	1						
<i>Zonotrichia capensis</i>	Roodkraaggors			2	2						

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.

Latin name	Dutch common name	Maximum number of 1x1 km atlas squares in a month									
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Acridotheres cristatellus</i>	Kuifmaina							1	1		1
<i>Acridotheres tristis</i>	Treurmaina	1	1	1			1	1	1	2	1
<i>Agapornis fischeri</i>	Fischers Agapornis							1	1	3	2
<i>Agapornis personatus</i>	Zwartmaskeragapornis						1	1	2	1	1
<i>Agapornis roseicollis</i>	Perzikkopagapornis	1	1	2	1	2	2	4	3	1	3
<i>Aix sponsa x Aix galericulata</i>	Hybride Carolina-eend x Mandarijneend										1
<i>Alectoris rufa</i>	Rode Patrijs	1	1	1			1	0	1	1	1
<i>Alisterus scapularis</i>	Australische Koningsparkiet						1	1			
<i>Alopochen aegyptiacus x Cairina moschata</i>	Hybride Nijlgans x Muskuseend										1
<i>Amazona aestiva</i>	Blauwvoorhoofdamazonen			2					1	1	
<i>Amazona amazonica</i>	Oranjevleugelamazonen	1	1	1							
<i>Amazona oratrix</i>	Geelkopamazonen						1				
<i>Amazonetta brasiliensis</i>	Amazonetaling					1		1		1	
<i>Amblyramphus holosericeus</i>	Roodkoptroepiaal			1	1	1					
<i>Anas bahamensis</i>	Bahamapijlstaart	4	4	3	5	6	4	6	5	2	4
<i>Anas capensis</i>	Kaapse Taling	1	1	1	1	2	1	1		1	
<i>Anas castanea</i>	Kastanjetaling		1								
<i>Anas cyanoptera</i>	Kaneeltaling	2	3	2	1	5		2	2	2	1
<i>Anas cyanoptera orinomus</i>	Andes Kaneeltaling										1
<i>Anas falcata</i>	Bronskopeend			1			1				
<i>Anas flavirostris</i>	Chileense Taling				1	2	2	2	1	1	
<i>Anas formosa</i>	Siberische Taling			1	1						1
<i>Anas georgica</i>	Bruine Pijlstaart						1	1	1		
<i>Anas hottentota</i>	Hottentottaling		1		1	1	1	2		2	2
<i>Anas hottentota x Anas versicolor</i>	Hybride Hottentottaling x Zilvertaling	1			1						
<i>Anas laysanensis</i>	Laysantaling			1						1	
<i>Anas luzonica</i>	Filippijnse Eend		1			1				1	
<i>Anas poecilorhyncha</i>	Vlekbekeend			1				1	1		1
<i>Anas puna</i>	Punataling				1	1				1	1
<i>Anas rhynchotis</i>	Australische Slobeend	1	1			1	2			2	1
<i>Anas sibilatrix</i>	Chileense Smient	4	4	6	6	6	7	9	8	8	5
<i>Anas sibilatrix x Anas acuta</i>	Hybride Chileense Smient x Pijlstaart										1
<i>Anas sparsa</i>	Afrikaanse Zwarte Eend								1		
<i>Anas undulata</i>	Geelsnaveleend							1			2
<i>Anas versicolor</i>	Zilvertaling	1			1	1	2	2		1	
<i>Anas wyvilliana</i>	Hawaiieend						1				
<i>Anser anser x Anser indicus</i>	Hybride Grauwe Gans x Indische Gans	1	2					2	1	2	1
<i>Anser cygnoides</i>	Afrikaanse Knobbelsgans					1	3	2	2	2	3
<i>Anser indicus x Anser anser forma domesticus</i>	Hybride Indische gans x Soepgans							2	2	2	1
<i>Ara ararauna</i>	Blauwgele Ara				1	2	1		1	1	1
<i>Ara macao</i>	Geelvleugelara	1	1	1	1	1	2	2	2	3	2

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Latin name	Dutch common name	Maximum number of 1x1 km atlas squares in a month									
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Aramides ypecaha</i>	Reuzenbosral				1	1					1
<i>Aratinga nenday</i>	Nandayparkiet				1					1	
<i>Aythya australis</i>	Australische Witoegeend									1	
<i>Aythya valisineria</i>	Grote Tafeleend			1		1					1
<i>Balearica regulorum</i>	Kroonkraanvogel	1		1		2	1	1	4	1	2
<i>Bombycilla japonica</i>	Japanse Pestvogel		2								1
<i>Bostrychia hagedash</i>	Hadada-ibis		1								
<i>Branta leucopsis x Anser indicus</i>	Hybride Brandgans x Indische Gans			2	1		1	1	1		1
<i>Branta sandvicensis</i>	Hawaiigans	1	1	1	1	3	1	4	3	1	2
<i>Bubo africanus</i>	Afrikaanse Oehoe										1
<i>Bubo virginianus</i>	Amerikaanse Oehoe					2					
<i>Bucephala albeola</i>	Buffelkoepeend			1	2	1	2	2	4	2	2
<i>Bucorvus leadbeateri</i>	Zuidelijke Hoorraaf				1		1				
<i>Buteo jamaicensis</i>	Roodstaartbuizerd						1		2	2	1
<i>Buteo swainsoni</i>	Prairiebuizerd									1	
<i>Buteogallus anthracinus</i>	Zwarte Buizerd										1
<i>Cacatua galerita</i>	Grote Geelkuifkaketoe							1			
<i>Cacatua goffiniana</i>	Goffins Kaketoe									1	
<i>Callipepla californica</i>	Californische Kuifkwartel			1			1	1	1	2	1
<i>Callonetta leucophrys</i>	Roodschoudertaling	1	1	3	5	7	3	5	8	5	2
<i>Caracara cheriway/plancus</i>	Kuifcaracara	1	2		1	2	1		2	3	3
<i>Cardinalis cardinalis</i>	Rode Kardinaal						1	2	1	1	1
<i>Carduelis spinoides</i>	Himalayagroenling				1						
<i>Carpodacus sibiricus</i>	Langstaartroodmus	1									
<i>Cathartes aura</i>	Roodkoppier				1	1	1	1			
<i>Cereopsis novaehollandiae</i>	Hoendergans				1	2	1	2	2		
<i>Ceryle rudis</i>	Bonte IJsvogel										1
<i>Chen rossii</i>	Ross' Gans	2	4	3	1		1	2	1	1	1
<i>Chenonetta jubata</i>	Manengans	3	2	5	4	8	8	3	1	2	4
<i>Chloephaga melanoptera</i>	Andesgans							2	1		1
<i>Chloephaga picta</i>	Magelhaengans	4	2	2	4	5	5	8	3	3	1
<i>Chloephaga poliocephala</i>	Grijskopgans										1
<i>Chloephaga rubidiceps</i>	Roodkopgans					1					
<i>Chrysolophus amherstiae</i>	Lady-Amherstfazant			1	1	1	2	2	2	1	2
<i>Chrysolophus amherstiae X Chrysolophus pictus</i>	Lady-Amherstfazant X Goudfazant			1	1	1	1	1	1	1	1
<i>Chrysolophus pictus</i>	Goudfazant	2	3	2	3	3	4	3	2	1	3
<i>Chrysomus icterocephalus</i>	Geelkaptroepiaal				1	1					
<i>Ciconia abdimii</i>	Abdime Ooievaar					2					1
<i>Colinus virginianus</i>	Boomkwartel										1
<i>Coracias abyssinicus</i>	Sahelscharrelaar		1								
<i>Coracias caudatus</i>	Vorkstaartscharrelaar			1							2
<i>Corvus albicollis</i>	Witnekraaf		2		1						1
<i>Corvus albus</i>	Schildraaf				1						1

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		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Corvus splendens</i>	Huiskraai	3	2	1	3	3	3	2	3	3	5
<i>Coscoroba coscoroba</i>	Coscorobazwaan					1		2	2	1	
<i>Coturnix japonica</i>	Japanse Kwartel							1	1		
<i>Crithagra mozambica</i>	Mozambiquesijs	1	3	2			1			1	
<i>Cyanochen cyanoptera</i>	Blauwvleugelgans	1	1		2	3	1	1	1	1	1
<i>Cyanopica cooki</i>	Blauwe Ekster							2	1		1
<i>Cyanoramphus novaezelandiae</i>	Roodvoorhoofdkekari		1				1				
<i>Cygnus buccinator</i>	Trompetzwaan					1					
<i>Cygnus melancoryphus</i>	Zwarthalszwaan	1	2		1	3	4	4	6	5	3
<i>Dendrocygna arborea</i>	Cubaanse Fluiteend						1	1			
<i>Dendrocygna autumnalis</i>	Zwartbuikfluiteend				1	1			2	1	1
<i>Dendrocygna bicolor</i>	Rosse Fluiteend	1	1	2	1	2	3	4	2	2	1
<i>Dendrocygna guttata</i>	Gevlekte Fluiteend							1			
<i>Dendrocygna viduata</i>	Witwangfluiteend	1	1	1	1	1	2	1	1	1	
<i>Dromaius novaehollandiae</i>	Emoe							1	1		
<i>Emberiza sahari</i>	Huisgors					1					1
<i>Eolophus roseicapilla</i>	Roze Kaketoe						1		1		
<i>Eophona migratoria</i>	Witvleugeldikbek	1	1	1	1	1					
<i>Erythrura gouldiae</i>	Goulds Amandine						1			1	
<i>Estrilda astrild</i>	Sint-Helenafazantje			1		1	2	1	1	1	2
<i>Eudocimus albus</i>	Witte Ibis		1		1		1		1	1	5
<i>Eudocimus ruber</i>	Rode Ibis		1	1	3	1			5	1	
<i>Euodice malabarica</i>	Loodbekje										1
<i>Euplectes afer</i>	Napoleonwever	2				1		2	1	2	2
<i>Euplectes franciscanus</i>	Oranje Wever			1						2	
<i>Euplectes hordeaceus</i>	Roodvoorhoofdwever						1		1		
<i>Euplectes macrourus</i>	Geelrugwidavink							1		1	1
<i>Euplectes progne</i>	Hanenstaartwida				1						
<i>Excalfactoria chinensis</i>	Chinese Dwergkwartel		1			1			1		2
<i>Garrulax albogularis</i>	Witkeellijstergaai								1		
<i>Garrulax cineraceus</i>	Baardlijstergaai			1							
<i>Garrulax elliotii</i>	Elliot's Lijstergaai					1					
<i>Garrulax poecilorhynchus</i>	Rosse Lijstergaai			1		1					
<i>Geopelia cuneata</i>	Diamantduif				1	3	2	2	2	2	1
<i>Geronticus eremita</i>	Heremietibis										2
<i>Grus japonensis</i>	Chinese Kraanvogel				2		1	4		2	6
<i>Grus vipio</i>	Witnekkraanvogel			1							
<i>Grus virgo</i>	Jufferkraanvogel		1								
<i>Gyps rueppelli</i>	Ruppells Gier	7									
<i>Haemorrhous mexicanus</i>	Mexicaanse Roodmus			1		1	1	1	2	3	3
<i>Haliaeetus leucocephalus</i>	Amerikaanse Zeearend								1	1	2
<i>Haliaeetus pelagicus</i>	Stellers Zeearend						3				
<i>Himantopus mexicanus</i>	Amerikaanse Steltkluut				4		1				

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		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Lamprotornis caudatus</i>	Groene Langstaartglansspreeuw		1	1	1			1			
<i>Lamprotornis chalybaeus</i>	Groenstaartglansspreeuw			1	1				1		
<i>Lamprotornis nitens</i>	Roodschouderglansspreeuw							1			
<i>Lamprotornis purpureus</i>	Purperglansspreeuw			2	1		1				
<i>Lamprotornis splendidus</i>	Prachtglansspreeuw					1					
<i>Lamprotornis superbus</i>	Driekleurige Glansspreeuw		2		1		2	1			1
<i>Leiothrix lutea</i>	Japane Nachtegaal		1		1	1	1	1	2	3	1
<i>Leptoptilos crumenifer</i>	Afrikaanse Maraboe		3	1				1			
<i>Leucopsar rothschildi</i>	Balispreeuw						1				
<i>Lonchura oryzivora</i>	Rijstvogel						1		1		1
<i>Lonchura striata domestica</i>	Japane Meeuw									1	1
<i>Lophodytes cucullatus</i>	Kokardezaagbek	1	1	1	1	2	2	1		1	
<i>Lophodytes cucullatus x Mergellus albellus</i>	Hybride Kokardezaagbek x Nonnetje	1								1	
<i>Lophura ignita</i>	Gekuijde Vuurrugfazant								1		
<i>Lophura nycthemera</i>	Zilverfazant				1		1		1		1
<i>Lophura swinhoii</i>	Swinhoes Fazant							1	1		1
<i>Malacorhynchus membranaceus</i>	Lepelbekeend							1	1	1	
<i>Marmaronetta angustirostris</i>	Marmereend			1	1	1		1			
<i>Meleagris gallopavo</i>	Kalkoen				2	1	1		2	1	2
<i>Melopsittacus undulatus</i>	Grasparkiet	1	2	4	4	4	4	4	9	6	7
<i>Merops bullockoides</i>	Witkapbijeneter								2		
<i>Milvago chimango</i>	Chimango								1		
<i>Minla ignotincta</i>	Roodstaartminla				1					1	1
<i>Mycteria ibis</i>	Afrikaanse Nimmerzat		1				1	1			
<i>Myiopsitta monachus</i>	Monniksparkiet	2	3	5	4	5	4	5	6	6	5
<i>Necrosyrtes monachus</i>	Kapgier							1			
<i>Neochmia ruficauda</i>	Binsenastrild									1	
<i>Neophema elegans</i>	Prachtparkiet										1
<i>Neophema pulchella</i>	Turkooisparkiet							1		1	1
<i>Netta peposaca</i>	Peposaka-Eend		1	2	3	1	4	2	1	3	2
<i>Nettapus auritus</i>	Afrikaanse Dwergeend									1	1
<i>Numida meleagris</i>	Helmparelhoen		1	1	5	2	4	3	3	3	3
<i>Ocyphaps lophotes</i>	Australische Kuifduif					1		2		1	
<i>Oena capensis</i>	Maskerduif		1								
<i>Onychognathus tristranii</i>	Tristrams Spreeuw		1				1	1	1		
<i>Oriolus auratus</i>	Afrikaanse Wielewaal				1	1					
<i>Oxyura vittata</i>	Argentijnse Stekelstaart				1	1		1			
<i>Parabuteo unicinctus</i>	Woestijnbuizerd	1	1	1	1	1	2	2	4	4	1
<i>Paradoxornis webbianus</i>	Bruinkopdiksnavelmees							1	1	1	2
<i>Paroaria coronata</i>	Roodkuifkardinaal					1				1	
<i>Passer iagoensis</i>	Kaapverdische Mus										1
<i>Passer luteus</i>	Soedanese Goudmus							1			
<i>Pavo cristatus</i>	Blauwe Pauw		2	3	3	6	7	6	8	9	8

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<i>Pelecanus onocrotalus</i>	Roze Pelikaan		1					2	1		
<i>Pelecanus rufescens</i>	Kleine Pelikaan				1	3	1	1		1	
<i>Phasianus colchicus x Chrysolophus pictus</i>	Hybride Fazant x Goudfazant										1
<i>Phoeniconaias minor</i>	Kleine Flamingo	4	2	4	2	5	4	3	4	3	3
<i>Phoenicopterus roseus</i>	Flamingo	2	3	3	4	4	2	3	2	3	3
<i>Phoenicopterus ruber ruber</i>	Caribische Flamingo	1	2	3	3	2	3	6	5	5	4
<i>Phoenicopterus spec.</i>	Flamingo spec.	2	4	4	3	4	2	2	2	3	1
<i>Pitangus sulphuratus</i>	Grote Kiskadie		1								
<i>Platalea alba</i>	Afrikaanse Lepelaar	1								3	2
<i>Platycercus adscitus</i>	Bleekkoprosella					1					1
<i>Platycercus caledonicus</i>	Geelbuikrosella										1
<i>Platycercus elegans</i>	Pennant rosella		1	1	2	2	1	2	4	2	1
<i>Platycercus eximius</i>	Prachtrosella					2	1	1	4	1	
<i>Plectropterus gambensis</i>	Spoorwiekvang		1			2	1	1			
<i>Ploceus baglafaecht</i>	Baglafaechtwever								1	1	
<i>Ploceus cucullatus</i>	Grote Textorwever	1		1	1	1			1	1	1
<i>Poicephalus senegalus</i>	Senegalpapegaaï		1	1	1	1	1	2	1	2	3
<i>Poicephalus senegalus mesotypu</i>	Oranjebuik Senegalpapegaaï									1	1
<i>Polytelis anthopeplus</i>	Regentparkiet						1				
<i>Polytelis swainsonii</i>	Barrabandparkiet										1
<i>Pomatorhinus ruficollis</i>	Roodkeelkruiplijster						1				
<i>Porphyrio poliocephalus</i>	Grijskoppurperkoet						1				
<i>Porphyrio porphyrio</i>	Purperkoet				1			0		0	1
<i>Psephotus haematonotus</i>	Roodrugparkiet				2	1	1	4	1	1	1
<i>Psittacara erythrogenys</i>	Ecuadoraratinga								1		
<i>Psittacula cyanocephala</i>	Pruimenkopparkiet		1				1	1		1	1
<i>Psittacula derbiana</i>	Lord Derby's Parkiet	1	1				1	1	1	1	1
<i>Psittacula eupatria</i>	Grote Alexanderparkiet	1	1	3	3	6	5	5	8	7	7
<i>Psittacula himalayana</i>	Grijskopparkiet							1			
<i>Psittacus erithacus</i>	Grijze Roodstaartpapegaaï		1		1		2	1		1	1
<i>Pycnonotus aurigaster</i>	Roetkopbuulbuul	1	1	2				1	1		
<i>Pycnonotus barbatus</i>	Grauwe Buulbuul				1					1	
<i>Pycnonotus cafer</i>	Roodbuikbuulbuul	1		2			1				
<i>Pycnonotus jocosus</i>	Roodoorbuulbuul		1	1				1			
<i>Pycnonotus leucotis</i>	Witoorbuulbuul							1	1		1
<i>Pycnonotus sinensis</i>	Chinese Buulbuul								1		
<i>Pyrrhura frontalis</i>	Bruinoorparkiet						1				
<i>Pyrrhura molinae</i>	Groenwangparkiet						1				1
<i>Quelea quelea</i>	Roodbekwever		1						1		
<i>Rhea americana</i>	Nandoe			1		1	2			1	3
<i>Rhodospiza obsoleta</i>	Vale Woestijnvink			1							
<i>Sarkidiornis melanotos</i>	Knobbeleend				1						
<i>Scopus umbretta</i>	Hamerkop	2			2	1					

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.

Latin name	Dutch common name	Maximum number of 1x1 km atlas squares in a month									
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<i>Spilopelia senegalensis</i>	Palmtortel		1		1	1		1	1	2	2
<i>Streptopelia roseogrisea</i>	Lachduif	1	1	1	1	2	3	2	3	3	1
<i>Streptopelia tranquebarica</i>	Rode Tortel			1					1		
<i>Sturnia pagodarum</i>	Pagodespreeuw										1
<i>Sturnia sinensis</i>	Mandarijnspreeuw										1
<i>Syrnaticus reevesii</i>	Koningsfazant	1		1		1	1	1	1		1
<i>Tadorna cana</i>	Kaapse Casarca	1	4		1	4	4	3	4	6	8
<i>Tadorna radjah</i>	Radjaheend	1	1	1	1	1					
<i>Tadorna tadornoides</i>	Australische Casarca	1	1	1	1	1	1	1	1	1	2
<i>Tadorna variegata</i>	Paradijscasarca	1			3	1	1	2	4	1	1
<i>Taeniopygia guttata</i>	Zebra-vink	1	1	2	5	1	3	4	3	4	3
<i>Tauraco persa</i>	Groene Toerako			1						1	1
<i>Thectocercus acuticaudatus</i>	Blauwkoparatinga								1		
<i>Thraupis episcopus</i>	Bisschopstangare						1				
<i>Threskiornis melanocephalus</i>	Zwartkopibis						1	2	9	2	
<i>Trachyphonus erythrocephalus</i>	Vuurkruinbaardvogel									1	
<i>Tragopan temminckii</i>	Temmincks Saterhoen									1	
<i>Turdus dissimilis</i>	Zwartborstlijster								1		
<i>Urocissa erythroryncha</i>	Roodsnavelkitta		2								
<i>Vanellus armatus</i>	Smidsplevier				2						
<i>Vidua macroura</i>	Dominicanerwida			1		1				1	1
<i>Vidua obtusa</i>	Breedstaartparadijswida		1								
<i>Yuhina diademata</i>	Diadeemmeestimalia			2	1						
<i>Zonotrichia capensis</i>	Roodkraaggors			2	1						

N.B. The number of km-squares depends on the distribution of birds, how vagrant the individuals are and the number of observers in the field.

## Appendix 3. Pathway definitions (UNEP, 2014)

Pathway	Vector	Description
RELEASE IN NATURE	Release in nature for use	<p>Throughout history, plant and animal species that have been a source of food or fulfil an agricultural purpose have been taken from their natural ranges and introduced into new regions to enhance food production for the local human population. This has occurred both in areas where either traditional food sources were not present in newly colonised areas and were subsequently introduced; or, where human groups expanding their territories have discovered new species, returned home and introduced these species as a new food source. Aside from the subject of the translocation, other species may also be removed from their natural range through their inadvertent transportation on or in the animal or plant being moved.</p> <p>A well-known example of this enhancing process would be the case of the European rabbit (<i>Oryctolagus cuniculus</i>) which was introduced in limited numbers to one farm in Australia and is now a nationwide pest species displacing many native species. Another global pest species that has been transported both intentionally and inadvertently is the African land snail (<i>Achatina fulica</i>) which has been introduced many areas of the world for a range of purposes including as novelty fauna, as a pet, for food etc. and is now a significant crop pest in many countries. The introduction of species to new areas for perceived enhancements is an ongoing process and a frequent source of novel invasive species.</p>
	Biological control	<p>Biological control agents are species that have been introduced to areas outside their natural range to regulate pest populations usually within agricultural crops and products. This is largely in response to a novel pest species affecting the productivity of a crop where there are no native predators available to control the population of the pest. A second species is introduced to control the pest species with the potential unintended consequence of the introduced predator species subsequently becoming a pest also. This was a frequent event during the twentieth century particularly during the period prior to and during the development of the discipline of ecology and a clear understanding of species in ecosystems.</p> <p>Examples of introductions of control species include the cane toad (<i>Bufo marinus</i>) which was introduced into Australia to control beetles that were damaging cane crops - the toad population exploded and has affected native herpetofauna species negatively as well as becoming a pest in its own right. A second example would be the European stoat (<i>Mustela erminea</i>), a species that was introduced into New Zealand to control the introduced rabbits (<i>Oryctolagus cuniculus</i>) and hares (<i>Lepus europaeus</i>), stoats soon became a significant predator of the native species. Although introductions of biological control agents are now tested, planned and controlled when undertaken formally, unfortunate introductions still occur around the world.</p>
	Erosion control/ dune stabilization (windbreaks, hedges...)	<p>This invasion pathway is a result of an example of how humans have sought to control their environment: the stabilization of mobile, fragile or man-made landscapes using plants and to assist in coastal reclamation projects. By introducing species with specific, useful attributes such as deep and spreading root systems it is possible to stabilize dunes or increase the resilience of otherwise malleable features such as shingle banks and steep hillsides from alteration and destruction by natural processes such as wave action or flooding.</p> <p>European marram grass (<i>Ammophilla arenaria</i>) was introduced into California to stabilise dunes, it spread along the entire western coastline of North America and has caused the destruction of native dune systems; crown vetch (<i>Securigaria vera</i>) was similarly introduced to North America from Europe for soil rehabilitation and erosion control but has become dominant in many habitats and is now an invasive pest species. Mexico, Hawaii, East Africa and many Caribbean islands have been subject to invading populations of Australian-pine (<i>Casuarina equisetifolia</i>) after it was introduced as a structural plant to assist in coastal reclamation and erosion stabilization projects.</p>

Pathway	Vector	Description
RELEASE IN NATURE	Fisheries	<p>Fishing is an important economic activity for many countries; many fish species have been taken from their natural range and introduced into a new watercourse or waterbody to create alternative or novel opportunities for commercial fishing activities; or, to provide a more productive source of food for local populations. Fish that are suitable for commercial harvesting, and large game-fish species can predate other fish, or out-compete native species causing significant changes to the natural, native ecosystem. Concerns over species introductions through this pathway include pest and disease species of fish.</p> <p>Common carp (<i>Cyprinus carpio</i>) have been introduced to a large number of countries to stock fisheries, however their feeding techniques of stripping and part-digesting all aquatic vegetation has adversely affected watercourses and waterbodies globally as well as threatening the survival of other aquatic fauna. Similarly lake trout (<i>Salvelinus namaycush</i>) have been introduced from their North American range to enhance the sport of fishing into many European countries and New Zealand where they outcompete and predate upon native species.</p>
	Hunting	<p>In many countries species have been introduced outside of their natural range to provide a source of sport: a prey for hunters. The species that are predominantly hunted for sport are either large herbivores, or large predators; the impacts from the introductions of species with specific food source requirements can severely alter the natural structure of the habitats and native species of the area to which these sport species are introduced into. Beyond this immediate impact to native habitats and species at the new location, moving large animals between countries can also transport other species including potential pest species and diseases.</p> <p>Wild boar (<i>Sus scrofa</i>) and red fox (<i>Vulpes vulpes</i>) have been introduced into countries outside their natural range for the purposes of hunting for sport, the former also providing a source of food, the latter a species that is hunted for the entertainment of the wealthier classes in Britain. Once established, feral populations of both species cause significant damage to the ecosystems of the countries into which they have been introduced due to their habits of foraging and predation respectively. The red fox has been nominated as one of the worst invasive species in the world.</p>
	Landscape/flora /fauna improvement	<p>With the rise in interest in horticulture, in particular during the intensive period of 19th Century global exploration, a large number of plant species were collected and moved from their natural ranges initially species were collected as curiosities, but later on they provided a source of novel garden plants. Similarly with new species of animal, an interest developed as to whether novel species could increase the productivity of, or diversify a landscape otherwise perceived as impoverished. Efforts to improve landscapes and species diversity have led to a vast number of species being moved from their natural range. The result of this are many locations globally that act as source points for non-native species invasions. Diseases and pests of plants and animals have also been spread with original sample organisms.</p> <p>During the 19th Century Japanese knotweed (<i>Fallopia japonica</i>) was introduced into gardens around the world as a landscaping plant due its fast growing nature, however it soon escaped the confines of gardens and has since spread prolifically creating mono-specific stands and depleting ecosystems globally. American agave (<i>Agave americana</i>), originally from Mexico, has been introduced into South America, the Pacific Islands, East Asia, Europe and Australia and is prolific in sand dunes, disturbed sites and in coastal areas. Grey squirrel (<i>Sciurus carolinensis</i>) was introduced into Britain from North America in the same period as a novel species, however it quickly bred and rapidly displaced the native equivalent squirrel species by not only out-competing the native, but also by being a carrier of a disease that severely damaged the native population.</p>

Pathway	Vector	Description
RELEASE IN NATURE	Conservation introduction	<p>Within the context of modern conservation projects translocations of species can be undertaken to secure their long-term survival. The potential issues with translocations are manifold both to the focal species and the source and destination areas; this is particularly significant in terms of translocations of species outside of their indigenous range. This can be an issue in mitigation translocation – where a species is moved out of the way of a development to ensure the continuity of the population of that species within an area. This may move the species into a system in which it was not previously present and the translocated species could have a harmful impact on the destination habitat and species.</p> <p>Where conservation programmes have, in an attempt to save one species, created an invasive threat it is where species have been moved outside their evolutionary context. The singida tilapia (<i>Oreochromis esculentus</i>) is critically endangered in its native Lake Victoria (largely as a result of the introduction of the Nile perch (<i>Lates niloticus</i>) which has caused the extinction of nearly 200 species within this waterbody), but when this species was introduced into African reservoir systems it has become an invasive pest within these catchments. The Australian paperbark tree (<i>Melaleuca quinquenervia</i>) is threatened in its native Australia, however is one of the most damaging invasive plants in the US state of Florida (Ricciardi &amp; Simberloff, 2008)</p> <p>The international guidelines available on the movement of species outside their native areas, within which translocation for conservation should be considered are relatively extensive and sit within the aims of the Convention on Biological Diversity and the Aichi Biodiversity Targets.</p> <p>The IUCN has six sets of guidelines: Prevention of Biodiversity Loss Caused by Alien Invasive Species (2000); Management of Ex-situ populations for Conservation (2013); World Commission on Protected Areas (2012), Ecological Restoration for Protected Areas: Principles, guidelines and best practices; Guide to Wildlife Disease Risk Assessment; IUCN Red List; and the Policy Statement on Sustainable Use of Wild Living Resources.</p>
	Other intentional release (bioremediation)	<p>Bioremediation is the process whereby a species is introduced into a damaged or polluted habitat to in some way improve the conditions that are present. The aim of the introduction is to over time improve the conditions at the site, or to make a site more amenable to utilization by humans for development or agriculture. This has happened frequently across the planet where the ecosystems of newly colonised lands/areas do not support traditional land management techniques that were developed in different conditions; also where, during times of strong economic growth, development has caused damage to natural systems that subsequent generations decide to remediate.</p> <p>The introduction of number of different species of earthworm (including <i>Dendrobaena octaeda</i>, <i>Dendrodrilus rubidus</i>, <i>Lumbricus rubellus</i>) into novel ecosystems to alter the productivity of soil for agriculture had the knock-on effect of the earthworms spreading outside the initial area of introduction and affecting nutrient cycling across many habitats - this irrevocably damaged natural ecosystems by changing the nutrient levels available. Novel detritivores may also out-compete or predate on native species causing knock-on effects in the food chain and the natural soil management processes.</p>
	Other intentional release (reintroduction)	<p>Reintroduction programmes are where species that were once locally native have gone extinct through hunting or habitat destruction by humans and are subsequently returned to this area through conservation programmes. Without a comprehensive impact assessment of the project restoring a previously naturally occurring species can have a negative effect if the habitat has been altered or if predators of this species have also become locally extinct. This is particularly important in the case of the loss of keystone species where during their absence the ecosystem has change stable state; the reintroduced species may become invasive in an altered ecosystem.</p> <p>An example would be the return of the North American beaver (<i>Castor canadensis</i>) to stretches of watercourse from which it had been previously trapped during the colonial expansion of North America. Beaver can cause considerable damage to urban or landscaped areas as their natural behaviour does not have a favourable effect outside more natural riparian structures.</p>

Pathway	Vector	Description
RELEASE IN NATURE	Other intentional release (waste management)	<p>Similar to bioremediation, waste management can incorporate processes whereby species are introduced into damaged or polluted habitat to improve the conditions that are present; or where species are used to breakdown large waste materials and remove contaminants such as heavy metals from manufacturing by-products. The aim of the introduction is to over time improve the conditions within polluted areas, or alter the waste product of human activity to less unpleasant organic material to create areas that are safe to use, or to create a product that is either safer to handle or something of commercial value.</p> <p>Frequently used species in waste management, particularly in municipal solid waste, are earthworms (e.g. <i>Lumbricus rubella</i>). These will be introduced to assist in the breakdown of waste products, particularly where local species of earthworm are not suitable for the commercial task. The knock-on effect of the earthworms spreading outside the initial area of introduction and affecting nutrient cycling across many habitats - this irrevocably damaged natural ecosystems by changing the nutrient levels available. Novel detritivores may also out-compete or predate on native species causing knock-on effects in the food chain and the natural soil management processes.</p>
		<p>The increase in significance of both the ability of the world to feed a growing population and regionally, for the food security of nations has led to a drive in the diversification of novel crop and farmed species within many countries. Productive agricultural species, and species that provide locally in-demand foodstuffs are frequently planted or farmed outside their native range; particularly pertinent to crop species are the ready availability of pollinators – many invertebrate species have been introduced into new areas to ensure that crops produce a strong yield. Whilst introduced into a relatively confined agricultural environment, wind-dispersal of seed or individual migration (for example) from this initial point of introduction has seen hundreds of species if plant and animal enter new ecosystems around the world.</p> <p>The African honey bee (<i>Apis mellifera scutellata</i>) was introduced as a pollinator to the Americas to bolster failing populations of European honey bee, itself an introduced species which was not productive in this new environment. This more aggressive species spread successfully and now causes economic, social and ecological problems. Bumblebees (<i>Bombus</i> spp.) and European honey bees (<i>Apis mellifera</i>) were introduced to New Zealand as pollinator species; these species nectar rob native plant species and out-compete native bee and other invertebrate species.</p>
ESCAPE FROM CONFINEMENT	Agriculture	<p>The increase in significance of both the ability of the world to feed a growing population and regionally, for the food security of nations has led to a drive in the diversification of novel crop and farmed species within many countries. Productive agricultural species, and species that provide locally in-demand foodstuffs are frequently planted or farmed outside their native range; particularly pertinent to crop species are the ready availability of pollinators – many invertebrate species have been introduced into new areas to ensure that crops produce a strong yield. Whilst introduced into a relatively confined agricultural environment, wind-dispersal of seed or individual migration (for example) from this initial point of introduction has seen hundreds of species if plant and animal enter new ecosystems around the world.</p> <p>The African honey bee (<i>Apis mellifera scutellata</i>) was introduced as a pollinator to the Americas to bolster failing populations of European honey bee, itself an introduced species which was not productive in this new environment. This more aggressive species spread successfully and now causes economic, social and ecological problems. Bumblebees (<i>Bombus</i> spp.) and European honey bees (<i>Apis mellifera</i>) were introduced to New Zealand as pollinator species; these species nectar rob native plant species and out-compete native bee and other invertebrate species.</p>
	Aquaculture	<p>Similar to escape from agricultural confinement, this pathway is the introduction of species to an ecosystem from fisheries. Species that are suitable as a commercial crop or those that would provide opportunities for creating a new source of nutrition are introduced into an area either directly into catchments or into controlled fish farms; those introduced directly into new catchments, or where a number of individuals escape the confines of the farm and populate the local watercourses with negative impacts on the natural systems. The movement of fish for commercial operations can also transport diseases and other aquatic organisms between areas and introduce new species unintentionally.</p> <p>Atlantic salmon (<i>Salmo salar</i>) are farmed in large sea-cages which are susceptible to damage. Domesticated farm stocks of Atlantic salmon when released unintentionally can damage wild populations of the same species by spreading disease and parasites to, compete with and hybridize with native fish species. Signal crayfish (<i>Pacifasticus leniusculus</i>) were introduced from North America into Britain to create a commercial crayfish farming industry, crayfish escaped into watercourses and spread throughout the entire country out-competing the native species of crayfish and spread with them crayfish plague that has caused near-extinction of the native crayfish.</p>

Pathway	Vector	Description
ESCAPE FROM CONFINEMENT	Botanical garden, zoo, aquaria	<p>Botanical gardens, zoos and aquaria have provided the opportunity to educate the general public about the diversity and value of global fauna and flora. Historically, the importation and study of rare, unique or agriculturally significant species has enhanced research within the scientific community and the understanding of global diversity. A lack of understanding of the viability of species in novel environments coupled with inadequate containment facilities precipitated plants and animals escaping their confines introducing new species into the surrounding ecosystem.</p> <p>The mangrove palm (<i>Nypa fruticans</i>) was introduced from its native Asia-Pacific range to West Africa, the Caribbean and Central America through planting in botanical gardens and subsequent spread by floating seeds where it displaces mangrove communities and damages the natural diversity of flora and fauna. The Burmese python (<i>Python molorus bivattatus</i>) is a classic example of an escaped animal from confinement within Florida where it has significantly altered the structure of the food chain within the native wetlands. Dozens more harmful released pet/aquarium species have resulted in significant ecological and financial harm.</p>
	Farmed animals, including animals under limited control	<p>Many species of fauna have been introduced into a new part of the world either as working animals or to provide a food source in an area otherwise supporting limited provisions. These animals, in many cases having been left semi-wild quickly expanded their range into the destination habitat and were only occasionally managed by humans. Overall the effect of a species adapting and establishing successfully, is one of the introduced species becoming invasive and can altering, or damaging host ecosystem.</p> <p>Dromedary camels (<i>Camelus dromedarius</i>) were introduced into the outback of Australia to provide transport for settlers traversing the vast expanses of the newly colonised continent; these camels successfully established and are now a threat to the indigenous habitats. Dromedaries have also established in the Canary Islands, however in lower numbers. Goats (<i>Capra aegagrus hircus</i>) and pigs (<i>Sus</i> spp.) are significant invasive problems in many countries, introduced for their hardiness and as a food source, the resilience of these species has ensured their success as highly damaging invasive species.</p>
	Forestry	<p>Commercial timber operations are a significant worldwide contributor to the spread of invasive tree species; tree species that have specific, required properties and that will produce a valuable crop are planted globally outside their natural range to provide for commercial forestry operations. The conifers are the predominant group of trees that are utilised for these operations and are capable of effective wind dispersal and can readily establish outside the controlled area of forestry plantation. The international shipping of young plants as well as the product from commercial timber operations spreads a host of invertebrate species.</p> <p>The Monterey pine (<i>Pinus radiata</i>) is native to California yet is used globally in forestry operations, in New Zealand in particular this has spread extensively outside areas of forestry operations and is damaging natural native areas. Fast growing species that are suitable for building materials and firewood have similarly been spread around the globe to provide a source of wood e.g. Propopis and Casuarina species and have subsequently become invasive.</p>



Pathway	Vector	Description
ESCAPE FROM CONFINEMENT	Fur farms	<p>Desirable animal products, such as fur, lead to the development of farming of animals for specific products for the fashion industry. These intensive farming operations operated predominantly within the late 19th and 20th centuries; animals escaped the confines of these farming operations in a variety of ways, including release by animal rights activists, and lead to the introduction of species in areas outside their natural range. The species chosen for farming were large mammals and many were capable of displacing native species and causing considerable environmental damage once establishing in their new habitats.</p> <p>The American mink (<i>Mustela vison</i>) was farmed for its fur in the UK and successive escapes from mink farms introduced this species to the watercourses where it proceeded to eradicate native mammal and bird species; the red fox (<i>Vulpes vulpes</i>) has also established as an invasive species as a result of escaping from fur farms in North America. The coypu (<i>Myocastor coypus</i>) has been introduced to Europe and North America from its native region in South America; this riparian species constructs deep burrows that destabilise river banks, dykes and irrigation facilities with environmental and financial costs.</p>
	Horticulture	<p>The breeding of new garden varieties of plant species by horticultural organisations across the world has led to localised introductions of modified species within their ancestor's natural range as well as modified and novel species introduced outside their ancestral evolutionary area. Seed dispersal, viable vegetative propagule production, or other escape from confined locations has led to the spread of non-native plant species from these points of introduction into surrounding ecosystems. Modified, or improved species will express novel traits, the potential effects of which are difficult to anticipate on a new ecosystem.</p> <p>Asparagus fern (<i>Asparagus densiflorus</i>) has been introduced to a number of countries from its native South Africa for horticultural purposes and has spread from gardens into natural areas lowering diversity and damaging ecosystems. New Zealand pygmyweed (<i>Crassula helmsii</i>) and water fern (<i>Azolla filiculoides</i>) were introduced into Europe by horticulturalists as oxygenators for ornamental ponds however both have spread into watercourses and lakes and are now a serious invasive problem.</p>
	Ornamental purpose	<p>The trade in species that are provide striking structure and colour, or show traits that make them suitable for landscaping in a variety of forms has ensured the movement of species around the world to improve or enhance municipal areas or private parks and gardens. Fauna that is aesthetically pleasing has been incorporated into development and introduced for events. Whilst the international trade in species is becoming more controlled, the focus of planting for appearance over that which is ecologically appropriate ensures that, for example, development design will incorporate plant species that are non-native to a particular region being introduced to ensure the desired visual effect is achieved.</p> <p>Mallard (<i>Anas platyrhynchos</i>) and starling (<i>Sturnus vulgaris</i>) have been introduced to countries outside their natural range to provide a colourful addition to the local fauna. The foraging habits and breeding success of these species have resulted in the successful invasion of their new territory displacing native species and becoming pest species. Common carp (<i>Cyprinus carpio</i>) and the Mayan cichlid have similarly been spread globally through the aquarium trade and both species can reach high densities, competing with and perhaps preying upon native species of fish reducing biodiversity and ecosystem function.</p>



Pathway	Vector	Description
ESCAPE FROM CONFINEMENT	Pet/aquarium trade	<p>The importance of the international trade in live vertebrate animals for pet and home aquarium use has increased over recent decades as an invasion pathway. Concerns related to this trade include not only species invasions but also the live animal trade is increasing in importance as a vector for animal diseases, including zoonotic diseases. The majority of emerging zoonotic diseases globally originate in wildlife. A recent global review documented that 63 disease agents, including many emerging human</p> <p>Recent invasive animal examples from the pet/aquarium sector in the United States include: red lionfish (<i>Pterois volitans</i>) and two giant constrictor snakes, the Burmese python (<i>Python molorus bivittatus</i>) and Northern African rock python (<i>P. sebae</i>). Dozens more harmful released pet/aquarium species have resulted in significant ecological and financial harm. Similarly, in Europe, the pet/aquarium trade resulted in high-profile invaders including, e.g., the 2009 report of the American red squirrel (<i>Tamiasciurus hudsonicus</i>) in Denmark. The pet trade remains an important pathway for invasions of animals in Europe. Species introductions include indirect effects of the aquarium trade where aquatic species other than the species being traded are transported within the water in the container of the subject species.</p>
	Research (in facilities)	<p>The increase in use of animals in research laboratories has led to the increased concern in the potential for invasion threats from escaped or released animals. Historically research laboratories have not always been able to contain their test subjects and a number have escaped; occasionally, and similar to the fur farms, animal rights activists have released animals from laboratories into the wild. Other potential pathways include the breeding and transfer of species that are on provided to schools for science education.</p> <p>Rhesus monkeys (<i>Macaca mulatta</i>), outside their native range of Central and Southern Asia, have formed colonies in parts of the US where they were imported for use in laboratories. Rusty crayfish (<i>Orconectes rusticus</i>) is transported across the US to be used in classrooms for school science programs; this species out-competes native crayfish, reduces fish populations and increases macrophyte abundance in watercourses it invades with consequential environmental and financial cost.</p>
	Other escape from confinement (fencing)	<p>Plant species that have specific uses in their natural range, for example creating boundaries between properties or stock-proofing between grazing areas, have been imported into new locations by colonising human groups to introduce their useful properties to new locations. Whilst this pathway is significantly less frequent than in the late 19th and early 20th centuries, introductions for practical purposes are ongoing. Plant species, outside their evolutionary range, are not subject to natural controls to maintain a balanced population and can establish locally and expand across significant areas.</p> <p>European gorse (<i>Ulex europaeus</i>) and species of the tribe bamboo (<i>Bambuseae</i>) are two introduced structural plant species that have escaped the confines of their introduced location and become serious pests, the former a significant weed in New Zealand, an example of the latter, the yellow grove bamboo (<i>Phyllostachys aureosulcata</i>), is spreading in the American mid-west and in north-eastern Europe.</p>

Pathway	Vector	Description
TRANSPORT - CONTAMINANT	Contaminant nursery material	<p>The transportation and import of plant species for horticulture in nurseries continues to move a large number of plant species from different locations around the world. Transporting the plant specimens ensures the movement of the soil around their roots which can support a diverse flora and fauna, a variety of fungi, invertebrates and potentially propagules of other plant species. The plants themselves are a potential source of stowaway pests and diseases. The transport of plants and their associated species through countries outside the natural range of all the species within the transporter has historically been, and in some cases continues to be a proven pathway of pest dispersal. The potential species dispersal routes within this pathway remain extensive and are of serious concern.</p> <p>Snails and even lizards have been distributed by the transport of nursery material from Europe to the New World and from the Caribbean to South America respectively. The African land snail (<i>Achatina fulica</i>), a species that can be spread by eggs or juveniles either in soil or on plant specimens, is now a serious pest on four continents. Common salvinia (<i>Salvinia minima</i>) has been introduced to North America and Spain from its native South America as a contaminant on nursery specimens and is a serious invasive threat, blocking watercourses and causing catastrophic eutrophication events.</p>
	Contaminated bait	<p>Fishing baits provide a diverse source of species outside their natural range. Sport fishing requires a range of suitable baits and transporting bait species between regions can and has also moved pest species and disease by simultaneously moving a variety of other fauna in water tanks and by moving diseased specimens. By transporting baits between countries, many species have been introduced unintentionally into new areas. This continues to be a source of serious invasive species with significant environmental and financial cost.</p> <p>The rusty crayfish (<i>Orconectes rustica</i>) was introduced into several States in the USA through the importation of bait and has subsequently damaged aquatic flora and destabilised the ecosystem of watercourses in which it now resides by out-competing and preying on many of the native aquatic species. Earthworms (<i>Lumbricus rubellus</i> and <i>L. terrestris</i>) have similarly entered new ecosystems through importation for bait with effects including significantly altering of nutrient cycling processes.</p>
	Food contaminant	<p>Global trade and food production has and continues to create mechanisms for the transportation of large volumes of fruit and vegetable species from producing countries to the rest of the world. There are two directions to this pathway: 1) crop species that have been introduced into countries to provide a more economic source of food have become invasive and 2) the crop product, when being transported to the vendor, has transported pest novel pest species associated with the crop. With an ever more dynamic global economy and developing relationships with producer countries the potential for the spread of costly disease and invasive species is ever more significant.</p> <p>Fruit flies (e.g. <i>Bactrocera tryoni</i>), plants (e.g. annual ragweed <i>Ambrosia artemisifolia</i> and Java grass <i>Cyperus rotundus</i>) and invertebrates (e.g. rough woodlouse <i>Porcellio scaber</i>) have all been transported from their natural range and into new locations, both to and from producing countries, where they have established and become damaging pest species affecting the viability of native species, the value of fruit crops, altering nutrient cycling processes and, in the case of <i>A. artemisifolia</i>, causing significant health-care costs through allergenic properties.</p>

Pathway	Vector	Description
TRANSPORT - CONTAMINANT	Live food	<p>Transportation of live food species can result in the movement of species that are potentially invasive, and can unintentionally transport other species, these include parasites and species in the gut of the food species. Food stuffs that are considered cultural have been significant pathways for invasive species historically, and remain so although biosecurity controls at borders are starting to control this point of entry. This pathway continues to be a serious threat to biosecurity and the environmental and economic welfare of countries and regions globally.</p> <p>Chinese mitten crab (<i>Eriocheir sinensis</i>) has been introduced into Europe through legal and illegal means and is now causing serious costly damage to watercourse structures and native invertebrate communities. The amethyst gem clam (<i>Gemma gemma</i>) was introduced into California by the live transportation of a duck, the duck was carrying clams in its crop. European rabbits (<i>Oryctolagus cuniculus</i>) have been introduced to many regions of the globe as a source of food and have caused significant grazing damage to ecosystem structure.</p>
	Contaminant on animals (excluding parasites and species transported by host and vector)	<p>The transportation of animals can also result in the movement of soil material in their hooves or feet that may also support viable propagules or seeds of plants and invertebrates. Seed will also be transported in the fur coats of many animals and similarly has the potential to transfer a species from one location to another. Food and water supplies for the stock in transfer also have the potential to be carriers of species novel to the destination ecosystem. This pathway continues to introduce novel species regionally and globally with significant environmental and financial impacts.</p> <p>Mesquite tree species (<i>Prosopis</i> spp.) have been spread regionally through animal movements; the 44 species of this genus suppress grassland and forage plants and invades wood pasture. Similarly woody bittercress (<i>Cardamine flexuosa</i>) has been introduced into many Asian and American countries most probably through seed attached to animals; this species is a serious arable weed and through its dense understory root mats can potentially alter successional processes. American limpet (<i>Crepidula fornicata</i>) was likely introduced into Western Europe through the transportation of live oysters and has been observed to alter sediment characteristics with costly impacts to shellfish farms.</p>
	Contaminant on plants (excluding parasites and species transported by host and vector)	<p>The transfer of plants from one location to another for commercial crop production or horticulture can result in viable propagules of another species also being transferred. This can occur either with a foreign species' seed being attached to the plant itself, seed or viable material being lodged in the root bowl or in associated soils. Transport of specific species may require containers of standing water, with moist environments or other environmental controls to ensure the viability of the product. These conditions may provide suitable habitat for other species. This pathway is becoming more significant as a source for novel pest species with a more globalized economy and cheaper shipping options.</p> <p>The tiger mosquito (<i>Aedes albopictus</i>), a carrier of dengue fever, west nile virus and Japanese encephalitis, was recorded within a container shipment of live plant material at Los Angeles port in 2001. The trade in ornamental plant species is opening up new pathways for novel pest species. An example of a plant species travelling as a contaminant on plant products is Asian melastome (<i>Melastoma candida</i>) which has spread prolifically from its native range in south-east Asia across the Pacific to Hawaii and the US creating monotypic thickets and causing extensive environmental damage with associated financial impacts.</p>
	Organic packing material (wood packing, etc.)	<p>Global transportation of goods and products for foreign markets requires a large volume of packing material. Wooden packing cases where the timber has not been treated has been commonly used and can support a number of species that would be living on or in the tree from which the timber and packing material was sourced. Some species can survive the timber processing and transport, or are drawn to the organic materials of the packing prior to departure of that packing from its source country. Wooden packing continues to be a source of invasive pest species.</p> <p>Pinewood nematode (<i>Bursaphelenchus xylophilus</i>) has been moved via this pathway from North America to Asia where it is causing enormous environmental and economic damage. The nematode kills pine trees. Chinese forest habitats, tourism and forestry sectors are under serious threat from this species. The common pine shoot beetle (<i>Tomicus piniperda</i>) and the Asian long-horned beetle (<i>Anoplophora glabripennis</i>) have been spread extensively around the world through this vector and similar to the nematode have costly environmental impacts as well as having negative effects on commercial forestry.</p>

Pathway	Vector	Description
TRANSPORT - CONTAMINANT	Parasites on animals (including species transported by host and vector)	<p>Animal species, through legitimate or illegitimate transportation, have the potential to be carrying other species associated with their natural habit. Symbiotic species, parasites and other diseases have been introduced into new ecosystems through this pathway. Whilst quarantine for travelling animals will prevent some transference from occurring, not all parasites and symbionts will be prevented from moving with animals. Importation of new breeding stock is a particularly prevalent source of new disease and microbial invasive species.</p> <p>Until recent alarms over the condition of bee colonies highlighted potential issues apiarists were spreading the varroa mite (<i>Varroa destructor</i>) extensively through the introduction of new queens into colonies. This mite is suspected of being an agent in the collapse of bee colonies globally. Other parasites of current global significance include beak and feather disease (BFDV), a devastating virus of psittacines, and chytridiomycosis (<i>Batrachochytrium dendrobatidis</i>), a fungus that affects a large number of amphibian species worldwide and one that is causing a serious threat of extinction to many species.</p>
	Parasites on plants (including species transported by host and vector)	<p>The movement of plant species between locations creates a risk to plant communities at the destination due to the potential of the presence of novel parasites on and within the tissues of the plant matter that is being moved. Viruses, fungi and mites are a few of the potential, microscopic and potentially undetectable organisms that have been unintentionally introduced by the transporting of plants across regions and ecological boundaries. This has historically been, and continues to be, a serious source of invasion of novel pest species.</p> <p>A significant group of plant pathogens that have had catastrophic impacts on economies and human survival are the blights (<i>Phytophthora</i> spp.). Potato blight has historically and continues to cause devastation to crops and has in the past seriously damaged economies. Eucalyptus rust (<i>Puccinia psidii</i>) has spread from Central and South America into the Caribbean, mainland USA and Hawaii on transported plant samples and causes serious dieback of compatible species including commercial fruit crops of guava (<i>Psidium</i> spp.) and ruberry (<i>Myrcia</i> spp.).</p>
	Seed contaminant	<p>The global trade in agricultural seed to provide new or more productive species to new locations considered either impoverished or less productive has created a pathway for the unintentional spread of invasive pest species. This is both through the lack of understanding of the traits of any species and the likely impact of its introduction into a novel ecosystem as well as the unintentional transportation of associated species whose seed is harvested or later contaminates the main product. The rise in demand for resilient agricultural crop seed globally and the increased transport of seed from regions developing new seed crops will serve to increase the chances of the dispersal of potentially invasive species.</p> <p>The giant sensitive tree (<i>Mimosa pigra</i>) and yellow star-thistle (<i>Centaurea solstitialis</i>) have been translocated from the Neotropics and the Mediterranean respectively to Australia, South-east Asia and California where they have become serious pest species. Both species reduce the suitability of grazing land for ungulates, therefore seriously affecting the value of the land, by shading out or out-competing grass species to create woody or herb-thickets. Giant sensitive tree will also dominate water course banks, increase silt levels, restrict water flow and support increased numbers of rats and invasive crab species with serious environmental and financial costs.</p>

Pathway	Vector	Description
TRANSPORT - CONTAMINANT	Timber trade	<p>Commercial timber operations, particularly in this case, for export has transported untreated wood between countries and otherwise unconnected regions of the planet. Similar to organic packing, the timber can support a number of species that would be living on or in the tree from which the timber was sourced. Some species will survive the timber processing and transport, or are drawn to the timber prior to departure of this product. The global trade in timber, along with an increase in commercial timber operations, continues to fuel this pathway transferring pest species between timber-growing regions.</p> <p>The citrus longhorn beetle (<i>Anolophora chinensis</i>), yellow crazy ant (<i>Anoplolepis gracilipes</i>) are two invertebrate species that have been unintentionally transported outside their native range in this manner both causing significant damage to destination ecosystems. The longhorn beetle, a pest in its native Asian range, has been introduced into Europe causing costly damage to commercial logging operations. The yellow crazy ant has been spread across the world from its original source region (unknown due to the high level of spread) and through its ability to forage night and day and extremely competitive foraging techniques is causing severe environmental damage through displacing keystone species and by degrading leaf litter, reducing seedling recruitment and speeding up microbial decomposition processes.</p>
	Transportation of habitat material (soil, vegetation, wood...)	<p>The transportation of vegetation matter, soil or other plant products occurs on large, commercial scales where vegetation and soil is transported between locations on machinery or other items. These processes provide the potential for large numbers of organisms to be transported along with these materials and will be moved to new locations. Fungi, virus, bacterium, plant seed or propagules, larvae and juvenile animals have all been transported in this manner from their naturally occurring range to new locations where some have been able to establish. The transshipment of habitat materials in large and relatively small volumes continues to be a serious threat to biosecurity globally.</p> <p>The coconut rhinoceros beetle (<i>Oryctes rhinoceros</i>), native to South-east Asia has been progressively spread across the Pacific during the 20th Century in decaying organic materials such as compost or sawdust. This beetle, outside its native range, where the natural controls that stabilize its population do not exist, is a serious pest of coconut, oil and date palms. The effect is serious economic pressure from loss of agricultural crop. Itch grass (<i>Rottboellia cochinchinensis</i>) has been spread from Africa and Australasia to North America and the Caribbean where it infests sugar cane fields and causes serious environmental and economic harm. A likely cause of spread through the American deep south was through the use of road matting material during the period of extensive oil exploration in the 1970s and 1980s.</p>
TRANSPORT - STOWAWAY	Container/bulk, including seafreight, airfreight, train, etc.	<p>Moving any items in bulk form, particularly organic matter of any form, between countries has caused the spread of organisms outside their ecological region. This is a particular concern where bulk containers are not screened for animals or plant matter, where the items being transhipped are not treated or processed. Biosecurity varies between regions and this pathway creates a serious threat to environmental stability and local economies. Aside from the potential for species to be transported as unintentional stowaways, large seaports, airports and rail freight yards are unnatural habitats covering large areas and support a novel range of habitats that can provide a suitable environment for these stowaways to establish.</p> <p>Non-native species of mollusc such as zebra mussel (<i>Dreissena polymorpha</i>) in ships water ballast, mosquitoes (<i>Aedes</i> spp.) arriving in the pressurised cabins and holds of aircraft, or the seeds of specialist plant species being drawn along the rail network are all examples of uncontrolled passengers passively being transported by the global passage of people and freight. Species such as these can create serious environment harm from, in the case of zebra mussel, out-competing native bivalves and growing into massive colonies blocking pipes, outlets etc. Mosquitoes spread diseases with health costs for human contagions and serious economic impacts from damage to livestock.</p>

Pathway	Vector	Description
TRANSPORT - STOWAWAY	Hitchhikers in or on plane	<p>Where pressurized aircraft cabins and holds are not screened or treated it is possible for mammals and invertebrates to enter these areas prior to a flight, survive the journey and be released on arrival at the destination. Whilst this may not always happen in adequate numbers for the species to establish in the new location, however it has been shown that for some invasive species the main vector for transference has been an aircraft.</p> <p>The house mouse (<i>Mus musculus</i>) and yellow crazy ant (<i>Anoplolepis gracilipes</i>) have been spread from their natural range by becoming accidental stowaways on aircraft causing these species to establish globally. Although the house mouse was spread extensively by seafaring explorers and navies the advent of air travel assisted in spreading this species further into new regions. The yellow crazy ant has been spread across the world from its original source region (unknown due to the high level of spread) and through its ability to forage night and day and extremely competitive foraging techniques is causing severe environmental damage through displacing keystone species and by degrading leaf litter, reducing seedling recruitment and speeding up microbial decomposition processes.</p>
	Hitchhikers on ship/boat	<p>Shipping is a relatively simple method of transference. Ships docked at one location are subjected to a large transferral of freight and passengers all of which may directly bring aboard species that are capable of surviving a voyage and have the potential to survive at any destination along the shipping route. Ships are capable of transferring species within their ballast, through species establishing themselves on the hull, through freight contents, a population of rodents present on board, and through passengers introducing species on board in purchases in new locations, or through seeds, larvae, fungal spores etc. on their possessions.</p> <p>Halophile seagrass (<i>Halophila stipulacea</i>) has been introduced through fragments attached to the hulls of recreational and commercial fishing vessels from the Western Indian Ocean into the Mediterranean and Caribbean. It is considered to be a serious threat in terms of out-competing native seagrass species and is inducing changes in sublittoral communities. The house crow (<i>Corvus splendens</i>) and domestic cat (<i>Felis catus</i>) are two stowaway species that have been transported between regions by sea-going vessels who's introduction have had significant environmental and economic costs to the new host nation through predation of and by out-competing native species.</p>
	Machinery/equipment	<p>Commercial and agricultural machinery used at a number of sites across a landmass, or between countries, can spread soil and plant matter between different operating locations. Soil and plant materials carry a range of plant seed or propagules, fungal mycorrhiza, invertebrate eggs or larvae. Mammals, reptiles, amphibians and birds have been known to nest, rest, lay-up or roost in machinery and species have been moved unintentionally when the machinery is moved between operations or projects. Road vehicles and trains passing between regions can disperse seed and plant propagules.</p> <p>This mechanism is particularly pertinent for plant species, barbed goat grass (<i>Aegilops triuncialis</i>) is an aggressive grass species that out-competes native species and has been spread across wide areas by passing road traffic. Burgrass (<i>Cenchrus echinatus</i>) has barbed seed such that it can attach to vehicles and has been spread widely in temperate zones causing environmental damage to coastlines. The snail-eating flatworm (<i>Platydemus manokwari</i>) has been introduced from Papua New Guinea into many Pacific Islands, through translocation of equipment and machinery, where it is predated upon and causing the extinction of many of the regions land snails.</p>



	Vector	Description
TRANSPORT - STOWAWAY	Angling/fishing equipment	<p>Fishing equipment, particularly that which is immersed for any period of time, can develop colonies of invertebrate and plant life. Where this equipment is not cleaned between use at different locations then there is ample potential for the spread of species between watercourses, catchments and habitats. Crayfish pots, boats, buoys are all examples of equipment that are regularly submersed and will rapidly develop local flora and fauna associated with their interface with the aquatic environment. This is a pathway that has serious potential impacts globally and localized policy and control systems are starting to change behaviour, however the threats to aquatic ecosystems remain high.</p> <p><i>Caulerpa</i> (<i>Caulerpa taxifolia</i>) is a seaweed species that is spread by sections of weed getting caught in boat propellers and fishing nets – this species is highly competitive and creates monotypic stands of weed and alters sub-littoral communities. Similarly curly waterweed (<i>Lagarosiphon major</i>) and rigid hornwort (<i>Ceratophyllum demersum</i>) are two species that have been spread significant distances into new catchments and countries by fishing equipment. Brown bullhead (<i>Amours nebulous</i>) are capable of spending long periods of time outside of water and have been translocated between water bodies in the nets of fishermen.</p>
	People and their luggage/equipment	<p>A common pathway of species dispersal is through travel, particularly when people travel with food or carry items that have medicinal properties. These will be animal or plant by-products, organic material, seeds etc. All of these items are either themselves a potential invasive pest threat, or will themselves be carrying species that could similarly become a threat. Migration and travellers visiting new countries frequently transport viable, alien species and may, in countries where biosecurity is lacking, unintentionally introduce a novel species into an ecosystem.</p> <p>Argentine ants (<i>Linepithema humile</i>) arrived in New Zealand with air passengers from South America and are causing costly damage to forests. Yellow crazy ants (<i>Anoplolepis gracilipes</i>) have spread to many parts of the world causing serious environmental and financial harm. Mice (<i>Mus musculus</i>) are capable of arriving in new locations simply by having climbed into a case or pack of a person travelling to a new location, and crawling out on arrival.</p>
	Ship/boat ballast water	<p>The ballast water that is pumped into tanks to stabilise cargo ships is continually loaded and discharged to balance a continually changing freight manifest. Water can be taken on in large quantities in one harbour and then discharged in the next; this may be a few kilometres away, or in a new country several thousand kilometres away. When the water is taken on board and likewise when it is discharged there are few controls on what is taken on board in the water, in this way species are spread around the planet and this vector has been the cause of the spread of a large number of pest species. Ships ballast water has been the introduction pathway for many damaging and costly invasive species.</p> <p>The Mediterranean (<i>Mytilus galloprovincialis</i>) and zebra mussels (<i>Dreissena polymorpha</i>), Chinese mitten crabs (<i>Eriocheir sinensis</i>), soft-shelled clam (<i>Mya arenaria</i>) have been spread extensively around the planet between ports in this manner. These species have caused costly environmental damage and, in the case of the burrowing mitten crabs, structural damage around ports, estuaries and in watercourses.</p>
	Ship/boat hull fouling	<p>Ships also move sessile species that require a holdfast when these attach themselves to the ship and form a small colony on a ship's hull. This can develop during a voyage, or between periods of renewed anti-fouling, and are spread merely by their normal processes of reproduction being on a mobile substrate. Depending on the methods of anti-fouling, when a ship is taken into dry dock and has its hull cleaned species that are removed, if not carefully disposed of, can establish locally when the dock is re-flooded or in adjacent waterbodies and drains.</p> <p>This vector provides for the spread of many mollusc, fanworm, algae and aquatic plant species. Green cabomba (<i>Cabomba caroliniana</i>), a persistent and competitive waterweed, has been transported attached to the hulls and entangled in the propellers of ships and developed into invasive colonies with severe environmental and economic impacts. The European fanworm (<i>Sabella spallanzanii</i>) is a major threat to benthic assemblages due to its potential to alter nutrient cycling processes in soft sediments; it is also highly competitive and will impact on commercial shellfish operations.</p>

Pathway	Vector	Description
TRANSPORT - STOWAWAY	Vehicles (car, train, ...)	<p>Simple, local spread of species can occur involuntarily when species or reproductive organs of species become trapped in cars or trains or other vehicles and are released at the destination. Passengers in a train might eat a fruit or vegetable and throw the remains out of the window inadvertently causing the establishment of a species not naturally present at that location. Seeds and propagules are picked up in the turbulence caused by passing trains and spread locally. Rodents will be spread through passage in road and rail vehicles.</p> <p>Walnut (<i>Juglans regia</i>) has been spread around the south of Great Britain by passengers ejecting uneaten nuts out of the train window, plants from which naturalized populations are developing. Oxford ragwort (<i>Senecio squalidus</i>) was spread along the rail network of the UK from Oxford where it had established in the botanical garden by the seeds being drawn along the tracks introducing a new grazing pest species into the country, the ballast bed providing suitable initial establishment habitat. Black rat (<i>Rattus rattus</i>), house mouse (<i>Mus musculus</i>) have all been spread across land-masses by transportation carrying disease and damaging local economies.</p>
	Other means of transport	<p>Any form of transportation that interacts with habitats at either end of its journey or continuously passes through a range of habitats and ecosystems has the potential to passively collect and deposit propagules, seeds, animals, fungi etc. and to cause their spread. The simple action of having a body passing between two points creates a vector for transport. This does not necessarily have to be a plane or a ship, a person walking through a field, over a mountain pass and through a second field will transfer species from the first to the second location. Transportation of humans and goods remains a serious point source of novel species introductions around the globe.</p> <p>A good example of a species that utilises any human vector is the Singapore ant (<i>Monomorium destructor</i>), a serious pest species that is spread by human trade, passage of individuals and goods. This species will gnaw holes in rubber, fabric and polyethylene causing significant damage to property and infrastructure; serious economic as well as environmental costs arise from the establishment of this species.</p>
CORRIDOR	Interconnected waterways/basins /seas	<p>If a new species is introduced into a new catchment, canal or river system, or new marine environment, the natural geographical structure of the ecosystem might provide a web of suitable connected habitat so that this novel species is now capable of self-distributing throughout this network. Construction of a canal between two bodies of water will create a new corridor between two previously unconnected areas and dispersal along this route will naturally occur creating an unnatural distortion of the communities of flora and fauna at either end and perhaps spreading out from any associated habitat long the route of the corridor.</p> <p>Chinese mitten crab (<i>Eriocheir sinensis</i>) not only spreads itself along canals but due to its burrowing habit it also damages the structure of the canal. The act of construction of new connective structures also has the potential to spread species, Japanese knotweed (<i>Fallopia japonica</i>) will spread rhizomatously and is also spread by vegetative propagules; watercourses with continual traffic whose wake causes minor erosion will release viable tissue of this species and will increase the spread along the watercourse, similar spreading behaviour is observed in Himalayan balsam (<i>Impatiens glandulifera</i>). The mitten crab and the knotweed are economically damaging and both cause structural damage; Himalayan balsam can out-compete many wetland plant species as well as woodland understory and will create monotypic stands with severe environmental consequences.</p>
	Ignorant Possession	<p>People travelling the world collect items of interest, pack them in their bags and take them home as souvenirs. Many countries have limited restrictions on what it is permitted to enter the country with, most simply do not check or make travellers aware that to carry organic material might be problematic or illegal. Attractive plant seeds or seed pods, items of jewellery made from seeds, carvings and statues, and foodstuffs may all either be or be carrying potentially damaging species. Human curiosity and a general ignorance of taxonomy and ecology is a significant cause of the spread of pest species.</p> <p>Many species of snake (Serpentes) have been recorded on planes, either being carried as pets, or smuggled; cicadas (Cicadidae), planthoppers (Fulgoroidea), aphids (Aphidoidea), scale insects (Coccoidea) are commonly recorded on fruit and vegetables being carried by unsuspecting travellers. Argentine ants (<i>Linepithema humile</i>) have been transported across the Pacific by unwitting tourists to New Zealand where they have formed massive colonies and damaged forest ecosystems.</p>



Pathway	Vector	Description
<b>OTHER</b>	Smuggling	<p>The large illegal market in the trade of plant and animals, derivatives, or parts thereof, is a continual concern for regional biosecurity. When people engage in the illicit removal and cross-border transference of species there is a real risk of simultaneous transferal of a pest species. Smuggling, when successful, actively supports the transport of parasites, plant seeds, organic matter and novel species into areas that are not capable of managing them in the natural environment. Any active removal of organisms or viable materials will ensure the spread of species outside of their natural areas intentionally or not.</p> <p>Over a 10 year period between 1990 and 2000 at the international airport in Hawai'i, 137 snakes were confiscated by biosecurity and customs staff from black-market traffickers. Snakes pose a significant risk to the environment in Hawaii and could cause serious harm to the local economy.</p>

## Appendix 4. Species selected by contributing experts fulfilling the horizonscan criteria

A complete overview of all the species meeting the horizonscan criteria but not assessed for ecological risk is contained in this appendix.

### Amphibians

Latin name	Dutch name	Synonym	English name	Criteria			Additional information
				1	2	3	
<i>Alytes dickhilleni</i>	zuidelijke vroedmeesterpad		Southern Midwife Toad		x		
<i>Ambystoma mexicanum</i>	axolotl		axolotl			x	No reproduction
<i>Apalone ferox</i>	Florida weekschildpad		Florida Softshell Turtle		x		No reproduction
<i>Apalone spinifera</i>	-		Spiny Softshell Turtle		x		No reproduction
<i>Bombina bombina</i>	roodbuikvuurpad		Red-bellied toad			x	No reproduction
<i>Bufo viridis</i>	groene pad		Green toad			x	No reproduction
<i>Chelodina longicollis</i>	slangenhals schildpad		Common Snake-necked Turtle		x		No reproduction
<i>Chelydra serpentina</i>	bijschildpad		Common Snapping Turtle		x		No reproduction
<i>Chrysemys picta</i>	Amerikaanse Sierschildpad		Painted Turtle		x		No reproduction
<i>Discoglossus pictus</i>	schijftongkikker		Painted Frog		x		
<i>Emydoidea blandingii</i>	-		Blanding's Turtle		x		No reproduction
<i>Emys orbicularis</i>	Europese Moerasschildpad		European Pond Terrapin		x		No reproduction
<i>Graptemys geographica</i>	-		Common Map Turtle, Northern Map Turtle		x		No reproduction
<i>Graptemys kohnii</i>	Mississippi zaagrugschildpad		Mississippi Map Turtle		x		No reproduction
<i>Graptemys pseudogeographica</i>	zaagrugschildpad		False map turtle		x		No reproduction
<i>Lithobates catesbeianus</i>	Amerikaanse brulkikker	Stierkikker	North American Bullfrog		x	x	
<i>Pelodiscus sinensis</i>	-		Chinese Soft-shelled Turtle		x		No reproduction
<i>Pelophylax bergeri</i>	Italiaanse poelkikker		Italian pool frog			x	
<i>Pelophylax sp.</i>	Groene kikkers diverse soorten		Water frog			x	
<i>Pleurodeles waltl</i>	ribbensalamander		sharp-ribbed salamander		x		
<i>Pseudemys rubriventris</i>	roodbuikschildpad		American red-bellied turtle		x		No reproduction
<i>Rana dalmatina</i>	springkikker		agile frog			x	
<i>Sternotherus odonatus</i>			Musk turtle		x		No reproduction
<i>Trachemys scripta (T.s. elegans, T.s. troostii &amp; T.s. scripta)</i>	Roodwangschildpad		Red Eared Slider (Tse), Cumberland slider (Tst)		x		No reproduction
<i>Triturus carnifex</i>	Italiaanse kamsalamander		Italian Crested Newt			x	
<i>Triturus marmoratus</i>	marmersalamander		Marbled newt			x	
<i>Xenopus laevis</i>	klauwkikker		African Clawed Toad		x		

**Criterion 1:** The non-native species has, to date, not reached the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.

**Criterion 2:** The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.

**Criterion 3:** The non-native species occurs in a limited distribution in Dutch nature that make it amenable to eradication.

Birds\*

Latin name	Dutch name	Criteria			At least 1 brood since 1998-2000	Also vagrant or winter visitor	Negative ecological effect?				Additional information
		1	2	3			No	Unknown	Possible	Yes	
<i>Acridotheres tristis</i>	Treurmaina			X			X	X			No reproduction
<i>Agapornis fischeri</i>	Fischer's Agapornis			X			X				No reproduction
<i>Agapornis personatus</i>	Zwartmaskeragapornis			X			X				No reproduction
<i>Aix sponsa</i>	Carolinaeend			X	X		X				
<i>Alectoris rufa</i>	Rode Patrijs			X	X		X		?		
<i>Alisterus scapularis</i>	Australische Koningsparkiet			X	?						
<i>Alisterus scapularis</i>	Koningsparkiet			X	X						
<i>Amazona oratrix</i>	Geelvoorhoofd Amazone		X				X				No reproduction
<i>Anas americana</i>	Amerikaanse Smient			X	X		X	X			
<i>Anas bahamensis</i>	Bahamapijlstaart			X	X		X				
<i>Anas capensis</i>	Kaapse Taling			X	X		X				
<i>Anas poecilorhyncha</i>	Vlekbekeend			X				X			No reproduction
<i>Anas sibilatrix</i>	Chileense Smient			X	X			X			
<i>Anser caerulescens</i>	Sneeuwgans			X	X		X				
<i>Anser canagicus</i>	Keizergans			X	X		X				
<i>Anser erythropus</i>	Dwerggans			X	X	X		X			
<i>Anser rossi</i>	Ross' Gans			X	X			X			
<i>Ara macao</i>	Geelvleugelara			X	X		X		?		
<i>Branta ruficollis</i>	Roodhalsgans			X	X	X		X			
<i>Bucephala albeola</i>	Buffelkop			X	X			X			
<i>Buteo jamaicensis</i>	Roodstaartbuizerd			X				X			No reproduction
<i>Callipepla californica</i>	Californische Kuifkwartel			X				X			No reproduction
<i>Chloephaga picta</i>	Magelhaengans			X	X			X			
<i>Chrysolophus amherstiae</i>	Lady Amherstfazant			X	X						
<i>Chrysolophus pictus</i>	Goudfazant			X				X			No reproduction
<i>Colinus virginianus</i>	Bobwhite, Boomkwartel			X				X			No reproduction
<i>Corvus splendens</i>	Huiskraai			X	X					X	

Latin name	Dutch name	Criteria			At least 1 brood since 1998-2000	Also vagrant or winter visitor	Negative ecological effect?				Additional information
		1	2	3			No	Unknown	Possible	Yes	
<i>Cygnus melanocoryphus</i>	Zwarthalszwaan			X			X				No reproduction
<i>Dendrocygne bicolor</i>	Rosse Fluiteend			X	X		X				
<i>Eophona migratorius</i>	Chinese Appelvink			X	X	X					
<i>Euodice malabarensis</i>	Loodbekje			X			X				No reproduction
<i>Leiothrix lutea</i>	Japanse Nachtegaal			X	X	X	X				
<i>Lophodytes cucullatus</i>	Kokardezaagbek			X	?	X					
<i>Meleagris gallopavo</i>	Kalkoen			X	X	X					
<i>Myiopsitta monachus</i>	Monniksparkiet			X	X		X		?		
<i>Numida meleagris</i>	Helmparelhoen			X	X	X					
<i>Nymphicus hollandicus</i>	Valkparkiet			X	X	X	?				
<i>Oxyura jamaicensis</i>	Rosse Stekelstaart			X	X					X	
<i>Parabuteo unicinctus</i>	Woestijnbuizerd			X			X				No reproduction
<i>Paradoxornis webbianus</i>	Bruinkopdiksnavelmees			X	X	X					
<i>Pavo pavo</i>	Blauwe Pauw			X	X	?	X				
<i>Pelecanus crispus</i>	Kroeskoppelikaan	X					X				No reproduction
<i>Pelecanus rufescens</i>	Kleine Pelikaan			X			X				No reproduction
<i>Phoenicopterus chilensis</i>	Chileense flamingo			X			X				No reproduction
<i>Phoenicopterus minor</i>	Kleine Flamingo			X			X				No reproduction
<i>Phoenicopterus roseus</i>	Flamingo			X		X	X				No reproduction
<i>Poicephalus senegalus</i>	Senegalpapegaai			X	X	X	X				

Latin name	Dutch name	Criteria			At least 1 brood since 1998-2000	Also vagrant or winter visitor	Negative ecological effect?				Additional information
		1	2	3			No	Unknown	Possible	Yes	
<i>Psittacula eupatria</i>	Grote Alexanderparkiet			X	X		X	?			
<i>Pycnonotus aurigaster</i>	Roetkopbuulbuul			X	X	X	?				
<i>Pycnonotus aurigaster</i>	Wenkrouwbuulbuul			X	X						
<i>Pycnonotus cafer</i>	Rode Buulbuul			X	X						
<i>Rhea americana</i>	Nandoe			X	X		?				
<i>Syrnaticus reevesii</i>	Koningsfazant			X			X				No reproduction
<i>Threskiornis aethiopicus</i>	Heilige Ibis			X	X					X	

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\* bird species that have been breeding in the Netherlands, Belgium, France, Germany or Great Britain (see section 2.2.1).

## Fish

Latin name	Dutch name	Synonym	English name	Criteria			Additional information
				1	2	3	
<i>Acipenser baerii</i>	Siberische steur		Siberian sturgeon			x	
<i>Acipenser gueldenstaedtii</i>	Russische steur		Russian sturgeon			x	
<i>Acipenser ruthenus</i>	sterlet		sterlet			x	
<i>Ameiurus melas</i>	zwarte Amerikaanse dwergmeerval		black bullhead			x	
<i>Ameiurus nebulosus</i>	bruine Amerikaanse dwergmeerval		brown bullhead			x	
<i>Aristichthys nobilis</i>	grootkopkarper		bighead carp			x	
<i>Carassius auratus</i>	goudvis		goldfish			x	
<i>Channa</i> sp.	Slangenkopvis		Snakeheads		x		No reproduction
<i>Clarias batrachus</i>	Wandelende meerval		Walking catfish		x(?)		
<i>Clarias gariepinus</i>	Afrikaanse meerval		African catfish			x	
<i>Coregonus albula</i>	kleine marene		vendace	x			
<i>Coregonus maraena</i>	grote marene		powan			x	
<i>Cyprinus carpio</i> x <i>Carassius</i> sp.	kruiskarper		Crosscarp			x	
<i>Gambusia affinis</i>	musketervis		Topminnow , western mosquitofish		x		
<i>Gambusia holbrooki</i>	musketervis		Eastern mosquitofish		x		
<i>Hypophthalmichthys molitrix</i>	zilverkarper		silver carp			x	
<i>Ictalurus punctatus</i>			channel catfish			x	
<i>Lepomis cyanellus</i>	groene zonnebaars	grasbaars	green sunfish	x			
<i>Lepomis macrochirus</i>			Bluegill	x			
<i>Lepomis megalotis</i>			longear sunfish	x			
<i>Micropogonias undulatus</i>	Amerikaanse knorrepos		Atlantic croaker			x	
<i>Micropterus dolomieu</i>	Zwartbaars/ zwarte baars		Smallmouth bass	x			
<i>Micropterus salmoides</i>	forelbaars	grootbekforelbaars	largemouth bass	x		x	
<i>Misgurnus anguillicaudatus</i>	Aziatische modderkruiper	Chinese modderkruiper	oriental weather loach			x	
<i>Morone americana</i>	Amerikaanse zeebaars		White bass	x			
<i>Morone chrysops</i> x <i>M. saxatilis</i>			White bass x Striped bass (Whiper)		x		
<i>Mylopharyngodon piceus</i>			Black carp, black Chinese roach		x(?)		
<i>Neogobius gymnotrachelus</i>	naakthalsgrondel		racer goby	x			
<i>Percottus glenii</i>	Amoergrondel		Rotan, Amur sleeper	x			
<i>Pimephales promelas</i>	dikkopelrits	Amerikaanse dikkopelrits	fathead minnow			x	
<i>Poecilia reticulata</i>	gup		guppy			x	
<i>Pomoxis annularis</i>	witte zilverbaars		White crappie	x			
<i>Pomoxis nigromaculatus</i>	zwarte zilverbaars		Black crappie	x			
<i>Salvelinus alpinus</i> x <i>S. fontinalis</i>			Elzasser saibling			x	
<i>Salvelinus fontinalis</i>	bronforel		brook trout			x	
<i>Sebastes schlegelii</i>	Schlegels roodbaars	wrakbaars	Korean rockfish			x	

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## Macroinvertebrates

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Agrilus planipennis</i>		Emerald ash borer			x	
<i>Aleurotuba jelinekii</i>	Witte vlieg				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2011
<i>Ammothea hilgendorfi</i>	Zeespin				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2013
<i>Arthurdendyus triangulatus</i>		New Zealand flatworm	x			
<i>Asterias amurensis</i>		Japanese seastar, northern Pacific seastar	x			
<i>Bellamyia chinensis</i>	Chinese moeraslak	Chinese mystery snail			x	
<i>Bispira polyomma</i>	Kokerworm				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Branchiobdella kozarovi</i>					x(?)	Nieuwsbrief Rivierkreeften nr. 4
<i>Bucculatrix ainliella</i>	Amerikaanse ooglapmot				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2011
<i>Bursaphelenchus xylophilus</i>		Pinewood nematode	x			
<i>Callopietromyia annulipes</i>	Noord-Amerikaanse pauwvlieg				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2011
<i>Cercopagis pengoi</i>		Fish-hook waterflea	x			
<i>Chelicorophium robustum</i>	Stevige slijkgarnaal				x(?)	Macrofaunanieuwsbrief 108
<i>Chelicorophium sowinskyi</i>					x(?)	Macrofaunanieuwsbrief 100
<i>Coptotermes formosanus</i>		Formosan subterranean termite	x			
<i>Corytucha ciliata</i>	Platanennetwants				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2011
<i>Eusarsiella zostericola</i>	Mosselkreeftje				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Gelidium vagum</i>	Zeewier				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Gyraulus parvus</i>					x(?)	Macrofaunanieuwsbrief 97, Jansen, E.A. (2008). Gyraulus parvus(Say, 1817), een nieuwe soort voor de Nederlandse fauna. Spirula, 366: 7-8.
<i>Gyrodactylus salaris</i>		Salmon fluke	x			
<i>Homarus americanus</i>		American lobster	x			
<i>Laonome</i> sp.					x(?)	Macrofaunanieuwsbrief 108
<i>Neomysis americana</i>	Aasgarnaal				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Obesogammarus obesus</i>		Scud			x	
<i>Orconectes rusticus</i>		Rusty crayfish	x			
<i>Pachycordyle michaeli</i>	Brakwaterpoliep				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Paralithodes camtschaticus</i>		Red king crab	x			
<i>Perforatus perforatus</i>	Vulkaantje				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2013
<i>Pileolaria berkeleyana</i>	Spiraalkalkkokerworm				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Pontogammarus robustoides</i>		Ponto-Caspian shrimp, Scud	x			
<i>Prokelisia marginata</i>	Slijkgrascicade				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Rapana venosa</i>	Geaderde stekelhoorn	Rapa whelk			x	
<i>Sinanodonta woodiana</i>	Chinese moerasslak	Swan mussel	x			
<i>Synidotea laticauda</i>	Estuariene pissebed				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2012
<i>Tropidostepes pacificus</i>	Wants				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2011
<i>Uromunna</i> sp.	Zeepissebed				x(?)	Nieuwe exoten gemeld op exotenthemadag van de Werkgroep Ecologisch Waterbeheer/NecoV 2013
<i>Varichaetadrilus harmani</i>	Borstwormen			x		
<i>Vespa velutina</i>		Asian hornet	x			
<i>Watersipora subtorquata</i>		Encrusting bryozoan	x			

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## Mammals

Latin name	Dutch name	Synonym	English name	Criteria			Additional information
				1	2	3	
<i>Alces alces</i>	Eland				x		
<i>Alopex lagopus</i>	Poolvos		Arctic fox	x			
<i>Arctictis binturong</i>	Beerarter				x		
<i>Asyprocta leporina</i>	Goudhaas	Goudagoeti			x		
<i>Atelerix albiventris</i>	Witbuikegel	Viertelige egel			x		
<i>Bison bison</i>	Bizon	Amerikaanse bizon			x		
<i>Callosciurus erythraeus</i>	Pallas eekhoorn	Roodbuikeekhoorn				x	
<i>Callosciurus finlaysonii</i>	Thaise eekhoorn	Finlaysoneekhoorn					
<i>Callosciurus prevostii</i>	Prevosteekhoorn	Driekleureekhoorn				x	
<i>Canis lupus dingo</i>	Dingo	Verwilderde hond			x		
<i>Castor canadensis</i>	Canadese of Noord-Amerikaanse bever		Canadian beaver	x			
<i>Cervus nippon</i>	Sikahert		Sika Deer			x	
<i>Cynictis penicillata</i>	Vosmangoest	Rode meerkat			x		
<i>Cynomys leucurus</i>	Witstaartprairiehond				x		
<i>Cynomys ludovicianus</i>	Zwartstaartprairiehond					x	
<i>Cynomys ludovicianus</i>	Rocky-Mountainsprairiehond	Zwartstaart prairiehond			x		
<i>Cynomys mexicanus</i>	Mexicaanse prairiehond				x		
<i>Cynomys parvidens</i>	Utahprairiehond				x		
<i>Dolichotis patagonum</i>	Mara				x	x	
<i>Dolichotis salinicola</i>	Kleine mara				x		
<i>Dremomys pernyi</i>	Perny-grondeekhoorn					x	
<i>Eira barbara</i>	Tayra				x		
<i>Equus quagga</i>	Steppezebra	Gewone zebra			x		
<i>Erethizon dorsatum</i>	Amerikaans stekelvarken					x	
<i>Eutamias minimus</i>	Amerikaanse chipmunk						
<i>Felis bengalensis</i>	Luipaardkat		Leopard cat	x			
<i>Fennecus zerda</i>	Fennek	Woestijnvos				x	
<i>Genetta genetta</i>	Genetkat			x	x		
<i>Glaucomys volans</i>	Noord-Amerikaanse vliegende eekhoorn					x	
<i>Helogale parvula</i>	Dwergmangoeste					x	
<i>Hydrochoerus hydrochaeri</i>	Capybara	Waterzwijn				x	
<i>Hydrochoerus hydrochaeris</i>	Capibara, waterzwijn		Capybara			x	No reproduction
<i>Hydropotes inermis</i>	Chinese waterree		Chinese water deer	x			
<i>Hystrix indica</i>	Witstaartstekelvarken					x	
<i>Jaculus jaculus</i>	Woestijnspringmuis	Kleine woestijnspringmuis				x	
<i>Lariscus insignis</i>	Dertienstreep grondeekhoorn					x	
<i>Leptailurus serval</i>	Serval					x	
<i>Macropus giganteus</i>	Grijze reuzenkangoeroe					x	
<i>Macropus robustus</i>	Bergkangoeroe	Wallaroo, euro				x	
<i>Macropus rufogriseus</i>	Bennett- of roodnekwallaby		Red-necked Wallaby			x	
<i>Macropus rufus</i>	Rode reuzenkangoeroe					x	

Latin name	Dutch name	Synonym	English name	Criteria			Additional information
				1	2	3	
<i>Macropus</i> sp. indet.	Wallaby sp. indet.					x	
<i>Mephitis macroura</i>	Gekraagd stinkdier					x	
<i>Mephitis mephitis</i>	Gestreept stinkdier	Gestreepte skunk				x	
<i>Mungos mungo</i>	Zebamangoeste	Mungo				x	
<i>Muntiacus reevesi</i>	Muntjak		Chinese Muntjac			x	
<i>Mustela putorius x furo</i>	Fret		Feral Ferret			x	
<i>Nasua nasua</i>	Rode neusbeer	Coatimundi's				x	
<i>Nasua</i> sp. Indet	Neusbeer					x	
<i>Nyctereutes procyonoides</i>	Wasbeerhond					x	
<i>Octodon degus</i>	Degoe					x	
<i>Paradoxurus hermaphroditus</i>	Loewak	Palmroller, koffierat				x	
<i>Petaurus breviceps</i>	Suikereekhoorn					x	
<i>Phodopus sungorus</i>	Siberische hamster	Russische dwerghamster				x	
<i>Potos flavus</i>	Kinkajoe (rolstaartbeer)					x	
<i>Potos flavus</i>	Rolstaartbeer	Kinkajoe				x	
<i>Prionailurus bengalensis</i>	Luipaardkat	Bengaalse tijgerkat				x	
<i>Procyon cancrivorus</i>	Krabbenetende wasbeer					x	
<i>Procyon lotor</i>	Wasbeer					x	
<i>Rousettus aegyptiacus</i>	Nijlroezet	Nijlrousette				x	
<i>Sciurus anomalus</i>	Kaukasuseekhoorn						
<i>Sciurus carolinensis</i>	Grijze eekhoorn	Noordamerikaanse Grijze eekhoorn	Eastern Grey Squirrel			x	
<i>Sciurus granatensis</i>	Roodstaartboomeekhoorn	Roodstaarteekhoorn				x	x
<i>Sciurus igniventris</i>	Peruaanse witnekeekhoorn					x	
<i>Sciurus lis</i>	Japanse eekhoorn					x	
<i>Sciurus niger</i>	Amerikaanse voseekhoorn	Zwarte eekhoorn				x	
<i>Sciurus variegatoides dorsalis</i>	Veelkleurige eekhoorn	Grote gevlekte boomeekhoorn				x	
<i>Spermophilus tridecemlineatus</i>	Dertienstreep grondeekhoorn					x	
<i>Sylvilagus floridanu</i>	Florida-konijn	Oostelijke katoenstaart					
<i>Tamias sibericus</i>	Siberische grondeekhoorn	Koreaanse grondeekhoorn	Siberian chipmunk			x	
<i>Tamias striatus</i>	Amerikaanse grondeekhoorn					x	
<i>Tamiasciurus hudsonicus</i>	Amerikaanse rode eekhoorn	Amerikaanse boomeekhoorn				x	
<i>Tamiops swinhoei</i>	Chin. gestreepte boomeekhoorn	Chinese boomeekhoorn				x	
<i>Ursus americanus</i>	Zwarte beer	Baribal				x	
<i>Ursus arctos</i>	Bruine beer					x	
<i>Vulpes corsac</i>	Steppevos					x	
<i>Vulpes lagopus</i>	Poolvos					x	

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## Plants

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Acacia dealbata</i>	<i>Mimosa</i>	Silver wattle, Blue wattle	x			
<i>Acaena novae-zealandia</i>		Pirri-pirri-bur		x		
<i>Acer cappadocicum</i>		Cappadocian Maple			x	
<i>Acer rufinerve</i>			x			
<i>Achnatherum calamagrostis</i>					x	
<i>Adiantum diaphanum</i>	Smal venushaar				x	
<i>Adiantum pedatum</i>					x	
<i>Adiantum raddianum</i>	Fijn venushaar				x	
<i>Agrostis scabra</i>	Zilverstruisgras				x	
<i>Akebia quinata</i>	Schijnaugurk	Five-leaf		x		
<i>Alchemilla alpina</i>		Alpine Lady's mantle			x	
<i>Allium christophii</i>					x	
<i>Allium moly</i>		Yellow Garlic			x	
<i>Allium pendulinum</i>		Italian Garlic			x	
<i>Allium roseum</i>	Roze look				x	
<i>Allium rotundum</i>	Ronde look				x	
<i>Allium sphaerocephalon</i>	Kogellook				x	
<i>Amorpha fruticosa</i>					x	
<i>Aponogeton distachyos</i>	Kaapse waterlelie	Cape-pondweed			x	
<i>Arabis collina</i>	Muurscheefkelk				x	
<i>Araujia sericifera</i>			x			
<i>Argyranthemum frutescens</i>		Paris Daisy			x	
<i>Artemisia selengensis</i>					x	
<i>Arundo donax</i>	Pijlriet	Giant reed		x		
<i>Asarina procumbens</i>	Kruipende leeuwenbek				x	
<i>Asperula taurina</i>		Pink Woodruff			x	
<i>Astilbe chinensis</i>		Tall False-buck's-beard			x	
<i>Baccharis halimifolia</i>	Struikaster				x	
<i>Beckmannia syzigachne</i>	American Slough-grass				x	
<i>Berberis aggregata</i>	Roze berberis				x	
<i>Bergenia crassifolia</i>		Elephant-ears			x	
<i>Bidens pilosa</i>		Black-jack			x	
<i>Bidens triplinervia</i>					x	
<i>Bromus lanceolatus</i>		Large-headed Brome			x	
<i>Broussonetia papyrifera</i>	Papiermoerbei				x	
<i>Buphthalmum salicifolium</i>	Wilgkoeienoog				x	
<i>Callicarpa bodinieri</i>					x	
<i>Callistephus chinensis</i>	China Aster				x	
<i>Campanula medium</i>	Mariëtteklokje				x	
<i>Campanula pyramidalis</i>	Piramideklokje				x	
<i>Capsicum annum</i>	Spaanse peper				x	
<i>Carduus personata</i>					x	
<i>Carex scoparia</i>					x	
<i>Carpobrotus edulis</i>	Hottentotvijg				x	

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Drosera filiformis</i>					x	
<i>Dryopteris cycadina</i>					x	
<i>Dryopteris erythrosora</i>					x	
<i>Dryopteris wallichiana</i>					x	
<i>Echinocystis lobata</i>	Egelkomkommer, Stekelaugurk	Wild cucumber, Wild balsam apple	x			
<i>Ehrharta erecta</i>	Rimpelgras				x	
<i>Eichhornia crassipes</i>	Waterhyacint	Water hyacinth			x	
<i>Elaeagnus pungens</i>	Stekelige olijfwilg				x	
<i>Eleutherococcus sieboldianus</i>					x	
<i>Elodea callitrichoides</i>	Sterrenkrooswaterpest	South American waterweed		x		
<i>Erica herbacea</i>	Sneeuwhei				x	
<i>Erica vagans</i>		Cornish Heath			x	
<i>Euonymus japonicus</i>		Evergreen Spindle			x	
<i>Eupatorium maculatum</i>					x	
<i>Eupatorium rugosum</i>					x	
<i>Euphorbia humifusa</i>	Liggende wolfsmelk				x	
<i>Euphorbia myrsinites</i>		Broad-leaved Glaucous-spurge			x	
<i>Euphorbia oblongata</i>		Balkan Spurge			x	
<i>Euphorbia prostrata</i>	Geribde wolfsmelk				x	
<i>Fallopia compacta</i>					x	
<i>Fraxinus americana</i>	Amerikaanse es				x	
<i>Fumaria parviflora</i>	Kleine duivenkervel				x	
<i>Fumaria vaillantii</i>	Roze duivenkervel				x	
<i>Gaultheria mucronata</i>	Parelbes, veenmyrte, bergthee	Prickly heath		x		
<i>Gaultheria procumbens</i>		Eastern Teaberry			x	
<i>Gleditsia triacanthos</i>	Valse christusdoorn				x	
<i>Gnaphalium undulatum</i>		Cape Cudweed			x	
<i>Gunnera tinctoria</i>	Gunnera, Reuzenrabarber	Giant-rhubarb, Chilean rhubarb, Chilean gunnera		x		
<i>Gypsophila perfoliata</i>					x	
<i>Helichrysum petiolare</i>		Silver-bush Everlastingflower			x	
<i>Helleborus cyclophyllus</i>					x	
<i>Heracleum persicum</i>			x			
<i>Heracleum sosnowskyi</i>		Sosnowski's hogweed	x			
<i>Hippocrepis emerus</i>	Struikpaardenhoeftklaver				x	
<i>Hydrangea macrophylla</i>					x	
<i>Hydrocotyle sibthorpioides</i>					x	
<i>Hyoscyamus albus</i>		White Henbane			x	
<i>Hypericum olympicum</i>					x	
<i>Impatiens cristata</i>	Ruig springzaad				x	
<i>Impatiens walleriana</i>					x	
<i>Ipomoea hederacea</i>	Klimopwinde				x	
<i>Juglans nigra</i>	Zwarte walnoot				x	
<i>Kalmia angustifolia</i>	Smalle lepelboom				x	
<i>Koeleria glauca</i>					x	

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Lactuca tatarica</i>	Strandsla				x	
<i>Lamarckia aurea</i>	Pluimstaartje				x	
<i>Ligularia stenocephala</i>					x	
<i>Limonium binervosum</i> subsp. <i>binervosum</i>					x	
<i>Linaria bipartita</i>					x	
<i>Linaria dalmatica</i>		Balkan Toadflax			x	
<i>Lindernia dubia</i>	Schijngenedekruid				x	
<i>Lonicera japonica</i>	Japanse kamperfoelie	Japanese honeysuckle	x			
<i>Loranthus europaeus</i>					x	
<i>Ludwigia peploides</i>	Kleine waterteunisbloem	Floating water-primrose			x	
<i>Lycium chinense</i>	Chinese boksdooen				x	
<i>Lysichiton americanus</i>	Moeraslantaarn	American skunk cabbage		x		
<i>Lysimachia ciliata</i>		Fringed Loosestrife			x	
<i>Lysimachia clethroides</i>					x	
<i>Lythrum junceum</i>	Kruipkattenstaart				x	
<i>Mahonia japonica</i>					x	
<i>Malope trifida</i>	Drielobbige malope				x	
<i>Mentha requienii</i>		Corsican Mint			x	
<i>Mimulus ringens</i>					x	
<i>Miscanthus sacchariflorus</i>					x	
<i>Moluccella laevis</i>		Bells-of-Ireland			x	
<i>Monarda didyma</i>					x	
<i>Muhlenbergia mexicana</i>					x	
<i>Nemesia melissaefolia</i>	Kransnemesia				x	
<i>Nemesia versicolor</i>					x	
<i>Nemophila maculata</i>					x	
<i>Nemophila menziesii</i>	Bosliefje				x	
<i>Nicotiana langsdorfii</i>					x	
<i>Nonea lutea</i>	Geel monnikskruid				x	
<i>Oenothera lindheimeri</i>					x	
<i>Oenothera stricta</i>		Fragrant Evening-primrose			x	
<i>Oryzopsis miliacea</i>					x	
<i>Ostrya carpinifolia</i>					x	
<i>Oxalis articulata</i>		Pink-sorrel			x	
<i>Oxalis debilis</i>	Stippelklaverzuring				x	
<i>Oxalis purpurea</i>					x	
<i>Oxalis tetraphylla</i>	Klavertje vier				x	
<i>Panicum barbipulvinatum</i>					x	
<i>Panicum hillmanii</i>					x	
<i>Panicum virgatum</i>		Switchgrass			x	
<i>Paspalum dilatatum</i>		Dallis-grass			x	
<i>Paspalum distichum</i>		Knotgrass, water finger-grass	x			
<i>Pennisetum flaccidum</i>					x	

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Persicaria pensylvanica</i>	Amerikaans perzikkruid				x	
<i>Persicaria perfoliata</i>			x			
<i>Persicaria virginiana</i>					x	
<i>Petasites pyrenaicus</i>	Winterheliotroop				x	
<i>Phlomis russeliana</i>		Turkish Sage			x	
<i>Phlox paniculata</i>	Phlox				x	
<i>Phlox subulata</i>		Moss Phlox			x	
<i>Phoenix dactylifera</i>	Dadel				x	
<i>Physalis ixocarpa</i>		Tomatillo			x	
<i>Physalis philadelphica</i>		Large-flowered Tomatillo			x	
<i>Piptatherum miliaceum</i>		Smilo-grass			x	
<i>Plantago afra</i>		Glandular Plantain			x	
<i>Polygonum affine</i>					x	
<i>Polygonum rurivagum</i>	Cornfield Knotgrass				x	
<i>Polystichum tsus-simense</i>					x	
<i>Prunus incisa</i>	Fujikers				x	
<i>Pteris cretica</i>	Lintvaren				x	
<i>Pueraria labata</i>	Kudzu	Japanese arrowroot	x			
<i>Pulmonaria obscura</i>	Ongevelekt longkruid				x	
<i>Pulmonaria rubra</i>		Red Lungwort			x	
<i>Reseda odorata</i>		Garden mignonette			x	
<i>Reseda phyteuma</i>	Kleine reseda				x	
<i>Rhus radicans</i>	Gifsumak				x	
<i>Rubus ellipticus</i>		Asian wild raspberry, cheeseberry, yellow Himalayan raspberry, yellow raspberry	x			
<i>Salix elaeagnos</i>	Grijze wilg				x	
<i>Salvia glutinosa</i>	Kleverige Salie				x	
<i>Salvia sclarea</i>	Scharlei				x	
<i>Sarracenia purpurea</i>		Purple Pitcherplant			x	
<i>Sasa palmata</i>		Broad-leaved Bamboo		x		
<i>Sauromatum venosum</i>					x	
<i>Scabiosa ochroleuca</i>					x	
<i>Schoenoplectus mucronatus</i>	Ribbelbies				x	
<i>Scopolia carniolica</i>	Scopolia				x	
<i>Sedum sieboldii</i>					x	
<i>Selaginella kraussiana</i>		Krauss's Clubmoss			x	
<i>Sempervivum arachnoideum</i>	Spinnenwebhuislook				x	
<i>Setaria parviflora</i>	Slanke naalbaar				x	
<i>Silene schafta</i>	Lijmkruid				x	
<i>Silphium perfoliatum</i>	Zonnekroon				x	
<i>Sisymbrium strictissimum</i>		Perennial Rocket			x	
<i>Sisyrinchium bermudiana</i>	Ruslelie				x	
<i>Sisyrinchium montanum</i>	Sisyrinchium				x	
<i>Sisyrinchium striatum</i>					x	

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Smilacina stellata</i>	Troslelietje				x	
<i>Smilax aspera</i>	Common Smilax	Common Smilax			x	
<i>Solanum aethiopicum</i>	Afrikaanse eierplant				x	
<i>Solanum carolinense</i>		Horse-nettle			x	
<i>Solanum laciniatum</i>	Kangarooe-appel				x	
<i>Solanum pseudocapsicum</i>	Oranje appelboompje				x	
<i>Solanum scabrum</i>		Garden Huckleberry			x	
<i>Solanum sisymbriifolium</i>		Red Buffalo-bur			x	
<i>Solanum villosum</i>	Donsnachtschade				x	
<i>Solidago nemoralis</i>	Grauwe guldenroede	Gray goldenrod	x			
<i>Sorghum x almum</i>			x			
<i>Spiraea alba</i>	Witte spirea	Pale bridewort, Meadowsweet		x		
<i>Spiranthes cernua</i>					x	
<i>Stylophorum lasiocarpum</i>					x	
<i>Tanacetum macrophyllum</i>		Rayed Tansy			x	
<i>Thalia dealbata</i>					x	
<i>Thunbergia alata</i>					x	
<i>Tradescantia fluminensis</i>	Vaderplant				x	
<i>Tribulus terrestris</i>	Maltezer kruis				x	
<i>Trifolium rubens</i>	Purperen klaver				x	
<i>Typha laxmannii</i>					x	
<i>Umbilicus rupestris</i>	Muurnavel				x	
<i>Verbascum virgatum</i>	Beklierd mottenkruid				x	
<i>Verbena rigida</i>		Slender Vervain			x	
<i>Zinnia peruviana</i>					x	

**Criterion 1:** The non-native species has, to date, not reached the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.

**Criterion 2:** The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.

**Criterion 3:** The non-native species occurs in a limited distribution in Dutch nature that make it amenable to eradication.

## Reptiles

Latin name	Dutch name	English name	Criteria			Additional information
			1	2	3	
<i>Elaphe shrenckii</i>	Russische rattenslang	Amur Ratsnake, Siberian Ratsnake			x	
<i>Elaphe</i> spp.	Aziatische rattenslangen	Asian ratsnakes		x		
<i>Heterodon nasicus</i>	westelijke haakneusslang	Western Hognose Snake		x		
<i>Lacerta viridis</i>	westelijke smaragdhagedis	green lizard		x		
<i>Lampropeltis triangulum</i>	melkslang	Scarlet kingsnake, milksnake		x		
<i>Natrix maura</i>	adderringslang	Viperine water snake		x		
<i>Natrix natrix persa</i> (subspecies-level)	Oostelijke ringslang	(European) Grass snake		x		
<i>Natrix tessellata</i>	dobbelsteenslang	Dice snake		x		
<i>Nerodia</i> spp.	Noord-Amerikaanse waterslangen	Northern/southern Water Snake		x		
<i>Pantherophis</i> spp. ( <i>P. guttatus</i> & <i>P. obsoletus</i> )	Noord-Amerikaanse rattenslangen	Rat snakes		x		
<i>Pituophis catenifer</i>	stierslang	Gopher snake		x		
<i>Podarcis siculus</i>	Ruine-hagedis	Italian Wall Lizard			x	?No reproduction
<i>Thamnophis</i> spp.	kousebandslangen	Garter Snake		x		
<i>Trachemys scripta elegans</i>	Roodwangschildpad	Red-eared terrapin		x		
<i>Vipera aspis</i>	aspisadder	Asp viper		x		
<i>Zamenis longissimus</i>	esculaapslang	Aesculapian Snake		x		

**Criterion 1:** The non-native species has, to date, not reached the Netherlands, but can probably access the Netherlands as a result of human mediated pathways and vectors.

**Criterion 2:** The non-native species has, to date, not been recorded in Dutch nature but is kept by private owners, zoos and children farms etc.

**Criterion 3:** The non-native species occurs in a limited distribution in Dutch nature that make it amenable to eradication.



## Appendix 5. List of potentially invasive species in the Netherlands

Scientific name	Informal grouping	Common name(s) English	Common names(s) Dutch	Occurrence in the Netherlands
<i>Acacia dealbata</i>	plants	Silver wattle, Blue wattle	Mimosa L.	Absent
<i>Acaena novae-zealandia</i>	plants	Pirri-pirri-bur		Present only in private / public collections
<i>Acipenser baerii</i>	fish	Siberian sturgeon	Siberische steur	Limited number of individuals
<i>Agrilus planipennis</i>	insects	Emerald ash borer		Limited populations
<i>Akebia quinata</i>	plants	Five-leaf	Schijnaugurk	Present only in private / public collections
<i>Alopex lagopus</i>	mammals	Arctic fox	Poolvos	Absent
<i>Ameiurus melas</i>	fish	Black bullhead	Zwarte dwergmeerval	Limited populations
<i>Amorpha fruticosa</i>	plants	False indigo	Indigostruik	Present only in private / public collections
<i>Aponogeton distachyos</i>	plants	Cape-pondweed	Kaapse waterlelie	Limited populations
<i>Arthurdendyus triangulatus</i>	worm	New Zealand flatworm		Absent
<i>Arundo donax</i>	plants	Giant reed	Pijlriet	Present only in private / public collections
<i>Asterias amurensis</i>	sea star	Japanese seastar, northern Pacific seastar		Absent
<i>Baccharis halimifolia</i>	plants	Salt bush, Eastern baccharis	Struikaster	Limited populations
<i>Bellamya chinensis</i>	molluscs	Chinese mystery snail	Chinese moerasslak	Limited populations
<i>Bursaphelenchus xylophilus</i>	worm	Pinewood nematode		Absent
<i>Callosciurus erythraeus</i>	mammals	Pallas's squirrel, Red-bellied tree squirrel	Pallas' eekhoorn	Limited populations
<i>Callosciurus finlaysonii</i>	mammals	Finlayson's squirrel	Thaise eekhoorn	Absent
<i>Carpobrotus edulis</i>	plants	Hottentot fig	Hottentotvijg	Limited populations
<i>Castor canadensis</i>	mammals	Canadian beaver	Canadese of Noord-Amerikaanse bever	Absent
<i>Cercopagis pengoi</i>	crustacean	Fish-hook waterflea		Absent
<i>Cervus nippon</i>	mammals	Sika deer	Sikahert	Limited number of individuals
<i>Coptotermes formosanus</i>	insects	Formosan subterranean termite		Absent
<i>Cortaderia selloana</i>	plants	Pampas grass	Pampasgras	Present only in private / public collections
<i>Corvus splendens</i>	birds	Indian house crow	Huiskraai	Limited populations
<i>Cotoneaster horizontalis</i>	plants	Wall cotoneaster, Rockspray	Vlakke dwergmispel	Limited populations
<i>Cotoneaster dammeri</i>	plants	Bearberry Cotoneaster		Present only in private / public collections
<i>Craspedacusta sowerbyi</i>	hydroid	Freshwater jellyfish		Limited populations*
<i>Crococsmia x crocosmiiflora</i>	plants	Montbretia	Crococsmia, Montbretia	Limited populations
<i>Cynomys ludovicianus</i>	mammals	Black-tailed prairie dog	Zwartstaartprairiehoond	Limited number of individuals
<i>Cyprinus carpio x Carassius</i> sp.	fish	Crosscarp	kruiskarper	Limited populations

\*Refers to the jellyfish lifestage. Hydroids are difficult to monitor therefore there is currently no clear evidence relating to their distribution in the Netherlands.

Scientific name	Informal grouping	Common name(s) English	Common names(s) Dutch	Occurrence in the Netherlands
<i>Cytisus striatus</i>	plants	Hairy-fruited Broom, Portuguese broom		Absent
<i>Echinocystis lobata</i>	plants	Wild cucumber, Wild balsam apple	Egelkomkommer, Stekelaugurk	Absent
<i>Eichhornia crassipes</i>	plants	Water hyacinth	Waterhyacint	Limited populations
<i>Elaphe shrenckii</i>	reptile	Amur Ratsnake, Siberian Ratsnake	Russische rattenslang	Limited populations
<i>Elaphe</i> spp.	reptile	Asian ratsnakes	Aziatische rattenslangen	Present only in private / public collections
<i>Elodea callitrichoides</i>	plants	South American waterweed	Sterrenkrooswaterpest	Present only in private / public collections
<i>Felis bengalensis</i>	mammals	Leopard cat	Luipaardkat	Absent
<i>Gaultheria mucronata</i>	plants	Prickly heath	Parelbes, veenmyrte, bergthee	Present only in private / public collections
<i>Gunnera tinctoria</i>	plants	Giant-rhubarb, Chilean rhubarb, Chilean gunnera	Gunnera, Reuzenrabarber	Present only in private / public collections
<i>Gyrodactylus salaris</i>	worm	Salmon fluke		Absent
<i>Heracleum sosnowskyi</i>	plants	Sosnowski's hogweed		Absent
<i>Heracleum persicum</i>	plants	Golpar, Persian Hogweed		Absent
<i>Homarus americanus</i>	crustacean	American lobster		Absent
<i>Hydrochoerus hydrochaeris</i>	mammals	Capybara	Capibara, waterzwijn	Limited number of individuals
<i>Hydropotes inermis</i>	mammals	Chinese water deer	Chinese waterree	Absent
<i>Lepomis cyanellus</i>	fish	Green sunfish	groene zonnebaars	Absent
<i>Lepomis macrochirus</i>	fish	Bluegill		Absent
<i>Lithobates catesbeianus</i>	amphibian	American bullfrog	Brulkikker	Limited populations
<i>Lonicera japonica</i>	plants	Japanese honeysuckle	Japanse kamperfoelie	Present only in private / public collections
<i>Ludwigia peploides</i>	plants	Floating water-primrose	Kleine waterteunisbloem	Limited populations
<i>Lysichiton americanus</i>	plants	American skunk cabbage	Moeraslantaarn	Present only in private / public collections
<i>Mephitis mephitis</i>	mammals	Striped skunk	Gestreept stinkdier	Limited number of individuals
<i>Micropterus dolomieu</i>	fish	Smallmouth bass	Zwartbaars/ zwarte baars	Absent
<i>Micropterus salmoides</i>	fish	Largemouth black bass	Grootbekforelbaars	Absent
<i>Morone americana</i>	fish	White bass	Amerikaanse zeebaars	Absent
<i>Muntiacus reevesi</i>	mammals	Chinese Muntjac	Muntjak	Limited populations
<i>Neogobius gymnotrachelus</i>	fish	Racer goby	Naakthalsgrondel	Absent
<i>Obesogammarus obesus</i>	crustacean	Scud		Limited populations
<i>Orconectes rusticus</i>	crustacean	Rusty crayfish		Absent
<i>Oxyura jamaicensis</i>	birds	Ruddy duck	Rosse stekelstaart	Limited populations
<i>Paralithodes camtschaticus</i>	crustacean	Red king crab		Absent
<i>Paspalum distichum</i>	plants	Knotgrass, water finger-grass		Absent
<i>Percottus glenii</i>	fish	Rotan, Amur sleeper	Amoergrondel	Absent
<i>Persicaria perfoliata</i>	plants	Mile a minute weed, asiatic tearthumb		Absent
<i>Pileolaria berkeleyana</i>	worm	Polychaete tubeworm		
<i>Pimephales promelas</i>	fish	Fathead minnow	Dikkopelrits	Limited populations

Scientific name	Informal grouping	Common name(s) English	Common names(s) Dutch	Occurrence in the Netherlands
<i>Pomoxis annularis</i>	fish	White crappie	witte zilverbaars	Absent
<i>Pomoxis nigromaculatus</i>	fish	Black crappie	zwarte zilverbaars	Absent
<i>Pontogammarus robustoides</i>	crustacean	Ponto-Caspian shrimp, Scud		Absent
<i>Procyon lotor</i>	mammals	Raccoon	Wasbeer	Limited number of individuals
<i>Pueraria labata</i>	plants	Japanese arrowroot	Kudzu	Absent
<i>Rapana venosa</i>	molluscs	Rapa whelk	Geaderde stekelhoorn	Limited populations
<i>Rubus ellipticus</i>	plants	Asian wild raspberry, cheeseberry, yellow Himalayan raspberry, yellow raspberry		Present only in private / public collections
<i>Sarracenia purpurea</i>	plants	Pitcherplant		Limited populations
<i>Sasa palmata</i>	plants	Broad-leaved Bamboo		Present only in private / public collections
<i>Sciurus carolinensis</i>	mammals	Grey squirrel	Grijze eekhoorn	Limited number of individuals
<i>Sciurus lis</i>	mammals	Japanese squirrel	Japane eekhoorn	Limited number of individuals
<i>Sciurus niger</i>	mammals	Fox squirrel	Amerikaanse voseekhoorn	Limited number of individuals
<i>Sinanodonta woodiana</i>	molluscs	Swan mussel	Chinese moerasslak	Limited populations
<i>Solidago nemoralis</i>	plants	Gray goldenrod	Grauwe guldenroede	Absent
<i>Spiraea alba</i>	plants	Pale bridewort, Meadowsweet	Witte spirea	Present only in private / public collections
<i>Tamias sibiricus</i>	mammals	Siberian chipmunk	Siberische grondeekhoorn	Limited populations
<i>Tamiasciurus hudsonicus</i>	mammals	American red squirrel	Amerikaanse rode eekhoorn	Limited number of individuals
<i>Threskiornis aethiopicus</i>	birds	Sacred ibis	Heilige ibis	Limited populations
<i>Trachemys scripta elegans</i>	reptile	Red-eared terrapin	Roodwangschildpad	Present in private / public collections. A number of individuals are also present in nature.
<i>Triturus carnifex</i>	amphibian	Italian crested newt	Italiaanse kamsalamander	Limited populations
<i>Triturus marmoratus</i>	amphibian	Marbled newt	marmersalamander	Limited populations
<i>Vespa velutina</i>	insects	Asian hornet		Absent
<i>Watersipora subtorquata</i>	bryozoan	Encrusting bryozoan		Absent
<i>Xenopus laevis</i>	amphibian	African clawed toad		Present only in private / public collections

## Appendix 6. Eradication through monitoring and early intervention

Measures aimed at eradicating invasive species are rarely successful, except in isolated areas or before alien species have spread too widely (Simberloff, 2003; Carrete & Tella, 2008; Pluess et al., 2012). When invasive species start to spread more rapidly, like the grey squirrel in the Italian Piemonte, the damage becomes visible, but the possibility of eradicating the species decreases (Bertoloni & Genovesi, 2005). The muskrat (*Ondatra zibethicus*) has been managed in the Netherlands since the early 1960s. Since then almost 10,000 muskrats have been destroyed and the species still persists today. To undertake this task, a nationwide organisation was set up currently involving at least 100 paid employees and incurring high management costs (H. Hollander, pers. comm.). To minimise costs, early intervention is therefore vital and monitoring of the initial stage of invasion may allow the detection of non-native species before they can affect community structure and ecosystem function (Puth & Post, 2005). Preventative monitoring may be combined with other forms of monitoring such as water quality assessments and evaluation of water management to increase productivity and cost efficiency. When organisms are identified early in the invasion process, many species, including insects, plants, and aquatic invaders of various taxa, can be eradicated, and a variety of management techniques have maintained others at low densities for long periods (Simberloff, 2009). The eradication of trees, pathogens, bacteria and viruses is likely to be most successful followed by non-native plants and invertebrates (Pluess et al., 2012). Fungi are the least likely organisms to be removed successfully. A number of requirements for the successful eradication of non-native species are suggested (Myers et al., 2000; Simberloff, 2002, 2009; Mack & Foster, 2004):

- Early detection and rapid intervention.
- The allocation of enough resources at the beginning and end of the project, including post-eradication assessment and further intervention if required.
- Existence of a person or agency with the authority to enforce action. Eradication will not succeed if a small minority allow the non-native species to persist.
- There should be enough knowledge of the species to allow the targeting of vulnerabilities. Knowledge of the species basic natural history will often be enough.
- Project leaders must be energetic, optimistic, and persistent even if occasional setbacks occur.

International cooperation, the implementation of sanitary measures and the paying of special attention to species introduced by the cultivation pathway have all been implicated in the successful eradication of non-native species (Pluess et al., 2012).

Primary hotspots listed in the horizonscan database may be used to identify locations where surveillance can be implemented for the early detection of non-native species and timely intervention. Additional activities that are recommended to prioritise locations for monitoring and facilitate early eradication are (Adapted from US Department of the Interior, 2008):

- Develop Coordinated Response Plan(s) - This plan would detail policies, command and authority structure, strategies, communications, roles and responsibilities, and response actions to be implemented.
- Perform Infestation Risk Assessment(s) – The purpose is to identify which locations are most at-risk of infestation within a geographic region of interest or management jurisdiction (hotspots). Analysis would be based on the physiological tolerances of the potentially invasive species in question and the conditions found at the specific location (e.g. water or soil chemistry and the presence of species specific vectors and pathways).
- Perform Facility Vulnerability Assessment(s) – This activity may be completed individually or following the infestation risk assessment(s) and consists of a detailed inventory of ecosystem services at the high risk location and how each component is likely to be affected by the non-native species should infestation occur. The results can be used to prioritize facility protection needs and actions.

It was difficult to determine specific hotspots for a number of potentially invasive species for the Netherlands. For example, ornamental plant may appear close to any garden or park where they have been planted. However, there are certain geographically specific hotspots such as the ports of Amsterdam and Rotterdam where regular monitoring and early intervention may be a cost effective measure.