

National Biodiversity Data Centre



Documenting Ireland's Wildlife

Ireland's invasive and non-native species



Trends in introductions



GLOBAL
BIODIVERSITY
INFORMATION
FACILITY

Citation:

O'Flynn, C., Kelly, J. and Lysaght, L. (2014). Ireland's invasive and non-native species – trends in introductions. *National Biodiversity Data Centre Series No. 2*. Ireland

National Biodiversity Data Centre. Series Editor: Dr Liam Lysaght

© National Biodiversity Data Centre 2014

ISSN 2009-6844 (Print) ISSN 2009-6852 (Online)

Acknowledgements:

The author would like to acknowledge in particular,

Invasive Species Ireland and its funding bodies, Northern Ireland Environment Agency and the National Parks and Wildlife Service for provision of the risk assessment data. Funders of the National Invasive Species Database contract; The Heritage Council and the Environmental Protection Agency.

More information can be found at <http://invasives.biodiversityireland.ie>



The National Biodiversity Data Centre is an initiative of the Heritage Council and is funded by the Heritage Council and the National Parks and Wildlife Service of the Department of Arts, Heritage and the Gaeltacht

Globally, invasive species are considered to be one of the major threats to native biodiversity

Summary

Invasive non-native species are a threat to our biodiversity, ecosystem functions and have a cost to our economy. With increased globalization there is an increase in the movement of non-native species around the world and the increasing and accelerating trend of new introductions of non-native species into Europe across all taxonomic groups and environments which corresponds to a global pattern. This indicates that in the foreseeable future the numbers of non-native species as well as their impact will increase.

This report provides, for the first time in Ireland, an overview of the apparent trends in the introduction of invasive alien species. Data on 377 recorded non-native species and 342 non-native potential invaders for the trends analysis are taken from the 2012 Invasive Species in Ireland risk assessment and National Invasive Species Database. Limitations to the analysis are highlighted and recommendations made for future work to fill key knowledge gaps.

Recorded non-native species in Ireland

Of the 377 recorded non-native species in Ireland that were risk assessed, the majority (66%) are at risk of low impact, 21% ranked with a risk of medium impact and 13% ranked as having a risk of high impact. The percentage of high impact species in Ireland is similar to other European countries that have undertaken risk assessments. The trend in introductions has increased dramatically since the beginning of the 20th Century and has accelerated further in the last decade.

This increase in introductions is apparent across all environments; 67% of all high and medium impact species occur in the terrestrial environment, 21% occur in freshwater environments and 12% in marine. The rate of increase is greatest for the freshwater environment since 1980, and it the only environment group where there is a larger number of high impact species than medium

impact species. This indicates that freshwater non-native species are more likely to have a high impact where they are introduced.

Half of the high and medium impact species are plants, a quarter are vertebrates and another quarter invertebrates. Significantly, there has been an unprecedented number of invasive invertebrates recorded since 1990 and vertebrates since 2000.

Most of the species are native to North America and Asia, but the source region for many of these is closer to Ireland, from already colonised areas. Pathway analysis is needed to identify source regions and whether species are being introduced through intentional trade or unintentional 'hitch-hiking'.

Potential invader non-native species to Ireland

In order to target limited resources efficiently to mitigate the threat of new non-native species a prioritised list of potentially invasive species, or horizon scanning, has been developed.

Horizon scanning suggests that the percentage of high and medium impact species arriving to Ireland will increase, with the greatest number of species occurring in the terrestrial and freshwater environments.

To date, the majority of invasive species in Ireland are plants, but the future trend may be towards invertebrate and vertebrate species comprising a greater percentage of all new arrivals, with invertebrates dominating the terrestrial environment and vertebrates the freshwater environment. However, it is the threat from high impact invertebrates that is of greatest concern for freshwater environments.

Of the potential invaders, the greatest numbers are likely to be native to Asia, North America and Europe respectively. The potential for species native to Europe to become high impact is of particular concern.

Knowledge gaps

The focus of this initial trend analysis has been on those species identified as having an impact, however, including all non-native introduced species would provide a more comprehensive overview of the general trends in Ireland.

Such an analysis is constrained by not having a definitive list of all non-native species for Ireland. The production of such a list would require an extensive audit of existing non-native species across all taxa and would be particularly challenging for many insect groups. Nevertheless, work on its compilation should commence, with the focus on development of systems to capture information in a systematic and formalised manner.

The trends analysis of marine species in this report was very insufficient due to the unavailability of data when populating the risk assessment database in 2012. Since then however,

much work is underway in Ireland to list all non-native marine species in support of fulfilling Descriptor 2 of the Marine Strategy Framework Directive where non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems. A non-native species inventory database for Ireland is desirable where this marine data is compiled and where additional attribute information is also collated to allow for categorization and trend analysis.

One significant recent development has been the increased reporting in the wild of traded pet species that have the potential to become invasive in Ireland. There is an absence of comprehensive information on the extent and scope of the pet species traded in Ireland on which to base an adequate risk assessment.

Recommendations:

| | |
|---------------------------|---|
| Recommendation 1: | Undertake an inventory and checklist of non-native species occurring in Ireland. |
| Recommendation 2: | As part of the inventory of the non-native species, capture attribute information to facilitate future risk assessment and trend analysis work. This non-native species inventory database would include additional attributes such as population status, number of sightings and distribution, known primary pathways, probable pathways, marine geographic regions, invaded habitat to a EUNIS * level. Post collation of the non-native species inventory database, trend analysis should be repeated. |
| Recommendation 3: | Ensure the non-native species inventory is interoperable with the Great Britain database of non-native species. |
| Recommendation 4: | Establish a database of pet, game and live food species traded or kept in Ireland to enable an overview of the threat posed by these sectors to be monitored. |
| Recommendation 5: | Increased monitoring of the distribution and spread of the medium impact species to better understand the threat posed. |
| Recommendation 6: | Continue to monitor species in the National Invasive Species Database to track distribution changes to support risk assessment. |
| Recommendation 7: | Provide continued support for citizen scientist surveillance, monitoring and reporting of invasive species. |
| Recommendation 8: | Determine the applicability of the non-native species inventory database for use also as a risk assessment tool. |
| Recommendation 9: | Create a protocol to improve the quality of data and information on non-native species being intercepted and introduced into Ireland to inform assessment and rapid response, especially for those species listed as having the potential to be high impact. |
| Recommendation 10: | Undertake an inventory of marine and brackish non-native species in Irish waters including information on status of establishment. |

* (EUNIS) European Nature Information System

On the island of Ireland the annual cost of invasive and non-native species is estimated to be €261 million.

Contents

| | |
|--|----|
| Summary | 3 |
| Recorded non-native species in Ireland | 3 |
| Potential invader non-native species to Ireland | 3 |
| Knowledge gaps | 4 |
| 1. Background | 7 |
| 1.1 Purpose of this report | 8 |
| 2. Methodology | 9 |
| 2.1 Temporal trend | 10 |
| 2.2 Environments | 10 |
| 2.3 Taxon groups | 10 |
| 2.4 Native regions | 10 |
| 2.5 Limitations | 10 |
| 3. Results | 11 |
| 3.1.1 Risk impact categories | 11 |
| 3.1.2 Date of first record | 12 |
| 3.1.3 Broad environments | 13 |
| 3.1.4.1 Marine environment | 19 |
| 3.1.4.2 Terrestrial environment | 20 |
| 3.1.4.3 Freshwater environment | 21 |
| 3.1.5 Receiving environment | 22 |
| 3.1.6 Native regions | 23 |
| 3.2 Future introductions of non-native species | 25 |
| 3.2.1 Ranking of potential species | 25 |
| 3.2.2 Potential introductions - broad environments | 25 |
| 3.2.3 Potential introductions - taxon groups | 26 |
| 3.2.4 Potential introductions - native regions | 28 |
| 4. Discussion | 29 |
| 4.1 Recorded species | 29 |
| 4.2 Potential invaders | 32 |
| 4.3 Knowledge gaps | |
| 4.4 Recommendations | 33 |
| 5. References | 34 |
| Appendix i – | 36 |
| Environment and taxon group summary tables | |
| Appendix ii – | 38 |
| List of species used for risk assessment | |

1 Background

Globally, invasive species are considered to be one of the major threats to native biodiversity, with the World Conservation Union (IUCN) citing their impacts as ‘immense, insidious, and usually irreversible’ (IUCN, 2000). Other direct drivers of biodiversity loss and ecosystem service reductions are habitat change, pollution, overexploitation, and climate change (Millennium Ecosystem Assessment, 2005). Invasive Alien Species (IAS) are a main cause of animal extinctions at the global scale (Clavero and García-Berthou, 2005) and in an IUCN analysis of Red List data, invasive species were highlighted to be the 3rd most severe threat to birds and mammals (Vié *et al*, 2009). The impact of invasive species not only affects our biodiversity and the ecosystem functions and services they provide, but they also impact on our economic activities and human health. In 2008, invasive species were estimated to cost approximately €12.7 billion per year in Europe (Kettunen *et al*, 2008) although the European Commission has acknowledged that this is likely to be an underestimate (COM, 2008). For Great Britain, the economic cost of invasive species is estimated to be £1.7 billion per annum (Williams *et al*, 2010) and €261 million is the current estimated annual cost of invasive and non-native species to Ireland and Northern Ireland (Kelly *et al*, 2013a).

With increased globalisation there is an increase in the movement of non-native species around the world (Hulme, 2009). Numerous non-native species, many introduced only in the last 200 years, have become successfully established over large areas of Europe (Hulme *et al*, 2009). Furthermore, biological invasions are widely expected to become a greater problem in the future (Lodge *et al*, 2006 and Sutherland, 2008). Research by the European Commission funded DAISIE* project, showed that non-native species are invading Europe at an unprecedented rate, 10,822 non-native species are listed for Europe of which 10-15% are expected to have a negative economic or

ecological impact (European Commission, 2008). This is supported by recent trend analysis of invasive alien species introductions at the European scale which also shows an overall increasing trend in the number of species being introduced (European Environment Agency, 2009 and 2010). The threat is likely to increase in the future unless robust action is taken at all levels to control the introduction and establishment of these species and address those already introduced (European Commission, 2011).

Prevention of invasive species establishment and spread largely depends on the promptness of response to the initial introduction(s). It is therefore crucial to improve early detection and early warning systems of invasion and establish efficient frameworks to guide decisions on eradication or management of new invasive species. Underpinning this is a need to know which are Ireland’s non-native species, which of those are considered invasive and which, if introduced to Ireland, might become invasive. This is done through a formal process known as a Risk Assessment. Risk assessment reviews the current knowledge on non-native species in a country and the region and categorises them as being of either high, medium or low risk of invasiveness. This categorisation is then used as the basis for policy formulation and mitigation strategies.

To date, two risk assessments have been undertaken in Ireland, first in 2007 and an expanded one in 2012, by Invasive Species Ireland, a cross-border invasive species initiative (Kelly *et al*, 2013b). From a very large number of non-native species that were assessed, the 2012 process identified 127 species as being of either high or medium risk. This list of 127 species forms the basis of action on invasive species in Ireland under the Invasive Species Ireland initiative, and the partner agencies. The National Biodiversity Data Centre works in close collaboration

* (DAISIE) Delivering Alien Invasive Species Inventories for Europe

This report is the first overview of the trends in the introduction of invasive species to the island of Ireland.

with Invasive Species Ireland and its partners to provide national co-ordination of data management and dissemination on Ireland's invasive species. The Data Centre maintains the National Invasive Species Database which provides distribution data on high and medium impact species. This work aims to facilitate updating of risk assessment undertaken by Invasive Species Ireland (see Kelly *et al*, 2013b) and establishes an early warning system to alert for new arrivals in the island of Ireland.

One of the benefits of maintaining a National Invasive Species Database is that the empirical data available for the Risk Assessment can also be used to document and assess the trends in the historic introductions of invasive species in Ireland. Such an assessment facilitates a greater understanding of invasive species in Ireland, in particular of when they were first recorded in the wild and which environments are most impacted upon. It also enables more effective decision-making in prioritising actions and resources for the future prevention, surveillance, monitoring and control of invasive species.

1.1 Purpose of this report

This report provides, for the first time in Ireland, an overview of the apparent trends in the introduction of invasive species using data from the 2012 risk assessment and National Invasive Species Database. It reviews the available data to undertake an analysis of the temporal trend of species recorded in Ireland for broad environments (terrestrial, freshwater, marine) and taxonomic groups (plants, vertebrates, invertebrates, others). Information on the potential origins and native regions of the introduced species is also presented. This analysis and report is seen as an important first step to a greater understanding of the past trends of introduction of invasive species to Ireland as well as providing some insight into what future trends may be on the horizon. As this is the first time such an analysis has been undertaken, limitations to the analysis are highlighted and recommendations made for future work to fill key knowledge gaps.

2 Methodology

The data used are sourced from the Invasive Species in Ireland 2013 prioritisation risk assessment database. The risk assessment process is detailed in a separate report by Invasive Species in Ireland (Kelly *et al*, 2013b). The methodology detailed below relates to analysis of the data contained within the risk assessment database for the purpose of looking at the trends in introduction of invasive species.


The risk assessment was carried out for 377 non-native species recorded in Ireland up to 2012 and 342 species considered to be potential invaders (i.e. not yet recorded in Ireland but identified as likely to arrive in future). These species were assessed, scored and ranked into impact categories of high, medium and low. For this report, analysis will focus on the high and medium impact category species. Cumulative graphs are used for trend analysis on the basis that the risk of establishment, spread, ecological and socio-economic damage of invasive alien species increases with the number of non-native species and individual introductions (European Environment Agency, 2010). As part of the risk assessment, species were categorised as either:

- Risk of high impact
- Risk of medium impact, or
- Risk of low impact

Separate assessments are carried out for recorded species on the island of Ireland and potential invaders. While the recorded and potential invader risk assessments are similar they evaluate the risk from different stages of the invasion process:

- For species recorded in Ireland, the risk assessment is based on questions relating to the species current status here, its ability to colonise successfully, invasion history, associated impacts, and management.
- For potential invasive species the risk assessment includes the likelihood of a species arriving to Ireland, its ability to survive in respect to suitable climate and habitat, its ability to spread and have an impact on the conservation goals and economy of an area.

Both the recorded and potential species assessments take into account control measures and societal factors that may limit or facilitate the spread of the species. The current trend in introductions analysis was based on these categorizations.



The trend in introductions has increased dramatically since the beginning of the 20th Century and has accelerated further in the last decade.

2.1 Temporal trend

For the present analysis, the date of first report of the species seen in the wild in Ireland is used. For species where the date of first arrival has not been documented, these are assigned to an 'unknown' date category.

2.2 Environments

Species were categorised into one of three broad environment groups, terrestrial, freshwater or marine. For species that can be found in more than one of these environments, the environment in which it is mainly seen, or was introduced to, is used.

2.3 Taxon groups

Species were assigned to a major taxon group. The four taxon categories used are plant, vertebrate, invertebrate and other. Fungi and algae are included in the 'other' category.

2.4 Native regions

The species native region is given by continent or other large geographical region as listed in the risk assessment database. The regions used are:

- | | |
|--------------------|-------------------------|
| • Africa | • Europe |
| • Asia | • Europe & Africa |
| • Australasia | • North America |
| • Eurasia | • South America |
| • Eurasia & Africa | • North & South America |

2.5 Limitations

The following limitations to the analysis are noted:

- Not all known non-native species in Ireland were included in the risk assessment process or for this trend analysis.
- No distinction is made between whether the species is established, naturalised or a casual occurrence in Ireland.
- There is a lack of marine data with very few marine species included in the risk assessment and therefore in this trend analysis report.
- The number of the non-native species ranked as medium or high impact is low, therefore any trend analysis is limited due to the low sample size.

3 Results

The results are presented separately for species already recorded in Ireland and for potential invader species.

3.1 Recorded species in Ireland

3.1.1 Risk impact categories

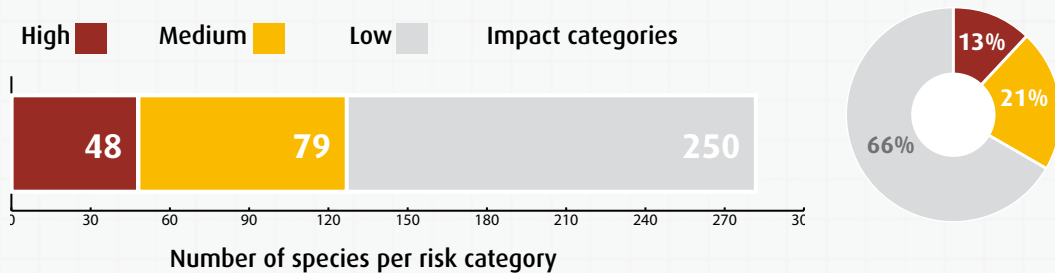


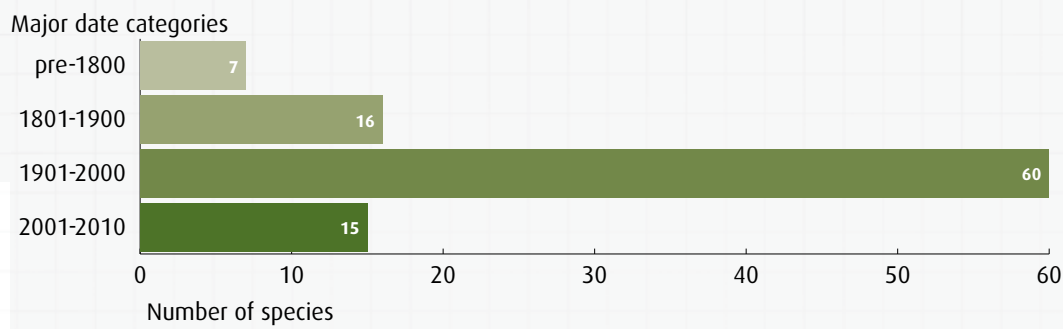
Figure 1. Number and percentage of species in each of the risk impact categories.

Of the 377 non-native species that were assessed, 250 (66%) are risk of low impact, 79 (21%) are risk of medium impact, and 48 (13%) are risk of high impact. (Figure 1). The 48 risk of high impact species are:

- American mink (*Neovison vison*)
- Asian clam (*Corbicula fluminea*)
- Asian sea-squirt (*Styela clava*)
- Black rat (*Rattus rattus*)
- Bloody-red shrimp (*Hemimysis anomala*)
- Brown hare (*Lepus europaeus*)
- Brown rat (*Rattus norvegicus*)
- Canada goose (*Branta canadensis*)
- Canadian waterweed (*Elodea canadensis*)
- Carpet sea squirt (*Didemnum vexillum*)
- Cherry laurel (*Prunus laurocerasus*)
- Chinese mitten-crab (*Eriocheir sinensis*)
- Chinese muntjac (*Muntiacus reevesi*)
- Chub (*Leuciscus cephalus*)
- Common cord grass (*Spartina anglica*)
- Crayfish plague (*Aphanomyces astaci*)
- Curly waterweed (*Lagarosiphon major*)
- Eel swimbladder nematode (*Anguillicola crassus*)
- Fallow deer (*Dama dama*)
- Feral ferret (*Mustela furo*)
- Floating pennywort (*Hydrocotyle ranunculoides*)
- Fringed water-Lily (*Nymphoides peltata*)
- Giant hogweed (*Heracleum mantegazzianum*)
- Giant knotweed (*Fallopia sachalinensis*)
- Giant rhubarb (*Gunnera tinctoria*)
- Grey squirrel (*Sciurus carolinensis*)
- Harlequin ladybird (*Harmonia axyridis*)
- Himalayan balsam (*Impatiens glandulifera*)
- Honey bee varroa mite (*Varroa destructor*)
- Hottentot fig (*Carpobrotus edulis*)
- House mouse (*Mus musculus*)
- Indian house crow (*Corvus splendens*)
- Japanese knotweed (*Fallopia japonica*) and hybrids
- New Zealand flatworm (*Arthurdendyus triangulatus*)
- New Zealand pygmyweed (*Crassula helmsii*)
- Nuttall's waterweed (*Elodea nuttallii*)
- Pacific oyster (*Crassostrea gigas*)
- Parrot feather (*Myriophyllum aquaticum*)
- Prairie dog (*Cynomys spp.*)
- Rhododendron (*Rhododendron ponticum*)
- Ruddy duck (*Oxyura jamaicensis*)
- Siberian chipmunk (*Tamias sibiricus*)
- Sika deer (*Cervus nippon*)
- Slipper limpet (*Crepidula fornicata*)
- Sudden oak death (*Phytophthora ramorum*)
- Wild boar (*Sus scrofa*)
- Wire weed (*Sargassum muticum*)
- Zebra mussel (*Dreissena polymorpha*)

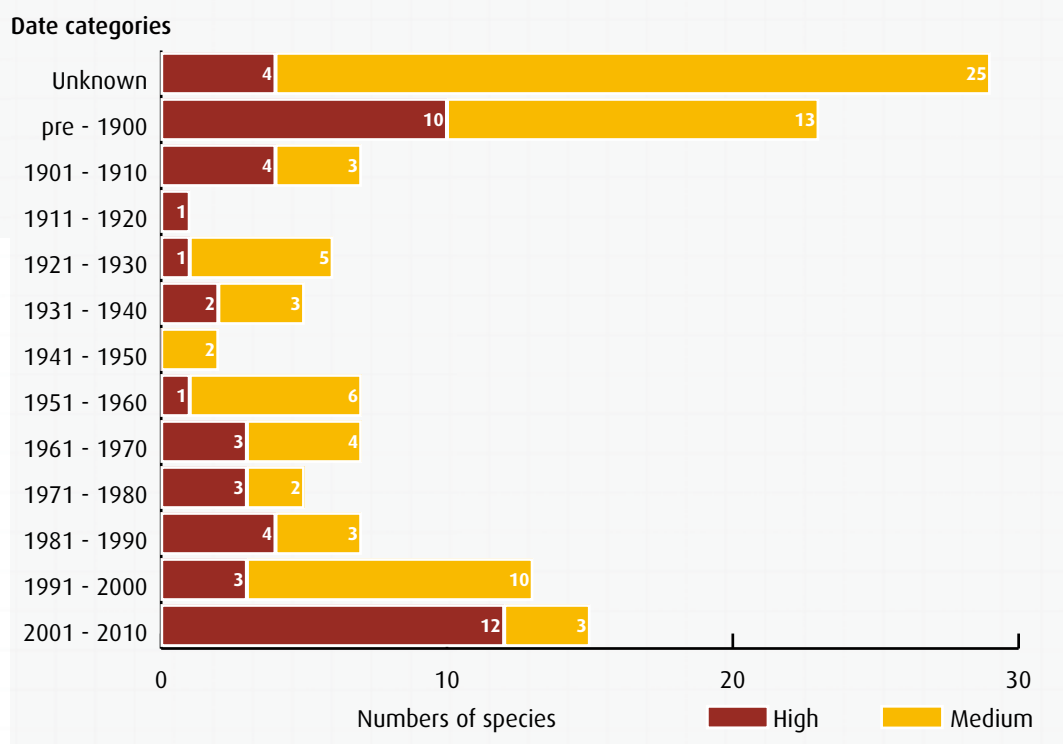
3.1.2 Date of first record

Figure 2. Number of species recorded by date category



The majority of species in Ireland were first recorded between 1901 and 2000 ($n=60$). This is nearly four times as many as were first recorded during the previous century ($n=16$) (Figure 2). In the first decade of this century (2001-2100) 15 species were recorded. If this trend were to continue there would be significantly more species introduced during this century than previously with a possible two and a half fold increase in the rate of introductions.

Figure 3. Number of high and medium impact species per date category



The number of introductions plotted by decade highlights the rate of introductions increasing in recent decades (Figure 3). Indeed over one and a half times as many high and medium impact species have been recorded in the last 50 years than during the first half of the 20th century. An average of 3.1 high impact and 3.7 medium impact species have been recorded per decade since 1901.

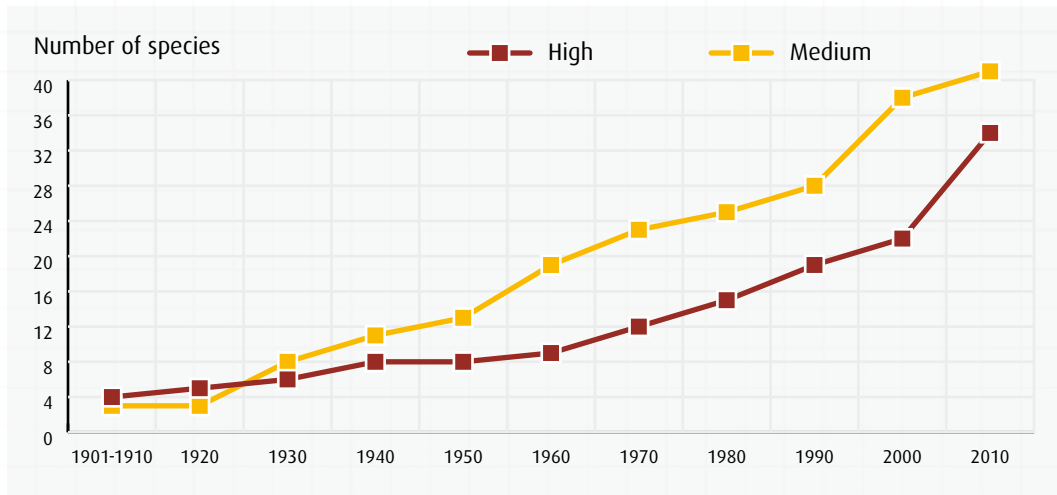


Figure 4. Cumulative trend in the number of high and medium risk species per decade from 1901 to 2010.

The rate of introduction for both high and medium impact species has increased steadily since the 1950s, with a rapid increase since 2000 (Figure 4).

3.1.3 Broad environments

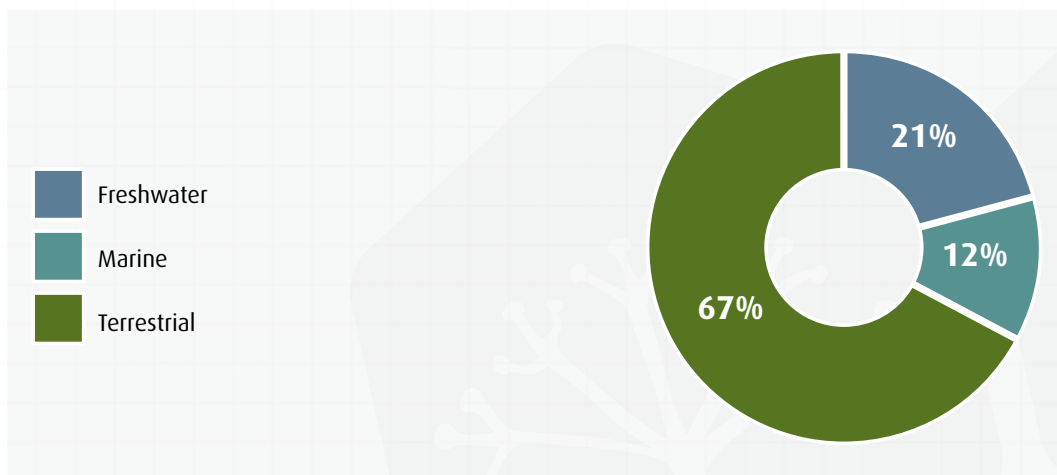


Figure 5. Percent of species in each broad environment category

67% of invasive species occur in the terrestrial environment, 21% in freshwater and 12% in the marine environment (Figure 5). The terrestrial and marine environments have been invaded by more medium than high risk species; for the freshwater environment the opposite is the case as there have been more high impact species (Figure 6).

Figure 6. Number of species recorded per impact category in each broad environment group

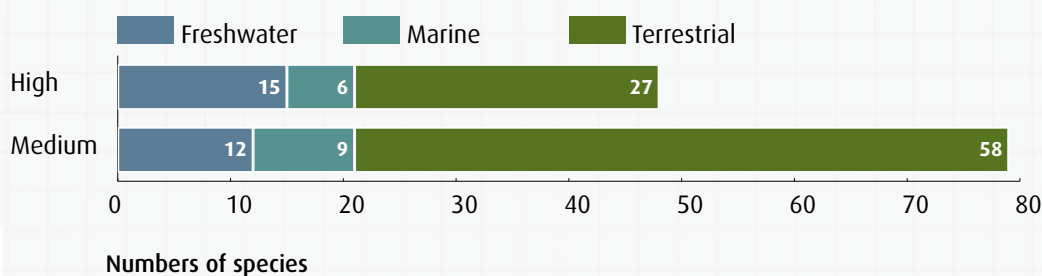
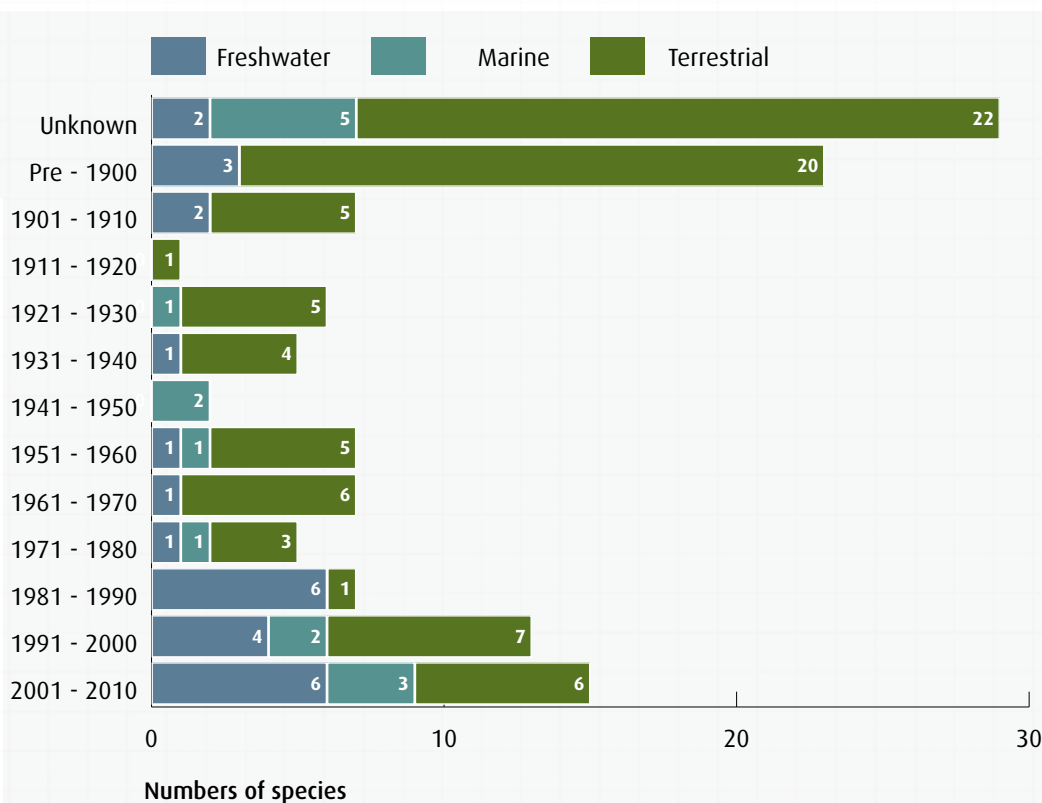


Figure 7. Number of species by broad environment for all date categories



An analysis of the date of the first records of invasive species by broad environment shows that half of all species were introduced either pre-1900 or their first date of sighting remains undocumented (Figure 7). This makes the detection of any trends difficult, but does show the long history of arrival of invasive species into Ireland.

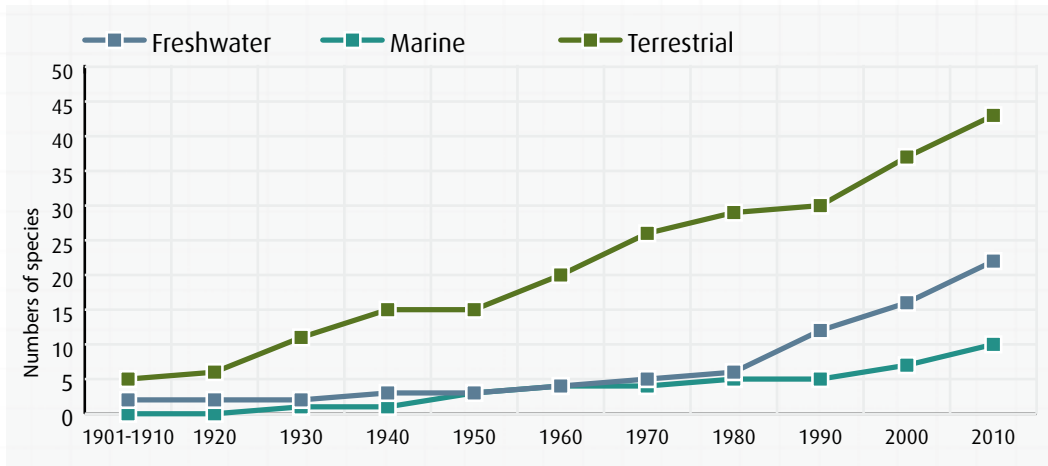


Figure 8.
Cumulative trend
in the number of
species recorded
per broad
environment from
1901-2010

Of the introductions since 1900 there is an overall increasing trend in the number of species recorded in each of the three broad environments (Figure 8). The greatest increase is for the freshwater environment since 1980, but there is also an increase apparent for the terrestrial and marine environments in since 1990.






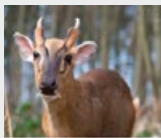






| | Unknown | pre-1900 | 1901 - 1910 | 1911 - 1920 | 1921 - 1930 | 1931 - 1940 | 1941 - 1950 | 1951 - 1960 | 1961 - 1970 | 1971 - 1980 | 1981 - 1990 | 1991 - 2000 | 2001 - 2010 | Total |
|-------------|---------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------|
| Terrestrial | | | | | | | | | | | | | | |
| High | 3 | 9 | 3 | 1 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 5 | 27 |
| Medium | 19 | 11 | 2 | 0 | 5 | 3 | 0 | 4 | 4 | 2 | 1 | 6 | 1 | 58 |
| Freshwater | | | | | | | | | | | | | | |
| High | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 4 | 1 | 5 | 15 |
| Medium | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 | 1 | 12 |
| Marine | | | | | | | | | | | | | | |
| High | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 6 |
| Medium | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 9 |

Table 1. Number of
high and medium
impact species
recorded in each
environment group
over time

Ten of the 15 high impact freshwater species were recorded in the last 30 years. The decade 2001 to 2010 was the decade with most high impact species (n=12) recorded for each of the three environments. The highest number of high impact species were recorded in the terrestrial environment, but the rate of increase is greatest for the freshwater environment.

With increased globalisation there is an increase in the movement of non-native species around the world.

The 12 high impact species recorded between 2001 and 2010

| | | | |
|--|---|---|---|
| <p>Floating pennywort (<i>Hydrocotyle ranunculoides</i>) First recorded: 2002 Status: Established in Northern Ireland. Action: Under eradication programme.</p> |  <p>WIKIcommons - GFDL</p> | <p>Siberian chipmunk (<i>Tamias sibiricus</i>) First recorded: 2007 Status: Not known to be established. Action: No control programme in place.</p> |  <p>Frank Kavanagh</p> |
| <p>Sea squirt (<i>Didemnum vexillum</i>) First recorded: 2005 Status: Established. Action: Removal underway at one site.</p> |  <p>Rohan Holt - CCW</p> | <p>Bloody-red shrimp (<i>Hemimysis anomala</i>) First recorded: 2008 Status: Established. Action: Research into impacts and control underway</p> |  <p>Marcin Penk</p> |
| <p>Chub (<i>Leuciscus cephalus</i>) First recorded: 2005 Status: Recorded from one river. Action: Under eradication programme.</p> |  <p>John Coyne - IFI</p> | <p>Muntjac deer (<i>Muntiacus reevesi</i>) First recorded: 2009 Status: Not known to be established. Action: Open hunting season in place.</p> |  <p>GB NNSS</p> |
| <p>Sudden oak death (<i>Phytophthora ramorum</i>) First recorded: 2005 Status: Established. Action: Survey and control of outbreaks underway at many sites.</p> |  <p>RHS.org.uk</p> | <p>Slipper limpet (<i>Crepidula fornicata</i>) First recorded: 2009 Status: Established at one site in Northern Ireland. Action: Survey work at that site continuing.</p> |  <p>GB NNSS</p> |
| <p>Chinese mitten crab (<i>Eriocheir sinensis</i>) First recorded: 2006 Status: Not known to be established. Action: No sighting since 2009.</p> |  <p>Alan Cullagh - SRFB</p> | <p>Asian clam (<i>Corbicula fluminea</i>) First recorded: 2010 Status: Established. Action: Research into impacts and control underway.</p> |  <p>Roy Anderson</p> |
| <p>Harlequin ladybird (<i>Harmonia axyridis</i>) First recorded: 2007 Status: Established. Action: Individual sighting control in place. Total eradication unlikely.</p> |  <p>Rollin Verlinde - GISD</p> | <p>Wild pig (<i>Sus scrofa</i>) First recorded: 2010 Status: Establishment uncertain. Action: Rapid response eradication undertaken in many locations.</p> |  <p>Shutterstock</p> |

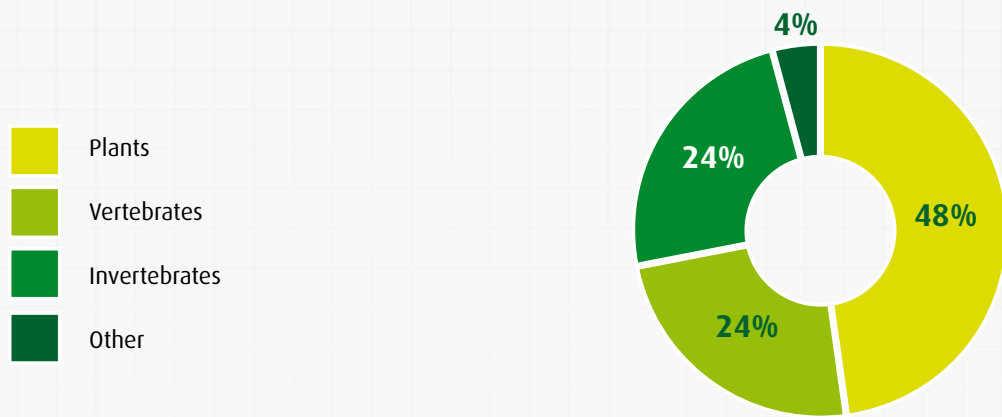


Figure 9. Percent of species per taxon group

48% of the high and medium impact species are plants, 24% are vertebrates and another 24% are invertebrates (Figure 7). The remaining 4% represent just five species, comprising two fungi and three algae.

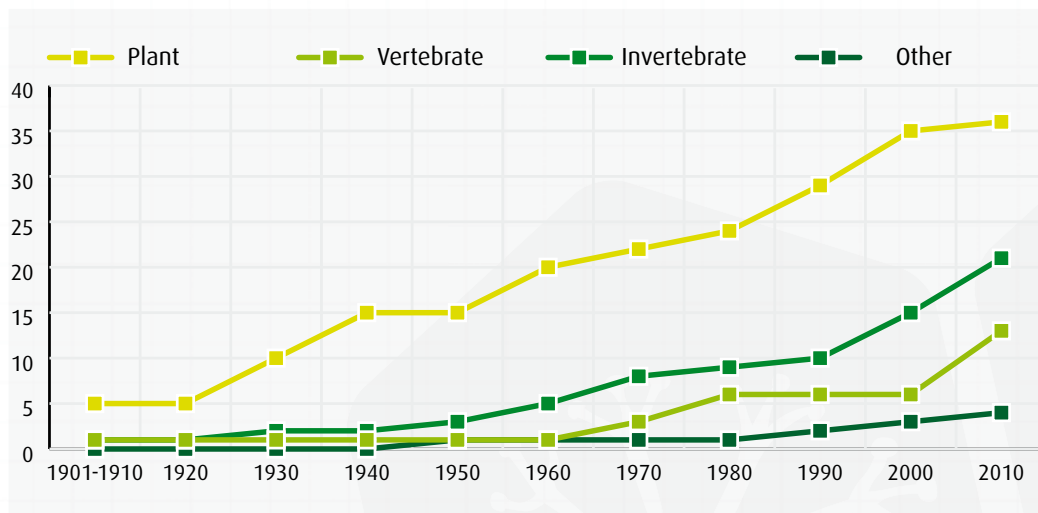
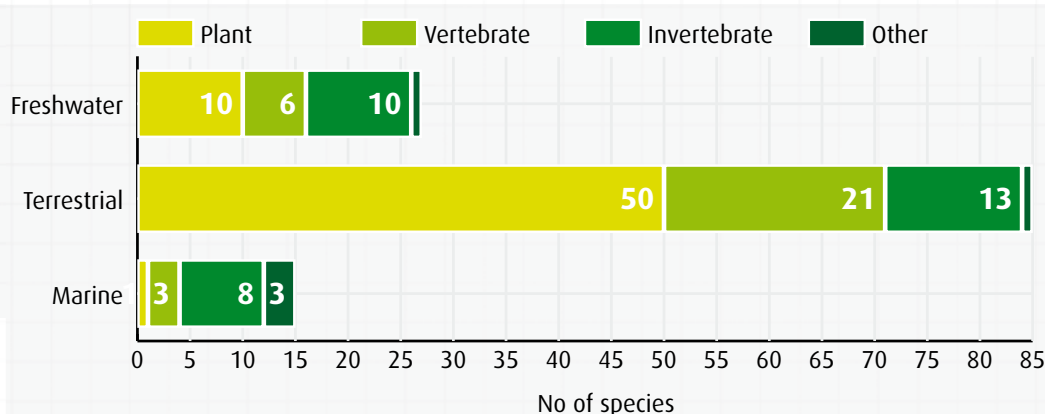


Figure 10. Cumulative trend in the number of plants, vertebrates, invertebrates and the 'other' taxon group first recorded in Ireland from 1901-2010

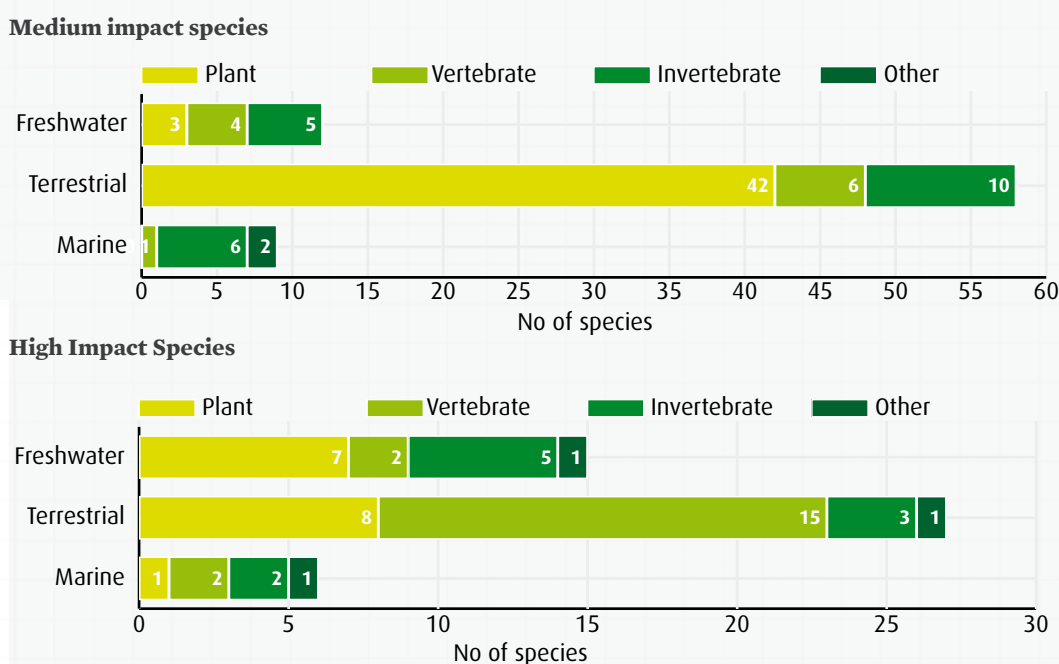
Over the last 110 years there has been a gradual increasing trend in the number of plants and invertebrates introduced but with an unprecedented acceleration in the number of invertebrates recorded since 1990 and vertebrates since 2000 (Figure 10).

Figure 11.
Number of plant,
vertebrate,
invertebrate and
'other' taxon
group species in
each of the three
environments



Most of the plant and vertebrate introductions are terrestrial species (Figure 11). Invertebrates are more evenly spread between the three environments with 41% terrestrial, 32% freshwater and 25% marine species. Plants dominate the terrestrial environment and invertebrates the marine environment, with equal numbers of plant and invertebrate species recorded in freshwater. Three of the five 'other' taxon group are found in the marine environment.

Figure 12. Number
of medium and
high impact
species per taxon
group in each
environment



Most plants are found within the terrestrial environment (Figure 12). However, the majority of terrestrial plants tend to be medium impact whereas the majority of freshwater plants tend to be high impact.

Most of the high impact species in the terrestrial environment are vertebrates.

The 15 high risk impact terrestrial vertebrates are:

- American mink (*Neovison vison*)
- Black rat (*Rattus rattus*)
- Brown hare (*Lepus europaeus*)
- Brown rat (*Rattus norvegicus*)
- Canada goose (*Branta canadensis*)
- Chinese muntjac (*Muntiacus reevesi*)
- Fallow deer (*Dama dama*)
- Feral ferret (*Mustela furo*)
- Grey squirrel (*Sciurus carolinensis*)
- Indian house crow (*Corvus splendens*)
- House mouse (*Mus musculus*)
- Prairie dog* (*Cynomys species*)
- Siberian chipmunk (*Tamias sibiricus*)
- Sika deer (*Cervus nippon*)
- Wild boar (*Sus scrofa*)

* The status of this species in the wild in Ireland needs to be reviewed.

3.1.4.1 Marine environment

15 high and medium impact species have been recorded in the marine environment.

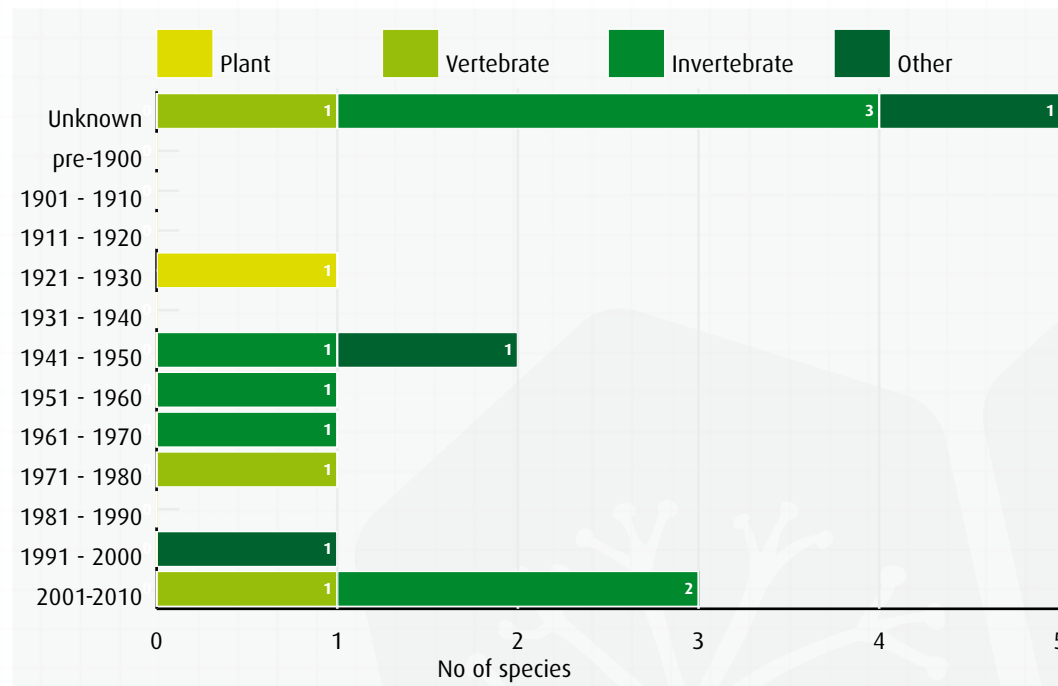


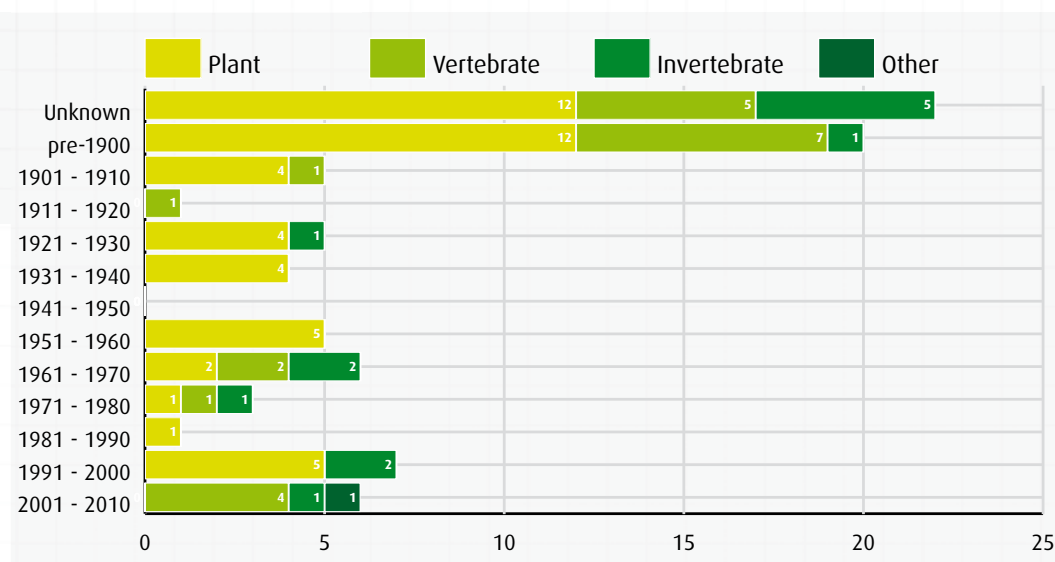
Figure 13. Number of marine species per taxon group

The small number of marine invasive species analysed and the fact that the first arrival dates of one third of these is unknown, makes it difficult to detect any meaningful trends (Figure 13). Improved reporting and study of invasive species in the marine environment is needed.

3.1.4.2 Terrestrial environment

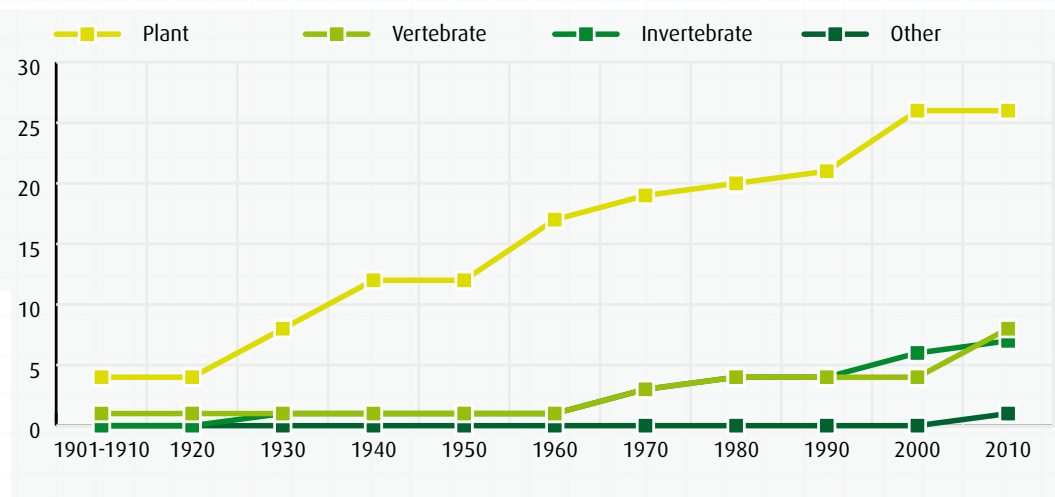
85 high and medium impact species have been recorded in the terrestrial environment.

Figure 14. Number of terrestrial species per taxon group



More than two and a half times more plants ($n=26$) have been recorded in the 20th Century than in the previous century ($n=10$)* (Figure 14). Most vertebrates were recorded in the first decade of the 21st Century and this was also the only decade that species in the 'other' category were recorded. On average, 2.3 plants, 0.8 vertebrates and 0.6 invertebrates were recorded every decade from 1901 to 2001.

Figure 15. Cumulative trend in the number of terrestrial species recorded per taxon group from 1901-2010



There is a staggered increased trend in the number of terrestrial plants, vertebrates and invertebrates recorded since 1960 and a spike in the number of species recorded since 1990. The rate of introductions may have levelled-off for plants, but is continuing for all other categories.

* 10 terrestrial plants were recorded from 1801-1900, 2 were recorded pre-1800 but are included under the pre-1900 date category in the histogram chart

3.1.4.3 Freshwater environment

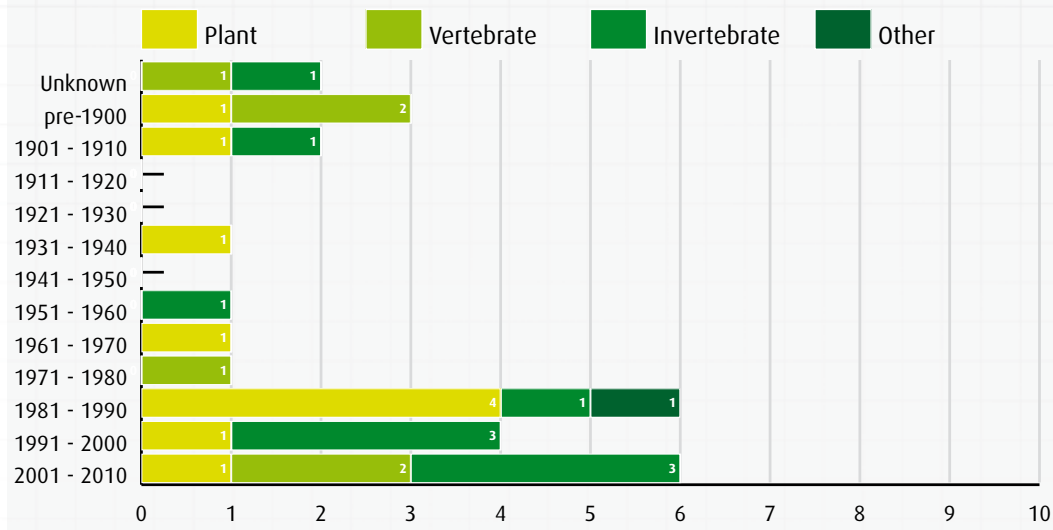


Figure 16. Number of freshwater species per taxon group

27 high and medium impact species were recorded in the freshwater environment, and two thirds of those introduced post 1900 have been recorded since the 1980s (Figure 16). An equal number of plants and invertebrates (n=10 each) were introduced to the freshwater environment with plants being recorded in six of the eleven decades from 1901. Most of the invertebrates (8 of 10) were recorded in the last two decades.

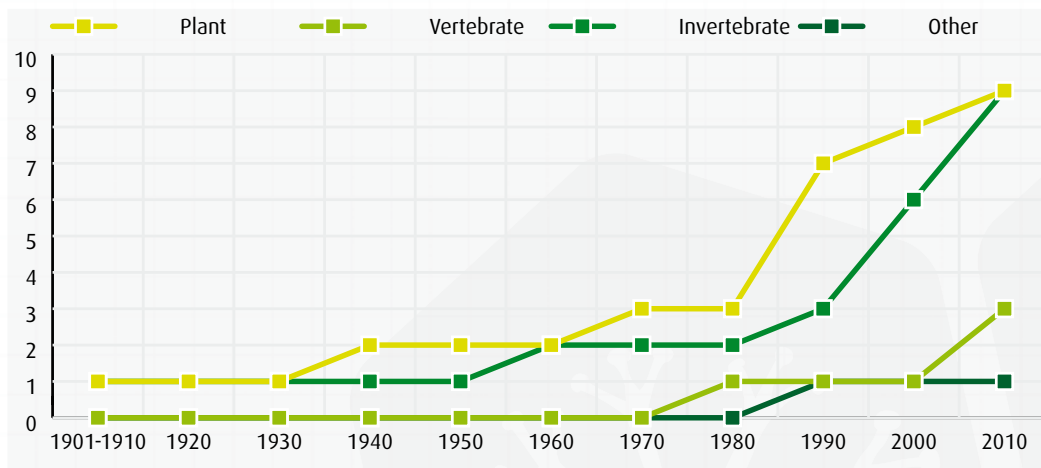


Figure 17. Cumulative trend in the number of freshwater species per taxon group from 1901-2010

There has been an increase in the number of species recorded in all four taxonomic groups since the 1980s with the most significant increases seen for plants and invertebrates (Figure 17).

Fourteen of the 22 freshwater species recorded since 1901 are high impact species. These are:

- Eel swimbaldder nematode (*Anguillicola crassus*)
- Canadian waterweed (*Elodea canadensis*)
- African curly waterweed (*Lagarosiphon major*)
- Ruddy duck (*Oxyura jamaicensis*)
- Crayfish plague (*Aphanomyces astaci*)
- New Zealand pygmyweed (*Crassula helmsii*)
- Nuttall's waterweed (*Elodea nuttallii*)
- Parrott's feather (*Myriophyllum aquaticum*)
- Zebra mussel (*Dreissena polymorpha*)
- Asian clam (*Corbicula fluminea*)
- Chinese mitten crab (*Eriocheir sinensis*)
- Bloody-red shrimp (*Hemimysis anomala*)
- Floating pennywort (*Hydrocotyle ranunculoides*)
- Chub (*Leuciscus cephalus*)

3.1.5 Receiving environments

Results of the analysis of receiving environment of freshwater, terrestrial and marine by taxon group is presented in Table 2. The figures provided are for high and medium impact species combined.

Table 2. Summary table of taxon groups per broad environment

Table 2.

| | Freshwater | Terrestrial | Marine | Total |
|----------------------------|------------|-------------|--------|-------|
| Vascular Plant | | | | |
| Fern | 1 | 1 | 0 | 2 |
| flowering plant | 9 | 49 | 1 | 59 |
| Vertebrate | | | | |
| Bird | 1 | 2 | 0 | 3 |
| bony fish (Actinopterygii) | 4 | 0 | 0 | 4 |
| Mammal | 0 | 19 | 0 | 19 |
| Reptile | 1 | 0 | 0 | 1 |
| Tunicate | 0 | 0 | 3 | 3 |
| Invertebrate | | | | |
| insect | | | | |
| beetle (Coleoptera) | 0 | 1 | 1 | 2 |
| non-insect | | | | |
| Annelid | 0 | 0 | 1 | 1 |
| Crustacean | 5 | 1 | 4 | 10 |
| flatworm (Turbellaria) | 0 | 4 | 0 | 4 |
| mite (Mesostigmata) | 0 | 1 | 0 | 1 |
| Mollusc (Gastropod) | 2 | 5 | 1 | 8 |
| Mollusc | 2 | 1 | 2 | 5 |
| roundworm (Nematoda) | 1 | 0 | 0 | 1 |
| Other | | | | |
| Alga | 0 | 0 | 3 | 3 |
| Fungi | 1 | 1 | 0 | 2 |

Flowering plants are the most common, followed by mammals, crustaceans and molluscs (gastropods) (Table 2). All but two of the vascular plant group are flowering plants.

Of the 30 vertebrates, most are mammals (19) in the terrestrial environment, bony fish in freshwater (4) and tunicates in the marine (3). Two bird species in terrestrial and one in freshwater, and a reptile also in freshwater make up the total.

Of the 31 invertebrates, most are crustaceans (10) with five freshwater, four marine and one terrestrial species. While there are 13 molluscs altogether these are split into distinct groups of mollusc gastropods (8) and molluscs (5). The remainder is comprised of four species of flatworm, two of beetles and one each of annelid, mite and roundworm.

The 'other' taxon group comprises three species of marine alga, and a freshwater and terrestrial fungus. The marine environment is the only environment where high or medium risk tunicates, annelids and alga were recorded.

3.1.6 Native regions

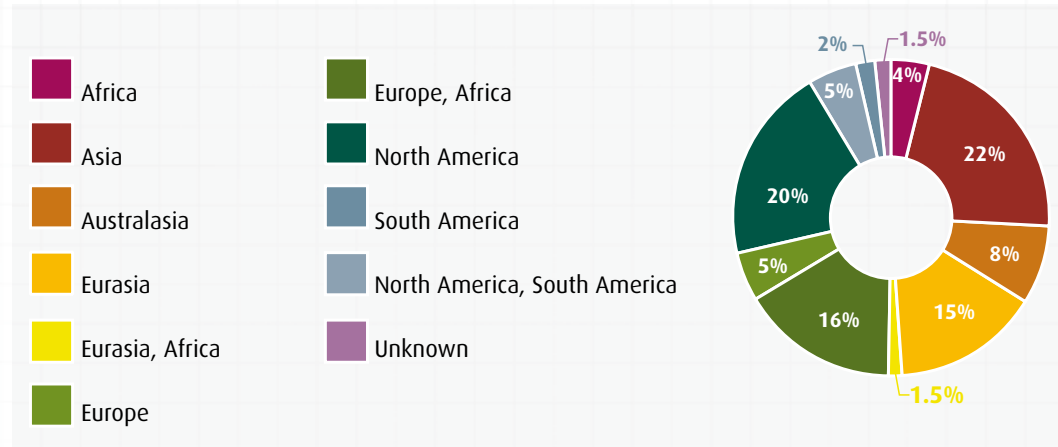


Figure 18. Percent species per native region

Most of the high and medium impact species in Ireland originate from Asia (22%) and North America (20%) (Figure 18). The third highest contributor of species is Europe (16%) including Great Britain, Eurasia (15%) and Australasia (8%), followed by Eurasia (15%) and Australasia (8%).

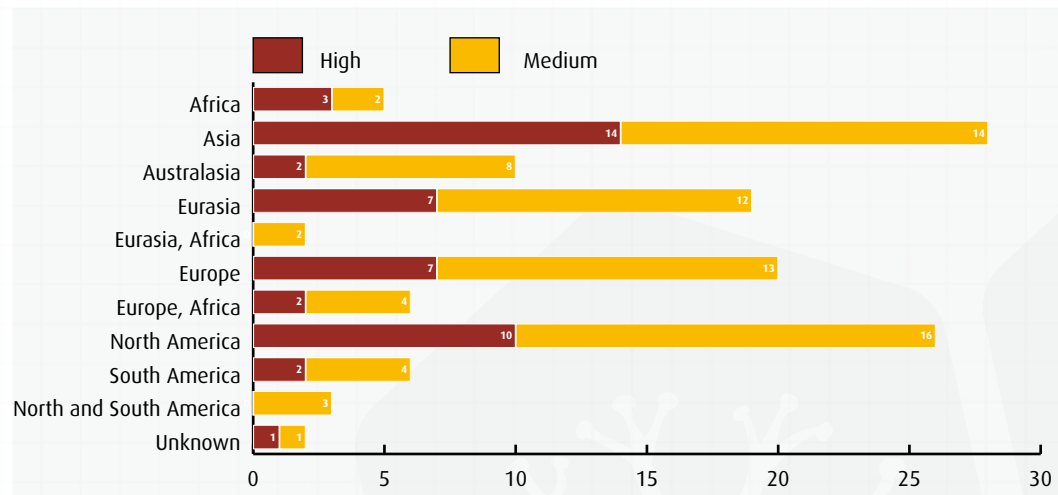
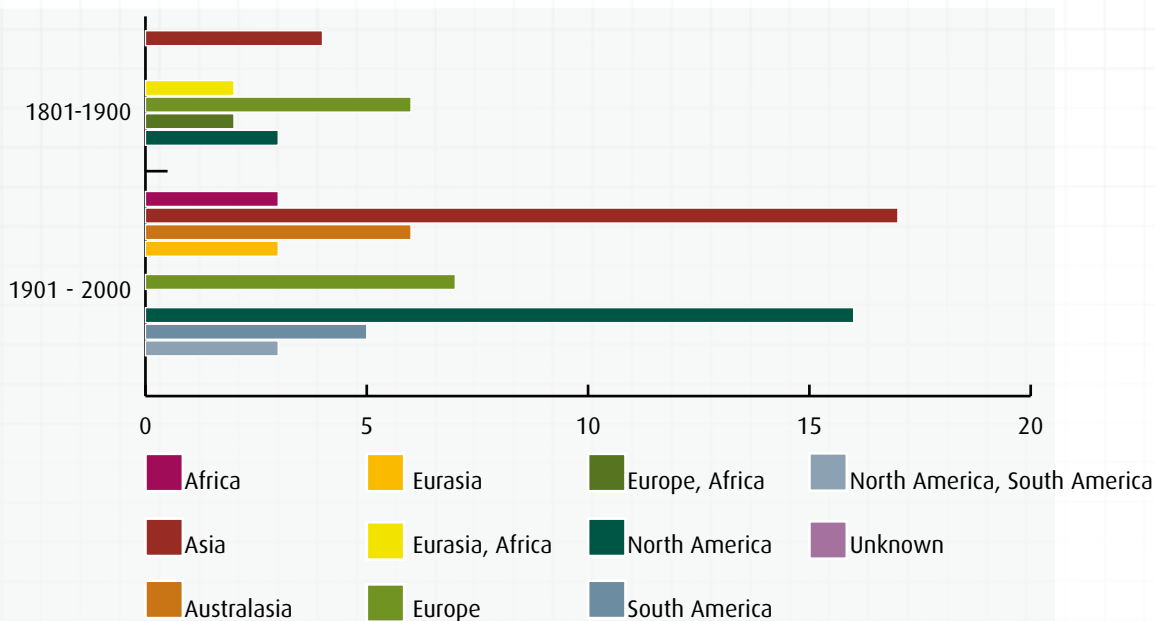


Figure 19. Number of species per native region displayed by high and medium impact categories

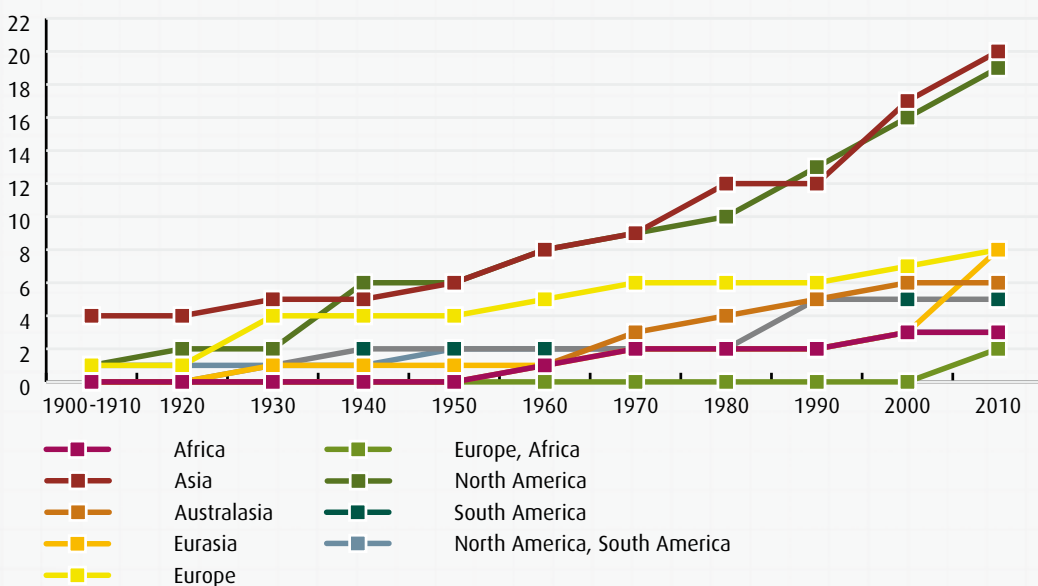
The largest number of high impact species are native to Asia (29%), followed by North America (21%), Europe (15%) and Eurasia (15%) (Figure 19). 20% of the medium impact species are native to North America, 18% are native to Asia followed closely by Europe (16%) and Eurasia (15%).

Figure 20. Number of species per native region over the last two centuries



Since 1900 there has been an increase in the numbers of species introduced from all regions except for the combined Eurasia & Africa region (Figure 20). The greatest increase was from Asia and North America which saw a five and four-fold increase respectively during the last century.

Figure 21. Cumulative trend in the number of species per decade per region from 1901-2010



There is an increased trend in number of species native to Asia and North America recorded in Ireland, with this trend increasing rapidly over the last twenty to thirty years (Figure 21). The trend in introduction of species from Europe is also increasing but at a slower rate. However, this graph does not fully reflect the true European influence as the majority of pre-1900 species were of European origin and these are not plotted in the graph.

3.2 Future introductions of non-native species

From a horizon scanning exercise, a further 342 species were identified as potential invaders to Ireland. The analysis presented in this section is based on these potential invaders.

3.2.1 Ranking of potential species

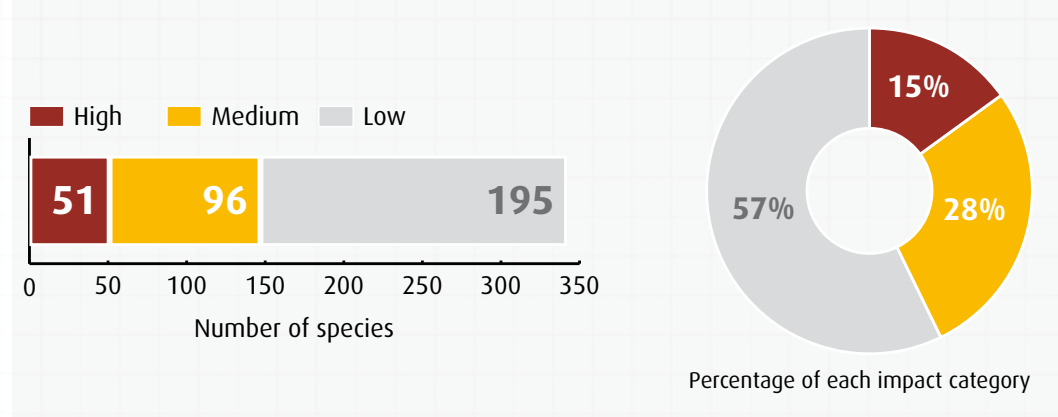


Figure 22. Number and percent of species in each impact category – potential invaders

15% of the potential invaders are ranked in the high impact species category (n=51), 28% as medium impact (n=96), and 57% as low impact species (n=195).

3.2.2 Potential introductions - broad environments

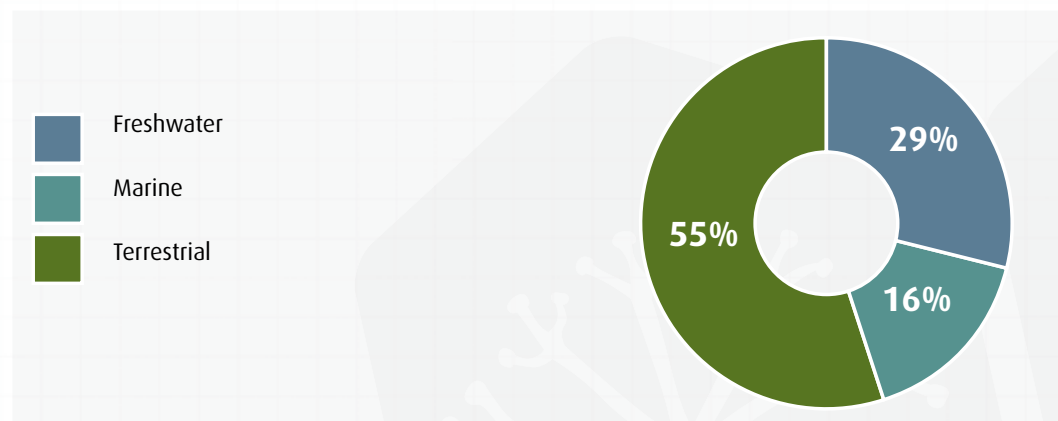
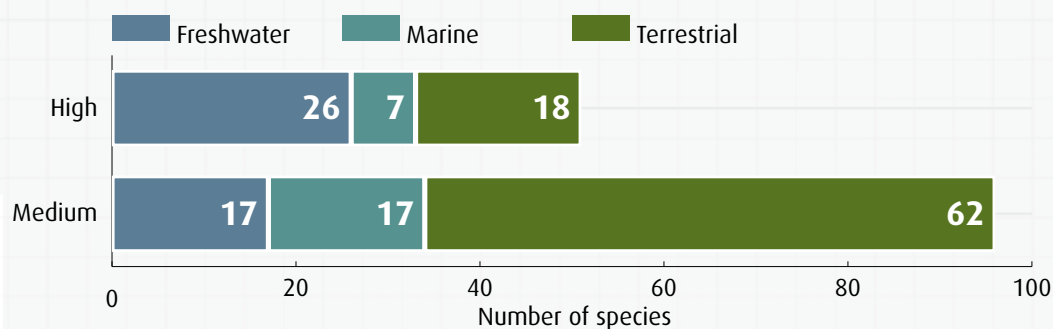


Figure 23. Percent of species in each broad environment category – potential invaders

55% of the species in the high and medium impact categories are terrestrial species, 29% are freshwater and 16% are marine species (Figure 23).

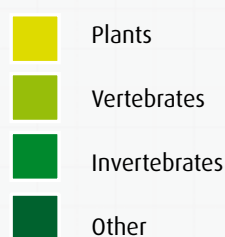
Figure 24. Number of species per broad environment – potential invaders



Of the high impact category species, 26 are freshwater, 18 are terrestrial and seven are marine. Of the medium impact category species, 62 are terrestrial with 17 terrestrial and marine. Significantly, a third more of the species are in the freshwater than terrestrial environment which is in contrast to those already in Ireland where almost double the species are terrestrial to freshwater. The larger number of freshwater species highlights the real future threat posed to freshwater environments from invasive species.

3.2.3 Potential introductions – taxon groups

Figure 25. Percent of species per taxon group – potential invaders



45% of the high and medium impact potential invaders are invertebrates, 31% are vertebrates and 19% are plants (Figure 25).

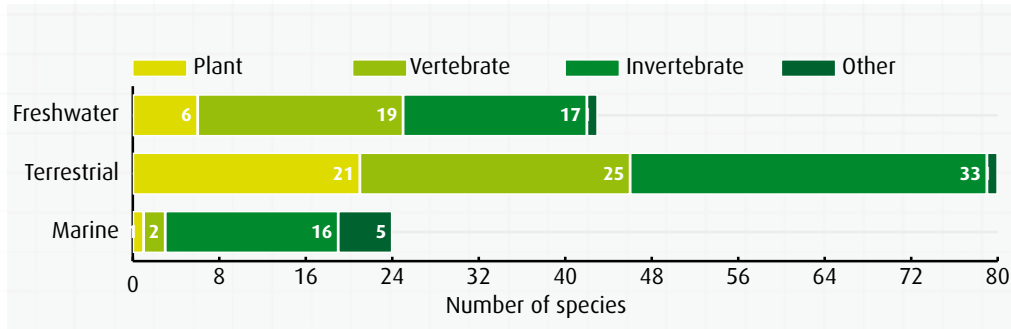


Figure 26.
Number of plant, vertebrate, invertebrate and 'other' taxon group species in each of the three environments – potential invaders

Half of the invertebrates are terrestrial with approximately one quarter each of freshwater and marine (Figure 26). Invertebrates dominate the marine environment comprising 16 of 24 potential marine invaders. There are also high numbers of terrestrial vertebrates ($n=25$) and freshwater vertebrates ($n=19$). Twenty one of the 28 species of the plants are terrestrial. Five of the seven 'other' taxon group are marine species.

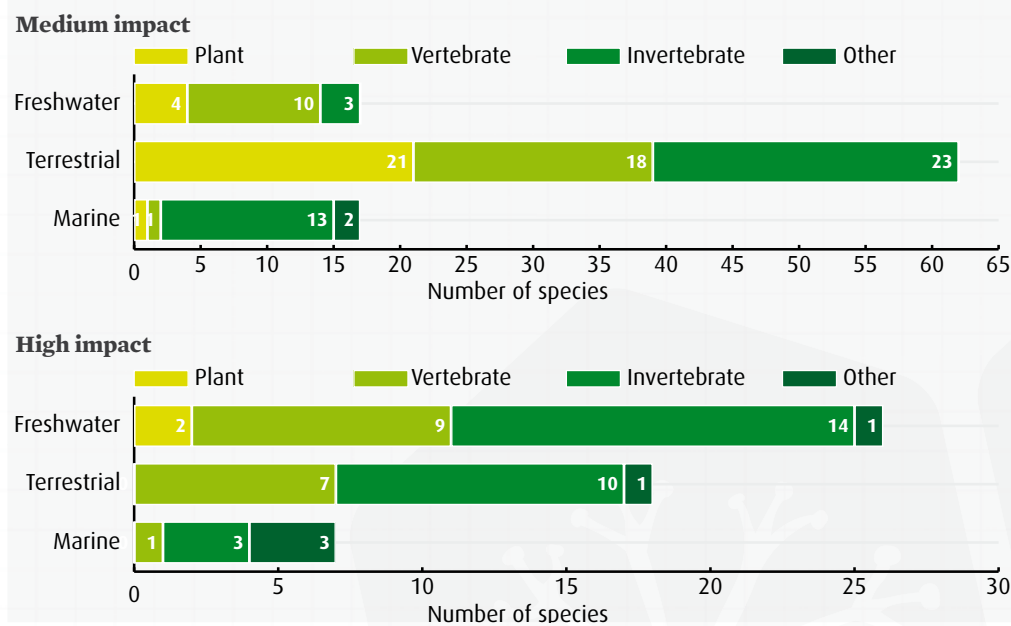


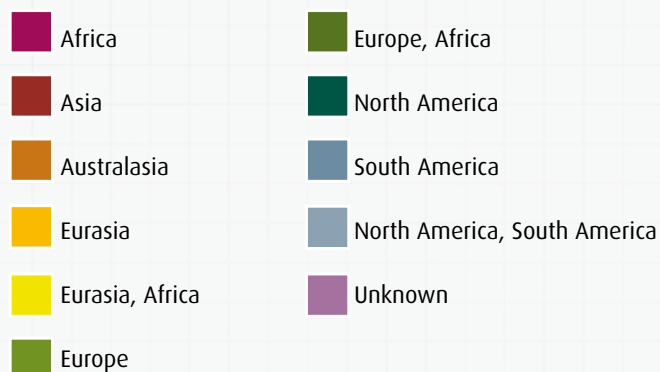
Figure 27. a and b. Number of medium and high impact species per taxon group in each environment – potential invaders

While none of the 21 terrestrial plants were risk assessed as having the potential to be high impact species, two of the six freshwater species were assessed as being high impact (Figure 27). The largest numbers of high impact species are invertebrates with most of those recorded in the freshwater and terrestrial environment. About half of freshwater vertebrates are assessed as high impact invaders and about one quarter of the terrestrial vertebrates.

The increased number of invertebrates to arrive in Ireland is of particular worry as this analysis shows that the majority of high impact species are likely to be invertebrates.

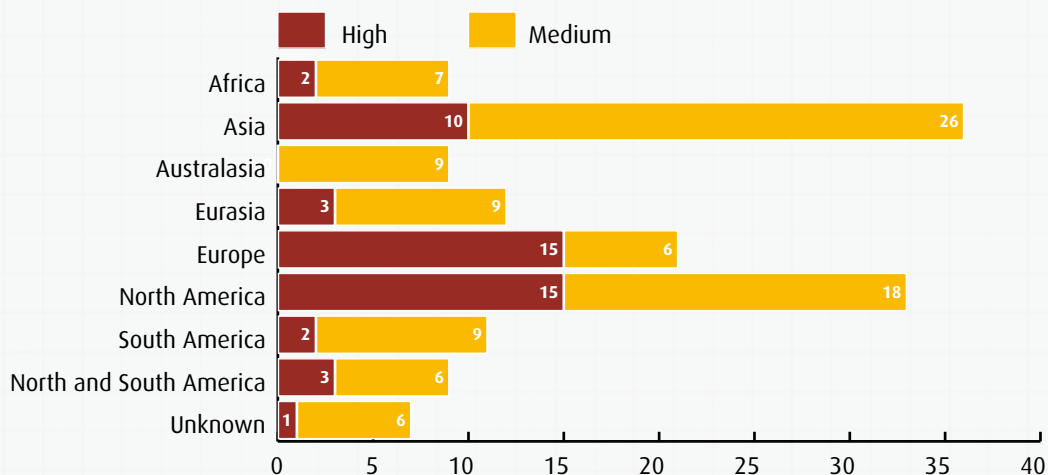
3.2.4 Potential introductions - native regions

Figure 28. Percent of species per geographic region – potential invaders



As with the recorded species, most of the potential invaders are native to Asia (24%) and North America (23%). 14% are native to Europe, 8% to Eurasia and 8% to South America (Figure 28). Australasia, Africa and North and South America contribute 6% each. 5% of the species are listed as unknown native origin.

Figure 29. Numbers species per native geographic region displayed by high and medium impact categories – potential invaders



For high impact species, both Europe and North America have the highest number of potential species native to them (15 species each) with Asia ranking third with 10 species (Figure 29). For the medium impact species the largest number of species are native to Asia (n=26) and North America (n=18).

4 Discussion

The process of biological invasion is changing constantly with new species arriving to our shores on a regular basis. There has been an increased understanding of invasive species issues in Ireland since the publication of the review of Invasive Species in Ireland (Stokes, 2006). However, there has been no attempt to understand the trends in introductions to help inform policy. The analysis presented here helps our understanding of historic trends and looks at new invader species which could potentially arrive in the near future. The focus of this report is on high and medium impact species and it suggests that there is an increasing trend in the introduction of species within these risk categories.

4.1 Recorded species

For analysis of trends, timeline data is required. For this, date of first report of the species is used (Roy *et al*, 2012). This approach works well for the high impact species as the date of first report is known for most. For the medium risk species there are many more unknown dates, thus reducing the level of accuracy in identifying trends.

Risk categories

Ranking species into risk of high, medium and low impact confirm what would be expected, namely; that the majority of invaders have a risk of low or medium impact, whereas only a small number are risk of high impact. In Ireland, the high impact species comprise 13% of the species having undergone a risk assessment. This percentage is consistent with that of other EU Member States.

The DAISIE study found that for Europe, about 15% of non-native species cause economic damage and a further 15% cause harm to biological diversity (DAISIE, 2008). In Norway, 15% of its non-native risk assessed species was categorised as severe impact (highest impact category) on ecology (T. Loennechen *pers comm.*) and in Great

Britain, 15% of its established non-native species have either negative ecological or human impact (Roy *et al*, 2012) although the level of impact is not stated. The level of distribution, establishment and ability to control or eradicate these high impact species will be species-dependant and in some cases a rapid response to eradicate them should be prioritised. In other cases, control or prevention of further spread is needed. For species such as the harlequin ladybird (*Harmonia axyridis*) for example, prevention of spread in Ireland may not be feasible once the species becomes established.

Date of first record

Overall there is an increased trend in the number of high impact species recorded in Ireland with the largest number of species recorded during the last decade from 2001-2010. The largest number of medium impact species was recorded from 1991-2000. This increasing trend in recent decades is similar to that seen in Europe, where the highest rates of introductions in Europe occurred in the last 25 years and suggest a recent step-change in biological invasions (Hulme, 2009).

While very few of the species were recorded pre-1800, some of the species in this date category are the most widespread and invasive, such as the brown rat (*Rattus norvegicus*). Four times as many species were first recorded during the 20th Century as in the 19th Century, and within the 20th Century more were recorded during the second half than the first. Hulme (2009) notes that '*post-1950, technical and logistic improvements have accelerated the ease with which commodities are transported across the globe and hindered the traceability of goods and the ease of intercepting pests. New sea, land and air links in international trade and human transport have established novel pathways for the spread of alien species*'. The recent large numbers of invasive species first reported from the wild may also be

due to greater awareness of invasive species, surveillance and monitoring for them along with provision of facilities to support identification and report sightings. Furthermore, citizen science plays a major role in early detection and reporting of sightings with half of the 12 high impact species first recorded in 2001-2010 being made by members of the general public. The infrastructure developed by the National Biodiversity Data Centre to promote and support submission and subsequent data verification of citizen science records, has proven invaluable in populating the National Invasive Species Database and, in triggering Ireland's invasive species Early Warning System. Zenetos (2012) notes that tracking the introduction and subsequent spread of invasive species is certainly challenging for the scientific community but that involvement of citizen science is one effective solution to overcome this difficulty.

Receiving environment

67% of invasive species are terrestrial, 21% freshwater and 12% marine species. Terrestrial non-native species are also the most numerous group in the Pan-European DAISIE database (DAISIE, 2013) and the NOBANIS* (2013) database.

When the numbers of species in each of the three environments are separated into both high and medium impact categories, the terrestrial environment is the most invaded by both categories, followed by freshwater then the marine. The freshwater environment is the only environment where there is a larger number of high impact species than medium impact species. This suggests that freshwater non-native species have a greater risk of becoming high impact when they are introduced. The number of marine species is comparatively low for both the high and medium impact categories. This may have more to do with insufficient data than actual low levels of risk from marine non-native species. There is an overall increased trend in the number of species recorded in each of the three broad environments. The steepest increase is in the freshwater environment post 1980. Significant

increased trends are also seen for the terrestrial environment in the last twenty years (1990-2010). When looking at just the high impact species recorded since 1901, the decade with most number of species recorded for each of the three environments was 2001 to 2010. Overall, the terrestrial environment has the largest number of high impact species recorded in it, but the most notable trend increase is for the freshwater environment. Two thirds of the high impact freshwater species were recorded in the last 30 years. The considerably higher number of terrestrial species recorded may be due to the greater ease and level of research and recording carried out on the terrestrial environment in comparison to the other environments.

Taxon groups

Almost half of the high and medium impact species are plants with a quarter each being vertebrates and invertebrates. The high numbers of plants with medium or high impact is mirrored in other European countries. The majority of high or severe impact species in Norway are also plants (Gedera *et al*, 2012) and just over half the naturalised plant species in Switzerland are documented as having some impact (DAISIE, 2009). From the 2013 risk assessment report (Kelly *et al*, 2013b), this high number of plants reflects the pathway of horticulture as the largest intentional pathway category. Interestingly most of the terrestrial plants are medium impact species but most of the freshwater plants are high impact. This highlights the concern that freshwater aquatic plants are likely to be high risk species. The high numbers of plants represented in the analysis also reflects the extensive work by Reynolds (2002) in *A catalogue of alien plants in Ireland*.

For most of the last 110 years there is a gradual increased trend in the numbers of plants and invertebrates recorded but with an unprecedented acceleration in the number of invertebrates recorded since 1990 and vertebrates since 2000. Hulme *et al* (2009) shows at the pan-European scale, while the number of terrestrial plants, terrestrial mammals and

*(NOBANIS) European Network on Invasive Alien Species (<http://www.nobanis.org/>)

terrestrial birds are decreasing in naturalisation, there is a significant increase in the numbers of terrestrial insects since 1971 and increasing numbers of terrestrial arthropods, inland aquatic invertebrates, marine fish and marine invertebrates.

In British brackish and marine waters, Minchin *et al* (2013) notes that the most frequent alien species taxonomic groups are the macroalgae, annelids, arthropods and molluscs. In the Minchin *et al* (2013) study, 90 alien species are listed from the British waters of which 58 are considered to be established. A study similar to this for Irish waters would be of great value in adding to our inventory of marine alien species. However, the difficulty remains in assessing marine species for risk of invasion impact. Katsanevakis (cited in Zenetos *et al*, 2012 p. 329) notes that there have been more than 1300 marine species introduced to European seas but the impact on local ecosystems has been studied for fewer than 100.

Native regions

Most of the invasive species are native to North America and Asia and the trend of increase from these regions is increasing rapidly. This is a similar trend to Norway where most non-native species originating outside of Europe tend to come from Asia and North America (Gederaas *et al*, 2007 and 2012). In Ireland, there is also a steady increase in species native to Europe but non-native to Ireland being introduced. In Great Britain, *'most of the non-native species that are established are from Europe however, in recent decades the rate of new arrivals originating from Europe is slowing and temperate Asia and North America are becoming both major contributors of non-native species'* (Roy *et al*, 2012). The *Handbook of Alien Species in Europe* illustrates that for most taxa an increasing proportion of introduced species [to Europe] are from other continents, especially the Americas and Asia (Hulme *et al*, 2009). Similarly, for non-native species in British brackish and marine waters, Minchin *et al* (2013) found that the majority of

species introduced to British waters originate from the North Pacific, particularly the north-west (e.g. Asia and Japan) followed by the North-west Atlantic (e.g. east coast of USA).

While the Great Britain and Norway studies are based on all non-native species introductions, the trends analysis work for this report is based on non-native species introductions that have also been analysed into risk impact category. This brings additional value to the trend data for these are the main regions where the highest numbers of species are likely to be of high or medium risk of impact. Further analysis into the breakdown of the native regions of specific taxon groups and the environments they were introduced to would help inform the climate change/habitat suitability for risk assessment and pathway analysis.

It is worth noting, however, that these are the native regions of the introduced species but not necessarily the regions from where the species were introduced. Inclusion of pathway analysis could potentially identify source regions and the main ways that the species are being introduced whether it is through intentional trade or unintentional 'hitch-hiking'.

4.2 Potential invaders

The reality for policy makers is the limited resources available to prevent and respond to all non-native species that pose a risk to environmental considerations. Therefore, policy makers require a prioritised list of potentially invasive species. This assessment acts as a horizon scanning exercise for Ireland. The development of the list of potential invasive species focused primarily on lists of species absent from Ireland but already identified as invasive species in Great Britain, Europe or key trading partners.

The effect of increased globalisation and free trade will inevitably result in the movement of species to new areas and environments.

Possible future categorisation of invaders

The current analysis of potential invasive species is a snapshot horizon scanning exercise. Many of the 342 non-native potential invasive species are also being highlighted in European and international invasive species databases, but there is always the potential for other undocumented species to be introduced and become invasive.

The analysis shows that in future, freshwater and marine environments are likely to receive more invasive species, and the terrestrial environments less. And a greater percentage of those arriving into freshwater environments are likely to be high impact species. By contrast, the majority of terrestrial species are likely to be medium impact.

Added to this, it is likely that in future almost half of all new arrivals may be invertebrates. Invertebrates will continue to be the main threat in marine environment, but significantly invertebrates may also become the main threat in terrestrial environments. In freshwater, the greatest threat will be posed by the vertebrates.

The increased number of invertebrates to arrive in Ireland is of particular worry, as this analysis also shows that the majority of high impact species are likely to be invertebrates.

Asia, North America and Europe will continue to be the native regions for the majority of future invasive species. However, it is likely that more species native to Europe (excluding Ireland) may become high impact in future.

One of the gaps identified in the horizon scanning process is the need for enhanced taxonomic invertebrate expertise to support diagnosis of early detection of non-native invertebrates in Ireland.

4.3 Knowledge gaps

This report is the first analysis of trends in introductions of invasive species in Ireland and has allowed for categorisation of introductions.

The analysis is limited to the species that are risk assessed as being high or medium impact in the 2012 Invasive Species in Ireland risk assessment and prioritisation process. Expanding the analysis to include as many non-native introduced species as possible would provide a more comprehensive overview of the general trends seen in Ireland, but this was not feasible for this initial analysis.

A significant gap in the study of non-native species in Ireland is the absence of a non-native species checklist and inventory. A checklist of non-native species would require an audit of existing non-native species across all taxa in all environments. For some taxon groups such as vascular plants, birds and mammals much of these data are already available and the task would not be too difficult. But for other taxon groups such as insects or non-insect invertebrates this task would be difficult with many species being listed as cryptogenic; namely, their native status cannot be determined. Notwithstanding the difficulties in compiling a checklist, the process of establishing an inventory should begin by capturing as much information as possible on species, then following up with protocols to enhance capture and collation of these data in the future. For instance, much work is currently underway in Ireland to list all non-native marine species in support of fulfilling Descriptor 2 of the Marine Strategy Framework Directive where non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems (European Union, 2008).

Ideally, a non-native species inventory for Ireland would closely mirror the fields and methodology used already in Great Britain, where a recent project has seen an inventory of 3,758 non-native species (or 85% of the total) established (Roy, *et al*, 2013). Such an approach would promote interoperability between the two databases to facilitate transfer for trend analysis, horizon scanning and for decision-making.

A non-native species inventory could provide up-to-date information on the current status and

distribution of taxa in Ireland. It could identify major trends and, if properly structured, used as a risk assessment tool. It would be particularly beneficial for the marine as it would increase the number of species included in the risk assessment.

Another area to improve is the monitoring of the distribution and spread of the medium impact ranking species with a concomitant improvement of documentation and communication of any impacts observed.

Currently there is paucity of information available on the pet species traded in Ireland, which is an issue as some with potential to become invasive have been reported in the wild. An openly accessible database of these traded species should be made available to better assess the risk of future introductions to the wild. Likewise, there is a need for game and live food species traded in Ireland to come within the scope of this database.

Surveillance, monitoring and reporting of introduced species through existing and developing monitoring systems, including greater use of citizen scientists is required. The sharing of data in a timely manner both within and outside Ireland is needed, but presently this does not occur within a structured framework. While the National Biodiversity Data Centre provides a centralised biodiversity distribution facility and works with many partners to collate and make available their biodiversity data, timely reporting of invasive and potentially invasive species is paramount to support early detection and rapid response to incursions.

4.4 Recommendations

Based on the outcomes of this analysis the following recommendations are made:

Recommendation 1: Undertake an inventory and checklist of non-native species occurring in Ireland.

Recommendation 2: As part of the inventory of the non-native species, capture attribute information to facilitate future risk assessment and trend analysis work. This non-native species inventory database would include additional attributes such as population status, number of sightings and distribution, known primary pathways, probable pathways, marine geographic regions, invaded habitat to a EUNIS level. Post collation of the non-native species inventory database, trend analysis should be repeated.

Recommendation 3: Ensure the non-native species inventory is interoperable with the Great Britain database of non-native species.

Recommendation 4: Establish a database of pet, game and live food species traded or kept in Ireland to enable an overview of the threat posed by these sectors to be monitored.

Recommendation 5: Increased monitoring of the distribution and spread of the medium impact species to better understand the threat posed.

Recommendation 6: Continue to monitor species in the National Invasive Species Database to track distribution changes to support risk assessment.

Recommendation 7: Provide continued support for citizen scientist surveillance, monitoring and reporting of invasive species.

Recommendation 8: Determine the applicability of the non-native species inventory database for use also as a risk assessment tool.

Recommendation 9: Create a protocol to improve the quality of data and information on non-native species being intercepted and introduced into Ireland to inform assessment and rapid response, especially for those species listed as having the potential to be high impact.

Recommendation 10: Undertake an inventory of marine non-native species in Irish waters including information on status of establishment.

5. References

- Carlton, J.T. (1996) Biological invasions and cryptogenic species. *Ecology* 77:1653-1655
- Clavero M, García-Berthou E (2005) Invasive species are a leading cause of animal extinctions. *Trends Ecol Evol* 20:110
- Commission of the European Communities (2008) Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the regions. *Towards an EU Strategy on Invasive Species*. Brussels, 3.12.2008. COM (2008) 789 final.
- DAISIE (2008) 11,000 alien species invade Europe. Press release issued 18/11/2008. Available online: http://www.europe-aliens.org/pdf/DAISIE_press_release_1.pdf [Accessed: March, 2013].
- DAISIE (2009) Handbook of Alien Species in Europe. *Invading Nature – Springer Series in Invasion Ecology, Volume 3*. Springer. ISBN: 978-1-4020-8279-5.
- DAISIE (2013) European Summary. DAISIE European Invasive Alien Species Gateway. Available online: <http://www.europe-aliens.org/europeSummary.do> [Accessed: 26/03/2013]
- European Environment Agency (2009) Progress towards the European 2010 biodiversity target – indicator fact sheets. Compendium to EEA Report No 4/2009. *EEA Technical report* No 5/2009
- European Environment Agency (2010) Invasive alien species in Europe (SEBI 010) - Assessment published May 2010. Available online: <http://www.eea.europa.eu/data-and-maps/indicators/invasive-alien-species-in-europe/invasive-alien-species-in-europe> [Accessed 20/03/2013]
- European Commission (2008) Commission presents policy options for EU strategy on invasive species. Press release: European Commission - IP/08/1890 05/12/2008. Available online: http://europa.eu/rapid/press-release_IP-08-1890_en.htm#fnB1 [Accessed 20/03/2013]
- European Commission (2011) *Our life insurance, our natural capital: an EU biodiversity strategy to 2020*. Communication from The Commission to the European Parliament, The Council, The Economic and Social Committee and the Committee of the Regions.
- European Union (2008) Directive 2008/56/EC of the European parliament and of the Council. Marine Strategy Framework Directive. *Official Journal of the European Union*. 25/06/2008
- Gederaas, L., Salvesen, I. og Viken, Å. (red.) (2007) Norsk svarteliste 2007 – Økologiske risikovurderinger av fremmede arter. 2007 *Norwegian Black List – Ecological Risk Analysis of Alien Species*. Artsdatabanken, Norway.
- Gederaas, L., Moen, T.L., Skjelseth, S. and Larsen L.-K. (eds.) (2012) *Alien species in Norway – with the Norwegian Black List 2012*. Norwegian Biodiversity Information Centre, Norway.
- Hulme, P. E. (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology*, 46: 10–18. doi: 10.1111/j.1365-2664.2008.01600.x
- Hulme, P.E., Roy, D.B., Cunha, T. & Larsson, T. B. (2009) A pan-European inventory of alien species: rationale, implementation and implications for managing biological invasions. *Handbook of alien species in Europe* (ed DAISIE), pp. 1-14. Springer, Dordrecht.
- IUCN (The World Conservation Union) (2000) *IUCN Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species*. Fifth Meeting of the Conference of the Parties to the Convention on Biological Diversity. (Nairobi, Kenya 15-26 May 2000).
- Kelly, J., Tosh, D., Dale, K., and Jackson, A. (2013a) *The economic cost of invasive and non-native species in Ireland and Northern Ireland*. A report prepared for the Northern Ireland Environment Agency and National Parks and Wildlife Service as part of Invasive Species Ireland.

Kelly, J., O'Flynn, C., and Maguire, C. (2013b) *Risk analysis and prioritisation for invasive and non-native species in Ireland and Northern Ireland*. A report prepared for the Northern Ireland Environment Agency and National Parks and Wildlife Service as part of Invasive Species Ireland.

Kettunen, M., Genovesi, P., Gollasch, S., Pagad, S., Starfinger, U. ten Brink, P. and Shine, C. (2008) *Technical support to EU strategy on invasive species (IAS) - Assessment of the impacts of IAS in Europe and the EU (final module report for the European Commission)*. Institute for European Environmental Policy (IEEP), Brussels, Belgium. 44 pp. + Annexes.

Lodge, D.M., Williams, S., MacIsaac, H.J., Hayes, K.R., Leung, B., Reichard, S., Mack, R.N., Moyle, P.B., Smith, M., Andow, D.A., Carlton, J.T. & McMichael, A. (2006) Biological invasions: Recommendations for US policy and management. *Ecological Applications*, 16, 2035–2054.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human well-being: Biodiversity Synthesis*. World Resources Institute, Washington, DC.

Minchin, D., Cook, E.J., Clark, P.F. (2013) Alien species in British brackish and marine waters. *Aquatic Invasions*. Vol. 8, Issue1: 3-19 Available online <http://www.aquaticinvasions.net/2013/issue1.html> [Accessed 25/03/2013]

NOBANIS (2013) *Country statistics. European Network in Invasive Alien Species*. Available online: <http://nobanis.org> [Accessed 26/03/2013]

Reynolds, S.C.P. (2002) A catalogue of alien plants in Ireland. *National Botanic Gardens, Occasional Papers* No. 14. Glasnevin. ISSN 0792-0422

Roy, Helen E., Bacon, Jim., Beckmann, Björn., Harrower, Colin A., Hill, Mark O., Isaac, Nick J.B., Preston, Chris D., Rathod, Biren., Rorke,

Stephanie L., Marchant, John H., Musgrove, Andy., Noble, David., Sewell, Jack., Seeley, Becky., Sweet, Natalie., Adams, Leoni., Bishop, John., Jukes, Alison R., Walker, Kevin J. and Pearman, David. (2012) *Non-Native Species in Great Britain: establishment, detection and reporting to inform effective decision making*. NERC Centre for Ecology & Hydrology, 110pp.

Sutherland, W.J. et al (2008) Future novel threats and opportunities facing UK biodiversity identified by horizon scanning. *Journal of Applied Ecology*, 45, 821–833.

Vié, J.-C., Hilton-Taylor, C. and Stuart, S.N. (eds.) (2009) *Wildlife in a Changing World – An Analysis of the 2008 IUCN Red List of Threatened Species*. Gland, Switzerland: IUCN. 180 pp

Williams, F., Eschen, R., Harris, A., Djeddour, D., Pratt, Shaw, R.S., Varia, S., Lamontagne-Godwin, J., Thomas, S.E. and Murphy, S. T. (2010) *The Economic Cost of Invasive Non-Native Species on Great Britain*. CAB/001/09

Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D., Garcia Raso, J.E., Cinar, M.E., Almogi-Labin, A., Ates, A.S., Azzurro, E., Ballesteros, E., Bianchi, C.N., Bilecenoglu, M., Gambi, M.C., Giangrande, A., Gravili, C., Hyams-Kaphzan, O., Karachle, P.K., Katsanevakis, S., Lipej, L., Mastrototaro, F., Mineur, F., Pancucci-Papadopoulou, M.A., Ramos Espla, A., Salas, C., San Martin, G., Sfriso, A., Streftaris, N., & Verlaque, M. (2012) Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science*, 13/2:328-352,2012.

Appendix i – Environment and taxon group summary tables

Terrestrial

| Terrestrial | Unknown | pre-1900 | 1900 - 1910 | 1911 - 1920 | 1921 - 1930 | 1931 - 1940 | 1941 - 1950 | 1951 - 1960 | 1961 - 1970 | 1971 - 1980 | 1981 - 1990 | 1991 - 2000 | 2001 - 2010 | Total |
|------------------------|---------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------|
| High | | | | | | | | | | | | | | |
| Plant | 1 | 3 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 8 |
| Vertebrate | 2 | 6 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 15 |
| Invertebrate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| High total | 3 | 9 | 3 | 1 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 1 | 5 | 27 |
| Medium | | | | | | | | | | | | | | |
| Plant | 11 | 9 | 2 | 0 | 4 | 3 | 0 | 4 | 2 | 1 | 1 | 5 | 0 | 42 |
| Vertebrate | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 6 |
| Invertebrate | 5 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 10 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Medium total | 19 | 11 | 2 | 0 | 5 | 3 | 0 | 4 | 4 | 2 | 1 | 6 | 1 | 58 |
| High & Medium combined | 22 | 20 | 5 | 1 | 5 | 4 | 0 | 5 | 6 | 3 | 1 | 7 | 6 | 85 |

Marine

| Marine | Unknown | pre-1900 | 1900 - 1910 | 1911 - 1920 | 1921 - 1930 | 1931 - 1940 | 1941 - 1950 | 1951 - 1960 | 1961 - 1970 | 1971 - 1980 | 1981 - 1990 | 1991 - 2000 | 2001 - 2010 | Total |
|------------------------|---------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------|
| High | | | | | | | | | | | | | | |
| Plant | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vertebrate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| Invertebrate | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| High total | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 6 |
| Medium | | | | | | | | | | | | | | |
| Plant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Vertebrate | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Invertebrate | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 6 |
| Other | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Medium total | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 9 |
| High & Medium combined | 5 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 1 | 0 | 2 | 3 | 15 |

Freshwater

| Freshwater | Unknown | pre-1900 | 1900 - 1910 | 1911 - 1920 | 1921 - 1930 | 1931 - 1940 | 1941 - 1950 | 1951 - 1960 | 1961 - 1970 | 1971 - 1980 | 1981 - 1990 | 1991 - 2000 | 2001 - 2010 | Total |
|------------------------|---------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------|
| High | | | | | | | | | | | | | | |
| Plant | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 3 | 0 | 1 | 7 |
| Vertebrate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 |
| Invertebrate | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 5 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| High total | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 4 | 1 | 5 | 15 |
| Medium | | | | | | | | | | | | | | |
| Plant | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 |
| Vertebrate | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 |
| Invertebrate | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 5 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Medium total | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 3 | 1 | 12 |
| High & Medium combined | 2 | 3 | 2 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 6 | 4 | 6 | 27 |

Appendix ii – List of species used for risk assessment

Recorded high impact species

| Species | Common Name(s) | Environment |
|-----------------------------------|--------------------------------|-------------|
| <i>Anguillicola crassus</i> | Swimbladder parasite | Freshwater |
| <i>Aphanomyces astaci</i> | Crayfish plague | Freshwater |
| <i>Arthurdendyus triangulatus</i> | New Zealand flatworm | Terrestrial |
| <i>Branta canadensis</i> | Canada goose | Terrestrial |
| <i>Carpobrotus edulis</i> | Hottentot fig | Terrestrial |
| <i>Cervus nippon</i> | Sika deer | Terrestrial |
| <i>Corbicula fluminea</i> | Asian clam | Freshwater |
| <i>Corvus splendens</i> | House crow | Terrestrial |
| <i>Crassostrea gigas</i> | Pacific oyster | Marine |
| <i>Crassula helmsii</i> | New Zealand pigmyweed | Freshwater |
| <i>Crepidula fornicata</i> | Slipper limpet | Marine |
| <i>Cynomys spp.</i> | Prairie dog | Terrestrial |
| <i>Dama dama</i> | Fallow deer | Terrestrial |
| <i>Didemnum vexillum</i> | Carpet sea squirt | Marine |
| <i>Dreissena polymorpha</i> | Zebra mussel | Freshwater |
| <i>Elodea canadensis</i> | American waterweed | Freshwater |
| <i>Elodea nuttallii</i> | Nuttalls pondweed | Freshwater |
| <i>Eriocheir sinensis</i> | Chinese mitten crab | Freshwater |
| <i>Fallopia japonica</i> | Japanese knotweed (and hybrid) | Terrestrial |
| <i>Fallopia sachalinensis</i> | Giant knotweed (and hybrid) | Terrestrial |
| <i>Gunnera tinctoria</i> | Giant rhubarb | Terrestrial |
| <i>Harmonia axyridis</i> | Harlequin ladybird | Terrestrial |

| Species | Common Name(s) | Environment |
|----------------------------------|------------------------|-------------|
| <i>Hemimysis anomala</i> | Bloody red shrimp | Freshwater |
| <i>Heracleum mantegazzianum</i> | Giant hogweed | Terrestrial |
| <i>Hydrocotyle ranunculoides</i> | Floating pennywort | Freshwater |
| <i>Impatiens glandulifera</i> | Himalayan balsam | Terrestrial |
| <i>Lagarosiphon major</i> | Curly waterweed | Freshwater |
| <i>Lepus europaeus</i> | Brown hare | Terrestrial |
| <i>Leuciscus cephalus</i> | Chub | Freshwater |
| <i>Muntiacus reevesi</i> | Chinese muntjac | Terrestrial |
| <i>Mus musculus</i> | House mouse | Terrestrial |
| <i>Mustela furo</i> | Feral ferret | Terrestrial |
| <i>Myriophyllum aquaticum</i> | Brazilian watermilfoil | Freshwater |
| <i>Neovison vison</i> | American mink | Terrestrial |
| <i>Nymphoides peltata</i> | Entire marshwort | Freshwater |
| <i>Oxyura jamaicensis</i> | Ruddy duck | Freshwater |
| <i>Phytophthora ramorum</i> | Sudden oak death | Terrestrial |
| <i>Prunus laurocerasus</i> | Cherry laurel | Terrestrial |
| <i>Rattus norvegicus</i> | Brown rat | Terrestrial |
| <i>Rattus rattus</i> | Black rat | Terrestrial |
| <i>Rhododendron ponticum</i> | Rhododendron | Terrestrial |
| <i>Sargassum muticum</i> | Wire weed | Marine |
| <i>Sciurus carolinensis</i> | Grey squirrel | Terrestrial |
| <i>Spartina anglica</i> | Common cord grass | Marine |
| <i>Styela clava</i> | Asian sea-squirt | Marine |
| <i>Sus scrofa</i> | Wild boar/feral pig | Terrestrial |
| <i>Tamias sibiricus</i> | Siberian chipmunk | Terrestrial |
| <i>Varroa destructor</i> | Honey bee varroa mite | Terrestrial |

Recorded medium impact species

| Species | Common Name(s) | Environment |
|--|----------------------------|-------------|
| <i>Acaena ovalifolia</i> | New Zealand bur | Terrestrial |
| <i>Acer pseudoplatanus</i> | Sycamore | Terrestrial |
| <i>Ailanthus altissima</i> | Tree of heaven | Terrestrial |
| <i>Allium triquetrum</i> | Three-cornered garlic | Terrestrial |
| <i>Ambrosia artemisiifolia</i> | Annual bur-sage | Terrestrial |
| <i>Antithamnionella ternifolia</i> | None identified | Marine |
| <i>Arcitalitrus dorrieni</i> | Sandhopper | Terrestrial |
| <i>Arion vulgaris</i> | Spanish slug | Terrestrial |
| <i>Australoplana sanguinea</i> | Australian flatworm | Terrestrial |
| <i>Azolla filiculoides</i> | Water fern | Freshwater |
| <i>Balanus improvisus</i> | Bay barnacle | Marine |
| <i>Berberis thunbergii</i> | Red leaf Japanese barberry | Terrestrial |
| <i>Berberis vulgaris</i> | European barberry | Terrestrial |
| <i>Botrylloides violaceus</i> | Red sheath tunicate | Marine |
| <i>Buddleja davidii</i> | Butterfly bush | Terrestrial |
| <i>Bunias orientalis</i> | Warty cabbage | Terrestrial |
| <i>Campanula rapunculoides</i> | Creeping bellflower | Terrestrial |
| <i>Candidula intersepta</i> | Wrinkled helicellid | Terrestrial |
| <i>Capra hircus</i> | Domestic goat | Terrestrial |
| <i>Caprella mutica</i> | Japanese skeleton shrimp | Marine |
| <i>Clematis vitalba</i> | Traveller's-joy | Terrestrial |
| <i>Codium fragile ssp. tomentosoides</i> | Green sea fingers | Marine |
| <i>Conyza canadensis</i> | Canadian horsetweed | Terrestrial |
| <i>Cornu aspersum</i> | Common garden snail | Terrestrial |
| <i>Corophium curvispinum</i> | Caspian mud shrimp | Freshwater |

| Species | Common Name(s) | Environment |
|----------------------------------|-----------------------------|-------------|
| <i>Cortaderia selloana</i> | Gray clubawn grass | Terrestrial |
| <i>Cotoneaster horizontalis</i> | Rock cotoneaster | Terrestrial |
| <i>Crocidura russula</i> | Greater white-toothed shrew | Terrestrial |
| <i>Cyprinus carpio</i> | Common carp | Freshwater |
| <i>Egeria densa</i> | Brazilian waterweed | Freshwater |
| <i>Elminius modestus</i> | Darwins barnacle | Marine |
| <i>Erucastrum gallicum</i> | Common dog-mustard | Terrestrial |
| <i>Euphorbia esula</i> | Leafy spurge | Terrestrial |
| <i>Fallopia baldschuanica</i> | Russian-vine | Terrestrial |
| <i>Ficopomatus enigmaticus</i> | Tube worm | Marine |
| <i>Gammarus pulex</i> | Gammarus shrimp | Freshwater |
| <i>Gammarus tigrinus</i> | Gammarus shrimp | Freshwater |
| <i>Gunnera manicata</i> | Chilean rhubarb | Terrestrial |
| <i>Hippophae rhamnoides</i> | Sea buckthorn | Terrestrial |
| <i>Kontikia andersoni</i> | None identified | Terrestrial |
| <i>Kontikia ventrolineata</i> | None identified | Terrestrial |
| <i>Lemna minuta</i> | Least duckweed | Freshwater |
| <i>Leuciscus leuciscus</i> | Dace | Freshwater |
| <i>Leycesteria formosa</i> | Himalayan honeysuckle | Terrestrial |
| <i>Lonicera japonica</i> | Japanese honeysuckle | Terrestrial |
| <i>Lupinus polyphyllus</i> | Garden lupin | Terrestrial |
| <i>Lysichiton americanus</i> | American skunk cabbage | Terrestrial |
| <i>Macropus rufogriseus</i> | Red-necked wallaby | Terrestrial |
| <i>Matteuccia struthiopteris</i> | Ostrich fern | Terrestrial |
| <i>Myodes glareolus</i> | Bank vole | Terrestrial |
| <i>Mytilicola orientalis</i> | Oyster redworm | Marine |

| Species | Common Name(s) | Environment |
|--|----------------------------|-------------|
| <i>Mytilus galloprovincialis galloprovincialis</i> | Mediterranean mussel | Marine |
| <i>Orobanche minor</i> | Clover broomrape | Terrestrial |
| <i>Oryctolagus cuniculus</i> | European rabbit | Terrestrial |
| <i>Oxalis pes-caprae</i> | African woodsorrel, | Terrestrial |
| <i>Parthenocissus quinquefolia</i> | Virginia-creeper | Terrestrial |
| <i>Pastinaca sativa</i> | Wild parsnip | Terrestrial |
| <i>Persicaria wallichii</i> | Himalayan knotweed | Terrestrial |
| <i>Physella acuta</i> | Bladder snail | Freshwater |
| <i>Potamopyrgus antipodarum</i> | Jenkins's spire snail | Freshwater |
| <i>Prunus serotina</i> | Black cherry | Terrestrial |
| <i>Pseudotsuga menziesii</i> | Douglas fir | Terrestrial |
| <i>Quercus cerris</i> | Turkey oak | Terrestrial |
| <i>Quercus ilex</i> | Evergreen oak | Terrestrial |
| <i>Quercus rubra</i> | Red oak | Terrestrial |
| <i>Ribes nigrum</i> | Black currant | Terrestrial |
| <i>Robinia pseudoacacia</i> | False acacia | Terrestrial |
| <i>Rosa rugosa</i> | Japanese rose | Terrestrial |
| <i>Rubus spectabilis</i> | Salmonberry | Terrestrial |
| <i>Rutilus rutilus</i> | Roach | Freshwater |
| <i>Sarracenia purpurea</i> | Pitcher plant | Terrestrial |
| <i>Senecio inaequidens</i> | Narrow-leaved ragwort | Terrestrial |
| <i>Solidago gigantea</i> | Giant goldenrod | Terrestrial |
| <i>Tandonia budapestensis</i> | Budapest slug | Terrestrial |
| <i>Tandonia sowerbyi</i> | Keeled (or Sowerby's) slug | Terrestrial |
| <i>Theba pisana</i> | White garden snail | Terrestrial |
| <i>Thlaspi arvense</i> | Field penny cress | Terrestrial |

| Species | Common Name(s) | Environment |
|--------------------------|----------------|-------------|
| <i>Trachemys scripta</i> | Common slider | Freshwater |

Potential invader high impact species

| Species | Common Name(s) | Environment |
|---------------------------------------|--|-------------|
| <i>Alexandrium catenella</i> | A toxin-producing dinoflagellate species | Marine |
| <i>Alytes obstetricans</i> | Midwife toad | Freshwater |
| <i>Astacus astacus</i> | Noble crayfish | Freshwater |
| <i>Astacus leptodactylus</i> | Turkish crayfish | Freshwater |
| <i>Batrachochytrium dendrobatidis</i> | Frog chytrid fungus | Freshwater |
| <i>Bemisia tabaci</i> | Tobacco whitefly | Terrestrial |
| <i>Bombus terrestris sub-species</i> | Bumblebee subspecies | Terrestrial |
| <i>Callinectes sapidus</i> | Blue crab | Marine |
| <i>Callosciurus erythraeus</i> | Pallas's squirrel | Terrestrial |
| <i>Cameraria ohridella</i> | Horse chestnut leaf miner | Terrestrial |
| <i>Capreolus capreolus</i> | Roe deer | Terrestrial |
| <i>Carassius auratus</i> | Edible goldfish | Freshwater |
| <i>Cercopagis pengoi</i> | Fishhook waterflea | Freshwater |
| <i>Chattonella cf. verruculosa</i> | None identified | Marine |
| <i>Corbicula fluminalis</i> | Freshwater clam | Freshwater |
| <i>Diabrotica virgifera</i> | Western corn rootworm | Terrestrial |
| <i>Dikerogammarus villosus</i> | Killer shrimp | Freshwater |
| <i>Diuraphis noxia</i> | Russian wheat aphid | Terrestrial |
| <i>Dreissena bugensis</i> | Quagga mussel | Freshwater |
| <i>Frankliniella occidentalis</i> | Western flower thrips | Terrestrial |
| <i>Geomyces destructans</i> | Bat white nosed syndrome (WNS) | Terrestrial |
| <i>Gyrodactylus salaris</i> | Salmon fluke | Freshwater |

| Species | Common Name(s) | Environment |
|----------------------------------|-------------------------|-------------|
| <i>Homarus americanus</i> | American lobster | Marine |
| <i>Hylastes ater</i> | Black pine bark beetle | Terrestrial |
| <i>Ludwigia grandiflora</i> | Water primrose | Freshwater |
| <i>Ludwigia peploides</i> | Water primrose | Freshwater |
| <i>Lymantria dispar</i> | Gypsy moth | Terrestrial |
| <i>Mesotriton alpestris</i> | Alpine newt | Semiaquatic |
| <i>Myiopsitta monachus</i> | Monk parakeet | Terrestrial |
| <i>Myocastor coypus</i> | Coypu | Semiaquatic |
| <i>Neogobius melanostomus</i> | Round goby | Marine |
| <i>Nyctereutes procyonoides</i> | Raccoon dog | Terrestrial |
| <i>Ondatra zibethicus</i> | Muskrat | Semiaquatic |
| <i>Orconectes limosus</i> | Spinycheek crayfish | Freshwater |
| <i>Orconectes rusticus</i> | Rusty crayfish | Freshwater |
| <i>Orconectes virilis</i> | Virile crayfish | Freshwater |
| <i>Pacifastacus leniusculus</i> | Signal crayfish | Freshwater |
| <i>Pimephales promelas</i> | Fathead minnow | Freshwater |
| <i>Procambarus clarkii</i> | Red swamp crayfish | Freshwater |
| <i>Procambarus marmoratus</i> | Marbled crayfish | Freshwater |
| <i>Procyon lotor</i> | Raccoon | Terrestrial |
| <i>Pseudorasbora parva</i> | Topmouth gudgeon | Freshwater |
| <i>Psittacula krameri</i> | Ring-necked parakeet | Terrestrial |
| <i>Rana catesbeiana</i> | North American bullfrog | Semiaquatic |
| <i>Rapana venosa</i> | Rapa whelk | Marine |
| <i>Salvelinus fontinalis</i> | Brook trout | Freshwater |
| <i>Sander lucioperca</i> | Zander | Freshwater |
| <i>Thaumetopoea processionea</i> | Oak processionary moth | Terrestrial |

| Species | Common Name(s) | Environment |
|---------------------------------|----------------|-------------|
| <i>Threskiornis aethiopicus</i> | Sacred Ibis | Terrestrial |
| <i>Undaria pinnatifida</i> | Japanese kelp | Marine |
| <i>Vespa velutina</i> | Asian hornet | Terrestrial |

Potential invader medium impact species

| Species | Common Name(s) | Environment |
|------------------------------------|---------------------------|-------------|
| <i>Acacia dealbata</i> | Silver wattle | Terrestrial |
| <i>Akebia quinata</i> | Five-Leaf akebia | Terrestrial |
| <i>Alopochen aegyptiacus</i> | Egyptian goose | Terrestrial |
| <i>Alternanthera philoxeroides</i> | Alligator weed | Freshwater |
| <i>Anopheles quadrimaculatus</i> | Common malaria mosquito | Terrestrial |
| <i>Anoplophora chinensis</i> | Citrus long-horned beetle | Terrestrial |
| <i>Anoplophora glabripennis</i> | Asian long-horned beetle | Terrestrial |
| <i>Anser indicus</i> | Bar-headed goose | Terrestrial |
| <i>Antithamnion nipponicum</i> | None identified | Marine |
| <i>Aphis gossypii</i> | Melon and cotton aphid | Terrestrial |
| <i>Arion lusitanicus</i> | Lusitanian Slug | Terrestrial |
| <i>Asclepias syriaca</i> | Common milkweed | Terrestrial |
| <i>Asterias amurensis</i> | Flatbottom seastar | Marine |
| <i>Aulacaspis yasumatsui</i> | Cycad aulacaspis | Terrestrial |
| <i>Aulacomya ater</i> | Cholga mussel | Marine |
| <i>Axis axis</i> | Axis deer | Terrestrial |
| <i>Bidens frondosa</i> | Bur marigold | Terrestrial |
| <i>Boiga irregularis</i> | Brown tree snake | Terrestrial |
| <i>Bubo bubo</i> | Eurasian eagle-owl | Terrestrial |
| <i>Bufo marinus</i> | Cane toad | Terrestrial |
| <i>Bursaphelenchus xylophilus</i> | pine wood nematode | Terrestrial |

| Species | Common Name(s) | Environment |
|-----------------------------------|-----------------------------|-------------|
| <i>Castor canadensis</i> | American beaver | Terrestrial |
| <i>Ceratitis capitata</i> | Mediterranean fruit fly | Terrestrial |
| <i>Chloephaga picta</i> | Magellan/upland goose | Terrestrial |
| <i>Cinara cupressi</i> | Cypress aphid | Terrestrial |
| <i>Clidemia hirta</i> | Kaurasiga | Terrestrial |
| <i>Contarinia quinquenotata</i> | Hemerocallis gall midge | Terrestrial |
| <i>Craspedacusta sowerbyi</i> | Freshwater jellyfish | Freshwater |
| <i>Cygnus atratus</i> | Black swan | Terrestrial |
| <i>Cyperus rotundus</i> | Cocograss | Terrestrial |
| <i>Dermacentor reticulatus</i> | European meadow tick | Terrestrial |
| <i>Disphyma crassifolium</i> | Purple dewplant | Terrestrial |
| <i>Eichhornia crassipes</i> | Water hyacinth | Freshwater |
| <i>Elaphe longissima</i> | Aesculapian snake | Terrestrial |
| <i>Elaphe spp</i> | rat snakes | Terrestrial |
| <i>Galinsoga quadriradiata</i> | Hairy galinsoga | Terrestrial |
| <i>Gambusia affinis</i> | Mosquitofish | Freshwater |
| <i>Glis glis</i> | Edible dormouse | Terrestrial |
| <i>Gracilaria vermiculophylla</i> | None identified | Marine |
| <i>Gymnocoronis spilanthoides</i> | Senegal teapant | Freshwater |
| <i>Hedychium gardnerianum</i> | Wild ginger | Terrestrial |
| <i>Hemigrapsus penicillatus</i> | Japanese Shore Crab | Marine |
| <i>Heracleum sosnowskyi</i> | Sosnowski's hogweed | Terrestrial |
| <i>Homalodisca vitripennis</i> | Glassy-winged sharp-shooter | Terrestrial |
| <i>Hydrocharis morsus-ranae</i> | European frog's-bit | Freshwater |
| <i>Hydroides dianthus</i> | Tubeworm | Marine |
| <i>Hydroides elegans</i> | Tubeworm | Marine |

| Species | Common Name(s) | Environment |
|---|------------------------|-------------|
| <i>Hypophthalmichthys molitrix</i> | Silver carp | Freshwater |
| <i>Ictalurus punctatus</i> | Catfish | Freshwater |
| <i>Imperata cylindrica</i> | Blady grass | Terrestrial |
| <i>Lasius neglectus</i> | Invasive garden ant | Terrestrial |
| <i>Leptinotarsa decemlineata</i> | Colorado beetle | Terrestrial |
| <i>Leuciscus idus</i> | Ide | Freshwater |
| <i>Linepithema humile</i> | Argentine ant | Terrestrial |
| <i>Macfadyena unguis-cati</i> | Cats claw vine | Terrestrial |
| <i>Melaleuca quinquenervia</i> | Broadleaf teatree | Terrestrial |
| <i>Misgurnus anguillicaudatus</i> | Weatherfish | Freshwater |
| <i>Mnemiopsis leidyi</i> | Comb jelly | Marine |
| <i>Molothrus spp</i> | cowbirds | Terrestrial |
| <i>Mytilopsis leucophaeata</i> | False dark mussel | Marine |
| <i>Ochlerotatus japonicus japonicus</i> | Asian bush mosquito | Terrestrial |
| <i>Odontella sinensis</i> | Chinese diatom | Marine |
| <i>Otiorhynchus porcatus</i> | None identified | Terrestrial |
| <i>Palaemon macrodactylus</i> | Migrant prawn | Marine |
| <i>Paralithodes camtschaticus</i> | Red king crab | Marine |
| <i>Pelophylax kl. esculenta</i> | Edible frog | Freshwater |
| <i>Pelophylax ridibundus</i> | Marsh frog | Freshwater |
| <i>Pittosporum undulatum</i> | Sweet pittosporum | Terrestrial |
| <i>Polygonum perfoliatum</i> | Mile-a-minute-weed | Terrestrial |
| <i>Pontogammarus robustoides</i> | None identified | Freshwater |
| <i>Potamocorbula amurensis</i> | brackish-water corbula | Freshwater |
| <i>Prokelisia marginata</i> | Spartina planthopper | Terrestrial |
| <i>Psittacula eupatria</i> | Alexandrine parakeet | Terrestrial |

| Species | Common Name(s) | Environment |
|--|-------------------------|-------------|
| <i>Pueraria montana</i> var. <i>lobata</i> | Kudzu | Terrestrial |
| <i>Reticulitermes lucifugus</i> | Mediterranean termite | Terrestrial |
| <i>Rhithropanopeus harrisii</i> | Estuarine mud crab | Marine |
| <i>Rhopilema nomadica</i> | Nomad jellyfish | Marine |
| <i>Rosa bracteata</i> | Macartney rose | Terrestrial |
| <i>Rusa timorensis</i> | Rusa deer | Terrestrial |
| <i>Sabella spallanzanii</i> | European fan worm | Marine |
| <i>Salvelinus namaycush</i> | Lake trout | Freshwater |
| <i>Selenochlamys ysbryda</i> | Ghost slug | Terrestrial |
| <i>Setaria verticillata</i> | Bristly foxtail | Terrestrial |
| <i>Sicyos angulatus</i> | Burcucumber | Terrestrial |
| <i>Solidago nemoralis</i> | Grey goldenrod | Terrestrial |
| <i>Solidobalanus fallax</i> | Warm-water barnacle | Marine |
| <i>Spodoptera littoralis</i> | African cotton leafworm | Terrestrial |
| <i>Tetropium castaneum</i> | Black spruce beetle | Terrestrial |
| <i>Tomicus piniperda</i> | Pine shoot beetle | Terrestrial |
| <i>Triadica sebifera</i> | Chinese tallow tree | Terrestrial |
| <i>Trichosurus vulpecula</i> | Brushtail possum | Terrestrial |
| <i>Wasmannia auropunctata</i> | Electric ant | Terrestrial |
| <i>Watersipora subtorquata</i> | None identified | Marine |
| <i>Xenopus laevis</i> | African clawed toad | Freshwater |
| <i>Zamenis longissimus</i> | Aesculapian snake | Terrestrial |



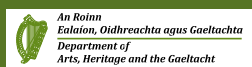
National Biodiversity Data Centre

Documenting Ireland's Wildlife



Beechfield House
WIT West Campus
Carriganore
Waterford

tel: +353 (0)51 306 240
email: info@biodiversityireland.ie
web: www.biodiversityireland.ie



The National Biodiversity Data Centre is an initiative of the Heritage Council and is funded by the Heritage Council and the National Parks and Wildlife Service of the Department of Arts, Heritage and the Gaeltacht.



The National Biodiversity Data Centre is operated by Compass Informatics Limited under a Service Level Agreement with the Heritage Council.