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Efficiency of policy measures for managing the introduction pathways of alien species in Estonia

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Species that are found out of their natural habitats can collectively be referred as alien species. Many of them are very useful for providing people benefits like food or shelter. Some introduced species, however, can become very harmful in new environments. They pose threats to other species, whole ecosystems and human health. They also impact the economy by e.g. causing losses in agriculture, forestry, and can affect water resources or recreation. These species are called invasive alien species (IAS). IAS are considered one of the biggest threats to biodiversity next to habitat loss and fragmentation, pollution, overuse of resources and global change. Rapidly growing trade and tourism have dramatically boosted the movement of species to places where they have never occurred. In addition, alien species problems are accelerated by the growing impact of climate change. Preventing the international movement of alien species and detecting their presence as early as possible is less costly than controlling their spread and eradication later. IAS spread to new areas through numerous pathways both intentionally and unintentionally. Some pathways are well regulated by international and national standards (plant and animal pests) but most are either partly or not regulated at all. The Convention on Biological Diversity has emphasized the urgent need to deal with unidentified pathways (identification and control). Estonia, as a member of the European Union (EU), faces challenges derived from its common market and free movement of goods (making movement of harmful organism easy). Unfortunately the EU has no common harmonized legislation, control or monitoring measures in place sufficient to deal with alien species. This way species introduced in other parts of Europe can also easily reach Estonia. Alien species problems in Estonia are not much different from other parts of the world: plant pests and animal diseases are regulated, but many other pathways are un-covered or even unidentified. An institutional framework exists but not all the issues are dealt with and there is a need for further cooperation and awareness about the issue. Identification and efficient control of alien species introduction pathways leads to a better overview of the problems and helps to put into place legal and policy measures that can, if not prevent, then least mitigate the potential harm that alien species cause.

Keywords: alien species, invasive alien species, non-native species, exotic species, introduction pathways of alien species, managing alien species introductions, threat reduction assessment (TRA).

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List of Abbreviations

BSASD	Baltic Sea Alien Species Database
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DAISIE	Delivering Alien Invasive Species Inventories for Europe
EASD	Estonian Alien Species Database
EPPO	European and Mediterranean Plant Protection Organization
EC	European Commission
EU	European Union
GISP	Global Invasive Species Programme
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
IAS	Invasive Alien Species
IMO	International Maritime Organisation
IPPC	International Plant Protection Convention
IUCN	The World Conservation Union.
MoE	Ministry of Environment (Estonia)
NOBANIS	The North European and Baltic Network on Invasive Alien Species
PPI	Plant Production Inspectorate (Estonia)
TRA	Threat Reduction Assessment
VFB	Veterinary and Food Board (Estonia)
WTO	World Trade Organisation

1. Introduction

Species that are found outside their natural areas are collectively referred as alien species. They find their way to new environments usually with intentional or unintentional help of human beings. These species are often very beneficial such as agricultural, forestry of ornamental species, providing people food, shelter or aesthetic beauty. However, not all the species introduced are benign. Some of them, upon the arrival into new environments, are able to naturalize, spread and become harmful to local biodiversity, human health or economy. Such species are called invasive alien species. About 10% of all introduced species can become naturalized in new areas, and out of these 10% will become invasive (Williamson 1996). Even though a small proportion of species becomes invasive, their negative impacts have been proven to be very big. Global Invasive Species Database (2008) estimates that the impact of invasive alien species to the global economy accounts for 5%, that is ca. 1.4 trillion US dollars. In addition, alien species are blamed to cause 40% of all animal extinctions. This is a considerable impact that cannot go unnoticed. Growth of global trade, travel and transport, as the main drivers behind invasions, continue to boost further introductions. Mr. Achim Steiner, Executive Director of the United Nations Environment Programme (UNEP), said on 22 May 2009, on the International Day of Biodiversity: "Alien invasive species have for too long been given a free ride — raising awareness among policy makers and the public and accelerating a comprehensive response is long overdue." Therefore more attention and more measures need to be taken to manage biological invasions (CBD 2009).

The problem of alien species has been gaining more attention also from the European Union, who is currently preparing The EU Strategy on Invasive Alien Species. The total monetary costs of invasive species in the EU have been estimated to be 12.7 billion EUR annually (EC 2008). The EU is encouraging its member states to deal seriously with alien species issues. The common market and free movement of goods in the EU, however, complicate the management of species introductions. There are more than 900 alien species in Estonia, and it is estimated that more than 4.7% of them are invasive (Ööpik 2007). The species causing the biggest harm in the nature are e.g. giant hogweeds, American mink and racoon dog, Chinese sleeper, Canada goose, not to mention noxious weeds and pests in agriculture. Estonia is spending millions of kroons per year for eradicating giant hogweeds. The issue of alien species management in Estonia is therefore a very current topic.

Prevention of introductions and early detection of alien species are less costly that eradication and control later. Therefore, taking measures to avoid the introductions and detect invasions at their earliest stage should be the first priority. In order to do that, it is important to know how species enter the country and what their subsequent spread mechanisms are. These alien species movements are called introduction pathways – "human action or inaction that enables a species to enter and stay in a new area or situation where it can become invasive" (Young 2006). CBD refers to the introductions as movements of species within or between the countries or areas beyond of national jurisdiction. There are numerous ways how species can enter the new areas starting from sectoral introductions like agriculture, forestry, moving on to the transportation means like ships or planes, and finishing by escapes and natural spread. Global Invasive Species Database (GISD) lists for example more than 30 introduction pathways. These pathways are varying in their nature and it is hard to deal with each pathway separately, Hulme *et al* (2008) proposes easier method for the pathway classifications - "the six pathway approach", which should guide to better management of introductions. According to this approach, alien species can arrive into new areas via commodity, transport vector or by natural dispersal (where they are already alien) and spread subsequently through six pathways: release, escapes, contaminants, stowaways, corridors and unaided movements.

There has not been much research on alien species introduction pathways or their management efficiency in Estonia. Existing data is scattered between different scientists, institutions and databases. Therefore, current research tries to map alien species introduction pathways in Estonia and see which are contributing to the introductions the most and how they are managed. Threat Assessment Tool is used to evaluate general effectiveness of the management measures in different taxonomical groups. Then the "six pathway approach" is applied to the "worst species" to try to exemplify how effective in detail are the measures to try to manage the pathways. The institutional effectiveness on the border and beyond for managing the introduction pathways of alien species is also analysed. The gaps and inconsistencies are identified and recommendations for the better management and control of alien species introduction pathways in Estonia are given.

1.1 Research aims and objectives

The overall aim of this thesis is to propose a selection of more efficient measures (legal, policy, and voluntary) to control and prevent the introduction of alien species into Estonia by identifying the main pathways of alien species introductions. The objectives are:

1. Identify the main pathways of alien species introductions;
2. Assess the efficiency of existing management measures and institutional framework(s) to control these pathways;
3. Suggestions for further actions of managing the main pathways; (e.g. regulations, public awareness, institutional cooperation).

This work can be useful for policy makers in Estonia for improving alien species management measures. It also gives an overview of the alien species pathways and management framework in Estonia. The work would also contribute to the improvements of institutional framework(s) for alien species management and control.

2. Methodology

2.1 Overall research design, scope

Research is based on current available information about alien species and pathways of their movements on international, European and Estonian level. It covers all alien plant and animal species in Estonia, not only invasive ones that are the most problematic. This is because the conditions under which species can become invasive are very different and depend on numerous factors. Therefore all alien species in this paper are considered as potentially harmful, unless proven harmless.

Thesis is based on overall presentation of the research about alien species and their introduction pathways. This is followed by the introduction pathways analyses and effectiveness of legislative, institutional and other measures to control those pathways. Finally the gaps are determined and recommendations given. Pathway analysis has been conducted on currently listed species in available databases. These include plants, terrestrial vertebrates and invertebrates, also aquatic freshwater and marine species. Other life forms like viruses, fungi, bacteria etc. are mentioned in literature review but are not included in the analyses. Genetically modified organisms that can also have alien features are omitted from the research, since they are usually considered separately and they are another large area of research.

In addition to legislation analyses for alien species management, it was thought that the research would benefit from the assessment of the effectiveness of the measures that would give quantitative outcomes. To do that, Threat Reduction Assessment (TRA) tool was used, designed to evaluate the success of conservation projects. Further, the outcome of TRA method (species lists) was used to apply six pathways approach framework to assess the efficiency of management measures.

2.2 *Methods of data collection and analyses*

Overall data collection and tools used

Methods of data collection for the general research include analyses of different literature (books, journals), Internet sources, databases, legal acts, policy papers and newspapers. All known available databases were used for pathway analyses, and these included The North European and Baltic Network on Invasive Alien Species (NOBANIS), Estonian Alien Flora Database (EAFD), The Baltic Sea Alien Species Database (BSASD), Estonian Alien Species Database (EASD) and complementary comparison data for the European pathways was drawn from DAISIE (Delivering Alien Invasive Species Inventories for Europe) database. The problems encountered in this part of research were connected mainly with outdated or incomplete datasets in the databases.

To assess institutional and legislative effectiveness of alien species management, in addition to other sources, interviews and electronic correspondence with different officials, experts and scientists from the following institutions were carried through: Ministry of Environment, Estonian Tax and Customs Board, Veterinary and Food Board, Plant Protection Inspectorate, Marine Institute of University of Tartu, Institute of Agricultural and Environmental Sciences of University of Life Sciences, NGO Centre for Nature Conservation and Estonian Ornithological Society. The problems of data collection in this part of research were minimal, mostly connected with unanswered electronic enquiries.

TRA method for assessing success of alien species measures

For assessing legislative effectiveness of alien species management, as mentioned in previous section, a TRA tool was used. It was developed by Margoluis and Salafsky (2001), and it provides TRA index, an indicator of the degree to which a project has succeeded in reducing the threats to biodiversity. TRA tool was used because it can be easily interpreted be by conservation managers and it is useful if there is a need for a fast, low-cost assessment of a project's success, and if there is a lack of baseline studies, like in the case of alien species in Estonia. To calculate TRA index for Estonian alien species, a method of Margoluis and Salafsky (2001), amended by Anthony (2008), and further developed by current research, was used.

The area under consideration was the whole country (land and water). Instead of multiple sites, different species groups where chosen according to best available expert knowledge in Estonia: plant and marine species, terrestrial (birds, mammals) and freshwater vertebrates and invertebrates. As for the types of threats, alien species of a chosen group were considered as different threats. The category "% threat reduced" in the worksheet was allowed to have negative values as proposed by Anthony (2008), since it was clear from the start that alien species problems had been growing over the years. The time period of assessment was chosen from 1994 to 2009, because in 1994 nature conservation legislation had for the first time provisions about alien species (incl. that introduction of alien species into the nature is prohibited).

To get the data for the TRA index calculation, a survey was prepared and worksheets with explanatory notes compiled and emailed to the experts of above mentioned species groups. They were species groups experts from the following institutions: plants experts from Institute of Agricultural and Environmental Sciences of University of Life Sciences, freshwater invertebrates expert from Centre for Limnology of University of Life Sciences, marine species expert from Marine Institute of University of Tartu, mammals expert from Tallinn Zoo, birds expert from Estonian Ornithological Society, terrestrial invertebrate expert from the Natural History Museum of University of Tartu and freshwater vertebrate expert from NGO Centre for Nature Conservation. They were asked to fill in the worksheet with maximum 10 most harmful alien species in their area of their expertise. The worksheets completed by the experts were for plants, birds and marine species (with complete data sheets), for freshwater invertebrates and terrestrial vertebrates (with incomplete data sheets). Terrestrial invertebrate and freshwater vertebrate species experts did not answer in timely manner. Annex 1 for the explanatory notes and experts answer sheets. The biggest problem for this part of data collection was not getting the experts answers.

Using TRA data for pathway analysis

The list of the worst alien species from the TRA exercise was further used in pathway analysis part of this research. For that, six pathways approach by Hulme *et al* (2008) was used, dividing pathways into release, escape, contaminant, stowaway, corridor, and unaided introductions. This approach was chosen because it is the latest, widely accepted (also used by the European Commission in preparation of EU Strategy on Invasive Species) pathways framework, which tries to facilitate more efficient management of alien species. It groups pathways in a way that they can be better connected to specific management strategies (Figure 4.4). The approach was modified in order to take into account the species movement inside the country as well. Pathways analyses in previous section was used as a complementary sorce of information. Same experts were contacted as for the TRA and asked to fill in the data about the pathways of introductions. The introductions were limited to Estonia, the time period was limitless, and one species could be marked on several pathways. Marine species, freshwater invertebrate species and mammal experts filled in the questionnaires. The rest of the data about the pathways was based on literature research. Since TRA analysis did not include terrestrial invertebrates and freshwater vertebrates, they are not inlcuded in the table, however, where possible, they are considered. The main limits for this part of research were insufficient expert replies.

Methods of data analysis

The method for pathway analysis of alien species introductions for this research was conducted with the data converted from different databases (mentioned in section of methods for data collection) to MS Excel worksheet, analysed and information summarized into graphs and tables, mainly using the following data fields: year of introduction, area of origin, type of introduction (intentional/unintentional) pathway of introduction of alien species.

For the TRA exercise, the worksheets were collected from the experts, the author of this research did calculations and final TRA index was found out for the species groups that had complete worksheets – plants, birds and marine species. Some species in columns for criteria rankings (e.g. for plants, had the same ranking for intensity and urgency) had the same rankings; in that case mean was calculated.

For the combined TRA and pathways section, data collected from the experts and from the literature about the pathways of introduction was analysed - pathways prioritized according to their importance (weight of the species) and management measures of these pathways assessed.

2.3 Limitations of work

Overall limitations of the research can be considered the lack of sufficient data about alien species and their introduction pathways. There were problems with the lack and uneven information gained from the databases and the limited or no reply from the experts in some cases. Next paragraphs describe the main limitations of different parts of this research.

Databases are compiled differently and can be interpreted in various ways (e.g. species missing due to different interpretations of alien status). NOBANIS database, used as the main source for pathway analyses, was also lacking information (especially about the terrestrial invertebrate pathways) and the pathways listed were not systematic or specific enough to make more detailed assessments of the threats posed by them.

The TRA method raised also different methodological questions and problems, some of which concern the lack of data. From direct limitations, it can be pointed out that since the experts were contacted by email, there were some data interpretation issues. Method works best when there is a group of people together at the same time finding the agreement and the confusions can be solved on spot (Anthony 2008). Due to logistical reasons this, however, was not possible. Further problems arouse from the absence of scientific data, since some scientists refused to use the "gut feeling" and therefore they left some parts of questionnaire blank ("% threat reduced" for mammals and freshwater invertebrates). This prevented finalizing calculations of some worksheets. There was also a fear that the data is used to replace proper scientific research, which was explained would not be the case. One expert also pointed out that the method lacked a place where to state that the alien species can have also a useful ecological effect (e.g. *Dreissena polymorpha* is preventing Lake Peipsi from extensive eutrophication, by filtering the water and eating algae). Another expert specific limitation can be the difference of the idea of threat sizes between the experts.

The TRA method has also taxonomical limitations, since the TRA index in this research cannot be compared across different taxonomical groups. Thus, taxonomical groups can only be compared in terms of their overall TRA index values, i.e. weather mitigation efforts are more or less successful in one group compared to another. To be able to compare TRA values across all species, survey should have been area or habitat based. This however, was not possible, since some scientists could not agree on comparing groups to one another, only species.

As for applying and combining “the six pathway” framework with the TRA method there were also some limitations. The list of species was limited as data concerning terrestrial invertebrates and freshwater vertebrates was not included and the list for most problematic species in other groups might not be representative for all, more than 900, alien species found in Estonia.

3. Alien species and problems – from international to local

For thousands of years natural barriers including mountains, deserts and oceans have kept different parts of the world separate which has made it possible to develop unique selection of species and habitats that we can enjoy in today's world. People have greatly influenced ecosystems across the globe and it has taken us just a few centuries to conquer these natural barriers (IUCN 2000). Constantly growing human population, coupled with increasing consumption rates have taken us far beyond the sustainable usage of natural resources. Greatly growing world trade keeps up the consumption levels with huge amounts of cargo moving continuously from one part of the world to the other. With trade, transport or tourism, numerous organisms are moved to new locations where they do not occur naturally. Often these species are beneficial to people and are used in sectors like fishing, forestry, agriculture, and horticulture all over the world. For example, the six most common crops in the world: wheat, rice, corn, soy, barley and sorghum cover more than 40% of world's cropland, contribute 55% of non-meat calories for humans and provide more than 70% of the global animal feed (Arizona State University 2009). These crops, in addition to horticulture and forestry species, have been intentionally transported far away from their origin and changed through selection to fit to special conditions to provide us food, shelter, soil stabilization etc (Mooney 2005). But there is also other side of the coin – not all the introduced species are beneficial and they can have serious negative side effects and these are explained below.

3.1 Alien species and dimension of the problem

Species that are found out of their natural habitats can collectively be referred as alien species. There are many terms used for these species. They are called alien, foreign, non-indigenous, non-native, new, non-native, or exotic (Shine *et al* 2000). The Convention on Biological Diversity (CBD) in its guiding principles defines alien species as "a species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce" (CBD 2002). IUCN (2000) emphasizes the importance of human agency in introductions of alien species, which are either intentional like commerce in living organisms or unintentional when species move for example through "stowaways" (attached to people or transportation modes like cars, planes, trains and so on) (Van Dyke 2008).

The number of non-native species is hard to predict. However some numbers can be presented where estimates exist e.g. there are approx. 50,000 non-native species in the USA, out of these 2,000 species of weeds and 2,000 species of insects have invaded the country in last 500 years. Out of 20,000 introduced species in the UK almost 1,200 have naturalized (Van Dyke 2008). Today there are as many native species in New Zealand as alien. Many countries' flora consists of around 20% of non-native species. It is estimated that ca. 3% of ice-free surface of the earth is dominated by alien species (Mooney 2001).

Taken to new environments alien species can stay there for long periods and cause no problems. However, some of them are not so benign and these are the ones who become problematic by causing harm to biodiversity, natural resources, human health and economy. These species are called invasive alien species (IAS). By CBD (2002) "invasive alien species means an alien species whose introduction and/or spread threaten biological diversity". IUCN (2000) offers wider term: "invasive species means an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity".

Only a small number of species introduced to new environments become invasive. There is so called "tens rule" of biological invasions set by Williamson (1996). About 10% of the introduced species can become naturalized in new areas, and out of these 10% will become invasive. Even though a small amount of alien species becomes invasive, their negative impacts have been proven very big, and over time the effects magnify.

Conditions under how and when alien species can become invasive are different and species specific. Therefore it is suggested, and highlighted also in The Global Strategy on Invasive Alien Species by Global Invasive Species Programme (GISP 2008) that "every alien species needs to be considered potentially invasive, until convincing evidence indicates that it presents no such threat" (McNeely *et al* 2001).

The magnitude of the alien species problem is illustrated by the fact that they are considered to be one of the biggest threats to biological diversity next to habitat loss and fragmentation, pollution, overuse of natural resources and global change (Van Dyke 2008). According to CBD (2009), since seventeenth century, alien species have contributed to around 40% of known animal extinctions. CBD, being the main international body that deals with threats to global biodiversity, has taken alien species issue to be one of its main concerns. To emphasize its commitment to the problem, CBD parties chose invasive alien species to be the theme of the International Day on Biological Diversity in 22 May 2009 stating that invasive alien species are “one of the greatest threats to biodiversity, and to the ecological and economic well-being of society and the planet” (CBD 2009).

Some of the most infamous cases of large-scale IAS damage include water hyacinth *(Eichornia crassipes)* blocking Africa’s water ways and proliferating in lake Victoria, rats killing native birds on the islands of Pacific ocean, zebra mussel (*Dreissena polymorpha*) affecting native molluscs and electric power generation in the Great Lakes of the US and Canada. There are also new fatal organisms and diseases that are threatening human, animal and plant life in from temperate to tropical climates (McNeely 2005).

Historical dimension of alien species movements

Transport and trade are the main contributors to biological invasions. Humans have been trading animals and plants more than thousand years. Defining time for the invasive species movements is considered to be at the end of Middle Ages (from around 1500) when Americas were discovered and exploration and colonization took place. Steady rates of increase in introduced species in Europe are documented from 1800 (Figure 3.1). Same trends are observed in North America with plants (Hulme 2009).

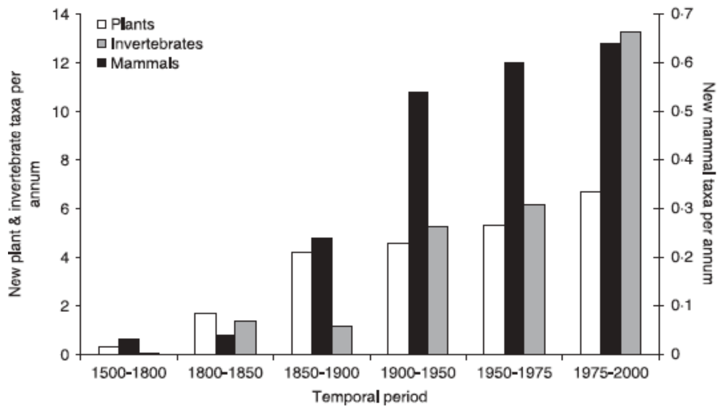


Figure 3.1. Annual increase of alien species in Europe since 1500. Source: Hulme 2009.

Second biggest wave of invasions happened with Industrial Revolution, when transportation and trade grew between continents and railways, canals, and roads were built and steam boats introduced. Invasions were boosted during 1820 to 1930 by 50 million Europeans who emigrated elsewhere to the world (McNeely 2006). Third and the most severe phase of invasions happened during last 25 years and is driven by globalization. The problem is expected to increase in the future (Hulme 2009).

3.2 Characteristics of IAS and the vulnerable environments

IAS are very common in all parts of the world, in all ecosystems, and in almost all taxonomic groups. Plants, trees and grasses provide good examples of IAS in terrestrial systems. Non-native algae, molluscs, and crustaceans often invade marine and coastal areas. Freshwater systems are mostly invaded by fish, invertebrates and aquatic weeds (CBD 2001). IAS show main following characteristics: 1) they can deliver seeds or breed at high rates/density at an opportune moments and places; 2) they are able to persist for long time at low densities under unfavourable conditions until better conditions arrive; 3) IAS are good ecological match for the environments and are often able to exploit local conditions better than native species (Van Dyke 2008). This characterization is not final and there are also many invasive species with different characteristics.

New environments often lack natural predators to keep the incomers under control. The chances for a species to become invasive are higher when area is similar to its native range (CBD 2009). Some ecosystems are more vulnerable than others. These are geographically and evolutionarily isolated areas like small oceanic islands, lakes, streams, and mountain ranges. Areas that are affected from human disturbance are also invasion prone.

These are urban-industrial areas, harbours, disturbed habitats, estuaries, water body edges etc. Low species diversity habitats are considered more susceptible to invasions than high diversity ones (species have established strong interactions) (McNeely *et al* 2001). Opposite opinion states that diverse ecosystems are more vulnerable, because they have higher resource heterogeneity for the invaders to benefit (Eriksson *et al* 2006; Westphal *et al* 2008). Human disturbance activities like agriculture or forestry are expanding constantly opening more ecosystems to invasions (McNeely *et al* 2001). One of the key aspects of the establishment of alien species into the environment is propagule pressure, referring to a degree to which ecosystem is exposed to different number of alien introductions (volume and frequency) (Hulme 2007). Overall, the degree the area is suffering from biological invasions depends on 1) ecosystem properties (resistance and disturbance levels); 2) propagule pressure; 3) invasive properties; and 4) native species ability to resist (Lonsdale 1999). Millennium Ecosystems

Assessment (2005) has drawn overview of main direct driving threats to biodiversity in different habitats (see Figure 3.2

Figure). As can be seen, island, coastal, inland water, and Mediterranean dry land habitats are affected the most, but the impacts are also growing on so far less impacted areas like boreal (incl. Estonia), temperate and tropical forests or tropical grasslands and savannas.

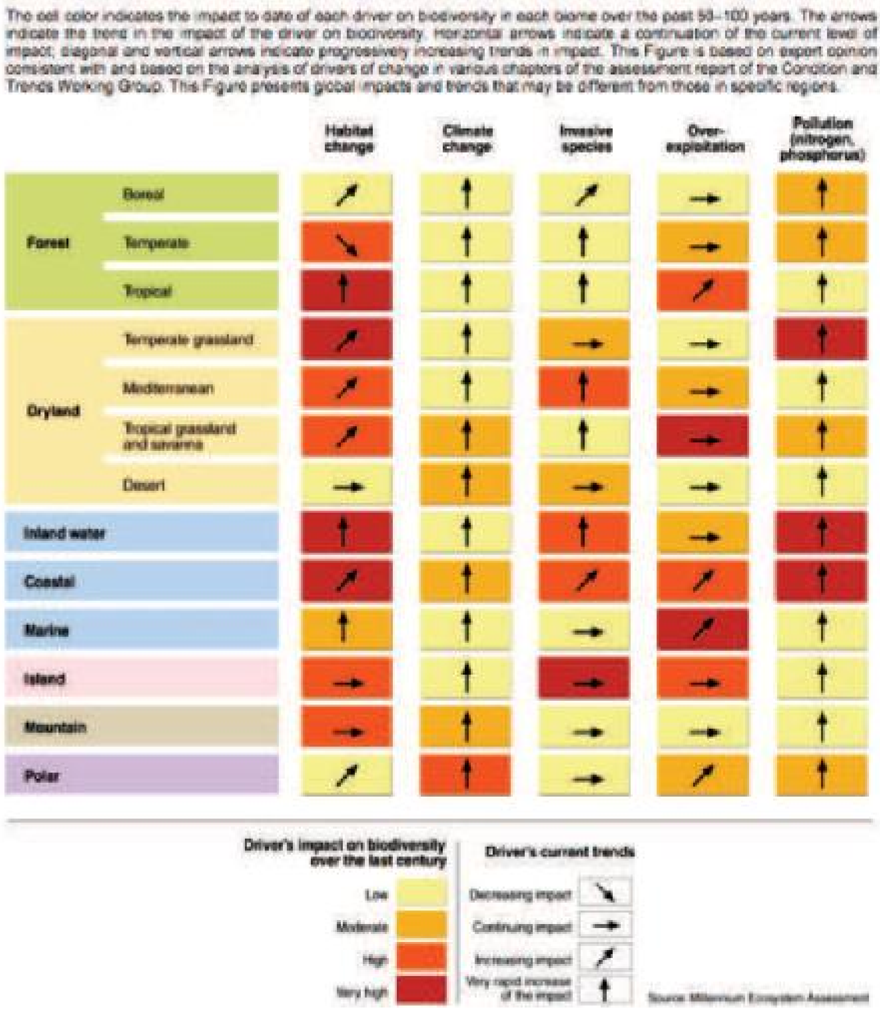


Figure 3.2. Threats to biodiversity. Source: Millennium Ecosystem Assessment 2005.

3.3 *Ecological, economical and human health effects of IAS*

IAS adverse ecological impacts include disturbing ecosystems and their functions e.g. altering forest fire cycles, nutrient and cycling, energy budgets, soil erosion and restoration, hydrology of the ecosystems (flood control), appearance and connectivity of habitats, crop pollination etc. IAS species specific impacts include out-competing and altering native species habitats, praying on local species or eating native flora, distribution of diseases and pathogens, hybridizing with local species and amplifying invasion effects with other alien species (Mooney 2005). Pimentel *et al* (2005) points out that IAS are threat to 42% of the endangered species. McNeely (2001) states pessimistically that if future invasions are to be grown significantly it would lead to homogenized world rather that the one that would be rich in biodiversity with distinctive species and ecosystems.

Alien species have many negative impacts on society's economies. IAS weeds lessen crop yields and increase the costs due to weed control. Introduced pathogens and pests destroy or reduce growth of crops, plants or trees. IAS in the nature parks degrade natural habitats and make the management more costly (McNeely 2006). Management costs of IAS are direct costs. Much bigger are indirect costs like non-market values and environmental consequences. Above-mentioned ecological services have both current use value and potential future value (option value). Concerning IAS there is a big area of uncertainty about the estimates of total economic costs (McNeely 2005).

According to Global Invasive Species Database (2008), the damage and costs of IAS is calculated to be 1.4 trillion USD annually, accounting for ca 5% of the world's GDP. IAS costs in the USA are estimated to cause major economic losses, adding up to 120 billion USD yearly (Pimentel *et al* 2005). In 1991 United States Department of Agriculture estimated the crop losses of weeds to be around 20 billion USD (50 to 57% due to IAS weeds) (Olson 2006). According to European Commission (2008) the costs to control IAS to EU (underestimated) are 12 000 million EUR per year. According to Arizona State University (2009) calculations the damage of IAS to agriculture in different countries is: 53% in the US, 31% in UK and 48% in Australia, 96% in South Africa, 78% in India and 112% in Brazil.

The dynamics of alien species effects on humans is complex and depends on many things like susceptibility of people, levels of development, settlement patterns etc. Malaria, dengue fever and other diseases have been spread by large projects like dams, irrigation schemes, land reclamation, and human resettlement. Opening up tropical forests has helped viruses to travel from wild hosts to humans (e.g. Argentine haemorrhage fever, Basia, Machupo, Guaranito viruses). Infectious diseases are often IAS transferred from animals to humans e.g. bird flu or West Nile virus. Exotic pests and pathogens can be blamed for the famine devastating crops or livestock. Bubonic plague carried by fleas from alien rats from Central Asia that millions of people in Europe and elsewhere; smallpox and measles spread from Europe after colonization of Americas and helped to bring down Inca and Aztec empires. Indirect health effects include usage of wide range of pesticides to get rid of alien weeds and pests (McNeely 2001).

3.4 Alien species interactions with global changes

Big global changes like habitat fragmentation, climate change and pollution affect resource availability and species distribution both in land and water ecosystems. Either by competition or affecting ecosystems, IAS interacts and feeds back to the global change elements (see Figure 3.2). Negative aspect of all the global change processes, however, is that most of them possibly favour biological invasions (Dukes and Mooney 1999).

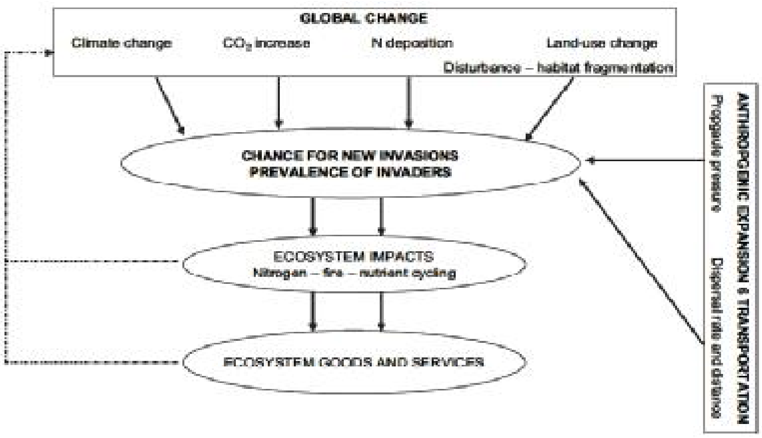


Figure 3.2. Global processes interactions with IAS. Source: Thullier 2007.

As climate change is currently a very urgent issue, considering its interactions with IAS is very topical. Climate change is helping IAS to conquer new areas and both factors interacting together can have devastating outcomes (Low 2008). Climate change can favour species that have traits like tolerance to disturbance, drier conditions and higher CO_2 levels etc (Thuiller *et al* 2007). Acting like disturbance factor, climate change can pave the way for the weeds and pests that colonize fast new disturbed areas (suffered from fires, floods etc) (Tim 2008). Thuiller *et al* (2007) also suggests that "climate change could alter almost very facet of invasion dynamics and every interaction between different factors", e.g. IAS have first quiescent phase with not much dispersion and then have expansion phase where they reproduce very rapidly. Climate change might trigger this rapid phase.

In order to survive with changing climate, many species have to relocate to higher latitudes, which can be noxious weeds, ornamentals escaping gardens or insects carrying diseases. The rate of species movements, however, will exceed the natural capacity of many species to do so. Plants will be more unfavoured than animals. IAS with their high dispersal rates, fecundity and human aided movement can have advantage in front of local species to keep the pace with the changing climate (Malcolm *et al* 2002). Climate change increases dynamism of communities, e.g. global warming is estimated to lead to higher turnover in European local communities (more than 40%) making them more susceptible to invasions. (Thuiller *et al* 2007).

Change can also negatively affect invasive species. Studies with plants from the USA (Bradley *et al* 2009) state that climate change can reduce the competitiveness of some IAS. It is important to follow the retreat of some species because that creates opportunities for restoration of native ones. This should be done before the new IAS might appear. This task is a future challenge for ecologists and land managers. Action could be taken in Europe for example with Japanese knotweed *(Fallopia Japonica)*, which is expected to shift northward with climate change (Dukes and Mooney 1999).

3.5 International agreements to deal with alien species

The volume of movements of goods with potential alien species in the world is so big that it requires international cooperation. Today, more than 50 intentional tools include alien species provisions, categorized in 3 big sections: 1) the longest existing ones protecting plant, animal and human life from pests and diseases by quarantine systems; 2) biodiversity focused agreements focusing on natural environment and; 3) technical measures to prevent IAS movement through trade and transport pathways (Shine *et al* 2005). The main ones are considered next.

- Convention on Biological Diversity (CBD 1992) is the only global treaty dealing with all IAS categories. Article 8h calls parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". IAS topic is also a crosscutting issue of CBD work programmes. In 2002 guiding principles to protect biodiversity against IAS were adopted, supporting three-stage approach dealing with IAS prevention of the introductions early determination, and eradiation if introductions cannot be avoided and stopping the spread and control of IAS as the last resort. Guiding principles consist of fifteen relevant points necessary to deal with IAS issue, including applying precautionary principle, ecosystems approach etc (CBD 2002). Estonia is a party to CBD.

- International Plant Protection Convention (IPPC) (1951) sets framework for activities to prevent the spread of pests that are harmful to plants and plant products (IPPC 1997). IAS species are listed as quarantine pests subject to control with the main focus on agriculture species causing economical harm. IPPC develops International Standards for Phytosanitary Measures (ISPM). IPPC has considered lately IAS effects also on natural environment (ISPM 5 and 11), but real measures are very few. IPPC regional office in Europe is European and Mediterranean Plant Protection Organization (EPPO) (Shine *at al* 2005). Estonia is a member of ICCP.

- The Office International des Epizooties (OIE) (intergovernmental organization) (1924) has standards on diseases for the trade with animals and products. It, however, does not cover animals that are invasive on their own right, but covers risks of wild species, that can be transferred from or to livestock from wild (Shine *et al* 2005).

- Convention on the Conservation of Migratory Species (CMS) (1979) states that there is a need to strictly control, prevent and minimize factors threatening migratory species. CMS has agreement on Conservation of African-Eurasian Migratory Waterbirds (AEWA) (2005) where IAS measures have been taken further. Estonia is party of CMS and AEWA.

- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (1973) does not directly deal with alien species issues. However, resolution 13.10 from 2004 states that parties should consider alien species issues when developing regulations on trade, with live animals and plants. Estonia is a member of CITES.

- Agreement Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) (1979) has been very active on IAS issues and it states that parties must strictly control the introduction of alien species (Art 11). Bern Convention has produced The European Strategy on Invasive Alien Species (2003). Estonia is a party of convention (Shine *et al* 2005).

Pathway and trade specific measures

- International Convention for the Control and Management of Ships' Ballast Water (BWM Convention) and Sediments of the International Maritime Organization (IMO) (2004), requires ships to undertake ballast water and sediments management in order to prevent, lessen and minimise the transfer of harmful aquatic organisms and pathogens. It will become in force after 30 states, with 35% of the gross tonnage of the world's merchant shipping, have ratified it (IMO 2004). As ballast waster is one of the biggest sources of IAS, its enforcement is crucial. By the end of 2008 only 17 countries with 15% of world's merchant fleet had ratified the convention (IMO 2008). Estonia has not yet ratified the convention, but the discussions and preparations have been going on for some years.

- UN Food and Agriculture Organization (FAO) has adopted several non-binding technical guidance covering also IAS. These include Code of Conduct for Responsible Fisheries (1995) covering effects of alien species on aquaculture. Technical guidance's are no. 2/1996 on precautionary approach to capture fisheries and species introductions, no. 5/1997 on aquaculture and code of conduct for exotic biological control agents from 1997.

- International Civil Aviation Organization (ICAO) has adopted resolutions that urge parties to support each other to minimize the risks of negative impacts of potentially invasive species via air traffic (Shine *et al* 2005).

- Trade related instruments are covered by World Trade Organization (WTO) regulations. Alien species issue is covered in WTO agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement 1995) and is relevant in the case of diseases and pests, where state may take measures against harmful organisms to protect human, animal and plant life or health. WTO accepts measures that follow IPPC, OIE or Codex Alimentarius Commission (food safety and human health). Most standards adopted do not take into account adequately the impacts on natural environment aspects (except for IPPC) (Shine *et al* 2005). In the absence of international standard, states can restrict trade based on scientific risk assessments witch are hardly practiced, due to burden of proof, because WTO is very cautious of hidden trade restrictions. Very often there is lack of scientific evidence and precautionary principle should be used, but measures taken based on that can be unacceptable for WTO. In addition trade laws do not cover domestic or unintentional part of IAS trade problems (Young 2006). Estonia is a member of WTO.

More specific overview about international and national measures applicable to Nordic and Baltic region can be found for example in www.nobanis.org.

Problems of international regime

Shortcomings of the international regime of alien species include lack of national capacity of legal and institutional frameworks, patchy application of instruments, and confusion around terminology. Liability and redress of environmental harm are not dealt with; risk assessment tools and funding are insufficient. Many measures are impractical because the species do not know political boundaries, instead approach that takes into account different bio-geographic regions should be considered. Problems arise with the species that might be harmful for one sector and resource for other (Riley 2005). Pathways that are generally poorly regulated, or not covered at all include hull fouling, freshwater introductions, live bait, aqua- and mariculture, inter basin water transport, pond and aquarium trade, scientific research, *ex-situ* animal breeding, forest planting, biocontrol, food and seed transport, humanitarian projects, development assistance, military actions, civil air transport and tourism. Dialogue on trade-related issues is undeveloped (Shine *et al* 2005; Miller *et al* 2006).

3.6 EU and alien species

Like any other part of the world, Europe is greatly affected by alien species. Although some authors suggest that Europe and its semi-natural ecosystems are more resistant to invasions due to long periods of human interactions and Europeans are more to be blamed to introduce their species to the rest of the world causing bigger damage. This position, however, is debated. The number of alien species introduced into Europe has been growing especially fast during the last 200 years with the Industrial Revolution, globalization and global change processes (Hulme 2007). There are 10 822 alien species identified in Europe (DAISIE 2008). As can be seen from Figure 3.4 most of them are terrestrial plants and invertebrates, or inland aquatic or marine species. It has been estimated that out of these 10-15% can have negative ecological or economic effects, many of them have multiple effects (EC 2008).

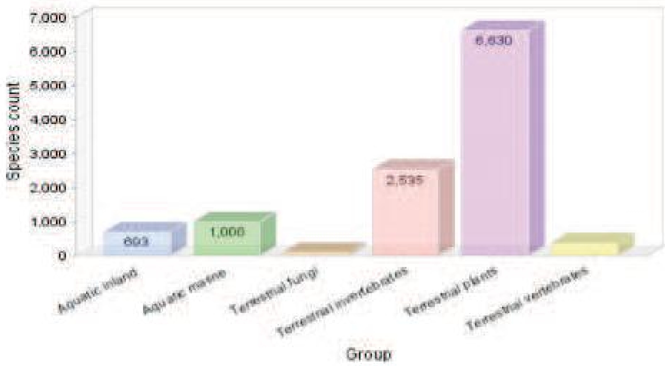


Figure 3.3. Alien species groups in Europe. Source: DAISIE 2008.

There are many species and ecosystems in Europe threatened by IAS. American mink *(Mustela vison)* has driven European mink near to extinction. Ruddy duck *(Oxyra jamaicensis)* is threatening native white-headed duck by hybridization. American gray squirrel *(Sciurus carolinensis)* can outcompete red squirrel. Crayfish plague *(Aphanomyces astaci)*, carried by alien crayfish, is threatening local crayfish species. European islands biodiversity is suffering from IAS effects. Fish parasites have greatly affected Nordic fisheries. Coypu *(Myocastor coypus)* and muskrat *(Ondatra zibethicus)* damage riverbanks and increase flood risks. American comb jelly *(Mnemiopsis leidyi)* has driven Azov and Black Sea sprat and anchovy resources to near extinction and has already arrived into the Baltic Sea. Japanese knotweed *(Fallopia japonica)* and giant hogweed *(Heracleum mantegazzianum)* compete with native plants, damage infrastructure and threaten human health. Annual ragweed *(Ambrosia artemisiifolia)* causes asthma and hay fever. Dense meadows of toxic algae *(Caulerpa taxifolia)* threaten Mediterranean costal ecosystems. American bullfrog *(Lithobates catesbeianus)* is a serious threat to native amphibians and ecosystems through competition, predation and distributors of diseases (European Strategy on IAS 2003).

Many IAS have caused great damage to European economy. Main impact has been damage to the ecosystems services that provide material flows and useful processes. Kettunen (2008) shows major harm from 125 species. From these, 57 cause damage to ecosystems services, 54 cause food provisioning losses (fish catch, livestock health, crop and wood production) and 3 species cause water provisioning losses (e.g. water hyacinth). There are species that cause erosion, alter fire cycles or damage infrastructures (e.g. Japanese knotweed) (EC 2008). Terrestrial vertebrates are considered to have the biggest economical impact followed by plants and invertebrates. Main costs in Europe are divided into control and eradication, forest and agricultural damage, fisheries loss, infrastructure damage and human health costs resulting from plant pests like fungi or insects, fouling organisms, allergens etc. These damages are e.g. to forestry by bark stripping by gray squirrel or to agriculture by western corn rootworm or by weeds like knotgrass or Bermuda buttercup (EC 2008). Total known monetary costs by the IAS are estimated to be about 12.7 billion EUR annually (Kettunen *at al* 2008). Some economic costs of alien species in Europe are listed in Annex 2.

3.6.1 Policy and legal context of IAS in the EU

While there are instruments for other major biodiversity threats like habitat loss or climate change, no comprehensive measure exists for alien species in the EU. Now, however, EU has recognized in highest political levels that more action is needed to tackle the IAS issues to be able to reach 2010 goal "halting the loss of biodiversity" of CBD and to lessen great economic losses of IAS. European Commission (EC) (2008) states that there is "a need for an EU strategy on invasive species and an effective early warning system and functioning response mechanisms at EU level". In fact Council Conclusions from May 2009 call for EU IAS strategy by 2010. Europe's number of countries, size and common market call for unified efforts to fight with IAS (European Strategy on IAS 2003). Trade is the major contributor of alien species and once placed on market, goods can move freely to all member states. Trade issues can be effectively dealt on the external border of the EU. Measures taken by one country can be abated if other states fail to take an action (EC 2008).

Although the EU does not have common legal framework on alien species, it touches topic in different legal acts. Main ones are wildlife trade regulation (338/97), plant health directive (2000/29/EC), veterinary legislation, and regulation concerning the use of non-native species in aquaculture (708/2007/EC). As can be seen from Table 3.1., there are many areas uncovered even in these acts (especially ecological, economical and human health issues) (EC 2008). Two nature conservation directives (92/43/EEC for habitats and 79/409/EEC for birds) only state that alien introductions should not harm local fauna and flora (EC 2008). EU members have different rules for biocontrol agents, which are mostly based on European and Mediterranean Plant Protection Organisation (EPPO) recommendations. EPPO gives guidance to most of plant health issues to EU, which are also recognised by WTO. EU international obligations concerning alien species are listed in Annex 3 (Hulme 2007).

Introduced species that might be threat to local species are briefly touched in wildlife trade regulations based on CITES convention, which allows to restrict species imports if it poses threat to native species. So far only four IAS are listed and are prohibited for imports to the EU, and these are American ruddy duck *(Oxyura jamaicensis)* the red-eared slider *(Trachemys scripta elegans)*, the American bullfrog *(Rana catesbeiana),* and the painted turtle *(Chrysemys picta)*. Spread of these species already present in the EU's territory, however, is not regulated (EC 2008).

Table 3.1. Alien species issues in relevant EU legislation. Source: EC 2008.

	Council Regulation 338/97	Directive 2000/29/EC	Veterinary Legislation	Council Regulation 708/2007
Legal basis	Article 130 S	Article 37	Article 37	Article 37
Ecological impact	////////////////*			X
Economic impact				X
Health (plant)		X		
Health (animal)			X	
Health (human)			//////////////////	
Special species group				X
Legal trade	X	X	X	X
Illegal trade				
Hitchhikers				
Border control measures in place	X	X	X	X
Assessment procedure established		X	X	

Dark zones = not regulated, X = regulated and ////////// = partial regulation

Although there are several alien species measures in the EU level, these are fragmented and inconsistent. Intentional introductions of alien species lack common risk analyses and unintentional introductions are mainly unregulated (EC 2008). EU law has its main focus on agricultural pests and diseases that affect plants and animals and farmed fish (aquaculture). It provides a good framework of measures harmonized with international livestock, phyto- and zoosanitary and trade rules. Procedures include biosecurity control by certification, quarantine measures, surveillance after import and spread control methods. Functioning of this system is based on known host and pest targets and clear economic benefits. It would be good bases for developing measures to regulate also the protection of natural environment. The challenge, however, is that the numbers of target species are orders of magnitudes bigger and economic benefits are more difficult to determine. Also measures that deal with pests and diseases have often proven to be ineffective for biodiversity protection (Hulme 2007).

Unregulated areas also include big sources of accidental introductions from forestry, agriculture, biocontrol, zoos and botanical garden species. There are not so many commitments for the eradication and control for already established species. Polluter pays principle is not applied where the agents of introductions should be responsible to undo the harm. Moreover, for alien species introductions, "polluter" is difficult to determine; most of the introductions are anonymous. Monitoring, identifying, reporting, and early warning of IAS are also quite poor (Hulme 2007). Risk assessments are poor e.g. EPPO estimates that 30 new horticulture species reach Europe every year without prior risk assessment. Different states also prioritise IAS issue differently. If uniform actions were taken, species introductions like zebra mussel to Baltic Sea, killer algae or comb jelly to Mediterranean Sea could have been prevented (Hulme 2007).

3.7 Alien species in Estonia

There is no systematic alien species data collection in Estonia. Institute of Agricultural and Environmental Sciences of the University of Life Sciences has most comprehensive data about plants (incl. trees). Marine Institute of Tartu University holds information about marine species. Many big organism groups, however, are uncovered (Eek and Kukk 2008). Estonian most comprehensive data about all major species groups can be drawn from The North European and Baltic Network on Invasive Alien Species database (NOBANIS) or from Nordic introduced species overviews (Ööpik *et al* 2008). University of Life Sciences list of neobiota is the most updated list for the alien plants (not public). For marine alien species Baltic Sea Alien Species Database gives the most up to date information (BSASD 2007).

3.7.1 Overview of alien species in Estonia

Species that are considered alien in Estonia have been introduced to the country by the end of last century. Plants are considered alien if they are introduced after the middle of the 18th century (Kull 2005). According to NOBANIS database, there are 940 alien species in Estonia (NOBANIS 2009). There are 924 species in Estonian Alien Species Database (EASD) (EASD 2009). The difference is probably because EASD is not updated. According to Ööpik (2007) out of all the alien species in Estonia 30% are naturalized and 4.7% have become invasive.

Next to 1538 native plants, there are 787 alien plants in Estonia (from 83 families and 381 genera). From all the neophytes 555 (see Table 3.2) have casual status (rely on repeated reintroductions), 232 have naturalized (non-invasive, reproduce over many life cycles without human intervention), and 37 are invasive. More species are introduced deliberately than accidentally. Invasive species are more often perennials and belong dominantly to *Rosaceae* or *Asteraceae* families (Ööpik *et al* 2008). The most vulnerable habitats to alien introductions are open habitats and dry meadows (Kull 2005).

Table 3.2. Classification of Estonian plants according to alien status. Source: Ööpik *et al* 2008.

Characteristic	Invasive status				
	All alien	Casual	All naturalised	Non-invasive	Invasive
No. of species	787	555	232	195	37
transition rates between stages (%)	100	70.5	29.5		
naturalised (%)				84.1	15.9
total (%)				24.8	4.7
Taxonomy					
no. of represented families	83	75	52	51	15
Origin (%)					
Europe	27.6	28.1	26.3	28.7	13.5
Eurasia	20.1	20.6	19.3	11.8	18.9
Eurosiberia	7.2	5.0	12.5	19.4	16.2
America	17.9	16.0	22.4	21.0	29.7
Asia	17.6	18.9	14.7	15.4	10.8
others	9.6	11.4	4.8	3.7	10.9
Introduction mode (%)					
deliberate	57	50	74	78	51
accidental	43	50	26	22	49
Life history (%)					
short-lived herbaceous	45	54	24	21	38
perennial herbaceous	33	29	41	41	46
shrubs and trees	22	17	35	38	16
Habitat preferences (%)					
only in human made	57	76	18	23	0
at least met in semi-natural/ natural	43	24	82	77	100

The worst invasive plant species in Estonia are hogweed species *(Heracleum sosnovskyi, Heracleum mantegazzianum)*. They spread very fast, threaten natural biodiversity and are poisonous to humans (its juice causes skin burns (blisters) and it emits toxic fumes). They are one of the few IAS species that have quite good distribution data collected and for which actual state eradication program is applied (see section 3.6.2 about resources allocated to alien species management). Figure 3.5 shows the distribution map of invasive hogweeds, counted in 1,100 colonies and in 1,200 hectares (MoE 2008).

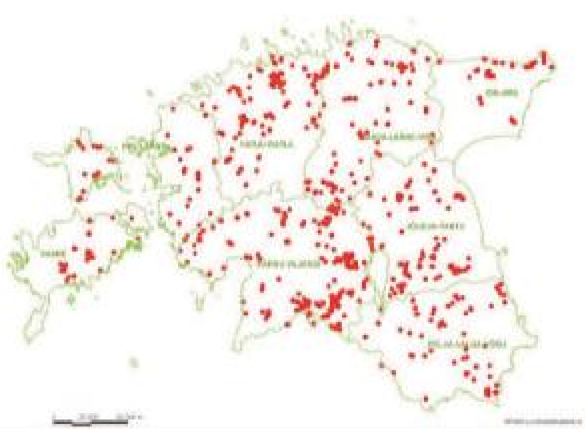


Figure 3.4. Colonies of giant hogweeds. Source: MoE 2008.

There are 13 species of alien birds listed in EASD and NOBANIS database. Out of them, common pigeon *(Columba livia)* is invasive, common pheasant *(Phasianus colchicus)* and Canadian goose *(Branta canadensis)* are marked as potentially invasive. Others are not considered problematic or they are random visitors. Common pheasant is released to the nature as a game bird and probably does not manage to survive winters, which might change with warming climate, although according to some birds experts, this will not happen in near future (Lilleleht. pers. comm.), others however, disagree. Canada goose is potentially the most problematic alien bird species, threatening local geese with hybridization and competition for food. It has not yet established permanent populations in Estonia (Kull 2005).

There are 60 mammal species in Estonia and out of those 5 or 6 are considered to be alien. Most problematic ones are American mink *(Mustela vison)* and raccoon dog *(Nyctereutes procyonoides).* American mink is responsible for outcompeting European mink and together with raccoon dog they are a great threat to small mammals and ground nesting birds. The former one is also vector for rabies. Eradication plan for raccoon dog is under development (will be ready by the end of 2009) (Eek pers. comm.). Species threatening Estonia, that have not yet arrived in the country are Canadian beaver *(Castor canadensis)* and gray squirrel *(Sciurus carolinensis).* They could phase out local European beaver *(Castor fiber)* and red squirrel *(Sciurus vulgaris)* accordingly (Kull 2005). From reptiles aggressive red-eared sliders *(Trachemys scripta*), disposed as s pets, can become problematic, since they are already local in Finland, and there have been cases where it has been able to survive the winter in Estonia (Eek and Kukk 2008).

The terrestrial invertebrates are the least researched group of species. However, attempts have been made to determine the alien status of some. There are 140 alien invertebrates listed in NOBANIS database (131 arthropods, 8 nematodes and 1 mollusc). There are seven species that are considered to be invasive, one potentially invasive, one not invasive and the rest are not specified. Most known species are e.g. Colorado potato beetle *(Leptinotarsa decemlineata)* harming potato fields and lately introduced potentially invasive earthworm *(Dendrobaena veneta)* used by anglers as a bait and can be bought from stores (Eek and Kukk 2008). One of the latest (from 2008) alien invertebrate findings is Spanish slug *(Arion lusitanicus)*, which has been spreading in neighbouring countries (Latvia, Finland). It is breeding fast, has a very wide food table, and can be devastating for different crops, garden plants, vegetables etc (Kiristaja 2008).

According to Baltic Sea Alien Species Database there are 121 alien species in the Baltic Sea, and about 79 of them have established and created viable populations. The most abundant are benthic and nectobenthic species. Most of them come from brackish-water or freshwater areas, mainly from North America or the Ponto-Caspian region (HELCOM 2009). Every year about 110 million tonnes of ballast water is released into the Baltic Sea, which is a big source of alien species introductions. The information about phyto- and zooplankton, and fish species is quite satisfactory, but data about smaller species is almost non-existent. The species with biggest impact to the Baltic Sea are soft-shell clam *(Mya arenaria),* waterflea *(Cercopagis pengoi)* and zebra mussel *(Dreissena polymorpha)* (Eek *et al* 2007) also American comb jelly *(Mnemiopsis leidyi)*, phytoplankton *(Prorocentrum minimum)* and polychaete *(Marenzelleria viridis)*. The most problematic fish species in the Baltic Sea is round goby *(Neogobius melanostomus)* (HELCOM 2009). All these species are also present in Estonian waters.

When we look at the whole aquatic environment in Estonia, there are 50 aquatic alien species in Estonian marine and in inland waters listed in NOBANIS database. Most of the species are invertebrates. There are 14 fish, 7 molluscs and 15 arthropods species. Freshwater species make up less than half of the aquatic aliens species. There are around 10 fish species that were introduced for aquaculture reasons in the past and at the moment they mostly do not pose a big threat. Potentially very problematic fish species in the future can be lately (in 2005) introduced Chinese sleeper *(Perccottus glenii)*. It can be very harmful to freshwater ecosystems due to its invasive features (tolerant to extreme conditions like the lack of oxygen, freezing and extreme pollution) (Tambets and Järvekülg 2005). In addition, alien crayfish species can threaten the only native crayfish *(Astacus astacus)* species in Estonia by out-competing and spreading crayfish plague. These species are signal crayfish *(Pacifastacus leniusculus)* and narrow-clawed crayfish *(Astacus leptodactylus)* (these are not yet established, but are present in neighbouring countries and are also imported into the supermarkets (Kaldre *et al* 2007). In 2008, first specimen of signal crayfish has been found in the nature in Estonia (Eek pers. comm.). Zebra mussel *(Dreissena polymorpha)* and amphipod *(Gmelinoides fasciatus)* are also listed as problematic invasive alien species. However, zebra mussel can be also useful in eutrophication relief of some polluted water bodies (Timm pers. comm.)

3.7.2 Measures taken in Estonia about alien species

There are several legal acts that directly or indirectly deal with alien species in Estonia. The most explicit ones include Nature Conservation Law, Forestry Law, and Fisheries Law. The main act dealing with alien species is Nature Conservation Law (2006) according to which (§ 57) it is prohibited to release alien species in the nature. It is also not allowed (§ 58) to release the specimens of local species brought from abroad (e.g. alien populations) into the nature. The same law (§ 49) allows eradicating harmful species based on eradication plan. Minister of Environment has also adopted a regulation (7.10.2004 no. 126) about alien species whose live specimens are prohibited for imports into the country. The list includes 13 plants and hybrids, 11 mammals, 1 bird, 11 fish (mostly aquarium species), 3 crayfish and 4 other invertebrate species (see Table 3.3 next page). These species cannot be imported into Estonia even for keeping in containment (except for scientific purposes with special permits from the Ministry of Environment) (List of species threatening… 2004). Minister has not issued any permits so far, even not to botanical gardens and zoos, although these species are kept there. Many of the listed species are already in the country, many species are not yet found in Estonia. The latter ones are in the list for preventative reasons because of their potential invasiveness (danger from neighbouring countries). The racoon dog and American mink are in the list with a special status and they are allowed to be kept in farms (except on the islands) with strict rules for buildings, fencing and cages set by the Minister of Environment. New animals can only be imported with permits and only for blood renewal (not more than 10% from the total number of animals kept in the farm per one year) (Eek and Kukk 2008).

Table 3.3. Alien species prohibited to import to the country.

Source: List of species threatening… 2004.

	Latin name	Common name
	Plants	
1	*Heracleum mantegazzianum*	Giant Hogweed
2	*Heracleum sosnowskyi*	Sosnowskyi Hogweed
3	*Acroptilon repens*	Russian knapweed
4	*Ambrosia spp*	Ragweed species
5	*Bidens frondosa*	Devil's Beggarticks
6	*Impatiens glandulifera*	Himalayan Balsam
7	*Solidago canadensis*	Canada goldenrod
8	*Solidago gigantea*	Giant goldenrod
9	*Reynoutria japonica (syn Fallopia japonica, Polygonum cuspidatum)*	Japanese knotweed
10	*Reynoutria sachalinensis (syn. Fallopia sachalinensis)*	Giant knotweed
11	*Reynoutria × bohemica*	Hybrif of previous two species
12	*Egeria densa*	Brazilian waterweed
13	*Elodea nuttallii*	Western waterweed
	Vertebrates	
14	*Castor canadensis*	Canadian beaver
15	*Cervus nippon*	Sika Deer
16	*Dama dama*	Fallow Deer
17	*Lutra canadensis*	Northern River Otter
18	*Mustela vison*	American Mink
19	*Nyctereutes procyonoides*	Raccoon Dog
20	*Odocoileus virginianus*	White-tailed deer
21	*Ondatra zibethicus*	Muskrat
22	*Oryctolagus cuniculus*	European Rabbit
23	*Ovis ammon*	Argali or mountain sheep
24	*Sciurus carolinensis*	Gray squirrel
25	*Oxyura jamaicensis*	Ruddy duck
26	*Umbra pygmaea*	Eastern mudminnow
27	*Pseudorasbora parva*	Stone moroko
28	*Opsariichthys uncirostris*	Three-lips
29	*Ameiurus nebulosus*	Brown bullhead
30	*Ameiurus melas*	Black bullhead
31	*Lepomis auritus*	Redbreast sunfish
32	*Lepomis gibbosus*	Pumpkinseed
33	*Lepomis macrochiru*	Bluegill
34	*Perccottus glenii*	Chinese sleeper
35	*Neogobius fluviatilis*	Monkey goby
36	*Neogobius gymnotrachelus*	Racer goby
	Invertebrates	
37	*Astacus leptodactylus*	Narrow clawed crayfish
38	*Orconectes limosus*	Spinycheek crayfish
39	*Pacifascatus leniusculus*	Dignal crayfish
40	*Globodera rostochiensis*	Yellow potato cyst nematode
41	*Bursaphelenchus xylopilus*	Pinewood nematode
42	*Hyphantria cunea*	Fall webworm
43	*Megachile rotundata (syn. Apis pacifica)*	Alfalfa leafcutter bee

The same law also determines the sanctions for violation of alien species provisions and the fines can be up to 18,000 EEK (1,153 EUR) or arrest (for legal persons the fine is up to 50,000 EEK (3,205 EUR)). In addition, there is fine for causing deterioration of natural environment and this is between 200 and 100,000 EEK (12.8 to 6,410 EUR) per alien species. According to Eek (pers. comm.) a new legal act with higher fines has been prepared and will be adopted during 2009.

Preventing animal escapes from the zoos and animal parks is also legally covered. Zoos and animal parks have to have permits from Environmental Board. For that they have to follow the rules for the cages and buildings set by the government Regulation on requirements for the planning and the buildings for keeping animals in zoos (2004).

When Nature Conservation Law prohibits the release of alien species in the nature, then Forestry Law gives an exception for that in the case of 13 alien tree species that are allowed to use for reforestation (4.12.2006 regulation no. 69 by Minister of Environment). These species are: 1) Black Spruce *(Picea mariana)*; 2) Serbian Spruce *(Picea omorika)*; Lodgepole Pine *(Pinus contorta)*; 4) European Larch *(Larix decidua)*; 5) Siberian Larch *(Larix sibirica)*; 6) Variety of Siberian and Russian Larch *(Larix sibirica var. rossica)*; 7) Japanese Larch *(Larix kaempferi)*; 8) Kurile Larch *(Larix gmelinii var. japonica)*; 9) Hybrid Larch or Dunkeld Larch *(Larix x eurolepis)*; 10) Douglas Fir *(Pseudotsuga menziesii)*; 11) Siberian Fir *(Abies sibirica)*; 12) The Northern Red Oak *(Quercus rubra)*; 13) Hybrid aspen *(Populus x wettsteini).*

Fisheries Law (§ 22) (2005) states that it is only allowed to import live specimens of non-native fish or other aquatic organisms and their fertilized eggs with the permit of Minister of Environment. The EU regulation concerning the use of non-native species in aquaculture (708/2007EC) is also directly applicable to Estonia.

It is prohibited to import and spread dangerous plants and plant pests according to Estonian plant protection legislation that is based on EU Directive 2000/29/EC (Directive on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community). Harmful organisms are animals, plants, viruses, mycoplasms or other pathogens. Directive covers the species that mostly have high economic importance (EC DG Health and… 2009). The species listed in the directive might be, but are not necessarily alien species. Principles of the directive are laid down by IPPC and accepted by the WTO SPS Agreement (see international obligations in section 3.4). Restricting the movement of any other species might be considered as breaching the international law by WTO (Eek and Kukk 2008). So, if Estonia would like to restrict movement of additional species e.g. alien species but it is lacking proper risk assessment, then it might face possible problems with WTO.

Many different institutions have responsibilities in connection with different areas of alien species management. Ministry of Environment (MoE) deals with developing legal acts and policy measures for alien species. Estonian Environment Information Centre is responsible for data gathering and information sharing. Environmental Board deals with alien species action plans and eradication measures. Environmental Inspectorate controls legal compliance to laws and regulations. Plant Production Inspectorate (PPI) deals with control of plants and plant products. Veterinary and Food Board (VFB) deals with animal health, food and feed issues. PPI and VFB are also present on border, together with the Estonian Tax and Customs Board to control the imports of plants and animals and the products made of them.

Resources allocated to alien species management in Estonia

The focal state agency dealing with alien species in Estonia is Ministry of Environment (MoE). Its responsibility is coordination of alien species issues in state and international level, including legal and policy matters, information sharing etc. During previous three years the resources available in the budget of Ministry of Environment have been less than 100,000 Estonian kroons (EEK) (1,500 EUR) per year. The money has been used to issue alien species book, pay for expert opinions (e.g. about crayfish plague), compile management plans for IAS species (e.g. for raccoon dog) compile reports, attend international conferences etc. (Eek pers. comm.). Environmental Board is responsible for practical management and eradication of IAS. So far only eradication of poisonous hogweed species has taken place. The eradication program has been financed by Environmental Investment Center and the following sums have been spent on eradication: 2.2 mil EEK in 2005, 3 mil EEK in 2006, 4 mil in 2007, 6.8 in 2008 and 4.6 mil is allocated for 2009. Program has managed to eradicate from 400 to 600 ha of hogweeds (out of 1,200 hectares) over the years (Environmental Investment Centre 2009).

3.8 Threat Reduction Assessment (TRA) for alien species

Often management measures efficiency or implementation success is assessed descriptively in various reports and overviews. Legislative and policy tools are described and assessed also in current research. In addition, it was decided to assess, how much alien species tools had been working in reality. For that, the Threat Reduction Assessment (TRA) tool was used (see methodology section), since it was fast and easy method to show if the measures taken have had some effects mitigating the threats posed by alien species. Anthony (2008) emphasizes that the main principle of TRA tool is to show that if the threats have been mitigated then management measures have been successful, if not, the management has failed. The tool is simple, fast, can merely be based on expert opinions, and does not have to be packed up by extensive scientific research.

Results of TRA

The TRA index for some species groups was calculated, depending on the feedbacks and inputs from the scientists. The TRA index for the marine species was -75% for which 8 most harmful species were listed (but 7 used for index calculations, since *Eriocheir sinensis* had incomplete dataset). The highest-ranking species were *Cercopagis pengoi, Marenzelleria spp* and *Neogobius melanostomus.* The TRA for the plants was –17%, for that 10+2 species were listed *(Heracleum* and *Aster* had 2 species listed in family). Aliens with the highest rankings were *Heracleum sp*, *Lupinus polyphyllus*, *Solidago canadensis* and *Galega orientalis.* The TRA for the birds had the highest negative index (-121%). For that 4 species were listed and *Columba livia (f. domestica)* and *Cygnys olor* had the highest rankings. From uncompleted worksheets, alien freshwater invertebrates had 5 species listed out of which *Gmelinoides fasciatus* and *Dreissena polymorpha* had the highest rankings. Six alien mammal species were listed and *Neovison vison* and *Nyctereutes procyonoides* had the highest rankings**.** See Annex I for specific results.

Discussion

Calculated TRA indices give a rough overview how the threats from different species groups have changed since 1994. As can be seen, all TRA's indices have negative values meaning that threats have been rising as the numbers of these alien species in these groups have mostly increased. Overall only two plants, *Heracleum spp* and *Elodea Canadensis*, have decreased in abundance, and only for *Heracleum spp* state eradication measures have been applied. When we look at the TRA indices for different species groups: birds (–121%), marine species (–75%) and plants (–17%), it looks that the mitigation measures taken over the years have been working the least on birds, followed by the marine species and then plants. All together it can be seen that measures taken to prevent and manage the alien species introduction and spread by the state have not been sufficient to stop the introduction of new and spread of the existing alien species. TRA exercise gave in addition to TRA index also a useful overview of the most problematic species considered by the species group experts.

It can be concluded that despite its general nature TRA method gave a measurable proof how the legislative measures have worked (rather not worked) in preventing the spread and introduction of alien species in Estonia. It also showed that only one intervention (in the case of eradicating *Heracleum spp*) had actually reduced the threat of the species. Alien species management and trials to reduce the threats by legislation, are, however very challenging, since there are many intentional and unintentional introductions that are hard to control, also many species can have very negative impacts, but it is impossible (or not feasible) to do anything about them (especially in the case of aquatic species). Many species introductions also depend on not only national, but also international law (e.g. ballast waters), so the problem might increase despite efforts taken locally. Another issue to consider here would be to imagine the current situation if the existing measures would not be taken at all.

4. Pathways of alien species introductions

Drivers behind invasions – income growth, transport and trade

The two main drivers of globalization, income growth and transport efficiency influence biological invasions greatly (Hulme 2009). The global number of alien species, their movement, and taxonomic or geographic distribution is in strong correlation with human trade and transport (Perrings *et al* 2005; Meyerson and Mooney 2007; Westphal *at al* 2008). A good invasions indicator can also be GDP (See Figure 4.1), which is connected to exports and capital investments like infrastructure (canals, roads, railways) that are good invasion pathways (Hulme 2009). GDP has grown 70% and 110% in last 25 years in developing and developed countries accordingly (UNCTAD 2007). Although economic growth and invasions are related, not much has been done to tackle the issue (Dasgupta 2007). Alien species numbers also correlate with the commodity sectors like horticulture, aquarium trade, grain shipments, or wild-birds trade (Hulme 2009).

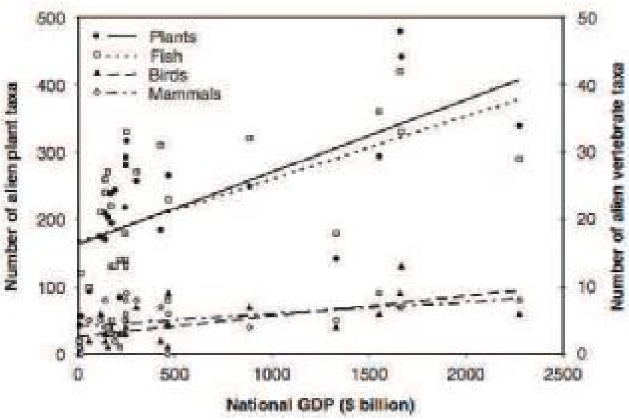


Figure 4.1. Link between GDP and alien species in 25 European states. Source: Hulme 2009.

In order to assess the invasions risks it is relevant to know the mechanisms, frequency, volume, destination, and origin of imports (Hulme 2009). Half of the world trade is dry cargo (UNCTAD 2007), which is very heterogeneous and poses invasion risks. World cargo is mostly carried by the sea (90%) with more than 50,000 ships with millions of tons of cargo daily (IMO 2008). Global cargo carrying fleet has grown four and air freight eight fold since 1970s (Figure 4.2).

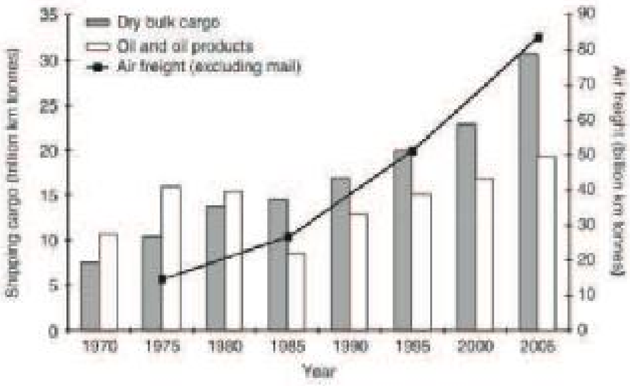


Figure 4.2. Change in world shipping and airfreight. Source: UNCTAD 2007.

In 2007 a record of 4.8 billion passengers travelled, 76.4 million planes took off, and 88.5 million metric tonnes of cargo were carried through world airports (ACI 2007). Table 4.1 shows that airports provide more penetration to environments than seaports. Out of 725,000 pest interceptions (in 1984 to 2000) in the USA, 73% occurred in airports and only 9% in seaports (McCullough *et al* 2006). However, greater risks from ships are not connected to cargo but to ballast waters and hull fouling. Former alone is estimated to carry 10,000 species daily (Streftaris *et al* 2005). Number of ports, volume of goods and frequency of visits influence the invasion risks (Hulme 2009).

Table 4.1. Transport networks and ports of entry to world regions. Data source: Hulme 2009.

		Length of transport network (km)			No. of ports of entry	
Region	Area (km²)	Roads	Rail	Inland canals	Seaports	Airports
Asia	48 670 642	7 301 968	410 410	160 259	179	4735
Africa	30 092 557	1 691 297	81 867	55 264	210	4571
Americas						
North	21 321 300	7 334 867	342 648	469 099	52	18 473
Central	758 883	204 122	18 889	6 452	118	1 752
South	17 818 505	2 399 260	87 586	104 793	98	1 797
Europe	5 952 610	5 996 840	285 852	22 520	134	2 427
Oceania	8 509 148	967 624	45 842	21 125	78	1 335

Besides the entry points, species are distributed in new regions by canals, roads, rails or even pipelines with transit of vehicles and goods. Road transport has constantly grown and is proven to be in correlation with higher number of alien species. Road and rail density is very high in Europe (Table 4.1) (Hulme 2009).

Towards management of biological invasions

Invasion assessments should be easy when goods traded, their origin, destination and suitability of receiving environment is known. Trade data however, has proven to be unreliable for real time risk assessment (Tatem *et al* 2006). Trade is temporally and spatially dynamic, changing in origins, destinations, types, volumes and methods of transfer (packaging, storage, handling). Although being main component of pathways management, it is very challenging to follow trade dynamics (Ruiz and Carlton 2003). Unregulated unintentional introductions make it even harder (Hulme *et al* 2008). Concentrating management only on species is also complicated. Species distributions are dynamic, depending on human transfers and environmental change. It is hard to predict invasion success and ecological effects of the species even if supply and species are known (e.g. species ecology is unknown or its behaviour in new area is very different from area of origin). Many times there is not enough knowledge of the species that are transferred (e.g. ballast waters can move hundreds of unknown species to new areas) (Ruiz and Carlton 2003).

Perrings *et al* (2005) highlight that in the times of dysfunctional trade regulations, tariffs and absence of definite risk assessments and individual species introduction data, it is best option to concentrate on pathway management. Hulme *et al* (2008) state that there is a need to support alien invasions risk assessments and pathway risk management is a good way to do it. There are many studies dealing with introduction pathways, their reliability, frequency or scale. Hulme *et al* (2008) also emphasize that although there is a need to investigate pathways, it is also important to translate the knowledge of it into suitable management responses, which to date is quite insufficient.

Alien species introduction pathways

"Alien species introduction pathway is a human action or inaction that enables a species to enter and stay in a new area or situation where it can become invasive" (Young 2006). CBD divides introductions simply into "intentional introductions" that refer to deliberate releases and "unintentional introductions" that are accidental releases. By CBD alien introductions are movement of species "either within a country or between countries or areas beyond national jurisdiction" (Miller *et al* 2006). This approach, however, takes into account only initial introduction to the region, disregarding subsequent spread that is especially important in Europe, where border spill over effects can have devastating effects (Hulme *et al* 2008).

Hulme *et al* (2008) also emphasize that there are many ways how alien species can enter the country, their pathways are in constant change, and increasing over time. Therefore it is quite complicated to regulate each pathway. Global Invasive Species Database (GISD) describes around 30 pathways of alien introductions (see Figure 4.3.).

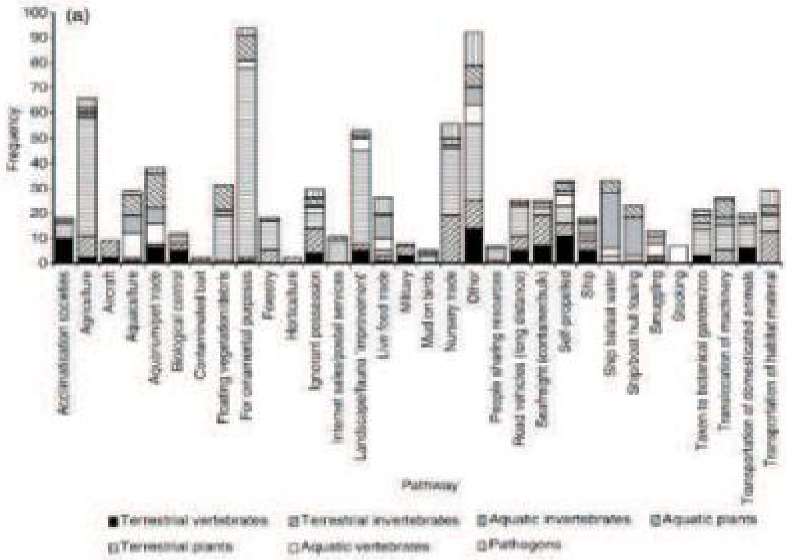


Figure 4.3. Frequency in different pathways by GISD. Data source: Hulme *et al* 2008.

Hulme *et al* (2008) therefore propose more pragmatic approach in pathways classification and arrange them in a way that takes into account also the drivers of invasion. It should guide towards effective management responses covering all species groups in all environments. See the previous classification rearranged according to the new pathway framework in Figure 4.4.

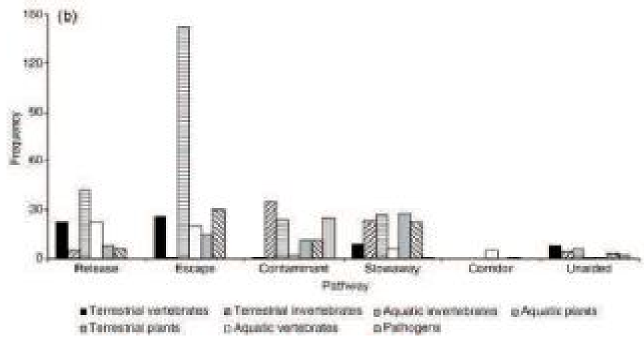


Figure 4.4. New simplified pathway categories. Source: Hulme *et al* 2008.

According to Hulme *et al* (2008) framework, alien species can arrive into the new region by three broad mechanisms: with commodity, via transport vector or dispersed naturally from neighbouring areas where species are already alien (see Figure 4.5.).

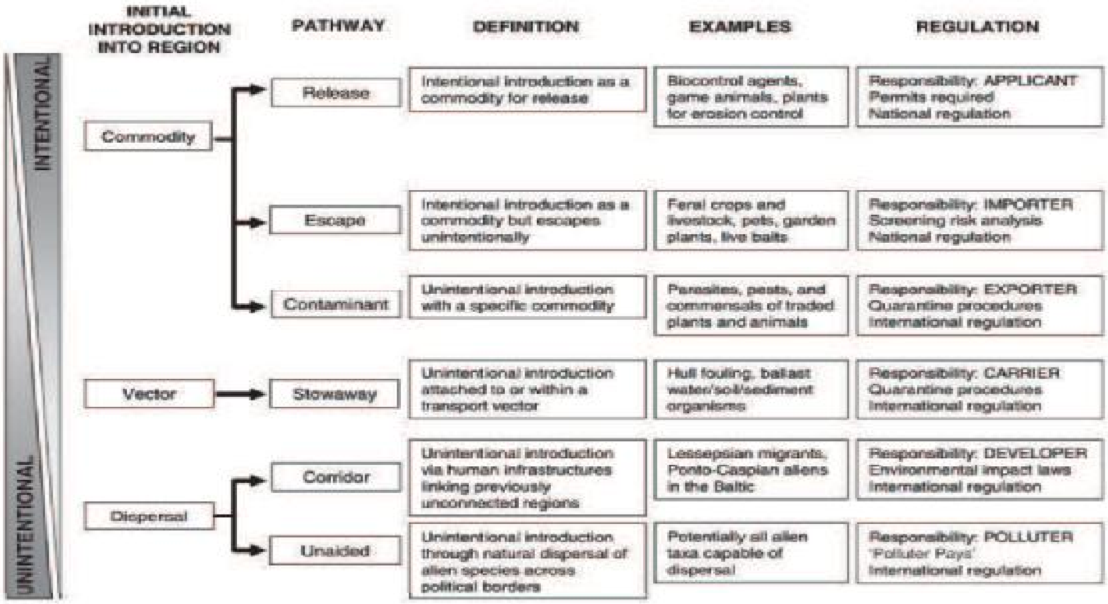


Figure 4.5. Framework of invasion mechanisms and pathways: Source: Hulme *et al* 2008.

These mechanisms are divided into six pathways, with lessening human intervention moving downwards. These are release, escape, contaminant, stowaway, corridor and unaided pathways. Species can arrive through several pathways:

1. Release – alien species that are traded as commodities are released intentionally e.g. biocontrol agents, game animals, landscape plants etc;
2. Escape – alien species traded as commodities that unintentionally escape from captivity e.g. gardens, fur farms, aquaculture etc;
3. Contaminant – aliens introduced unintentionally as commodity contaminants e.g. weed seeds in shipments of grain, pathogens of live goods (incl. timber);
4. Stowaway – human transport via vectors like ships, trains, planes, cars etc. Aliens hide in vehicles and travel along unintentionally e.g. in ship hulls, ballast waters, soils attached to vehicles etc;

5. Corridor – human facilitated natural dispersal via infrastructures (connecting previously isolated areas) e.g. canals, tunnels, bridges;
6. Unaided – species move naturally to new country, whereas it was introduced to the starting point by one of the previous five pathways.

European Commission that is currently dealing with alien species policy development at the EU level has accepted the same approach (EC 2008). European alien species introduction pathways are quite versatile. When we look at the intentional introductions, then alien plants are mostly introduced for improving land cover, aquatic invertebrates as baits, and number of vertebrates have been released for improving local fauna or game (Table 4.2). Invertebrates, pathogens and vertebrates have often been introduced also as biocontrol agents.

Table 4.2. Species introduced to Europe as releases or escapes. Source: Hulme *et al* 2008.

	Reptiles and amphibians	Birds	Mammals
Releases			
Agriculture	1	0	12
Biological control	2	1	3
For food/game	8	61	31
Fauna 'improvement'	28	44	47
Research	2	0	0
Escapes			
For food	10	7	4
As pet	9	75	12
From zoos	1	48	20
From fur farms	0	0	27

When we look at the unintentional introductions then plants are often escapes from gardens as ornamentals or from fields as feral crops. Animals have escaped from livestock, fur or fish farms, or are pet disposals. Contaminants like pathogens, pests, parasites travel with their hosts. Insects to Europe come vastly via international plant trade (Kenis *et al* 2007). Soil provides a good media for the transport of eggs, seeds, spores, microorganisms etc. From stowaways, ships (ballast, hulls), trains, planes serve as good pathways. Corridors, like canals connecting rivers have contributed to invasions between regions, previously isolated (e.g. from Black and Caspian Seas to the North and Baltic Seas) (Hulme *et al* 2008). When species are already in the region, then they spread naturally. It has been estimated that speed of terrestrial species movements can be 89 km and marine 50 km per year^{-1} (Pyšek and Hulme 2005; Gorsholz 1996). Some examples of the spread are of ruddy duck *(Oxyra jamaicensis)* from Spain to the UK, spread of raccoon dog *(Nyctereutes procynoides)* from former USSR to the Western Europe or harlequin ladybird *(Harmonia axyridis)* from Belgium to rest of the

Europe (Hulme *at al* 2008). Trends in introductions and pathway comparisons in some European regions can be found in Table 4.3.

Table 4.3. Trends in pathways of introductions in Europe. Source: Hulme *at al* 2008.

	Pathway category							
Taxon/region	Release	Escape	Contaminant	Stowaway	Corridor	Unaided	Unknown	Source
Vascular plants								
Czech Republic	103	671	267	24	0	7	15	Pyšek, Sádlo & Mandák (2002)
Germany	424	479	511	361	0	7	40	Kühn & Klotz (2002, 2003)
Scotland	7	186	39	35	0	0	4	Welch *et al.* (2001)
Mediterranean islands	130	660	80	110	0	0	26	Hulme *et al.* (2007)
Insects								
Austria and Switzerland	12	1	199	110	0	14	18	Essl & Rabitsch (2002); Kenis (2005)
France	66	1	334	181	0	4	11	A. Roques, unpubl. data
Reptiles and amphibians								
Europe	39	9	6	6	0	3	59	Gasc *et al.* (1997); Lever (2003)
Birds								
Europe	61	43	0	2	0	8	15	Lever (2006); Long (1981)
Mammals								
Europe	71	20	1	6	0	1	2	Long (2003)
Fish								
Spain and Portugal	22	4	1	0	0	0	0	Garcia-Berthou *et al.* (2005)
Ireland	8	2	0	0	0	1	0	D. Minchin, unpubl. data
Baltic States	32	0	0	1	0	0	0	Olenin (2005); Olenin, Leppäkoski & Daunys (2007)
European Russia	34	3	1	1	12	5	1	Panov, unpublished
Aquatic invertebrates								
Ireland	30	6	16	17	0	1	4	D. Minchin, unpubl. data
Baltic States	30	3	1	15	3	12	2	Olenin (2005); Olenin, Leppäkoski & Daunys (2007)
European Russia	18	0	4	46	26	8	6	Panov, unpublished
Aquatic plants								
Ireland	6	14	2	4	0	4	8	D. Minchin, unpubl. data
Baltic States	3	3	0	0	0	0	1	Olenin (2005) Olenin, Leppäkoski & Daunys (2007)
European Russia	1	0	0	5	2	3	0	Panov, unpublished

When managing pathways Hulme *et al* (2008) explain that "the six pathway approach" could assist to develop regulations that cover all main targets based on shared features of pathways. Rules should be developed for sectors according to their pathway (e.g. ornamental plant traders, importers of commodities etc). As mentioned in European policy measures overview (section 3.6.1), in Europe polluter pays principle, where the introducer should take responsibility of introductions, is poorly promoted. If responsible party is being determined, it is easier to organise management and regulations. It should also be pointed out that legislation designed to manage past invasion scenarios might not be enough for the future. Historically most common pathways were releases, escapes and contaminants, but today more species come by stowaways, along corridors or spread from neighbouring countries without any help of humans.

4.1 *Alien species pathways into Estonia by taxonomic groups*

Estonia does not have a comprehensive alien species pathway analyses about different taxonomic groups combined into a single document. Current section aims to do that and also indicate temporal and spatial trends (areas of origin) of species movements. There has been thorough analysis about alien plants by Ööpik *et al* (2008) briefly mentioned in section 2.6. Current analysis is based on The North European and Baltic Network on Invasive Alien Species (NOBANIS) database, Estonian Alien Flora Database (EAFD) and Baltic Sea Alien Species Database (BSASD). The introduction pathways into Estonian are also compared with the European data presented by the EU project Delivering Alien Invasive Species Inventories for Europe (DAISIE 2008).

4.1.1 Pathways for alien plants

There are 787 alien plants listed in EAFD. More than half of the known introductions (453) have occurred before 1900s. After 1980, around 50 new introductions took place (EAFD 2009). Origins of introductions are mostly from Europe (30%), Eurasia (20%), and Asia and America (both 18%). However, when we look at the plants that have become invasive, then the biggest proportion, 30%, is from America (list of 37 naturalized invasive plant species can be found in Annex 4). When looking at the introduction type of the plants then we can see that 57% account for deliberate and 43% for accidental introductions (for invasives both types are equal) (Ööpik *et al* 2008). When we look at sectoral pathways (see Figure 4.6), we can see that horticulture alone is responsible for more than half (52%) of the alien plant introductions, followed by agriculture (15%) and forestry (3%). The rest are combination of former, and considerable proportion of pathways is not known 26%.

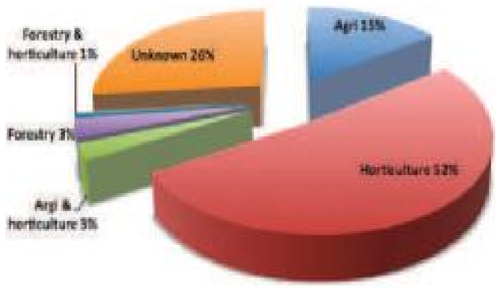


Figure 4.6. Alien plant introduction pathways. Data source: NOBANIS 2009.

When we look at European alien plant species data (Figure 4.7), the main pathways listed are: ornamentals, unintentional release, escapes, horticulture, seed contaminants, unknown, fauna (probably meant flora) improvement, agriculture, transportation, commodity contaminant, and others. As in Estonia, also in Europe, horticulture and ornamentals (both categorized probably under horticulture in Estonia) are the main pathways for alien plants. European pathway categories are quite mixed, e.g. intentional introductions are in the same graph as horticulture, the latter being in itself already intentional. Nevertheless, European pathways are also relevant to consider in Estonia.

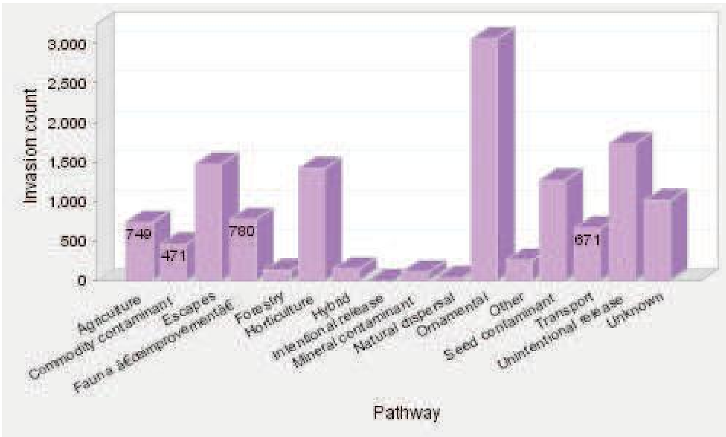


Figure 4.7. Main pathways for terrestrial plants in Europe. Data Source: DIASIE 2008.

4.1.2 Pathways for terrestrial vertebrates

There are ca 20 species of alien terrestrial vertebrates (13 birds, 5 mammals) and one alien amphibian species listed in NOBANIS database. More than half of the introductions have happened after 1950s. Species natural distribution ranges vary (see figure Figure 4.8), the most regions contributing to introductions are Asia, followed by Europe and North America. When looking at the alien distribution details then mammals come mostly from central or eastern parts of Asia (deer's and raccoon dog) or North America (muskrat and American mink). As for birds, many arrive through southern parts of Europe (natural spread).

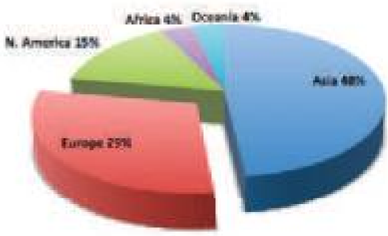


Figure 4.8. Native ranges for alien terrestrial vertebrates. Data source: NOBANIS 2009.

When we look at the types of known introductions then we can see that intentional introductions prevail and many of species have found their way to the nature through escapes (mink, raccoon dog) (see Table 4.4). Hunting and aquaria have one species listed, common pheasant *(Phasianus colchicus)* and marsh frog *(Rana ridibunda)* respectively.

Table 4.2. Types and pathways of introductions for terrestrial vertebrates (NOBANIS 2009).

Introduction type		**Pathway**	
Intentional	5	Escapes	6
Intentional & unintentional	3	Hunting	1
Unintentional	2	Aquaria	1
Unknown	9	Unknown	11

From data about terrestrial vertebrates for Europe (Figure 4.9) we can also see that quite high number of introduction pathways is unknown. Other important pathways are hunting, escapes from zoos, escaped pets, natural dispersal and transportation. Considerable number of introductions comes also from farms and fauna improvement. When looking at European pathways, one also has to be careful in Estonia about natural dispersal of potentially invasive species from neighbouring countries, e.g. Canada beaver *(Castor canadensis)* and Canada goose *(Branta canadensis)* that are already numerous in Finland. Aquaria and pet escapes can also be of concern e.g. red-eared slider *(Trachemys scripta)*.

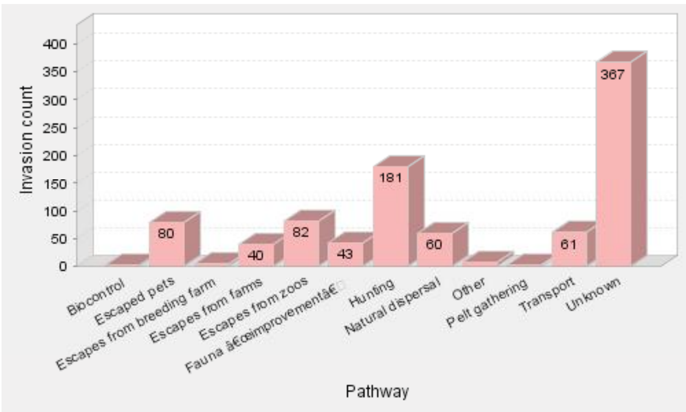


Figure4.9. Terrestrial vertebrates introduction ways in Europe. Data source: DAISIE 2008.

4.1.3 Pathways for terrestrial invertebrates

There are 140 alien invertebrates listed in NOBANIS database. Natural distribution area for many species is unknown (68%). Known species are introduced proportionally from all around the world, starting from Asia (32%) (mostly Central-Asia), followed by North America (24%) and then by Europe and Africa (both 14%) (see Figure 4.10).

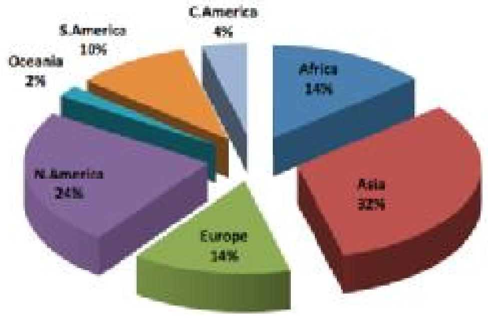


Figure 4.10. Regions of origin for terrestrial vertebrates. Data source: NOBANIS 2009.

From the data available, it can be seen that quite some species (14) are cosmopolitan and many (16) come from different climatic regions like tropics or subtropics. The introductions types are mostly unknown (66), but out of known, more are introduced intentionally (49) than unintentionally (24). As for certain pathways of introductions, the information is insufficient to make substantial conclusions. Biocontrol is mentioned once and horticulture five times, which probably is, if more data was available, pathway to more species. Lately introduced invasive slug *Arion lusitanicus,* is probably introduced via horticulture.

When we look at the European invertebrate data (see Figure 4.11), then the pathways that contribute to species introductions are more numerous. The most important ones are horticulture, ornamentals, stored products, biocontrol, seed contaminants, forestry, transportation means etc. These are relevant also for Estonia.

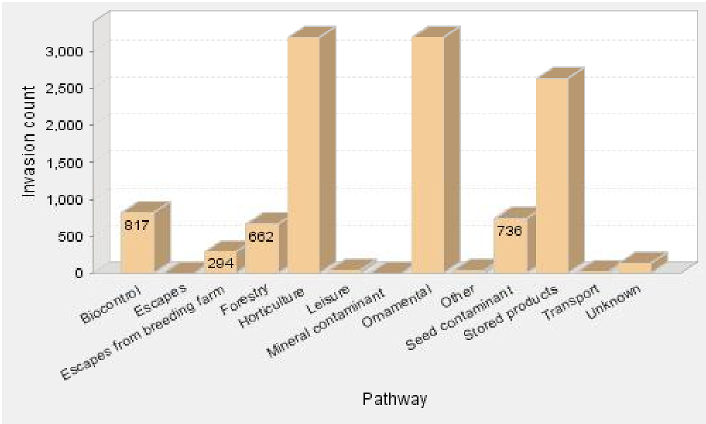


Figure 4.11. Pathways for European alien terrestrial invertebrates. Data source: DAISIE 2008.

4.1.4 Aquatic environment

The Baltic Sea

There are 121 alien species in the Baltic Sea and 79 of them have established status. Considerable amount of species (55) are introduced into the Baltic Sea with vessels. Most species have been introduced after 1900. When we look at the origin of alien species of the Baltic Sea (see Figure 4.12), we can observe that more than half come from North America and Ponto-Caspian region (BSASD 2007).

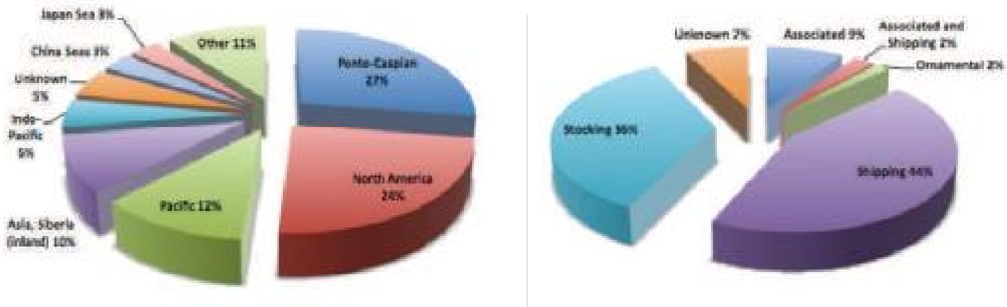
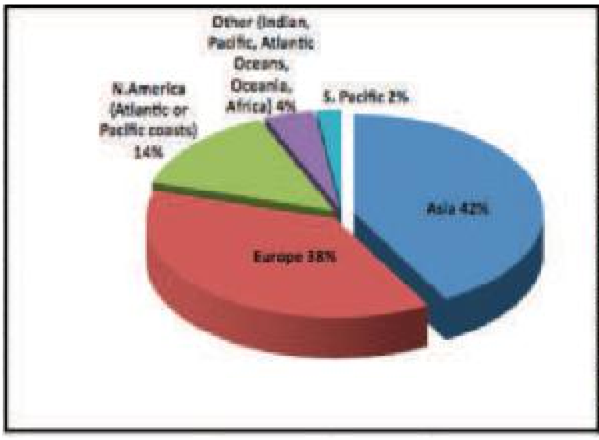


Figure 4.12. Aliens species origins and pathways in Baltic Sea. Data Source: BSASD 2007.

Figure 4.igure 4.12 also shows that intentional introductions are less important in the Baltic Sea than unintentional, which are made up from stocking (37%) and ornamental introductions (2%). Unintentional (and unknown) introductions account for the rest – shipping (ballast water, hull fouling, rafts, inland canals) with 44%, associated (with aquaculture) with 9% (BSASD 2007).

4.1.5 Pathways for Estonian aquatic alien species

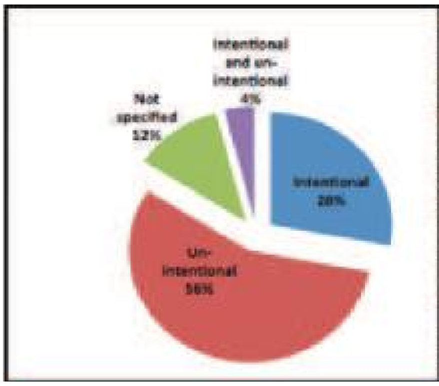
There are about 50 aquatic alien species in Estonian marine and freshwater environments. As for the origin, the biggest number of them comes from Asia (see Figure 4.13), with the most important contributing region being Ponto-Caspia. Species from Europe come from southern or eastern Europe or Russian European areas. Europe probably serves vastly as a secondary introduction source. North America is also contributing to quite some extent with the number introductions.



Distribution details	No. of times species mentioned
Ponto Caspia region	23
USA & Canada and Atlantic and Pacific coasts	5
Unknown	4
Siberia	3
China	2
Russia, Korea, Amur River basin	2
Southeast Asia	2
Adriatic Sea basin	1
Atlantic and Pacific Coast of N. and S. America, Indian Ocean	1
Atlantic Coast of N. Africa, the Mediterranean Sea, the Red Sea, the Black Sea, south of the North Sea	1
Eastern Asia	1
Global	1
New Zealand	1
Northern hemisphere	1
Russia, Kazakhstan, Turkmenistan, Jordan, Egypt, Algeria	1
Russia, Ukraine, Central Asia	1

Figure 4.13. Areas contributing to aquatic invasions in Estonia. Data source: NOBANIS 2009.

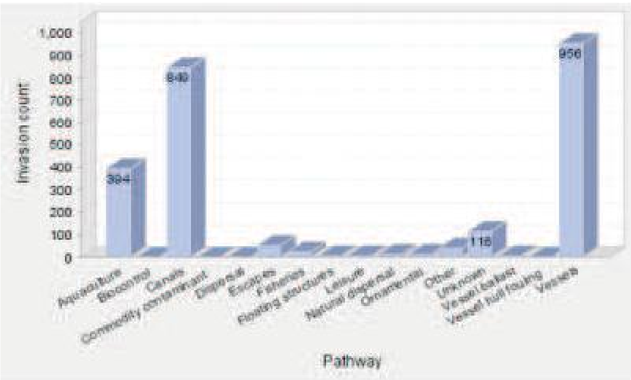
Vast number of aquatic introductions are unintentional, and the main pathways are ballast water and sediments (mostly invertebrates) or a combination of different pathways (hull fouling, aquaculture, river canals) (see Figure 4.14). For example problematic marine fish round goby *(Neogobius melanostomus)* arrived to the Baltic Sea with ballast waters from Ponto-Caspian region. Intentional introductions are mostly associated with aquaculture in freshwaters (fish, crayfish etc). Chinese sleeper *(Perccottus glenii),* big threat for freshwater communities, first found in Estonia in 2005, was initially introduced to St Petersburg for aquaria. River channelling is also problematic pathway. It is serving as a secondary introduction pathway from European-Asian region e.g. this is how secondary introduction of crustacean *(Paramysis intermedia)* into Estonia took place. Many pathways are also unknown.

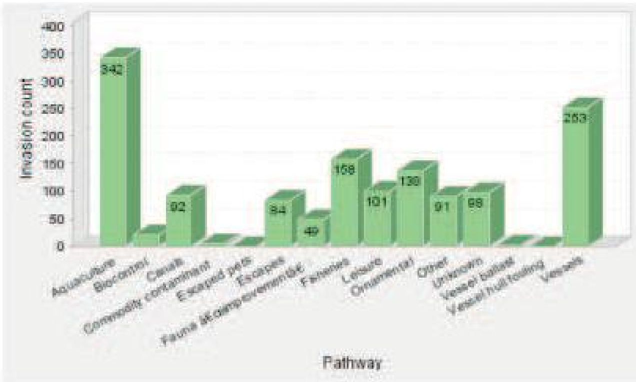


Introduction pathway	%
Ballast water & sediments	28
Aquaculture	24
Unknown	16
Aquaculture, secondary introduction	8
Ballast water	8
Aquaculture, ballast water & sediments	4
Aquaria	4
Hull fouling	4
Hull fouling, ballast water & sediments	4
Ballast water & sediments, secondary introduction	2
River canals	2

Figure 4.14. Introduction type and pathways for aquatic aliens: Data source: NOBANIS 2009.

As for the whole Europe we can see (Figure 4.15) that the main introduction ways for marine species are vessels, canals and aquaculture. For the inland aquatic species, the pathways are more diverse starting from aquaculture and vessels, followed by the fisheries, ornamental, leisure, canals, escapes and faunal improvements.





a) aquatic marine

b) aquatic inland

Figure 4.3. Aquatic marine (a) and aquatic inland (b) alien species introduction pathways to Europe (DAISIE 2008).

4.2 Summarizing pathways

As can be seen from the pathway analyses section above, there are multiple pathways that alien species can enter to the country. Following paragraph summarizes the main pathways identified for the alien species in Estonia according to different taxonomical groups.

Plants

Intentional introductions prevail over unintentional. Most important pathways are:

- horticulture (incl. ornamental);

- agriculture;

- forestry.

Main conclusions for the plants are that it is important to concentrate on intentional as well as unintentional introductions of alien plant species. From sectoral pathway, horticulture needs the biggest attention as well as agriculture and forestry. As pathways for Estonia are not specific enough, and almost one third is unknown, then many potentially important pathways are probably not listed (natural dispersal, commodity contaminants or transportation means). Future introductions may have more contributions from tourism and Internet trade. When looking at regions of introductions, then special attention should be paid to the species imported from America, since invasiveness potential from there is the highest.

Terrestrial vertebrates

Intentional introductions prevail over unintentional. Pathways listed are:

- escapes from captivity;

- hunting release.

Vertebrate species have been mainly introduced intentionally, which have often escaped from captivity (racoon dog, American mink). Hunting also presents a threat if hunters have a need to introduce new species in order to broaden their hunting opportunities (e.g. common pheasant). However, these pathways seem to be more prevalent in the past, which still should not be disregarded. It seems that currently raising problematic pathways can be escapes and natural distribution of the species from the neighbouring areas. Also it should be kept in mind that the species from the same climatic conditions from Asia and North America pose bigger invasion potential.

Terrestrial invertebrates

Intentional introductions prevail over unintentional. Main pathways are:

- horticulture (incl. ornamental);

- biocontrol.

For terrestrial invertebrates it can be concluded that most known introduction types are intentional and most specific pathways are unknown. This can mean that many different pathways can contribute to the introductions e.g. in addition to horticulture, forestry, agriculture (incl. seed, feed, food contaminants, stored products etc.), transportation means, natural spread, etc. many different regions contribute to introductions of terrestrial invertebrates. Invertebrate introductions are often hard to detect because of their small size, and there is a lot of data missing.

Aquatic species

Unintentional introductions prevail mainly over intentional ones. Main pathways listed are:

- ship ballast waters and sediments;
- aquaculture;
- hull fouling;
- canals.

To conclude about Estonian aquatic alien species introduction pathways, unintentional introductions prevail more in marine environment. Main pathways for marine species are ballast water and sediments and hull fouling. As for freshwater environments, aquaculture and aquaria (also pet release) are more important pathways. Canals serve as secondary introduction pathways for both. In addition, for freshwater environments, leisure activities (like angling) can have potential negative impacts (e.g. carrying crayfish plague with fishing gear, releasing alien crayfish or fish, using alien baits etc). Asia, especially Ponto-Caspian region and North America are regions where most invasive or potentially invasive aquatic species come from. These are often the areas with the same climatic conditions.

For more general conclusions it can be said that the pathways contributing to the introduction of the alien species into Estonia vary between different species groups and types of introductions. Many introductions have taken place during last couple of decades, reflecting the signs of globalization pressures like increase in trade and tourism. Main areas contributing with bigger number of species (especially invasive) seem to be North America, Asia (for aquatic introductions Ponto-Caspian region) and Europe (also as secondary source). This is probably because of the similarity in ecological conditions. There is considerable amount of data missing and many pathways are unknown. However, in general, intentional introductions prevail over unintentional in terrestrial environments and in aquatic environments, especially marine, the introductions are more unintentional. The pathways listed in the databases are quite general and are covering mostly bigger sectoral pathways like horticulture, agriculture, forestry, ballast waters, aquaria and aquaculture etc. However, more detailed data would be useful in order to assess the specific pathways, their importance and weight, to be able to make better conclusions, probable predictions and prepare management strategies.

4.3 Six pathway approach and effectiveness of policy measures

In the previous sections main alien species introduction pathways according to taxonomical groups into Estonia were determined. As it was seen, different types of introductions and various pathways contribute to alien species movements. As explained in the beginning of section 4, alien species can enter the country through numerous pathways that are in constant change. Therefore Hulme *et al* (2008) proposes more pragmatic framework for classifying alien introductions - "the six pathway approach" that would guide towards better management of introductions (see Figure 4.5). This section tries to apply "the six pathway approach" to worst alien species in Estonia to see what measures are taken, how efficient they are, and where are gaps and inconsistencies within each pathway. For exemplifying reasons analysis in the table is limited to the worst species, since they pose the biggest threat to Estonian biodiversity. However, where relevant, all alien species issues are considered, to learn from past experiences and try to avoid the future introductions. The outcomes of analyses guide towards recommendations for the better management of alien species pathways in Estonia. The re-categorized introductions pathways according to the new framework into release, escape, contaminant, stowaway, corridor and unaided pathways can be seen in Table 4.5.

Table 4.3. The six pathway approach applied to worst alien species

Rank	Initial introduction / Pathway / Taxonomic group/species	Commodity: Release	Commodity: Escape	Commodity: Contaminant	Vector: Stowaway	Dispersal: Corridor	Dispersal: Unaided	Counts	% Threat Reduced	TRA Index	Regulation/comments
											Nature Conservation Law - release of all the alien species in the nature is prohibited
	Marine species									-75	
1	*Cercopagis pengoi*				1		1	2	-90%		No ballast water treatment. IMO voluntary measures accepted
2	*Marenzelleria spp.*				1		1	2	-90%		Same as previous
3	*Neogobius melanostomus*				1		1	2	-100%		Same as previous.
4	*Eriocheir sinensis*						1	1	n/a		Same as previous.
5	*Carassius gibelio*		1				1	2	-70%		Escapes historical.
6	*Balanus improvisus*				1		1	2	-90%		No ballast water treatment. IMO voluntary measures accepted.
7	*Dreissena polymorpha*				1		1	2	-20%		Same as previous.
8	*Gammarus tigrinus*				1		1	2	-100%		Same as previous
	Pathway for the group	**0**	**1**	**0**	**6**	**0**	**8**				
	Plants									-28.1	
1	*Heracleum sp. (mantegazzianum, sosnowskyi)*	1	1				1	3	90%		In the list of prohibited species. Eradication measures taken on a local level
2	*Lupinus polyphyllus*		1				1	2	10%		Also ornamental species. Escapes frequent.
3	*Solidago canadensis*		1				1	2	30%		In the list of prohibited species. Sold in garden stores
4	*Galega orientalis*	1	1				1	3	-40%		Used as fodder in agriculture. Escaped frequently. Abundant
5	*Populus balsamifera*		1				1	2	-20%		Ornamental usage. Escaped frequent. Rare
6	*Aster sp. (lanceolatus x salignus)*		1				1	2	40%		Historical escape. Abundant.
7	*Impatiens parviflora*		1				1	2	10%		Historical escape. Abundant.
8	*Rosa rugosa*		1				1	2	-20%		Sold as ornamental. Abundant.
9	*Rumex confertus*			1			1	2	20%		Historical. Contaminant?
10	*Elodea canadensis*		1				1	2	10%		Historical escape. Used in aquaria. Abundant. No management measures, natural decline
	Pathways for the group	**2**	**9**	**1**	**0**	**0**	**10**				
	Birds									-12.1	
1	Columba livia (f.	1	1				1	3	0		In the list of hunted species.
2	Cygnus olor (Gm.)		1				1	2	330%		Spreads naturally.
3	Branta canadensis (L.)						1	1	-30%		In the list of hunted species.
4	Phasianus colchicus L.	1	1					2	-30%		In the list of hunted species. However released for hunting.
	Pathways for the group	**2**	**3**	**0**	**0**	**0**	**3**				
	Freshwater invertebrates								n/a		
1	*Orconectes fasciatus*	1						1			Releases in the past.
2	*Dreissena polymorpha*				1			1			Probably with ballast waters
3	*Paramysis lacustris*	1						1			Same as previous. Releases in the past
4	*Paramysis intermedia*				1			1			
5	Chelicorophium				1			1			Not known.
	Pathways for the group	**2**	**0**	**0**	**5**	**0**	**0**				
	Mammals								n/a		
1	*Mustela vison*		1				1	2			List of hunted species. Strict regulations for farms. Escapes from farms continuing
2	*Nyctereutes procyonoides*	1					1	2			List of hunted species. Management plan under way
3	*Rattus norvegicus*				1			1			Can be eradicated as pests
4	*Ondatra zibethica*	1					1	2			List of hunted species. Prohibited for import.
5	*Rattus rattus*				1			1			Can be eradicated as pests.
6	*Mus musculus*				1			1			
	Pathways for the group	**2**	**1**	**0**	**3**	**0**	**3**				
	Counts of pathways	**8**	**14**	**1**	**12**	**0**	**24**				

Unaided pathway

As can be seen from Table 4.5 unaided pathway has the highest number of species listed. Unaided movement takes place when species move to new areas on their own, whereas initial introductions to the region have taken place by some other pahtway. For most alien species in the table unaided pathway was marked as secondary introduction, since after initial introductions, the species spread naturally inside the country. As for the management measures that need to be taken, they can be divided between preventative measures and measures that are dealing with the species already present in the country. To take preventative measures, international cooperation and information sharing are essential. It is important to know which species are already creating problems in the neighbouring areas so national monitoring plans can be set in a timely manner.

There are some measures taken to prevent new alien species introductions into Estonia. As for information sharing, Estonia is participating in a regional alien species portal NOBANIS for North and Central Europe. The database gives useful information about alien species and their status in the neighbouring countries. However, it has never been analyzed in depth about potentially problematic species behind the borders and database is not regularly updated. The same goes for updating DAISIE database for the whole Europe (data currently used there, is drawn from NOBANIS). In order to be well informed about the potential invasions and also be a responsible neighbour, info sharing about species movements in regional level should be well in place. What concerns movement of harmful organisms to plants or plant products for agriculture and horticulture or animal health issues, then according to Kalda ja Pihlakas and Mõttus (pers. comm.) effective alert and information exchange systems exist to detect the presence of harmful organisms in the EU.

There is almost no monitoring of alien species taking place in Estonia. Data exists only for few species, e.g. for giant hogweeds *(Heracleum sp)*. Ornithologists have also quite good overview about bird species in the country. Information about the spread, abundance and trends of most alien species is very insufficient (Ööpik pers. comm.). This was also exemplified during data collection for the TRA analysis, when some scientists could not finish the assessments, because they did not have any information about the species status in the nature. Lack of monitoring prevents to set proper management measures and detect potentially harmful invaders in an early stage, when significant harm has not yet occurred. As for sharing the data inside the country, Estonian Alien Species Database exist, however, it is also outdated and needs further inputs (incl. spatial data for alien species).

As for managing unaided movements inside the country, the table shows some measures that are currently in place for alien species. Overall Nature Conservation Law prohibits release of alien species in the nature. For the plants, eradication program exist for the giant hogweed species *(Heracleum sp).* From the mammals American mink *(Neovison vison),* raccoon dog *(Nyctereutes procyonoides)* (management plan under preparation)*,* muskrat *(Ondatra zibetica)*, and from the birds Canada goose *(Branta canadensis)*, feral pigeon *(Columba livia f. domestica)* and common pheasant *(Phasianus colchicus)* are listed as hunted species. All named species, except the birds, are also prohibited for imports.

As for the efficiency of measures taken, it can be said that overall, when we look at the % of threats reduced, the management measures do not seem to be working to stop the spread of these alien species. Only giant hogweed species have decreased in numbers as a result of a direct management measures. Also Canadian waterweed *(Elodea Canadensis)* has decreased in abundance, but this is due to natural reasons (Ööpik pers. comm.). As for birds, Canada geese numbers have increased, which might indicate that hunting does not have expected effect. As no monitoring data exists and TRA was not completed for mammals, the efficiency of the measures for them is impossible to assess. Some measures taken seem to be useful, but in reality this might not be the case, e.g. being in the list of hunted species may not make a big difference, since almost all named aliens that are allowed to hunt, are not appealing to the hunters. Here some additional bonuses could be applied.

As for managing unaided movements, stopping the spread or eradicating the species, is usually the last and most expensive resort of species management. Sometimes it is not feasible or reasonable to take extensive management measures, since some species might already be entirely naturalized or in such environments that their spread is impossible stop (e.g. rats or mice, pigeons, swans, some plants and most of the aquatic species). To manage unaided movements, measures are mostly concentrated on the worst cases, when species have spread so much that they are already causing extensive damage. It would be more easy to stop the spread at an earlier stage. This, however is not done, since no monitoring exists to detect problematic species at an early stage. Not all the management measures can be taken by the state. Here voluntary measuers could be promoted to stop the unaided movements of some species (e.g. educating farmers etc).

Escapes

After unaided pathways, next important pathways determined to contribute to alien species introductions are escapes. These are species movements that take place accidentally from captivity e.g. gardens, fur farms etc. As seen from the Table 4.5, under this pathway mostly plants, birds, one mammal, and one marine species are listed.

When we look at the plants listed and combine the data with previously conducted pathway analyses (see section 4.1.1) then most of escapes have happened from agricultural or horticultural (incl. ornamental) activities. Today, Nature Conservation Law prohibits release of alien species in the nature, so theoretically people should look after that the escapes from their gardens and fields would not happen. This provision, however, seems not to be practiced. Moreover, many species are already widely spread in the nature, so people consider them part of native flora and stopping the spread might seem unreasonable.

Species from the worst list that are sold and grown for ornamental reasons are Canada goldenrod *(Solidago Canadensis),* large-leaved lupine *(Lupinus polyphyllys),* Rugosa rose *(Rosa rugosa)* and Ontario balsam poplar *(Populus balsamifera)*. Fodder galega *(Galega orientalis)* is grown as agricultural fodder (discussed under release). The fact that these species are still sold and cultivated, are probably greatly contributing to the escapes. Canada goldenrod is already prohibited for imports; however, its seeds are still sold in the stores. Galega and large-leaved lupine have been also suggested to be prohibited for imports by plant experts (Ööpik pers. comm.). The rest of the plants are historical escapes and main pathway for them currently is natural spread (see unaided pathway). Better control should be exercised over species that are prohibited for imports.

For mammals, escape is listed as the pathway of introduction for American mink *(Neovision vision)*. Historically minks were escapes from the fur farms. Today strict regulations to mink farms are in place, so their escapes should be prevented. They are also in the list of hunted species, and restricted for imports. Main pathway for the mink today is unaided movement. As for overall escapes for birds and mammals, the regulation is in place, since the zoos and animal parks have to have permits from the minister of environment and they have to follow standards set by regulations (see section 3.7.2). As for birds, pigeons and swans are already very common and additional measures seem to be unreasonable to take (e.g. eradication of swans would be unacceptable by public). Common pheasant *(Phasianus* *colchicus)* will be discussed under release. Prussian carp's *(Carassius gibelio)* the escape is historical, its also very widely spread, and no measures today are feasible.

Apart from the worst species escapes discussed above, problematic issues under escapes today can be considered pet or bait escapes. To get rid of unwanted pets, people dispose them to the nature where they can spread and become invasive e.g. the case with releasing aggressive red-eared slider *(Trachemys scrypta)* (see section 3.7.1), or emptying aquariums with fish or plants to the water bodies where they spread further. Angling activities, like using non-native live baits such as earthworms (e.g. *Dendrobaena veneta*), or buying alien live crayfish from the stores and releasing to water bodies, should also be kept an eye on. Many issues are, however, a matter of public education (Tambets pers. comm).

Stowaway

Next pathway contributing to alien introductions is stowaway. Through stowaway, species are unintentionally transported via transportation vector. When we look at the Table 4.5, then it can be seen that stowaway is the most important vector for aquatic introductions. In the case of three mammals listed (two rats and a mouse), their introductions are historical and are not of relevance today. Stowaway for aquatic species is travelling with ships ballast waters and sediments and fouling on the hulls of the ships and boats. Stowaway is more important for marine species, but there are also three freshwaters species listed, that have entered the country via ballast waters.

As ballast waters and sediments are the main contributor to aquatic invasions, it is very important that this pathway would be managed efficiently. As for today, international measures exist, but they are implemented insufficiently. There are existing voluntary measures for ballast water treatment set by IMO (Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens) (IMO 1997). According to Ojaveer (pers. comm.) it is unlikely that many ships follow the guidelines and no overviews about it exist. As mentioned in section 3.5, the most important international tool for preventing alien species movements with ballast waters and sediments is IMO BMW Convention, which is not in force yet due to insufficient number of ratifications by states. It is crucial that the convention would be ratified as soon as possible and the measures prescribed there taken.

As for the Baltic Sea, it is important that all the states would ratify the convention, and take the measures, because species introduced to one part of the Baltic Sea, can easily move to another. It is positive that HELCOM (Baltic Marine Environment Protection Commission) countries around the Baltic Sea have agreed to ratify the BMW Convention by 2010 and latest by 2013 (HELCOM 2009). As a party to HELCOM, Estonia has the same commitments. According to Ojaveer (pers. comm.) the process is not easy and the investments to the ports infrastructure and control mechanisms would be very expensive (magnitude of tens of millions of Estonian kroons). As the slow speed of current actions and low priority settings by politicians, it is not likely that Estonia will meet the target. As part of a preparation in joining the convention, Estonian Marine Institute has proposed areas for the release of ships ballast waters (see Figure 4.16). It is quite questionable, however, how effective designated areas would be in prevention of new introductions (Ojaveer pers. comm.), since they are much closer to the coast than advised by BMW Convention (less than 50 nautical miles, instead of advisable 200 miles). This, however, is due to the specific properties of the Baltic Sea.

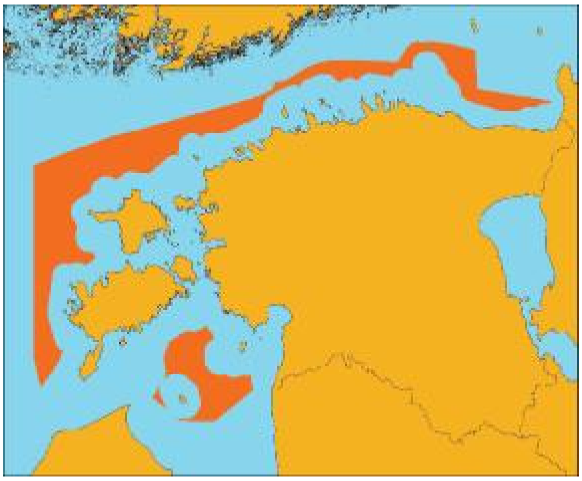


Figure 4.16. Recommended ballast water release areas in Estonian waters (Eek *et al* 2007).

When we look at the overall aquatic alien species invasions, as was also seen in pathways analyses in section 4.1.5., hull fouling as a stowaway is another important contributor to aquatic invasions. However, the EU and international measures are almost nonexistent in regulating this pathway. The problem could be pointed out by Estonia e.g. in the EU level (Ojaveer pers. comm.).

If we additionally consider stowaways on land, then transportation means such as trucks or trains etc serve as a pathways where the species might be "hitchhiking" e.g. on the tyres or cabins of the vehicles. As for measures taken to manage the species movement by transportation means on land, they seem to be non-existent. Usually standards are set for the goods carried e.g. phytosanitary certificates for the purity of seeds, timber etc (PPI 2009). However, to minimize the threat, and notice the new introductions at earlier stage, monitoring plans could be set at the major entry points to the country (railways, international roads, ports and airports etc).

Release

Release is an intentional introduction of the species to the natural environment to improve e.g. local fauna or flora. Table 4.5 shows that release is relevant in the case of mammals, birds and freshwater invertebrates. Intentional introductions should be covered by management measures the best, since Nature Conservation Law prohibits the release of non-native species in the nature. For the mammals raccoon dog *(Nyctereutes procyonoides)* and muskrat *(Ondatra zibetica)* are listed as releases, but today this is no more the case. There are strict regulations for racoon dog fur farms and they can only be brought to the country for blood renewal to the existing farms (see 3.7.2). Muskrats are also prohibited for imports. When we look at the birds, then the release of feral pigeon *(Columba livia (f. domestica*) is no more relevant topic, since it is already naturalized. Common pheasant is grown in the farms and released in the nature for hunting, and as explained in section 3.7.1. there are some cases that it has survived the winters. Here, a precaution should be taken, since it is not sure if the species can become abundant. As for plants, hogweeds *(Heracleum sp)* are no more released (historically used for agriculture and ornamental reasons), however, fodder galega *(Galega orientalis)* is grown in agriculture. Plant ecologists have suggested to ban its cultivation, because it has invasive characteristics and spreads into natural environments, however, agricultural sector disagrees and continues the cultivation (Ööpik pers. comm). There is a need to reach an agreement about these species. As for two freshwater invertebrates listed in the table, they are historical releases, and today intentional releases for fauna improvement reasons should not occur according to fisheries and nature conservation legislation (see 3.7.2).

When we look at the release cases of alien species beyond the worst list, then forestry regulation is worth separate mentioning. As shown in pathway analyses in section 4.1.1, forestry as a sector provides considerable amount of alien introductions, but not enough precaution is taken in this case. As was mentioned in legislation overview, there are 13 alien three species, set by ministerial regulation, that are allowed to be used for reforestation purposes. However, Mötler (2008) states that there has not been any thorough risk assessments for all the species in the list that would justify their inclusion. From timber production point of view, these species do not have considerable advantage over the local species. The status of many species is unknown, but several of them have been classified as potentially invasive trees in our neighbouring countries. These species are for example Lodgepole Pine (in Denmark), European and Siberian Larch (in Finland), Douglas Fir (in Lithuania) and Northern Red Oak (in Poland, Latvia and Lithuania). Further risk assessments should be undertaken to determine the status of the species in the list.

Contaminants

Contaminants are unwanted organisms, such as pests or parasites that are transported with a specific commodity such as plants, feed, seeds, and animals. As for this exercise, only one plant species *Rumex confertus* was listed as contaminant, the pathway for it is historical and not very certain). Cominants can definately be an important pathway. If we look at the regulations, then inside the EU, plants, food, feed and seeds trade for commercial purposes have quite strict regulations and good control measures in place (see section border control in 4.4).

Corridors

Corridors are unintentional introductions via human infrastructure linking previously unconnected bioregions. Corridors did not have any species listed in current exercise, but they can be important it the case of secondary introductions, via activities like canal building and waterways connecting (see also aquatic species pathway analysis in section 4.1.5). Many alien species have reached the Baltic Sea through corridors. Here international legislation should be applied, which according to Ojaveer (pers. comm), is currently non-existent. Estonia could support the development of international and EU level measures for dealing with the issue. In Estonian case, environmental impact assessment laws can be applied. Hulme *et al* (2008) suggests that responsible party in this case should be the developer.

Conclusions for six pathway analyses

This analyses helped to prioritise the pathways according to their importance for species introductions. It helped to see what management measures are taken to control each pathway and how they are working in each case. We can see that many species have been introduced through more than one pathway. Several species have at least two pathways marked, since after initial introductions, unaided pathways contribute to further spread. As can be seen from the table, aquatic species are clearly the least regulated group. Overall lack or unefficiency of measures is reflected in the numbers of % threat reduced, showing that the abundance of almost all worst alien species have increased over the years. Another issue is the lack of knowlege about the change in numbers of other species groups like mammals, freshwater invertebrates (latter probably increasing, since no measures are in place).

Movement of species to and within the country is also historically changing. As can be seen from Figure 4.17 the importance of many pathways have changed over the years. Today, unaided movements are still important, stowaways have moved ahead of escapes and number of releases have also decreased. These trends are coinsiding with the explanations by Hulme *et al* (2008) about the historical changes of importance of pathways (changing from releases, escapes, contaminants, to stowaways, corridors or unaided spreads).

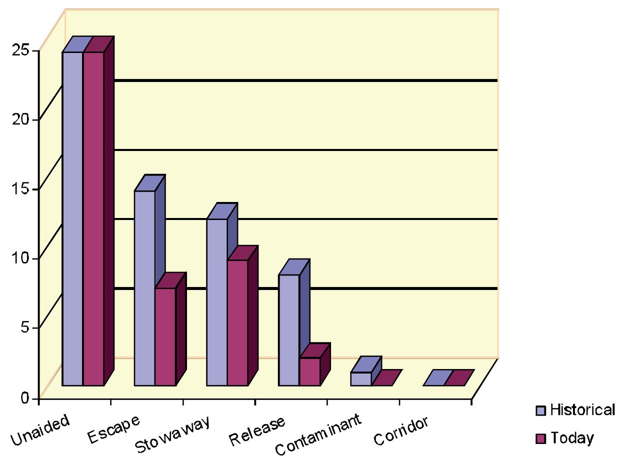


Figure 4.17. Comparison of historical and current importance of the pathways (axes Y shows number of species counted).

As for overall conclusions about each pathway, it can be said that unaided movements are important for all the species. Taking proper management measures and assessing the efficiancy of existing ones, are hindered by the lack of monitoring data about the species and their movements. Generally measures are taken for the worst species and not much has been done for preventing new introductions, which would be less harmful for the biodiversity and cheaper for the country. Escapes today are more relevant for the plants, where invasive species are either cultivated or sold as ornamentals. Historical escapes are not so important anymore, but new dangers are posed by pet or bait escapes. Stowaways are most important for aquatic species, where ballast waters and sediments are the biggest risk and currently unmanaged. Releases are mostly historical and generally well managed today, however some species (galega, common phaesant, alien tree species) are not proven to be totally harmless to be released carelessly in the nature. Contaminants and corriors had almost no species listed, however, they are porbably important pathways, first having good management measures in place and measures for the second are almost inexistent.

4.4 Institutional control of alien species – effectiveness and gaps

As considerable amount of species move to the country through transport and trade, then it was considered relevant to assess the institutional effectiveness to manage the species introductions on the border and beyond. Next paragraphs will analyse in depth the measures taken by different institutions responsible for controlling the species movements into the country. This analysis was conducted in depth, because of institutional demand for getting a good overview of alien species control situation in Estonia. In the end some issues beyond the borders will be discussed. The analysis of this section of the work will pave the way to recommendations for improving the institutional framework of managing alien species introductions.

Border control

Estonia is part of European Union (EU), which means being part of common market and having free movement of people and goods. Also being part of Schengen visa system means that there is no more border control between the members. The control exists on the land with Russia in eastern border. More destinations from third countries are covered by Tallinn Airport. Border control is mostly applicable to the goods that come outside of Schengen countries. There are some goods that have special status and can be controlled also when moving inside the EU (Eek and Kukk 2008).

Animals control by the Veterinary and Food Board

All live animals and animal products that come from outside the EU are controlled on the border by the Veterinary and Food Board (VFB) according to the relevant legislation (Veterinary Supervision over Trade in, Import and Export of Animals and Animal Products

Act (2004). All animals and animal goods that are subject to control are the same all over the EU and are set by the Commission Decision 2007/275/EC (concerning lists of animals and products subject to controls at border inspection posts). VFB's competence lays only with issues that can be harmful to animal or human health. There is one recognized border inspection post for the imports of live animals (for equidae and ungulates) at Luhamaa border point in southeast Estonia on the border with Russia. The rest of food and feed products can be imported into Estonia through other border points (approved for different goods): Muuga and Paldiski ports in North Estonia and Narva in the East Estonia on the border with Russia. Other animals (including pets), that are not equidae or ungulates, before entering Estonia, have to have veterinary control conducted in some other member states' border point recognized in the EU. VFB has the right to physically control and indentify of all the goods under its jurisdiction. VFB official has obligation to control all the live animals going in or out of the country (in starting point or final destination of the delivery) and are meant for trade inside the EU. On suspicion, VFB can also control the goods during their transportation inside Estonia (VFB 2009).

Upon the arrival of animal into Estonia from the other member state, the VFB will check the documentation, identity and visual health of animals. If these species are for example tropical fish, crayfish, mink or raccoon dog, which imports as invasive alien species is prohibited or restricted in Estonia, the documentation is controlled, but VFB does not check if the species are listed as alien and if their imports is allowed or not. Stopping the delivery because of the alien species, is out of their competence (Kalda ja Pihlakas 2009). So the delivery is released into the country because there is no customs control when trading inside the EU. Things would improve if VFB while checking the documentations of animals, determines also their alien species status. Logically VFB officials are better experts on animal issues than customs officials and customs has to deal in addition with many other issues (Brosman 2009).

Food and feed, its imports and subsequent handling, is also a responsibility of VFB. According to Kalda and Pihlakas (2009) there have not been remarkable cases where harmful alien species have been travelling with animals or with food and feed. Food and feed products have to follow strict EU standards for packaging and transportation, which makes accompanying organisms a quite rare occasion.

Plants control by Plant Protection Inspectorate (PPI)

The main control institution for plants and plant products in Estonia is Plant Production Inspectorate (PPI). They have obligation to check plants and plant products and other objects (e.g. wooden packaging) on the border that fall under the EU plant health directive (Directive 2000/29/EC), which is incorporated into Estonian plant protection legislation. The species listed in the directive might be, but are necessarily not the species that are alien to the countries, but they are most certainly harmful one way or the other to the plants or plant products and may cause significant economic or environmental losses in the EU (Mõttus pers. comm). There are certain plants and plant products which imports is prohibited, some have to follow strict requirements and they have to be accompanied with phytosanitary certificate of the country of origin. The importer from outside of EU has to be registered in official Plant Health Register. Upon arrival on the border PPI is controlling the conformity (documents, identity and plant health) of the delivery. PPI has also right to control the vehicles inside the country. Before phytosanitary checks are completed, the goods may not be released by the customs (PPI 2009).

Soil and timber can be major threats when it comes to movement of harmful organisms (insects, nematodes etc.) from one area to another. It is prohibited to transport soil or compost from outside the EU. Plant materials should all be transported with growth substrate (PPI 2009). All wood packaging material from coniferous timber has to be treated (with heat etc), in accordance with international phytosanitary standard (ISPM 15) and marked accordingly. From 1st of July 2009 the wood packaging material has to be also free from bark, making sure that quarantine pests are eliminated. PPI is controlling timber and packaging material together with customs according to the monitoring programs (PPI 2009). Requirements for wood imports depend on its origin. From certain areas imports is not allowed, or has to follow strict standards e.g. coniferous timber from Turkey or Kazakhstan has to be either from pest free zones, be bark free, fumigated, chemically treated etc. All imported timber from outside the EU is controlled by PPI. For timber from inside the EU monitoring plans with special measures (set by EU) exist for pests like very harmful pinewood nematode *(Bursaphelenchus xylophilus)* (PPI 2009).

There are 15 recognized border points (half of them are only for timber) for plants and plant products imports from outside the EU where PPI is conducting import controls, and these are: Orava and Narva railway, Luhamaa ja Narva roadway, Muuga, Paldiski Lõuna and

Põhja, Paljassaare, Meeruse, Bekkeri, Pärnu, Kunda ja Sillamäe ports and Tallinna airport and Estonian Post (PPI 2009). According to PPI (Mõttus 2009) phytosanitary control is performed on a quite good level, when it comes to complying with the EU and Estonian regulations and PPI's area of competence. For the moment, Estonia has been able to avoid serious outbreaks of harmful organisms connected to plants and plant heath issues. One problematic introduction pathway is postal packages and Internet shopping, because people can order plants, plant products, seeds, bulbs etc from all over the world (that might be harmful or be accompanied by harmful organisms). Postal service directs suspicious deliveries to customs control. Customs also chooses control objects based on risk assessments. If plants are discovered, PPI inspectors are called to check the delivery. As mentioned above Estonian Post is a recognised border point for PPI, where they work upon call-outs. What concerns commercial trade and use of plants and plant products, this is quite well controlled. Private persons travelling and bringing along (on purpose or unknowingly) prohibited plants and plant materials can be a problem (controlled together with customs and PPI, but might not be discovered). There are also risks, if people bring into Estonia plants and plant material originating from certain EU member states that have cases with problematic species.

So, PPI only controls on the border the organisms that might be threat to plants and plant products, agricultural production or environment in accordance to the above-mentioned EU directive. Alien species that are listed in ministerial regulation and which are prohibited to import into the Estonia (see Table 3.3) fall out of the competence of PPI.

Control on the border by Estonian Tax and Customs Board (customs)

When control of animals and plants for commercial purposes in the border is mostly done by VFB and PPI, then overall control of non-commercial activities - plants, animals and pets accompanying regular travellers, are the responsibility of the Estonian Tax and Customs Board (customs). However, if customs officer finds a plant or animal from private persons, they will be sent to PPI or VFB officers. The customs exercises the control over alien species based on the alien species list prohibited for imports (see Table 3.3). Information about alien species is also inserted to the electronic informative control system of the customs called RIHO, meant for custom officials.

As mentioned above, there is no regular border control between the EU countries. If there is a need to control inside the EU it is more complicated and can be done on serious cases like one the suspicion of murrain or epidemic (Eek and Kukk 2008). There are only random controls based on risk assessment or if the customs official spots something suspicious (or there are limits to some imports), then they can stop a car or a tourist. There are certain profiles for the countries and persons for control and these are in constant change. Of course, when planning control, state security issues are the highest priority (e.g. arms or drugs). The latest cases with travellers when alien species deliveries have been stopped on the border have been with leeches (due to CITES rules) and with alien crayfish species from 2008 and 2009 (Eek and Kukk 2008; Brosman 2009).

It is impossible to control 100% of the travellers and goods they are carrying. For example with the declared goods the control is also complicated by the fact that if the documentation does not indicate, and the traveller does not mention, or some other way (e.g. hidden products that are being searched) that it might be an alien species, the species will cross the border. Also the customs officials might not recognize the species by the appearance and the name. It is quite impossible to detect the species that are hidden in the suitcases, pockets or on the bodies of the people (Brosman 2009).

Estonian customs tariff system does not include prohibited alien species for imports, because the insertion is based on the codes for different products and alien species do not have separate codes. If there is a code for a product, there is information accompanying it, indicating the necessary action that needs to be taken making the control much easier. It is complicated to assign separate numbers to alien species, since there are product codes that are mostly the same in the whole EU and based on that the goods are also taxed. Plants are coded as other live plants, most animals are other animals (mammals, crayfish etc). The information about the alien species is added to the tariff system. This however, does not prevent declaring the goods for release into the country by the system (Brosman 2009).

Pets (up to 5 specimen) can be brought into the country from all the international traffic checkpoints (VFB 2009) and these are checked by customs. For example if someone e.g. wants to bring in aquarium fish for their own use (whose imports is prohibited), then customs can confiscate it, but only in the case it finds it. Estonia is a party to the CITES convention, that does not deal with the alien species directly, but some species in its lists can be endangered in one country but invasive in another. So if there is such species on the border it can be confiscated by the customs and be dealt with the institution that has been appointed by the Ministry of Environment (Eek and Kukk 2009).

Plants issues control problems

Although control exists and quite good level, there are also some inconsistencies. To exemplify that, e.g. from the importation documents for aquarium plants, acquired from PPI (from the dates 02/09/2006, 03/04/2007, 11/09/2007), it was discovered that aquarium plant large-flowered waterweed (or Brazilian waterweed) *(Egeria densa, Egeria densa-special)* was allowed to be imported. According to national regulation (Table 3.3), the imports of these species are not allowed. These plants when released to the natural watercourses have fast distribution and high invasiveness potential. Nevertheless, the import was allowed. According to investigations and questioning different officials, the procedure goes as follows. If import is connected to plants or plant products, the customs contacts Plant Production Inspectorate that inspects and checks that there are no species that are not allowed to be imported according to the EU Directive 2000/29/EC. As large-flowered waterweeds does not fall under this directive and is not under the PPI competence, the import of the plants is not stopped by the PPI. The latter points out that this is customs obligation to check the lists and phase out alien species. However, since customs has to check everything from cars to clothing, this task is more difficult to them than for PPI, who is controlling the plant-connected goods anyway and decides when they are fine to be released in the country. In that sense PPI competence could be broadened (Brosman pers.comm). However PPI (Mõttus pers. comm.) does not agree with that position emphasizing that there is a need for legally assigned responsibility and additional qualifications for PPI to conduct such inspections. Seems that alien species control issues need to be further discussed to achieve institutional agreement and more efficient ways of control.

Overall, it would be logical if PPI, in addition to controlling 2000/29/EC directive species list, would cover alien plant species issues on the border, since they are trained professionals and might recognise species easier than customs officials (provided there would be some additional training). It would also take away the need to double-control plant issues by both, PPI and customs. But as controlling alien species is not currently PPI’s competence, the control lays on customs officials. This issue, however, needs to be negotiated and agreed between institutions, and if needed, legal competence broadened. Mõttus, however (pers. comm.) emphasizes that control of plants and plant products should be conducted based on EU law that is applicable also to Estonia (directive 2000/29/EC that is also recognized by international law), which is not the case with the list of alien species prohibited for imports.

Animals control issues

Veterinary and Food Board (VFB) deals only with issues that might threaten animal or human health. If imported animals are sick or the animal products, feed or food do not follow the standards, do not have proper documentation, or pose a threat to human and animal life, the importation will not be allowed by VFB. However, if there is a threat to the natural environment, e.g. as it is the case with alien species, this is out of the competence of the VFB. For example if the alien crayfish species are imported and they do not have any signs of disease (e.g. crayfish plague) then they are approved by VBF, although they might be threat to the natural environment when released to the nature. VBF does not look at the accompanying organisms (hitchhikers) that might be associated with different delivery packages. As all the issues besides human and animal health, are out of VBF competence, it falls solely on customs responsibility that, as mentioned above, has very many other things to control. In order to improve the situation according to Kalda and Pihlakas (2009) VFB officials need to be more informed about alien species issues. If they recognize alien species, they can, in a timely manner, contact the relevant officials (first of all the customs) who have the competence for further actions. Currently when contacting Environmental Inspectorate (on general number 1313) who covers all the environmental issues, the action has proven to be not very fast and efficient. Better institutional cooperation about alien species should be in place and information and experts network about the alien species should be developed. VFB does not recognize the need to broaden its legal competence to include the official control over alien species, however they are open to cooperation and willing to forward the information in case they discover relevant information about alien species.

Control beyond border

According to Mõttus (2009) production and sales of plant and plant products inside the country is quite well controlled. All registered nurseries are inspected at least once a year. There is good control and cooperation with botanical gardens and PPI. Under the special regulation and with the licence from PPI, species can be imported for scientific purposes that are otherwise restricted to bring into the country. Retail and wholesale plant material sellers are also controlled and inspections are made in fairs and markets. They have to be registered in the Official Plant Health Register. The same applies to exporters of plants and plant materials, who are also inspected. The biggest problem still remains with private persons who acquire uncontrolled plant material that can be or carry potentially harmful organisms.

Bringing this kind of material into private gardens may cause a significant damage to the environment.

Estonian Environmental Inspectorate (EEI) is responsible to oversee the compliance of the alien species provisions in the Nature Conservation Law. In reality EEI has done controls on American mink and raccoon dog farms and invasive crayfish species that have been imported to country illegally for the sales in supermarkets (Eek and Kukk 2008). Additional measures should be taken to check if stores (e.g. pet stores and plant stores) are not selling animals or plants prohibited for imports (like Canada goldenrod, aquarium fish, large-flowered waterweed).

Conclusions about institutional effectiveness on controlling alien species issues

Overall it can be said that control of plant and plant products and animals is quite well organised concerning the competence of above-mentioned institutions. There are some institutional agreements that need to be settled in order to enhance the border control of the alien species that are prohibited for imports. If these species are for some reasons imported, the control inland should be stricter. Here, Environmental Inspectorate plays a key role. As Mõttus (pers. comm.) and Brosman (pers. comm.) emphasize, however good the control is, it can never detect everything hundred percent. It is especially hard now, when being part of the EU and having no more inside border controls. Internet shopping, postal packages and bringing species along from travels are especially hard to control. The most important way to improve the situation here is to raise the public awareness.

5. Recommendations

The following section lists several recommendations that can be helpful in managing the alien species introduction pathways to help to avoid and better manage current and future movements of alien species. Recommendations are based the outcomes of all the parts of this research. Additional measures are proposed to enhance better institutional cooperation and raise public awareness.

Research and monitoring

Monitoring of alien species today is almost non-existent. Good monitoring system would help to prevent new introductions and stop the spread of existing. It would help planning more efficient management measures and later assess their effectiveness. The monitoring should take place covering different areas and pathways including: 1) entry points of potential invaders (ports, railway stations, abandoned land); 2) around the natural habitats that are near the entry points, where the new species probably reach first (Kull 2005). The overall research of alien species has been insufficient so far. The data is scattered between different institutions and experts. There is also need to research the invasion biology of the aliens and the eradication methods (Ööpik pers. comm.). More research is needed to get better and more specific overview of alien introduction pathways (especially for invertebrates).

To get an idea about potentially harmful alien plant species, the experts have indicated the need for an overview of the species that are imported to the country for horticultural or ornamental reasons. There should be an institution assigned to hold a register for gathering the information about what species and in which quantities are imported to the country. This would be a good research base for the scientists to determine and flag out species that can have invasive features (Ööpik 2007).

International information sharing and cooperation

International cooperation and information sharing is crucial in alien species management. It is useful to exchange information and learn from other countries experience. As for predicting the species invasions, it is important to keep an eye on the neighbouring countries so called "black lists" to get the idea what could be potentially problematic species in the future. It is also important to constantly update the relevant databases (NOBANIS, DAISIE), so possibly affected countries in the region would have most up do date information that would enable to take swift actions if needed. There is a need to update Estonian Alien Species Database. The species data there is incomplete and outdated. The database should be also connected to spatial GIS data. In addition, while doing this research, it was suggested to add alien species topic to the Estonian Nature Observation Database. It is based on observations of the private people and can be found at http://eelis.ic.envir.ee/kaart2/index.php?topic=1&meny=EST&subtopic=1. This database can, in the absence of current monitoring data about alien species, be of help to observe some species movements.

Legislation

As described in the pathway analyses, ballast water and sediments are the main contributor for aquatic alien species introductions. The most important international tool currently to manage ballast water and sediments is IMO BMW Convention, however, it is not in force yet. Estonia should make all efforts to join the convention as soon as possible and take measures proposed, in order to prevent and minimize further alien species introductions. It should fully take part in HELCOM initiative for the Baltic Sea countries, to join the convention by 2010, latest by 2013. In addition, hull fouling of alien species, as a very important pathway of aquatic invasions, is internationally uncovered. Here, Estonia could take an initiative e.g. propose on the EU level the development of an international tool for hull fouling. Before relevant international binding rules come into force, voluntary measures should be taken to avoid the additional invasions. Estonia should also support the developing international legislation for canal building and river connecting, because connecting different bioregions can serve as an important pathway for introductions.

Ministerial regulation about the alien species prohibited for imports (Table 3.3) should be amended. Form the communication with the experts; the species that should be added to the list are Australian Swamp Stonecro (*Crassula helmisii),* fodder galega *(Galega orientalis)* (yet to be settled with agriculture sector) and large-leaved lupine *(Lupinus polyphyllus)* (Ööpik pers.comm.). From mammals maral *(Cervus elaphus sibiricus)* should be added to the list, because it can hybridize with local red deer *(Cervus elaphus* L.*)* and give viable offspring. From birds Canada goose *(Branta Canadensis)* should be added to the list due to its ability to compete and hybridize with local *Branta* and *Anser* species. In addition some experts point out that the regulation needs to be reassessed, since species there are not listed based on proper risk assessments (Ööpik pers. comm.). There are also two species that need to be taken out from the regulation, because they are already listed in plant protection legislation (yellow potato cyst nematode *(Globodera rostochiensis)* and pinewood nematode *(Bursaphelenchus xylopilus)*).

Solving cross-sectional disagreements

As explained in the pathway analyses about the releases, in the case of some species, there are disagreements between nature conservation and sectorial interests. For example cultivating fodder galega *(Galega orientalis)* in agriculture, releasing common pheasant *(Phasianus colchicus* L*)* for hunting purposes or allowing use alien tree species for forest recultivation. Ecologists have raised concerns that these species are not proven to be entirely harmless. For these and other potentially problematic species, thorough risk assessments should be carried out.

General policy tools

When considering more general policy tools, then at this moment there is Estonian Nature Conservation Development Plan being compiled by the Ministry of Environment. The plan should clearly state problems that alien species pose to the Estonian biodiversity, economy and human health. It should include clear ideas and propose actions, how to manage alien species problems. It should include the importance of determining and managing most important alien species pathways. This plan and other initiatives could be used for raising aliens species agenda among politicians and decision makers. At the EU level Estonia should support strong alien species action. It is also important to support the adoption of EU strategy of alien species (currently being developed) and possibility of creating alien species management centre for the EU as proposed by Hulme *et al* (2009).

Public awareness

More public awareness about overall effects of alien species should be promoted. This can be done in various ways, selection of which is listed here:

- Promoting local species, e.g. in gardening stores there can be brochures which explain what local or less harmful species can be purchased instead of alien species;

- Educating travellers, e.g. putting up information in the airports, ports, rail and bus stations with the explanations how to travel responsibly and what are the consequences of alien species introductions.
- Targeting Internet shoppers, e.g. about responsible purchase of species via Internet. Before placing the order, they should be sure that the species is legal and also not potentially harmful to the nature. There could be a web-page that helps them or contact institution/person answering the questions and giving advice;
- Educating leisure and hobby activists like anglers or hunters, e.g. encourage them not to use unknown/alien baits, or carrying organisms from one water body to another. There is a need to clean equipment and boats to avoid crayfish plague and organisms that might foul the hulls of boats. Hunters should not release alien game species to the nature.

Raising awareness of commercial users

Pets-hops can give information to their clients about the threats that biodiversity suffers in the case when some species are released in the nature. In order to do that e.g. MoE could organize workshops or education programs for the shop owners, this should be done in cooperation with the scientists. There should be overview about the shops, and what they sell, and which are potentially harmful species. For example aquarium fish and some aquarium plants when emptied to the pond or lake can survive and spread easily in the nature.

The same pattern of action could be used for the horticulture: forest nurseries, garden shops etc. They could consult with the scientists what species to import and replace the risky ones with less risky ones, if possible, with the local ones (Eek and Kukk 2008). For that, horticulture community needs to be informed and educated. Then plant sellers can add information to the species and educate the customer e.g. when planting in the gardens to take care that the species would not spread out of there etc. For example instead of Canada goldenrod *(Solidago canadensis)* a local goldenrod *(Solidago virgaurea L.)* can be used, or instead of alien poplar species local aspen species could be planted (Eek and Kukk 2008).

Improving institutional control and cooperation

There is definitely a lot of room for improving cooperation between different institutions to organise better alien species management in state level. After the discussions with several officials the issues like the need for better cooperation, education of officials, rapid and efficient information sharing, improving control etc were pointed out. These issues can be taken on board by the MoE as the leading coordinator of alien species issues on state level.

There are many institutions that have responsibility to deal with different parts of alien species issues: Ministry of Environment, Environmental Board, Environmental Inspectorate, Plant Production Inspectorate, Veterinary and Food Board, Estonian Tax and Customs Board and Estonian Environment Information Centre. Cooperation and info sharing according to some officials of these institutions is not sufficient and needs improvement. This could be facilitated by the Ministry of Environment, as the main policy leader in the field of alien species. It should be more active institutional coordinator on alien species issues and organize better info sharing, facilitate better institutional cooperation, enhance international cooperation and guide public awareness raising issues. There is of course need for more resources for dealing with IAS issues on state level.

As for better overall institutional coordination (e.g. like there is for GMO's, or protected species etc), there could be a panel of experts called together at MoE to advise the minister of environment on alien species issues. The panel could analyze topical alien species issues and propose solutions. They can also suggest the priority of the species that would need state management plans and later approve them for adoption. They could also propose amendments to regulations and advise on species that should be either banned or restricted.

Next, institutional recommendations to enhance border control, in order to prevent the new introductions of alien species into Estonia, will be listed. These are based on the consultations between the officials of PPI, customs, VFB and MoE.

Estonian Tax and Customs Board

- There is a need to educate customs officials on the alien species topics (workshops, visual and practical examples);
- There is a need for a contact person/an expert of alien species for the customs, who would react fast to the enquiries, which might arise on spot with the incoming goods;
- Customs web-page could have separate page with alien species info (e.g. list of species with photos and explanations);

- Improving the control over alien plant and animal species (prohibited for imports) should be further discussed and cooperation enhanced between the customs, PPI and VFB.

Veterinary and Food Board

- Needs more training and information about alien species;
- There is a need for contact person who would give expert opinion when lacking it internally;
- There is a need for a network of contacts and well functioning institutional framework e.g. clear understanding who to contact if there is a need for rapid action, when the issue is out of VFB competence, since the movement of goods on the border needs to be fast.

Ministry of Environment

- Coordinate the institutional cooperation – promote the efficiency of the control on the border, help in negotiating the most efficient control methods;
- Organise the workshops for the customs, PPI and VFB officials on alien species;
- Release information materials for the public – web-pages, publications etc.

Conclusions

Next to climate change and habitat loss, invasive alien species are one of the most important threats to the global biodiversity. They cause significant harm to whole ecosystems, economies and human health. There are more than 50,000 alien species in the USA and more than 10,000 in Europe, with the estimated costs of 120 billion dollars and 12.7 billion euros respectively. Growth of global trade and tourism has accelerated the problem and new invasions are happening every day. These numbers show the seriousness of the alien species problem and call for urgent actions to deal with them.

According to Young (2006) “alien species introduction pathway is a human action or inaction that enables a species to enter and stay in a new area or situation where it can become invasive”. The best and the cheapest option is to prevent new invasions or detect them at a very early stage. In order to do that there have to be proper management strategies in place. Prerequisite for an efficient strategy is knowledge about the pathways the species can enter new environments. These pathways are very versatile, changing over time and they are in constant increase – starting from agriculture, forestry or pet escapes and ending in ballast waters, aircrafts and Internet trade. Global Invasive Species Database lists more than 30 different pathways of alien introductions.

There are more than 900 alien species in Estonia and new invasions are happening every year. Therefore Estonia has a need to manage the biological invasions in an efficient way. There is not a good overview about alien species introduction pathways and their importance in Estonia. Therefore this research aimed to detect the most important pathways, see what measures are taken to manage them, how efficient they are and what can be done to improve the situation.

In order to get an overview how different species contribute to the biological invasions into to Estonia, introduction pathway analyses for the main taxonomic groups was conducted. The pathways contributing to species introductions are various and the main trends are similar to the rest of the Europe. In terrestrial environments, intentional introductions prevail and in aquatic unintentional are more common. Introduction pressure has been rising over the last decades and the most harmful species come from North America or Asia, from the areas with similar bio-geographic conditions. For the plant introductions, horticulture, agriculture and forestry are the most important pathways; for terrestrial vertebrates, escapes and hunting releases were mentioned; for invertebrate's horticulture and bio-control were pointed out (mostly no data). Aquatic alien species introductions happen mostly via ballast water and sediments or hull fouling (more for marine species), aquaculture (more freshwater species), and canals. Many pathways of introductions are unknown and potentially important ones might be unlisted. The existing pathways in the databases are quite general and lack specificity. There is a need for more information, especially about invertebrates.

After determining the pathways according to taxonomic groups it was seen that there are several pathways that contribute to invasions. Managing all these pathways is complicated also because one species can come to the country through several pathways. Further, to assess the management efficiency of introduction pathways and see where the main gaps are, "the six pathway approach" proposed by Hulme *et al* (2008) was used. It classifies the pathways in a way that takes into account the drivers of invasions, multiple pathway options for one species, and guides towards better management suggestions. The re-categorized introduction pathways according to the new framework were releases, escapes, contaminants, stowaways corridors and unaided pathways. Based on the worst species analyses it was found that most of the species move to the country through more than one pathway. Overall management measures have not been sufficient to stop the spread of existing or stopping the new introductions, and aquatic species are clearly the least regulated group. Further paragraphs conclude relevant issues for each pathway.

Unaided pathway is the most important for all alien species. This is because after initial introduction, species continue spreading naturally. Main management strategies are either preventing the entry to the country or minimising the impacts (where possible eradicating) of species already present. For prevention, it is important to have a good international cooperation and info-sharing system in place. In Estonia, this is exisiting to some extent (e.g. paricipating in regional database), but needs to be further enhanced, e.g. analysing so called „black lists" of the neighbours. To manage alien species present in the country and to avoid new introductions, there needs to be proper monitoring system in place, which in Estonia is almost non-existent. This prevents to take proper management measures and makes the assessment for the existing ones difficult. Seems that overall measures taken are not working very well, since threats have been rising (based on calculated threat reduction index) for the birds (–121%), plants (-17%), and marine species (–75%). Only one intervention (in the case of eradicating *Heracleum spp*) has actually reduced the threat of the species.

Escapes, determined as the second most important pathway, were historically more important. Today, escapes happen more for the plants, where invasive species continue escaping from the gardens or fields because they are still cultivated or grown as ornamentals (or sold in stores). This is happening even for the ones that are prohibited for imports (e.g. Canada goldenrod). New dangers for the fauna are posed by pet or bait escapes. Managing the escapes by the state needs to be enhanced. Main measure to undertake is to educate the public (stop the escapes from the gardens; explain consequences of pet and bait escapes; promote growing local species etc.). Imports and use of some species could be prohibited (e.g. fodder galega or larged-leaved lupine). Control over already banned species could be enhanced (e.g. Canada goldenrod, alien crayfish sales).

The next important introduction pathways are stowaways. They are most relevant for aquatic invasions where species move to new areas via ships ballast waters and sediments or foul the hulls of the ships or boats. For ballast waters the most important international measure, that would grately lessen aquatic invasions, is IMO ballast water and sediments convention (BWM Convention), that is currently not in force and voluntary measures are not undertaken. It is importatnt to join and take measures that are proposed by this convention as fast as possible. There are no existing international tools for hull fouling, which development should be promoted.

Releases are mostly historical and generally well managed today, however some species released (galega, common phaesant, alien tree species) are not proven to be totally harmless to be released in the nature. There should be proper risk assessments in place. In some cases cross-sectoral disagreements need to be solved e.g. between nature conservation aims and forestry, agriculture and hunting interests.

Contaminants and corriors had the least species listed in the analyses, however, they are potentially important pathways. Most probable contaminants can be species accompaning food, feed, seed or animal deliveries, which trade is quite well managed at the EU level. Corridors are more important for regional level, but international measures for them seem to be non-existent. Therefore measures for controlling this pathway should be promoted on international level.

If we conclude about the institutional control it can be said that control of plant, plant products and animals is quite well organised concerning the competence of involved institutions. There are some institutional disagreements that need to be settled in order to enhance the border control of the alien species that are prohibited for imports. If these species are for some reasons imported, the control inland should be stricter. Here, Environmental Inspectorate plays a key role. Also overall institutional cooperation of alien species needs to be enhanced so efficient control, management, and info sharing could take place that would facilitate to better management of all the introduction pathways.

However good the control is, it can never detect all the introductions. It is especially hard now, when being part of the European Union and having no more inside border controls. Internet shopping, postal packages and bringing species along from travels are especially hard to control. The most important way to improve the situation is to raise the public awareness. Secretary General of the United Nations stated on the International Day of Biodiversity on 22 May 2009 that individuals have a huge responsibility in preventing biological invasions. They have to be responsible travelers and take care that they would not transport species from one place to another "A simple rule applies: leave living organisms in their natural habitats and bring home only memories!"

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ANNEXES

(see Annexes file)

Annex 1. Threat reduction assessment (TRA) calculation explanatory notes and experts answer sheets.

Annex 2. Monetary costs of alien species in EU (millions/EUR): Source EC 2008

Annex 3. International measures dealing with alien species relevant for EU. Source: Hulme 2007.

Annex 4. List of naturalised invasive alien plants in Estonia. Source: Ööpik *et al* 2008.

ANNEXES

Annex 1. Threat reduction assessment (TRA) calculation explanatory notes and experts answer sheets

I) Explanatory notes emailed to experts

Threat Reduction Assessment (TRA) for **Conservation** (by Richard Margoluis and Nick Salafsky, 2001).

Background information

TRA (Threat Reduction Assessment) is originally designed for the evaluating the success of the conservation projects. TRA gives **Threat Reduction Assessment Index (TRA Index),** a summary indicator of the degree to which a project has succeeded in reducing the threats to biodiversity at a particular site. TRA is calculated over certain period of time related to project interventions (it also allows comparisons of the performance of projects between different sites).

TRA is based on data collected with simple techniques, e.g. interviews with the experts. Collected data can be easily interpreted by conservation managers to evaluate if the projects or interventions have been generally successful.

Explanation for the filing in the questionnaire

In this particular exercise for my master thesis, we have customized the calculating TRA index for alien species. The site considered is the whole Estonia and the areas are different groups of alien species: terrestrial vertebrates, terrestrial invertebrates, freshwater vertebrates, freshwater invertebrates, marine species, and plants.

With this method there is no need for specific scientific trials to back up the data filling in the questionnaire. It is solely based on the expert opinions of the people dealing with the species.

I ask You to fill in your area of expertise of alien species in the worksheet presented below in **Table 2** (page 3). It is easy and does not take more than 10 min. I have prefilled some columns for you. After your input, I will complete further calculations.

See the worksheet example in **Table 1** and explained below:

- The site is covering the whole Estonia;
- Site description: is Species group: freshwater invertebrates;
- Assessment period: 1994 -2009 (the time period during when there have been legal instruments in place stating that the introduction of alien species into the nature is not allowed, *(Kaitstavete Loodusobjektide Seadus, Looduskaitseseadus).*

Following columns need the expert (your) input (later fill in Table 2, columns:

- Threats: List a maximum 10 worst alien freshwater invertebrates in Estonia;
- Area: Rank the listed species **relative** to each other. The portion of habitat(s) in the site that the species affect *e.g.* **if you have 5 species**, assign number 5 to

the one that affects the most habitat(s) and number 1 to the species that affects the smallest area;

- Intensity: Rank the species relative to each other in the sense of intensity, the impact or severity of destruction caused by them. Within the area, will the alien species cause major damage to the habitat(s) or causes minor changes? Again, if you have 5 species, assign number 5 to the worst species and 1 to the least intense from the list;
- Urgency: immediacy of threat, is it current? Assign the highest number (again relative to each other) to the species that needs to be dealt first, that is the most urgent;
- Total ranking: will be calculated (numbers will be added, none of the criteria will be considered more important than the other) by the worksheet composer;
- % threat reduced: finally determine the degree (%) to which each threat has been reduced (the % the alien species problem has increased or decreased, compared to zero presence, 100% reduced threat means that the species is not present anymore). Estimate (as a %) the degree to which the threat of each alien species has been mitigated since 1994. Consider area, intensity and urgency together here, *e.g.* if the threat has DECREASED by 30%, then indicate '30%'; if the threat has INCREASED by 30%, then write '-30%' For a species that was absent in 1994, but is now in Estonia, this would mean '-100%'. When the species number has doubled then write also '-100%'. If the species numbers have gone up tree times then write '-200%'. You can include IAS's that were absent in 1994 but have become established since.

- The compiler of the worksheet will calculate further steps. Raw score is calculated by multiplying reduced threat and total ranking. Further raw score for all the species is added up. To get the index, finally the total raw score is divided by total ranking and then converted to percentages. Finally in the example below the TRA index turned out to be -22% meaning that the threat of these 5 freshwater alien species increased by 22%.

Table 1. Example worksheet (if you decide to list e.g 5 species)

Site Name: Estonia	
- (Site Description) Species group: Alien freshwater invertebrate species	
Assessment Period: 1994 -2009	Completed on: April 2009
Completed by: name of expert	

	Threats	Criteria Rankings			Total Ranking	% Threat Reduced	Raw Score
		Area	Intensity	Urgency			
1	Species A	5	2	5	12	30%	3,6
2	Species B	4	3	2	9	- 20%	- 1,8
3	Species C	3	1	1	5	-50%	-2,5
4	Species D	2	4	4	10	0%	0
5	Species E	1	5	3	9	- 100%	-9
etc							
TOTAL		15	15	15	**45**		**-9,7**

TRA Index Formula	Total Raw Score	↓	Total Ranking	↓	Convert to Percentage			TRA Index	
TRA Index Calculation	- 9,7	/	45	=	- 0,22	x	100	=	-22

Table 2. Your worksheet

Site Name: Estonia	
- (Site Description) Species group: Alien freshwater invertebrate species	
Assessment Period: 1994 -2009	Completed on: April 2009
Completed by: Henn Timm	

	Threats	Criteria Rankings Area	 Intensity	 Urgency	Total Ranking	% Threat Reduced	Raw Score
1	Species A						
2	Species B						
3	Species C						
4	etc.						
5							
6							
7							
8							
9							
10							
TOTAL							

TRA Index Formula	Total Raw Score	↓	Total Ranking	↓	Convert to Percentage			TRA Index	
TRA Index Calculation									

Experts for the exercise contacted: a) terrestrial vertebrates (mammals and birds) – Tiit Maran and Vilju Lilleleht; b) terrestrial invertebrates – Jaan Luig; c) plants – Merle Ööpik; c) marine species – Henn Ojaveer; d) freshwater vertebrates and invertebrates – Meelis Tambets and Henn Timm.

References

Margoluis, R. and N. Salafsky. 2001. Is our project succeeding? A guide to Threat Reduction Assessment for conservation. Washington, D.C.: Biodiversity Support Program. A version of this work was published in Conservation Biology13 (4): 830-841;

Anthony, B. P. Use of Modified Threat Reduction Assessments to Estimate Success of Conservation Measures within and Adjacent to Kruger National Park, South Africa. Conservation Biology, Volume 22, No. 6, 1497–1505.

II) Expert answer sheet for alien marine species

Site Name: Estonia	
- (Site Description) Species group: Alien marine species	
Assessment Period: 1994 -2009	Completed on: 01 May 2009
Completed by: Henn Ojaveer, Estonian Marine Institute of University of Tartu	

	Threats	Criteria Rankings			Total Ranking	% Threat Reduced	Raw Score
		Area	Intensity	Urgency			
1	*Cercopagis pengoi*	8	6	4	18	- 90% (arrived in 1992)	- 16.2
2	*Marenzelle-ria spp.*	6	7	5	18	- 90% (arrived in 1991)	- 16.2
3	*Neogobius melanosto-mus*	1	8	8	17	- 100%	- 17
4	*Eriocheir sinensis*	5	4	6	15*	n/a (no data)	n/a
5	*Carassius gibelio*	4	1	7	12	- 70%	- 8.4
6	*Balanus improvisus*	7	3	1	11	- 30% (based on larval assessment in Bay of Riga)	- 3.3
7	*Dreissena polymorpha*	3	5	2	10	- 20% (very rough estimation since the distribution has expanded)	- 2
8	*Gammarus tigrinus*	2	2	3	7	- 100%	- 7
	TOTAL	36	36	36	**93**		**- 70.1**

TRA Index Formula	Total Raw Score		Total Ranking		Convert to Percentage				TRA Index
TRA Index Calculation	- 70.1	/	93	=	- 0.65	x	100	=	**- 75**

* Total ranking 15 *for Eriocheir sinensis* was omitted from TRA index calculations, since % of threat reduce was not marked by the expert.

III) Expert answer sheet for the alien plant species

Site Name: Estonia	
(Site Description) Species group: Alien plants	
Assessment Period: 1994 -2009	Completed on: May 2009
Completed by: Merle Ööpik, Toomas Kukk and Tiiu Kull, Estonian University of Life Sciences	

Threats		Criteria Rankings			Total Ranking	% Threat Reduced	Raw Score
		Area	Intensity	Urgency			
1	*Heracleum sp. (manteg.; sosnovsky)*	9	10	10	29	30%	8.7
2	*Lupinus polyphyllus*	7	9	9	25	- 10%	- 2.5
3	*Solidago canadensis*	8	7	7	22	- 35%	- 7.7
4	*Galega orientalis*	6	8	8	22	- 60%	- 13.2
5	*Populus balsamifera*	4	6	6	16	- 20%	- 3.2
6	*Aster sp. (lanceolatus, x salignus)*	5	4	3-5 (4)	13	- 40%	- 5.2
7	*Impatiens parviflora*	10	1-2 (1.5)	1	12.5	- 10%	- 1.25
8	*Rosa rugosa*	2	5	3-5 (4)	11	- 20%	- 2.2
9	*Rumex confertus*	3	3	3-5 (4)	10	- 20%	- 2
10	*Elodea canadensis*	1	1-2 (1.5)	2	4.5	10% (less in nature, depending of the year)	0.45
TOTAL		55	55	55	**165**		**- 28.1**

TRA Index Formula	Total Raw Score		Total Ranking		Convert to Percentage				TRA Index
TRA Index Calculation	- 28.1	/	165	=	0.170	x	100	=	**- 17**

IV) Expert answer sheet for alien bird species

Site Name: Estonia							
- (Site Description) Species group: Birds							
Assessment Period: 1994 -2009				Completed on: April 2009			
Completed by: Vilju Lilleleht, Estonian Ornithological Society							
Threats		Criteria Rankings			Total Ranking	% Threat Reduced	Raw Score
		Area	Intensity	Urgency			
1	*Columba livia (f. domestica)*	3	4	4	11	0	0
2	*Cygnus olor* (Gm.)	4	3	2	9	- 350%	- 31.5
3	*Branta canadensis* (L.)	2	2	3	7	- 50%	- 3.5
4	*Phasianus colchicus* L.	1	1	1	3	- 50%	- 1.5
TOTAL		10	10	10	**30**		**- 36.5**

TRA Index Formula	Total Raw Score		Total Ranking		Convert to Percentage				TRA Index
TRA Index Calculation	- 36.5	/	30	=	1.21	x	100	=	**- 121**

V) Expert answer sheet for alien freshwater invertebrate species

Site Name: Estonia	
- (Site Description) Species group: Alien freshwater invertebrate species	
Assessment Period: 1994 -2009	Completed on: April 2009
Completed by: name of expert, Henn Timm, Estonian University of Life Sciences	

Threats		Criteria Rankings			Total Ranking	% Threat Reduced	Raw Score
		Area	Intensity	Urgency			
1	*Gmelinoides fasciatus*	4-5 (4,5)	5	5	14,5	n/a*	n/a
2	*Dreissena polymorpha*	4-5 (4,5)	1-2 (1,5)	1-4 (2,5)	8,5	n/a	n/a
3	*Paramysis lacustris*	1-3 (2)	3-4 (3,5)	1-4 (2,5)	8	n/a	n/a
4	*Paramysis intermedia*	1-3 (2)	3-4 (3,5)	1-4 (2,5)	8	n/a	n/a
5	*Chelicorophium curvispinum*	1-3 (2)	1-2 (1,5)	1-4 (2,5)	6	n/a	n/a
TOTAL		15	15	15	**45**		n/a

TRA Index Formula	Total Raw Score		Total Ranking		Convert to Percentage				TRA Index
TRA Index Calculation		/		=		x		=	

* n/a - non applicable, the % threat reduced was not assessed.

VI) Expert answer sheet for alien mammal species

Site Name: Estonia	
- (Site Description) Species group: Alien terrestrial vertebrates	
Assessment Period: 1994 -2009	Completed on: April 2009
Completed by: Tiit Maran, Tallinn Zoo	

Threats		Criteria Rankings			Total Ranking	% Threat Reduced	Raw Score
		Area	Intensity	Urgency			
1	*Neovison vison*	5	5	6	16	n/a	n/a
2	*Nyctereutes procyonoides*	6	4	5	15	n/a	n/a
3	*Rattus norvegicus*	2-4 (3)	1-3 (2)	3	8	n/a	n/a
4	*Ondatra zibetica*	1	2	4	7	n/a	n/a
5	*Rattu rattus*	2-4 (3)	1-3 (2)	2	6	n/a	n/a
6	*Mus musculus*	2-4 (3)	1-3 (2)	1	6	n/a	n/a
TOTAL		21	21	21	**58**		n/a

TRA Index Formula	Total Raw Score		Total Ranking		Convert to Percentage	TRA Index
TRA Index Calculation						

* n/a - non applicable – the % threat reduced was not assessed

Annex 2. Monetary costs of alien species in the EU (millions/EUR). Source: EC 2008.

Species	Biome/taxa	Region	Cost item	Cost	Reference
Carpobrotus spp.	Terrestrial plant	Spain	Control/eradication	0.29	Andreu & Vilà 2007
Eucalyptus spp.	Terrestrial plant	Spain	Control/eradication	1.59	Andreu & Vilà 2007
Fallopia japonica	Terrestrial plant	UK	Eradication	0.01	Child et al. 2001
F. japonica, F. bohemica, F. sachalinensis	Terrestrial plant	Czech Rep.	Control/containment	0.02	Křivánek 2006
Heracleum mantegazzianum	Terrestrial plant	Czech Rep.	Control/containment	0.01	Křivánek 2006
H. mantegazzianum	Terrestrial plant	Denmark	Control	0.06	Nielsen et al. 2005 REF???
H. mantegazzianum	Terrestrial plant	UK	Control	0.19	Shaw 2003
H. mantegazzianum, F. japonica, F. bohemica, F. sachalinensis, Impatiens glandulifera, Rudbeckia laciniata	Terrestrial plant	Czech Rep.	Control/containment	0.02	Křivánek 2006?
Pennisetum setaceum	Terrestrial plant	Spain	Control/eradication	0.02	Andreu & Vilà 2007
Pinus strobus, Larix decidua	Terrestrial plant	Czech Rep.	Control/containment	0.05	Hanzelka & Hadincová 2003
Rhododendron ponticum	Terrestrial plant	UK	Control	66.26	Gritten 1995
Anoplophora chinensis	Terrestrial invertebrate	Italy	Control	0.30	Tomiano pers. comm.
Branta canadensis	Terrestrial vertebrate	Germany	Eutrophication	1.02	Gebhart 1996
C. nippon	Terrestrial vertebrate	Scotland	Control	0.82	White & Harris 2002
Chrysolophus pictus	Terrestrial vertebrate	Germany	Damages	1.26	Gebhart 1996
Felis catus, Rattus sp.	Terrestrial vertebrate	Italy	Eradication	0.19	Scalera & Zaghi 2004
F. catus, Rattus sp.	Terrestrial vertebrate	France	Eradication	0.21	Scalera & Zaghi 2004
F. catus	Terrestrial vertebrate	UK	Control	5.82	White & Harris 2002
Hystrix hodgsoni	Terrestrial vertebrate	UK	Eradication	0.03	Smallshire & Davey 1989
Muntiacus reevesi	Terrestrial vertebrate	UK	Control	0.02	White & Harris 2002
Mustela vison	Terrestrial vertebrate	UK	Eradication	0.55	Moore et al. 2003
M. vison	Terrestrial vertebrate	Estonia	Eradication	0.12	Scalera & Zaghi 2004
Myocastor coypus	Terrestrial vertebrate	UK	Eradication	0.45	Gosling & Baker 1989
M. coypus	Terrestrial vertebrate	Italy	Riverbank damages	2.14	Panzacchi et al. 2007
M. coypus	Terrestrial vertebrate	Italy	Agricultural damages	0.19	Panzacchi et al. 2007
M. coypus	Terrestrial vertebrate	Italy	Control	0.52	Panzacchi et al. 2007
Oryctolagus cuniculus	Terrestrial vertebrate	Germany	Control	5.11	Gebhart 1996
O. cuniculus	Terrestrial vertebrate	UK	Control	41.18	White & Harris 2002
O. cuniculus, Rattus sp. M. coypus, M. vison	Terrestrial vertebrate	France	Control/eradication	0.29	Scalera & Zaghi 2004
O. cuniculus, Rattus sp.	Terrestrial vertebrate	France	Eradication	0.23	Scalera & Zaghi 2004
Lithobates catesbeianus	Terrestrial vertebrate	UK	Eradication	0.01	Adriaens & Briggs 2002
Rattus norvegicus	Terrestrial vertebrate	UK	Eradication	0.26	Scalera & Zaghi 2004
Sciurus carolinensis	Terrestrial vertebrate	UK	Control	0.46	White & Harris 2002
Azolla filiculoides	Freshwater plant	Spain	Control/eradication	1.00	Andreu & Vilà 2007
Crassula helmsii	Freshwater plant	UK	Control	0.86	Shaw 2003
Eichhornia crassipes	Freshwater plant	Spain/Guadiana Basin	Control/eradication	3.35	Andreu & Vilà 2007
Dreissena polymorpha	Freshwater invertebrate	Spain	Infrastructure & boat damage	2.00	Alonso 2006
Oxyura jamaicensis	Freshwater vertebrate	Spain	Eradication	0.06	Cevallos pers. comm.
O. jamaicensis	Freshwater vertebrate	UK	Eradication	0.76	Scalera & Zaghi 2004
Chattonella spp.	Marine algae	Norway	Toxic bloom	7.45	Hopkins 2002
Chrysochromulina polylepis	Marine algae	Norway	Toxic bloom	8.16	Hopkins 2002
Cercopagis pengoi	Marine invertebrate	Gulf of Finland	Decline fish catches	0.02	Panov et al. 1999
Rhopilema nomadica	Marine invertebrate	Levantine coast	Infrastructure damage	0.04	Galil & Zenetos 2002, Golani & Rosenthal 2007

Annex 3. International measures dealing with alien species relevant for Europe. Source: Hulme 2007.

Bern Convention on the Conservation of European Wildlife & Natural Habitat

Bonn Convention on Migratory Species of Wild Animals

European Community Directives:
- Birds Directive
- Habitats Directive

FAO Code of Conduct on Responsible Fisheries

International Conferences on the Protection of the North Sea:
- Integration of Fisheries & Environmental Issues
- Bergen Ministerial Declaration on the Protection of the North Sea

International Council for the Exploration of the Sea (ICES):
- Code of Practice on the Introductions & Transfers of Marine Organisms

International Maritime Organisation (IMO):
- Guidelines for the Control & Management of Ships' Ballast Water

International Plant Protection Convention

North Atlantic Salmon Conservation Organisation (NASCO):
- Resolution to Minimise the Threats to Wild Salmon Stocks from Salmon Aquaculture
- Resolution to Protect Wild Salmon Stocks from Introductions & Transfer
- Guidelines for Action on Transgenic Salmon

OSPAR Commission for the Protection of the Marine Environment of the NE Atlantic:
- Annex V of the OSPAR Convention

United Nations:
- Convention on the Law of the Sea
- Convention on Biological Diversity Convention on the Law of Non-navigational Uses of International Water Courses
- Alien Species: Guiding Principles for the Prevention, Introduction & Mitigation of Impacts

The World Conservation Union (IUCN):

Annex 4. List of 37 naturalized invasive alien plants in Estonia. Source: Ööpik *et al* 2008.

Taxon	Family	First reported presence in the area	Estimated abundance (S: scattered or occasional; U: uncommon; C: common)	Introduction mode (D: deliberate; A: accidental)	Habitat (N: natural, S: seminatural, H: human-made)	Origin	Life history
Amelanchier spicata	Rosaceae	1934	S	D	N,S,H	America	shrub
Aster lanceolatus	Asteraceae	1903	S	D	S,H	America	perennial
Aster × salignus	Asteraceae	1920	S	D	S,H	Homeless	perennial
Bromus inermis	Poaceae	1805	C	D, A	N,S,H	Eurasia	perennial
Bunias orientalis	Brassicaceae	1796	C	A	N,S,H	Eurosiberia	biennial/perennial
Chaenorhinum minus	Scrophulariaceae	1903	S	A	S,H	Europe	annual
Chamomilla recutita	Asteraceae	1777	S	D	S,H	Eurasia	annual
Chamomilla suaveolens	Asteraceae	1923	C	A	S,H	Circumpolar	annual
Cichorium intybus	Asteraceae	1777	S	D	S,H	Eurosiberia	perennial
Conyza canadensis	Asteraceae	1784	C	A	S,H	America	annual
Cotoneaster lucidus	Rosaceae	1863	S	D	N,S,H	Asia	shrub
Echinochloa crus-galli	Poaceae	1839	S	A	S,H	Eurasia	annual
Elodea canadensis	Hydrocharitaceae	1905	C	A	N,S,H	America	perennial
Epilobium adenocaulon	Onagraceae	1930	C	A	N,S,H	America	perennial
Erucastrum gallicum	Brassicaceae	1923	S	A	S,H	Europe	annual/biennial
Galega orientalis	Fabaceae	1907	S	D	N,S,H	Asia	perennial
Galinsoga ciliata	Asteraceae	1941	S	A	S,H	America	annual
Heracleum sosnowskyi	Apiaceae	1957	S	D	N,S,H	Asia	perennial
Impatiens parviflora	Balsaminaceae	1852	C	A	N,S,H	Eurasia	annual
Juncus tenuis	Juncaceae	1955	S	A	S,H	America	perennial
Lactuca serriola	Asteraceae	1803	S	A	N,S,H	Eurosiberia	annual
Lactuca tatarica	Asteraceae	1931	S	A	N,S,H	Circumpolar	perennial
Lepidium densiflorum	Brassicaceae	1931	U	A	S,H	America	annual/biennial
Lolium perenne	Poaceae	1791	C	D	S,H	Eurosiberia	perennial
Lupinus polyphyllos	Fabaceae	1907	S	D	N,S,H	America	perennial
Medicago × varia	Fabaceae	1925	S	D	S,H	Eurasia	perennial
Melilotus albus	Fabaceae	1839	C	A	N,S,H	Circumpolar	annual/biennial
Petasites hybridus	Asteraceae	1777	S	D	N,S,H	Europe	perennial
Populus balsamifera	Salicaceae	1805	S	D	N,S,H	America	tree
Rosa rugosa	Rosaceae	1925	S	D	N,S,H	Asia	shrub
Rumex confertus	Polygonaceae	1933	S	A	N,S,H	Eurasia	perennial
Sambucus racemosa	Caprifoliaceae	1805	C	D	N,S,H	Eurasia	shrub
Sambucus nigra	Caprifoliaceae	1777	S	D, A	S,H	Europe	shrub
Saponaria officinalis	Caryophyllaceae	1777	C	D	S,H	Eurosiberia	perennial
Senecio viscosus	Asteraceae	1839	C	A	N,S,H	Europe	annual
Solidago canadensis	Asteraceae	1807	S	D	N,S,H	America	perennial
Trifolium hybridum ssp. *hybridum*	Fabaceae	1791	C	D	N,S,H	Eurosiberia	biennial/perennial