INVASIVE SPECIES IN IRELAND

Prepared for
Environment & Heritage Service and
National Parks & Wildlife Service

by

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Executive summary

1. Invasions by non-native species are a major threat to global biodiversity. Terrestrial and aquatic habitats can be negatively affected, resulting in grave damage to conservation and economic interests, such as agriculture, forestry and civil infrastructure. In some cases public, animal and plant health may also be threatened.

2. Northern Ireland and the Republic of Ireland have international obligations to address invasive species issues, principally the Convention on Biological Diversity, International Plant Protection Convention, Bern Convention and the Habitats Directive. The National Parks and Wildlife Service of the Department of the Environment, Heritage and Local Government of the Republic of Ireland and the Environment and Heritage Service of The Department of the Environment for Northern Ireland commissioned this all-Ireland review of invasive species with the objective of presenting recommendations to both Governments in March 2004.

3. This report documents the effects of invasive non-native species, recognising that many non-native species do not become invasive but provide considerable benefits to society, particularly in relation to agriculture, forestry and aquaculture. The impacts of invasive species on Irish biodiversity are categorized according to whether the introduction has had a negative, positive or no significant impact upon native biota. Negative impacts are further categorized according to the mechanism by which native biota are affected. For example, through competition, herbivory, predation, alteration of habitat, introduction of parasites and pathogens or dilution of native gene pools.

4. The vectors and pathways by which non-native species are transported are numerous and result from the diverse array of human activities which operate over a range of scales. Primary introductions often result from the accidental transport of species, for example via hull fouling or ballast water. Secondary introductions result from the expansion of exotic species from the initial place of establishment. Secondary spread will normally include a wider range of vectors that may act either separately or together. International and national measures need to take account of these pathways so that contingency plans for management, control and prevention of spread are feasible. There is an urgent need to engage with the commercial sector early in this process to retain their support in the development and maintenance of flexible and effective codes of practice.

5. In Ireland the most prominent of the negative impacts appears to be direct competition with native biota, whilst alteration to habitats and the influence of parasites and pathogens are also important. Specific habitat types currently under threat in Ireland from invasive species include freshwater river systems, ponds, mesotrophic lakes, native woodland, lowland heath, coastal floodplain, coastal saltmarsh and coastal sand dunes. A variety of native species are also threatened by invasives, including red squirrels, white-clawed crayfish, red deer and earthworms.

6. We recommend 10 key actions that will reduce the risks of invasions, help control and manage new and established invasive species, monitor impacts, raise public awareness, improve legislation and address international obligations:

Key Action 1. Detailed risk assessments and contingency plans should be urgently prepared for species that are likely to invade Ireland in advance of their arrival.

Key Action 2. Barriers to a rapid and decisive response to new invasions should be minimized by high level cross-jurisdictional and inter-departmental support for and funding of contingency plans.

Key Action 3. The ecological and economic impact of long-standing alien species and technology for their control should be investigated in detail in order to plan and execute cost-effective strategies for control and eradication.

Key Action 4. Legislative provisions should be analysed and new legal frameworks developed specifically for dealing with invasive species, while facilitating beneficial introductions.

Key Action 5. A framework, including support for specialist identification skills, should be established for the collation and cross-border exchange of information on non-native species.

Key Action 6. Measures for the prevention and eradication of invasive species should be incorporated into agri-environment schemes.

Key Action 7. The dissemination of information to the public and the engagement of stakeholders, particularly in the commercial sector, should be prioritised by developing online, educational and scientific resources, and by targeted public awareness campaigns.

Key Action 8. The use of native species in amenity planting and stocking and related community actions to reduce the introduction and spread of non-native species should be encouraged.

Key Action 9. The two jurisdictions should continue to work through international mechanisms to improve the regulatory and policy framework for dealing with invasive non-native species.

Key Action 10. A cross-border specialist group should establish a dedicated agency to lead on invasive species issues, beyond the immediate actions prioritised above.

Contents

Executive summary 2
Background to the project 7
i. Introduced species 7
ii. Recent work in Great Britain 7
iii. Purpose of this review 7
iv. Report structure 8
v. Project team 8

Section 1: The effects of introduced species on native biodiversity in Ireland
1.1 Introduction: The costs and benefits of non-native species 10
1.2 Classification of the impacts of introductions on native biodiversity 10
1.3 The importance of population dynamics 12
1.4 Impacts of invasive species in Ireland 12
1.5 The domino effect of invasive species 13
1.6 Genetic impacts 14
1.7 Summary of impacts on biodiversity 14
1.8 Impacts of invasive species on the Irish tourism industry 14
1.9 Ireland's international obligations 14
1.10 Irish priorities 15

Section 2: Vectors for the introduction and spread of non-native species
2.1 Introduction 32
2.2 Vectors 32
2.3 Biological control 33
2.4 Wildfowl and game stocking 35
2.5 Horticulture, amenity and ornamental planting, stocking and collections 36
2.6 Pet shops, aquaria and scientific institutions 36
2.7 Fur farming 37
2.8 Forestry 37
2.9 Agriculture 38
2.10 Aquaculture and mariculture 38
2.11 Accidental introductions 40
2.12 International freight, tourism and travel 40
2.13 Fishing equipment, angling and pleasure boats 41
2.14 Ports 41
2.15 Shipping 45
2.16 Hull fouling 45
2.17 Ballast water and its sediments 46
2.18 Parasites and pathogens carried by invasive species 47
2.19 Inland waterways: a pathway for movement of invasives 47
2.20 Conclusions – Irish priorities 47

Section 3: Legislation pertaining to invasive species
3.1 Introduction 53
3.2 International instruments 53
3.3 Biodiversity conservation 53
3.4 The Convention on Biological Diversity (CBD) 54
3.5 The Bern Convention on the Conservation of European Wildlife and Natural Habitats, June, 1982 54

3.6	The Bonn Convention on the Conservation of Migratory Species of Wild Animals, June, 1979	55
3.7	Convention on Wetlands of International Importance as Waterfowl Habitat (Ramsar Convention)	55
3.8	World Conservation Union (IUCN) Guidelines for the prevention of biodiversity loss caused by invasive alien species (2000)	55
3.9	Agenda 21	56
3.10	Ministerial Conference for the Protection of Forests in Europe (MCPFE)	56
3.11	International Maritime Organization (IMO) Guidelines for the control and management of ship's ballast water to minimize the transfer of harmful aquatic organisms and pathogens	57
3.12	International Council for the Exploration of the Sea (ICES) Code of Practice on the introduction and transfer of harmful marine organisms	57
3.13	United Nations Convention on the Law of the Sea (UNCLOS)	58
3.14	Food and Agriculture (FAO) Code of Conduct for responsible fisheries, 1995	58
3.15	International Plant Protection Convention (IPPC)	58
3.16	Food and Agriculture (FAO) Code of Conduct for the import and release of Exotic Biological Control Agents, 1995	58
3.17	World Trade Organization (WTO) Agreement on Sanitary and Phytosanitary measures (SPS Agreement)	58
3.18	Convention on International Trade in Endangered Species of wild fauna and flora (CITES)	59
3.19	International Civil Aviation Organization (ICAO) Resolution on preventing the introduction of invasive alien species	60
3.20	Wildlife Trade Regulations	61
3.21	Habitats Directive	61
3.22	Birds Directive	62
3.23	Environmental Impact Assessment Directive	62
3.24	Water Framework Directive	62
3.25	Fish Health Directive	63
3.26	Forest Reproductive Material Directive	63
3.27	Plant Health Directive	63
3.28	Animal Health Directives	63
3.29	Plant Protection Products Directive	64
3.30	The importance of rapid response to emergency legislation	64
3.31	Wildlife (Northern Ireland) Order, 1985	68
3.32	Wildlife Act, 1976	68
3.33	The Conservation (Nature, Habitats etc.) Regulations (Northern Ireland), 1995	69
3.34	Environmental Protection Agency Act, 1992	69
3.35	Heritage Act, 1995	69
3.36	The Plant Health Order (PHO) (Northern Ireland), 1993	70
3.37	The Plant Health (Wood and Bark) Order (Northern Ireland), 1993	70
3.38	The Seed Potatoes Regulations (Northern Ireland), 2001 (S.I. No. 188)	71
3.39	Marketing of Ornamental Plant Propagating Material, 1995 (Amended 1999)	71
3.40	Noxious Weeds (Northern Ireland) Order, 1977	72
3.41	Legislative approach to invasive plant species in the Republic of Ireland	72
3.42	Forest Legislation	72
3.43	Animal Health	73
3.44	Aquaculture and Mariculture Legislation	74

3.45 Enforcement of domestic legislation 77
3.46 Escapees from private collections 77
3.47 Biological Control 78
3.48 Escapees and genetic pollution of wild populations 78
3.49 Discussion and Conclusions 78
3.50 Cross-border cooperation 79

Section 4: Risk assessment and practical management of invasive species
4.1 Detection and capacity for mitigation measures 82
4.2 Monitoring and surveillance 82
4.3 The decline of trained taxonomists 83
4.4 Access to private land 86
4.5 Risk assessment 86
4.6 Risk assessment of species and habitats in Ireland under threat from non-native invasive species 87
4.7 Vulnerable habitats in Ireland 89
4.8 Vulnerable species: the need for conservation 91
4.9 Research needs for risk assessment 94
4.10 The importance of social and economic stability in risk reduction 95
4.11 Pest Risk Analysis 95
4.12 Forecasting future introductions 97
4.13 Public awareness and education issues 100
4.14 Target audiences and key issues 100
4.15 Developing the culture 101
4.16 Cost analysis: decision-making under uncertainty 102
4.17 The Polluter Pays Principle 103
4.18 Priority setting in conservation: trade related conflicts 103
4.19 Incorporation of protection schemes into existing agri-environment schemes 104
4.20 Accessibility of scientific results to policy makers 107
4.21 Containment and eradication vs. sustainable control through biological and integrated methods 107
4.22 Comparison with disease epidemics 107
4.23 Willingness to pay 108
4.24 Lessons learned from other countries A) New Zealand 114
B) Cross-border co-operation: Canada/America/Mexico 119
4.25 Summary 121

Section 5: Recommendations to the two jurisdictions 124

Acknowledgements 131
References 132
Appendix 1: Non-native estuarine and marine species that are known to be established in Ireland 145
Appendix 2: Non-native marine and estuarine species that may become established in Irish and British coastal waters 146
Appendix 3: Alien plants considered to be established in natural and semi-natural habitats in Ireland 147
Appendix 4: Alien plants considered to be established mainly in artificial habitats in Ireland 148
Appendix 5: Non-native animal species known to be present in Ireland 149
Glossary 150

Background to the project

i Introduced species

Introduced species and genetic material have a major impact on biodiversity. When non-native species become invasive they can transform ecosystems, and threaten native and endangered species. The problems caused by invasive non-native species are so serious that the introduction of these species is identified as one of the main causes of biodiversity loss worldwide. This has been recognised in decisions on alien species agreed by the contracting parties to the Convention on Biological Diversity (CBD), including Ireland and the United Kingdom. Proposals for addressing the impact of alien species on native biodiversity have been published in the biodiversity action plans produced in both Northern Ireland (*Biodiversity in Northern Ireland: Recommendations to Government for a biodiversity strategy 2002*) and the Republic of Ireland (*The National Biodiversity Plan for Ireland 2002*).

Recommendation 48 of *Biodiversity in Northern Ireland* is that the Government should "Review the past and current effects of introduced species and genetic material in Ireland, assess the risks of further introductions, and apply the guiding principles of the Conference of parties of the CBD". The Environment and Heritage Service (EHS) has a set target to "Complete a review of introduced species and genetic material in conjunction with the Republic of Ireland and make recommendations to the Minister by March 2004".

Action 28 of The National Biodiversity Plan for Ireland is to "Prepare strategies in consultation with Northern Ireland, to control introduced species and to prevent, or minimise, future (accidental or deliberate) introduction of alien species, which might threaten biodiversity. Unless clearly safe, all deliberate introductions of non-native species into Ireland will require a risk assessment."

The current project addresses the requirements of these two documents by undertaking an all-Ireland review of introduced species and by developing recommendations which can be proposed to the two Governments by March 2004.

ii. Recent work in Great Britain

There has been much recent research activity relating to introduced species in Great Britain. A review of non-native species policy was published by the Department of the Environment, Food and Rural Affairs (DEFRA) in March 2003. This evaluated the effectiveness of current statutory and non-statutory procedures, identified vectors of invasive species, put forward practical and proportionate proposals and identified appropriate organisations to take forward any measures recommended. The scope of the review excluded micro-organisms, invaders of agricultural crops and GMOs but included involvement of all appropriate stakeholders.

iii. Purpose of this review

The aims of this project are to review the impact of existing and potential future alien species on native biodiversity in Ireland and to recommend actions to Government in both jurisdictions that will address the requirements of the CBD decisions on alien species and improve their capacity to avoid or limit the ecological impact of alien species.

iv. Report structure

The report is structured as follows:

Section 1: The effects of introduced species on native biodiversity in Ireland.

Section 2: Vectors for the introduction and spread of non-native species.

Section 3: Legislation pertaining to non-native species.

Section 4: Practical management of invasive species.

Section 5: Recommendations to the two jurisdictions.

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Section 1: The effects of introduced species on native biodiversity in Ireland

1 The effects of introduced species on native biodiversity in Ireland

1.1 Introduction: the costs and benefits of non-native species

Non-native species bring both costs and benefits which may accrue to different sectors of society (Callaghan, 2003). Benefits are wide-ranging and include new crop or pasture species, new aquaculture opportunities, ornamental plants and fish and novel biological control agents for economic pests. Costs include damage to existing economic interests, harm to native species and habitats, and the, often substantial, costs associated with preventing introductions of harmful species, monitoring existing populations and conducting control or eradication schemes.

The damage to native species and ecosystems worldwide caused by invasive non-native species is estimated to be as serious as the loss and degradation of habitats (IUCN, 2000). The economic and social costs of non-native species can be immense. A particularly prominent case is the introduction of the European zebra mussel *Dreissena polymorpha* to the Great Lakes of North America. Zebra mussels smother native clams and mussels and cluster around warm water outflow pipes from power stations. Mitigating the damage caused by zebra mussels has so far cost the USA 5 billion dollars (Marine Conservation Society, 2001).

Williamson's (1992, 1993) 'tens rule' suggests that 10% of non-native species imported into a region subsequently appear in the wild, 10% of these establish themselves as self-sustaining populations and 10% of the established species, i.e. 0.1% of imported species, then become invasive. Of established, non-native species in the UK, 8.5% of vertebrates, 6.5% of insects and 13.6% of plants have been described as having pest status though this is often a subjective term (Brown, 1986). A more recent review of the proportions of non-native species which are designated as "pests" is lacking. However it is worth noting that the designation of a non-native species as a "pest" generally reflects its potential to cause economic losses rather than impacts on biodiversity.

On a global scale, the most severe impacts of non-native species on native biodiversity have occurred on remote islands, where the native flora and fauna is less diverse, more isolated and so is more susceptible to invasion (Drake & Mooney, 1989). Ireland is comparatively isolated from continental Europe, reflecting its separation by sea since the last glaciation. As a result Ireland is home to a reduced number of native species in comparison with much of continental Europe (Costello, 1993). In the recent past, the majority of species introductions to Ireland have originated from Great Britain, also an island. Thus a filtering effect has been in operation, Ireland being the last land mass in a fragmented chain. As a result of its geographical location the number of introductions of alien species into Ireland has been smaller in comparison to much of continental Europe. However increasing global trade and migration over the last century have led to a marked increase in the rates of species introductions to Ireland, resulting in more frequent and noticeable impacts upon native biota.

1.2 Classification of the impacts of introductions on native biodiversity

The impacts of introductions on Irish biodiversity may be categorized according to whether the introduction has had a negative, positive or no significant impact upon native biota. Negative impacts may be further categorized according to the

mechanism by which species are affected.

a) Competition Competitive impacts arise when non-native invaders and native species compete for resources (Table 1.1).
b) Herbivory Introduced herbivores may directly affect plant populations through grazing and trampling (Table 1.2) and have indirect effects by altering habitat. This could be a particular problem in more isolated ecosystems or on islands where species may have evolved without grazing pressure.
c) Predation Non-native species may kill and/or eat native species (Table 1.3), or themselves sustain higher populations of native or non-native predators.
d) Parasites or pathogens Introduced species may be parasites or pathogens (Table 1.4).
e) Alteration of habitat form or function. Introduced species alter the water table, fire regime, soil properties or vegetation structure and can make habitats unsuitable for native species (Table 1.5).
f) Genetic impacts. Hybridization may occur between non-native species and related native species (Table 1.6). The change in genetic constitution and in phenotype can be considered a loss in biodiversity, whilst hybridization may dilute the degree of local adaptations of native species to the local environment. Examples of hybridization have been most frequently reported for species of birds on a global scale (Cade 1983), although fish, mammals and plants are also affected. A particularly prominent Irish example is the hybridization between native red deer (*Cervus elaphus*) and Sika deer (*Cervus nippon nippon*) (Hayden & Harrington, 2000). A second consideration is the introduction of species of foreign provenance, for example many trees used in forestry are imported rather than using seed of local origin.

Post-invasion effects on the affected environment may be identified only at the community level, or after long term growth in the density/abundance of the invasive species. A lack of native predators in the invaded environment can result in alien predator populations achieving far higher densities in the invasive range than in the native range. The concept of hyperpredation (Smith & Quinn, 1996) predicts that an introduced prey species, well adapted to high predation pressure, could induce the extinction of an indigenous prey, through the sudden increased population size of an introduced predator. Alternatively, negative post-invasion effects may result from an alteration in the population dynamics of the invasive species. For example, within a new environment an invasive species may have a higher reproductive rate, reproduce at an earlier age or increase the number of reproductive events during its lifetime, subsequently resulting in greater population sizes in the introduced range than in the native range.

The assessment of alien species based on their effects on biodiversity may not be appropriate for alien species that have only recently established wild populations (Bullock *et al.*, 1996). Species that do not seem to be causing problems may still be expanding their range and/or building up populations, and may become a problem at a later date. It should be expected that assessing whether species achieve some stability in their numbers could be a lengthy process. An Irish example of this phenomenon is the belated explosive spread of American Willowherb (*Epilobium ciliatum*). This is a weedy, rosette-forming alien perennial from North America, first recorded in Ireland in County Wicklow in 1958 (Doogue *et al.*, 1985). After a delay of

approximately 20 years this species began to spread in Ireland in an explosive manner typical of many successful introduced species (R. Forbes, pers. comm.). *Epilobium ciliatum* has been known to form hybrids with native willowherbs, *E. hirsutum* and *E. montanum*, and is known to compete with the latter (Doogue *et al*., 1985). Whilst the impact of this process on native biodiversity appears minimal at present, it illustrates the potential for delayed rapid expansion of populations.

1.3 The importance of population dynamics

To gain a thorough understanding of the processes contributing to the decline of a native species or habitat as a result of the impact of an invasive species requires knowledge of the local and regional population dynamics of both, and the time scales over which such processes operate. Without such knowledge, predictive power and economic forecasting will be severely limited.

Populations are frequently subject to delicate balances unobservable to the casual eye and fluctuations in the processes maintaining these balances may result in rapid declines or increases. Some populations appear to be self regulating, in that specific processes are initiated when the population reaches a certain density of individuals (density-dependent processes). Other processes occur irrespective of the size of a population (density-independent processes). Quantifying the various density-dependent and density-independent processes that determine population size allows one to forecast the potential distribution of a species, i.e. the proportion of habitat where the births and immigrants exceed the deaths and emigrants, allowing population persistence. Some of the stabilizing processes operating in populations and the consequences of their disruption as a result of invasive non-native species are discussed below. Box 1.1 summarizes some of the main population processes involved in species invasions.

1.4 Impacts of invasive species in Ireland

Invasive species can have varying and complex effects on native biodiversity and economics. A few individual species are seen to have both positive and negative effects. An example of an accidental introduction known to have multiple influences is the brown seaweed, *Sargassum muticum*, commonly known as wire weed, strangle weed or “Jap weed”. This species has increased the biological productivity of previously unproductive waters, in that it frequently colonises habitats not utilised by native algae. *S. muticum* stands can also provide shelter to young fish and crustaceans and fishermen have reported higher catches of eels, mullet, bass and prawns in seaweed stands (Davison, 1996). Negative impacts are attributed to *S. muticum* in that it simultaneously competes with native plant species, fouls marinas and aquaculture structures and clogs the intake pipes of boats and coastal power stations (Table 1.1). Dense growth on commercial shellfish beds may hinder shellfish growth and harvesting and buoyant *S. muticum* plants can float off, carrying away the shellfish to which they are attached (Davison, 1996; Strong, 2003).

Intentional introductions have been made in Ireland mainly for some specific economic gain. The intentional introduction of common cordgrass *Spartina anglica* was initially thought beneficial in protecting Irish coastlines from erosion before subsequent negative impacts were identified (Case Study 1.1). Introductions of fish species for sport fishing have generated increased

tourist revenue but also impacted upon native fish populations (Table 1.1).

1.5 The domino effect of invasive species

Ecological processes are interlinked, resulting in a series of "knock-on" effects due to disruption of one initial component within an ecosystem. In Ireland, the introduction of the roach *Rutilus rutilus* has been implicated in the reduction of populations of several fish species through competitive superiority (Johannson & Persson, 1986). Native Atlantic salmon and brown trout *Salmo trutta* may be affected (Kennedy & Strange, 1978), rudd *Scardinius erythropthalmus* species have been displaced (Cragg-Hine, 1973) and perch *Perca fluviatilis* populations are highly susceptible to roach introductions (Johannson & Persson, 1986). The roach has, however, improved feeding for birds, to the extent that great crested grebe *Podiceps cristatus* and cormorant *Phalacrocorax carbo* populations have increased (Winfield *et al.*, 1994). However, increased winter feeding for cormorants in Lough Neagh has been implicated in increasing predation pressures by these birds on young salmonids in the River Bush (Kennedy & Greer, 1988), an example of hyperpredation.

Finally, the indirect impacts of an invasive species upon habitat sustainability are unknown. Bottom feeding fish can result in increased nutrient loading in lake environments, resulting in damage to an ecosystem and reduction of its amenity value (Table 1.5).

Competitive effects

Examples of direct competition between native and invasive species are documented in Table 1.1. *Rhododendron ponticum*, an invasive plant species, reduces native plant cover due to the dense shade spread by the many, low-lying branches of the plant (Case Study 1.2).

Herbivory

A number of economically damaging examples of herbivory by non-native species exist in Ireland (Table 1.2). The impacts of herbivory are not necessarily related to the size of an individual; invertebrate species like the red lily beetle *Lilioceris lilii* can cause extensive damage as can larger animals like the grey squirrel *Sciurus carolinensis* (Case Study 1.3) and sika deer *Cervus nippon*.

Predation

New Zealand flatworm *Arthurdendyus triangulatus* is the most serious predatory introduced species in Ireland, due to the choice of earthworms as a prey item (Table 1.3). Earthworms are fundamental in maintaining soil quality and their loss or reduction in numbers could have extensive economic impacts on agricultural production.

Parasites and pathogens

Some non-native parasites and pathogens in Ireland have been introduced via the aquaculture industry (Table 1.4). The high densities at which farmed fish populations are kept have resulted in increased probability of disease transfer from farmed fish to native populations.

Alterations to habitat

Invasive plant species in Ireland appear to be documented more frequently as the instigators of habitat change, although non-native fish species have also impacted significantly on freshwater lakes (Table 1.5). Giant hogweed *Heracleum mantegazzianum* in particular is responsible for alteration in river habitats (Case Study 1.4).

1.6 Genetic impacts

Hybridizations between native and non-native species of both plants and animals have been observed in Ireland (Table 1.6). Sika deer are perhaps one of the most extreme cases as they hybridise with the native red deer resulting in viable hybrids (Case study 1.5). An example of economic importance is the genetic impact of escaped farmed Atlantic salmon on native populations (Case study 4.1). To determine the likelihood and impact of such genetic change an experiment was undertaken, in a natural spawning tributary of the Burrishoole system in western Ireland, to compare the performance of wild, farmed and hybrid Atlantic salmon progeny (McGinnity *et al.*, 2003). This study demonstrated that farmed and hybrid progeny can survive in the wild to the smolt stage and these smolts can survive at sea and home to their river of origin. This indicates that escaped farm salmon can produce long-term genetic changes in natural populations. While some of these changes may be advantageous from an angling management perspective, they are likely, in specific circumstances, to reduce population fitness and productivity (McGinnity *et al.*, 2003).

1.7 Summary of impacts on biodiversity

In Ireland the most prominent negative impacts, in terms of the number of studies reporting the effects of non-native invasive species, appears to be direct competition with native biota (Table 1.1), whilst alteration to habitats (Table 1.5) and the influence of parasites and pathogens (Table 1.4) jointly take second place. However, the most serious impacts in terms of economic damage remain to be assessed.

1.8 Impacts of invasive species on the Irish tourism industry

Invasive species can potentially both enhance and detract from the economic value of the natural landscape. Natural biodiversity is a highly valuable asset to Ireland's tourist industry and the protection of this valuable resource should be a priority. Unintentional species introductions which reduce the capacity for tourist activities (such as Giant Hogweed restricting riverbank access) degrade the economic value of the landscape. Alternatively, the stocking of rivers with fish such as rainbow trout has increased the attraction of Ireland as a venue in which sport fishing can be enjoyed within an enriched landscape.

The Tourism Policy Review Group (2003) state that "the Irish tourism industry is, arguably, the most important Irish-owned sector of enterprise, national and regional wealth creation and employment generation". The economic contribution of tourism is of particular value, given its very low import content in comparison with other exports and its significant contribution to regional development.

It is vital that any features which are perceived as unique to the Irish landscape are retained as regional attractions, as it is these features which enhance Ireland's appeal as a tourist attraction. Examples of such features could include red squirrels and Irish hares.

1.9 Ireland's international obligations

The biodiversity plans for Northern Ireland and Ireland must meet international obligations. For example, the main danger posed by introductions of the North American ruddy duck, *Oxyura jamaicensis*, is that it threatens the survival of a long-term European species, the white-headed duck *Oxyura leucocephala*,

which is not found in Ireland but is a native species of conservation interest in continental Europe (Hughes, 1996). Ruddy ducks from feral UK populations began to reach Spain in the mid-1980s and threaten the white-headed duck with extinction through hybridisation and competition.

1.10 Irish Priorities

An essential priority is to integrate information across the island of Ireland, in order to quantify population distribution and abundance across landscapes and increase our knowledge of the population dynamics of both native and invasive species. The Centre for Environmental Data and Recording (CEDaR), established in 1994 by the Ulster Museum and funded by EHS provides local records for Northern Ireland. However, there is a need to develop and maintain a comprehensive database of species for the Republic of Ireland. Case-specific studies in Ireland remain a priority, in that identification of the regulatory processes determining population growth rates in Ireland will aid in both conserving natives and reducing the distribution and abundance of invasive species. Further exploration of the consequences of non-native species invasions should be investigated through assessment of the ecological impacts of functional and performance consequences on affected species, on habitats, ecological processes and ecosystems. Increased accessibility of scientific results should be made available to policy makers, through categorizing the existing research and presenting it in a non-technical and easily accessible manner.

Box 1.1 Examples of population processes affecting the invasive properties of non-native species

Minimum Viable Population (MVP)

The Minimum Viable Population (MVP) is the minimum population size below which the population will go extinct through ecological or genetic factors (Lehmkuhl 1984, Wielgus, 2002). If populations are isolated from immigration they may be potentially limited by low internal genetic variability, stemming from small population size and potential inbreeding. Populations of invasive species may be prevented from reaching a sufficiently high density to maintain positive population growth rates due to competition, predation or herbivory from native species, fluctuating environmental conditions or maladaptation.

Allee effects

Allee effects are positive relationships between any component of individual fitness and either numbers or density of individuals of the same species (Stephens *et al.*, 1999). Allee effects indicate that populations will be depressed at very low levels of abundance. Small populations, below a lower threshold, are proportionally more prone to extinction (Stephens & Sutherland, 1999). Allee effects will slow the rate of advance of an invasive species (Lewis & Kareiva, 1993). However, native species' ranges may be truncated, even where suitable habitat is available, should their populations fall below a threshold as a result of competition with an invasive species.

Dispersal

To gauge the effects of invasive species accurate information is needed on species' distribution and spread. Immigration from source populations towards the edge of a species range may maintain positive population growth rates in the recipient sink populations (Pulliam, 1989). The rate of spread of a species is often determined by processes at the fringe of a population where densities are low and under the influence of Allee effects. Among native species, the disruption of dispersal processes, such as increased death rate during dispersal attributable to the introduction of a novel predator, would reduce population persistence.

Positive density-dependent habitat selection

For mobile species, distribution patterns may be based not only on their ability to disperse successfully but also decisions on site selection influenced by competition within habitats. Site occupancy will reflect habitat quality, with high quality habitats being occupied first and animals only moving to poorer quality habitats at high density. This type of density-dependent habitat selection has been termed the buffer effect (Kluyver & Tinbergen, 1953) because poor quality habitat effectively buffers good quality habitat from any changes in numbers when total population size fluctuates. Buffer effects result in increases in range size with abundance, as individuals either expand into or contract out of poorer quality habitats as population size changes (Watkinson *et al.*, 2003). However, in a situation of competitive displacement by invasive species, alterations in native communities may result from enforced migration. Alternatively habitat quality may be insufficient effectively to buffer the native population from an overall reduction in size.

Metapopulation processes

The population dynamics of organisms can vary according to the distribution of individuals at a range of spatial scales (Telfer *et al.* 2001, Hanski *et al.* 2002). Metapopulation theory (Levins, 1970; Levins & Culver, 1971) considers the regional dynamics of species through investigation of the proportion of suitable habitat patches that are occupied relative to the rates of colonization and extinction. Reductions in habitat quality as a result of the introduction of invasive species could disrupt metapopulation dynamics of native species and reduce their persistence.

Case study 1.1 Common cordgrass *Spartina anglica*

Category of introduction Intentional.

Reasons for introduction *Spartina anglica* was introduced during the 1940s to increase sediment accretion in coastal protection schemes (Bleakley 1979). It has been effective in this respect.

Pathway for introduction *S. anglica* is a relatively new species formed from the hybridization of *S. alterniflora* and *S. maritima* approximately 100 years ago. The natural distribution of *S. anglica* is thought to be between Poole, Dorset and Pugham, Sussex and possibly northern France, all other distributions round the world being intentional introductions. Between 1924 and 1936 more than 175, 000 fragments and many seed samples from Poole Harbour were shipped to 130 sites round the world (Hubbard, 1965). *S. anglica* spreads vegetatively and once established can cover large areas rapidly.

Problems caused by the introduction In the past *Spartina* has been associated with lowering invertebrate faunal diversities and densities and changing the course of mudflat-saltmarsh succession by altering plant communities, although there is recent controversy regarding these effects (McCorrey *et al*. 2003). *S. anglica* replaces the mudflat habitat with a less diverse, monospecific sward and subsequently reduces the intertidal feeding ground for waders and other birds. Mud and saltflat communities based on bottom-dwelling microalgae will decline, being replaced by food webs driven by the supply of *Spartina* detritus. *Spartina* also alters the physical shape of coastal areas. Prior to colonization, in areas where the norm is gently-sloping mudflats and shallow estuaries, *Spartina* alters the landscape to form badly drained marshes that commonly have steeply sloping seaward edges and deep, steep-sided channels (McCorrey *et al*. 2003). As a result flooding can be a problem, particularly near river mouths. In addition infestations can block some navigational channels and reduce the recreational amenity value of an area.

How the effects could be mitigated
S. anglica is a relatively new species and therefore there are relatively few herbivores and diseases that affect the plant, even in its native range. However due to its low genetic variability, and the fact that the plant spreads largely by vegetative means, *S. anglica* is potentially vulnerable to parasite and pathogen infestation. In Northern Ireland the 1985 Wildlife Order makes it an offence to plant, or cause to grow in the wild, any species of *Spartina*. Partially successful attempts have been made to control *S. anglica* spread on Bull Island, Dublin, on Strangford Lough and on Lough Foyle since the early 1970s with herbicide applications.

Invasion dynamics outside of Ireland *Spartina* is native to the Atlantic and Gulf coasts of North America but an aggressive, exotic invader in the Pacific Northwest. Recent greenhouse studies have shown that *Spartina* clones were severely stressed or killed by moderate populations of *Prokelisia marginata*, a leafhopper common in *Spartina's* home range (Daehler & Strong, 1997). Research is currently underway in America to evaluate the host range of *P. marginata* and to prepare a parasite-free and disease-free culture for distribution as a biological control agent.

References
Bleakley, B. 1979. *Spartina* – an unwelcome immigrant, *Irish Hare*, 2, 10-12.
Hubbard, J.C.E., 1965. *Spartina* marshes in southern England. VI. Pattern of invasion in Poole Harbour. *Journal of Ecology*, 53; 799-813.
McCorrey, M, Curtis, T.G.F. & Otte, M.L., 2003. *Spartina in Ireland*. In *Wetlands of Ireland, distribution, ecology, uses and economic value*. Otte, M.L. (ed.) University College Press Dublin, 44-50.

Case study 1.2 *Rhododendron ponticum*

Category of introduction Intentional.

Reasons for introduction Ornamental plant.

Pathway for the introduction
Rhododendron was brought to Britain as seed from southern Spain in 1763. From Kew Gardens the species was distributed widely across Britain and Ireland. Initially it was unpopular; its mauve flower colour was unfashionable at the time and it was also relatively expensive to buy. A severe UK winter (1879-1880) revealed the extreme hardiness of *R. ponticum* and the species became increasingly used as game cover on sporting estates, as wildlife habitat and as a windbreak. The plant began to propagate itself by wind-dispersed seed, reducing the cost of seedlings, and by 1849 the plant suddenly became fashionable as an ornamental. The plant has been used extensively as rootstock for other rhododendrons in horticulture and it can be beneficial to the tourist industry. It is now a rampant invasive species in Killarney (Cross, 1981, 1982; Kelly 1981), where upwards of 650 acres (260 ha) of Killarney National Park are completely infested.

Problems caused by the introduction
The plant invades three habitats that are considered internationally important under the Habitats Directive: upland oak woods, bogs and heath. *Rhododendron* plants form impenetrable thickets which cast deep shade and reduce native plant cover (Rotherham & Read, 1988). The plants also secrete allelopathic toxins which reduce regeneration of native plants. Tissues of *Rhododendron ponticum* contain high concentrations of phenols, which are highly toxic if ingested by herbivores, and there are few natural enemies. The plant is difficult to control because of successful regeneration after cutting, herbicide application or fire. *Rhododendron ponticum* spreads locally by layering (vegetative spread) and abundantly through the production of huge numbers of tiny wind dispersed seeds and it is economically expensive to control. The plant is an economic pest for forestry as it affects natural regeneration, establishment, management and harvesting. Rhododendron is also host to the plant fungus *Phytophthora ramorum* which has been detected at three locations on nursery stock in Northern Ireland and three locations on "wild" stands in the Republic of Ireland. This fungus has caused extensive problems in California as the causative agent of "Sudden Oak Death", although European oak species appear more resilient.

Control methods
Practical control includes manual labour, mechanical removal, herbicide application (Imazapyr and Glyphosate) and stem injection with herbicides (Edwards *et al.*, 1993, 1996, 1997, 1999, 2000). Physical methods of control may cost between £1500 – 7000 (€ 2236-10435) per hectare at the upper end of the range and require hard physical labour. The general costs of herbicide are estimated at £85 – 400 (€ 127-600) per hectare for the chemicals alone. However, the waxy foliage can provide a barrier to herbicide uptake and there are health and environmental risks associated with volatilization, drift and leaching into watercourses. There is a strong case for biological control and a number of natural enemies have been identified in the native range of the species, including a rust fungus from Portugal.

Invasion dynamics outside of Ireland
The plant is native to Turkey and Spain but severely invasive and ecologically damaging in Britain. It has also naturalized in France, Belgium and New Zealand but is not regarded as an invasive problem there. Even in its native habitat, the plant is considered a pest of managed forests in northern Turkey.

References

Cross, J.R., 1981. The establishment of *Rhododendron ponticum* in the Killarney oakwoods, SW Ireland. Journal of Ecology, 69, 807-824.

Cross, J.R., 1982. The invasion and impact of *Rhododendron ponticum* in native Irish vegetation. Journal of Life Sciences Royal Dublin Society, 3, 209-220.

Edwards, C., Tracy D. & Morgan J., 1993. *Rhododendron* control by imazapyr. Research Information Note 233, Forestry Commission, Edinburgh

Edwards, C, & Morgan J.L., 1996. Control of *Rhododendron ponticum* by stump applications of herbicides following mechanical clearance. Proceedings Crop Protection in Northern Britain II, 213-218.

Edwards, C. & Morgan J., 1997. Cut stump applications with imazapyr. Forestry Commission Research Information Note 293, Edinburgh

Edwards, C., Clay D.V. & Dixon F.L., 2000. Stem treatment to control *Rhododendron ponticum* under woodland canopies. Aspects of Applied Biology, 58, 39-46.

Edwards, C., 1999. Herbicide control of *Rhododendron ponticum* following mechanical clearance by hydraulic flail. Proceedings Crop Protection in Northern Britain

Kelly, D.L., 1981. The native forest vegetation of Killarney , south-west Ireland : an ecological account. Journal of Ecology, 69, 437-472.

Rotherham I.D. & Read D.J., 1988. Aspects of ecology of *Rhododendron ponticum* L. with special reference to its competitive and invasive properties. Aspects of Applied Biology, 16, 327-335.

Case study 1.3 American grey squirrel *Sciurus carolinensis*

Category of introduction Intentional.

Reasons for introduction Recreational and aesthetic.

Pathway for the introduction
Introduced from England into Ireland at Castle Forbes, Co. Longford in 1911 (Watt, 1923), where six pairs were released for aesthetic reasons. Within ten years they had reached pest proportions. From County Longford they were recorded in Westmeath (1927), Cavan (1946), Fermanagh (1946) and Armagh (1953). Grey squirrels have spread freely since their introduction, colonising areas of deciduous woodland and Ireland's extensive hedgerow network. There have been some natural barriers to the spread of the grey squirrel: the River Shannon slowed its expansion westwards, Lower Lough Erne northward and Lough Neagh/Lower Bann River into the north-east. In all cases, however, the grey squirrel has overcome these obstacles, e.g. crossed bridges as is the case in the Lower Bann River.

Background to the introduction
At the time of the introduction to Ireland there was less knowledge of the possible harm likely to result from releasing non-native mammals. At this time, the movement of plants and animals around the world was regarded favourably by many people. There was a perception that non-native species were welcome exotic enhancements to familiar native flora and fauna, rather than potential problem species.

Problems caused by the introduction
The grey squirrel is a long-established invasive non-native species which has impacted significantly on native wildlife and also causes economic damage. Grey squirrels can cause considerable damage to forests by stripping bark from a wide range of broadleaf and coniferous species. The spread of the grey squirrel throughout Ireland has been associated with a decline in red squirrel populations. They out-compete the native red squirrel and it has been proposed that they spread the parapox virus to red squirrels. The competitive advantage of the grey squirrel over the red squirrel is thought to be greatest in areas with a higher proportion of deciduous tree species. Currently control of the impacts of grey squirrels can only be achieved through by killing animals. Public acceptability needs to be considered in respect of methods of control of mammals and other techniques have been investigated. Experimentation with immuno-contraception has given disappointing results after a promising start.

How the introduction might have been prevented
It is unlikely that the introduction of grey squirrels could have been prevented given the mindset of the time and the number of similar introductions into Britain. If the spread of the grey squirrel were to have been halted a concerted effort would have been needed at a very early stage. Even so, once they spread from the estate at Castle Forbes it would have been nearly impossible and containment and control are now the best options.

Invasion dynamics outside Ireland
Grey squirrels are well established in most of England, Wales and southern Scotland, and have colonised many urban areas in these regions. As far as woodlands are concerned, the grey squirrel is probably the most damaging non-native species that Britain has had to contend with. The extinction of the red squirrel in England and Wales is a possibility in the foreseeable future, although they are more secure in Scotland. The grey squirrel is also causing problems in northern Italy.

References
Hayden, T. & Harrington, R., 2000. *Exploring Irish Mammals*. Townhouse, Dublin.

Case study 1.4 Giant hogweed *Heracleum mantegazzianum*

Category of introduction Intentional but subsequent spread has been accidental.

Reason for introduction Ornamental plant

Pathway for the introduction
Giant hogweed spreads mainly along river and canal corridors. Colonization and spread have been mainly in a downstream direction reflecting the dependence of the plant upon seed dispersal by flowing water. Other pathways for spread are railway lines and roadways where the plant can be abundant on areas of waste ground.

Background to the introduction
Hogweed was first recorded in Ireland in the late 19th century, although the exact date is not known. The plant was recorded as "naturalized" in the country in Blackrock Park in Dublin in 1902. In 1987 *H. mantegazzianum* was recorded in 23 vice-counties in the island of Ireland. By 1989 the species had extended its distribution to a further 7 vice-counties, a spread which had been primarily along river corridors (Caffrey, 1994). Figure 1.1 shows the distribution of giant hogweed in Northern Ireland and the Republic of Ireland up to 1989 and since 1989.

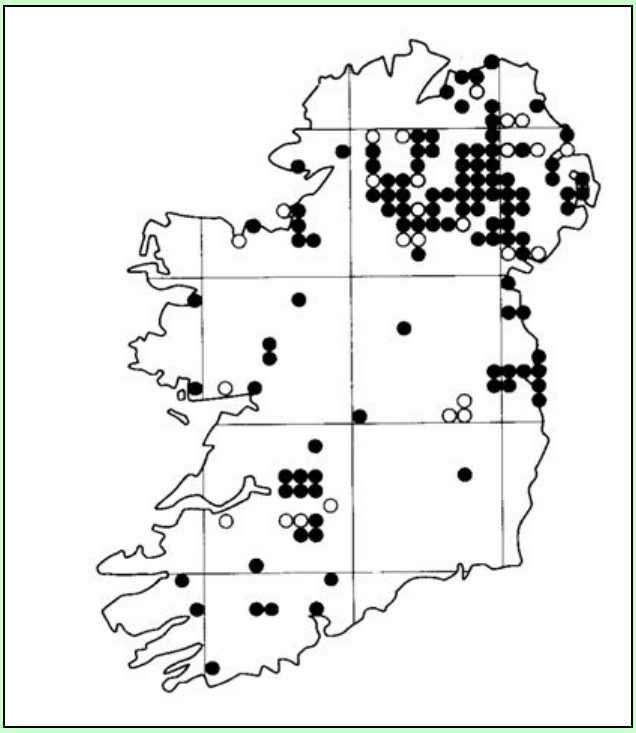


Figure 1.1. Distribution of *Heracleum mantegazzianum* in Ireland. Black circles are sites recorded prior to 1989. White circles are additional sites recorded since 1989. (Reproduced from Wade *et al*. 1997)

Problems caused by the introduction
Giant hogweed poses a health hazard to humans as skin contact with the sap of the plant causes irritation, particularly in direct sunlight. Symptoms include skin blisters and rashes which appear 24 - 48 hours after contact and often require hospital treatment. Post-inflammatory hyper-pigmentation can persist for 6 years after initial contact. On some sections of Ireland's more popular salmonid and coarse fishery rivers (e.g. Newport in County Tipperary, Mulkear in County Limmerick, Bride in County Cork and Dee in County Louth) dense bankside infestations have developed restricting access to the water. Financial and

social implications for angling clubs and local tourism are considerable. The plant also excludes indigenous herbaceous plants which are essential in maintaining riverbank stability. In winter *H. mantegazzianum* dies back, exposing the soil which is washed into rivers, altering substrate characteristics and providing favourable conditions for abundant aquatic plant growth, whilst rendering river substrates unsuitable for salmon spawning. In addition *H. mantegazzianum* hybridizes with the native *H. sphondylium*, although hybrids have low pollen fertility (Grace & Nelson, 1981).

How the introduction might have been prevented

In Northern Ireland the planting of *H. mantegazzianum* was made illegal under the 1985 Wildlife Order. In the Republic of Ireland the Office of Public Works undertook a recent 4-year control/eradication programme (1998-2002) in the Mulkear River catchment, devising a protocol which when applied over a 4-year period will deplete the seedbank and reduce the possibility of re-infestation of an area (Caffrey, 1994).

References

Caffrey, J.M., 1994. Spread and management of *Heracleum mantegazzianum* (Giant Hogweed) along Irish River Corridors. *Ecology and management of riverside plants*. De Waal, L.C., Child, L.E., Wade, M., Brock, J.H.(eds) England: John Wiley & Sons Ltd. pp. 67-76.

Lundstrom, H. & Darby, E., 1994. The *Heracleum mantegazzianum* (Giant Hogweed) problem in Sweden: suggestions for its management and control. *Ecology and management of riverside plants*. De Waal, L.C., Child, L.E., Wade, M., Brock, J.H.(eds) England: John Wiley & Sons Ltd. pp. 93-100.

Tiley, E.D. & Philip, B., 1994. *Heracleum mantegazzianum* (Giant Hogweed) and it control in Scotland. *Ecology and management of riverside plants*. De Waal, L.C., Child, L.E., Wade, M., Brock, J.H.(eds) England: John Wiley & Sons Ltd. pp. 101-110.

Case study 1.5 Sika deer *Cervus nippon*

Category of introduction Intentional.

Reasons for introduction Recreational and aesthetic.

Background to the introduction

One stag and three hinds were introduced from London into Ireland by Lord Powerscourt at his estate in County Wicklow. None of the original records exist and the stock of the original animals cannot, therefore, be confirmed. Lord Powerscourt bred these animals successfully and some were transported to other Irish counties including Limerick, Fermanagh, Tyrone and Kerry. The sika deer acclimatised very well, and there were at least 100 of them in the Powerscourt estate by 1884. Hybrids were also noticed in the same year (Hayden & Harrington, 2000). The sika (and sika/red hybrids) continued to flourish and eventually escaped from the deer park in 1922, during a period of political unrest. Since 1936 the sika deer have colonised large areas of land in Co. Wicklow, and have spread to counties Wexford, Kildare and Carlow. The main reason for the rapid colonisation of the Wicklow area by sika deer from the 1930s onwards was the extensive afforestation of upland areas of the Wicklow Mountains under the tree planting schemes of the state forestry board (1930-1950s), thereby creating large tracts of habitat suitable for sika deer. In 1865 one stag and two hinds were transported to the Killarney area (Muckross Lake), where Lord Kenmare released them into the wild for hunting purposes. Whitehead (1964) estimated that by 1935 the herd numbered between three and five thousand, with numbers decreasing to one thousand by 1948 with no reason cited.

The spread of sika deer, especially in Killarney, is in part due to the presence of woodland or forest in early successional vegetation state and also the presence of the invasive plant species *Rhododendron ponticum*. Sika deer exhibit preferences to these habitats and extensively use the *Rhododendron* for cover.

Problems caused by the introduction

Sika deer pose a threat to the genetic integrity of the native red deer (Hayden & Harrington, 2000). Sika deer and red deer hybridise and the hybrids are fertile and have no apparent competitive disadvantage compared to red or sika deer (Hayden & Harrington, 2000).

Sika deer can become a serious pest of commercial forestry and agriculture. They reduce timber production by browsing leader shoots of young trees, by scoring the bark with antlers and by stripping bark with the teeth. The major impact is the damage they cause to newly planted trees (Hayden & Harrington, 2000). The problems associated with sika deer lies in their destruction of saplings, which prevents regeneration within some tracts of woodlands which represent the last vestiges of primordial woodlands in Ireland. The native Yew wood (*Taxus baccata*) on Muckross peninsula is unique to Ireland and has been subjected to heavy grazing by sika deer. In upper regions of Looscaunagh wood there is effectively no regeneration, where the ground vegetation is heavily grazed and churned up by sika deer. In 1976 greater awareness of the importance of the natural woodlands in the area and the growing concern about their survival prompted the Office of Public Works and the Forestry and Wildlife Service to propose an annual cull of sika deer. The proposed cull was introduced in 1979 with the Forestry staff culling in areas leased to the Forestry dept and park staff culling within the park itself.

Invasion dynamics outside Ireland

Sika deer are highly adaptable in their feeding habits and show seasonal variation in habitat preferences in relation to food abundance. Their colonizing ability has resulted in the displacement of red deer and other cervid species in the USA.

References

Hayden, T. & Harrington, R., 2000. *Exploring Irish Mammals*. Townhouse, Dublin

Whitehead, G., 1964. Japanese sika deer in Ireland. *The Deer of Great Britain and Ireland*. Routledge and Keegan-Paul, London.

Case study 1.6 Roach *Rutilus rutilus* (Contributed by R. Rosell)

Category of introduction Intentional.

Reasons for introduction Recreational

Background to the introduction

Ireland's truly native freshwater fish fauna consists only of species able to colonise Inland waters from marine environments after the end of the last glaciation. Half of the current list of 22 freshwater species is considered to be postglacial introductions. In lowland waters, Roach are now Ireland's most abundant species, dominating biomass in many lakes. The history of roach introduction and subsequent, in many cases deliberate, spread has been documented by Fitzmaurice (1981) and others.

Roach were introduced into Ireland, along with dace, in 1889, when specimens brought from England as bait for pike accidentally escaped into the Co. Cork Blackwater (Went 1950). By 1940 the entire river Blackwater system was colonised by both roach and dace. In 1905, The Baronscourt lakes on the Foyle system were stocked with roach, to provide food for pike (Hale 1956). These fish are thought to have been transferred from the original introduction site in the Cork Blackwater. The roach subsequently disappeared from the Baronscourt lakes, but some must have moved downstream to the River Strule, giving rise to populations in the Rivers Strule and Fairywater.

The Cork Blackwater and Foyle system Strule/Fairywater populations remained isolated for some time, until in 1931 roach were deliberately transferred into Galbally Lake, on the Erne system. In 1960 dredging of the outflow of this lake allowed fish to escape to the River Erne. The first roach in the Erne river system were noted in coarse fishing competitions in 1963 and by 1966 roach were a common feature of anglers' catches (Mercer 1968, Kennedy and Fitzmaurice 1973). By 1973 they had colonised the entire upper Erne system, and rapidly became the dominant fish by biomass in the whole system (Cragg- Hine 1973, Rosell, 1994).

From the Upper Erne system roach passed, possibly via the (then semi-derelict) Ballyconnell canal to the Shannon system, then spreading throughout the 1970s to a wide range of sites, assisted by transport as anglers live bait for pike. By the early 1980s they were widespread throughout Ireland, including the Foyle, Shannon, L Neagh/River Bann, Boyne, Shannon, Corrib and Lee systems. (Fitzmaurice 1981). During the late 1980s and 1990s spread continued and by 2000 they had reached every major river catchment in Ireland, probably absent only from a few montane or small coastal systems without recreational pike fisheries. The latest new site is Lough Melvin, Co Leitrim, where Roach/rudd hybrids were noted in 2002 (Delanty & O'Grady, 2002)

Problems caused by the introduction

Initially, roach were not thought likely to have any major impact on other native or previously introduced fish (Went, 1950). This assessment proved, however, to be wrong. Following roach population explosion in Lower Lough Erne, rudd, a much earlier introduction to Ireland, disappeared (Cragg-Hine 1973), and this pattern has been repeated everywhere roach have been introduced to large lakes containing rudd. Rudd are now largely confined to small, isolated lakes without roach or to densely weeded sites where they are apparently more able to compete with Roach (Winfield, 1986).

Roach can have severe ecological consequences, particularly when lakes become enriched from mesotrophic to eutrophic conditions. Their ability to reach a large biomass and heavily graze zooplankton can exacerbate the algal blooms associated with nutrient enrichment in lakes. They can apparently accelerate the switch from clear water mesotrophy to a turbid water eutrophic state, effectively altering their environment to their own requirements. Biomanipulation experiments in Finland have shown significant water quality benefits following large-scale roach removal (Horppila et al 1994). It is probable that the high biomass

reached by roach in Irish lakes has contributed to the effects of eutrophication. (Rosell and Gibson 1994)

The latest invasive introduction to Irish freshwater, the Zebra Mussel, may now act to control roach populations by removing some of its plankton food source. This may not, however come with any significant benefit to any of the native species affected by roach and/or eutrophication. In the long term, it is probable that the only viable roach (and Zebra mussel) control strategy likely to maintain elements of the affected native biodiversity is maintenance of low trophic status through effective control of nutrient loads to freshwater (Rosell et al 2003).

References

Cragg-Hine, 1973. Coarse fish and fishery management in Northern Ireland. Proceedings of the 6th British Freshwater fisheries conference, University of Liverpool.

Delanty, K., & O'Grady, M.F., 2002. Lough Melvin Fish survey report. Central Fisheries Board.

Fitzmaurice. P. 1981. The Spread of roach Rutilus rutilus in Irish waters. Proceedings of the second British Freshwater Fisheries Conference, University of Liverpool, 154-161.

Hale, P. A., 1958. Roach Rutilus rutilus occurring in Co Tyrone. Irish Naturalists Journal, 12. 160-169.

Horppila, J. 1994b. The diet and growth of roach in lake Vesijarvi and possible changes in the course of biomanipulation. Hydrobiologia, 294, 34-41.

Kennedy, M., & Fitzmaurice, P., 1973, Occurrence of Cyprinid Hybrids in Ireland. Irish naturalists Journal 17, 349 – 351.

Mercer, J.P., 1968. Roach *Rutilus rutilus* L., a new record from Co Fermanagh.

Rosell, R. S., 1994. Changes in fish populations in Lower Lough Erne: a comparison of 1972-3 and 1991-2 gill net survey data. *Biology and Environment: Proceedings of the Royal Irish academy*, **94B**, 275-283.

Rosell, R. S., & Gibson. C.E., 2000. Interlinked changes in fish populations and their environments in Lower Lough Erne, Northern Ireland. *Verhandlungen der Internationale Vereinigung fur Limnologie,* **27**, 2095-2099.

Rosell, R.S., Maguire, C., MacOscar, K., & Roberts, D. 2003. Changes in fish population of Lower Lough Erne, Ireland, following invasion by Zebra mussels. Abstracts of papers presented at the Society of European Freshwater Sciences conference, Edinburgh, July 2003.

Went, A.E.J., 1950. Notes on the Introduction of some freshwater fish into Ireland. *Journal of the Department of Agriculture, Dublin,* **47**, 119-124.

Winfield, I.J., 1986. The influence of simulated macrophytes on the zooplankton consumption rates of juvenile roach, rudd and perch. *Journal of fish biology* **29** (A) 37-48.

Table 1.1 Negative impacts of non-native species on Irish biodiversity: competition

Non-native species	Ecosystems or habitats affected	Impacts
a) Vascular plants		
Rhododendron ponticum	Woodland, grassland, heath	Invasions into natural broadleaf woodland in Killarney & Glenveagh National Parks and acidic soils in the west of Ireland. Plants form dense stands which cast deep shade and reduce native plant cover (Usher, 1987). Lowland heath vegetation and soils are changed enormously by invasion (Mitchell *et al.,* 1997). The plants also secrete toxins into the soil which reduces regeneration of native plants.
Australian swamp stonecrop *Crassula helmsii*	Native aquatic flora	All species form dense stands that shade out native flora, particularly Giant Hogweed (Wyse Jackson, 1989). Dense infestations of *Crassula helmsii* can choke native aquatic plants and deplete the waters of oxygen resulting in competition for limiting resources.
Giant hogweed *Heracleum mantegazzianum*	River banks	
Japanese knotweed *Fallopia japonica*		
Indian balsam *Impatiens glandulifera*	Range of habitats	
Entire leaved cotoneaster *Cotoneaster integrifolius*	Dense flowered orchid *Neotinea maculata*	*Cotoneaster integrifolius* is spreading in Knockninny and Balmore and reducing habitat availability at sites supporting the rare dense flowered orchid.
Salmonberry *Rubus spectabilis*	Native deciduous woodlands	This woody shrub produces dense stands preventing regeneration of native trees. It is spreading in plantations in Armagh and broadleaved plantations in Donegal and elsewhere.
b) Seaweed		
Japanese brown algae/wire weed *Sargassum muticum*	Native coastal marine habitats and plants	Spread in Strangford Lough where it is likely to compete with eelgrass (*Zostera* species) and indigenous algae, as it does on the French Atlantic coast. e.g. *Laminaria saccharina.* Fouling of ships, marinas, moorings, nets, shellfish and aquaculture structures also takes place.
c) Invertebrates		
Zebra mussels *Dreissena polymorpha*	Native fish populations *Anodonta* spp.	High densities of filter feeders like zebra mussels reduce phytoplankton and zooplankton levels which decreases food availability for juvenile fish. Zebra mussels also compete for resources such as space with native freshwater mussels and other benthic invertebrates such as chironomids and webspinning caddis flies in the littoral zone.
d) Vertebrates		
Grey squirrel *Sciurus carolinensis*	Red squirrel *Sciurus vulgaris*	Grey replacing red over much of its former range. Greys have a feeding advantage in deciduous woods (Gurnell, 1983, 1989), possibly due to better ability to tolerate phytotoxins in acorns (Kenwood & Holm, 1993).
Farmed Atlantic salmon *Salmo salar*	Native Atlantic salmon *Salmo salar*	Adult farmed salmon escapees are less successful at reproducing in the wild but their offspring are highly sexually precocious, outcompeting native salmon in river environments.
Introduced fish species e.g. roach *Rutilus rutilus*	Native fish populations Tufted duck *Aythya fuligula*	Either competitive replacement of native fish or formation of introduced × native hybrids There is also evidence that roach compete for the same benthic food as tufted duck, with reductions in the populations of duck being causally linked to roach population increases (Winfield *et al.*, 1992; Winfield *et al.*, 1994)

Table 1.2 Negative impacts of non-native species on Irish biodiversity: herbivory

Non-native species	Ecosystem or species affected	Impacts
Japanese sika deer *Cervus nippon nippon*	Native woodlands and native red deer	Grazing damages coppice regrowth in woodlands (Kay, 1993). Numbers in County Wicklow are inflicting some damage to commercial forestry.
Canada geese *Branta canadensis*	Reed bed, saltmarsh and other vegetation	Damage by overgrazing, particularly in the Lough Erne area of County Fermanagh.
Feral goats *Capra hircus*	Native vegetation	Damage by overgrazing
Red lily beetle *Lilioceris lilii*	Lilies and fritillaries	Defoliation of plants, damage to flowers, seed capsules and stems during heavy infestations (Anderson *et al.,* 2002)
Grey squirrel *Sciurus carolinensis*	Native trees, reafforestation programmes and commercial plantations	Bark-stripping of trees by the grey squirrel causes extensive damage (Case Study 1.3).

Table 1.3 Negative impacts of non-native species on Irish biodiversity: predation

Non-native species	Ecosystems or species affected	Impacts
New Zealand flatworm *Arthurdendyus triangulatus*	Earthworms	Reduces earthworm populations to undetectable levels, thus impacting soil processes.
American mink *Mustela vison*	Native birds, mammals, fish and crustaceans along waterways	Impacts some waterbird species but the magnitude of the effects are unknown (Ferreras & Macdonald, 1999).
Freshwater shrimp *Gammarus pulex*	Native shrimp *Gammarus duebeni celticus*	Decline in native invertebrate community diversity through competition and predation mechanisms; which has a potential unknown effect on the diet of native fish species (Dick, 1996; MacNeil *et al*., 2000).
Introduced piscivorous fish e.g. Pike *Esox lucius*	Native fish species e.g. salmon *Salmo salar*	Predation by piscivorous fish introduced as stocking fish in freshwater river systems

Table 1.4 Negative impacts of non-native species on Irish biodiversity: parasites and pathogens

Non-native species	Ecosystems or species affected	Impacts
Plant fungus *Phytophthora ramorum*	Native oak trees	This fungus, carried by *Rhododendron ponticum* is believed to have caused extensive problems in California as the causative agent of "Sudden Oak Death", although European oak species appear more resilient.
Bee ectoparasites *Varroa destructor* (formerly *V. jacobsoni*)	Native honey bees *Apis mellifera*	Causes large declines in commercial hives. Honey bees are generalists and rarely the sole pollinator of any plant. Due to the lack of knowledge about pollination in Ireland it is unclear whether this reduction in commercial honey bees will have a large or small impact on native plant species that rely on pollination (R. Paxton, pers. comm.)
Farmed Atlantic salmon *Salmo salar*	Native Atlantic salmon *Salmo salar* Native sea trout *Salmo trutta*	The increase in numbers of farmed salmon has increased the incidence of the copepod ectoparasites. The collapse of sea trout populations in the west of Ireland is due to increased infection by sea lice from salmon farms (Marine Work Group, ROI 2003).
Protistan *Bonamia ostrea*	Native flat oysters	Losses of flat oysters due to the disease may be in the region of 80% or more in the Republic of Ireland (Marine Work Group, ROI 2003). Northern Ireland currently has a disease free status regarding *B. ostrea*.
Parapox virus	Red squirrels *Sciurus vulgaris*	Grey squirrels are believed to act as a carrier to the disease which red squirrels are extremely susceptible to, although the prevalence of the disease in Ireland is unknown.
Dutch elm fungus *Ceratocystis ulmi*	Elm trees *Ulmus* spp.	Spread by beetles of the genus *Scolytus*, or through roots of adjacent trees. Indirectly affects invertebrates dependent on elm and many farmland birds (Osbourne, 1985)
Eel swimbladder nematode *Anguillicola crassus*	Freshwater eels *Anguilla anguilla*	First reported in Lower Lough Erne in 1998 this nematode considerably reduces eel fishery profits and is now widely distributed in Ireland (Evans *et al.*, 2001)
Crayfish plague *Aphanomyces astaci*	White-clawed crayfish *Austropotamobius pallipes*	Since the first confirmed outbreak of the plague fungus in Lough Lene, Co. Westmeath in 1987 (Reynolds, 1998) and its suspected recurrence elsewhere (Reynolds, 1988), repeated surveys have indicated the loss of stocks from several midland lakes (Matthews & Reynolds, 1992; Matthews *et al.*, 1993)

Table 1.5 Negative impacts of non-native species on Irish biodiversity: habitat alteration

Non-native species	Ecosystem or species affected	Impacts
Giant hogweed *Heracleum mantegazzianum* Japanese knotweed *Fallopia japonica* Indian balsam *Impatiens glandulifera*	Riparian habitats Aquatic freshwater habitats	As well as being aggressive colonists of river banks and shading local flora, in winter plants die back, exposing soil which is eroded into rivers, altering substrate characteristics, providing favourable conditions for abundant aquatic plant growth and rendering the river substrates unsuitable for salmon spawning (Caffrey, 1994; Lucey, 1994).
Non-native conifers/plantations	Aquatic freshwater biota	Planted on poorly buffered acid/acid-sensitive soils partly blamed for increased acidification of uplands. Subsequent felling generates more acid stream water (Neal *et al.*, 1992) which can have a consequent effect on fish populations.
Cordgrass *Spartina anglica*	Coastal floodplain environments Native bird species	Rapid colonization of *Spartina* over sites with large wintering population of waders and wildfowl reduces habitat availability for feeding and roosting. *Spartina* alters shallow estuaries to form badly drained marshes that commonly have steeply sloping seaward edges and deep, steep-sided channels. Results include increased flooding, blockage of navigational channels and reduced recreational amenity value of an area.
Zebra mussels *Dreissena polymorpha*	Aquatic freshwater habitats	Significant removal of material from the water column to the benthic environment by zebra mussels increases water clarity and thus increases macrophyte growth. The species also causes fouling in water pipes (Minchin & Moriarty 2002)
Tench *Tinca tinca*	Various native species	Bottom-feeding fish increase water turbidity by churning sediment while feeding. Declines in aquatic plants consequently cause reduction in invertebrate populations such as snails and dragonflies. De-oxygenated sediment disturbed through fish feeding activities can release nutrients, in particular phosphorus, which in turn increases crops of phytoplankton resulting in a more eutrophic habitat.
Sea buckthorn *Hippophae rhamnoides*	Sand dune ecosystems	Nutrient enrichment, increased stabilization and acceleration of succession occurs. Sea buckthorn also changes the composition of mesofauna and ground beetle communities (Binggeli *et al.*, 1992).

Table 1.6 Negative impacts of non-native species on Irish biodiversity: genetic

Non-native species	Ecosystem or species affected	Impacts
Farmed fish	Native fish populations	Experiments in NW Ireland demonstrate that farmed and hybrid progeny can survive in the wild, indicating that escaped farm salmon can produce long-term genetic changes in natural populations (McGinnity *et al*., 2003).
Bumblebee *Bombus terrestris terrestris*	Bumblebee *Bombus terrestris audax*	*B. terrestris terrestris* was introduced from mainland Europe for commercial agriculture and hybridizes freely with the native Irish bumblebee *B. terrestris audax,* which could lead to a breakdown in local adaptation to the Irish environment (M. Brown, pers comm.)
Japanese sika deer *Cervus nippon nippon*	Native red deer *Cervus elaphus*	A potential threat to the genetic integrity of the native red deer herd present in Killarney National Park.
Spanish bluebell *Hyacinthoides hispanica*	Native bluebell *Hyacinthoides non-scripta*	*H. hispanica* hybridizes with the native *H. non-scripta* and the hybrid is widespread in County Down to the exclusion of the native bluebell. The hybrid is also common in County Cork (O' Mahony, 1991, 1996, 1997) and around Doldrum Bay (Reynolds, 2002).
Midland hawthorn *Crataegus laevigata*	Common Hawthorn *Crataegus monogyna*	Midland hawthorn hybridizes freely with native species of hawthorn, threatening the genetic integrity of the native species (Jones & Evans, 1994).

Section 2: Vectors for the introduction and spread of non-native species

2 Vectors for the introduction and spread of non-native species

2.1 Introduction

For millennia, the natural barriers of oceans, mountains, rivers and deserts provided the isolation essential for unique species and ecosystems to evolve (IUCN, 2000). Many of these natural barriers have been undermined by modern transportation, enabling species to travel large distances to regions where they are not native. The globalisation and growth in the volume of trade and tourism, along with the emphasis on free trade, provide more and continued opportunities for species to be spread accidentally or deliberately (IUCN, 2000). Customs and quarantine practices, developed to protect health and economic interests against diseases and pests, have often been found inadequate safeguards against species that threaten native biodiversity (IUCN, 2000).

Europe is a major trading bloc with many contiguous states that has highly-developed free trade arrangements. Live plants and animals are translocated, intentionally and unintentionally, in the course of routine trading activities within and between states. Potentially invasive alien species may easily reach neighbouring states or ecologically different parts of the same state (Genovesi & Shine, 2003).

Humans have introduced most of the non-native species in Ireland, intentionally or accidentally. Many artificial introductions are of such long standing, however, that they are generally accepted as part of the Irish countryside, e.g. sycamore *Acer pseudoplatanus* and rabbits *Oryctolagus cuniculus* (Bullock *et al.*, 1996).

By comparison with Britain and continental Europe, the terrestrial and freshwater fauna of Ireland is relatively impoverished reflecting Ireland's isolation by sea since the last glaciation (Costello, 1993). The lower diversity of species, the absence of particular groups, and the lack of a coevolutionary history with invaders, may influence the susceptibility of Ireland to invasive species (Minchin, 2000).

2.2 Vectors

A better understanding of how alien species are spread, together with the knowledge of the critical numbers needed to form new populations and when and where this is most likely to happen, will greatly aid the management of invasive species. The routes by which alien species enter new areas are known as *pathways* while the way they travel to new destinations are known as *vectors* (UNEP, 2001). Pathways and vectors for alien species are numerous (Table 2.1) and can be a result of a diverse array of human activities operating over a range of scales in time and space (UNEP, 2001).

Primary introductions result from the accidental transport of species such as on fouled hulls or in transported water including ballast. Shipping, activities and air transport of living organisms are the main modes of transmission for primary introductions (Minchin & Gollasch, 2002).

Secondary introductions result from the expansion of the alien species from its first location of establishment. This secondary spread will normally include a wider range of vectors that may act either separately or together (Minchin & Gollasch, 2002). Some vectors may transport fundamentally different sets of organisms; for example, mussels attached to hulls, species sheltering within the mussel clumps, species encrusting the mussels, species burrowing into the mussel shells, and pathogens or microalgae inside the mussels. Conversely, some species

may be spread by several different vectors; for example, larval mussels may be transported amongst the plankton in ballast water; adult mussels as hull foulers, as species for aquaculture or as accidentally introduced species associated with stock for culture (ICES CM, 2003).

Some species have more than one possible vector. For example the seaweed *Codium fragile tomentosoides,* which was unintentionally introduced to Ireland, may have been introduced attached to shellfish such as oysters, attached to ships' hulls, as spores in ballast tanks or conceivably through natural rafting and floating (Eno *et al.,* 1997). Some species have been introduced via one vector and have spread via another vector/pathway. For example, *Codium fragile atlanticum*, was unintentionally introduced to southwest Ireland in association with shellfish, from where it has spread through rafting or floating (Eno *et al.,* 1997). Table 2.1 summarises the vectors for the introduction of non-native species.

Some vectors may be classed as both intentional and accidental. For example, in the case of aquaculture and mariculture, species are intentionally introduced for farming purposes. However, some of the animals may escape and result in the unintentional introduction of new species or their associated flora and fauna into a new environment. As a result of this potential risk, aquaculture and mariculture activities are strictly monitored and regulated to reduce the risk to an economically important industry in both Northern Ireland and the Republic of Ireland.

2.3 Biological control

Biological control involves the introduction of a predator, parasite or pathogen of a particular pest species in order to suppress the pest species population (Fasham & Trumper, 2001). The control agent should be host-specific and should not attack native species. Native species usually have natural enemies that appear to regulate the population at a lower density than the maximum possible. Natural enemies include predators, pathogens, parasites or herbivores (Bullock *et al*., 1996).

Problems occur when a species is moved from its native range to an area where these enemies are not present. In this case a biological control programme may be initiated in order to remove the invasive species. One of the characteristics of a biologically controlled system of populations is that prey and predator, or host and parasite populations are often reciprocally density-dependent (Caltagirone & Huffaker, 1980). For all practical purposes these systems can be self-sustaining and permanent. In theory, biological control offers the ideal solution to the problems associated with invasive species. Pest species subjected to biological control programmes throughout the world include aquatic plants, terrestrial plants, herbivorous arthropods, predatory and parasitic arthropods, non-arthropod invertebrates and vertebrates. Non-native biological control agents have rarely been released into the wider environment in the British Isles; most applications are of biological control agents into glasshouses (Fasham & Trumper, 2001).

Biological control programs can be initiated to support species that have themselves been introduced. For example, the accidentally introduced eucalyptus psyllid *Ctenarytaina eucalypti*, has caused economic damage to a commercial eucalyptus plantation in County Kerry (Purvis *et al*., 2002). In order to reduce this deleterious impact, an Australian parasitoid wasp *Psyllaephagus pilosus*, was introduced as a control agent (Chauzat *et al*., 2002).

Table 2.1 Summary of the vectors for the intentional and accidental introduction of non-native species.

Intentional Introductions
1. Biological control
2. Wildfowl and game stocking
3. Horticulture, amenity and ornamental planting, stocking and collections
4. Pet shops, aquaria and scientific institutions
5. Fur farming
6. Forestry
7. Agriculture
8. Aquaculture and mariculture

Accidental Introductions
1. International freight, tourism and travel
2. Fishing equipment, angling and pleasure boats
3. Ports
4. Shipping
   a. hull fouling
   b. ballast water and its sediments
5. Parasites and pathogens carried by invasive species
6. Inland waterways
7. Aquaculture and mariculture
8. Horticulture, amenity and ornamental planting, stocking and collections
9. Pet shops, aquaria and scientific institutions

The grass carp *Ctenopharygdon idella* is used sometimes in the UK to control aquatic weeds but can bring about excessive reduction of beneficial aquatic plants (Stott, 1974; Crivelli, 1995). This may affect native invertebrate species that use areas of invasive aquatic plants. Thus biological control agents, although chosen to be host-specific, may switch to feed on other species and affect non-target organisms.

Howarth (1991) listed factors affecting the degree of risk to non-target organisms:

Permanency of the agent in the environment. The chances of a non-target organism being adversely affected increases with the length of time the control agent is in the environment. The more generations for which an agent persists, the greater is its potential to spread, and the greater is the risk of host and habitat shift.

Host range. Agents with narrow host ranges are less likely to affect other species and those with a broad host range have greater potential to affect non-target organisms.

Habitat range. Species with a greater habitat range can invade a greater number and variety of communities.

Genetic adaptability. The generation time of invertebrates is much shorter than that of higher organisms, and consequently they have a greater tendency for genetic change. The shift from ecological specialisation to generalisation in some rapidly reproducing short-lived species may have a relatively simple genetic basis.

Behaviour of the control agent. Dispersal ability, host-searching and host-handling abilities can enhance a control agent's chances of increasing habitat range and attacking non-target organisms.

Vulnerability of the target region. Most extinctions caused by biological control agents have occurred on islands or in freshwater habitats. In part this may be due to the greater use of biological control on islands, and to superior documentation of extinctions in these habitats.

Indirect effects on native organisms resulting from biocontrol programs. Indirect effects resulting from biocontrol programs in Ireland remain largely unstudied. However, comparative examples from elsewhere in Europe suggest that the potential for indirect influences upon native biota exists. Biocontrol of rabbits *Oryctolagus cuniculus* using *Myxoma* in the UK is believed to have resulted in the extirpation of the large blue butterfly *Maculina arion* through a series of indirect effects that fatally linked this species with rabbits (Moore, 1987). The large blue required nests of the ant *Myrmica sabuleti* for the development of their larvae. These ants in turn had become dependent on rabbit grazing to maintain open habitat for their nests, so biocontrol of the rabbits with the *Myxoma* virus initiated a cascade of interactions believed to have led to the extinction of the large blue in the UK in 1979 (Thomas, 1995).

Food-web interactions can also result from the introduction of biocontrol agents. For example, if an established biocontrol agent is ineffective at reducing its host densities, populations of the biocontrol agent are likely to remain abnormally high due to abundant food resources (Pearson & Callaway, 2003). High concentrations of a particular biocontrol agent can provide an increased source of food for native consumers. Many native organisms are food limited and food subsidies to key native organisms can serve to restructure community interactions, whether inputs come from native or exotic sources.

2.4 Wildfowl and game stocking

Ireland has a long history of introducing species for sport; past introductions included pheasant *Phasianus colchicus*, red-legged partridge *Alectoris rufa*, fallow deer *Dama dama* and rainbow trout *Oncorhynchus mykiss*. All of these species breed to some degree in the wild and compete with native species and alter their habitats. In addition, plant species were introduced as game cover (e.g. snowberry *Symphoricarpos albus*) (Fasham & Trumper, 2001).

Bait organisms used for angling may be exported beyond their normal range and may be discarded alive to the wild to form new populations. An example of a bait organism brought into Northern Ireland is the freshwater shrimp *Gammarus pulex* (Case Study 2.2). This species was introduced as prey for the native Brown trout in the Ballinderry River system in Northern Ireland. Since its introduction this species has spread in Northern Ireland and more recently in the Republic of Ireland (Kelly *et al.*, 2003).

Numerous bird species have established wild populations either through deliberate releases or accidental escapes. Examples include the ruddy duck *Oxyura jamaicensis* and the mandarin duck *Aix galericulata.* The ruddy duck is thought to be an uncommon breeding resident in Ireland, with populations found in Lough Neagh (approximately 89 birds), Portmore Lough (approximately 54 birds) and in Limerick and northeast of Limerick. The presence of ruddy ducks in Ireland has been linked to the

expansion of the English feral population (NI Bird Report, 1999). Mandarin ducks are found in Tollymore, County Down where there is an estimated population of 20-30 pairs (NI Bird Report, 1999).

Mammal introductions include deer species such as sika deer *Cervus nippon*, which were introduced to deer parks, subsequently invading woodlands and hybridising with the native red deer *Cervus elaphus* (Hayden & Harrington, 2000).

2.5 Horticulture, amenity and ornamental planting, stocking and collections

Many animal and plant species have been introduced into Ireland solely for their decorative qualities (Bullock *et al.*, 1996). Ornamental gardening began in Ireland during the medieval period with specimens coming from Europe and West Asia, then later Africa, the Far East and the Americas as trade routes opened across the world. Many of these ornamental species have escaped from private gardens, parks and garden centres and have established wild populations. Some of these species have then become invasive by spreading to natural habitats, particularly along river corridors. Examples of invasive terrestrial plants introduced to Ireland in this manner include Rhododendron *Rhododendron ponticum*, giant hogweed *Heracleum mantegazzianum*, Japanese knotweed *Fallopia japonica* and Himalayan balsam *Impatiens glandulifera*. Invasive ornamental aquatic plant species introductions include stonecrop, *Crassula helmsii*.

In addition, large-scale planting of public areas such as road verges has not only commonly included non-native species, but also non-native strains of native species (Fasham & Trumper, 2001). Examples of the latter include hybrids of bird's-foot trefoil *Lotus corniculatus*, oxeye daisy *Leucanthemum vulgare* and red clover *Trifolium pratense*.

2.6 Pet shops, aquaria and scientific institutions

Animals imported as pets and domestic animals can find their way into the wild, either by deliberate release or accidental escape, where they may subsequently breed. Examples include feral and domestic cats (which have been known to hybridise with wild cats *Felis silvestris* in Scotland).

The valuable trade in ornamental fish presents an interesting case. In Northern Ireland, import of ornamental fish and plants is allowed subject to the granting of an Import Licence and compliance with EU requirements (DARD, 2003). Voluntary trade organisations have taken the lead in reducing illicit trade and associated spread of invasive species and vectors of disease. It has been suggested that the international trade in tropical and ornamental fish has been responsible for the direct spread of diseases such as Epizootic Ulcerative Syndrome in (caused by the bacteria *Yersinia ruckeri*) in a number of European countries. However, most ornamental fish are introduced to closed systems where they present little threat. Escapes and deliberate releases do occur but trade organisations have had a demonstrable role in encouraging responsible ownership.

In May 2003, The Department for Environment, Food and Rural Affairs (DEFRA) issued an Order under the Diseases of Fish Act 1937, prohibiting the movement of fish to and from two fish farms in Worcestershire, following an outbreak of Spring Viraemia of Carp (SVC). SVC is a serious viral disease affecting common and ornamental carp as well as a variety of other wild species including tench, roach, rudd and pike. SVC is widespread in many European

and Asian countries from where fish are imported, legally and illegally, into the United Kingdom (E-Fish Business, 2003a). Again, legitimate trade will present less of a problem than illicit activities.

In the case of scientific institutions, zoological gardens and aquaria, there are many exotic organisms held. Unfortunately, the secondary spread of such organisms is apparently common-place (Bullock *et al.*, 1996).

By way of indicating the variety of non-native species being introduced, Table 2.2 lists 30 species of aquatic plant that were imported into the Republic of Ireland in 2002. These imports were licensed for sale in aquarium and garden centres. As yet, no invasive properties have been identified in these species.

2.7 Fur farming

The farming of animals for their pelts is another long-standing reason for the introduction of non-native species (Bullock *et al.*, 1996). In Ireland, the American mink *Mustela vison* was first introduced in the early 1950s for fur farming, and soon escaped and established feral populations. The population densities of American mink in Ireland are believed to be at, or near, the carrying capacity of the environment and in all cases appear self regulating (Smal, 1991). Availability of the crayfish *Austropotamobius pallipes* appears to be a major factor in determining mink numbers and stability within populations in Ireland (Bullock *et al.*, 1996).

Legislation for the regulation of fur farms does exist in Ireland. The Department of Agriculture and Food in the Republic of Ireland brought in a licensing scheme in 1966 and similar regulations were introduced for Northern Ireland in 1968. From the 1st January, 2003 the Fur Farming (Prohibition) (Northern Ireland) Order 2002 made it illegal to conduct fur farming in Northern Ireland. The Government in the Republic of Ireland has not made plans to ban fur farming in the Republic of Ireland. Currently there are six mink and two fox fur farms in the Republic of Ireland (Compassion in World Farming, 2003).

2.8 Forestry

Many native trees are slow growing and site-sensitive species. In the past the land available for afforestation was often on exposed marginal agricultural land. This resulted formerly in little economic justification for the planting of native trees for commercial forestry. Faster growing, non-native conifer species were widely planted in Ireland on these marginal soils. Furthermore, the commercial basis of the forestry industry in the UK relies greatly on introduced tree species, particularly Sitka spruce from North America (Forestry Authority, 1998).

These faster growing non-native species have been known to invade some semi-natural and disturbed habitats beyond areas where they have been planted (Bullock *et al.*, 1996). In addition, planting of species beyond their native habitats and the use of non-local provenance stock is common in the commercial, amenity and ornamental forestry sectors. However, forestry departments increasingly recognise the importance of broadleaf native woodland. In recent years land of higher fertility has become available for forestry in Ireland thereby enabling the establishment of commercial native broadleaved plantations. In the Republic of Ireland the Forest Service national target is 30% of annual afforestation by 2006. The Forest Service also grant aids the protection of native woodlands and the establishment of new native woodland through its Native Woodland Scheme. UK Forestry Guidelines highlight the need to plant at least 5% of the area

of any new conifer woodland with broadleaved trees or shrubs (Forestry Authority, 1998).

2.9 Agriculture

Since humans first moved from one region to another, crop species have been moved with them. Agriculture has been responsible for many plant introductions over the years (Fasham & Trumper, 2001). Many long-established species were originally introduced for their utility value, e.g. most agricultural crops like maize, wheat, tomatoes, herbs, medicinal plants and also species introduced for pasture improvement (Bullock *et al.*, 1996). Long-established species also include archeophytes and more recently established (post 1700) neophytes (Preston *et al.*, 2002). Seeds of other plant species have also been accidentally imported with crop seeds, and some crop species themselves have become established in the wild. Examples include wild oat *Avena fatua*, and fodder crops such as Alsike clover *Trifolium hybridum*. Oil seed rape *Brassica rapa* is now a common sight on roadsides, field margins and disturbed ground adjacent to areas where the crop has been planted. Agriculture is a main secondary vector for the spread of invasive non-native species.

2.10 Aquaculture and Mariculture

Aquaculture and mariculture have long been recognised as important vectors for introductions of non-native species, both deliberate and accidental.

Both aquaculture and mariculture are particularly important for the rural economy. In Ireland, aquaculture is a particularly important industry; the volume of production in 2001 was 60,935 tonnes, worth €107 million (M. Mathies, BIM, pers. comm.). In general, introductions arising from aquaculture and mariculture are intentional and are regulated, approved and positively in line with government regulations. Aquaculture facilities are strictly licensed in the Republic of Ireland by the Department of Communications, Marine and Natural Resources (DCMNR) and by the Department of Agriculture and Rural Development (DARD) in Northern Ireland.

The international trade in live fish, shellfish and eggs for aquaculture, fisheries and the exotic food market has increased in recent years (Fasham & Trumper, 2001). A variety of non-native species are farmed in Ireland, including Pacific oysters *Crassostrea gigas,* the manila clam *Tapes semidecussatus*, the Japanese abalone *Haliotis discus hannai* and the European abalone *Haliotis tuberculata.*

Bord Iascaigh Mhara (BIM), an agency with responsibility for developing the Irish sea fishing and aquaculture industries has actively promoted the development of new opportunity species under its aquaculture diversification programme. This aims to increase aquacultural output from novel species in line with the more traditionally produced species such as salmon and mussels. This programme is vitally important in helping sustain rural employment and wealth creation in these communities.

The global market in seafood results in the long distance transport of live organisms for immediate consumption and these non-native organisms can be accidentally released into new environments where they can establish reproducing populations (Chapman *et al.*, 2003).

Table 2.2. Licensed imports of aquatic plants to the Republic of Ireland in 2002 (ICES CM 2003/ ACME:041)

Species	Number	Country of Origin
Alternantherna bettzicklana	20	Indonesia
Alternantherna lilacina	10	Indonesia
Alternantherna ocipus	20	Indonesia
Alternantherna reinckii	10	Indonesia
Ammannia gracilis	20	Indonesia
Bacoma amplexicaulis	10	Indonesia
Bacopa monnieri	10	Indonesia
Caboma aquatica	10	Indonesia
Echinodorus latifolius	10	Indonesia
Echinodorus pervensis-amazonicus	20	Indonesia
Elodea densa (Egeria densa)	10	Indonesia
Eustralis stellata	10	Indonesia
Hemigropsis sp.	10	Indonesia
Hydrocotyle leucocephala	20	Indonesia
Hygrophila lacustris	10	Indonesia
Hygrophila polysperma	40	Indonesia
Hygrophila corymbosa	20	Indonesia
Hygrophila salicifolia	10	Indonesia
Hygrophila siamensis	20	Indonesia
Lilaeopsis novae-zelandiae	10	Indonesia
Limnophila aromatica	30	Indonesia
Limnophila sessiflora	10	Indonesia
Ludwegia arcuata	10	Indonesia
Ludwegia repens-palustris	20	Indonesia
Micranthemum umbrosum	10	Indonesia
Nomaphila angustifolia	10	Indonesia
Nomaphila sp.	10	Indonesia
Physostegia purpurea	20	Indonesia
Rotala nanjenshan	20	Indonesia
Rotala wallichif	10	Indonesia

Holcik (1991) estimated that in Europe over 30% of introduced inland fish species originated from aquaculture. In the Republic of Ireland, BIM has been involved in supporting trials with Icelandic, Swedish and Canadian Arctic charr, *Salvelinus alpinus*. Arctic charr is native to Ireland. However, the Irish strain matures at a small size and is not well suited to culture, therefore more suitable strains have been imported (M. Mathies, BIM, pers. comm.). Furthermore, novel species aquaculture has been going on for years in Ireland supported by DCMNR, BIM, UnaG, TMT, the SRA and some of the Universities.

During the 1940s and 1950s the native oyster was imported as spat from areas in France with dense natural settlements. Oyster production increased in Ireland following trials with the Pacific oyster *Crassostrea gigas* which started in the late 1960s (Utting & Spencer, 1992). In the following years various species of exotic molluscs were used in trials with the intention of increasing aquaculture production. These were subject to periods of quarantine so as to ensure a disease-free stock (Minchin & Eno, 2002). An example was the introduction of the Japanese scallop *Patinopecten yessoensis*, from Japan to Ireland in 1990 (Minchin, 2003). The original introduced stock was not released into the wild, and only the F1 generation of scallops was released in 1990 and were held in

hanging culture near Carnsore Point on the south-east coast, alongside the native scallop *Pecten maximus*.

In Ireland, the Pacific oyster *Crassostrea gigas* is produced in Irish hatcheries but is also imported from hatcheries in Britain and the Channel Islands and France. Cultivation takes place on all Irish coasts with the main production in Carlingford Lough and Dungarvan Bay. Following the 1993 European Free-Trade Agreement, the trade in half-grown Pacific oysters from France has resulted in the oyster-gut parasite *Mytilicola orientalis* being introduced to Ireland. In 1993 samples taken from Carlingford Lough, Dungarvan, Cork Harbour, and Oysterhaven revealed the presence of this organism (Holmes & Minchin 1995).

Irish oyster growers continue to be advised against bringing in half-grown oysters because of the high risk of importing unwanted biota. Movements of Pacific oysters have also been implicated in the spread of the Japanese brown alga *Sargassum muticum*.

Most marine salmon farms are liable to infestations of parasites and pathogens, probably originating from local wild salmon stock. Since the late 1980s it has been suggested that infection of wild post-smolt sea trout *Salmo trutta* by sea lice from non-native fish in fish farms has caused serious population reductions in the west of Ireland (Marine Work Group, Marine Institute, 2003). The collapse of sea trout populations from Galway Bay to Clew Bay has coincided with areas of intensive salmon farming and there is a widespread perception that increased infection by sea lice from salmon farms is an important factor (Marine Work Group, Marine Institute, 2003). However, there is now legislation in place in the Republic of Ireland to regulate and control sea lice and this regulation is part of every salmon farmer's licence conditions (M. Mathies, BIM, pers. comm.).

It has been the policy in the Republic of Ireland, since the 1960s, to refuse requests for shellfish and fish imports from unapproved areas, including oysters grown in France (Minchin & Rosenthal, 2002). However, EU free trade agreements did not take ecological matters fully into account and non-native species have been spread with species destined for aquaculture or mariculture (Minchin & Rosenthal, 2002).

A list of invertebrate species and fish species imported into the Republic of Ireland in 2002 is presented in Tables 2.4 & 2.5. All of these imports were licensed and regulated under the Fisheries (Amendment) Act, 1997. Under this Act any import of fish or shellfish has to be accompanied by the relevant movement documents and health certification requires that they be proven disease free before they are imported (M. Mathies, BIM pers. comm.). These tables highlight the diversity of species being imported from a range of areas.

2.11 Accidental introductions

The intentional import and release of species can give rise to unintentional introductions of species through vectors linked to the international trade in organisms (Fasham & Trumper, 2001). Species may also be introduced through activities not directly concerned with the transport of and trade in live organisms.

2.12 International freight, tourism and travel

Non-native species are commonly transported via freight and tourism, e.g. with the import of plants and plant products. For example, the New Zealand flatworm *Arthurdendyus triangulatus* was accidentally introduced to Northern Ireland in

growing media (e.g. soil) traded in pots, trays and root-balled plants (Case Study 2.1). In addition, pathogenic organisms can be introduced via imports of live or dead animals or plants.

2.13 Fishing equipment, angling and pleasure boats

Movements of infested fishing gear or boats may allow species to colonise new regions (Wallentinus, 1999). Small boats may also be carried on trailers and are well understood as being important in overland species transmissions. Animals may be either carried in bait wells as larvae or attached to hulls, with re-immersion leading to the fouling biota being rubbed off (Minchin, Lucey & Sullivan, 2002). The trailer itself may also transmit species.

A threat that has already been recorded in Ireland is crayfish plague, caused by the fungus *Aphanomyces astaci.* The plague is usually introduced with the North American signal crayfish *Pacifastacus leniusculus* (Palmer, 1994). In October, 1987 the plague was recorded in Ireland in Lough Lene (Mathews & Reynolds, 1990) and destroyed most of the stock of native crayfish in one lake system. Outbreaks of the disease have not been noted since. The North American signal crayfish is not yet present in Ireland and, therefore, was not the vector responsible for the introduction of the plague to Ireland. Crayfish plague can be introduced into a water-body by water, fish or equipment that has been in contact with signal crayfish and these may have been the vectors in the case of crayfish plague in Ireland (Mathews & Reynolds, 1990). The spores of the fungus are able to survive in moist conditions such as on muddy boots and fishing gear (Holdich & Reeve, 1991). The spread of crayfish plague is difficult to control because it could be carried from one population to another by many different vectors (Holdich & Reeve, 1991).

2.14 Ports

A large number of organisms can be carried in a viable state to ports and waterways where shipping is the principal activity. A large variety of activities take place in ports (Rosenthal, 1997) and so ports may act both as donor and recipient for invasive species. In ports, vectors are likely to overlap because many people normally live in these regions and engage in a wide range of relevant activities. Many aquaculture activities are near ports or within natural bays due to the shelter and the proximity to markets. However, there is a risk that organisms carried with ships may impact on survival, compromise growth of the culture species or result in a product being unmarketable (Minchin & Gollasch, 2003). Because exotic species are likely to be present in ports, there are opportunities for the spread of these species with smaller boats (Minchin & Gollasch, 2003). Furthermore, marinas are frequently found in port regions and many boats may remain here for some time, allowing a build up of fouling biota (Minchin & Gollasch, 2003). Managing the overlap of vectors in such regions may lead to hard decisions regarding whether some activities should be restricted so as to reduce risk. Ports will benefit from studies of the exotic species present, particularly when there is a risk of that port acting as a donor to other regions. Irish harbours have been the recipient for invasive species. For example, an oyster gill condition was noted in about 22% of Pacific oysters *Crassostrea gigas* and 12% of native oysters *Ostrea edulis* in Cork Harbour in the autumn of 2000 and in 15% of Pacific oysters in Waterford Harbour in October, 2001 (Minchin, 2002). However, cryptogenic species may be responsible for this condition.

Table 2.3 Examples of vectors of intentional or accidental introductions that have resulted in the spread of non-native species to either Northern Ireland or the Republic of Ireland. It is important to note that some of the vectors can be classified as being both intentional and accidental vectors.

Intentional Introduction Vectors	**Non-native species**
Biological control	*Myxoma* virus,
	Psyllid parasitoid wasp *Psyllaephagus pilosus*
Wildfowl and recreational fishing stocking	Pheasant *Phasianus colchicus*
	Rainbow trout *Oncorhynchus mykiss*
	Freshwater shrimp *Gammarus pulex*
Horticulture, amenity and ornamental planting and stocking	Himalayan balsam *Impatiens glandulifera*
Pet shops and aquaria	Spring viraemia of carp
Fur farming	American mink *Mustela vison*
Forestry	Sitka spruce *Picea sitchensis*
Agriculture	Wild oat *Avena fatua*
	Oil seed rape *Brassica rapa*
Aquaculture and mariculture	Canadian Arctic charr, *Salvelinus alpinus*
	Pacific oyster *Crassostrea gigas*
Accidental Introduction Vectors	**Non-native species**
International freight, tourism and travel	New Zealand flatworm *Arthurdendyus triangulatus*
Fishing equipment, angling and pleasure boats	Crayfish plague fungus *Aphanomyces astac*
	Zebra mussel *Dreissena polymorpha*
	Wire weed Sargassum muticum
Ships' hull fouling	Possibly Red Algae *Antithamnionella ternifolia*
	Tubeworm *Ficopomatus enigmaticus*
	Tunicate *Styela clava*
Ships' ballast water and its sediments	Tubeworm *Ficopomatus enigmaticus*
	Codium fragile subsp. tomentosoides
Parasites and pathogens	Nematode bladder parasite *Anguillicola crassus*
Horticulture, amenity and ornamental planting and stocking	New Zealand flatworm *Arthurdendyus triangulatus*
Agriculture	Bearded Darnel *Lolium temulentum*
Aquaculture	Red seaweed *Polysiphonia subtilissima*
	Wire weed *Sargassum muticum*
	Oyster-gut parasite *Mytilicola orientalis*

Case study 2.1 New Zealand flatworm *Arthurdendyus triangulatus*

Category of introduction Accidental.

Reasons for introduction Economic trade. Through lack of precautionary measures to prevent the introduction of non-native invertebrates and other organisms in soil imported as a growing medium for living plants.

Pathway for the introduction
It was first discovered in Belfast in 1963. There is anecdotal evidence of earlier infestations. The introduction was associated with the plant trade. New Zealand flatworms arrived into Northern Ireland in association with potted plants of *Narcissus*.

Background to the introduction
UK plant trade with New Zealand because it is part of the Commonwealth.

Problems caused by the introduction
The problem caused by the New Zealand flatworm is the impact it has on earthworm biodiversity possibly resulting in their local extirpation. The New Zealand flatworm is a predator of the earthworms which keep our soils in good condition and are a source of food for many animals. The flatworm has been known to reduce earthworms to below detectable levels and hence poses a threat to native earthworms and the ecosystems dependent on earthworms, including agricultural production.

How the introduction might have been prevented
Stricter phytosanitary measures. Had there been knowledge of the species and the risk of its introduction, some trade measures may have been deemed appropriate to prevent the introduction from New Zealand in planting material, e.g. by only allowing bare rooted plants or requiring growing media accompanying plants to be sterile. Additionally a good level of awareness of the risk of moving it in plant material could have limited its spread once the introduction had taken place.

Research
The effect of the New Zealand flatworm on earthworm species diversity and the effect on the food chain is currently being undertaken (Moore *et al.*, 1998).

Invasion dynamics outside Ireland
Limited largely to the British Isles – Scotland, Ireland and Northern England. There is evidence that the New Zealand flatworm has limited tolerance of climatic variation and may only be a problem in areas that have a similar climate to its native habitat.

References
Moore, J.P., Dynes, C. & Murchie, A.K., 1998. The status and public perception of the New Zealand flatworm, *Artioposthia triangulata* (Dendy) in Northern Ireland. *Pedobiologia*, 2;563-571.

Case study 2.2 Fresh water shrimp *Gammarus pulex*

Category of introduction
Intentional

Reasons for introduction Recreational and economic.

Pathway for the introduction
Human vector. Introduced to several rivers in connection with fish farming practices, spreading rapidly in the North of Ireland and more recently in the Republic of Ireland.

Background to the introduction
Gammarus pulex was introduced in the 1950's by humans to provide additional feeding for native brown trout in the Ballinderry River system in Northern Ireland.

Problems caused by the introduction
The amphipod community has changed dramatically, from a single species to a patchwork of mixed species communities. *Gammarus pulex* displaces the native *Gammarus duebeni celticus*. The reduction and decline of the native invertebrate community distribution and diversity occurs through both competitive and predation mechanisms. The change in the diet of the native trout to that dominated by the introduced *G. pulex* has unknown effects on the population biology of trout.

How the introduction might have been prevented
Increased community awareness of the consequences of invasive species. Legislation preventing the introduction of non-native species as bait for angling.

Invasion dynamics outside Ireland
G. pulex is native to mainland Great Britain and to parts of Europe. *G. pulex* is also invasive in the Isle of Man and in Brittany in Northern France. In both areas it has displaced the native *G. d. celticus* in large areas of the natives distribution.

References
Kelly, D.W., Dick, J.T.A., Montgomery, W.I. & Macneil, C., 2003. Differences in composition of macroinvertebrate communities with invasive and native *Gammarus* spp. (Crustacea: Amphipoda). *Freshwater Biology*, 48; 306-315.

2.15 Shipping

Over millennia, marine species have dispersed throughout the oceans by natural means, carried on currents and attached to floating logs and debris. Shipping activities are believed to be primarily responsible for the majority of modern species introductions in the marine environment (ICES CM, 2003). Shipping transports over 80% of the world's commodities and transfers approximately 3 to 5 billion tonnes of ballast water internationally each year. The majority of introduced invertebrates have arrived in association with shipping either as fouling organisms or in ballast water. The spread of already established non-native marine species can be exacerbated by ships travelling along the coast.

2.16 Hull fouling

The phenomenon of ships and boats carrying exotic species on their hulls has been occurring for many centuries (Minchin & Eno, 2002). This is because when ships are in dry-dock they are supported on wooden blocks, the hull beneath does not get painted with antifoulants and at this point fouling may freely develop once the ship is reimmersed (Bullock *et al.,* 1996). Ships may have well developed fouling communities including mussels and oysters (Minchin & Eno, 2002). Serpulid and spirorbid polychaetes have spread extensively as fouling organisms both on ships and oysters (Zibrowius & Thorp, 1989). Furthermore, several invertebrates spread to new areas as a result of hull fouling could spawn when exposed to temperature fluctuations while entering the new ports and leave behind a viable inoculum of zygotes that could form a founder population (Minchin & Gollasch, 2003). One species, the 'shipworm', a boring bivalve, *Teredo navalis*, became extensively distributed as a result of hull fouling. This species has been recorded in Cork Harbour but no recent records exist (Minchin & Sheehan, 1999), perhaps as a result of reduced habitat availability. The Australasian barnacle *Elminius modestus* became established on the south coast of Britain carried on warships returning from the Pacific during the Second World War (Crisp, 1958). It has since spread and become abundant in many sheltered estuaries in Britain, Ireland and northern Europe.

Studies on species introductions in Europe suggest that hull fouling is an important vector of invasive species (Gollasch, 2002) and fouling organisms can occur in great numbers. However, since the use of tributyltin (TBT) as a toxic ingredient in hull paint coatings in the early 1970s, no further exotic species that can be attributed to hull fouling have occurred in Cork Harbour (Minchin & Sheehan, 1999). The deleterious effects of TBT, however, include altering of embryonic development, metamorphosis, 'imposex' (superimposed male features on female neogastropods leading to sexual impairment in some species) in neogastropods and the disappearance of some species in areas with high contamination both in water and in sediments (Mansueto *et al.*, 2003). In Cork Harbour the poor recruitment and decline of the scallop fishery is consistent with the relative levels of TBT contamination (Minchin *et al.,* 1987). There are also known impacts of TBT on the culture of molluscs (Alzieu & Heral, 1984) and salmonids (Short & Thrower, 1987).

2.17 Ballast water and its sediments

Ballast water is usually carried in segregated ballast water tanks or in emptied cargo holds and is taken on board in ports, waterways and the open ocean (IMO, 2000). Ballast water is essential to the safe and

efficient operation of modern shipping, providing balance and stability to unladen and partly laden ships. Ships usually carry ballast water when no cargo is carried. However, even when the ship has a full load of cargo, some ballast water will remain in ballast tanks (Minchin & Gollasch, 2002). Ballast water may pose a serious ecological, economic and health threat because alongside the intake of ballast water, organisms, suspended solids and chemicals, including industrial and human wastes, are also pumped onboard (IMO, 2000). As the tanks will be filled and drained in different sequences either singly or collectively, the ballast water in one tank may be composed of water and sediments from several ports (Gollasch, 1996).

There are thousands of marine species that may be carried in ballast water; constituting those that are small enough to pass through ballast water intake ports and pumps. These include bacteria and other microbes, small invertebrates and the eggs, cysts and larvae of various species (IUCN, 2001). Discharge of ballast water or sediment into the waters at ports may result in the establishment of harmful aquatic organisms and pathogens which may pose threats to indigenous human, animal and plant life, and the marine environment (IMO, 2000). In 14 recent European ballast studies approximately 990 species were recorded from ballast tanks (water and sediment), ranging from bacteria to 15 cm long fishes (Gollasch *et al.,* 2003). The problem is compounded by the fact that virtually all marine species have life cycles that include a planktonic stage or stages (IMO, 2000). Thus, even species in which the adults are unlikely to be taken on board in ballast water because they may be too large or live attached to the seabed, may be transferred in ballast during their planktonic phase (IMO, 2000).

The ballast water discharged into Ireland mainly originates from British and other European ports (Minchin, 1996a; Minchin & Eno, 2002). Species that expand their ranges and colonise greater numbers of ports will subsequently increase the risk of their spread to Britain and Ireland on established trading routes. A study on ballast discharges in Ireland in 1994/5 showed that the greatest volumes were discharged in Cork Harbour and the Shannon Estuary (Minchin, 1996a). Trade with Baltic Sea ports to Irish estuaries could result in introductions of some Ponto-Caspian species that have colonised parts of the Baltic Sea (Minchin & Eno, 2002). The amount of ballast water discharged into Irish waters has been calculated to be 1.5 million cubic metres per year (Minchin, 1996a). This is likely to increase, however, with the expansion of port facilities (Minchin, 1996a).

In response to the threats posed by invasive marine species, the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, in its Agenda 21 called on the International Maritime Organization (IMO) and other international bodies to take action to address the transfer of harmful organisms by ships. The IMO has been addressing this issue and a number of remedies are being investigated including ballast water exchange by ships at sea. This method might well be the best practical option but does have shortcomings, in that it is not fully effective in removing organisms from ballast and may be subject to ship safety limits (Topfer, 2002). Ships that empty ballast tanks in bad weather can be structurally compromised which could lead to the loss of the vessel and its crew (Minchin, 2001).

2.18 Parasites and pathogens carried by invasive species

Parasites or pathogens may be carried by invasive species and transmitted to native species. The native species may be detrimentally affected by the new parasite or pathogen. In Ireland a potential threat is the spread of the parapox virus to the native red squirrel species by the invasive grey squirrel species. The origins of parapox virus are unknown, but antibodies of the virus have been found in grey squirrel populations in Northern Ireland (Northern Ireland Forest Service, 2003). Recent outbreaks of the virus in England have almost wiped out local populations (National Farmers Union, 2003). It has been found that the parapox virus is endemic in some grey squirrel populations, but rarely results in death in the grey squirrels (Gurnell *et al*., 2003). It would appear that Grey Squirrels act as a reservoir host for the virus, which if passed on to red squirrels, results in death (Gurnell *et al*., 2003).

One further example is that of imported stocks of the oriental eel *Anguilla japonica*, in which the lack of proper quarantine procedures ultimately led to the spread of the nematode bladder parasite *Anguillicola crassus* arriving into Germany and spreading from there. It has since become established in Ireland. This nematode parasite surrounds the airbladder of the freshwater common eel *Anguilla anguilla*. This parasite was first discovered in Ireland in Waterford in 1997. In 1999 it was recorded in the Lower Shannon River in Lough Derg and in the Erne catchment. This parasite was probably introduced by its infective stage being released in water used to refresh eels in a truck fitted with tanks with consignments eels captured in Britain before arriving in Ireland (Minchin, 2003). However, it is possible that the infective stage could be carried with copepods released with ships' ballast water or with water associated with imported fish for stocking rivers (Minchin, 2003). The introduction of this parasite may have long-term consequences for not only Irish eel populations, but also the North Atlantic stock which is declining for other reasons (Dekker, ICES WG reports).

2.19 Inland waterways: a pathway for the movement of invasive species

The existence of old canal systems and new waterways has allowed for the ready transmission of species, either by moving on their own accord or by inadvertently being carried by boats (ICES, 2003). The opening up of new waterways and restoration of canals creates corridors which allow the spread of non-native species by natural dispersal and via water crafts. An example of inland waterways aiding the spread of an invasive species in Ireland is the spread of the zebra mussel *Dreissena polymorpha* from the River Shannon to Lough Erne via the Shannon-Erne Waterway which was opened in 1994 (Case Study 2.3). A further example of invasive species being spread through inland waterways on small boats is the case of the tubeworm, *Ficopomatus enigmaticus*, which was noted in 1995 at a small boat marina in a shallow artificial lagoon on the Shannon Estuary and it is likely that it was carried on the hulls of pleasure boats from the only other known population in Cork Harbour (first recorded there in 1971) (Minchin & Gollasch, 2003).

2.20 Conclusions - Irish priorities

This review highlights the variety of vectors and pathways for the introduction and spread of invasive species in Ireland. Some vectors are hard to identify and a better understanding of how invasive species are spread together with research and data on the critical numbers needed to

form new populations, and when and where this is most likely to happen, will greatly aid the understanding of the vectors of non-native species.

There are many vectors responsible for the introduction of non-native species into Ireland and it is not always clear which vectors are responsible for some introductions. In many cases more than one vector may be responsible.

In terms of priorities, the vectors responsible for the majority of invasive species introductions into Ireland appear to be related to shipping, effecting both deliberate and accidental introductions, and to the import of plants and associated material via horticulture. In the case of shipping, forty marine and brackish water exotic species have been recorded in Ireland (Appendix 1).

It is extremely difficult to monitor and regulate vectors. It is likely that shipping will continue to be an important vector and the port regions with a complement of exotic species, such as Cork Harbour and the Shannon estuary, may expect to receive more invasive species due to their sheltered conditions. Furthermore, in the coming century, should predicted changes in climate occur, natural ranges of organisms native to northern Europe are likely to change providing new opportunities for exotic species to expand their ranges (Minchin & Gollasch 2002).

The horticulture trade is another important vector with little data available on the numbers of species being introduced via this vector. This particular vector will be difficult to monitor and campaigns aimed at trade sectors and the general public will be necessary to generate increased awareness.

Research is necessary to increase the frequency and utility of risk assessment exercises so that a precautionary approach may be adopted to prevent the introduction of new species rather than trying to remove them once they have become established and invasive. In the long-term proactive measures are likely to be more cost effective than reactive control measures in both economic and ecological terms.

Case study 2.3 Zebra mussel *Dreissena polymorpha*

Category of introduction Unintentional.

Pathway for the introduction

The zebra mussel were noted in Ireland around 1994 and became invasive over the later 1990s (Pollux *et al.,* 2003). The main vector for the primary introduction of the zebra mussel was boating, accidentally attached to the hulls of second hand boats imported from Britain or the Netherlands (Minchin *et al*., 2003; Pollux *et al*., 2003). These boats, imported for private use mainly on the Shannon Navigation system, were lifted from British waters onto trailers, transported to Ireland by ferry and lifted into Irish waters within a day. They were introduced to the Lower Shannon River in 1994 and were recorded in the Limerick docks at the top of the Shannon estuary in the spring of 1995.

Following the establishment of zebra mussels they became attached to leisure craft and were carried upstream via locks and swing bridges to the entire navigation on Loughs Derg (11,600 ha), Ree (10,500 ha), Key (900 ha) and several smaller lakes by 1996. From the River Shannon Waterway they were accidentally carried into the Erne on the bottom of boats. By 1996 zebra mussels had become established in Lower Lough Erne via the recently restored Shannon-Erne Waterway in 1994 (Figures 2.1).

Background to the introduction

Several events in 1993 may have created an invasion window: the abolition in January 1993 of VAT on second hand boats within the EU, the introduction of a certificate of competence for second hand boats in England and an exchange rate favouring exports from the UK to Ireland. This combination of events resulted in an increase in a dispersal vector for zebra mussels: second hand boats, moving from England to Ireland. Human activities enabled the expansion of the zebra mussel and its further spread was made possible by a combination of natural and human-mediated dispersal mechanisms (Minchin *et al*., 2003).

Problems caused by the introduction

Economic: water treatment plants, fish hatcheries and hydroelectric power stations in the Erne and Shannon systems have had to be modified to exclude zebra mussels. Education and public awareness campaigns have had to be financed.

Ecological: There have been widespread ecological impacts in both the Erne and Shannon systems. There have been changes in the abiotic components of the ecosystem with alterations in some nutrient concentrations, a dramatic increase in water clarity. A substantial decrease in the abundance of the phytoplankton and zooplankton communities have been recorded and these alterations of the food web have had impacts on fish recruitment. Zebra mussels have impacts on fish populations through alterations of the food web. Heavy infestations of zebra mussels may interfere with the feeding, respiration and reproduction of freshwater mussels and may impede locomotion. In extreme cases, zebra mussels can cause sufficient freshwater mussel mortality to eliminate populations.

How the introduction might have been prevented

The zebra mussel invasion occurred as a result of the removal of an economic barrier. As this was an accidental introduction it would have been difficult to prevent, but key to prevention is awareness among those sectors and people engaged in practices that can spread invasive species, such as importing boats. A guiding policy or code of conduct would be a step in the right direction. In the zebra mussel management strategy codes of practice for boat importers, tourism sector, sand abstractors, fisheries managers, anglers, boaters, marina/ slipway managers, environmental agencies and researchers have been recommended. Initial steps include deciding which sectors need basic training and then deciding whether sectors require specific codes of practice for their activities or if legislation is needed.

Boats which are moved between different water systems should have been carefully cleaned and all aquatic plant material attached to the engine or trailer should have been removed.

Invasion dynamics outside Ireland

The zebra mussel has been expanding its range over the last 200 years from the Black Sea and Aral-Caspian Sea basins. This post-glacial range expansion throughout Europe was facilitated by the development of a canal network linking the major European river systems. Zebra mussels are continuing to expand their range in Europe with the associated economic and ecological impacts. However it is the invasion of the Great Lakes and subsequent rapid spread in North America that have resulted in major impacts such as shutting down the water supply to Detroit and cooling water supply to a nuclear power station. Economic impacts are massive with cumulative costs from 1998-2000 estimated at between $750 million and 1 billion. Major ecological change as a result of the zebra mussel invasion has been documented in North America, in particular the extinction of many endemic unionid species. Impacts noted have included severe fouling of man-made structures, of fish spawning grounds, changes in fish populations, increases in water clarity and alteration of plankton communities in North America

References

Minchin, D., Maguire, C.M. & Rossell, R., 2003. The zebra mussels (*Dreissena polymorpha.* Pallas) invades Ireland: human mediated vectors and the potential for rapid international dispersal. *Biology and Environment*, 103B (1); 23-30.

Pollux, B., Minchin, D., Van der Velde, G., Van Alen, T., Yeo, S., Der Staay, M. & Hackstein, J., 2003. Zebra mussels (*Dreissena polymorpha*) in Ireland, AFLP-fingerprinting and boat traffic both indicate an origin from Britain. *Freshwater Biology*, 48: 1127-1139.

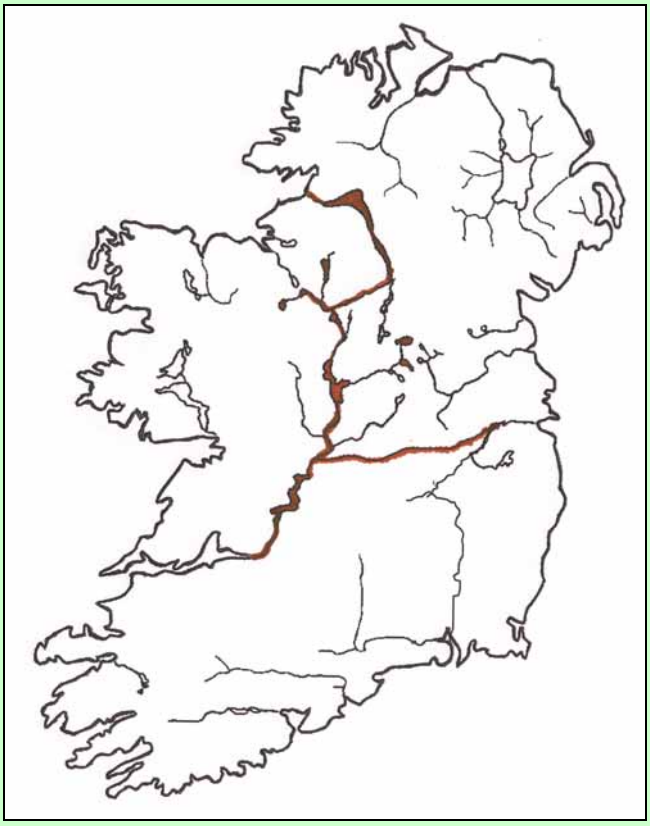


Figure 2.1 The current distribution of Zebra mussels in Ireland (C. Maguire, pers. comm.).

Table 2.4 Licensed imports of fish to the Republic of Ireland in 2002 (ICES CM 2003/ ACME:041)

Species & stage	Quantity (Consignments)	Country of Origin
Oncorhynchus mykiss eggs	14,000 (6)	Isle of Man
Oncorhynchus mykiss eggs	1,700,000 (4)	Denmark
Oncorhynchus mykiss eggs	200,000 (1)	England
Oncorhynchus mykiss eggs	1,320,000 (5)	N. Ireland
Oncorhynchus mykiss	306,230 (13)	N. Ireland
Oncorhynchus mykiss	100,000 (1)	Wales
Salmo salar eggs	3,286,500 (6)	Scotland
Salmo salar juveniles	1,957,000 (2)	Scotland
Salmo salar	6,650,000 (5)	Iceland
Salmo trutta	1,800 (2)	N. Ireland
Hippoglossus hippoglossus	1,200 (1)	Isle of Man
Psetta maxima fry	50,000 (1)	France

Table 2.5 Licensed imports of invertebrates to the Republic of Ireland in 2002 (ICES CM 2003/ ACME:041)

Species & stage	Quantity (Consignments)	Country of Origin
Crassostrea gigas (hatchery)	17,400,000 (11)	France
Crassostrea gigas (hatchery)	36,665,000 (54)	England
Crassostrea gigas (hatchery)	10,185,000 (14)	Guernsey
Crassostrea gigas	2.75mt (3)	England
Nereis sp.	426kg	England

SECTION 3: Legislation pertaining to non-native species

3 Legislation pertaining to non-native species

3.1 Introduction

The problems created by invasive alien species in Ireland are similar to those in many European States. Some of the principal constraints acting on prevention and control may include outdated or inadequate legislation and poor co-ordination between government agencies, neighbouring States and other stakeholders (Genovesi & Shine, 2003). In Ireland, in both jurisdictions, several departments and agencies have responsibility for managing some aspect of the problems caused by invasive species and so several different legislative instruments and environments may be relevant (e.g. plant and animal health and quarantine; nature conservation; wildlife protection, etc.).

Beyond domestic legislature, the problems of non-native species are addressed by international and European legislation. Many international instruments or technical guidelines deal directly or indirectly with invasive alien species (Table 3.1). These binding or voluntary instruments often provide the baseline from which domestic legislatures develop policy, legislation and management frameworks to address invasive species issues (Genovesi & Shine, 2003).

European environmental law and policy exerts an enormous influence on the nature and direction of environmental regulation in both jurisdictions (Turner & Morrow, 1997). Over 200 pieces of environmental legislation have been adopted by the EC during the past two decades which have considerably strengthened the protection afforded to Ireland's environment as a whole (Turner & Morrow, 1997). The conservation of biodiversity in Ireland has been strengthened and expanded by EC law, most notably by the Birds and the Habitats Directives and also by the EIA Directive (Buckley, 1998) (Table 11).

There is currently no fully comprehensive national strategy for prevention and mitigation of both invasive plant and animal species in either jurisdiction, although the National Biodiversity Plan and Biodiversity in Northern Ireland both support the development of such a strategy. In this section we review the existing legislation affecting invasive alien species. The different instruments and legislations are reviewed in three sections, international, European and domestic. These three sections are summarised in Tables 3.1, 3.2 and 3.4.

3.2 International instruments

There are a number of international treaties or instruments which identify a common problem such as invasive alien species, they set overall goals and policies and general obligations and organise technical and financial cooperation. However, the responsibility for achieving the goals rests largely with the countries themselves. Not all the agreements are legally binding, therefore, although they can make recommendations to the member countries, they cannot affect the legislation of these countries. The international instruments are described in sections 3.2 to 3.18.

3.3 Biodiversity conservation

The main international instruments for nature conservation that specifically address invasive species include the Convention on Biological Diversity (Rio de Janeiro, 1992), The Convention on the Conservation of European Wildlife and Natural Habitats (The Bern Convention, Bern, 1979) and The Convention on the Conservation of migratory species of wild animals (The Bonn Convention, Bonn, 1980). There are also international instruments which relate to the protection of specific habitats including Convention on Wetlands of International Importance as Waterfowl Habitat (Ramsar Convention, Paris, 1994) and Ministerial Conference for the Protection of Forests

in Europe (MCPFE, Vienna, 2003). Finally there is Agenda 21 which was adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, June, 1992. There are further international agreements which deal with maritime issues.

3.4 Convention on Biological Diversity

The Convention on Biological Diversity (CBD) of 5th June, 1992 requires its contracting parties, as far as is possible and appropriate, "to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species".

This Convention also addresses liability for damage caused by introductions where insufficient or ineffective measures have been taken to eradicate the species once released. The responsibility to implement the Convention lies with the individual countries and, to a large extent, compliance will depend on informed self-interest and peer pressure from other countries and from public opinion.

Contracting parties to the Convention on Biological Diversity are committed under Article 8 to take action to:

"(k) develop or maintain necessary legislation and/or other regulatory provisions for the protection of threatened species or populations;

(l) where a significant adverse effect on biological diversity has been determined....regulate or manage the relevant process and categories of activities.

Furthermore, Article 13 of the Convention commits contracting parties to:

"(a) Promote and encourage understanding of the importance of, and the measures required for, the conservation of biological diversity, as well as its propagation through media, and the inclusions of these topics in education programmes...".

The implications of the CBD are that contracting parties have to take account of IAS and aim to prevent introductions, control invasive species and develop legislation. The contracting parties of the Convention have to report on what has been done to implement the Convention, and how effective this is in meeting the objectives of the Convention. These reports are submitted to the Conference of the Parties (COP) - the governing body that brings together all countries that have ratified the Convention.

3.5 The Bern Convention on the Conservation of European Wildlife and Natural Habitats

This Convention provides a regional framework for implementation of the CBD in Europe and brings together the majority of European States concerned with biodiversity conservation (Genovesi & Shine, 2003). It has given particular attention to invasions over the last twenty years and adopted a wide range of policy and technical recommendations.

Article 11(2) of the Bern Convention states that Contracting parties:

"(b) strictly control the introduction of non-native species," and "inform neighbouring States if accidental introductions have occurred."

It obliges Member States to ensure that the deliberate introduction to the wild of non-native species is regulated so as not to prejudice the implementation of national legislation directed at the preservation of species. The Convention also outlines how Contracting parties should set up mechanisms for inter-State co-operation, notification and consultation in order to co-ordinate precautionary and control measures for invasive species. There is potential in this Convention to facilitate and promote national and European co-operation on IAS issues. This is a vital issue as many non-native species in Ireland have been introduced either directly or

via other EU countries, including Great Britain.

3.6 The Bonn Convention on the Conservation of migratory species of wild animals

This Convention highlights "the protection of (the) habitats (of migratory species) from disturbances, including strict control of the introduction of, or control of already introduced exotic species detrimental to the migratory species".

Article V(5)(e) of The Bonn Convention states that contracting parties should provide for strict control of the introduction of exotic species (or control those already introduced) which would be detrimental to native species.

Article III(4)(c) states that the Contracting parties agree "to the extent feasible and appropriate, to prevent, reduce or control factors that are endangering or are likely to further endanger species, including strictly controlling the introduction of, or controlling or eliminating, already introduced exotic species."

There is potential in this Convention for providing the basic instruments for contracting parties to address the issue of IAS.

3.7 Convention on Wetlands of International Importance as Waterfowl Habitat (Ramsar Convention)

In Resolution VII.14 on invasive species and wetlands The Ramsar Convention encourages Contracting Parties to address the environmental, economic and social impact of invasive species on wetlands within their jurisdictions. It also urges Contracting Parties to (adapted from Fasham & Trumper, 2001):

- prepare a list of alien species in wetlands and identify and prioritise those which pose a threat to wetlands and wetland species, and those which may be adequately controlled or eradicated;
- target priority invasive species with a view to control or eradicate and implement other related international programmes;
- assess the environmental, economic and social impact of the movement and transport of non-native species on the global spread of invasive wetland species;
- review existing legal and institutional measures and, where necessary, adapt legislation and measures to prevent the introduction of new and environmentally dangerous non-native species and the movement or trade of such species within their jurisdictions;
- develop capacity for the identification of new and environmentally dangerous alien species (including those being tested for agricultural and horticultural use) and the promotion and enforcement of legislation and best practice management;
- encourage education towards the identification and control of, new and environmentally dangerous alien species and
- co-operate with other Contracting Parties to exchange information and experience, increasing the overall capacity to deal with wetland invasive species and promote regional coordination of invasive species programmes. However, Ramsar is not legally binding.

3.8 World Conservation Union (IUCN) Guidelines for the prevention of Biodiversity loss caused by invasive alien species (2000)

These guidelines are a set of guiding principles and recommendations for preventing the introduction of, controlling and eradicating non-native species. The aim of these guidelines is to prevent further biodiversity loss through the effects of non-native species, and to assist government and management agencies to give effect to Article 8(h) of the CBD.

The objectives of these guidelines are:

1. to increase awareness of IAS affecting native biodiversity in all regions of the world;
2. to encourage prevention of IAS introductions as a priority issue requiring national and international action;
3. to minimise the number of unintentional introductions and to prevent unauthorised introductions of IAS;
4. to ensure that intentional introductions, including those for biological control purposes, are properly assessed in advance, with full regard to potential impacts on biodiversity;
5. to encourage the development and implementation of eradication and control programmes for IAS, and increase the effectiveness of these programmes;
6. to encourage the development of a comprehensive framework for national legislation and international cooperation to regulate the introduction of IAS and the eradication and control of IAS;
7. to encourage research and communication to address the problem of IAS worldwide.

IUCN have also produced a code of practice on the Translocation of Living Organisms (IUCN, 1987). This document outlines how the introduction of non-native species should only be considered if there are benefits to man or natural communities and if no native species is considered suitable. The code also states that no non-native species should be introduced into any natural habitat and not into any semi-natural habitat unless there are important reasons (Fasham & Trumper, 2001). The code sets out guidelines for the assessment of the potential effects of a proposed introduction.

The state members of IUCN from the Republic of Ireland are the National Parks and Wildlife Service and The Heritage Council. In the UK, the Department for Environment, Food and Rural Affairs (DEFRA) is the State member of IUCN.

3.9 Agenda 21

Agenda 21 was adopted by the United Nations Conference on Environment and Development on 14th June 1992. Agenda 21 is a plan for global, national and local action in every area in which humans impact on the environment. The issues dealt with that are relevant to invasive alien species are the protection of forests from disease and the uncontrolled introduction of exotic plant and animal species; the adoption of appropriate rules on ballast water discharge to prevent the spread of exotic species; the strengthening of the legal and regulatory framework for mariculture and aquaculture; and the control of noxious aquatic species that may destroy other aquatic species.

The successful implementation of Agenda 21 is primarily the responsibility of Governments. National strategies, plans, policies and processes are crucial in achieving this and international co-operation should support and supplement such national efforts

3.10 Ministerial Conference for the Protection of Forests in Europe (MCPFE)

MCPFE is an ongoing initiative for the co-operation of approximately 40 European countries to address common threats and opportunities related to forests and forestry.

One of the guidelines addresses the conservation of native tree species and provenances. This states that “native species and provenances should be preferred where appropriate. The use of species, provenance, varieties or ecotypes outside their natural range should be discouraged where their introduction would endanger important or valuable indigenous ecosystems, flora and fauna. Introduced species may be used where their potential negative impacts have been assessed and evaluated over sufficient time, and where they provide more benefits than

do indigenous ones in terms of wood production and other functions. Where introduced species are used to replace local ecosystems, sufficient action should be taken at the same time to conserve native flora and fauna."

3.11 International Maritime Organisation (IMO) Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens

Legislative developments on alien species at an international level have been in process in the United Nations IMO for nearly a decade. The IMO has produced guidelines (IMO Assembly Regulation A.868(20)) in response to the threat of ballast water introducing invasive species. These guidelines provide advice on the control and management of ship's ballast water to minimise the risk of unwanted organisms and pathogens from the ballast water and the sediment discharged.

These Guidelines provide tools which, if correctly applied, will help to minimize the risks associated with ballast water discharge.

3.12 International Council for the Exploration of the Sea (ICES) Code of Practice on the introduction and Transfer of Marine Organisms, 1994

This Code of Practice recommends procedures to decrease the risk of detrimental effects from the introduction and transfer of marine organisms. The code outlines the recommended actions to be undertaken prior to new intentional introductions.

Member countries contemplating a new introduction are expected to submit to the ICES Council a detailed evaluation of the introduction including:

- the stage in the life cycle proposed for the introduction,
- the native range,
- the donor location,
- the target areas for release,
- the biology and ecology of the species as these pertain to the introduction and
- information on the receiving environment.

A detailed analysis of the potential impacts on the aquatic ecosystem must be included reviewing;

- the ecological, genetic and disease impacts and relationships of the proposed introduction in its natural range and donor location;
- the expected ecological, genetic and disease impacts and relationships of the introduction in the proposed release site and projected range, as well as vectors for further distribution and
- economic assessment where appropriate.

Following approval the translocation procedure should involve the following.

- Establishment of a stock for artificial propagation (i.e. a brood stock) in quarantine.
- Sterilization of effluents from the quarantine premises.
- Evaluation of the health status of the stock. The translocation should proceed only with a healthy stock.
- A limited release into open waters of the first generation progeny to assess ecological interactions with native species.
- Continued study and monitoring of the outcome.
- Submission of progress reports to ICES.

Ongoing translocations that are part of commercial practice require periodic inspection of material prior to translocation. If any pathogens or pests are discovered the translocation must be discontinued and/or quarantine, inspection and control must be implemented. The genetic impacts of the pests/pathogens on the native species must be evaluated.

Both jurisdictions in Ireland are member countries of the International Council for Exploration of the Sea (ICES) and are consequently obliged to comply with the code. Unfortunately this Code of Practice has not always been closely adhered to (Reise *et al.*, 1998). Although there is an urgent need to strengthen quarantine regulations, no new EC legislation has been implemented.

3.13 United Nations Convention on the Law of the Sea (UNCLOS)

This Convention, in Article 196, requires Member States to take all necessary measures to prevent, reduce and control the intentional or accidental introduction of non-native species to a particular part of the marine environment, which may cause significant detrimental effects.

3.14 Food and Agriculture Organisation (FAO) Code of Conduct for Responsible Fisheries, 1995

This Code outlines guidelines on the precautionary approach for fisheries and species introductions. This FAO Code of Conduct also facilitates the setting up of legal and administrative frameworks for responsible aquaculture and sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity.

3.15 International Protection Plant Convention (IPPC)

The International Plant Protection Convention (IPPC) is an international treaty to which 117 governments currently adhere. The purpose of this Convention is to secure common and effective action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control. The Convention extends to the protection of natural flora and plant products. It also includes both direct and indirect damage by insects, including weeds. The provisions extend to cover conveyances, containers, storage places, soil and other objects or material capable of harbouring plant pests. National Plant Protection Organisations (NPPOs) and Regional Plant Protection Organisations (RPPOs) work together to help contracting parties meet their IPPC obligations. The regional plant protection organisation responsible for co-operation and plant protection in Europe is the European and Mediterranean Plant Protection Organisation (EPPO).

3.16 Food and Agriculture Organisation (FAO) Code of Conduct for the Import and Release of Exotic Biological Control Agents, 1995

In 1995, the FAO set out a Code of Conduct for the import and release of exotic biological control agents. This Code sets out the responsibilities of government authorities and importers and exporters of biological control agents capable of self-replication used for research and for environmental release. This code aims to facilitate the safe import, export and release of exotic biological control agents by introducing internationally acceptable procedures for all public and private bodies involved, particularly where national legislation does not exist (Fasham & Trumper, 2001).

3.17 World Trade Organisation (WTO) Agreement on Sanitary and Phytosanitary measures (SPS Agreement)

The WTO has an agreement on sanitary and phytosanitary measures in relation to trade (SPS agreement), which provides binding rules to ensure that governments extend free market access to each other's products and services. Countries can implement national regimes to protect human, animal and plant life from the problems arising from the entry, establishment or spread

of pests, diseases and disease carrying organisms (Fasham & Trumper, 2001). Import restrictions put in place by countries must be based on scientific evidence. The Agreement requires that SPS measures are based on international standards, guidelines or recommendations, and should be based on scientific principles.

3.18 Convention on International Trade in Endangered Species of wild fauna and flora (CITES)

CITES is an international binding agreement between Governments. The aim of CITES is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Species covered by CITES are listed in three appendices. Trade between countries of live or dead specimens of the species in these appendices is strictly controlled; export and import licences are required, and can only be issued if certain conditions are met. CITES is implemented in EC law by the Wildlife Trade Regulation (EC Regulations 338/97 and 939/97).

1. Appendix I lists species threatened with extinction which are or may be affected by trade.
2. Appendix II lists species which 1) may become threatened with extinction unless trade is subject to strict control and 2) species which need to be regulated so that trade in species covered in 1) can be brought under effective control.
3. Appendix III lists species which any contracting party identifies as being subject to regulation within its jurisdiction and which requires the co-operation of other parties to control trade (Fasham & Trumper, 2001).

3.19 International Civil Aviation Organisation (ICAO) Resolution on Preventing the Introduction of Invasive Alien Species

Resolution A-32-9 of the ICAO encourages contracting states to use their civil aviation authorities to assist in reducing the risk of introducing potentially invasive species to areas outside their natural ranges through civil air transport.

Table 3.1 International instruments concerning non-native species relevant to Ireland (adapted from Fasham & Trumper, 2001)

Name	Year	Subject	Web address
Convention on Biological Diversity (CBD)	1993	Biodiversity Conservation	http://www.biodiv.org
Bern Convention on conservation of European wildlife and Natural Habitats.	1982	Biodiversity Conservation	http://conventions.coe.int/treaty/en/treaties/html/104.htm http://www.nature.coe.int/english/main/bern/texts/rec9757.htm
Bonn Convention on the Conservation of Migratory Species of Wild Animals	1983	Biodiversity Conservation	http://www.wcmc.org.uk/cms/
IUCN Guidelines for the prevention of Biodiversity loss caused by alien invasive species	2000	Biodiversity Conservation	http://www.iucn.org/themes/ssc/pubs/policy/invasivesEng.htm
Convention on Wetlands of International importance especially as Waterfowl Habitat (Ramsar Convention)	1975	Biodiversity Conservation	http://www.ramsar.org
Agenda 21	1992	Biodiversity Conservation	http://www.igc.org/habitat/agenda21
Ministerial Conference for the Protection of Forest in Europe	1993	Biodiversity Conservation	http://www.minconf-forests.net/
International Maritime Organisation (IMO) Guidelines for the control and management of ships' ballast water to minimise the transfer of harmful aquatic organisms and pathogens	1997	Aquatic environment	http://www.imo.org
International Council for Exploration of the Sea (ICES) Code of Practice on the Introductions and Transfers of Marine Organisms, 1994	1994	Aquatic environment	http://www.ices.dk/pubs/itmo.pdf
United Nations Convention on the Law of the Sea (UNCLOS)	1994	Aquatic environment	http://www.un.org/depts/los/losconv1.htm
Food and Agriculture Organisation (FAO) Code of Conduct for Responsible Fisheries	1995	Phytosanitary measures	http://www.fao.org/fi/agreem/codecond/ficonde.asp
International Plant Protection Convention (IPPC)	1951	Phytosanitary measures	http://www.fao.org/WAICENT/FAOINFOR/AGRICULT/agp/agpp/PQ/Default.htm
Food and Agriculture Organisation (FAO) Code for the Import and Release of Exotic Biological Control Agents.	1996	Phytosanitary measures	http://www.fao.org/
Convention on International Trade in Endangered species of wild fauna and flora (CITES)	1975	Trade-related agreements	http://www.cites.org
WTO Agreement on Sanitary and Phytosanitary measures (SPS Agreement)	1995	Trade-related agreements	http://www.wto.org/english/tratop_e/sps_e/spsagr.htm
International Civil Aviation Organisation (ICAO) Resolution on Preventing the Introduction of Invasive Alien Species	1998	Transport	http://www.icao.int/icao.int/icao/en/res/a32_9.htm

European legislation

3.20 Wildlife Trade Regulation

The Wildlife Trade Regulation 338/97/EC protects species of wild fauna and flora by regulating trade. Commission Regulation 939/97/EC provides detailed guidelines concerning the implementation of this Regulation. Together these two Regulations are termed the Wildlife Trade Regulation which implements CITES, and sets out rules for the import, export and re-export of species which are deemed an ecological threat to native EC flora and fauna, and provisions to restrict the internal movement of these species (Fasham & Trumper, 2001).

A species which has been recorded as a serious risk can be listed under Article 9.6 of CITES to prohibit their importation into the EU, and restrictions placed on the holding and/or movement of such animals within the community. This Regulation has the possibility, therefore, to restrict the trade and import of potential invasive alien species, such as the signal crayfish *Pacifastacus leniusculus* or the Chinese mitten crab *Eriocheir sinensis*. Restrictions should be instigated ideally with the voluntary compliance of industry bodies and imposition without consultation can lead to conflicts.

3.21 Habitats Directive

This Directive promotes the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements, and to contribute to the general objective of sustainable development (Clerkin, 2002). The HD aims to protect bio-diversity through the conservation of natural habitats of wild fauna and flora throughout the EC (Turner & Morrow, 1997). The Directive gives full legal force, at EC level, to the actions laid down by the Bern Convention and the Bonn Convention. Although it contains provisions for the protection of specific species of wild animals and plants, the Directive is primarily concerned with the general issue of habitat protection and the creation of a network of European protected sites known as 'Natura 2000'.

Article 22 of the Directive requires member states 'to ensure that the deliberate introduction into the wild of any species which is not native to their territory is regulated so as not to prejudice natural habitats within the natural ranges or the wild native fauna and flora, and if they consider it necessary, prohibit such introductions.' Article 22 of the Directive also requires member states to study the desirability of reintroducing native animals and plants of European protected species where it might contribute to the conservation of such species. However, member states should only undertake the reintroduction of such species if the results of the study establish that such a reintroduction 'contributes effectively to re-establishing these species at a favourable conservation status'.

The Directive provides a legal basis that obliges Member States to protect Natura 2000 sites. Along with the Birds Directive, this Directive provides the main legislative framework and driver for the prevention of the introduction of non-native species by means of the potential threat they pose to protected areas. Member states must take measures to maintain in 'a favourable condition', the habitats and species for which the sites have been selected, or, where necessary, take action to restore them. Natura 2000 sites are Special Protection Areas (SPAs), classified under the Birds Directive, or Special Areas of Conservation (SAC), designated under the Habitats Directive.

An example of the legal status provided by the Directive is the Magheraveely Marl Loughs SAC in County Fermanagh, Northern Ireland. These four marl loughs have strong isolated populations of white-clawed crayfish *Austropotamobius pallipes* and have been selected as an SAC site because of the presence of these Annex II species and because of the hydrological isolation and the absence of crayfish plague from Northern Ireland. The white-clawed crayfish is the only species of crayfish found in Ireland, where it is protected under the 1976 Wildlife Act and the Wildlife Order (Northern Ireland) 1985. It is classified as a vulnerable and rare

species in the World Conservation Union (ICUN) Red List of threatened animals, listed as a protected faunal species in Appendix III of the Bern Convention and is listed in Annex II of the EU Habitats Directive. The protection given to this site by the Directive is that the addition of e.g. signal crayfish, a potential competitor but also carrier of crayfish plague, would be in contravention of this Directive as it would be a direct threat to this SAC site. The Member State would then be obliged to undertake measures to remove the threat to the SAC site.

3.22 Birds Directive

The Birds Directive applies to birds, their eggs, nests and habitats. The Directive provides for the protection, management and control of all species of naturally occurring wild birds in the Member States and requires that Member States take measures to conserve a diversity of habitats for all species of wild birds naturally occurring within their territories in order to maintain populations at ecologically and scientifically sound levels. The Directive also requires that Member States take special measures to conserve the habitat of certain species of conservation concern and of migratory species. In particular it requires Member States to identify areas for special protection of the rare or vulnerable species listed in Annex I (Article 4.1) and for regularly occurring migratory species (Article 4.2) and for the protection of wetlands, especially wetlands of international importance. These areas are known as Special Protection Areas (SPAs). The Directive provides a legal basis that obliges Member States to protect the SPA sites.

Article 11 of the Birds Directive states that, “member states shall see that any introduction of species of bird which do not occur naturally in the wild state in the European territory of the member states does not prejudice the local flora and fauna”.

3.23 Environmental Impact Assessment Directive

Although not directly relevant to IAS, the Environmental Impact Assessment Directive requires environmental assessments for development which could strengthen the conservation of biodiversity. The EIA procedure ensures that environmental consequences of projects are identified and assessed before authorisation is given. When developments include the use of non-native species, the potential effects on the environment needs to be determined and assessed (Fasham & Trumper, 2001) and this Directive facilitates this.

3.24 Water Framework Directive

The Water Framework Directive is a substantial EC legislation and principally addresses the anthropogenic effects on water from the source to coastal waters. The WFD requires that all inland and coastal waters reach a "good status" by 2015. This is to be undertaken by establishing a river basin district structure within which demanding environmental objectives will be set, including ecological targets for surface waters. When negative impacts on water quality are identified the WFD requires that steps be taken to improve water quality to return the water quality to as close a ‘pristine’ state as possible (Minchin & Gollasch, 2003). Perhaps ironically the regulations on the discharges of wastewater from industry and municipal water works may result in less toxic run-off from port areas which may provide more habitats suitable for exotic species invasion (Minchin & Gollasch, 2003).

This Directive has the power to protect river basins and Ireland would be in contravention of this Directive if these protected sites were affected by invasive alien species. The Directive requires that a river basin covering the territory of more than one Member State is assigned to an International River Basin District (IRBD). The issue of river basins in the island of Ireland has been addressed in a recent joint North/South consultation paper on international river basin districts and administrative arrangements for implementation of the Water Framework Directive. The Department of the

Environment for Northern Ireland and the Department of the Environment and Local Government in the Republic of Ireland have proposed the delineation of three international river basin districts within which appropriate administrative arrangements must be in place to ensure that water management is co-ordinated in accordance with the Directive. Each Member State must ensure that the environmental objectives of this Directive are met by 2015.

3.25 Fish Health Directive

The principle EU legislation governing fish health in aquaculture and the aquarium trade is The Fish Health Directive concerning the animal health conditions governing the placing on the market of aquaculture animals, including ornamentals, and products. This Directive prohibits the import of live or dead fish from zones within the EC not certified as free of certain diseases.

3.26 Forest Reproductive Material Directive

The EC Forest Reproductive Material Directive facilitates the restriction of the marketing of forest reproductive material of unsuitable origin in all or parts of the Member States where it could adversely affect biodiversity or genetic resources (Fasham & Trumper, 2001). This Directive can apply to 46 species, from which the Member States select the species they wish to regulate.

Permission to prohibit or restrict marketing of forest reproductive material will be granted only where there is reason to believe;

- that the reproductive material would, as a result of its phenotypic or genetic characteristics, have an adverse effect on forestry, environment, genetic resources or biodiversity on the basis of:
  I) evidence relating to the region of provenance or the origin of the material, or
  II) results of trials or scientific research carried out in appropriate locations, either within or outside the Community, or,
- that the use of the said reproductive material would, on account of its characteristics have an adverse effect on forestry, environment, genetic resources or biodiversity in all or part of that Member State, on the basis of trials, research, or results obtained from forestry practice concerning survival and development of planting stock in relation to morphological and physiological characteristics.

3.27 Plant Health Directive

This Directive has been amended and was consolidated into Directive 2000/29/EC (Fasham & Trumper, 2001). This Directive facilitates protective measures against the introduction of organisms harmful to plants or plant products and measures to prevent their spread within the Community. The Directive primarily protects agricultural, forestry and horticultural plant species, but can also be applied to wild species.

3.28 Animal Health Directives

The Animal Health Directives aim to prevent the spread of diseases. The Directives are primarily concerned with trade in agricultural animals, but can also be applied to wild species. They are implemented by Directives 90/42/EEC, 64/432/EEC, 91/496/EEC, Directive 92/65/EEC and 90/425/EEC.

Consignments of live animals have to be inspected by an official veterinarian prior to intra-community movement and certified free of infectious or contagious disease. As a further precaution against the spread of disease, destination countries are empowered to conduct spot checks on imported consignments at the point of destination, or at any point in the transport chain, including points of entry (Fasham & Trumper, 2001).

The removal of internal border controls has resulted in a situation where monitoring on live animals and animal products imported into the EC from outside the EC are required at the external border. The Directive requires that live animals and animal products may only be imported into the EC through an approved Border Inspection Post and require full

documentation, identity and physical checks by an official veterinarian before being permitted to enter into free circulation within the Community.

3.29 Plant Protection Products Directive

This Directive concerns the placing of plant protection products on the market and provides an authorisation system where plant protection products cannot be sold or used in an EC country unless they have been authorised under the Directive of that Country.

Plant protection products are defined as active substances and preparations containing one or more active substances intended to protect plants against harmful organisms. "Active substance" means any substance or micro-organism, including viruses, which has a general or specific action against harmful organisms or on plants.

3.30 The importance of rapid response to emergency legislation

Legislative processes are often slow when rapid movement is necessary in order to consolidate defence against a specific pest species. The EU has been forced to pass a number of emergency amendments to previous Commission Decisions in order to safeguard against further spread of a pest species within the European Union (Table 3.3). In order to combat the threat of invasive species a flexible legal system is required which retains the ability to disseminate information rapidly when necessary.

Table 3.2 EU legislation relating to risk alerts regarding pest species

EU Legislation	Description
Commission Decision 2001/218/EC	Temporary emergency measures in respect of wood packing comprised in whole or in part of non-manufactured coniferous wood originating in Canada, China, Japan, and the United States. The legislation is aimed at preventing the introduction into Irish and EU forests of the pine wood nematode *Bursaphelenchus xylophilus* and other serious forest insect pests and diseases.
Amended 2003/127/EC	Non-conifer wood packing, originating in China only, under existing separate legislation aimed at preventing the introduction of Asian long horn beetle (*Anoplophora glabripennis*), shall be stripped of its bark and shall be free of insect holes greater than 3 mm across or shall be kiln dried to below 20 % moisture content.
Commission Directive 93/49/EEC	The schedule applies to the growing of crop and ornamental propagating material (including rootstocks), and ornamental plants derived there from, of all the genera and species referred to in Annex to Directive 91/682/EEC, and to rootstocks of other genera and species referred to in Article 4 (2). Material must be checked for viruses and shown to be derived from stock which is virus free.
Council Directive 2000/29/EC	Implements protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. Plant health checks for products originating in non-member countries. Bans of specific plant products, producers must be officially registered and subject to plant health checks, the satisfactory completion of which results in a plant passport for movement within the EU. Harmful organisms include pests of plants or of plant products which belong to the animal or plant kingdoms, or which are viruses, mycoplasmas, or other pathogens.
Commission Decision 2002/7/57/EC	To prevent the introduction and spread of *Phytothora ramorum* within the European community. This species is known to cause Sudden Oak Death in California.
Commission Decision 96/490/EC	Following a programme of intensive sampling to prove absence of *Gyrodactylus salaris* in the UK, special safeguard measures have been awarded to prevent movement of salmonid fish from areas that are, or may be, infected with *Gyrodactylus salaris*, to the UK.

Table 3.3 European legislation relevant to non-native species (after Fasham & Trumper, 2001)

Name	Year	Subject	Web address
Wildlife Trade Regulation: Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora by regulating trade therein Commission Regulation (EC) No 939/97 laying down detailed rules concerning the implementation of Council Regulation (EC) No 338/97 Commission Regulation (EC) NO 191/2001 suspending the introduction into the Community of specimens of certain species of wild fauna and flora	1997	Trade-related agreements/Biodiversity conservation	http://europa.eu.int/eur-lex/en/lif/dat/1997/en_397R0338.html http://europa.eu.int/eur-lex/en/lif/dat/1997/en_397R0939.html http://www.ukcites.gov.uk/pdf/20files/a191_2001.pdfl
Habitats Directive: Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora	1992	Biodiversity conservation	http://europa.eu.int/eur-lex/en/lif/dat/1992/en_392L0043.html
Birds Directive: Council Directive 79/409/EEC on the conservation of wild birds	1979	Biodiversity conservation	http://europa.eu.int/eur-lex/en/lif/dat/1979/en_379L0409.html
Environmental Impact Assessment Directive Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment Council Directive 97/11/EC amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment	1985 1997	Environmental protection	http://europa.eu.int/eur-lex/en/lif/dat/1985n_385L0337.html http://europa.eu.int/eur-lex/en/lif/dat/1997/en_397L0011.html
Water Framework Directive Council Directive 2000/60/EC	2000	Environmental protection	http://europa.eu.int/comm/environment/water/water-framework
Forest Reproductive Material Directive Council Directive 1999/105/EC on the marketing of forest reproductive material	1999	Phytosanitary & biodiversity	http://europa.eu.int/eur-lex/en/lif/dat/1999/en_399L0105.html
Plant Health Directive Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the community	2000	Phytosanitary measures	http://europa.eu.int/eur-lex/en/lif/dat/2000/en_300L0029.html
Plant Protection Products Directive Council Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products on the market	1991	Phytosanitary measures	http://europa.eu.int/eur-lex/en/lif/dat/1991/en_391L0414.html
Fish Health Directive Council Directive 91/67/EEC concerning the animal health conditions governing the placing on the market of aquaculture animals and products	1991	Sanitary measures	http://europa.eu.int/eur-lex/en/lif/dat/1991/en_391L0067.html

Animal Health Directives Council Directive 90/425/EEC concerning veterinary and zootechnical checks applicable in intra-Community trade in certain live animals and products with a view to the completion of the internal market.	1990	Sanitary measures	http://europa.eu.int/eur-lex/en/lif/dat/1990/en_390L0425.html
Council Directive 91/496/EEC laying down the principles governing the organisation of veterinary checks on animals entering the Community from third countries	1991		http://europa.eu.int/eur-lex/en/lif/dat/1991/en_391L0496.html
Council Directive 64/432/EEC on animal health problems affecting intra-Community trade in bovine animals and swine	1964		http://europa.eu.int/eur-lex/en/lif/dat/1964/en_364L0432.html
Council Directive 92/65/EEC laying down animal health requirements governing trade in and imports into the Community of animals, semen, ova and embryos not subject to animal health requirements laid down in specific Community rules referred to in Annex A (I) to Directive 90/425/EEC.	1992		http://europa.eu.int/eur-lex/en/lif/dat/1992/en_392L0065.html

Case study 3.1 Conflicts between EC free trade agreements and national conservation policies (adapted from Fasham & Trumper, 2001)

A problem faced by many European Governments is the ability to restrict imports without violating trade agreements. A recent case concerned a ruling by the European Court of Justice (ECJ) in 1998 relating to the import of bees to a Danish island. The focus of this example is to establish principles concerning intra-EC trade and biodiversity conservation.

In 1993 the Danish Minister for Agriculture and Fisheries issued Decision No. 528 which prohibited the keeping of nectar-gathering bees on the island of Læsø, other than those of the subspecies *Apis mellifera mellifera*. Any existing swarms of other bees had to be destroyed, removed, or the queen replaced with an inseminated queen of the specific species. The aim was to conserve the population of Brown Bee subspecies from hybridization with other bee species.

Criminal proceedings were initiated by the Danish Government against a resident of Læsø for continuing to keep a swarm of another bee species after Decision No. 528 came into force. The defendant argued that the Decision constituted a measure having effect equivalent to a quantitative restriction on imports contrary to Article 30 of the Treaty of Rome. He further contended that the Læsø Brown Bee was not unique to the island and threatened with extinction, so that Article 36 could not be used to justify the restriction. The public prosecutor argued that the effects of the Decision were entirely internal to Denmark and thus Article 30 did not apply. The national court referred the case to the ECJ for a ruling.

The case raised questions about whether such restrictions come within the scope of Article 30 of the Treaty of Rome, and if so, whether such restrictions can be justified. The ECJ has consistently confirmed that all trading rules enacted by Member States which are capable of hindering (directly or indirectly, actually or potentially) intra-community trade are to be considered as measures having an effect equivalent to quantitative restrictions; such measures are prohibited under Article 30 of the Treaty of Rome, unless their application can be justified by a public-interest objective taking precedence over the movement of free goods. Article 36 allows for measures which would otherwise be prohibited under Article 30 if they can be justified on the grounds of "protection of health and life of animals". However the ECJ has described a prohibition on imports as the most extreme form of restriction.

The effect of the Decision on trade of each subspecies of bee was analyzed separately and concluded to discriminate in favour of the Danish (and in particular Læsø) production of the Brown Bee relative to non-Danish Brown Bee. However it is indistinctly applicable in respect of other bee species. In view of this the ECJ concluded that the Decision did fall under the scope of Article 30. However, the opinion of the Court's Advocate was that a legitimate aim of Article 36 would be protection below the subspecies level (for example subgroups within a subspecies) and the population in question need not be in immediate danger of eradication. It is also possible to justify indistinctly applicable restrictive measures by reference to the mandatory requirement of environmental protection as supported by the CBD. Therefore Decision No. 528 was justified by reference to both Article 36 and the CBD.

The ruling of the ECJ was that:

1. "A national legislative measure prohibiting the keeping on an island such as Læsø of any species of a bee other than the subspecies *Apis mellifera mellifera* constitutes a measure having an effect equivalent to a quantitative restriction within the meaning of Article 30 of the EC Treaty.
2. "A national legislative measure prohibiting the keeping on an island such as Læsø of any species of a bee other than the subspecies *Apis mellifera mellifera* must be regarded as justified, under Article 36 of the treaty, on the ground of the protection of the life and health of animals."

This ruling determines that national conservation law can over-ride trade regulations. However, this does not infer that any and every restrictive measure adopted by a Member State pursuant to the CBD is justified. The judgement itself is specific in that it refers only to Læsø and to the specific bee species in question. Restrictive measures cannot be justified if it is possible to achieve the same result by less stringent measures.

References

Judgement of the Court 03-12-1998. Anklagemyndighed v. Ditlev Bluhme. http://www.asser.nl/EEL/cases/HvJEG/697j0067.htm

Fasham, M. & Trumper, K., 2001. Review of non-native species legislation and guidance. DEFRA, Bristol, U.K

Domestic legislation

3.31 Wildlife (Northern Ireland) Order, 1985

A number of pieces of legislation in both jurisdictions directly concern the keeping, release and control of non-native species, reflecting EC legislation and international agreements, such as the EC Habitats Directive, the Convention on Biological Diversity and the Bern Convention. The most important relevant piece of legislation in Northern Ireland is the Wildlife (NI) Order, 1985. This Order was designed to implement the Bern Convention and also implement the species requirements of the Birds Directive. Article 15 of the Wildlife Order implements Article 22 of the Habitats Directive, which prohibits the introduction of foreign plant and animal species into the wild in Northern Ireland, the intention being to prevent further instances of the ecological damage caused by the introduction of non-native species (Turner & Morrow, 1997).

Article 15 makes it an offence to 'release or allow to escape into the wild' any animal that: (i) is not 'ordinarily resident in and is not a regular visitor to Northern Ireland in a wild state' or (ii) is listed in Part I of Schedule 9 of the Wildlife (NI) Order. Article 15 also states that if any person 'plants or otherwise causes to grow in the wild' any plant listed in Part II of Schedule 9 they will be guilty of an offence.

In addition, an introduced species of animal, once it is established in the wild, and any plant, established or not, that is known to have detrimental effects on the environment, may be added to Schedule 9. It is illegal to release, or allow to escape into the wild, any species listed in this Schedule.

Schedule 8 lists non-native plant and animal species that have become widely established in the UK (i.e. that are normally resident), that it is nevertheless illegal to release, or to allow escape in order to prevent increased numbers of these species in the wild. Related offences include digging up of Schedule 8 plants for relocation or for artificial propagation to provide stock for reintroduction, supplementation or introduction. Sale provisions cover material which is alive or dead, also any derivative (including seeds) from the plant. The legislation does not restrict the collection of seed from wild plants for sowing elsewhere unless it is seed of a Schedule 8 species.

This Order provides the basis for restricting the introduction and deliberate spread of alien species but does not allow for control efforts. This Order is currently under review.

3.32 Wildlife Act 1976

The Wildlife Act, 1976 in the Republic of Ireland covered many aspects of nature conservation but was enacted prior to most recent international instruments, as listed above. The Wildlife (Amendment) Act 2000 complements and strengthens the 1976 Act and provides a legal basis for Ireland to ratify CITES and implement the EC Wildlife Trade Regulations. It provides for control of international trade and holding, possession or domestic trade in specimens of species listed under those regulations (Shine, 2002) and includes "stronger protection for species and their habitats, including control of wildlife trade, introductions of alien species and a regulatory system for commercial shoot operations". The Wildlife Acts are the main basis for the protection of flora and fauna and the control of activities that may adversely affect their conservation.

With regard to non-native species: it is prohibited, without licence,

- to release, wilfully cause to escape or transfer within the State for the purpose of establishment in the

wild any species of wild animal or spawn and any wild bird or the eggs thereof;
- plant or otherwise cause to grow in a wild state in any place in the State any species of flora, or the flowers, roots, seeds or spores thereof.'

The Wildlife (Amendment) Act, 2000 also strengthens the legal basis for controlling the introduction of potentially invasive alien species. The Minister may issue regulations prohibiting possession or introduction of any species of wild bird, animal or flora, or part, product or derivative thereof that may be detrimental to native species (Shine, 2002). Where a non-native species has been introduced, measures can be taken, as far as feasible and appropriate under the Wildlife Act, to ensure that such introductions do not pose a potential hazard to native stocks.

Under the Regulation on the Control of Importation of Wild Animals and Wild Birds, 1989, the importation of live wild animals or birds is subject to licence by the Minister.

3.33 The Conservation (Nature Habitats, etc.) Regulations (Northern Ireland), 1995

These Regulations implement the European Habitats Directive in Northern Ireland and control the introduction of native plants and animals of European protected species into areas of Northern Ireland by means of the licensing system set out in regulation 39 (Turner & Morrow, 1997). The purpose of this licensing scheme is for:

- "conserving wild animals or wild plants or introducing them to particular areas;
- protecting any zoological or botanical collection;
- preserving public health or public safety or other imperative reasons of overriding public interest including those of a social or economic nature and beneficial consequences of primary importance for the environment;
- preventing the spread of disease;"

3.34 Environmental Protection Agency Act, 1992

The Environmental Protection Agency Act, 1992 in the Republic of Ireland provided for the establishment of the Environmental Protection Agency (Maguire *et al.,* 1999).

This is an independent body and was established in 1993. The functions of the Agency are:

1. the licensing, regulation and control of the activities for the purposes of environmental protection;
2. the monitoring of the quality of the environment, including the establishment and maintenance of data bases of information related to the environment and making arrangements for dissemination and availability to the public of such information;
3. the provision of support and advisory services for the purposes of environmental protection to local authorities and other public authorities;
4. the promotion and co-ordination of environmental research and the carrying out or arranging for such research;
5. liaising with the European Environment Agency; and
6. other functions in relation to environmental protection as may be assigned or transferred to it by the Minister under sections 53 or 54 of the Act, including functions arising from European Community obligations, or any other international convention or agreement to which the State is, or becomes a party.

3.35 Heritage Act, 1995

The purpose of the Heritage Act 1995 in the Republic of Ireland was to set

up the Heritage Council and to give the Minister a number of powers and functions in relation to the national heritage. The Heritage Council, an independent State body established under the Heritage Act 1995, defines priorities for identification, protection and enhancement of wildlife, archaeology, architecture and inland waterways (Shine, 2002). It includes a statutory committee on wildlife.

Legislative approach to invasive plant species in Northern Ireland

In Northern Ireland the Department of Agriculture and Rural Development (DARD) has produced five major legislative documents which regulate against infestations of non-native plant pests and outbreaks of non-native plant diseases.

3.36 The Plant Health Order (PHO) (Northern Ireland), 1993

This legislation is in place to protect Northern Ireland against the introduction and spread of invasive species associated with plants and plant products. The legislation is enforced by DARD Quality Assurance Branch (QAB) and in principle covers the import of plants and plant products from two sources, 1) Non-European Union Countries and 2) Great Britain and other Member States.

1) Non-European Countries

All plant and plant products imported from non-EU countries have to be accompanied by a phytosanitary certificate, which is issued by the Plant Protection Service of the exporting country. This certificate confirms that the material meets the Plant Health requirements of the EU. Checks are carried out at border control points before the material is released into free circulation.

2) Great Britain and other Member States

Within the EU there is in principle free movement of all plant and plant products. This change took place (from Phytosanitary Certificates and border checks) in 1993, when the plant passport system was introduced. All plant material being moved as part of trade within or between Member States that has the potential to pose a major threat or carry a quarantine pest must be accompanied by a plant passport. In Northern Ireland businesses registered by DARD have the authority to issue plant passports. The same rules apply throughout the EU. Each registered business must have a nominated person who is given a list of responsibilities which include carrying out plant health checks. In essence the industry at large takes responsibility for ensuring that plant material moving in trade meets the legislative requirements of each Member State.

3.37 The Plant Health (Wood & Bark) Order (Northern Ireland), 1993

This Order describes the conditions to be met before wood, isolated bark and used forest machinery may be introduced into Northern Ireland. Wood used to wedge or support parts of cargo including packing material, spacers and pallets are also considered. Temporary emergency measures have been initiated several times and this order amended in relation to the tree pest *Anoplophora glabripennis* (Motschulsky) (Amendment S.I. 389, 1999), the pine wood nematode *Bursaphelenchus xylophilus* (Steiner et Bührer) (Amendment S.I. 401, 2001) and more recently against the introduction and spread of the pest, *Phytophthora ramorum*, a fungus identified as causing Sudden Oak Death Syndrome in species of oak in the USA and harm to other species of plants (Amendment S.I. 175, 2003). The latter imposes controls on wood of four species of

forest tree, *Acer macrophyllum*. *Aesculus californica*, *Lithocarpus densiflorus* and *Quercus* spp.. Wood of this description which originates in the USA and is despatched to the EC after 12th April 2003 must be accompanied by a phytosanitary certificate issued in compliance with the various requirements of the Schedule. These amendments have not always been successful. Amendment S.I. 285, 2002 removed the protected zone in respect of the pest *Pissodes* spp. which was present in Great Britain and spread to Northern Ireland and Ireland in 2002.

DARD makes a six monthly review of their contingency plan measures and will continually amend the plan to accommodate all parties involved in contingency measures.

3.38 The Seed Potatoes Regulations (Northern Ireland), 2001 (S.I. No. 188)

Under Schedule 1 of these regulations seed potatoes must be grown, harvested, stored, prepared for marketing, transported, handled and graded so as to minimize the risk of contamination by such harmful diseases or pests as notified by the department (DARD). A certificate is issued by the Department once they are satisfied that the regulations have been upheld. For example, seed potatoes must be taken from a crop which is free from a number of outlined diseases and pests, e.g. Wart Disease (*Synchytrium endobioticum* (Schilb.) Perc.), Brown Rot (*Ralstonia solanacearum* (Smith) Yabuuchi *et al.*) and Colorado Beetle (*Leptinotarsa decemlineata* (Say));

Schedule 9 describes measures to prevent spread, by means of seed potatoes, of disease or pests and lists the individual tolerances to pest species on potatoes originating internally within the UK and outside of the UK. The majority of individual tolerances are nil for potato pest species.

The Potatoes Originating in Egypt (Amendment) Regulations (Northern Ireland) 2003 are implemented in Northern Ireland Commission Decision 2002/903/EC, which renews the framework within which potatoes may be imported from Egypt into the territory of the European Community for the 2002/2003 season. This authorizes Member States temporarily to take emergency measures against the dissemination of *Pseudomonas solanacearum* (now referred to as *Ralstonia solanacearum* Smith (Yabuuchi)) from Egypt. The importance of this Order is the mechanism it exemplifies for imposing emergency measures to prevent the introduction of a harmful alien species.

3.39 Marketing of ornamental plant propagating material, 1995 (Amended 1999)

These Regulations are implemented in Northern Ireland Council Directive 98/56/EC on the marketing of propagating material of ornamental plants. Commission Directive 1999/68/EC lists varieties of ornamental plants kept by suppliers under Directive 98/56; and Commission Directive 1999/66/EC sets out requirements regarding the labelling or documents required by the supplier pursuant to Council Directive 98/56.

The Regulations set quality standards to be met by ornamental plant propagating material of all species when marketed and set conditions to be satisfied by suppliers. Regulation of citrus propagating material is emphasized.

The past history of organisms is also taken into account. In addition to meeting the requirements of Regulation 4, flower bulbs shall have been derived directly from material which, at the time the crop of bulbs

concerned was growing, was checked and found to be substantially free from any harmful organisms and diseases or any signs or symptoms of such organisms and diseases.

3.40 Noxious Weeds (Northern Ireland) Order, 1977

This Order enables authorised officers to enter any land for the purpose of ascertaining whether any noxious plant, as listed in schedule 1, or part of a plant which is a noxious weed is present. The Order gives the officers the power to ensure that landowners cut down and dispose of or otherwise destroy noxious weeds.

3.41 Legislative approach to invasive plant species in the Republic

All EU legislation necessarily applies to the Republic of Ireland also. Domestic legislation also exists. For example, producers and traders in plants and plant products covered by the plant passport system are required to officially register with the Department of Agriculture and Food. Each registered person or firm is allocated a registration number, which must be recorded on plant passports issued by the person or firm. The objective is to facilitate trace-back should a quarantine problem subsequently arise. Registered growers/traders are required to notify the Department of any outbreak of harmful organisms on their premises, to facilitate Department inspections of their crops and premises and to retain documentary records for inspection.

A variety of plant species require passports to enter Ireland under the Department of Agriculture and Food recommendations. These are listed in Table 3.4.

Plants of fireblight host, *Populus* spp and of the conifers, listed at (1) to (3) in Table 3.4, must be accompanied by plant passports valid for the protected zone of Ireland. The other plants, listed at (4) to (7), must be accompanied by plant passports valid for movement of such material within the European Union. Plants other than the above do not require plant health documentation when being moved for personal use within the European Union.

3.42 Forestry legislation

The Forest Service of the Department of Agriculture and Food in the Republic of Ireland, and the Forest Service of DARDNI are responsible for forest policy and management. The protection of the forest estate against the introduction of dangerous forest pests and diseases is the responsibility of the forestry body in each jurisdiction and is implemented under the provisions of the EU Plant Health Directive and enforced in Northern Ireland by the Forestry Inspectorate (Forest Service, 2002) and by the Forest Service in the Republic of Ireland.

<u>Northern Ireland</u>

The Forest Reproductive Material Regulations (Northern Ireland), 2002 controls the quality of seeds, plants and cuttings marketed for forestry purposes. These regulations extend the definitions and classifications that apply to forest reproductive material. The regulations require that forestry reproductive material at market is required to be clearly labelled and identified, to be well adapted to the site it was collected from, and is of high quality. The regulation also requires that people who market or import forest reproductive material, in the course of business or trade, place their name on the "Register of Suppliers of Forest Reproductive Material".

<u>Republic of Ireland</u>

Forestry in Ireland operates within a legal and regulatory framework. The Irish National Forest Standard outlines

the basic criteria and indicators relating to the implementation of Sustainable Forest Management in Ireland (SFM). It lists a series of qualitative and quantitative measures by which progress towards the practice of SFM can be monitored under forest conditions. The Code of Best Forest Practice lists all forestry operations and the protocol by which these operations should be carried out to ensure the implementation of SFM in Ireland.

The Forestry Acts, 1946, 1956 and 1988 contain provisions for controlling felling. The Forestry Act, 1988 established Coillte and amended penalties relating to felling offences. The European Communities (Marketing of Forest Reproductive Material) Regulations 2002 (S.I. 2002/618) gives legal effect to Council Directive 1999/105/EC.

3.43 Animal health

Long-distance transport and non-localised centres for the processing of livestock have been implicated in the spread of several agricultural diseases through Europe, including foot and mouth disease (FMD), classical swine fever (CSF) and BSE (Elbers *et al.*, 1999; Adam, 2001, Alexandersen *et al.*, 2003).

Northern Ireland

The Animals and Animal Products (Import and Export) Regulations (Northern Ireland) 1995 (S.R. 1995 No. 52), as amended by the Animals and Animal Products (Import and Export) (Amendment) Regulations (Northern Ireland) 1997 (S.R. 1997 No. 87) refer mainly to the import and export of livestock. The recent amendments introduce new provisions affecting transporters, dealers and owners of assembly centres who handle cattle and pigs. These provisions are designed to further reduce the risk of disease being spread while cattle and pigs are being moved across the Community.

Republic of Ireland

A number of EU directives have been translated into Irish law at the instigation of the Department of Agriculture and Food. The European Trade in Animals and Animal Products Regulations was transposed into Irish law as S.I. No. 289, 1994. Persons importing animals, pets, semen, ova, embryos, poultry and hatching eggs and those accepting delivery as consignees, products of animal origin (e.g. meat, blood, bones, wool, and manure) must register 24 hours notice of intent with the Import Registration Section of the Department of Agriculture and Food, Dublin. Veterinary Checks on Products Imported from Third World Countries Regulations 2000 (S.I. No. 292 of 2000) require assessment of live animals. An importer must give at least 24 hours notice of intent to import Animals/Products from Third World Countries to the Department of Agriculture and Food.

In the Republic of Ireland a licence is required for the importation of hay, straw and peat moss litter from all countries (including Great Britain). No licence is required in respect of any hay, straw or peat moss litter of Northern Ireland origin. "Hay" includes grass, moss, clover, *lucerne, sainfoin*, rushes, ferns, reeds, bracken, heather, alfalfa meal and pieces of surface earth containing roots of the following: namely, grass and other small plants of whatsoever kind. Application for a licence is required 7 working days in advance of import and the completed form sent to Animal Health and Welfare Division. This legislation is documented under section 4 of the Foot and Mouth Disease (Hay, Straw and Peat Moss Litter) Order 2001 (S.I. No. 49, amended to S.I. No. 89 and subsequently S.I. No. 239).

3.44 Aquaculture and mariculture legislation

Aquaculture production is regulated by an extensive system of national and EU legislation, which includes provisions for the prevention of importation of diseased stock.

Northern Ireland

In Northern Ireland the introduction of non-native species of fish, eggs and gametes is regulated by the Fisheries Act (Northern Ireland), 1966, the Fish Health Regulations, 1992 and the Fish Health (Amendment) Regulations, 1993-1994.

The Fisheries Act (Northern Ireland) 1966 empowers the Department of Agriculture and Rural Development of Northern Ireland to introduce legislation to prohibit the introduction, unless under permit, into certain waters of fish species which would be detrimental to the fishery. The other regulations seek to prevent the introduction of certain disease species to the UK and prohibit the import of live or dead fish from zones not approved as free of these diseases. These apply to native and non-native fish species.

Republic of Ireland

In the Republic of Ireland, the Department of Communications, Marine and Natural Resources (DCMNR) develops and coordinates the management and conservation polices for sea and inland fisheries, aquaculture and fish processing. It is also responsible for harbour and foreshore development, dumping at sea, marine pollution, shipping and implementation of relevant conventions.

The Fisheries Act, 1980 provided for the establishment of the Central Fisheries Board (CFB) and regional fisheries boards. The CFB has operational responsibility for the management of inland fisheries and sea angling; conservation and protection of fish stocks and their habitat optimising the amenity value of fisheries, recreational and environmental values and some enforcement of pollution controls in accordance with any directions given by the Minister for the Marine and Natural Resources under section 8(1)(b) of the Fisheries Act 1980.

The Fish Health Directive 1991 was transposed into Irish Law as S.I. Number 253 of 1996. This instrument aims to prevent the distribution of contagious fish diseases whilst promoting trade in aquaculture animals. Important fish diseases are categorised into List 1, 11 and 111 diseases, together with their susceptible species.

Further to this, parts of the Irish aquaculture industry is adhering to voluntary quality control schemes, that have an impact on alien species control, namely through the EN 45011 third party independently accredited Bord Iascaigh Mhara (BIM) quality schemes for salmon, trout and mussels. A fourth quality scheme for oysters is currently under development. The management of stock health is part of these quality assurance schemes with provisions made for different species. Non-compliance with these schemes will have to be followed by corrective action or the producer will not receive the quality mark under the scheme. Provisions include that fish farmers adhere to Council Directive 91/67/EEC on the movement of eggs, gametes or fish to another member state. Veterinary certification and Fish Transfer Licences have to be obtained for movements of fish into and within Ireland, which are issued by DCMNR. Records of Health Certification and Fish Transfers Licences have to be maintained and made available on request (M., Mathies, BIM, pers. comm.).

Table 3.4 Plant species subject to the plant passport requirement

Restricted material	Latin name	Common name
(1) Fireblight (*Erwinia amylavora*) host material	*Amelanchier*	Serviceberry
	Chanomeles .	Quince
	Cydonia	Quince
	Cotoneaster	
	Crataegus	Whitethorn
	Cydonia	Rose family
	Eriobotrya	Loquat
	Malus	Crab apple
	Mespilus	Medlar
	Photinia davidiana	Chinese photinia
	Pyracantha	Firethorn
	Pyrus	Pear
	Sorbus	Rowan, Mountain Ash, Whitebeam
	Stranvaesia .	
(2) Plants of *Populus*	*Populus*	Poplars
(3) Plants of conifer species	*Abies*	Fir
	Laryx	Larch
	Pinus	Pine
	Picea	Spruce
	Pseudotsuga	Douglas Fir
(4) Plants of *Prunus,* other than *Prunus laurocerasus* and *Prunus lusitanica*	*Prunus*	Plums, cherries, almonds, apricots, laurel, blackthorn, damson etc.
(5) Plants of *Rhododendron* species (other than *Rhododendron simsii*) and *Virburum*	*Rhododendron*	
	Virburum	
(6) Plants of *Fortunella*, *Poncirus* and *Citrus* spp. and their hybrids	*Fortunella*	
	Poncirus	
	Citrus	
(7) Plants of *Humulus lupulus* and *Vitis* spp.	*Humulus*	Golden Hop, Vine
	Vitis	

Table 3.5 Domestic legislation relevant to non-native species

Name	Year	Jurisdiction	Subject	Web address
Wildlife (Northern Ireland) Order	1985	NI	Biodiversity conservation	http://www.northernirleand-legislation.hmso.gov.uk/legislation/northernireland/nisr/yeargroups/1980-1989/1985/198501c/aos/n017.htm
Wildlife Act Wildlife (Amendment) Act	1976 2000	ROI	Biodiversity conservation	http://www.irishstatutebook.ie/zza39y1976.htm http://www.irishstatutebook.ie/ZZA38Y2000.html
The Conservation (Nature Habitats, etc.) Regulations	1995	NI	Biodiversity conservation	http://www.hmso.gov.uk/sr/sr1995/Nisr_19950380_en_1.htm
Environmental Protection Agency Act	1992	ROI	Biodiversity conservation	http://www.irishstatutebook.ie/zza4y1992.htm
Heritage Act	1995	ROI	Biodiversity conservation	http://www.irishstatutebook.ie/zza4y1995.htm
The Plant Health Order (PHO)	1993	NI	Phytosanitary measures	http://hmso.gov.uk/si/si1993/uksi-19931320_en_1.htm
The Plant Health (Wood & Bark) Order	1993	NI	Phytosanitary measures	http://www.forestry.gov.uk/forestry/infd-5azlcat
The Seed Potatoes Regulations	2001	NI	Phytosanitary measures	http://hmso.gov.uk/si/i1991/uksi-19912206_en_1.htm
Marketing of ornamental plant propagating material (Amended 1999)	1995	ROI	Phytosanitary measures	http://www.irishstatutebook.ie/zzsI201i1999.htm
The Forest Reproductive Material Regulations	2002	NI	Forestry	http://www.legislation.hmso.gov.uk/si/si2002/20023026.htm
Marketing of Forest Reproductive Material Regulations S.I. 2002/618	2002	ROI	Forestry	http://www.irishstatutebook.ie/
The Foot and Mouth Disease (Hay, Straw and Peat Moss Litter) Order	2001	ROI	Sanitary measures	http://www.irishstatutebook.ie/8zsI49y2001.htm
Forestry Act	1988	ROI	Forestry	http://.laws.justice.gc.ca/en/f_30/
Plant Health Act	1967	NI	Phytosanitary measures	http://www.forestry.gov.uk/forestry/Lcou-4usgdn
Animals and Animal Products (Import and Export) (Amendment) Regulations	1997	NI	Sanitary measures	http://www.hmso.gov.uk/sr/sr20010312.htm
Fisheries Act	1966	NI	Sanitary measures	http://www.dardni.gov.uk/consultations/can03022.htm
Fish Health Regulations(Amendment)	1993-1994	NI	Sanitary measures	http://www.hmso.gov.uk/si/si1992/uksi-19923300_en.1.htm
The Fisheries Act	1980	ROI	Fisheries	http://www.web2.gov.mb.ca/laws/statutes/ccsm/f090e.php
Dumping at Sea Act	1996	ROI	Marine	http://www.irishstatutebook.ie/zza8y1981.htm

3.45 Enforcement of domestic legislation

Interpreting existing legislation is not easy (for example, there is no definition of "the wild" – does it include gardens or semi-confined areas from which there is the possibility or probability of escape?) and partly because many introductions are unintentional or accidental and hence potentially covered by the defence. This lack of clarity has led to few prosecutions in both jurisdictions. Both the Wildlife (Northern Ireland) Order 1985 and the Wildlife (Amendment) Act 2000 require reviewing and updating to ensure that they are effective in the control of IAS.

A key problem is the lack of people with the power to enforce domestic legislation, increasing dependence on the support of key sectors, notably trade and transport, to establish codes of conduct that will be complied with and enforced by trade associations.

There are a number of problems regarding legislative matters within both jurisdictions. These concerns are outlined below (adapted from DEFRA, 2003)

1. Time delays are created by inflexible codes of practice for regulation of industries and trade sectors. There is a need to adopt codes of practice that are more flexible and gain the support of the trade sectors which they involve.

2. Fines for criminal offences are very low in comparison to the potentially huge costs of damage, control and repair and do not, therefore, constitute an effective deterrent.

3. There is unequal treatment of plants and animals in law.

4. There is a general lack of power to prohibit the sale of non-native species, especially where this involves sale via the internet and possibly import.

5. Lists of relevant species need to be updated.

6. There is a lack of duty of care placed on any particular sector.

7. There is no consideration of threats from unintentional introductions via new developments (for example by soil contaminated with Japanese knotweed, or use of non-native plants or genotypes).

8. There is a lack of enforcement powers, for example, a right of entry to check for species or to undertake control and the need to ensure that agencies and local authorities are accountable for taking action with respect to relevant named species.

3.46 Escapes from private collections

There are a large number of illegal releases or escapes from private collections of non-native species. It is difficult to police legislation in countries where the keeping of exotic animals in captivity is common in zoos, aquaria etc. and the accidental or deliberate release of non-native species may occur. Most established zoos have representative collections of non-native species and records of these are kept in a system known as the International Species Information System (ISIS). Both Northern Ireland and the Republic of Ireland failed to transpose the EU Zoos Directive, intended to improve the conservation role of zoos, by the deadline of April 10th 2002. However, the Zoos Directive was finally implemented in 2003; zoos must now hold a licence to operate and are subject to strict

inspections by national competent authorities.

3.47 Biological control

There is no specific legislation in either jurisdiction regarding the import of non-native species for the purpose of biological control. The Department of Environment, Heritage and Local Government grant licences for importing animals under the Wildlife Act, 1976 – Section 52 (Control of Importation of Wild Animals and Birds Regulations, 1989). The Wildlife (Northern Ireland) Order grants similar licences in Northern Ireland.

The necessary legislative control systems for biological control are not very clear in either jurisdiction. Research is required to access biological control practise. Risk Assessments should be mandatory for such introductions.

The European FAO Code of Conduct for the import and release of exotic biological control agents facilitates the safe import, export and release of exotic biological control agents. This Code introduces internationally acceptable procedures for all public and private bodies involved, particularly where national legislation does not exist. Both jurisdictions need to implement this Code to monitor biological control agents.

3.48 Escapees and genetic pollution of wild populations

Efficient monitoring of fish farm escapees requires co-ordinated regional effort. Responsibility for the management of the Irish Salmon Fishery lies with the Department of Communications, Marine and Natural Resources (DCMNR) and is administered through the seven Regional Fisheries Boards (East, South, South West, Shannon, West, North West and North). The boards enforce fisheries legislation and carry out inspection at sea and on inland waters. This surveillance is further enhanced by naval surveillance co-ordinated through the Central Fisheries Board. Each region is further sub-divided into districts for administrative and management purposes, of which there are 17 in Ireland.

Enforced legislation preventing salmon escapees appears weak. In July 2003, Bord Iascaigh Mhara introduced its *Environmental Code of Practice for Aquaculture Companies and Trades* (ECOPACT). This code concerns stock health management. It is a recommended action under the code to implement the Irish Salmon Growers' Association (ISGA) *Code of Practice for the prevention of stock escapes of Irish farmed salmonids.* Yet enforcement of this procedure appears non-existent.

The importance of freshwater habitat quality and stocks of wild salmon populations is highly prioritized in Ireland. Under the EU supported Tourism Angling Measure (TAM, 1995-1999):

- € 15.6 million was spent on freshwater habitat improvements;
- 2000 km of freshwater habitats were resurveyed and rehabilitation was carried out on 400 km and
- 22 fish counters have been installed on significant salmon rivers over the past 6 years.

3.49 Discussion and conclusions

As outlined in this section, there are many international instruments and European Directives and Codes which are relevant to invasive alien species (Tables 3.1, 3.3 & 3.4). Whether these instruments are legally binding is of great importance to how they effect legislation in both jurisdictions. Many of the European Directives have been transposed into Irish and Northern Irish Law. However, it would appear that this has little effect, with the exception of the protection afforded to

protected sites. Although there are many Acts and Orders in both jurisdictions which relate to some extent to non-native species, there does not appear to be the legislative power to act and either prevent or control invasive species.

A major problem is the lack of access to private land, which in itself can prevent a potentially invasive species being removed before it spreads to a wider area. In the case of animal health Government officials have the power to gain access to private lands to remove a potential hazard. However, this does not seem to be the case for invasive species.

A good model which currently exists in Northern Ireland and the Republic is the legislation which exists for plant health. The Department of Agriculture and Rural Development (DARD) produced four legislative documents which regulate against infestations of non-native plant pests and outbreaks of non-native plant diseases. This system could be applied to different sectors of legislation and could be used as a basic model for invasive species legislation. Although legislation does exist in both jurisdictions it urgently needs to be reviewed and updated. Box 3.1 highlights some key recommendations for IAS legislation. These recommendations are dealt with in more detail in sections four and five.

3.50 Cross border cooperation

Co-operation between the Republic of Ireland and Northern Ireland was formalised under the Belfast agreement on the 10th April, 1998. This established a North/South Ministerial Council with power to develop common policies on topics with a cross-border and all-Ireland benefit (including animal and plant health, environment, inland waterways, inland fisheries and marine matters) (Shine, 2002). The role of this Council is consultation between those with executive responsibilities in Northern Ireland and the Irish Government and to develop co-operation and action within the island of Ireland. The Council will implement this through an all-island and cross-border basis

The Council's Environment Sector has initiated cooperative work on environmental research, an environmental information database and the development of catchment strategies for water quality (Shine, 2002).

The International Designations Group (IDG) is a more informal arrangement which has operated for many years and involves representatives of Ireland through NPW, Northern Ireland, JNCC and DEFRA. This group meets to discuss and co-operate on biodiversity issues of mutual concern (Shine, 2002). The group is primarily concerned with environmental designation issues but also addresses other issues as the need or interest arises.

These groups have potential to provide support for a cross-border invasive species forum. A cross-border group, forum or agency could lead and coordinate the efforts of responsible agencies and government departments dealing with IAS in both jurisdictions. At present these issues and the different government departments responsible for invasive species issues are unclear. A forum/agency would provide one centralised group responsible for IAS issues.

The agency would become the primary point of reference and guidance for the management of all issues pertaining to non-native species and should be financed by the two jurisdictions and an interdepartmental budget, which incorporates contingency measures, should be agreed upon in advance of an issue arising.

The agency should be co-chaired by the most relevant government departments, most probably the Department of Environment (N.I.) and the Department of the Environment, Heritage and Local Government (R.O.I), though key inputs will be required from other departments, most notably agriculture, trade and transport. Linkages should also be fostered with public health departments for guidance in the construction of contingency plans in the event of an invasive species becoming a public health hazard.

The agency would:

1. Engage with stakeholders and relevant sectors to raise awareness to develop and encourage best practices to avoid unwanted introductions and to assist education and awareness measures.
2. Lead the development and implementation of a national strategy on invasive alien species.
3. Provide a focus for high-level decision making.
4. Consult with scientific authorities to obtain technical advice on decision-making related to IAS
5. Establish contingency plans including framework agreements to for plan implementation.
6. Lead the policy and legal review process.
7. Co-ordinate input from different agencies to national and European policy making and programmes.

Box 3.1 Recommendations for legislative approach to prevention of problems caused by invasive and alien species (adapted from De Klemm, 1994; Eno *et al.,* 1997).

The effects of invasive species may be impossible or extremely costly to control once the introduced species has become established. Prevention is consequently vital.

- Any legislation should be based on the precautionary principle which is gradually becoming an accepted basis for the development of environmental law. This means that the rule for deliberate introductions should be that permits are in principle denied, unless it can be shown that there are at least good scientific reasons to believe that the proposed introduction will be harmless.
- Quarantine procedures should be given legal force and become binding upon permit-issuing authorities. This could be achieved within the European Community.
- To prevent escapes from captivity or deliberate releases etc. the implementation of the precautionary principle requires strict controls on imports of live specimens of those species which may survive in the European environment. Import controls should be accompanied by prohibitions or restrictions on the possession, sale and transport of exotic species.
- Special precautions need to be taken to avoid accidental introductions into particularly sensitive areas.
- All legislation regulating the introduction of alien species should empower enforcement personnel to inspect premises and to seize and destroy specimens of introduced species which are illegally imported or possessed.
- An integrated holistic approach should be adopted. All these rules should be applicable to all species, whether terrestrial, freshwater or marine.

When prevention has failed and an introduced species has become established, there is clearly a need to try to eradicate it as quickly as possible before it is too late.

Section 4: Risk assessment and practical management of invasive species

4. Risk assessment and practical management of invasive species

4.1 Detection and capacity for mitigation measures

The three stage hierarchical approach to invasive species, adopted by the CBD, stresses that prevention is generally far more cost-effective and environmentally desirable than measures taken following the establishment of a non-native species. Therefore prevention should be given priority. However, prevention measures will sometimes fail and if an invasive non-native species has already been introduced then further measures will be necessary. A key issue to contend with is justification of resource allocation between preventive measures and actions in mitigation of existing problems.

The second and third stages of the CBD approach are addressed in this chapter. These are 1) the monitoring and surveillance and 2) the capacity to take mitigation measures for non-native species. While the nature of biogeographical processes ensures that sealing a land mass against invading wildlife is impossible, much can be achieved to reduce the number of future invasions and the damage created by those that slip through the safety net.

A key step in the management of biological invasions is an understanding of the frequency with which a species is introduced into a specific area, the size of each introduction and the subsequent pattern of spread across the natural landscape, all of which emphasise the need for regular surveillance. Likewise, ill-informed and/or poorly constructed control regimes are expensive and often fail to yield sustainable results.

The development of a structured approach to assess the impact and management of individual non-native species is highly desirable. Control attempts should not be the only response to the identification of non-native species; as such a policy would be prohibitively expensive. The DEFRA review (2003) recommends that a targeted response should be able to accommodate a range of management options, from acceptance of the presence of a species with ongoing review of their changing status, through to mitigation measures such as containment or control.

4.2 Monitoring and surveillance

Surveillance is the act of undertaking repeated surveys and monitoring is surveying against a standard, to determine subsequent changes (DEFRA, 2003). To be efficient a monitoring scheme must incorporate a number of different elements including:

- recording of all invasive/native species across taxa, including proactive recording of key invasive species of concern

- changes in numbers and distribution of invasive/native species over time and analysis within and among taxa

- changes in phenology (the seasonal activity) of native/invasive species within and among taxa

- maintaining lists of species which have not yet been recorded in Northern Ireland or the Republic of Ireland but are known to have been accorded pest status elsewhere in north-west Europe and in regions of similar climatic regime.

It may be advisable to sample areas at different spatial scales. In order to maximise information for a given cost it could be necessary to combine extensive, inexpensive sampling with intensive, expensive sampling of smaller sub-samples. The value of sampling at finer scales may often be

predicted in advance of an investigation, though this would benefit from tools for predictive economic analysis.

Additional monitoring concerns include the importance of temporal and spatial scale with respect to new and established invaders and the limitations of extrapolating across scales set in the context of the apparent urgency of advice based on results. Within the scientific community, concerns have been raised regarding the prevalence of anecdotal evidence, inconsistency in documentation and metrics used; dominance of single trophic-level studies and the emphasis on ecological (theoretical) outcomes rather than mechanisms of control or mitigation. Management efforts should attempt to co-ordinate monitoring strategies across geographic regions.

Comparison of the availability of databases between the north and south indicates at a glance that the frameworks for monitoring and the associated availability of data appear better developed in Northern Ireland (Box 4.1, Table 4.1). However, this is not necessarily the case; it is merely that the consolidation of relevant records under one central agency increases ease of access to a larger group of people. It is recommended that such a recording framework is adopted in the Republic, although the need for individual organizations to maintain a specialist interest in identifying certain taxa remains high.

The Northern Ireland Biodiversity Group (2002) identified gaps in knowledge of regional biodiversity: not all species inhabiting Northern Ireland have yet been identified; some groups such as fungi, lichens and most invertebrates are poorly described. Records are frequently out-of date and this has partially been attributed to a lack of enthusiastic and competent field recorders and inadequate or difficult identification keys for certain groups (Northern Ireland Biodiversity Group 2002).

4.3 The decline of trained taxonomists

Taxonomic research has a large input from non-professional or amateur researchers, in addition to professionals working at museums or universities. The decline of taxonomy and the number of taxonomists within the professional community has been widely publicized but trends in the activities of amateur taxonomists are unclear. Because amateurs contribute many valuable species records this may have a disproportionate impact upon the information available for conservation planning and therefore represents an under-appreciated threat to developing policies on invasive species (Hopkins & Freckleton 2002).

A study evaluating the changing role of both amateur and professional taxonomists was conducted by Hopkins and Freckleton (2002). Contributions by British-based authors to Entomologist's Monthly Magazine over the past century were reviewed. Results showed that both amateur and professional taxonomy have undergone a long and persistent decline since the 1950s, in terms of both the number of contributors and the number of papers contributed.

A useful innovation would be to consolidate information so that the public is provided with clearly defined access routes for information on identifying non-native species. Currently key personnel tend to be inundated with queries on identification from the general public. This work load tends to peak during the summer months when people spend an increasing proportion of time outdoors and also during the breeding seasons of particularly conspicuous and attractive species.

Box 4.1. Biological Recording in Northern Ireland

The Centre for Environmental Data and Recording (CEDaR) was established in 1995 at the Ulster Museum supported by grant aid from the Environment and Heritage Service (EHS). The CEDaR project is a partnership between Ulster Museum, EHS and the recording community throughout Northern Ireland. The core objectives of CEDaR are: to store information related to the geology and distribution of the flora and fauna within Northern Ireland and its coastal waters and make these data available.

Computerised datasets held by CEDaR include:

- NI Vascular Plants Database/BSBI Atlas 2000 Project
- NI Mammal Survey data
- NI Littoral and Sublittoral data
- Butterflies and Moths data
- Birds data (RSPB data, Raptor Study Group and Northern Ireland Birdwatchers' Association)
- A range of invertebrate datasets

CEDaR is increasingly accepted as the focal point for the collation and storage of environmental records related to Northern Ireland. The achievements of the project have been recognized recently by the consortium developing the National Biodiversity Network (NBN) in the United Kingdom. The NBN will be a partnership of local and national custodians of wildlife information proving access to all within a framework of standards. The essence of NBN is the importance of co-ordinating information on a national basis. Within the framework, CEDaR has been described as a suitable model for developing Local Records Centres.

Table 4.1 Organizations holding databases on native and exotic flora and fauna in the Republic of Ireland

Organization	Type of organization	Holdings
Research Section of the National Parks and Wildlife Service designated as the National Reference Centre for Biodiversity (formerly the Irish Biological Records Centre until 1988)	Government	Irish flora and fauna
The National Museum	Government	Irish flora and fauna
The National Botanic Gardens at Glasnevin	Government	Irish flora
Department of Communications, Marine and Natural Resources (Marine Division)	Government	Inland and marine fish species
Department of Agriculture and Food (Forest Service)	Government	Native/imported tree species
Central Fisheries Board	Government	Aquatic vegetation and fish
The Marine Institute	Statutory body	Fish species/inshore species
Coillte Teoranta	Semi-state body	Native/imported tree species
Teagasc (Irish Agriculture and Food Development Authority)	State forest body	Plants and invertebrates (see also REPS scheme)
Birdwatch Ireland	Conservation NGO	Countryside/garden bird surveys
Irish Peatland Conservation Council	Conservation NGO	Wetland plants/amphibian surveys
The Irish Wildlife Trust	Conservation NGO	Irish Mammals
The Vincent Wildlife Trust	Conservation NGO	British and Irish mammals
The Cork County Bat Group	Conservation NGO	Bat surveys
The Botanical Society of the British Isles (Ireland)	Conservation NGO	Local flora/butterfly surveys
The Dublin Naturalists' Fieldclub	Conservation NGO	Local flora and fauna
The Irish Seedsavers Association	Conservation NGO	Native grains and fruits
National Association of Regional Game Councils	Hunting and conservation NGO	Local predator information (local fauna)
Universities		Various
Commercial consultancies (Environmental Impact Statements)		Various
Private individuals		Various

4.4 Access to private land

A large proportion of land within Northern Ireland and the Republic of Ireland is privately owned. However, the sequence of events following the discovery of an invasive species on private land remains unclear. Additionally, the difficulties of conducting research on privately owned parcels of land may result in a bias towards a restricted set of community types (Hilty & Merenlender 2003). Another pitfall of not conducting research on private land is the potential, particularly in landscape-scale studies, for unrepresentative sampling because public and private lands may differ in biodiversity and productivity. Such trends could lead to erroneous conclusions (Hilty & Merenlender 2003). There may also be a dearth of information relating to prevalence of a particular species on private land.

One of the reasons for which landowners might be reluctant to allow research being carried out on their land is concerns over liability and property damage. Interrelated factors identified by Hilty & Merenlender (2003) that may indicate an increased or decreased probability of a landowner being receptive include property size, average income, past experience with agencies or researchers, education level, political affiliations and geographic location. In rural communities, an individual's interest in and knowledge of biodiversity can be predicted at least partly on the basis of membership in hunting and environmental organizations, age and education level (Clements 1996, Macdonald & Johnson 2000). If representatives of these local organizations contact landowners about the research before the researcher does, participation and access to sites is much more probable.

Alternatively, researchers can be discouraged from using private land due to concerns regarding the transfer of property and alterations in site usage part way through a study. Therefore continuing participation of the landowner cannot be guaranteed. Researchers may perceive limitations to the research design resulting from the restrictions imposed by landowners. For example, studies that require a random-sampling design may present problems if the rejection rate for land access is high or biased in some way. Additional constraints may be placed on the researcher's ability to disseminate the results.

4.5 Risk assessment

As the range of IAS continues to grow, science and management are forced to predict and manage only the most serious species. This requires the adoption of a management framework that can encompass ecosystem change and pragmatic acceptance of invasive species as part of ecosystem dynamics. Such a management system must allow change within a range of predefined limits of acceptable change, identified by bioeconomic tools such as "aesthetic injury levels", while also effectively highlighting areas where these limits are broken and action is required. A suitable framework requires the flexibility to incorporate new research and thinking in a manner that is fundamentally pro-active in approach.

A variety of public agencies, organizations and individuals have compiled lists of the invasive species regarded as the most detrimental within their respective regions of interest. Unfortunately, the factors used to determine which species are included on many of these lists are not explicit, making it difficult or impossible to compare or compile different lists and leaving these lists open to concerns that they were produced on a subjective or *ad hoc* basis. To address this problem, a standard set of criteria for categorizing and listing non-native invasive species

according to their overall impacts on biodiversity in a large area, such as a particular habitat or ecological region, is required. Use of these criteria can make the process of listing invasive species more objective and equitable, rendering the resultant lists more useful to researchers, land managers, regulators, consumers and commercial interests, such as the horticultural sector. An example would be criteria which are designed to distinguish between species that are capable of causing high, medium, low or negligible impacts to native biodiversity within a specified region.

In 2001 the Global Invasive Species Programme (GISP) proposed a 'pied list' for governing the trade of species, which contains:

- A 'black list': species whose importation is prohibited;
- A 'white list': species classified as beneficial or low risk, whose importation is allowed under conditions restricting the use of the species to specific purposes (research, public education, others) or with approved holding facilities. 'White lists' may be developed at national or sub-national level and should only include species that have undergone risk assessment.
- A 'grey list': any species not yet known to be harmful or harmless. Any species not included on either the 'black' or 'white' list.

To evaluate the potential risk it is necessary to have monitored the spread of invasive species and any trends in their distribution and abundance over rapid time scales. This could enable forecasting of the potential time frame in which a population will begin to expand in size.

4.6 Risk assessment of species and habitats in Ireland under threat from non-native invasive species

In addition to the species mentioned in Section 1: Tables 1.1 to 1.6 there are a number of species which have not yet been recorded in Ireland but could cause significant problems if they became established here, as demonstrated in Great Britain and elsewhere in Europe. Examples include non-native crayfish species, such as Turkish crayfish, *Astacus leptodactylus* and North American signal crayfish, *Pacifastacus leniusculus*, which can both host the crayfish plague responsible for decimating native crayfish and freshwater fish populations in both Great Britain and Europe. Northern Ireland currently has legislation in place to prevent the importation of non-native crayfish for aquaculture purposes. However, there is currently no legislation preventing the importation of live crayfish as food items. Restaurants and fish and wholesale markets are advised to follow the Crayfish Code of Practice, although no legal enforcement exists. The one diagnosed outbreak of crayfish plague in Ireland is believed to be the result of fungal spores introduced by fishermen on wet gear (Reynolds, 1998). The reintroduction of native crayfish to Lough Lene sometime after the eradication of infected native crayfish appears to have been successful.

A second example of serious concern is *Gyrodactylus salaris*, a parasite which infects the skins and fins of salmon and can both kill and cause serious harm. This parasite is native to waters of the Baltic in Russia, where its impact upon native fish populations is small. However *G. salaris* is thought to have been introduced to Norway by stocking with resistant Swedish stock in the mid-1970s. The only known means of

eliminating the parasite is to poison the whole river system and re-stock. By 1984 the Norwegian salmon fisheries had sustained losses of between 250-500 tonnes per year (Johnsen & Jensen 1986).

The high frequency of traffic between Great Britain and Ireland and their close proximity renders each susceptible to detrimental species introductions from the other. A prominent invasive species present in Great Britain is zander *Stizostedion lucioperca*, a fish introduced for sport. Other fish species present in Great Britain that could become invasive in Ireland are chub, *Leucisus cephalus* and ruffe, *Gymnocephalus cernua*. Species not found in Ireland which are native to Great Britain, such as the muntjac deer *Muntiacus reevesi* could considerably reduce grazing and pasture quality. A notable invasive of rivers in Great Britain is the Chinese mitten crab *Eriocheir sinensis*, which causes erosion to soft sediment banks of the Thames and consequently concern in terms of flood defence measures. For these species it is important that action is undertaken to assess the risk of their introduction. If a particular species does pose a significant risk, efforts to reduce the risk of introductions and, if the species is found in the wild, control/eradication programmes should be urgently considered.

Several attempts have been made to predict the characteristics of a successful invader (Williamson, 1996). Morphological, physiological and life-history traits might predict the probability of a non-native species becoming more or less invasive when introduced to a new region. Crawley *et al*. (1996) conducted an analysis to compare native and non-native British plants, but found only that the latter were taller, had larger seeds and more protracted seed dormancy. Such an analysis compares native with successful non-native species. Rejamanek & Richardson (1996) conducted a comparative analysis of invasive and non-invasive non-native pine species (in the genus *Pinus*) in the USA, and found that the former had greater seed mass, faster growth and more frequent seeding. Ehrlich (1986) reported that successful invertebrate invaders are likely to be mobile species, generalist in their feeding habits, with short generation times, high population genetic variation and the ability to function in a wide range of physical conditions. Simberloff (1989) could make no generalizations about the invasive potential of insect species. A recent review of previous studies reported that it is not possible to arrive at general conclusions between species' attributes and invasive ability (Manchester & Bullock, 2000).

It has been suggested that an invasion will only be successful where the climate of a region being invaded is similar to that of a species' native region. However, both Williamson (1996) and Mack (1996) found as many exceptions to this rule as there are supporting cases. It is also possible that genetic and breeding characters, such as inbreeding, asexuality, polyploidy or heterozygosity are related to invasiveness. Invaders of the British flora are not characterized by particular genetic characteristics (Gray, 1986). Williamson (1996) concluded that genetic studies offered no generalities of predictive use.

Species that are more abundant and have a larger range in their native region might be expected to be more invasive, because these parameters can be seen as a surrogate for wide ecological amplitude or good dispersal (Manchester & Bullock, 2000). Williamson (1996) reported some evidence to support this hypothesis, but concluded that it does not have good predictive potential.

Certain families (e.g. the Poaceae and Asteraceae in plants) and genera (e.g. *Bromus, Cirsium, Poa*) contain a majority of the world's problem plant species (Mack, 1996). Because related species share traits, species from these taxa might be expected to be more invasive than species from other taxa. A similar idea is that if a species has been a successful invader of a region then its congenerics might be invasive as well. However, Mack (1996) and Williamson (1996) reported that there are too many exceptions for these to be useful rules. Therefore, it is vital to make case-specific studies of those species which are potentially invasive in Ireland.

It is accepted that disturbed habitats such as urban wasteland, arable fields and riverbanks are generally more readily invaded (Smallwood, 1994). Conversely, undisturbed natural and semi-natural communities tend to contain few, if any, recently introduced non-native species. Thus plant communities may be ranked in terms of their 'invasibility', based upon the proportion of bare ground and on the frequency and intensity of soil disturbance (Crawley, 1987). Therefore, whilst there is some information on the susceptibility of different habitat types to invasions, predictions of precisely which habitats will be invaded by which species, and which of those habitats will be most affected by such invasions, cannot be made with any degree of certainty (Manchester & Bullock, 2000). This suggests that only a detailed ecological study of a species and its potential habitats can allow accurate prediction of the invasiveness of an introduced species. This was the general conclusion of the SCOPE (Scientific Committee on Problems of the Environment of the International Council of Scientific Unions) programme on biological invasions (Kornberg & Williamson 1987; Drake & Mooney, 1989).

The presence of an invasive alien species in an ecosystem thus depends on the survival and invasion rate of the invasive alien and ecosystem resilience (Figure 4.1). The speed of establishment is susceptible to various factors, in particular human intervention. The unpredictable nature of species invasions means that fully quantitative and economic assessments can rarely be prepared. The quantifications which are usually attempted are calculations of the area endangered by a non-native species and costs to individual enterprises whose gross margin budgets can be readily obtained.

4.7 Vulnerable habitats in Ireland

A variety of habitats within Northern Ireland and the Republic of Ireland are designated for protection at national or European level. A number of these habitats (Table 4.2) are under threat from invasive non-native species; for example freshwater river systems are being degraded due to the introduction and spread of ornamental plants (Case study 1.4) and freshwater fish species. Old oak woodlands and dry and wet heath sites are threatened by rhododendron, sea buckthorn is infiltrating sand dune systems and coastal habitats are being degraded by Canada geese *Branta canadensis* and common cordgrass *Spartina anglica*.

Habitats in Ireland listed on the Habitats Directive are protected as Special Areas of Conservation (SACs), while sites that are important for birds are protected as Special Protection Areas (SPAs). Additional priority sites receive local protection as Natural Heritage Areas, National Nature Reserves or Areas of Special Scientific Interest (ASSIs). he breakdown of protected areas is shown in Table 4.3. In the Republic of Ireland SACs cover a land area of 1.1 million ha. The land area covered by SPAs and NHAs is

258061 ha and 907672 ha respectively. In Northern Ireland SACs cover a region of 65100 ha and SPAs (designated as SPAs only) cover an additional area of 70700 ha (Source: http://www.jncc.gov.uk/idt/spa/default.htm).

Reserve creation is a primary line of defence in the conservation of native species. Unfortunately, this leads to the concept of "full protection versus no protection" and recent research has shown that maintenance of the intervening matrix is also of considerable importance, especially for species which regularly disperse between different habitats (Baillie *et al.*, 2000; Ray *et al.*, 2002, Selonen & Hanski, 2003). Furthermore, for species to be maintained (rather than just represented) we must conserve ecological and evolutionary processes beyond, as well as within, reserves (Balmford *et al.*, 2000). Unfortunately there are currently limitations in quantifying how far these additional conservation objectives are met. Species representation tends to be the most widely used metric of conservation performance, and it is hoped that insights gained from comparative performance between regions can be used to predict geographical areas where the need for more sophisticated measures of conservation performance is high.

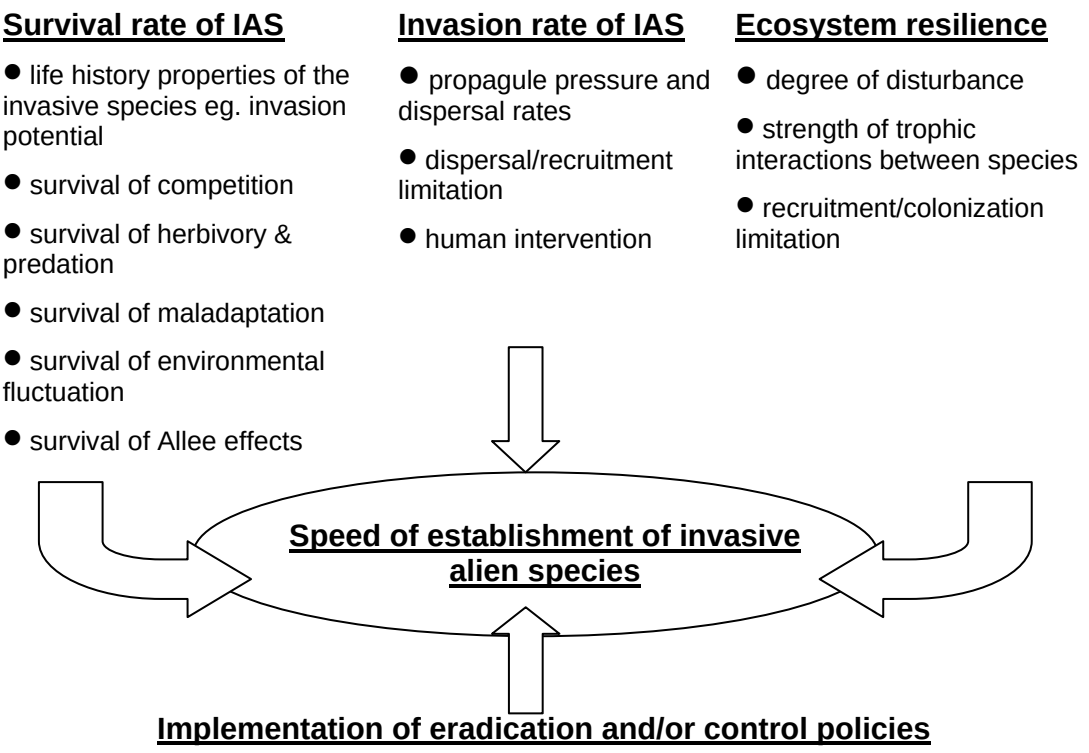


Figure 4.1 Processes influencing ecosystem resilience and the potential speed of establishment of invasive alien species**.**

Article 8 of the Convention on Biological Diversity obliges contracting parties to establish protected areas for conservation. Balmford and Gaston (1999) hypothesize that this can be achieved in networks of smaller reserves, provided their design is based on how well different sites complement one another biologically, rather than on more commonly used criteria, such as species richness or the availability of site acquisition. This hypothesis is based on the scenario that an inefficient reserve design, whose cumulative representation of biodiversity rises only slowly with increasing area is inferior to a network chosen using a complementarity-based algorithm, which reduces the area needed to achieve a particular conservation goal. This increase in efficiency requires species lists for each candidate site which can be expensive to obtain, yet can still ultimately result in economic saving.

4.8 Vulnerable species: the need for conservation

A number of species are selected as priorities for conservation in both the UK and, more specifically, in Northern Ireland (Northern Ireland Biodiversity Group 2002). Maintenance of these species is important to conserve both natural ranges and genetic diversity. A number of Northern Ireland species which do not have UK action plans were identified as requiring Northern Ireland action plans. Action plans for the Irish hare, chough and curlew have since been drafted (Northern Ireland Biodiversity Group 2000). Ireland's National Biodiversity Plan (2002) promotes similar actions for species of conservation concern. Both national reports additionally recommended that the lists should be viewed as provisional, pending further biodiversity research.

Genetic threats to native species can arise either as a consequence of declining population size, the introduction of invasive species, or even the introduction of native species of non-local provenance, with different genetic composition from local stock. An example of the latter would be the importation of forest trees from sources on the continent. Despite being the same species, genetic differences might result in a different capacity of the stock to survive in the Irish environment, or a different palatability to native insects. We endorse the suggestion made by the DEFRA Review Group (2003) that native plants of local provenance should be stipulated for use in commercial, conservation or amenity planting schemes, particularly within or near areas of conservation interest.

A second example outlining the dangers of introducing non-native genotypes is the introduction of non-native salmon for brood stock. Interbreeding between introduced fish and local wild populations has resulted in detrimental impacts in wild populations (Case study 4.1).

One of the most seriously affected sectors to suffer from the importation of different genetic strains of a species is the glasshouse industry. The introduction of strains of previously established insect species which are resistant to an array of insecticides is an increasing concern (Dunne 2003). An example is the cotton-melon aphid *Aphis gossypii* Glover which, until recent years, was a rarely encountered pest of certain glasshouse crops. However, in recent years a strain has been occurring on chrysanthemums and cucumbers that is resistant to all the usual organophosphate, carbamate and synthetic pyrethroid aphicides and is susceptible only to nicotine spray (Dunne 2003). The increased use of insecticides on populations of insect species with short generation times has serious implications for pesticide resistance in wild insect species.

Table 4.2 Examples of priority habitats and invasive and potentially invasive species that threaten their favourable status

Priority Habitat	Invasive threats
Upland mixed ashwoods	*Sciurus carolinensis*
Upland oakwood	*Rhododendron ponticum*
Wet woodland	*Impatiens glandulifera*
Lowland woodland pasture and parkland	*Prunus laurocerasus*
Lowland heathland	*Rhododendron ponticum*
Limestone pavement	*Fagus sylvatica*
Aquifer-fed naturally fluctuating waterbodies	*Heracleum mantegazzianum*
Ancient and/or species-rich hedgerows	*Crataegus laevigata*
Cereal field margins	*Arthurdendyus triangulates*
Eutrophic standing waters	*Heracleum mantegazzianum*
Mesotrophic lakes	*Rutilus rutilus*
Marl lakes	*Pacifastacus leniusculus*
Rivers	*Gammarus pulex*
Mud habitats in deep water	*Dreissena polymorpha*
Blanket bog	*Picea sitchensis*
Coastal sand dunes	*Hippophae rhamnoides*
Coastal saltmarsh	*Spartina anglica*
Saline lagoons	*Spartina anglica*
Seagrass beds	*Spartina anglica*
Tidal rapids	*Sargassum muticum*

Table 4.3. Designated nature protection areas in Ireland. These designations include marine areas.

Designation	Approximate land area ('000 ha)	
	Northern Ireland	Republic of Ireland
Special Areas of Conservation (SACs)*	65	1,100
Natural Heritage Areas (NHAs)	n/a	907
Special Protection Areas (SPAs)	70.7	258

*In the Republic of Ireland, terrestrial SACs are a subset of NHAs.

Case Study 4.1 Atlantic salmon *Salmo salar*

Category of introduction: Atlantic Salmon are native Irish species protected under Annex II of the Habitats Directive. However, non-native salmon are introduced to fish farms that benefit economically from their superior growth rates.

Reasons for introduction: Commercial production of farmed fish for sale.

Pathway for introduction: Growing salmon and other fin fish in sea pens exposes the farm operation to certain risks that can lead to escapes. The pens can be damaged due to weather (storms), persistent predators such as seals that try to get at the fish, industrial accidents (human error or equipment malfunction) and vandalism.

Problems caused by the introduction: Adult farmed salmon are competitively and reproductively inferior in the wild and their escape and subsequent interbreeding with wild salmon disrupts local adaptations and reduces the genetic diversity of wild salmon populations (Fleming *et al*., 2000). Interbreeding can potentially change the genetic make-up, fitness (i.e. recruitment in subsequent generations) and life history characteristics of wild salmon. In order to assess the impact of such genetic changes on wild stocks, experimental simulations of escapees were carried out in a 10 year, 2 generation project on a tributary of the River Burrishoole in Western Ireland (McGinnity *et al*., 2003). Farm salmon were found to be larger and competitively displaced wild parr, thus reducing wild smolt output, which is equivalent to a loss of part of the freshwater habitat (McGinnity *et al*., 2003). The hybrids were intermediate in survival. Even modest numbers of farm escapees and modest levels of stocking can result in <5% to 30% declines in fitness, stocking with non-native salmon is likely to have similar effects (McGinnity *et al*., 2003). Farmed salmon may also be carriers of diseases and parasites unknown in the wild that have the potential to reduce wild populations. Therefore increased emphasis needs to be placed on preventing escaped farm salmon from entering rivers. From an economic perspective farm salmon escapees may also pose a threat to producers seeking to brand their products as organic.

How the introduction may have been prevented: Stock records are essential to accurately quantify the potential scale of a problem should an incident occur, notify appropriate legislative departments and initiate attempts to recapture the fish.

Invasion dynamics outside of Ireland: Farmed salmon populations appear to threaten wild salmon populations throughout the North Atlantic (Fleming *et al*., 2000).

References

Fleming, I.A., Hindar, K., Mjolnerod, I.B., Jonsson, B., Balstad, T. & Lamberg, A. (2000) Lifetime success and interactions of farm salmon invading a native population. *Proceedings of the Royal Society of London Series B*, 267, 1517-1523.

McGinnity P., Prodohl P., Ferguson K., Hynes R., O' Maoileidigh N., Baker N., Cotter D., O' Hea B., Cooke D., Rogan G., Taggart J., & Cross T. (2003) Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon. *Proceedings of the Royal Society of London, Series B*: **270**, 2443-2450.

4.9 Research needs for risk assessment

The effects of alien species on native biodiversity, the rate at which effects proceed, and the time scales over which negative impacts can be detected are still not fully understood. "Just Ecology" consultants were commissioned to undertake a report to the UKBAP invasive group (Callaghan 2003), which recommends a variety of potential research areas, some of which we consider merit inclusion here. Further research should aim to incorporate:

1. *Basic biology, database and monitoring*. Improved knowledge of the basic biology of introduced species: compilation of a database of current information about actual and potential problem species, improved monitoring and surveillance of invasives/natives.
2. *Indirect impacts on species*. Assessment of indirect impacts on native species, e.g. on dependent/specialist herbivores, by altering competitive interactions, disease/pathogens etc. Determination of functional and performance consequences for the population.
3. *Functional impacts*. Assessing the ecological impacts of functional/performance consequences on affected species, on habitats, ecological processes and ecosystems.
4. *Genetic impacts*. Assessment of direct impacts through gene flow and introgression within-species and gene flow between introduced and native species and hybridization. Determination of functional/ performance consequences for the population.
5. *Genetic conservation*. Improve current knowledge of the range of genetic variation represented in priority, native species, assessing the potential impacts of introduced genes and grouping of species according to their vulnerability to genetic change and the need for genetic conservation.
6. *Decision support system*. Identify direct/indirect impacts, ranking species according to threat posed. Understand different agents of change. Develop a decision support system for defining thresholds of unacceptable change, determining when to take action and what action to take.
7. *Removal of aliens*. Experiments to determine which invasive species can be effectively removed. Considerations include recruitment potential, landscape patterns/dynamics and cost-benefit analyses.
8. *Scientific basis for management*. Developing the scientific rationale for management techniques, tools and measures, run from a decision support system as a precursor to taking action. Research to inform appropriate responses to observed /predicted effects and to evaluate management options, including operational responses, educational and economic policy and legislation.
9. *Risk assessment*. Develop biodiversity risk assessment for screening imports of exploited species or related commercial products, in order to identify the role of different vectors/pathways for introduced species .
10. *Cost-benefit analysis* of introductions. Produce environmental accounts for introduced species and evaluate the economics of new proposals to commercially exploit species. Consider loss of biodiversity benefits and services and costs to industry.
11. *Impacts of controlling diseases/parasites*. Investigate the effects of controlling introduced disease/parasites on other species at all relevant scales (individual, sub-population or population).

12. *Long-term forecasting*. Investigate long-term adaptive changes of non-native species in relation to climate change, through monitoring genetic change and phenotypic indicators.

Risk reduction

4.10 The importance of social and economic stability in risk reduction

The most influential conservation priority-setting approaches emphasize biodiversity and threats to it when deciding where to focus investment. However, the socio-economic and political attributes of nations clearly influence the uptake and delivery of conservation actions. An analysis by O'Connor *et al.*, (2003) examined a combination of biological and sociological variables in the context of a "return on investment" framework for establishing conservation priorities. Only a few countries emerged as high priorities irrespective of which factors were included in the analysis (O'Connor *et al.*, 2003). Some countries that ranked highly as priorities for conservation when focusing solely on biological metrics, did not rank highly when governance, population pressure, economic costs and conservation need were considered (e.g. Columbia, Ecuador, Indonesia and Venezuela). Whilst considerations within Ireland differ from these examples, priority-setting is rarely divorced from political agendas. The need for cross-border policies is particularly poignant in Ireland.

4.11 Risk Analysis

By way of a model for organising risk analysis, the management of plant pests provides guidance. Specific organizations such as the EPPO, the European Plant Protection Organization have specific Risk Assessment Schemes. Such schemes incorporate an initiation stage and a quantitative and qualitative risk assessment (http://www.eppo.org/QUARANTINE/PRA/prassess_figures.html).

In the Irish case it is difficult to predict how a cross-border situation would be addressed, both in terms of legislative procedures and financial responsibility for ecosystem restoration. For example, if a threat arose within or near to a particular SAC which spans Northern Ireland and the Republic of Ireland (Table 4.4) there may be additional barriers to rapid action. For example, Lough Melvin is an important resource for tourism due to the high level of recreational fishing. The infiltration of an invasive alien species resulting in a detrimental impact on the fishing industry would be of serious economic concern to both countries. Identification of the jurisdictional and legislative barriers to immediate action is required. It is recommended that a standard protocol is designed to combat the complications of cross-border invasions.

Table 4.4 cSACs in Northern Ireland that adjoin cSACs in the Republic of Ireland (Source: http://www.jncc.gov.uk/ProtectedSites/SACselection/adjoining_csacs.htm)

UK cSAC		**Republic of Ireland cSAC**	
Site code	Site name	Site code	Site name
UK0016603	Cuicagh Mountain	IE0000584	Cuilkcagh-Anieran Uplands
UK0030047	Lough Melvin	IE0000428	Lough Melvin
UK0016621	Magheraveely Marl Loughs	IE0001786	Kilrooskey Lough Cluster
UK0016607	Pettigo Plateau	IE0001992	Tamur Bog
UK0016607	Pettigo Plateau	IE0002164	Lough Golagh

An example of a cross-border scenario is illustrated by the sequence of events depicted in Figure 4.2. In this hypothetical situation a member of the public is brought into contact with an "unusual species", which we shall consider to be American signal crayfish, discovered in Dawson's Lough (H365165), in the north of the Republic close to the border. This individual may then take one of several options, they may choose not to act or they could dispatch the item to a local conservation office in Belturbet, a local fisheries officer, or a museum in Dublin. The choice of destination will influence the length of time to arrive at a positive identification of the species. Once the species has been identified, by one of a limited number of capable individuals, National Parks and Wildlife Service may be informed of a potential threat. Authorization to conduct survey sampling of Dawson's Lough would reveal the presence of American signal crayfish at low abundance. The threat to the site south of the border could be perceived as low, as this area is not a designated SAC. However, it must be remembered that signal crayfish are highly mobile and can move over land (Alderman & Wickins, 1996). North of the border lies Lough Erne, the whole of which is a designated SAC and Magheraveely Marl Loughs, for which native freshwater crayfish are a designating feature. Therefore a differential exists in the prioritization of the threat between the north and south.

No formal mechanism exists for transfer of information and cross-border communication in this matter, yet it is probable that NPWS staff would personally inform their counterparts at EHS in the north. Senior level authorization will be required to authorize surveying of sites north of the border in order to determine the extent of the local threat. Access to private land may be restricted and trained personnel may be scarce. Thus there may be a requirement to train staff at short notice. Species-specific information may also be lacking, increasing the difficulty in ascertaining the degree of threat and possibility of eradication. Nonetheless it is probable that attempts will be made to evaluate the extent of the distribution and the probability of success of control or eradication methods. Co-ordination of

any eradication policy between north and south will be essential due to the connectivity of this ecosystem. It is possible that either EHS or NPWS may lack the scope or manpower to act on this matter and may advertise a contract to tender, leading to initial feasibility studies and eventually eradication, evaluation and post-evaluation. The time scale of this process is delayed by the lack of pre-defined pathways, resulting in the initiation of an eradication policy after a considerable delay of up to several years, by which time the crayfish will have reproduced and increased their numbers.

The alternative scenario considers a situation whereby the unusual species is dispatched direct to a cross-border invasive species agency, where identification takes place and a specific contingency plan is set in motion. This would necessarily require a broad advertising campaign targeted at the general public and possibly the maintenance of a web-based invasive species site, all of which would come under the general remit of the invasive species agency. In this case an eradication campaign could be initiated in 3 months or less, based on framework agreements with contractors working to an established plan. This rapid response would considerably reduce the possibility of the crayfish completing its reproductive cycle before eradication, increasing ease of eradication and reducing cost.

4.12 Forecasting future introductions

Long term consideration of the potential future introductions of invasive alien species in relation to changing climatic regimes is of importance for predicting the kind of organism that could become more invasive in Ireland in the future. The potential for synergistic effects, two processes acting concurrently to accelerating rates of change is likely to increase in the future, due to the increasing pressures of habitat fragmentation, climatic alteration and increased disturbance. A case study of the role of climate in predicting species invasions of invertebrate fauna into Ireland is documented below (Case Study 4.2).

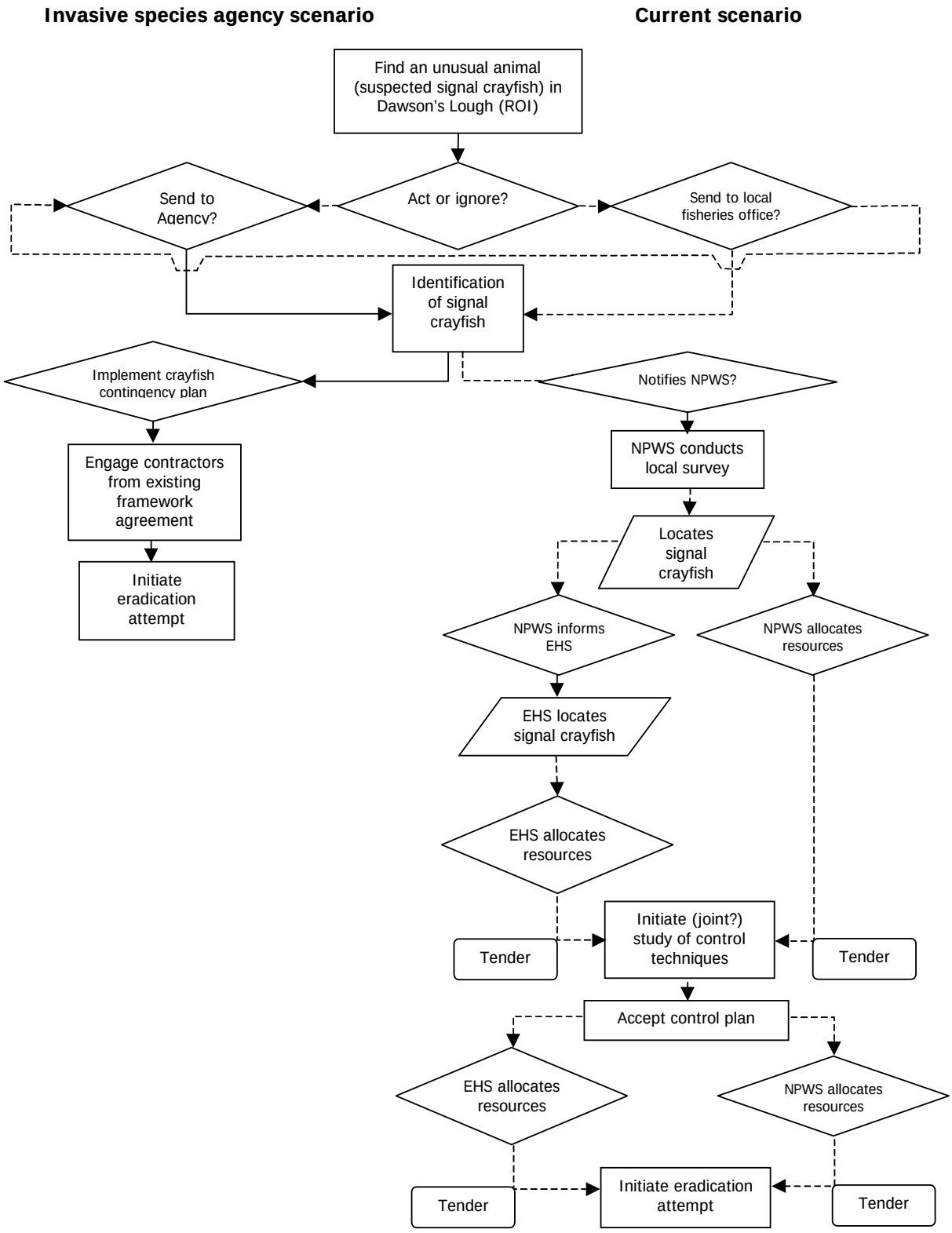


Figure 4.2 Hypothetical scenario of decisions and processes affecting the cross-border response to finding a potential new invasive species near the border. Dotted lines indicate risk prone stages. The key factor is the development of a contingency plan, comprising the detailed processes and decisions, lead by a cross-border body in advance of the discovery of the invasive. Thus the potential delays occur before the invasion occurs. As delays arise from a post-hoc response the chances of success rapidly diminish.

Case Study 4.2 The role of climate change in predicting species invasions

Climate change means that the ranges of many insects, including those that are not native to Ireland, are likely also to change. This may be accelerated by alterations in land-use. In Ireland, alien invertebrate species have been recorded originating from Australia, Asia, America and mainland Europe (Figure 4.3, Anderson, 2003). The proportion of alien species represented within the different invertebrate groups differs; alien species comprise a high proportion of the total fauna within the flatworms and, to a lesser extent, within groups such as slugs, snails, isopods and millipedes (Figure 4.4, Anderson, 2003). Recent rapid climatic trends have been observed within Northern Ireland including: increases in winter precipitation and night temperatures, increased cloudiness and reduced sunshine hours and milder winters with significant increases in minimum and maximum temperatures. Increases in temperature are likely to favour both cryptozoic and thermophilic fauna while increased precipitation and cloudiness will favour cryptozoic and hygrophilous fauna.

One example of a recent species invasion believed to be attributable to climate is that of the Lily Beetle *Lilioceris lilii*, a garden pest discovered in Belfast in 2002 (Anderson & Bell, 2002). This species is native to Eurasia and occurs across the north Palaearctic land mass and became established in the British Isles during the nineteenth century (Cox, 2001). Despite being erratically resident in southern Britain for many years, marked expansion northwards from the south-east counties of England appears to have occurred only within the last 20 years or so. The appearance of *L. lilii* in Northern Ireland is by far its most northerly and westerly site, a significant step in range expansion believed to have been facilitated by climate change (Anderson & Bell, 2002).

If current trends continue we can predict increases in the flux of damp loving organisms with a reduced influx of diurnal thermophilic organisms. This will result initially in a greater range of non-native slugs, snails, millipedes and flatworms and fewer new beetles, dragonflies, bees or butterflies. The potential economic consequences are difficult to evaluate but slugs are considered garden pests and create horticultural damage. The impact of flatworms is likely to cause serious long-term damage to earthworm populations in Ireland (see Case Study 2.1). This will have a consequent long-term effect on soil quality, such as increased surface litter accumulation, a lack of bypass flow for surface drainage, widespread increasing surface compaction and increased soil acidity.

References

Anderson, R. 2003. Workshop Presentation, “Patterns of terrestrial invertebrate invasions as a guide to future trends”. All-Ireland Invasive Alien Species Workshop, Dublin, 26th November 2003.

Anderson, R. & Bell, A.C. 2002. A first record of the Lily Beetle Lilioceris lilii (Scopoli) in Ireland (Chrysomelidae: Criocerinae). *The Coleopterist*, **11**, 90.

Cox, M.L. 2001. The status of the Lily Beetle Lilioceris lilii (Scopoli, 1763) in Britain (Chrysomelidae: Criocerinae). *The Coleopterist*, **10**, 5-20.

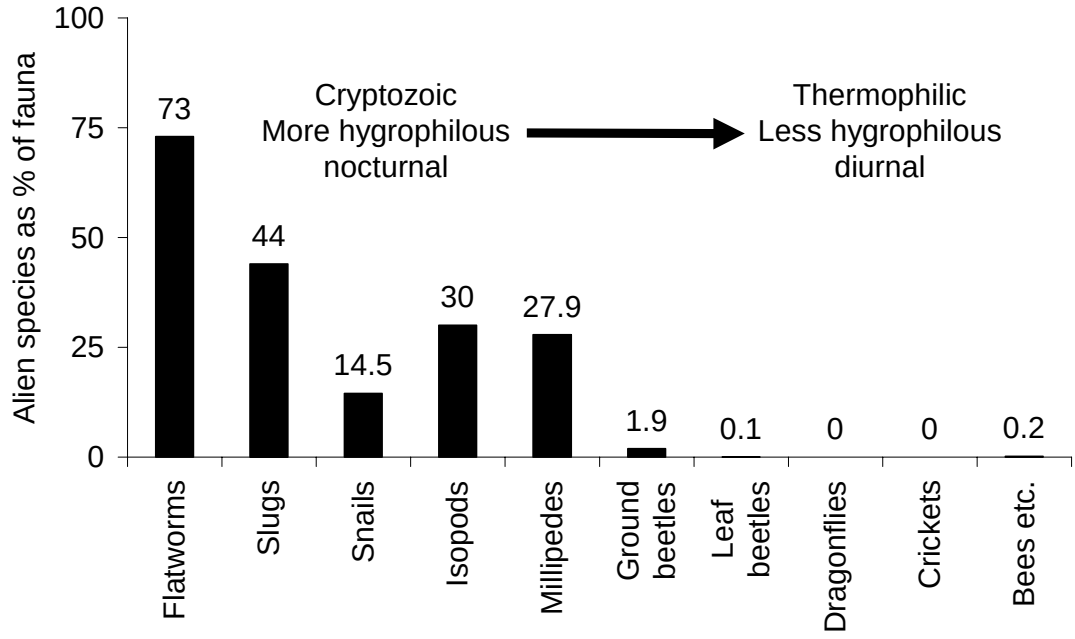


Figure 4.3 Representation of non-native species among invertebrate taxa in Ireland (Reproduced by courtesy of R. Anderson).

4.13 Public awareness and education issues

The fact that management and eradication programs are likely to be more successful if supported by an informed and co-operative public is frequently stated. An awareness of the community benefits arising from co-operative policies on IAS can increase the willingness of the public to contribute (occasionally even financially) to any attempts to rectify the problems. The DEFRA review group (2003) point out that reducing the number of inadvertent offenders also allows enforcement agencies to concentrate on persistent criminal offenders.

Public use of the internet has the dual potential to both increase the risk of invasive species imports (through the acquisition of rare and unusual plant and animal species) and it is an efficient tool to disseminate precautionary information to the public on the correct protocols to follow to reduce risks to native biodiversity.

The DEFRA review (2003) identifies key target audiences for improving awareness in relation to the problems of non-native species.

4.14 Target audiences and key issues

Issues which must be addressed to the general public, such as the risks of unwanted introductions through the dumping of garden waste. Educated naturalists within the general public who are able to contribute a wealth of information on the distribution and spread of invasive species

Professional groups with important roles to play, including policy makers, civil servants and ministers. Operational professionals, (e.g. agriculture, forestry, landscape or planning professionals) and other groups of professionals such as horticulturists or pet-trade professionals. The activities of each of these groups and the guidance and advice they provide to the public will be instrumental in raising awareness or alternatively causing problems.

4.15 Developing the culture

"Thinking green" has been on the increase for many years. However, many European countries still lag behind the custodial mindset prevalent within countries such as New Zealand, although the policies of such countries do benefit from the advantage of lower population densities. New Zealand has a heightened sense of responsibility regarding its native species due to the decimation during European colonization of a number of natives. For example the kiwi, kaka and other endemic birds declined in New Zealand as a direct result of the invasion of Eurasian rats (King, 1984). The approach to invasive species issues within Ireland is currently rather negative, based upon restrictive measures rather than encouraging an ethos of custodial care in the national psyche. Ireland also has the distinct disadvantage of having a car-based, ferry-driven tourist economy, placing high responsibility on both the local public and incoming tourists to safeguard against invasive species. Therefore it is recommended that considerable efforts are made towards public education regarding invasive species issues, in particular at points of entry into the country but also to raise the generalized level of awareness. As a means of promoting such a culture the DEFRA Review Group (2003) suggest a number of key basic messages are propagated, which we have adapted for the Irish situation.

- awareness of the potential risks of releases and escapes into the environment

- understanding of the consequences of moving plants and animals around N. Ireland and the Republic of Ireland

- understanding of the risks and consequences of introductions, especially to islands, remote areas and freshwaters

- understanding of the concepts of the values of native biodiversity and the term "native"

- awareness of the potential risks of what is brought back from abroad

- understanding of the need for the control and management of invasive non-natives and understanding of the risks of failure

- also understanding that only a minority of non-native species cause problems and that many have and will continue to enrich people's lives

In developing the means to achieve these ends the DEFRA Review Group advance several key considerations.

- ensuring the simplicity of the message to build up understanding

- avoiding the use of the words that have had negative associations with human activities, thus using, for example, the term "non-native" rather than "alien"

- advance planning to address concerns about animal welfare ahead of any control measures, recognizing that control measures should be undertaken to high standards that ensure the welfare of animals

- developing an awareness culture where the risk of invasive non-native species is considered a legitimate concern, ensuring that those undertaking any actions have a "licence to operate"

- dealing with any public assumption that reporting the presence of individuals of a non-native species will automatically lead to their death or removal

- overcoming professional and scientific concerns about scientific accuracy to convey a message

effectively: it is important to strike the right balance

The way in which the information is delivered needs to be targeted for each specific group. For example, it has been suggested that ferry and aeroplane tickets should carry information regarding instructions on what not to bring into the country. Specialist press should be used to target naturalists and the more informed members of the public, such as gardeners and anglers.

A key step will be the introduction or increase of information regarding invasive species in core curricula in primary and secondary education. Tertiary education tends to specialize in this area to a greater extent; yet improvements could be made regarding the specific concerns of non-native species to agriculture, forestry, ecology and land management. Some universities run courses in risk management, generally targeted towards providing short and long term relief in the aftermath of a disaster. Training in the management of invasive species could be included within such courses as a form of risk analysis.

4.16 Cost analysis: decision-making under uncertainty

The information necessary to conduct traditional cost-benefit analysis and risk assessment is largely inadequate and much of the existing ecological risk assessments are based on subjective information. The technology of risk assessments for introduced species is still at an early stage. Confidence limits about estimates of likelihood that a species will become a pest are large, increasing the probability of making a highly costly false hypothesis of no negative effect (Simberloff & Alexander, 1998).

A large proportion of management relating to invasive species is steeped in a "search-and destroy" mentality. In the case of rapid action against a species which is detected early a large amount of information on population biology of the particular species is not necessarily essential to eliminate the problem. Because of their rapid population growth and high dispersal abilities introduced species are one target at which it is better to "shoot first and ask questions later" (Simberloff, 2003). One concern is that successful eradication of the invasive species could feasibly be attributed to good luck rather than the particular management strategy used. For example, severe drought or a prolonged period of below average temperature may actually have had a greater detrimental effect upon the population than the control strategy did. Therefore, unless application of the same eradication procedure during a second invasion is initiated very rapidly, it will not necessarily be successful. It is recommended that where economically viable, efforts are made to identify the quantitative effects of a specific management treatment in contributing to a successful eradication. Certainly, attempts to eradicate long-standing invasions will require substantial biological knowledge of both the ecosystem and the population biology of the species. This will allow a better estimate of the probability of a successful campaign, avoiding wastage of time and public money (Simberloff, 2003), and enabling the prediction of situations where sudden removal of an alien species may generate a further disequilibrium, resulting in greater damage to the ecosystem.

Uncertainty is inherent in ecological systems and this can be countered by developing effective management options that adjust for different levels of risk and uncertainty. The use of mathematical models is fundamental to this procedure. However modelling can only play a

role in this process if there is close interaction between modellers and resource managers. Some of the most successful management tools have been applied using an economically-based system of cost, risk and benefit measures applied in a location-specific manner.

Location-specific indicators of "damage" may be structured to represent economic concepts of capacity to produce a service, differential value of services at different locations, scarcity and replaceability of services and risk of service flow disruptions (Wainger & King 2003). The use of computer programs (such as Geographical Information Systems GIS), can allow these factors to be quantified at multiple scales. For example, different potential benefits from a treatment come into play over the extent of a park, aquifer recharge zone, or county.

4.17 The Polluter Pays Principle

The costs of damage, control and repair work are typically met by the taxpayer, or industrial sectors whose economic interests are affected. The DEFRA Review (2003) considered that the level of those fines available do not constitute a deterrent. It was recommended that, where such releases constituted a criminal offence or wilful negligence, then the "polluter pays" principle should be invoked, allowing the courts to have the option of imposing fines bearing some relation to the cost of reparation. The costs of inspection, monitoring or management are open to the "polluter pays" principle and consideration needs to be given to the legal framework for imposing and collecting fines, or imposing an insurance requirement (DEFRA, 2003). In different circumstances these might include imposing the cost of management on those responsible for the release or introduction of damaging invasive non-native species. The potential costs of control may provide the basis for determining financial costs. However, insurance companies could experience difficulty in identifying potential underwriters, due to the complexity of assessing the financial risk posed by invasive species.

4.18 Priority setting in conservation: trade related conflicts

The need to conserve biological diversity and landscape quality often conflicts with social, economic and political motivations. In the past the general perception has been that trade-led economic growth will naturally lead to better environmental quality because economic growth increases public demand for stricter environmental standards. However this is most probable for reversible and local environmental damage that directly lowers living standards, such as polluted drinking water, and, notoriously, has not functioned for cumulative and difficult-to-reverse forms of environmental damage, such as primary forest destruction, greenhouse gas build up and increasing infiltration of invasive species (Yu *et al.*, 2002). Geographical differences in market pressure and population density result in differing accessibility levels to markets, which influences the potential for serious invasive species problems.

Promoting moves towards increasing consumption of local produce may be beneficial in reducing the impact of invasive species through a reduction in imports, but the outcome is not straightforward. For many consumers discriminating between products on the basis of provenance rather than price remains a luxury they cannot afford (Stephens *et al.*, 2003). One obvious mechanism for promoting the competitiveness of

local produce is to tax long-distance transport of goods in a realistic way, taking into account the damage caused to the environment, the economy, human health and national infrastructure (Stephens *et al.*, 2003). Congestion charging is now accepted in several countries in northern Europe and the Far East, suggesting that the public might be prepared to accept realistic charging of transport for the environmental costs that it incurs.

4.19 Incorporation of protection schemes into existing agri-environment schemes

Under the General Agreement on Tariffs and Trades (GATT) administered by the World Trade Organization (WTO) subsidies from the government to specific industries or companies are disallowed if they deter imports or boost exports, and thereby distort trade. Subsidies are considered perverse when they cause not only economic but also environmental harm in contributing to resource degradation (Yu *et al.*, 2002); examples include subsidies within the farming and fishing industries. Increasing concern over the environmental impact of agriculture in Europe has led to the introduction of Agri-Environment schemes. These schemes compensate farmers financially for any loss of income associated with measures that aim to benefit the environment or biodiversity. Environmentally Sensitive Areas (ESAs) were the first agri-environmental initiative provided for in European legislation, under the Farm Structure Regulation 797/85 of 1985. In 1992 the CAP reforms were accompanied by Regulation 2078/92 which required member states to establish tailored Agri-environment schemes. There are currently Agri-Environment schemes in 26 out of 44 European countries (Kleijn & Sutherland 2003).

Inclusion of measures for the prevention and eradication of IAS could feasibly be incorporated into the Irish Rural Environmental Protection Scheme (REPS) as outlined below. This scheme would have the additional benefit of utilizing existing legislation.

Box 4.2 The Irish Rural Environmental Protection Scheme (REPS)

The Irish Rural Environmental Protection Scheme (REPS) consists of one scheme with only 11 compulsory measures and a further 6 "Supplementary Measures". The basic scheme is comprehensive and addresses biodiversity and environmental protection, training courses and keeping of farm and environmental records. The REPS aims to conserve wildlife habitats and endangered species of flora and fauna as well as address environmental problems.

REPS measures

1. Waste management, liming and fertilization plan
2. Grassland management plan
3. Protection of water courses and wells
4. Retention of wildlife habitats
5. Maintenance of farm and field boundaries
6. Ban on chemicals near hedgerows and waterbodies
7. Protection of historical and archaeological features
8. Maintenance and improvement of the visual appearance of the farm and farmyard
9. Production of tillage crops without growth regulators
10. Familiarity with environmentally friendly farming practices
11. Keeping of farm and environmental records

Five compulsory measures are particularly relevant to biodiversity conservation. All Supplementary Measures are primarily aimed at conservation aspects and only apply in designated areas.

REPS Supplementary Measures

1. National Heritage Areas
2. Rejuvenation of degraded areas
3. Local breeds in danger of extinction
4. Long-term set-aside
5. Public access and leisure activities
6. Organic farming

The inclusion of an additional REPS measure aimed at preventing the infiltration and spread of invasive alien species would be beneficial as the scheme has been widely taken up. The value of the REPS scheme has been attributed to its universal geographic availability, voluntary nature, comprehensiveness, tailoring to individual farm limited payments (which control the extent to which larger farms can benefit proportionately from the scheme) and financial training incentives (Emerson & Gilmour, 1999). The REPS budget for 2004 is €260 million and 45, 000 farmers are currently involved, which constitutes one third of the utilizable agricultural land (2004 Estimates for Public Service, Department of Finance).

Box 4.3 ESA Schemes in Northern Ireland

For the whole of the UK 9 different schemes exist of which only one, the "Organic Aid Scheme" is truly horizontal. Others can be applied in certain regions or address specific biotopes. Overall, there is a strong emphasis on wildlife conservation in UK AEP schemes. The concept of Environmentally Sensitive Areas (ESA) was originally developed in the UK and first implemented under regulation 797/85. Wildlife conservation in the wider countryside is addressed by the Countryside Stewardship Scheme. Hart and Wilson (2000) record that the highest uptake is the ESA scheme, accounting for 58% of the AEP budget and 74% of the area, followed by the Countryside Stewardship Scheme, allocated 21% of the budget and 7% of the area.

The Department of Agriculture in Northern Ireland launched the Countryside Management Scheme (CMS) in 1999. This scheme has a tiered approach, Tier 1 focusing on a general set of measures aimed at the maintenance of more extensive farming systems and Tier 2 and 3, which adopt measures that exceed the baseline management practice and are aimed at habitats or features where specific management prescriptions must be instigated. Tier 2 focuses on priority habitats in Northern Ireland, which if present on a farm must be brought under agreement, whilst Tier 3 offers the potential to create optional habitats on a farm, for example buffer zones.

Current expenditure in Northern Ireland on agri-environment schemes amounts to about £7.5 million or just over 3 per cent up take. This compares with spending on similar schemes in the Republic of Ireland of over £200 million (Session 2001-02, Northern Ireland Affairs Committee Publications - Appendices to the Minutes of Evidence, Appendix 13, Supplementary Memorandum submitted by Friends of the Earth Northern Ireland).

4.20 Accessibility of scientific results to policy makers

Although a considerable amount of research has been carried out on the relationships between agricultural practices and biodiversity in Ireland the results are often unpublished or in journals that are hard to access. In order to influence the relevant policy makers it is essential that the existing science is inventoried, reviewed and presented in a non-technical and easily accessible way. A mechanism to promote effective information exchange and technology transfer between researchers would help to prevent wastage in terms of repetition, and to focus new projects on policy-relevant issues.

Control of IAS

4.21 Containment and Eradication vs. Sustainable Control through Biological and Integrated Methods

In the long-term if the eradication of an IAS is not feasible or resources are not available for its eradication, containment and long-term control measures should be implemented (UNEP 2003). The aim of control is to reduce the density and abundance of an IAS in order to keep its impact to an acceptable level in the long term. Before starting a control programme, ideally a cost/benefit analysis should be carried out, desired outcomes should be clearly defined and appropriate monitoring of the results should be planned (Genovesi & Shine, 2003). Control methods should be selected with regard to their efficiency, and selectivity, with due consideration of the negative effects they may cause (Genovesi & Shine, 2003).

A variety of different techniques may be utilized to control or eradicate a species.

- physical/mechanical e.g. trapping, shooting
- chemical e.g. poisoning
- biological e.g. directed use of specific disease, use of immuno-contraceptives

Whatever the strategy used its long-term success is critically dependent on support from different areas, including financial support, staff commitment and the support of the public.

4.22 Comparisons with disease epidemics

Some successful examples of control can be found in the Public Health Sector. For example, rabies, once prevalent has been virtually eliminated in the UK and Ireland due to a successful control program.

During the last century rabies was rife throughout parts of Central and Western Europe. Foxes have been the main host but other mammals have also been infected, including not only dogs and cats, but also cattle, horses, badgers, martens, sheep, deer, goats and racoon dogs, providing a large host range. However, non-carnivores pose a low risk of transmitting the virus to humans. The Kennedy Report (2000), states that during the last 10 years the incidence of endemic, fox-adapted rabies in Western Europe has fallen dramatically and it appears to have been virtually eliminated from the EU. However, in November 2002 one death occurred in Scotland from European Bat Lyssavirus, contracted by a bat conservationist from Daubenton's Bat. The virtual eradication of rabies in Western Europe has been largely due to the success of co-ordinated wildlife vaccination programs, together with the availability of effective commercial vaccination for domestic animals. Some EU member states have continued to report occasional cases of rabies in domestic animals imported from non rabies-free countries.

More recent legislation has relaxed the 6-monthly quarantine procedure for pets, an alteration that the public are willing to pay for. From December 11th 2002 pets no longer have to be caged for 6-months in quarantine prior to entering the UK. Animals entering Britain through the EU pet passport scheme will be eligible for onward travel to the Republic of Ireland. The passport scheme means that pets must be fitted with an identifying microchip after getting a rabies vaccination, blood tests and extensive veterinary checks, all at the cost of the individual owner.

DEFRA acknowledge the benefit of research relating to the containment of disease epidemics, a recent job advertisement (5/2/04) based at the University of Oxford and funded by DEFRA seeks to analyse foot and mouth disease control strategies.

4.23 Willingness to pay

Consumer preference surveys amongst urban and suburban residents have provided further evidence of the high value placed on aesthetic environmental quality. A study conducted by Jetter and Paine (2004) attempted to quantify the comparative public value of chemical, biorational (bacterial) and biological control options for management of an introduced urban forest pest. This is one of the first attempts to evaluate public perception and willingness to pay a tax to support landscape biological control.

Differing combinations of control options were allocated fluctuating prices. When the price of all options was low residents preferred the biological control option. As the allocated price for all options rose an increase in preference was seen for the bacterial and chemical options. However, when prices became high preferences shifted again to the natural enemy option (Jetter & Paine, 2004). The social characteristics of respondents were also evaluated, with the conclusion that it may be possible to generate social and financial support from urban residents for classical biological control options (Jetter & Paine, 2004).

Case study 4.3 The eradication of the muskrat *Ondatra zibethica*

Category of introduction: Muskrats are rodents native to North America that were intentionally introduced to Great Britain for fur farming in the 1920s.

Background to the introduction: Muskrats are generalist herbivores which damage native plants and crops (Warwick, 1940). Additionally these rodents cause damage to drainage systems by burrowing. Escapees soon established populations in the wild so that by 1932 there were feral colonies in 14 different counties in Britain (Fairley, 2001). Further imports were halted due to the Destructive Imported Animals Act (1932). An eradication scheme was initiated by the Ministry of Agriculture. The muskrat was a known pest in Europe (Sheail, 1988), therefore information was available in order to assess the effort required, the costs involved and the probability of success which justified government funding (Gosling & Baker, 1989). The relatively mild climate in Britain and an abundant food supply ensured an extended breeding season for *O. zibethica* from February to November, facilitating a potential of 6 to 7 litters of 8 young per female per year (Warwick, 1940). By 1936 the animals were eradicated in England after a total of 4,500 had been killed.

Muskrat was first imported into Ireland in 1929 into County Tipperary and it is likely that 3 individuals were imported (Fairley, 2001). A further two were imported into County Wicklow. Escaped animals quickly spread to the River Nenagh, Black Lough, Annagh Lough and Lough Nagelane (Fairley, 2001). Muskrats built up in number unnoticed for a time due to their elusive behaviour and nocturnal habits (Fairley, 2001). The Department of Agriculture became increasingly concerned, not only about the undermining of riverbanks but more especially over the possibility of the rats reaching the new hydroelectric installation at Ardnacrusha on the River Shannon, below Killaloe at the southern end of Lough Derg.

Eradication methods: During 1931 and in 1933 the *Foot and Mouth Disease (Importation of Rodents and Insectivora) Order* prevented the further import of muskrats, after a slight delay resulting from uncertainty as to whether muskrats could actually transmit the disease (Fairley 2001). This Act was followed by the *Destructive Imported Animals Bill*, in February 1933 and the *Destructive Imported Animals Act (Northern Ireland)*, March 1933 which dealt primarily with muskrats. Finally, the *Musk Rats Act* (1933) in the Republic of Ireland initiated an intensive trapping programme which ran from September, 1933 until April, 1935 when the muskrat was believed to have been eradicated. The success of the scheme was partly attributable to the commendable short time interval between the discovery of the infestation and the commencement of destruction (Fairley, 2001). The unavoidable delay required to draw up and enact the necessary legislation was partially offset by an exceptional dry summer of 1933, which had detrimental effects on the muskrat population and continued into the winter of 1933; thus trapping was unhindered by flooding (Fairley, 2001).

References

Fairley, J. (2001) *A Basket of Weasels. The weasel family in Ireland and other furred Irish beasts : bats, the rabbit, hares and some rodents*. Published privately, Belfast, Northern Ireland.

Gosling, L.M. & Baker, S.J. (1989) The eradication of the muskrats and coypus from Britain. *Botanical Journal of the Linnean Society*, 38, 39-51.

Sheail, J. (1988) The extermination of the muskrat (*Ondatra zibethicus*) in inter-war Britain. *Archives of Natural History*, 15, 155-170.

Warwick, T. (1940) A contribution to the ecology of the musk-rat (*Ondatra zibethica*) in the British Isles. *Proceedings of the Zoological Society of London, Series A*, 110: 165-201.

Case study 4.4 Control of Giant Hogweed in Ireland

Background to the introduction: As mentioned in Section 1 Giant Hogweed was an accidental introduction, is detrimental to vulnerable habitats and requires a control strategy. Studies on the distribution of *H. mantegazzianum* in Ireland and the UK show that the plant is still in an expansive mode and that "further expansion into new ecologically and socially sensitive areas is likely" (Caffrey, 1999). These studies have further revealed that ten years ago there were still a number of large catchments in Ireland which were free from the plant (Wade *et al.*, 1997). It is recommended that efforts are made to effectively curtail the spread of the plant in regions that are already infested to maintain areas free from invasion.

Table 4.3 Incidence and extent (estimated area in m^2) of *Heracleum mantegazzianum* sites in Northern Ireland, 1993 (Reproduced from Wade *et al.*, 1997).

	Infestation level							
	Low		Common		Dominant		Total	
County	Area m^2	No. sites	Area m^2	No. sites	Area m^2	No. sites	Area m^2	No. sites
Armagh	17	4	722	11	20	1	759	16
Down	1,052	4	6,400	7	12,050	8	19,502	19
Fermanagh	28	3	12,035	2	150	1	12,213	6
Londonderry	0	0	122	3	60	3	182	6
Tyrone	23	0	395	9	20,110	13	20,528	25
TOTAL	1,120	14	19,674	32	32,390	26	53,184	72

Eradication methods: It was recognized that long term control and ultimate eradication can only be achieved through the implementation of a national, co-ordinated and comprehensive management strategy that involves all interested groups (Wade *et al.*, 1997). Giant hogweed populations can only be perpetuated via seeds and control measures applied before flowering and seed set will limit recruitment to subsequent generations, and, if applied systematically over a number of years, will ultimately deplete the seed bank reserve. The longevity of seeds in the soil is unknown, although there are indications that the vast majority of viable seeds germinate within one year (Tiley *et al.*, 1996).

Success of eradication methods: Results from extensive trials have demonstrated the susceptibility of *H. mantegazzianum* to glyphosate (Williamson & Forbes, 1982; Powell, 1988; Caffrey, 1994; Tiley & Philip, 1997). These studies have resulted in the creation of a step-by-step protocol for the long-term control of *H. mantegazzianum*, using glyphosate (Caffrey, 1999). This methodology, if strictly adhered to could lead to successful eradication of the plant if the areas are not reinfested from external sources.

Eradication program on the Mulkear Catchment

Praeger (1939) reported large localized populations of *H. mantegazzianum* in the Mulkear Catchment. The level of infestation increased dramatically from 1970 to 1990, affecting practically all beneficial use of the water-course (Caffrey, 1994). In 1997 the Office of Public Works compiled maps detailing the distribution of the plant in the catchment, which indicated that an area of 35 km^2 was overgrown by the plant. A contractor was commissioned to undertake a 4-year control/eradication program with follow up monitoring on the entire catchment using the protocol described above. This programme commenced in 1998 and ran until 2002.

References

Caffrey, J.M. 1999. Phenology and long-term control of *Heracleum mantegazzianum*. *Hydrobiologia*, 415, 223-228.

Caffrey, J.M. 1994. The spread and management of Giant Hogweed *Heracleum mantegazzianum* (Somm. and Levier) along Irish River corridors. In de Waal, L.C. et al. (eds) *Ecology and Management of Invasive Riverside Plants*. John Wiley & Sons: 67-76.

Powell, F. 1988. Giant Hogweed control in NE Scotland. Plant Press Nr; 4.

Praeger (1939) A further contribution to the flora of Ireland. *Proceedings Royal Irish Academy* 45B: 231-254.

Tiley, G.E.D., Dodd, F.S. & Wade, P.M. 1996. *Heracleum mantegazzianum* Sommier & Levier. Biological Flora of the British Isles. *Journal of Ecology*, 84, 297-319.

Tiley, G.E.D. & Philip, B. 1997. Observations on the flowering and seed production of *Heracleum mantegazzianum* in relation to control. In Brock, J.H. et al. (eds) *Plant Invasions*. Backhuys Publishers, Leiden, 123-138.

Wade, M., Darby, E.J., Courtney, A.D. & Caffrey, J.M. 1997. *Heracleum mantegazzianum*: a problem for river managers in the Republic of Ireland and the United Kingdom. Brock, J.H. *et al*. (eds) *Plant Invasions*. Backhuys Publishers, Leiden, pp. 139-151.

Williamson, J.A. & Forbes, J.C. 1982. Giant Hogweed: *Heracleum mantegazzianum*: its spread and control with glyphosate in amenity areas. *Proc. 1982 British Crop Protection Conference – Weeds*: 967-972.

Case study 4.5 Biological control of the eucalyptus psyllid

Category of introduction: Intentional as a biological control agent.

Background to the introduction: The potential for using a biological control agent within Ireland has been investigated in relation to economic maintenance of a commercial eucalyptus plantation. In Ireland commercial production of eucalyptus species started in 1993. Approximately 28 hectares are devoted to the production of eucalyptus forest. In 1998 approximately 4 million eucalyptus stems (worth 1.5 million Irish pounds = 2 million Euro) were exported to European and American markets (Forest, 2000). Accidental introduction of eucalyptus psyllid (*Ctenarytaina eucalypti*) in Ireland coincided with the start of this new industry and eventually proved disastrous. Despite a high chemical usage (5 to 7 pesticide applications per season) insecticides proved ineffective because the insects eggs were found to be resistant to damage (Chauzat *et al.*, 2002) and the terrain in many eucalyptus plantations is unsuitable for applying sprays (Dunne *et al.*, 2001). No previous attempt had been made to control an outdoor pest in Ireland using classical biological control. However, Teagasc and University College Dublin initiated a trial project to explore the potential of a natural predator, a parasitic wasp, *Psyllaephagus pilosus* as a control agent. An import licence was obtained from the Department of Environment, Heritage and Local Government.

Eradication methodology: Documentation regarding the previous importation and release of *P. pilosus* in California and Europe was sufficient to enable the Irish Department for Arts, Heritage, Gaeltacht and the Islands to grant an import licence. In May 1998 approximately 2,000 parasitized psyllid nymphs and 200 adult wasps were collected from a commercial plantation in south-east France and released on a eucalyptus plantation near Kilgarvan in County Kerry (Dunne *et al.*, 2001). The extent of psyllid parasitism and the dispersal of the wasp were studied at different geographical levels: within the release site, in the greater Kerry area and eventually in other Irish regions (Chauzat *et al.*, 2002). At the end of the 1999 growing season 100% parasitism of psyllid populations was reached in all commercial plantations in Kerry. Signs of establishment were evident elsewhere in County Dublin and County Waterford.

Success of the scheme: No insecticides have been used at the release site since the introduction of the wasp and chemical applications have been reduced substantially or eliminated at other commercial eucalyptus plantations in the County Kerry area, with the dual benefit of reduced production costs and increased environmental acceptability in continental European markets (Dunne *et al.*, 2001) In Ireland the spread of the wasp to other commercial plantations was less rapid than that observed in France and this has been attributed both to a lack of host plant within the natural environment and climatic differences between the two countries (Chauzat *et al.*, 2001). Dunne *et al.*, (2001) consider this case to be a successful example of biological control in a climate which differs substantially from that of the parasite's native range in Australia and attribute its success to the efficiency of the parasite in finding the host insect to which it is naturally adapted. It is important to emphasize that all the species in this case study are not native to Ireland and the introduced wasp is specific to the target organism, creating a low risk inexpensive solution to an economically damaging problem.

References

Chauzat, M-P., Purvis, G. & Dunne, R. 2001. A foreigner in Ireland. *Biologist*, 48, 133-135.

Chauzat, M-P., Purvis, G. & Dunne, R. 2002. Release and establishment of a biological control agent, *Psyllaephagus pilosus* for eucalyptus psyllid (*Ctenarytaina eucalypti*) in Ireland. *Annals of Applied Biology*, 141, 293-304.

Dunne, R., Chauzat, M-P, Fitters, P., Purvis, G. & Donovan, M. 2001. *Biology and control of some pests of hardy nursery stock, ornamentals and soft fruit*. *Teagasc* End of Project Report 4464, Horticulture and Farm Forestry Series No. 25, Kinsealy Research Centre, Dublin.

Forest, M. 2000. A valuable tree – by gum. *Biologist*, **47,** 139 – 142.

Case study 4.6 Eradication of the Roe Deer in County Sligo during 1901.

Category of introduction: Roe deer (*Capreolus capreolus*) were successfully introduced in the early 1870s to Lissadell, Co. Sligo, which was the seat of the Gore-Booth family.

Background to the introduction: Information on this introduction was compiled by J. Fairley from previously unpublished records in the Gore-Booth Archive (Public Record Office of Northern Ireland) and from examination and measurement of all trophy material in Lissadell House. It is usually assumed that in the late 1900s deer were shot only for sport or the pot. However descriptions by Thomas Killagon, a butler in service, mention migration of individuals from the original site of entry, Lissadell, a general indication that the population had reached the carrying capacity of the area (Fairley *et al.* 2002). An eyewitness account composed by Killagon describes the migration of deer within a 20km radius from the original source. Killagon records,

"as years went by they became so numerous that they became a pest to the new plantations by nipping off the leading shoots of young trees. It was decided to have a big drive and weed them out."

In the late 1890s compensation for damage was being paid to at least one neighbour, a Mr Young Warren of "Cooladrummon", although continued compensation was obviously a point for argument, as recorded in a letter dated 12th June 1901 which reads,

"you were notified of last year that I did not intend giving any compensation for damage caused by harts and rabbits. I am also informed that it was for damage caused by these animals that you were compensated in past years."

Eradication methods: Extensive culling is believed to have taken place between 1896 and 1898 and records show that the last of the roe deer were shot around 1905 (Fairley *et al*. 2002). The population density of deer was calculated retrospectively by Fairley *et al.* (2002) using the 1885 revision of the 6 inch ordnance survey map and game-keepers accounts of the number of deer shot. A minimum population density of 0.31 per ha was derived for 1901. Fairley considers that the population exceeded this value for at least a period of time around the turn of the century, as the estimate does not consider probable culling before 1900 which may already have considerably reduced population density. Comparison with values of population density for Roe deer derived in British forests (Staines & Ratcliffe, 1991) to those at Lissadell were high, emphasizing the superior conditions there for Roe deer (Fairley *et al.* 2002).

This account demonstrates that the problems of invasive species are not new. However, they have increased in prevalence and speed within the last century due to increased global trade and migration.

References

Fairley, J., Gore-Booth, J. & Shiel, C., 2002. The Roe deer of Lissadell. *Deer*, **12**; 243-249.

Staines, B.W. & Ratcliffe, P.R. 1991. Roe Deer. In: *The Handbook of British Mammals*. Eds Corbet, G.B. & Harris, S. pp518-525. 3rd Edition, Blackwell, Oxford.

4.24 Lessons learned from other countries

Ireland suffers from the unusual situation of containing two jurisdictions within a relatively small land mass surrounded by sea. Benefit can be gained from analysis and evaluation of comparative, island and cross-border situations. We have chosen to focus firstly upon New Zealand, an island which structures its invasive species policy within an umbrella organization known as the Biosecurity Council. A second case study considers the United States, which operates high level trading across a landmass encompassing a wide variety of different climates and more than 12000 km of internal land boundary.

A) New Zealand

New Zealand is adversely affected by non-native invasive species; approximately 40% of the flora, 76% of the fish species and nearly 20% of the bird species are exotic in origin (Vitousek *et al.*, 1997). A large proportion of the country's economy is derived from ecological tourism and therefore this resource is considered worth protecting. The country as a whole has developed a highly-integrated approach to dealing with invasive species issues which involves high-level cabinet responsibility.

A hierarchical approach has been adopted, as recommended in the CBD Interim Guiding Principles for non-native species:

1) keeping unwanted non-native species out of the country;
2) eradicating any unwanted non-native species which are not yet widespread; and,
3) where eradication is impractical, controlling the impacts of non-native species.

The legal framework is based on two main items of legislation: the Biosecurity Act (1993), which deals with unwanted organisms and accidental releases; and the Hazardous Substances and New Organisms Act (1996), which deals with licensing intentional imports of new organisms. Administration of these Acts is principally the responsibility of the Ministry of the Environment, the Ministry of Agriculture and Forestry and the specially created Environmental Risk Management Authority (ERMA). Non-native species issues also have cabinet representation in the portfolio of the Minister of Food, Fibre, Biosecurity and Border Control. However, criticisms of the current legislation include a lack of explicit objectives for biosecurity, a strong emphasis on maintaining trade relationships, perhaps at the cost of the precautionary principle embedded in the CBD, and the high compliance cost and complexity associated with the approval process for importing new plant material (Fasham & Trumper, 2001). In addition, the issue of non-native species management on private land has not been fully addressed (Christenson, 2000).

Domestic legislation

Hazardous Substances and New Organisms Act 1996 (HSNO)

This Act deals with the assessment of applications to import new organisms and to release them from containment. It established the Environmental Risk Management Authority (EMRA) to conduct such assessments and judge applications. The Act is administered by the Ministry for the Environment. However, the implementation of the Act is the responsibility of ERMA.

Enforcement of the introduction of new organisms into New Zealand occurs at the border and is carried out by Customs and the Ministry of Agriculture and Forestry (MAF). MAF also ensures compliance with controls placed by ERMA on experiments and restricted field trials of new organisms. ERMA oversees the

enforcement activity of the other agencies to avoid duplication or gaps in the system.

Provisions are made for ensuring compliance which include Infringement Notices and Compliance Orders. Fines for breaching HSNO regulations include up to $NZ 500, 000 for an offence and an additional $NZ 50, 000 a day for a continuing offence. Imprisonment can occur for up to 3 months. In addition a court can order a convicted offender to remedy or mitigate the effects of non-compliance at their own cost, or to pay the costs of such action, and can also require a new organism to be destroyed.

The enforcement agencies include:
- ERMA New Zealand – monitoring of enforcement performance and inquiries;
- Maritime Safety Authority – issues on board any ship
- Civil Aviation Authority – issues with aircraft and airports
- Land Transport Safety Authority (LTSA) – powers to deal with issues on road and rail
- Police – deal with vehicles and rail
- City and district councils (territorial local authorities) – cover public places.

Allied enforcement agencies are:
- Ministry of Agriculture and Forestry – powers under the Biosecurity Act
- Customs Department – deals with border controls

Biosecurity Act 1993

This Act has 2 major components: prevention of the introduction on unwanted organisms not already established in New Zealand (i.e. border controls) and management of unwanted organisms that are already, or will become, established.

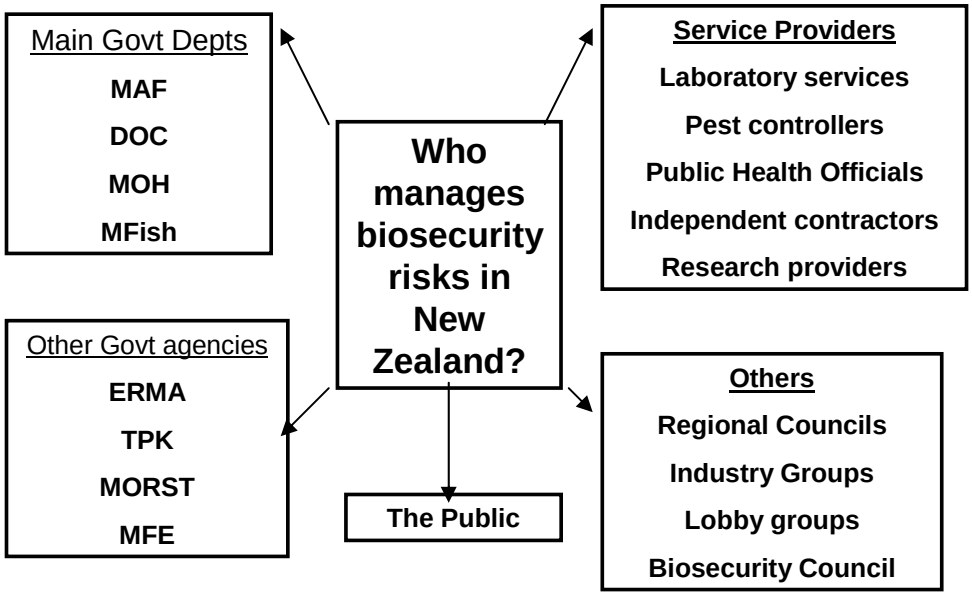
It is an "empowering" rather than a "requiring" Act in that there is no requirement on any particular agency to take action in relation to the presence of a harmful organism (Fasham & Trumper, 2001). It provides for an integrated system of biosecurity risk management, comprising border controls, monitoring and pest management strategies and allows for the declaration of a "biosecurity emergency" in the event of an introduction of a new organism that has the potential to cause significant economic or environmental loss.

One distinction between these two Acts is whilst the Biosecurity Act sets up a process for ongoing management and monitoring of unwanted organisms, HSNO makes no provision for managing or monitoring the effect of alien organisms once they have been approved for release from containment (Fasham & Trumper, 2001).

Four government departments have operational powers under the Biosecurity Act: the Ministry of Agriculture and Forestry (MAF), the Ministry of Fisheries (MFish), the Minister of Health (MoH) and the Department of Conservation (DoC). These departments all report on their activities under the Act to the Minister of Food, Fibre, Biosecurity and Border Control, a specific cabinet portfolio, created in 1997.

A Biosecurity Council was established at the same time to co-ordinate biosecurity policy and implementation, comprising 4 chief executives of the Departments involved, the Chief Executives of the Ministry for Research, Science and Technology (MoRST), the Ministry for the Environment (MfE) and the Environmental Risk Management Agency (ERMA), a representative of local government and an independent chairperson. The four main departments take operational responsibility for different aspects of biosecurity. A Biosecurity Technical Forum provides the Council with technical and policy advice.

(a)



(b)

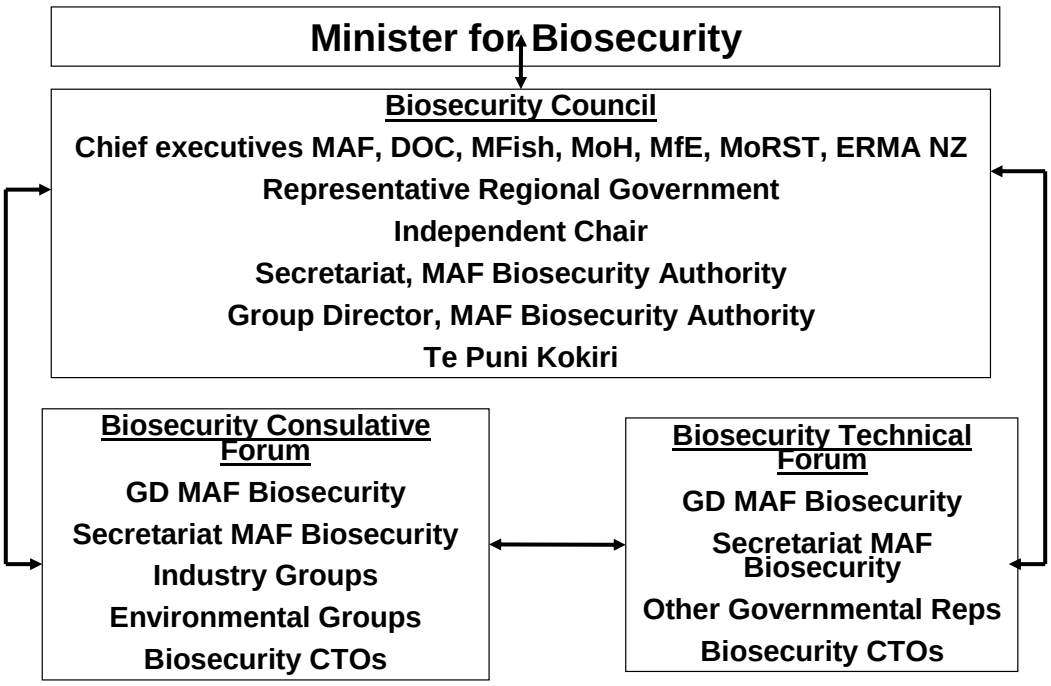


Figure 4.4 a) Relationships between the different biocontrol agencies in New Zealand and b) structure of the Biosecurity Council.

Box 4.5 Authorized procedures under New Zealand's Biosecurity Act 1993
(Source: Fasham & Trumper, 2001)

The Biosecurity Act 1933 grants the following powers to inspectors and other authorized persons appointed under the Act:

- request any person to assist in carrying out the provisions of the Act
- detain people in a biosecurity control area
- search people (police only)
- enter a place and inspect
- apply for a warrant to inspect a dwelling house or a marae
- enter in respect of offences
- following entry, record information and take actions necessary to eradicate pests or unwanted organisms
- apply articles or substances from aircraft above a place
- use dogs and devices to assist in exercising a power
- seize and dispose of unauthorized goods
- search and seize evidence
- seize abandoned goods
- intercept baggage
- examine organisms
- apply an article or substance to a place
- prohibit or control certain tests (power through Order in Council)
- give direction
- vaccinate or treat, etc.
- destroy organisms on non-payment of fees
- give a quarantine direction
- destroy imported organisms
- act in default where legal directions have not been complied with
- declare a restricted place
- declare a controlled area
- apply roadblocks, cordons, checkpoints etc. on application to a District Court Judge

A number of other acts have been devised to conserve biodiversity. These are:

- **Resource Management Act 1991 (RMA)**, covers land use planning controls
- **Conservation Act 1987**, covers the management of trout and salmon
- **Wild Animal Control Act 1977**, controls harmful species of non-native wild animals and regulates the operation of recreational and commercial hunters
- **Wildlife Act 1953**, protects all native and naturalized vertebrates by default but may be withdrawn if the animal becomes a problem
- **Forests Act 1949**, prohibits the import into or export from New Zealand of any tree, seed, timber or timber product which may be injurious to any tree

Control of entry

Intentional introductions

Any individual wishing to import a new organism (as defined by the HSNO) must apply for permission from ERMA.

An initial assessment places the application into one of four categories.

1. Certain organisms are prohibited from even passing through New Zealand
2. Section 36 of the Act sets out minimum standards that the organism must meet to be allowed entry. These involve predictions relating to the potential effects of the organism on native species and habitats.
3. If ERMA is satisfied that the organism is not an unwanted organism under the Biosecurity Act, that it is highly improbable that it will form a self-sustaining population anywhere in New Zealand and that it meets the conditions set out in Section 36, the application may be approved without controls.
4. If the organism does not fall clearly into one of these categories the application is assessed under the full application process.

The full application process involves advertising the application, receiving submissions and holding a hearing. Potential scenarios that must be considered include the ability of the organism to establish a self-sustaining population, the ease with which the organism could be eradicated and whether the positive effects of the organism outweigh its negative effects. In addition the ERMA must have particular regard to the views of the Department of Conservation.

The ERMA can then approve the application without conditions, approve for introduction into containment or decline the application. There is no right of appeal on the decision except on points of law. If new information suggests that an organism in containment should have its approval withdrawn, ERMA may reassess the approval and if necessary require the organisms to be destroyed at the owner's expense. There are provisions in the Act that allow the use of new organisms without approval where this is necessary to deal with an emergency, for example, the import of a live vaccine to deal with a disease outbreak.

Control of unwanted introductions

New Zealand has the advantage of being surrounded by sea, rather than a land-locked country, which allows for greater security at its borders. All vessels and aircraft must enter at a registered port or airport, all of which have suitable facilities for border control operations. Biosecurity border control is separate from the main customs and immigration control but is carried out alongside CITES control.

Before shipping any "risk good" to New Zealand the sender must ensure that it complies with the

relevant Import Health Standard and the goods cannot be imported if no such standard exists (Fasham & Trumper, 2001).

Control and eradication

The Risk Management System is hierarchical, involving import controls (via import health standards as above), border control, monitoring within borders, pest management strategies (PMS) and a provision for emergency measures. Within New Zealand PMS can be either National or Regional, each of which must be subjected to a review process every 5 years. Once a strategy has been approved, the management authority has considerable control over implementation, such that land owners may be required to conduct pest control work at their own expense (see Box 4.3).

Evaluation

The Office of the Parliamentary Commissioner for the Environment published a review of New Zealand's biosecurity strategy in December 2000, with assessment of strengths and weaknesses. The key findings were as follows:

- the Biosecurity Council provides good co-ordination of strategic and policy advice; and
- the Ministry of Agriculture and Forestry had received international recognition in managing biosecurity risks to agriculture and trade;

However the review also states that:

- biosecurity emergency management funding and strategies need clarification to ensure that responsibilities are met
- the role, functions and responsibilities of the Biosecurity Council need to be revised to ensure that the Minister for Biosecurity receives timely and appropriate advice; and
- the proposed Biosecurity Strategy needs to explicitly state the government's outcomes and objectives for biosecurity.

The report recommends that in the light of New Zealand's vulnerability to non-native species, biosecurity issues should be treated with the same concern as issues of national security.

Comparison with New Zealand raises awareness of the need for Ireland to develop a more structured form of risk assessment. Risk assessment protocols require legislative support and monitored enforcement in order to achieve their intended aims.

B) Cross-border co-operation: Canada/America/Mexico

North America is highly vulnerable to invasive species due to the high level of trade and the geographical and physical context of Canada, the United States and Mexico. The entire land mass encompasses enormous climatic and environmental variation and the physical structure by which species can be transferred between ecosystems is heightened by the developed infrastructure of the countries. This extremely diverse array of ecosystems is connected to each other and the rest of the globe by:

- 7.5 million km of roads (including 6.3 million in the United States)
- 46, 000 km of navigable inland waterways
- 390, 000 km of rail lines
- 18, 000+ airports (including 18 of the 30 busiest airports in the world)
- 580 water ports and facilities
- more than 12, 000 km of land boundaries crossed by 132 legal ports of entry along the U.S. – Canada

border and 25 legal ports of entry between the U.S. and Mexico

(Airports Council International 2003, U.S. CIA Worldfact Book 2003)

Therefore the level of connectivity in North America exceeds that found in many equivalent land masses (North American Commission for Environmental Co-operation 2003). The three North American Free Trade Agreement (NAFTA) countries account for more than half the world's airports and only Asia, with 49 countries and more than twice the total land area has comparable amounts of road and rail infrastructure (Fasham & Trumper 2001). The United States alone accounted for 10% of the world's port calls in 2000, with 48% of the active world fleet, nearly half of all vessels, calling at U.S. ports (U.S. DOT-MARAD 2001).

Canada is the largest and Mexico the second largest trading partner of the United States (International Trade Administration – Trade and Economy: Data and Analysis http://www.ita.doc.gov/td/industry/otea/).

Canada is Mexico's fourth largest trading partner and Mexico is Canada's fifth largest trading partner. The United States is the largest trading partner for each of the other two countries. Between the US and Canada over 200 million border crossings took place in 1999 and over 300 million border crossings took place between the U.S. and Mexico (US DOT-BTS-2003).

Each country has a range of national, regional and international regulations to which it subscribes. At a regional level the US and Canada participate in a wide variety of bilateral and multilateral efforts to co-ordinate their efforts to reduce the threat of invasive species and share information on eradication techniques. Efforts are focused towards common concerns such as agricultural concerns (e.g. bovine spongiform encephalopathy), shared boundary waters (e.g. ballast water management in the Great Lakes) and other mutual concerns (e.g. West Nile virus). Staff of the Animal Plant Health Inspection Service (APHIS) and the Canadian Food Inspection Agency (CFIA), frequently meet to discuss issues. The Canada-U.S. Consultative Committee on Agriculture, established in 1998, discusses phytosanitary issues with a primary motivation to strengthen trade relations. However the U.S. and Canada have not developed a comprehensive strategy for joint prevention and management of invasive species.

The U.S and Mexico Consultative Committee on Agriculture, established in 2002 also discusses phytosanitary issues, although again with a focus on improving trade relations.

Trilaterally, Canada, Mexico and the U.S. have also signed a memorandum to establish a North American Animal Health Committee which attempts to create a co-ordinated response to specific threats such as foot-and-mouth disease and started developing a standard for treating solid wood packaging materials (U.S. General Accounting Office 2002).

The Commission on Environmental Cooperation (CEC) addresses regional environmental concerns in North America, helps prevent potential trade and environmental conflicts and promotes the effective enforcement of environmental law, all as part of its mandate under the North American Agreement on Environmental Co-operation (NAAEC). The CEC has initiated a project that seeks to protect North America's marine and aquatic ecosystems from the effects of aquatic invasive species.

The North American Plant Protection Organization (NAPPO) develops regional phytosanitary standards for Canada, the United States and Mexico. The Inter-American Biodiversity Information Network (IABN) Invasive Species Network (13N) is an internet based forum for technical and scientific co-operation among Western Hemisphere countries to share and use biodiversity information relevant to decision-making and education. To more effectively address priorities of continental significance and boost the concerted efforts of the three countries of the North American bioregion, the Canada/Mexico/U.S. Trilateral Committee for Wildlife and Ecosystem Conservation and Management was established in 1996. The Trilateral Committee has a variety of functions:

- assist coordination, cooperation and development of partnerships among wildlife agencies of the three countries and other interested groups
- facilitate programs/projects for conservation and management of biological diversity and ecosystems of mutual interest
- implement the conservation priorities of each country
- develop, implement, review and coordinate specific cooperative actions
- facilitate communication on issues that span international boundaries

The Trilateral Committee is headed by:

a) directors of the Canadian Wildlife Service, the
b) U.S. Fish and Wildlife Service, and
c) The Coordinating Unit for International Affairs of the Mexican Ministry of Environment and Natural Resources (SEMARNAT)

An indication of the degree of attention invasive species issues receive is provided by the fact that the last annual plenary session chose to hold a day long meeting focused solely on this issue. (http://www.trilat.org/annual_meetings/viii_mtg/invasives_plenary/trilateral_invasivesplenary_report_11july03.htm.)

There is an obvious need for the establishment of a cross-border, inter-departmental invasive species forum in Ireland, both to reduce time delays in the initiation of control programs and to co-ordinate cross-border schemes effectively.

4.25 Summary

This chapter details the importance of monitoring and surveillance, risk assessment and risk reduction and control and eradication policies from a cost-efficient perspective. It appears advisable to maintain financial support for the acquisition of knowledge in certain areas, such as monitoring and surveillance. Flexibility of approach appears to be the key factor in co-ordinating a successful and sustainable control policy.

The collection of case studies presented here indicates that a beneficial outcome can be achieved, although the process usually requires the expenditure of substantial sums of money in order to reduce the potential of a more devastating financial impact at a later date. Increased investment in amalgamating research efforts and disseminating the results to targeted audiences will contribute to safeguarding Ireland's biodiversity in the future.

Funding research into risk analysis scenarios and models incorporating ecological processes is vital in enabling more accurate simulations of the probable events following a species introduction. Examination of literature relating to the forecasting of disease epidemics and containment policies should be

incorporated into investigations of invasive alien species, enabling assessment of the actions required at different hierarchical levels within and between organizations.

Co-ordination of a response over the land mass of Northern Ireland and the Republic of Ireland is essential if a reduction or eradication policy is to succeed. Contingency plans should be formulated to establish an efficient protocol for cross-border cases. Examples exist within other countries of the formulation of cross-border councils, such as the Trilateral Council for Ecosystem Conservation and Management in the North American continent. The adoption of a cross-border, inter-departmental forum between Northern Ireland and the Republic of Ireland is suggested. Invasive species issues could then be addressed under one body, in a similar fashion to the legislative structure in New Zealand.

Serious consideration needs to be given to the financial support framework for rectifying damage to biological communities. Alternative sources of funding should be considered, for example the adoption of severe financial penalties payable by the individuals or companies responsible.

Continuing efforts to increase economic production will result in little abatement of the current problems. Inventing new methods of control may temporarily diminish population densities of invasive alien species, yet ultimately adaptation of species is likely to prevail. However, the application of forethought, combined with ecological knowledge, political willpower and improved forecasting of risk can have a substantial impact on reducing the damage caused by invasive alien species, both to biological diversity and government finances.

Section 5: Recommendations to the two jurisdictions

5 Recommendations to the two jurisdictions

REDUCING RISK

KEY ACTION 1: Detailed risk assessments and contingency plans should be urgently prepared for species that are likely to invade Ireland in advance of their arrival.

An immediate pro-active approach to invasive species policies is required. In the current absence of an over-arching body initial stopgap measures should be implemented by units that are linked into existing active departments. Senior level authorization within current departments should be used as an impetus to motivate preventative actions in advance of a species entering the country, to ensure a rapid and co-ordinated response from additional agencies before the species becomes established. Provision should be made for the inclusion of contingency plans to deal with the unexpected occurrence of species that cross existing sectoral responsibilities.

Action 1.1: In consultation with interested stakeholders a list of problem species, designated by risk level, should be developed immediately for priority action.

A "High Risk List" could be drafted which would require the licensing and even exclusion of species Ireland. A list of further species where more evidence is required regarding their potential to cause problems (a "Medium Risk List") and also a list of species whose potential impact is judged on present evidence to be minimal (a "Low Risk List") are developed. Lists should be flexible and subject to frequent evaluation, in order to safeguard against the potential for a rapid population explosion in an invasive species currently perceived as low risk.

Action 1.2: A catalogue of scientific research relating to invasive species issues should be established and made available.

Focus on identification and eradication/control methods will be of particular benefit. Scientific advances should be made available to policy makers, through categorizing research and presenting it in a non-technical and easily accessible manner.

Action 1.3: Lists of species which have become invasive in other parts of the world should be maintained.

Particular attention should be devoted to Great Britain, European neighbours and principal trading partners, which may play host to a range of species with a high potential for establishment in Ireland. In future a centralized reference point should be designated for the storage of this information.

Action 1.4: The full consequences of potential invasions by non-native species should be established by extending investigations of ecological impacts into a cost-based environmental impact assessment.

Environmental economic tools exist that allow evaluation of the aesthetic and economic injury caused by invasive species. Establishing a means whereby damage can be costed allows an assessment of the appropriate allocation of resources to prevent and mitigate the problem.

RESPONDING TO NEW INVASIONS

KEY ACTION 2: Barriers to a rapid and decisive response to new invasions should be minimized by high level cross-jurisdictional and inter-departmental support for and funding of contingency plans.

Immediate action often presents the only opportunity for cost-effective eradication. Therefore detailed assessment of the impact of a newly invasive species should be conducted concurrently if possible and should incorporate cost estimation and cost-benefit analyses to agreed criteria. Management aims should be agreed in advance and appropriate monitoring of the results should be conducted.

The effectiveness of control programmes should be evaluated from a population demography perspective, identifying the quantitative effects of a particular management treatment. This should continue beyond the end of management regimes to determine that further invasion does not occur and that the problem has been resolved.

Action 2.1: Engagement with specific industrial and trade and commerce sectors should be initiated at the outset in the creation of control schemes to clarify feasible management objectives.

Action 2.2: A budget should be made available to support the development of control techniques for putative invasive non-native species.

Action 2.3: Programmes should be developed that allow the restoration of native habitats and species following the removal of invasive species.

CONTROL AND MANAGEMENT OF ESTABLISHED INVASIVE SPECIES

KEY ACTION 3: The ecological and economic impact of long-standing alien species and technology for their control should be investigated in detail in order to plan and execute cost-effective strategies for control and eradication.

In the case of well established invasive species control efforts that are unsupported by ecological studies have the potential for significant wastage of resources. Management plans should be designed with a view to the population biology of the invasive species and models can be used to determine the necessary effort to realise conservation objectives.

LEGISLATIVE REQUIREMENTS

KEY ACTION 4: Legislative provisions should be analysed and new legal frameworks developed specifically for dealing with invasive species, while facilitating beneficial introductions.

Action 4.1: An analytical review of legislation pertaining to non-native species should be undertaken by environmental law specialists.

Assessment of the strengths and weaknesses of the present legislative framework have been made from an ecological/management perspective. However, an analysis from an academic legal perspective by an environmental lawyer would highlight specific areas for improvement. Particular attention should be paid to European and domestic legislation and on cross-border constitutional arrangements.

Action 4.2: Governments should work with industries and trade organisations to encourage the development of legal underpinning for codes of conduct that define and allocate duty of care.

Codes of practice are more rapid than the law to initiating flexible responses to changing circumstances but require legal underpinning for ultimate sanction. The aquaculture industry provides particularly useful models in this area, e.g. the Environmental Code of Practice for Irish Aquaculture Companies and Traders (ECOPACT), launched by the Department of Communications, Marine and Natural Resources on behalf of Bord Iascaigh Mhara (BIM). Profitable commercial organizations operate to high standards to generate the greatest amount of long term profit. It is proposed that the application of such codes of practice should be encouraged by a reward in addition to a sanction-based system.

Action 4.3: Consultation processes regarding codes of practice and legislative development should be initiated with stakeholders.

Stakeholders, particularly trade and commercial organisations, should be fully consulted and engaged in development of invasive non-native species policies and actions. It is especially important to encourage north-south co-operation in this matter.

Action 4.4: The scope for implementing "polluter pays" principle for preventing invasions should be investigated.

Consideration should be given to identifying circumstances where responsibility for costs should lie with those responsible for the illegal introduction of the non-native species.

Action 4.5: Licensing arrangements should remain in place whereby desirable non-native species can be introduced, for commercial reasons and/or for biological control.

It is important to retain the potential use of non-native species as biocontrol agents, as this is frequently a less costly form of control. Proposals to commercially exploit new species should require legally enforceable risk assessments, including cost-benefit analyses that consider the potential loss of ecosystem goods and services.

MONITORING RISKS AND PROBLEMS

KEY ACTION 5: A framework, including support for specialist identification skills, should be established for the collation and cross-border exchange of information on non-native species.

Action 5.1: A centralized biological recording unit should be developed in the Republic of Ireland.

This centre would be similar to the Centre for Environmental Data and Recording (CEDaR), currently based at the Ulster Museum and funded by the Environment & Heritage Service, in order to maintain data on native and non-native flora and fauna. In each jurisdiction a single organization should have lead responsibility for co-ordinating the collation of data on non-native species. Efforts should be made to store data in a manner that is transferable between the different BRCs.

Action 5.2: Recording schemes should be developed for species which possess invasive qualities, involving separate monitoring criteria for land of differing protection categories and vulnerability to species invasions.

The protocol for recording schemes should be subject to the approval of a centralized agency. Financial support should be provided by governments, where there is currently insufficient means to monitor establishment and spread, or through capacity building of appropriate NGOs or volunteers. Monitoring criteria should be developed with separate consideration for areas of protected land and land which is currently unprotected. An example of a stratified recording and protection scheme is provided by the Water Framework Directive (2000). A department in each jurisdiction needs to be identified with responsibility for monitoring and surveillance.

Action 5.3: Authority should be granted to a monitoring agency to require landowners to comply with monitoring of invasive species on private land.

Monitoring and surveillance of biodiversity on private land should be encouraged to maintain a true representative picture of biodiversity in Ireland. Such a procedure requires a high level of communication between researchers and landowners.

Action 5.4: Taxonomic experts should be engaged to train personnel for monitoring tasks and for deployment at key points of entry.

Monitoring of invasive species is inhibited by a lack of competent recorders and taxonomic expertise is not widely accessible. A full audit should be undertaken to determine the skills base in this field in Ireland and to identify potential barriers to its effective use. The production of identification keys for invasive species is a priority.

AGRI-ENVIRONMENT SCHEMES

KEY ACTION 6: Measures for the prevention and eradication of invasive species should be incorporated into agri-environment schemes.

Examples include the Rural Environmental Protection Scheme (REPS) in the Republic of Ireland and the Countryside Management Scheme (CMS) in Northern Ireland.

EDUCATION AND RAISING AWARENESS

KEY ACTION 7: The dissemination of information to the public and the engagement of stakeholders, particularly in the commercial sector, should be prioritised by developing online, educational and scientific resources, and by targeted public awareness campaigns.

Action 7.1: Establishment of websites, e-mail discussion groups, workshops and conferences, to disseminate information on invasive species, their prevention and control, both nationally and internationally should be developed.

Action 7.2: Awareness campaigns should be initiated to raise public consciousness of non-native invasive species problems.

The campaigns should be constructed around a small number of key concepts and should use simple, clear terminology and plan in advance to deal with controversial issues. Information should be deliverable through easily accessible media such as television, radio and the press and through media targeted to key areas, activities and locations, such as garden centres, angling clubs, pet shops and airports.

Action 7.3: Targeted information should be broadcast to specific groups such as specialist societies and professions.

This information should include detailed professional and scientific analysis of the issues associated with invasive non-native species and should focus on the particular information needs of specified sectors, such as recreational fisheries and horticultural industries. Material should be presented in a fashion that is appropriate both to non-scientists and the public as well as scientific and research communities.

Action 7.4: Education on invasive species and their implications should be retained and improved within school curricula and higher education centres.

COMMUNITY ACTIONS

KEY ACTION 8: The use of native species in amenity planting and stocking and related community actions to reduce the introduction and spread of non-native species should be encouraged.

Action 8.1: Native species of local provenance should be encouraged for use in conservation or amenity planting schemes and to stock freshwaters in situations where a choice exists.

Any proposed new introductions should be submitted to a centralized agency, stipulating the species or sub-species of proposed introduction. Proposed introductions located in the vicinity of areas of conservation interest should be subject to higher scrutiny.

Action 8.2: Promote public acceptance of moves towards increased consumption of local produce.

Increased efforts towards sustainability and reduction of unnecessary freight haulage could reduce the impact of invasive species through a reduction in imports. When considering this scenario the implications for trade would need to be carefully assessed in discussion with commercial organizations and the relevant government departments.

INTERNATIONAL ACTIONS

KEY ACTION 9: The two jurisdictions should continue to work through international mechanisms to improve the regulatory and policy framework for dealing with invasive non-native species.

Action 9.1: The two jurisdictions should continue to work through international mechanisms to improve the regulatory and policy framework for dealing with invasive non-native species issues.

This should include input to the Convention on Biological Diversity, the International Plant Protection Convention, the International Maritime Organization's work to address unintentional introductions of marine non-native species through ballast water transfer, the International Civil Aviation Organization's consideration of unintentional introduction of non-natives via aircraft, the Bern Convention's work on a European approach and also the European Commission's work to consider how the EC Wildlife Trade Regulations might best be utilized to address invasive non-native species issues.

Action 9.2: Northern Ireland and the Republic of Ireland should support the development of international trade agreements relating to invasive non-native species, in order to retain their reputation as a responsible trading partner.

Efforts should be made to reduce the accidental export of native Irish species which may become invasive in other countries.

CROSS-BORDER SPECIALIST GROUP AND AGENCY

KEY ACTION 10: A cross-border specialist group should establish a dedicated agency to lead on invasive species issues, beyond the immediate actions prioritised above.

Action 10.1: Establishment of a cross-border forum or NDPB to guide the establishment of a centralized invasive species agency.

The forum should include policy makers from relevant departments, scientists from statutory agencies, research institutions, NGOs and independent authorities and also representatives from industrial, trade and commerce sectors. This combined expertise should cover knowledge of species biology, introductory pathways and options for feasible eradication and containment. The forum should consist of three working groups to advise on terrestrial, freshwater and marine environments.

Action 10.2: Establishment of a cross-border, inter-departmental agency under the guidance of the cross-border forum.

The agency would become the primary point of reference and guidance for the management of all issues pertaining to non-native species. The agency should be financed by the two jurisdictions and an interdepartmental budget, which incorporates contingency measures, should be agreed upon in advance of an issue arising.

The North-South Ministerial Council may provide a suitable umbrella under which to form this agency, either as a new North/South Implementation Body analogous to the present six bodies, or by the Council's approval of collaboration between existing bodies under the present Area for Co-operation of 'Environment'.

The agency should be co-chaired by the most relevant government departments, most probably the Department of Environment (N.I.) and the Department of the Environment, Heritage and Local Government (R.O.I), though key inputs will be required from other departments, most notably agriculture, trade and transport, and agency representatives from Great Britain. Inclusion of trade and transport sectors is vital in establishing codes of conduct that will be complied with and enforced by trade associations.

Linkages should also be fostered with public health departments for guidance in the construction of contingency plans in the event of an invasive species becoming a public health hazard, as was the case for West Nile Virus in the United States.

The agency should be supported by a secretariat staff to fulfil its remit of research, advisory and communication services, constructed in such a way that urgent matters can be expedited rapidly.

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References

Adam, D., 2001. Fears arise over BSE infection in UK abattoirs. *Nature*, **411**; 728.

Airports Council International (ACI) 2003. The World's Busiest Airports. http://www.airports.org/traffic/yeartodate.asp

Alexandersen, S., Kitching, R.P., Mansley, L.M. & Donaldson, A.I., 2003. Clinical and laboratory investigations of five outbreaks of foot and mouth disease during the 2001 epidemic in the United Kingdom. *Veterinary Record*, **152**; 489-496.

Anderson, R., 2003. Workshop Presentation, "*Patterns of terrestrial invertebrate invasions as a guide to future trends*". All-Ireland Invasive Alien Species Workshop, Dublin, 26th November 2003.

Anderson, R. & Bell, A.C., 2002. A first record of the Lily Beetle *Lilioceris lilii* (Scopoli) in Ireland. *Coleopterist*, **11**; 90.

Alderman, D.J. & Wickins, J.F. 1996. Crayfish CULTURE, Laboratory Leaflet No. 76, CEFAS, Lowestoft, MAFF.

Alzieu, C. & Heral, M., 1984. Ecotoxicological effects of organotins compounds on oyster culture. In: Persoone, G., Jaspers, E. & Claus, C. (eds) *Ecotoxicological Testing for the Marine Environment*, Volume 2. State University of Ghent and Institute of Marine Scientific Research, Bredene, Belgium.

Baillie, S.R., Sutherland, W.J., Freeman, S.L., Gregory, R.D. & Paradis, E. 2000. Consequences of large-scale processes for the conservation of bird populations. *Journal of Applied Ecology*, **37**; Suppl. 1, 88-102.

Balmford, A. & Gaston, K.J., 1999. Why Biodiversity surveys are good value. *Nature*, **398**; 204-205.

Balmford, A., Gaston, K.J., Rodrigues, A.S.L. & Alexander, J., 2000. Integrating costs of conservation into international priority setting. *Biological Conservation*, **14**; 597-605.

Baretta-Becker, J.G., Duursma, E.K., & Kuipers, B.R., (eds), 1992. *Encyclopaedia of marine sciences*. Springer-Verlag, Berlin.

Binggeli P., Eakin, M., Macfadyen, A., Power J. & McConnell, J.,1992. Impact of the alien sea buckthorn (*Hippophae rhamnoides* L.) on sand dune ecosystems in Ireland. In Carter, R.W.G., Curtis, T.G.F. & Sheehy-Skeffington, M.J. (eds) *Coastal dunes. Geomorphology, ecology and managemen*t; 325-337. Balkema, Rotterdam.

Bleakley, B. 1979. *Spartina* – an unwelcome immigrant. Irish Hare, 2, 10-12.

Bord Iascaigh Mhara, 2003. *Ecopact, Environmental code of practice for Irish aquaculture companies and traders*. Bord Iascaigh Mhara, Ireland.

Brown, K.C., 1986. *Animals, plants and micro-organisms introduced to the British Isles*. London, Department of the Environment.

Buckley, P., 1998. Legislation and protected areas for the conservation of biological diversity. In: *Irish heritage and environmental directory* 1999. Deevey, M.B (ed); 13-30. The Heritage Council and Archaeology, Bray, Ireland.

Bullock, J.M., Hodder, K.H., Manchester, S.J. & Stevenson, M.J., 1996. Review of information, policy and legislation on species translocations. JNCC Report No. 261. Joint Nature Conservation Committee, Peterborough, U.K.

Cade, T.J., 1983. Hybridisation and gene exchange among birds in relation to conservation. In: *Genetics and conservation*. Schonewald-Cox, C.M., Shambers, S.M., MacBryde, B. & Thomas, W.L. (eds); 288-309. Benjamin Cummings, London.

Caffrey, J.M., 1994. Spread and management of *Heracleum mantegazzianum* (Giant Hogweed) along Irish River Corridors. In: *Ecology and management of riverside*

plants. DeWaal, L.C., Child, L.E., Wade, M. & Brock, J.H. (eds); 67-76. John Wiley & Sons Ltd, England.

Caffrey, J.M. 1999. Phenology and long-term control of *Heracleum mantegazzianum*. *Hydrobiologia*, **415**; 223-228.

Callaghan, D., 2003. Alien species research requirements for delivery of the UK biodiversity Action Plan – Discussion Paper. Just Ecology. URL: www.justecology.co.uk

Carlton, J.T., 1987. Mechanism and patterns of transoceanic marine biological invasions in the Pacific Ocean. *Bulletin of Marine Science*, **41**; 452-465.

Chapman, J.W., Miller, T.W. & Coan, E.V., 2003. Live seafood species as recipes for invasion. *Conservation Biology*, **117** (5); 1386-1389.

Chauzat, M.P., Purvis, G. & Dunne, R., 2002. Release and establishment of a biological control agent, *Psyllaephagus pilosus* for eucalyptus psyllid (*Ctenarytaina eucalypti*) in Ireland. *Annals of Applied Biology*, **141**; 293-304.

Chauzat, M-P., Purvis, G. & Dunne, R. 2001. A foreigner in Ireland. Biologist, **48**; 133-135.

Christenson, M. 2000. Global Invasives Species Project: Country Report: New Zealand. http://iucn.org/themes/law/elp_invasives.NZ.htm

Clements, K.L., 1996. An assessment of rural landowners' attitudes and knowledge about beavers, biodiversity, and conservation. *Bulletin of the Ecological Society of America*, **77;** 84.

Clerkin, S. 2002. Incorporating biodiversity considerations in policy. Biology and Environment, *Proceedings of the Royal Irish Academy*, **102B**, (32); 177-182. Royal Irish Academy.

Compassion in World Farming, 2003.

Costello, M.J., 1993. Biogeography of alien amphipods occurring in Ireland, and interactions with native species. *Crustaceana*, **65**; 287-299.

Council of the European Communities, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities **L206/35, 22.7.92**; 7-50.

Cox, M.L., 2001. The status of the Lily Beetle *Lilioceris lilii* (Scopoli, 1763) in Britain (Chrysomelidae: Criocerinae). *The Coleopterist*, **10**; 5-20.

Cragg-Hine, D., 1973. Coarse fish and fisheries management in Northern Ireland. *Proceedings of the sixth British coarse fish conference*; 52-59. University of Liverpool, UK.

Crawley, M.J., 1997. What makes a community invasible? In: *Colonization, succession and stability*. Gray, A.J., Crawley, M.J. & Edwards, P.J. (eds); 429-453. Blackwell Scientific Publications, Oxford, UK.

Crawley, M.J., Harvey, P.H. & Purvis, A., 1996. Comparative ecology of the native and alien floras of the British Isles. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences*, **351**; 1251-1259.

Crivelli, A.J., 1995. Are fish introductions a threat to endemic freshwater fishes in the northern Mediterranean region? *Biological Conservation*, **72**; 311-319.

Cross, J.R., 1981. The establishment of *Rhododendron ponticum* in the Killarney oakwoods, SW Ireland. *Journal of Ecology*, **69**; 807-824.

Cross, J.R., 1982. The invasion and impact of *Rhododendron ponticum* in native Irish vegetation. *Journal of Life Sciences Royal Dublin Society*, **3**; 209-220

Daehler, C.C. & Strong, D.R., 1997. Reduced herbivore resistance in introduced smooth cordgrass (*Spartina alterniflora*) after a century of herbivore-free growth. *Oecologia*, **110**; 99-108.

Davison, D.M., 1996. *Sargassum muticum* in Strangford Lough, 1995-1998. A review of the introduction and colonization of Strangford Lough MNR and cSAC by the

invasive brown algae *Sargassum muticum*. Report to the Environment & Heritage Service, D.O.E. (N.I.).

Department for Environment, Food and Rural Affairs (DEFRA), 2003. Review of non-native species policy. Report of the working group. DEFRA publications, London.

Department for Environment, Transport and Regions (DETR), 1997. The regulation and control of the release of non-native animals and plants into the wild in Great Britain. Department of the Environment, Transport and Regions, London.

Dick, J.T.A., 1996. Post-invasion amphipod communities of Lough Neagh, Northern Ireland: influences of habitat selection and mutual predation. *Journal of Animal Ecology*, **65**; 756-767.

Doogue, D., Kelly, D.L. & Wyse Jackson, P.S., 1985. The progress of *Epilobium ciliatum* Rafin. (E. adenocaulon Hausskn) in Ireland, with some notes on its hybrids. *Irish Naturalists Journal*, **21**; 444-446.

Drake, J.A. & Mooney, H.A., 1989. *Biological invasions: a global perspective*. John Wiley & Sons, Chichester.

Dunne, R., 2003. Some recent insect and mite introductions to Ireland. In *Biological Invaders: the impact of exotic species*. Moriarty, C. & Murray, D. (eds); 115-118. Royal Irish Academy, Dublin.

Dunne, R., Chauzat, M-P., Fitters, P., Purvis, G. & Donovan, M. 2001. Biology and control of some pests of hardy nursery stock, ornamentals and soft fruit. Teagasc End of Project Report 4464, Horticulture and Farm Forestry Series No. 25, Kinsealy Research Centre, Horticulture and Farm Forestry, Dublin, Ireland.

Edwards, C., Tracy D. & Morgan J., 1993. *Rhododendron* control by imazapyr. *Research Information Note* **233**; Forestry Commission, Edinburgh

Edwards, C. & Morgan, J.L., 1996. Control of *Rhododendron ponticum* by stump applications of herbicides following mechanical clearance. *Proceedings Crop Protection in Northern Britain II*:213-218

Edwards, C. & Morgan J., 1997. Cut stump applications with imazapyr. *Forestry Commission Research Information Note* **293**; Edinburgh

Edwards C., Clay D.V. & Dixon F.L., 2000. Stem treatment to control *Rhododendron ponticum* under woodland canopies. *Aspects of Applied Biology*, **58**; 39-46

Edwards C., 1999. Herbicide control of *Rhododendron ponticum* following mechanical clearance by hydraulic flail. *Proceedings Crop Protection in Northern Britain*

E-Fish Business, 2003a. Imports of fish from other parts of the European Union (EU). [URL: http://www.efishbusiness.co.uk/importinside/default.asp

Elbers, A.R.W., Stegeman, A., Moser H., Ekker, H.M., Smak, J.A. & Pluijmers, F.H., 1999. The classical swine fever epidemic 1997-1998 in the Netherlands: descriptive epidemiology. *Preventory Veterinary Medicine*, **42**; 157-184.

Ehrlich, P.R., 1986. Which animal will invade? Ecology of Biological Invasions of North America and Hawaii. In *Ecological Studies 58*. Mooney, H.A. & Drake, J.A. (eds); 79-95. Springer-Verlag, New York.

Emerson, H.J. & Gillmor, D.A., 1999. The Rural Environment Protection Scheme of the Republic of Ireland. *Land Use Policy*, **16**; 235-245.

Eno, N.C., 1996. Non-native marine species: their effects and controls. *Aquatic Conservation: Marine and Freshwater Ecosystems,* **6**; 215-228.

Eno, N.C., 1998a. Non-native marine species in British waters: ballast water introductions. *International Council for the Exploration of the Sea Cooperative Report No*. **224**; 43- 49.

Eno, N.C., 1998b. The introduction to British waters of non-native marine molluscs and their implications for nature conservation interests. *Journal of Conchcology, Special Publication* No. **2**; 287-294.

Eno, N.C., Clark, R.A. & Sanderson, W.G., 1997. Non-native marine species in British waters: a review and directory. *Joint Nature Conservation Committee*, Peterborough, U.K.

European and Mediterranean Plant Protection Organisation (EPPO), 2001. *Pest risk assessment scheme* (decisions-making scheme). URL: http://www.eppo.org//QUARANTINE/PRA/prassess_scheme.html.

European Communities (Natural Habitats) Regulations, 1997. SI NO. 94/1997. Amended by the European Communities (Natural Habitats) (Amendment) Regulations 1998, SI No. 233/1998. *Acts of the Oireachtas and statutory instruments*. Dublin, Stationary Office.

Evans, D.W., Matthews, M.A. & McClintock, C.A., 2001. The spread of eel swim bladder nematode *Anguillicola crassus* through the Erne system, Ireland. J*ournal of Fish Biology*, **59**; 1461-1420.

Fairley, J., 2001. *A basket of weasels*. Published privately, Belfast, Northern Ireland.

Fairley, J., Gore-Booth, J. & Shiel, C., 2002. The Roe deer of Lissadell. *Deer*, **12**; 243-249.

Fasham, M. & Trumper, K., 2001. *Review of non-native species legislation and guidance*. Ecoscope Applied Ecologists, Stocks Bridge Way

Ferreras, P. & Macdonald, D.W., 1999. The impact of American mink *Mustela vision* on water birds in the upper Thames. *Journal of Applied Ecology*, **36**; 701-708.

Fleming, I.A., Hindar, K., Mjolnerod, I.B., Jonsson, B., Balstad, T. & Lamberg, A. 2000. Lifetime success and interactions of farm salmon invading a native population. *Proceedings of the Royal Society of London Series B*, **267**; 1517-1523.

Forest, M. 2000. A valuable tree – by gum. *Biologist*, **47**; 139-142.

Forest Service, 2000. *Code of best forest practise – Ireland*. Forest Service, Department of Communications, Marine and Natural Resources.

Genovesi, P. & Shine, C., 2003. *European Strategy on Invasive Alien Species, third draft. Convention on the conservation of European wildlife and natural habitats*. Council of Europe, Strasbourg.

Gibbons, D.W., Reid, J.B. & Chapman, R.A., 1993. *The new atlas of breeding birds in Britain and Ireland, 1988-1991*. T. & A.D. Poyser, London.

Global Ballast Water Programme. International Maritime Organisation. URL: http://www.globallast.imo.org

Gollasch, S., 1999. The Asian decapod *Hemigrapsus penicillatus* (de Haan, 1835) (Grapsidae, Decapoda) introduced in European waters: status quo and future perspective. *Helgoländer Meeresunterschungen*, **52**; 359-366.

Gomulkiewicz, R. & Holt, R.D., 1995. When does evolution by natural selection prevent extinction? *Evolution*, **49**; 201-207.

Gosling, L.M. & Baker, S.J. 1989. The eradication of the muskrats and coypus from Britain. *Botanical Journal of the Linnean Society*, **38**; 39-51.

Grace, J. & Nelson, M., 1981. Insects and their pollen loads at a hybrid *Heracleum* site. *New Phytologist*, **87**; 413-423.

Gray, A.J., 1986. Do invading species have definable genetic characteristics. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, **314**; 655-674.

Gurnell, J., 1983. Squirrel numbers and the abundance of tree seeds. *Mammal Review*, **13**; 133-148.

Gurnell, J., 1989. Demographic implications for the control of grey squirrels. In: *Mammals as pests*. Putman R. (ed.); 131-143. Crook Helm, London, UK.

Hanski, I., Breuker, C.J., Schops, K., Setchfield, R. & Nieminen, M. 2002. Population history and life history influence the migration rate of female Granville fritillary butterflies. *Oikos*, 98; 87-97.

Hayden, T. & Harrington, R., 2000. *Exploring Irish Mammals*. Townhouse, Dublin.

Hilty, J. & Merenlender, A.M., 2003. Studying biodiversity on private lands. *Conservation Biology*, **17**; 132-137.

Holdich, D.M. & Reeve, I.D., 1991. Distribution of freshwater crayfish in the British Isles, with particular reference to crayfish plague, alien introductions and water quality. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **1**; 139-158.

Holmes, J.M.C. & Minchin, D. 1995. Two exotic copepods imported into Ireland with the Pacific oyster, *Crassostrea gigas*.

Holt, R.D. & Keitt, T.H., 2000. Alternative causes for range limits: a metapopulation perspective. *Ecology Letters*, **3**; 41-47.

Hopkins, G.W. & Freckleton, R.P., 2002. Declines in the numbers of amateur and professional taxonomists

Howarth, F.G., 1991. Environmental Impacts of Classical Biological Control. *Annual Review of Entomology*, **36**; 485-509.

Hubbard, J.C.E., 1965. *Spartina* marshes in southern England. VI. Pattern of invasion in Poole Harbour. *Journal of Ecology*, **53**; 799-813.

Hughes, B., 1996. The ruddy duck *Oxyura jamaicensis* in the Western Palearctic and the threat to the white-headed duck *Oxyura leucocephala*. In: *The Introduction and Naturalization of Birds*. Holmes, J.S. & Simons, J.R. (eds); 79-86. HMSO, London, UK.

ICES (International Council for the Exploration of the Sea). URL: http://www.ices.dk

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:08 2000. Study group on Ballast and other ship vectors. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Meeting ACME:07 2001. Study group on Ballast and other ship vectors. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:05 2002. Study group on Ballast and other ship vectors. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:03 2003. Study group on Ballast and other ship vectors (SGBOSV). Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Meeting ACME:07, 2000. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:08, 2001. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:06, 2002. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:04, 2003. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:07, 2000. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:06, 2002. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ICES CM/ACME:03 2003. Study group on Ballast and other ship vectors (SGBOSV). Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ICES CM/ACME:05 2002. Study group on Ballast and other ship vectors. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ICES CM/ACME:07 2001. Study group on Ballast and other ship vectors. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ICES CM/ACME:08 2000. Study group on Ballast and other ship vectors. Advisory committee on the marine environment.

ICES (International Council for the Exploration of the Sea) Council Meeting ACME:08, 2001. Working group on introductions and transfers of marine organisms. Advisory committee on the marine environment.

IMO (International Maritime Organisation). Conventions in development. URL: http://www.imo.org/Conventions/contents.asp?topic_id=261&doc_id=690

IMO (International Maritime Organisation), 1997. Guidelines for the control and management of ships' ballast water to minimise the transfer of harmful aquatic organisms and pathogens. IMO Resolution A.868 (29)1997.

Invasive alien species and the International Plant Protection Convention, Braunschweig, Germany, 22-26 September, 2003.

IUCN (World Conservation Union), 2000. Guidelines for the prevention of biodiversity loss caused by alien invasive species. IUCN, Gland, Switzerland.

IUCN (World Conservation Union). URL: http://iucn.or/themes/law/Treatiestable.htm

IUCN (World Conservation Union). Species survival commission (SSC). URL: http://iucn.org/themes/ssc/pubs/policy/invasivesEng.htm.

Irish Tourism: responding to change, 2003. *Interim report of the Tourism Policy Review* Group to Mr John O Donaghue, Minister for Arts, Sport and Tourism.

IUCN, 2000. Guidelines for the prevention of biodiversity loss caused by alien invasive species. IUCN, Gland, Switzerland.

IUCN. URL: http://iucn.or/themes/law/Treatiestable.htm

Jetter, K. & Paine, T.D. 2004. Consumer preferences and willingness to pay for biological control in the urban landscape. *Biological Control* (in press)

Johannson, L. & Persson, L., 1986. Planktivorous fish. In *Carbon dynamics in eutrophic temperate lakes*. Riemann, B. & Sondergaard, M. (eds); 237-266. Elsevier Science, Amsterdam.

Johnsen, B.O. & Jensen, A.J. 1986. Infestations of Atlantic salmon, (*Salmo salar*), by *Gyrodactylus salaris* in Norweigan rivers. *Journal of Fish Biology*, **29**; 233-241

Joint North/South Consultation paper on International River Basin Districts and administrative arrangements for implementation of the EC Water Framework Directive (200/60/EC), 2003. Managing our shared waters.

Jones, A.T. & Evans, P.R., 1994. A comparison of the growth and morphology of native and commercially obtained European *Crataegus monogyna* Jacq. (Hawthorn) at an upland site. *Watsonia*, **20**; 97-103.

Kay, Q., 1993. Genetic differences between populations of rare plants, *BSBI News*, **64**; 54-56.

Kelly, D.L., 1981. The native forest vegetsation of Killarney, south-west Ireland: an ecological account. *Journal of Ecology*, **69**; 437-472.

Kelly, D.W., Dick, J.T.A., Montgomery, W.I. & Macneil, C. 2003. Differences in composition of macroinvertebrate communities with invasive and native Gammarus spp. (Crustacea: Amphipoda). *Freshwater Biology*, **48**; 306-315.

Kennedy, G.J.A. & Strange, C.D., 1978. Seven years on – a continuing investigation of salmonid stocks in Lough Erne tributaries. *Journal of Fish Biology*, **12**; 325-330.

Kennedy, G.J.A. & Greer, J.E., 1988. Predation by cormorants, *Phalacrocorax carbo* (L.), on the salmonid populations of an Irish river. *Aquaculture and Fisheries Manual*, **19**; 159-170.

Kenward, R.E. & Holm, J.L., 1993. On the replacement of the red squirrel in Britain - a phytotoxic explanation. *Proceedings of the Royal Society of London Series B-Biological Sciences*, **251**; 187-194.

King, C.M. 1984. *Immigrant Killers. Introduced predators and the conservation of birds in New Zealand,* Oxford University Press, Auckland.

Kleijn, D. & Sutherland, W.J., 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology*, **40**; 947-969.

Kluyver, H.N. & Tinbergen, L., 1953. Territory and the regulation of density in titmice. *Archives Neerlandaises de Zoologie,* **10**; 265-289.

Kornberg, H. & Williamson, M.H., 1987. *Quantitative Aspects of the Ecology of Biological Invasions. Proceedings of a Royal Society Discussion Meeting*. The Royal Society, London, UK.

Lehmkuhl, J.F. 1984. Determining size and dispersion of minimum viable populations for land management planning and species conservation. *Environmental Management*; 8, 167-176.

Levins, R., 1970. Extinction. *Lectures on Mathematics in the Life Sciences*, 2. Gerstenhaber, M. (ed.); 77-107. American Mathematics Society, Providence, RI.

Levins, R. & Culver, D., 1971. Regional coexistence of species and competition between rare species. *Proceedings of the National Academy of Sciences USA*, **68**; 1246-1248.

Lewis, M. & Kareiva, P., 1993. Allee dynamics and the spread of invading organisms. *Theoretical Population Biology*, **43**; 141-158.

Lucey, J., 1994. Records of the Giant Hogweed *Heracleum mantegazzianum* Somm. & Lev., along southern Irish rivers and streams with a revised distribution map for the region. *Bulletin of the Irish Biogeographical Society*, **17**; 2-6.

Lundstrom, H. & Darby, E., 1994. The *Heracleum mantegazzianum* (Giant Hogweed) problem in Sweden: suggestions for its management and control. *Ecology and management of riverside plants*. De Waal, L.C., Child, L.E., Wade, M., Brock, J.H.(eds) England: John Wiley & Sons Ltd. pp. 93-100.

Macdonald, D.W. & Johnson, P.J., 2000. Farmers and the custody of the countryside: trends in loss and conservation of non-productive habitats 1991-1998. *Conservation Biology*, **13**; 1262-1272.

Mack, R.N., 1996. Predicting the identity and fate of plant invaders: emergent and emerging approaches. *Biological Conservation*, **78**; 107-121.

MacNeil, C., Elwood, R.W. & Dick, J.T.A., 2000. Factors influencing the importance of *Gammarus* spp. (Crustacea: Amphipoda) in riverine salmonid diets. *Archives fur Hydrobiologie*, **149**; 87-107.

Maguire, B., O'Reilly, M. & Roche, M.S., 1999. *Irish Environmental Legislation*. Round Hall Sweet & Maxwell, Dublin.

Manchester, S.J. & Bullock, J.M., 2000. The impacts of non-native species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology*, **37**; 845-864.

Mansueto, C., Villa, L., D'Agati, P., Marcianò, V., Pellerito, C., Fiore, T., Scopelliti, M., Nagy, L. & Pellerito, L., 2003. Effects of tributyltin (IV) chloride on fertilisation of *Styela plicata* (Ascidiacea: Tunicata): II. Scanning and transmission electron microscopy studies. *Applied Organometallic Chemistry*, **14**; 553-560.

Marine Conservation Society, 2001. Alien species Factsheet. URL: http://www.mcsuk.org/

Marine Work Group, 2003. Fish farming? Must be Mad! Ireland. URL: www.mwg.utvinternet.com/aquaculture

Mathews, M. & Reynods, J.D., 1990. Laboratory investigations of the pathogenicity of *Aphanomyces astaci* for Irish freshwater crayfish. *Hydrobiologia*, **203**;121-126.

Mathews, M. & Reynolds, J.D., 1992. Ecological impact of crayfish plague in Ireland. *Hydrobiologia*, **234**; 1-6.

Matthews, M.A., Reynolds, J.D. & Keatinge, M.J., 1993. Macrophyte reduction and benthic community alteration by the crayfish *Austropotamobius pallipes* (Lereboullet). *Freshwater Crayfish*, **9**; 289-299.

McAree, D., 2002. The forest service biodiversity plan. *Biology and Environment: Proceedings of the Royal Irish Academy*, **102B**, (3); 183-184. Royal Irish Academy.

McCorrey, M, Curtis, T.G.F. & Otte, M.L., 2003. Spartina in Ireland. In *Wetlands of Ireland, Distribution, Ecology, Uses and Economic Value*. Otte, M.L. (ed.) University College Press Dublin, 44-50.

McGinnity, P., Prodohl, P., Ferguson, K., Hynes, R., O' Maoileidigh, N., Baker, N., Cotter, D., O' Hea, B., Cooke, D., Rogan, G., Taggart, J., & Cross, T. 2003. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon. *Proceedings of the Royal Society of London, Series B*: **270**; 2443-2450.

Minchin, D. Duggan, C.B. & King, W. 1987. Possible influence of organotins on scallop recruitment. *Marine Pollution Bulletin*, **18**; 604-608.

Minchin, D. & Duggan, C.B., 1988. The distribution of the exotic ascidian, *Styela clava* Herdman, in Cork Harbour. *Irish Naturalists' Journal*, **22**(9); 388-393.

Minchin, D. & Sheehan, J., 1995. The significance of ballast water in the introduction of exotic marine organisms to Cork Harbour, Ireland. *International Council for the Exploration of the Sea* C.M. 1995/0:1 15pp.

Minchin, D., 1996a. Desk assessment of discharges of shipping ballast water in Ireland. C.M. 1996/E:11 Marine Environmental Quality Committee. *International Council for the Exploration of the Sea*, Reykjavík.

Minchin, D., 1996b. Management of the introduction and transfer of marine molluscs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**; 229-244.

Minchin, D. & Sheehan, J., 1999. Cork Harbour, Ireland, as a focal point for the introduction of exotic marine species. ICES Co-op Res Rept No **224**; 12-23.

Minchin, D., 2000a. Modes of introduction of exotic animals into Irish waters. In: *Biodiversity: The Irish Dimension*. Rushton, B.S. (ed.); 147-155. Royal Irish Academy, Dublin.

Minchin, D., 2000b. Dispersal of zebra mussels in Ireland. *Verhandlungen Internationale Vireinigung Limnologie*, **27**; 1576-1579.

Minchin, D., 2001. Introduction of Exotic Species. In *Encyclopedia of Ocean Sciences*. Steele, J., Thorpe, S. & Turekian, K. (eds.); 878-889. Harcourt Publishers Ltd., Kent.

Minchin, D. & Eno, C. 2002. Exotics of coastal and inland waters of Ireland and Britain. In: *Invasive Aquatic Species of Europe: Distribution impacts and management*. Leppäkoski, E., Gollasch, S. & Olenin S. (eds); 206-216. Kluwer Academic Publishers, Dordreicht, The Netherlands.

Minchin, D. & Gollasch, S. 2002. Vectors – how exotics get around. In: *Invasive Aquatic Species of Europe: Distribution impacts and management*. Leppäkoski, E., Gollasch, S. & Olenin S. (eds); 206-216. Kluwer Academic Publishers, Dordreicht, The Netherlands.

Minchin, D. & Moriarty, C. 2002. Zebra mussels and their impact in Ireland. In: C. Moriarty & D.A. Murray. *Biological Invaders: the impact of exotic species*. Royal Irish Academy, Dublin, pp. 72-78.

Minchin, D. & Rosenthal, H. 2002. Exotics for stocking and aquaculture, making correct decisions. In: *Invasive Aquatic Species of Europe: Distribution impacts and management*. Leppäkoski, E., Gollasch, S. & Olenin S. (eds); 206-216. Kluwer Academic Publishers, Dordreicht, The Netherlands.

Minchin, D., Maguire, C.M. & Rossell, R. 2003. The zebra mussels (*Dreissena polymorpha.* Pallas) invades Ireland: human mediated vectors and the potential for rapid international dispersal. *Biology and Environment*, **103B** (1); 23-30.

Minchin, D. & Gollasch, S. 2003. Fouling and Ships' Hulls, how changing circumstances and spawning events may result in the spread of exotic species. *Biofouling*, **19**; 11-112.

Mitchell, R.J., Marrs, R.H., LeDuc, M.G. & Auld, M.H.D., 1997. A study of succession on lowland heaths in Dorset, southern England: changes in vegetation and soil chemical properties. *Journal of Applied Ecology*, **34**; 1426-1444.

Moore, J.P., Dynes, C. & Murchie, A.K., 1998. The status and public perception of the New Zealand flatworm, *Artioposthia triangulata* (Dendy) in Northern Ireland. Pedobiologia, 2;563-571.

Moore, N.W., 1987. *The Bird of Time*, Cambridge University Press.

National Farmers Union Countryside. Rural News, Monday 17th March, 2003. URL: http://www.nfucountryside.org.uk/news/showarchivenews.asp?newsid=674

Neal, C., Reynolds, B., Smith, C.J., Hill, S., Neal, M., Conway, T., Ryland, G.P., Jeffrey, H., Robson, A.J. & Fisher, R., 1992. The impact of conifer harvesting on stream water pH, alkalinity and aluminium concentrations for the British uplands – an example for an acidic and acid sensitive catchment in mid-Wales. *Science of the Total Environment*, **126**; 75-87.

Northern Ireland Biodiversity Group, 2000. *Biodiversity in Northern Ireland. Recommendations to Government for a Biodiversity Strategy*. The Stationary Office, Norwich.

Northern Ireland Forest Service. *Red Squirrels: causes of red squirrel decline*. URL: http://www.nics.gov.uk/forestserviceni/environment/red_squirrels/causes_of_decline

O'Connor, C., Marvier, M. & Kareiva, P., 2003. Biological vs. social, economic and political priority-setting in conservation. *Ecology Letters*, **6**; 706-711.

Ó Críodáin, C., 2002. Incorporation of biodiversity conservation into the work of DÚCHAS. *Biology and Environment: Proceedings of the Royal Irish Academy*, **102B**, (3); 189-162.

O' Mahoney, T. (1991) A report on the flora of Cork (v.cc. H3-H5), 1990. *Irish Botanical News* **1**; 17-19.

O' Mahoney, T. (1996) A report on the flora of Cork (v.cc. H3-H5), 1995. *Irish Botanical News,* **6**; 35-40.

O' Mahoney, T. (1997) A report on the flora of Cork (v.cc. H3-H5), 1996. *Irish Botanical News*, **7**; 33-36.

Osborne, P., 1985. Some effects of Dutch Elm disease on the birds of a Dorset dairy farm. *Journal of Applied Ecology*, **22**; 681-691.

Owen, J., 2003. Salmon farm escapees threaten wild salmon stocks, *National Geographic,* June 2003.

Pearson, D.E. & Callaway, R.M., 2003. Indirect effects of host-specific biological control agents, *Trends in Ecology & Evolution*, **18**; 456-461.

Pollux, B., Minchin, D., Van der Velde, G., Van Alen, T., Yeo, S., Der Staay, M. & Hackstein, J. 2003. Zebra mussels (*Dreissena polymorpha*) in Ireland, AFLP-fingerprinting and boat traffic both indicate an origin from Britain. *Freshwater Biology*, **48**; 1127-1139.

Powell, F. 1988. Giant Hogweed control in NE Scotland. *Plant Press Nr*, **4**.

Praeger. 1939. A further contribution to the flora of Ireland. *Proceedings Royal Irish Academy* **45B**; 231-254.

Preston, C.D. & Croft, J.M., 1997. *Aquatic plants in Britain and Ireland*. Henley Books, Colchester, England.

Preston, C.D., Pearman, D.A. & Dines, T.D., 2002. *New Atlas of the British and Irish Flora - an atlas of the vascular plants of Britain, Ireland, the Isle of Man and the Channel Islands*. Oxford University Press, Oxford.

Pulliam, H.R., 1989. Source, sinks and population regulation. *American Naturalist*, **132**; 652-661.

Purvis, G., Chauzat, M.P., Segonds-Pichon, A. & Dunne, R., 2002. Life history and phenology of the eucalyptus psyllid, *Ctenarytaina eucalypti* in Ireland. *Annals of Applied Biology*, **141**; 283-292.

Ray, N., Lehmann, A. & Joly, P. 2002. Modelling spatial distribution of amphibian populations: a GIS approach based on habitat matrix permeability. *Biodiversity and Conservation*, **11**; 2143-2165.

Red Squirrels in South Scotland. *Information sheet 6: Disease in Squirrels*. URL:
http://www.red-squirrels.org.uk/pdf/6DiseaseInSquirrels02.pdf

Reise, K., Gollasch, S. & Wolff, W.J., 1998. Introduced marine species of the North Sea coasts. *Helgolander meeresuntersuchungen*, **52** (3-4); 219-234

Rejmanek, M. & Richardson, D.M. 1996. What attributes make some plant species more invasive? *Ecology*, **77**; 1655-1661.

Reynolds, J.D., 1988. Crayfish extinctions and crayfish plague in Ireland. *Biological Conservation*, **45**; 279-285.

Reynolds, J.D., 1998. Conservation management of the white-clawed crayfish *Austropotamobius pallipes* Part 1. *Irish Wildlife Manuals*, No. 1, Dúchas, The Heritage Service, Dublin.

Reynolds, S.C.P., 2002. *A catalogue of Alien Plants in Ireland*, National Botanic Gardens, Glasnevin, Ireland.

Rosell, R.S., Maguire, C.M. & McCarthy, T.K. 1999. First reported settlement of zebra mussels *Dreissena polymorpha* in the Erne system, County Fermanagh, Northern Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*, **98B** (3); 191-193.

Rotherham, I.D. & Read, D.J. 1988. Aspects of ecology of Rhododendron ponticum L. with special reference to its competitive and invasive properties. *Aspects of Applied Biology*, **16**; 327-335.

Selonen, V. & Hanski, I. 2003. Movements of flying squirrel *Pteromys volans* in corridors and matrix habitat. *Ecography*, 26; 641-651.

Sheail, J. 1988. The extermination of the muskrat (*Ondatra zibethicus*) in inter-war Britain. *Archives of Natural History*, **15**; 155-170.

Shine, C. 2002. *Report on the implementation of the Bern Convention in Ireland (Draft). Convention on the conservation of European wildlife and natural habitats*. Council of Europe, Strasbourg.

Short, J.W. & Thrower, F.P., 1987. Toxicity of tri-n-butyl-tin to Chinook salmon *Onchorhynchus tshawytscha*, adapted to seawater. *Aquaculture*, **61**; 193-200.

Simberloff, D., 1989. Which insect introductions suceed and which fail. In: *Biological Invasions*. Drake, J.A., Mooney, H.A., diCastri, F., Groves, R.H., Kruger, F.J. Rejmanek, M. & Williamson, M. (eds); 61-75. John Wiley & Sons, Chichester, UK.

Simberloff, D. & Alexander, M., 1998. Assessing risks to ecological systems from biological introductions (excluding genetically modified organisms). In: *Handbook of environmental risk assessment and management*. Calow, P. (ed). Blackwell, Oxford, UK.

Simberloff, D., 2003. How much information on population biology is needed to manage introduced species? *Conservation Biology*, **17**; 83-92.

Smallwood, K.S., 1994. Site invasibility by exotic birds and mammals. *Biological Conservation*, **69**; 251-259.

Smith, A.P. & Quinn, D.E., 1996. Patterns and causes of extinction and decline in Australian conilurine rodents. *Biological Conservation*, **77**; 243-267.

Staines, B.W. & Ratcliffe, P.R. 1991. Roe deer. In: *The Handbook of British Mammals*. Eds Corbet, G.B. & Harris, S. PP. 518-525. 3RD Edition, Blackwell, Oxford.

Stephens, P.A., Jules, N.P. & Sutherland, W.J., 2003. Agriculture, transport policy and landscape heterogeneity. *Trends in Ecology and Evolution*, **18**, 555-556.

Stephens, P.A. & Sutherland, W.J., 1999. Consequences of the Allee effect for behaviour, ecology and conservation. *Trends in Ecology, Evolution and Conservation*, **14**; 401-405.

Stephens, P.A., Sutherland, W.J. & Freckleton, R.P., 1999. What is the Allee effect? *Oikos*, **87**; 185-190.

Stott, B., 1974. Biological control of water weeds. In: *Biology in pest and disease control*. Price Jones, D. & Solomon, M.E. (eds); 233-238. Blackwell Scientific Publications, London, UK.

Strasser, M., 1999. *Mya arenaria* – an ancient invader of the North Sea coast. *Helgoländer Meeresunterschungen*, **52**; 309-324.

Strong, J.A., 2003. *The environmental impact of* Sargassum muticum *around the coastline of Northern Ireland*. PhD Thesis, Queens University of Belfast.

Telfer, S., Holt, A., Donaldson, R. & Lambin, X. 2001. Metapopulation processs and persistence in remnant water vole populations. *Oikos*, 95; 31-42.

The Forestry Authority, 1998. The UK Forestry Standard. *The Government's approach to sustainable forestry*. Department of Agricultrue for Northern Ireland, Forestry Commission, Edinburgh.

The Kennedy Report, 2000. *Memorandum on Rabies Prevention and control*. Department of Health. URL: www.doh.gov.uk/memorandumonrabies/

The Tourism Policy Review 2003. *Final report – New Horizons for Irish Tourism: An agenda for Action*, Tourism Policy Review Group.

Thomas, J.A., 1995. The ecology and conservation of *Maculinea arion* and other European species of large blue butterfly. In: *Ecology and Conservation of Butterflies*. Pullin, A.S. (ed); 181-197. Chapman and Hall, London.

Tiley, E.D. & Philip, B., 1994. *Hercaleum mantegazzianum* (Giant Hogweed) and it control in Scotland. *Ecology and management of riverside plants*. De Waal, L.C., Child, L.E., Wade, M., Brock, J.H.(eds) England: John Wiley & Sons Ltd. pp. 101-110.

Tiley, G.E.D., Dodd, F.S. & Wade, P.M. (1996) *Heracleum mantegazzianum* Sommier & Levier. Biological Flora of the British Isles. *Journal of Ecology*, **84**; 297-319.

Tiley, G.E.D. & Philip, B. (1997) Observations on the flowering and seed production of *Heracleum mantegazzianum* in relation to control. In Brock, J.H.et al. (eds) *Plant Invasions*. Backhuys Publishers, Leiden, 123-138.

TRAFFIC, 1998. *European Community Wildlife Trade Regulations: Reference Guide*. URL: http://www.europa.eu.int/comm/environment/cites/legislation_en.htm

Turner, S. & Morrow, K., 1997. *Northern Ireland Environmental Law*. Gill & Macmillan, Dublin.

UNEP (United Nations Environment Programme), AEWA/TC 4.16, 2003. *Guidelines on avoidance of introduction of non-native migratory waterbird species*. African-European migratory water bird agreement. Tahskent, Uzbekistan.

UNEP/CBD/SBSTTA/6/INF/3 2001. Invasive alien species: A comprehensive review of activities for the prevention, early detection. Convention on biological diversity.

UNEP/CBD/SBSTTA/6/INF/11 2001. Invasive alien species: Status, impacts and trends of alien species that threaten ecosystems, habitats and species. Convention on biological diversity.

United States Central Intelligence Agency (CIA) 2002. *World Factbook*. Washington, D.C: CIA

United States Department of Transportation – Bureau of transportation statistics (USDOT/BTS) 1997. *North American Transportation Highlights*, Washington, DC: USDOT. 1997. World Transportation Directory <http.//www.bts.gov/programs/tt/wtd/>

United States Department of Maritime Administration (USDOT/MA) 2002. Marad Statistics. http://www.marad.dot.gov/MARAD_statistics/sheet003.htm 2001 Vessel calls at U.S. Ports. 2000 Washington, DC, gao.

United States General Accounting Office (GAO). October 2002. *Invasive species*. Report to Executive Agency Officials. Washington, DC: gao.

Usher, M.B., 1987. Scope-international synthesis symposium on the ecology of biological invasions, held at the East-West Center, Honolulu, Hawaii, USA. *Environmental Conservation*, **14**; 84-85.

Utting, S.D. & Spencer, B.E., 1992. Introductions of marine bivalve molluscs into the United Kingdom for commercial culture – case histories. *International Council for the Exploration of the Sea*.

Vitousek, P.M., D'Antonio, C.M., Loope, L.L., Rejmanek, M. & Westbrooks, R. 1997. Introduced species: a significant component of human caused global chhange. *New Zealand Journal of Ecology*, **21**; 1-16.

Wade, M., Darby, E.J., Courtney, A.D. & Caffrey, J.M. (1997) *Heracleum mantegazzianum*: a problem for river managers in the Republic of Ireland and the United Kingdom. Brock, J.H. *et al*. (eds) *Plant Invasions*. Backhuys Publishers, Leiden, pp. 139-151.

Wainger, L.A. & King, D.A., 2003. Decision-making under uncertainty: how much risk reduction can we afford? Conference presentation. Invasive Plants in Natural and Managed Systems, November 5-7, Ft. Lauderdale, Florida.

Warren, M.S., Hill, J.K., Thomas, J.A., Asher, J., Fox, R., Huntley, B., Roy, D.B., Telfer, M.G., Jeffcoate, S., Harding, P., Jeffcoate, G., Willis, S.G., Greatorex-Davies, J.N., Moss, D. & Thomas, C.D., 2001. Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature*, **414**; 65-69.

Warwick, T. 1940. A contribution to the ecology of the musk-rat (*Ondatra zibethica*) in the British Isles. *Proceedings of the Zoological Society of London, Series A*, **110**; 165-201.

Watkinson, A.R. & Sutherland, W.J., 1995. Sources, sinks and pseudo-sinks. *Journal of Animal Ecology*, **64**; 126-130.

Watkinson, A.R., Gill, J.A. & Freckleton, R.P., 2003. *Macroecology and microecology: linking large-scale patterns of abundance to population processes*. British Ecological Society Annual Symposium, 2002. Blackwell Scientific Publishing, Oxford.

Watt, H.B., 1923. The American Grey Squirrel in Ireland, *Irish Naturalist*, **32**; 95.
Whitehead, G., 1964. Japanese sika deer in Ireland. *The Deer of Great Britain and Ireland*. Routledge and Keegan-Paul, London.
Wielgus, R.B. 2002. Minimum viable populations and reserve sizes for naturally regulated grizzly bears in British Columbia. *Biological Conservation*; 381-388.
Wildlife (Amendment) Act 2000 NO. 38/2000. *Acts of the Orieachtas and Statutory Instruments*. Dublin, Stationary Office.
Wildlife (Northern Ireland) Order, 1985. HMSO SI 1985/171(NI 2)
Williamson, J.A. & Forbes, J.C. 1982. Giant Hogweed: *Heracleum mantegazzianum*: its spread and control with glyphosate in amenity areas. *Proc. 1982 British Crop Protection Conference – Weeds*: 967-972.
Williamson, M., 1992. Environmental risk from the release of genetically modified organisms (GMOs) - the need for molecular ecology. *Molecular Ecology*, **1**; 3-8.
Williamson, M., 1993. Risks from the release of GMOs - ecological and evolutionary considerations. *Evolutionary Trends in Plants*, **1**; 5-9.
Williamson, M., 1996. *Biological Invasions*. Chapman & Hall, London, UK.
Winfield, I.J., Winfield, D.K. & Tobin, C.M., 1992. Interactions between the roach *Rutulis-rutulis* and waterfowl populations of Lough Neagh, Northern Ireland. *Environmental Biology of Fishes*, **33**; 207-214.
Winfield, I.J., Tobin, C.M. & Montgomery, C.R., 1994. The fish of Lough Neagh. Part E. Ecological studies of a fish community. In: *Lough Neagh: The ecology of a multipurpose water resource*. Wood, R.B. & Smith, R.V. (eds); 451-471. Kluwer, The Netherlands.
Wyse Jackson, M., 1989. Observations on the Irish distribution of a plant with serious public health implications: Giant Hogweed (*Heracleum mantegazzianum*). *Bulletin of the Irish Biogeographical Society*, **12**; 94-112.
Yu, D.W., Sutherland, W.J. & Clark, C., 2002. Trade versus environment. *Trends in Ecology and Evolution*, **17**; 353

Appendix 1. Non-native estuarine and marine species that are known to be established in Ireland. (after Minchin & Eno, 2002)

	Species
Algae	*Heterosigma akashiwo*
	Gyrodinium aureolum
	Antithamnionella ternifolia
	Antithamnion densum
	Asparagopsis armata
	Laurencia brongiartii
	Polysiphonia subtilissima
	Colpomenia peregrina
	Alexandrium tamarense
	Sargassum muticum
	Codium fragile ssp*. atlanticum*
	Codium fragile ssp*. tomentosoides*
	Antithamnionella spirographidis
	Bonnemaisonia hamifera
	Polysiphonia harveyi
	Cryptonemia hibernica
Angiosperma	*Spartina anglica*
Cnidaria	*Gonionemus vertens*
Nematoda	*Anguillicola crassus*
Annelida	*Ficopomatus enigmaticus*
Crustacea	*Balanus amphitrite*
	Elminius modestus
	Limnoria tripunctata
	Porcellidium ovatum
	Balanus improvisus
	Myicola ostraea
	Mytilicola orientalis
	Mytilicola intestinalis
	Corophium sextonae
	Herrmannella duggani
Tunicata	*Phallusia mammilata*
	Styela clava

Appendix 2. Non-native marine and estuarine species that may become established in Irish and British coastal waters, invasive species in bold. (Sourced from Minchin & Eno, 2002)

Species	Taxon	Likely Vector	Nature of Impact
Coscinodiscus wailesii	diatom	ships, naturally	covers nets with mucilage
Pfiesteria piscicida	dinoflagellate	ships ballast water	fish mortalities, toxins
Gymnodinium catenatum	dinoflagellate	ships ballast water	paralytic shellfish poisoning
Undaria pinnatifida	brown alga	fouling ships/ boats	competition
'Dasysiphonia sp'	red alga	fouling ships/boats	Fouling cage netting
Grateloupia doryphora	red alga	natural spread	may have commercial use
Gyrodactylus salaris	monogenean	salmonids	reduced salmonid stocks
Corbula flammula	bivalve	aquatic plants?	extensive fouling
Nuttalia obscurata	bivalve	aquaculture	productive species
Mytilopsis leucophaeta	bivalve	hull fouling	extensive fouling
Ensis americanus	bivalve	natural spread	high biomass, fishery
Ocinebrellus inornatus	gastropod	oysters	eolluscan predator
Rapana venosa	gastropod	ballast, oysters	molluscan predator
Crepidula fornicata	gastropod	oysters	competition, habitat changes
Pseudostylochus ostreae	flatworm	oysters	molluscan predator
Marenzellaria viridis	polychaete	ships or naturally	high biomass
Cercopagus pengoi	ostracod	ships ballast	high biomass in estuaries/ lakes
Caprella mutica	caprellid	ship fouling	fouling fish culture nets
Hemimysis anomala	mysid	ships ballast	high biomass in estuaries
Paralithodes camtschaticus	crab	ships ballast	bivalve mortality, fishery
Hemigrapsus penicillatus	crab	ships, oysters	omniverous, habitat changes
Homarus americanus	lobster	trade, releases	hybridisation with *H. gammarus*
Rithropanopeus harrisi	crab	ships	high biomass locally
Eriocheir sinensis	crab	ships ballast	predator, habitat changes

Appendix 3. Alien plants considered established in natural and semi-natural habitats in Ireland. Some of the alien plants listed below are quite localized or rare and many are also established in artificial habitats. Semi-natural habitats include hedgerows but not road verges. Invasive species are highlighted in bold (adapted from Reynolds 2002).

Acaena novae-zelandiae	*Cotoneaster simonsii*	*Lolium multiflorum*	*Ribes nigrum*
Acaena ovalifolia	*Crepis vesicaria*	*Lupinus arboreus*	*Ribes rubrum*
Acer pseudoplatanus	*Crocosmia × crocosmiiflora*	*Lysichiton americanus*	*Ribes uva-crispa*
Adoxa moschatellina	*Cymbalaria muralis*	*Malus domestica*	*Rubus spectabilis*
Allium carinatum	*Elodea canadensis*	*Matricaria discoidea*	*Rumex pulcher*
Allium triquetrum	*Elodea nuttallii*	*Matteuccia struthiopteris*	*Salix fragilis*
Alnus incana	*Epilobium brunnescens*	*Mentha × gracilis*	*Salix viminalis*
Anisantha diandra	*Erica cilaris*	*Mentha × piperita*	*Sarracenia purpurea*
Aster spp. & hybrids	*Erica terminalis*	*Mentha requienii*	*Saxifraga × urbium*
Azolla filiculoides	*Fagus sylvatica*	*Mimulus guttatus*	*Sedum album*
Berberis vulgaris	***Fallopia japonica***	*Mimulus × robertsii*	*Sedum dasyphyllum*
Bryonia dioica	*Fuchsia magellanica*	*Mycelis muralis*	*Selaginella kraussiana*
Calystegia pulchra	*Gaultheria mucronata*	*Nymphoides peltata*	*Senecio cineraria*
Calystegia silvatica	*Geranium pyrenaicum*	*Oenothera glazioviana*	*Sisyrinchium californicum*
Carpobrotus edulis	*Gunnera tinctoria*	*Oenothera stricta*	***Spartina anglica***
Chenopodium murale	*Haloragis micrantha*	*Orobanche minor*	*Stratiotes aloides*
Chenopodium polyspermum	*Hebe × franciscana*	*Pastinaca sativa*	*Symphoricarpos albus*
Cirsium oleraceum	***Heracleum mantegazzianum***	*Petasites fragrans*	*Tamus communis*
Claytonia sibirica	***Hippophae rhamnoides***	*Picea sitchensis*	*Tellima grandiflora*
Clematis vitalba	***Impatiens glandulifera***	*Pinus contorta*	*Tolmiea menziesii*
Cornus sericea	*Juncus planifolius*	*Pinus sylvestris**	*Verbena officinalis*
Cotoneaster franchetii	*Lagarus ovatus*	*Poa palustris*	
Coptoneaster horizontalis	*Leycesteria formosa*	*Populus nigra†*	
Cotoneaster integrifolius	*Libertia formosa*	***Rhododendron ponticum***	

*now considered native in ROI. †Native status uncertain

Appendix 4. Alien plants considered established mainly in artifical habitats in Ireland. Artificial habitats include cultivated, managed and waste ground, walls, pavements, road verges and railways. Some of the alien plants listed below are rare and some are also established in natural and semi-natural habitats e.g. *Erysimum cheiri*, *Rosa rugosa* and *Veronica filiformis* (adapted from Reynolds 2002).

Aegopodium podagraria	*Erysimum cheiranthoides*	*Medicago sativa subsp. Varia*	*Sambucus rupestre*
Althaea officinalis	*Erysimum cheiri*	*Melilotus albus*	*Senecio fluviatilis*
Antirrhinum majus	*Fallopia sachalinensis*	*Melilotus officinalis*	*Senecio squalidus*
Armoracia rusticana	*Festuca heterophylla*	*Mentha spicata*	*Senecio viscosus*
Avena fatua	*Fumaria bastardii*	*Mentha suaveolens*	*Silybum marianum*
Avena strigosa	*Fumaria muralis*	*Mentha × villosa*	*Sinapis alba*
Barbarea intermedia	*Geranium phaeum*	*Mercurialis annua*	*Sisymbrium orientale*
Brassica napus	*Hesperis matronalis*	*Misopates orontium*	*Smyrnium olusatrum*
Buddleja davidii	*Hieracium gougetianum*	*Myrrhis odorata*	*Soleirolia soleiroloo*
Centranthus rubber	*Hieracium grandidens*	*Papaver hybridum*	*Spartina pectinata*
Chaenorhinum minus	***Hieracium maculatum***	*Papaver somniferum*	*Stachys arvensis*
Chelidonium majus	*Hirschfeldia incana*	*Pentaglottis sempervirens*	*Symphytum tuberosum*
Chenopodium bonus-henricus	*Hordeum murinum*	*Persicaria amplexicaulis*	*Symphytum × uplandicum*
Chrysanthemum segetum	*Hyacinthoides hispanica*	*Persicaria bistorata*	*Tanacetum parthenium*
Cicerbita macrophylla	*Hyacinthoides non-scripta × hispanica*	*Persicaria campanulata*	***Tanacetum vulgare***
Cichorium intybus	*Hydrocotyle moschata*	*Persicaria wallichii*	*Thlaspi arvense*
Conyza bilbaoana	*Hypericum calycinum*	*Petroselinum crispum*	*Trifolium hybridum*
Conyza canadensis	***Hypericum hircinum***	*Peucedanum ostruthium*	*Urtica urens*
Coronopus didymus	***Inula helenium***	*Pilosella aurantiaca*	*Valerianella carinata*
Cruciata laevipes	***Juncus tenuis***	*Plantago media*	*Verbascum vigatum*
Diplotaxis muralis	*Kickxia elatine*	*Poa compressa*	*Veronica cista-galli*
Draba muralis	*Lamiastrum galeobdolon subsp.argentatum*	***Prunus domesticus***	*Veronica filiformis*
Epilobium ciliatum	*Lamium album*	***Prunus laurocerasus***	*Veronica peregrine*
Epilobium pedunculare	*Lepidium draba*	***Raphanus raphanisttrum subsp. raphanistrum***	*Veronica persica*
Epilobium tetragonum	*Linaria purpurea*	***Rapistrum rugosum***	*Vicia sativa subsp. segetalis*
Erigeron karvinskianus	*Malva neglecta*	***Reseda alba***	
Erinus alpinus	*Medicago arabica*	***Rosa rugosa***	

Appendix 5. Non-native animal species known to be present in Ireland

Common name	Latin name
MAMMALS	
Hedgehog	*Erinaceus europaeus*
Bank vole	*Clethrionomys glareolus*
Grey Squirrel	*Sciurus carolinensis*
Brown rat	*Rattus norvegicus*
Ship rat (probably restricted to islands and docks)	*Rattus rattus*
Brown hare	*Lepus europaeus*
Rabbit	*Oryctolagus cuniculus*
Fallow deer	*Dama dama*
Sika deer	*Cervus nippon*
American mink	*Mustela vison*
BIRDS	
Canada goose	*Branta canadensis*
Mandarin duck	*Aix galericulata*
Ruddy duck	*Oxyura jamaicensis*
Red-legged partridge	*Alectoris rufa*
Pheasant	*Phasianus colchicus*
Greylag goose	*Anser anser*
Collared dove	*Streptopelia decaocto*
FRESHWATER FISH (not postglacially native)	
Rainbow trout	*Oncorhynchus mykiss*
Rudd	*Scardinius erythropthalmus*
Tench	*Tinca tinca*
Roach	*Rutilus rutilus*
Pike	*Esox lucius*
Perch	*Perca fluviatilis*
Bream	*Abramis brama*
Carp	*Cyprinus carpio*
Dace	*Leucisus leucisus*
Gudgeon	*Gobio gobio*
Minnow	*Phoxinus phoxinus*
INVERTEBRATES	
New Zealand flatworm	*Artioposthia triangulata*
Flatworms – 8 species	Tricladida
Slugs – 14 species	Mollusca
Millipedes – 11 species	Diplopoda
Terrestrial isopods/hoppers – 10 species	Crustacea
Freshwater shrimp	*Gammarus tigrinus*
Freshwater shrimp	*Gammarus pulex*
Freshwater shrimp	*Crangonyx pseudogracilis*
Zebra mussel	*Dreissena polymorpha*
Beetles – 14 species	Coleoptera
Bees, ants, ichneumons etc. – several gall wasps	Hymenoptera
Honeybee parasite	*Varroa jacobsoni*
Florida leafminer	*Liriomyza trifolii*
South American leafminer	*Huidobrensis*
Western flower thrips	*Frankliniella occidentalis*
Sweet-potato whitefly	*Bemisia tabaci*
Aphid	*Echinothrips americanus*
Lupin aphid	*Macrosiphum albifrons*
Colorado beetle	*Leptinotarsa decemlineata*

Glossary

Alien species: 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.

Aquaculture: The cultivation of aquatic organisms by human effort for commercial purposes. For the cultivation of marine organisms, often molluscs and crustaceans, in seawater the term 'mariculture' is also used.

Archaeophytes: Long established members of the local flora (before 1700).

Bern Convention: Convention on the Conservation of European Wildlife and Natural Resources.

Biological diversity (biodiversity): The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

BIP: Border Inspection Posts.

BRC: Biological Records Centre.

CBD: Convention on Biological Diversity.

CBD Guiding Principles: Guiding Principles for the prevention, introduction and mitigation of impacts of alien species that threaten ecosystems, habitats or species (annexed to Decision VI/23 adopted by the Conference of the Parties to the CBD, The Hague, April, 2002).

CFB: Central Fisheries Board.

CITES: Convention on International Trade in Endangered Species.

Complementarity: A property of sets of species that exists when at least some of the species in one set differ from the species in a second set.

Cryptogenic species: A species of unknown origin.

Cryptozoic species: Invertebrates which have an affinity for dark places.

EC: European Community

ECOPACT: Environmental Code of Practise for Aquaculture Companies and Traders

EPA: Environmental Protection Agency.

EPPO: European and Mediterranean Plant Protection Organisation.

Establishment: The process of an alien species in a new habitat successfully producing viable offspring with the likelihood of continued survival.

EU: European Union

FAO: Food and Agriculture Organisation of the United Nations

FMD: Foot and mouth disease

Fouling: (biological) Growth of sessile algae and animals, especially on a ship's bottom or other artificial underwater structures, or in water-intake apparatus, also termed 'biofouling'.

GISP: Global Invasive Species Programme

Hygrophilous: Insects with an affinity for wet places.

ICES: International Council for the Exploration of the Sea.

IDG: The International Designations Group.

IMO: International Maritime Organisation.

Introduced species: Any species introduced by human agency into a geographical region outside its natural range. The term includes non-established ('alien') species and established non-natives, but excludes hybrid taxa derived from introductions ('derivatives').

Introduction: The movement by human agency, indirect or direct, of an alien species outside of its natural range (past or present). This movement can be either within a country or between countries or areas beyond national jurisdiction.

Intentional introduction: The deliberate movement and/or release by humans of an alien species outside its natural range.

Invasive species: A non-native species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of changes, and threatens native biological diversity (or has the potential to do so). An alien species whose introduction and/or spread threaten biological diversity.

IRBD: International River Basin District.

ISGA: Irish Salmon Growers Association.

ISIS: International Species Information System.

IUCN: World Conservation Union.

Natural range: The geographical range of a species in historical times (i.e. since the beginning of the Neolithic Age (ca 3,500 BC), prior to any changes to that range as a result of human agency.

Neophytes: a plant which was introduced to our area by man (or animal naturally from an area in which it was present as an introduction) and became naturalised after AD1500.

NGO: Non-Government Organisation.

Non-established introductions: Species that are introduced through the agency of man but have not become established and are incapable of establishing self-sustaining or self-propagating populations without deliberate intervention by man.

Non-native species: A species that has been introduced directly by human agency (deliberately or otherwise) to an area where it has not occurred in historical times and which is separate from, and lies outside, the area where natural range extension could be expected. The species has become established in the wild and has self-maintaining populations.

NPPO: National Plant Protection Organisation.

NPWS: National Parks and Wildlife Service.

OIE: Office International des Epizooties.

Pathway: The routes by which invasive alien species enter new habitats.

PHO: Plant Health Order.

QAB: Quality Assurance Branch.

Risk analysis: (1) the assessment of the consequences of the introduction and of the likelihood of establishment of an alien species using science-based information (i.e., risk assessment), and (2) to the identification of measures that can be implemented to reduce or manage these risks (i.e., risk management), taking into account socio-economic and cultural considerations.

Thermophilic: Species with an affinity for high temperatures.

UNCED: United Nations Conference on Environment and Development

UNEP: United Nations Environment Programme.

Unintentional introduction: An unintended introduction made as a result of a species utilising humans or human delivery systems as vectors for dispersal outside its natural range.

Vagrant (species): Individuals of a species which, by natural means, move from one geographical region to another outside their usual range, or away from usual migratory routes, and which do not establish a self-maintaining, self-regenerating populations in the new region.

Vector: The means by which invasive alien species travel to new destinations.

Vice-county: The standard geographical area for county-based botanical recording, this approximates to administrative counties in most cases.

WFD: Water Framework Directive.