10. Non-Indigenous Species and Biological Invasions: Summary of Issues

Problem

Biological invasions by non-native or "alien" species are widely recognised as a significant component of human-caused global environmental change, often resulting in a significant loss in the economic value, biological diversity and function of invaded ecosystems. In the United States, the cost of biological invasions has been estimated to total $97 billion hitherto for 79 major bioinvasions. Member States of the European Union have a commitment to strictly control the introduction of non-indigenous species and eradicate those alien species which threaten ecosystems, habitats or species. The use of non-native species in farming, forestry, aquaculture and for recreational purposes has increased in Britain during this century. Species may be imported because they grow faster (offering increased economic returns), because they feed on and suppress other species (biological control species), or simply because people like them (pets and many garden plants). In addition to these deliberate introductions, agricultural trade may itself facilitate the spread of aliens directly through accidental introduction of non-native species or indirectly by modifying the natural environment so that it becomes more susceptible to invasion.

Impact

In the UK rhododendron reduces the biodiversity of Atlantic oakwoods, while American mink is held partially responsible for the decline in water vole populations. Hybridisation has occurred between non-native sika and native red deer as well as between native and non-native plants. Japanese knotweed undermines flood defences and the impact of bark stripping by grey squirrels reduces forestry production. Alien species can also affect human health e.g. phytophotodermatitis through contact with giant hogweed or leptospirosis spread by the brown rat.

Areas at Risk

While deliberate introductions can be regulated and controlled to some degree, unintentional introductions are harder to prevent, even with rigorous inspection and quarantine procedures.

- Arable and Animal Production Most of the major crops grown in the UK are non-native but accidental contamination of grain supplies or feedstuffs presents a more diverse route for the introduction of non-native plant species into the United Kingdom. Crops deliberately introduced into the United Kingdom, and most seed contaminants, will have only a minor impact outside of a managed agricultural environment. Nevertheless, past trends are not a guarantee that crops introduced in the future will not pose a threat to the environment.
- Fur farms Historically an important source of non-native species source of non-native species that will close as of January 1 2003 under the Fur Farming Prohibition Act 2000.

- Horticulture The majority (58%) of non-native plants naturalised in the UK result from garden escapes and it is increasingly recognised that the composition of the UK non-native flora strongly reflects horticultural trends. Some of the most pernicious and invasive non-native plants are the result of garden escapes. The horticulture trade is an important source of accidental introductions of agricultural pests
- Aquaculture The introduction of non-native fish and plants into UK freshwaters either deliberately or accidentally, e.g. common carp, have resulted in dramatic habitat changes by increasing the turbidity of freshwaters, destroying or replacing macrophytes or predating native fish
- Forestry To date, conifer plantations represent almost 6% of the land area of the British Isles. Many non-native conifers set seed and regenerate naturally in Britain. Successful invasion of native woodlands by non-native conifers may be restricted to the pine, birch and oak woods on strongly acid soils, yet could dramatically alter the species composition and function of these ecosystems.

Future Scenarios

Global change is predicted to favour non-native invasive species, and agriculture may accelerate invasions through increased eutrophication, disturbance and overgrazing. The growth in international trade and commerce will continue to increase the movement of species between countries and continents, both deliberately and unintentionally. Thus, further non-native species introductions, a number of which will have economic or ecological impacts, should be expected in the future. The changing face of British agriculture will also contribute to the success of biological invasions as the market moves towards alternative agricultural production, including extending the commercial exploitation of non-native species.

Practical Remedies

There have been relatively few successful control eradication programmes against non-native species. Control measures are generally not implemented until a species becomes a problem, by which stage they are very expensive and require extensive research into the ecological, economic and political aspects of management. Future remedies focus on changes to UK legislation:

- Update existing lists of invasive species for which release into the wild is an offence
- Prohibit sales of invasive species
- Establish in legislation a more precautionary approach to the release of non-native species
- Speed up the review process so responses to newly invading species can be more efficient
- Manage the control of invasive species at a national scale, possibly through a Lead Agency
- Include agricultural introductions within legislation

Linkages

Biodiversity: currently threatened by biological invasions
Nutrient surpluses: facilitate the spread of invasive species

Research Priorities

The research approach should prioritise:

- Assessment of the impact of specific non-native species on ecosystem
- Identification of the relative importance of ecosystem traits that might influence their risk from invasion by alien species
- Development of models to predict why outbreaks occur and how species spread within ecosystems and across landscapes, and test predictions
- Exploitation of results to develop management guidelines with stakeholders to prevent and/or control invasion where economically or environmentally appropriate.

10. Non-Indigenous Species and Biological Invasions: Critical Commentary

10.1. Background

Biological invasions by non-native or "alien" species are widely recognised as a significant component of human-caused global environmental change, often resulting in a significant loss in the economic value, biological diversity and function of invaded ecosystems (Mooney & Hobbs, 2000; Mack *et al.,* 2000; Pimentel *et al.,* 2001). In the United States, the cost of biological invasions has been estimated to total $97 billion hitherto for 79 major bioinvasions (Pimentel *et al.,* 2001).

In the British Isles, the most recent and comprehensive audit of non-native species pertains exclusively to Scotland, which is host to at least 988 alien species (Welch *et al,* 2001). The non-natives comprise 824 vascular plants, 6 bryophytes, 13 mammals, 49 bird species (but only 8 breeding species), 16 fish, 22 insects, 50 molluscs, 5 other invertebrates and 1 amphibian (Welch *et al,* 2001). The trend for the entire British Isles is likely to be similar though, with the larger area covered, numbers of taxa will necessarily be greater. For example, the most recent estimates for non-native vascular plants for the entire British Isles is 1387 (Stace, 1997).

The UK has been fortunate, so far, in that the majority of recently introduced non-native species have not caused major adverse ecological impacts. In fact, some charismatic non-native species, such as the little owl (*Athene noctua*), common pheasant (*Phasianus colchicus*), rabbit (*Oryctolagus cuniculus*) or the horse chestnut (*Aesculus hippocastanum*), are now widely accepted as part of UK biodiversity.

There is, as yet, little evidence that introductions to the UK have led to species extinctions, as witnessed in other countries (Manchester and Bullock, 2000). The biota of the UK is essentially continental in character and native species are unlikely to be excluded throughout their whole range by non-native invaders. However, certain species introduced to the UK have caused problems for biodiversity, some of which have a high profile. These include the ruddy duck (*Oxyura jamaicensis*), Canada goose (*Branta canadensis*), grey squirrel (*Sciurus carolinensis*), coypu (*Myocastor coypus*), American mink (*Mustela vison*), North American signal crayfish (*Pacifastacus leniusculus*), zander (*Stizostedion lucioperca*), rhododendron (*Rhododendron ponticum*), Japanese knotweed (*Fallopia japonica*), Australian swamp stonecrop (*Crassula helmsii*) and the New Zealand Flatworm (*Artioposthia triangulata*). For example, rhododendron reduces the biodiversity of Atlantic oakwoods (Peterken, 2000) and the American mink is held partially responsible for the decline in water vole populations (Rushton *et al.*, 2000). Concern has been expressed regarding the threat of Australian swamp stonecrop to the five remaining populations of starfruit (*Damsonia alisma*) in the UK.

A subtler, but potentially more serious, impact of non-native species is the possibility of hybridisation with native species. Hybridisation has occurred between non-native sika deer (*Cervus nippon nippon*) and native red deer (*Cervus elaphus*), as well as between native and non-native oaks (*Quercus* spp) and willowherbs (*Epilobium* spp.) Hybridisation may introduce maladaptive genes to wild populations or result in a vigorous and invasive hybrid.

There have also been major economic impacts with weeds and animal pests causing damage to agriculture, forestry, aquaculture and other sectors (Williamson, 1999). Examples of direct economic impacts include the damage caused by Japanese knotweed to flood defences and the impact of bark stripping by grey squirrels on forestry production (Sheail, 1999). Alien species can also affect human health e.g. phytophotodermatitis through contact with giant hogweed (*Heracleum mantegazzianum*) or leptospirosis spread by the brown rat (*Rattus norvegicus*).

The use of non-native species in farming, forestry, aquaculture and for recreational purposes has increased in Britain during this century (Manchester and Bullock, 2000). Species may be imported because they grow faster (offering increased economic returns), because they feed on and suppress other species (biological control species), or simply because people like them (pets and many garden plants). In addition to these deliberate introductions, agricultural trade may itself facilitate the spread of aliens directly through accidental introduction of non-native species or indirectly by modifying the natural environment so that it becomes more susceptible to invasion. While deliberate introductions can be regulated and controlled, at least to some degree, unintentional introductions can be much harder to prevent even with rigorous inspection and quarantine procedures.

The aim of this critical commentary is to produce a balanced review of the current literature on biological invasions most pertinent to the role which agriculture (including forestry and horticulture) may play in the spread and impacts of non-native species. For the purposes of the commentary, terms relating to the status of a species are defined using the International Union for the Conservation of Nature (IUCN) guidelines: `non-native', `non-indigenous', `alien' or `exotic' refers to a species or race that does not occur naturally in an area, i.e. it has not previously occurred there, or its dispersal into the area has been mediated by humans. The scope of the review does not cover genetically modified organisms or the impact of non-native pathogens.

10.2. Arable and Animal Production

Most of the major crops grown in the UK are non-native e.g. rape (*Brassica napus*), wheat (*Triticum aestivum*), potato (*Solanum tuberosum*), oat (*Avena sativa*), as are most livestock e.g. sheep (*Ovis aries*) and cattle (*Bos taurus*). Similarly, many fruit trees are aliens e.g. plum (*Prunus domestica*), pear (*Pyrus communis*), apple (*Malus domestica*). In addition, many alien plants have been introduced to improve the forage content of pastures e.g. clovers (*Trifolium hybridum*, *T. incarnatum*), lucerne (*Medicago sativa*), swamp meadow grass (*Poa palustris*). Approximately 7% of all non-native plants in the British Isles are feral crops, several of which are widespread (Table 1). This is not surprising given the long period over which these species have been cultivated in the British Isles and the geographic scale of introduction. With the exception of *Lolium multiflorum*, widespread species rarely dominate the local vegetation nor pose a major risk to the natural environment (Welch *et al.,* 2001). The limited invasion partly reflects the requirement of many crops to exist in a highly managed and artificial environment e.g. high disturbance, low competition, high nutrients. In the absence of soil disturbance, rapid secondary succession (principally the growth of perennial species) tends to lead to local

extinction of non-woody feral crops (Crawley and Brown, 1995). Nevertheless, past trends are not a guarantee that crops introduced in the future will not pose a threat to the environment.

Table 1. Most abundant non-native plants arising from the agricultural sector broken down by source. National abundance is recorded as the number of 10km x 10km cells in the UK Plant Atlas occupied by each species (Perring & Walters 1972). Local abundance is collated from national flora (Stace 1997)

Species	Common Name	National abundance			Local abundance
		England	Scotland	Ireland	
Feral Crops					
Malus domestica	Apple	1318	192	385	scattered
Lolium multiflorum	Italian Rye Grass	1172	389	177	dominant
Prunus domestica	Wild Plum	701	79	143	scattered
Medicago sativa	Lucerne	621	29	26	frequent
Brassica rapa	Turnip	616	93	337	frequent
Brassica napus	Rape	492	174	11	frequent
Fodder Contaminants					
Trifolium hybridum	Alsike Clover	1051	294	124	frequent
Symphytum x uplandicum	Russian Comfrey	603	148	218	scattered
Melilotus albus	White Melilot	432	18	5	scattered
Melilotus altissimus	Tall Melilot	426	4	4	frequent
Poa palustris	Swamp Meadow-grass	65	32	3	scattered
Seed contaminants					
Veronica persica	Common field Speedwell	1467	433	498	frequent
Avena fatua	Wild oat	766	59	11	scattered
Chrysanthemum segetum	Corn Marigold	679	480	402	frequent
Melilotus officinalis	Ribbed Melilot	645	41	9	frequent
Sinapis alba	White Mustard	571	80	125	frequent
Aquarium Escapes					
Elodea canadensis	Canadian Pondweed	1043	234	255	dominant
Elodea nuttallii	Nuttall's Waterweed	253	15	4	dominant
Crassula helmsii	New-Zealand Pigmyweed	181	3	3	dominant
Elodea callitrichoides	South-American Waterweed	15	0	1	frequent
Garden Escapes					
Tanacetum parthenium	Feverfew	1212	379	177	scattered
Symphoricarpos albus	Snowberry	937	285	476	dominant
Rhododendron ponticum	Rhododendron	833	448	222	dominant
Fallopia japonica	Japanese Knotweed	789	294	259	dominant
Armoracia rusticana	Horse-radish	1111	39	47	dominant
Veronica filiformis	Slender Speedwell	746	299	137	dominant
Impatiens glandulifera	Himalayan Balsam	790	132	136	dominant
Petasites fragrans	Winter Heliotrope	660	57	310	dominant

Accidental contamination of grain supplies or feedstuffs presents a more diverse route for the introduction of non-native plant species into the United Kingdom. Seed contaminants are among some of the most widespread non-native weeds in the USA (Gerlach, 1999). Approximately 14% of non-native plants in the British Isles have been introduced by this means. The *Cereal Seed Regulations 1993 & Amendment Regulations 1995* set standards for "other seed contaminants" (i.e. species other than the traded species) and make it an offence to sell seed that do not meet them. The standards are much more stringent than those of pre-EC legislation and this suggests that the occurrence of non-native introductions from seed contaminants may reflect historical practices rather than current trends. Nevertheless, even today, cereal seed samples are contaminated by alien crops e.g. *Brassica* spp., *Daucus carota*, as well as non-native weed species e.g. *Cerastium tomentosum*, *Lolium temulentum* (Hay, 2000). Although contamination is often less than 1%, given the large numbers of seed sown each year, this can amount to a sizeable pool of introductions. Many of the seed contaminants are "convergent weeds", species that share many characteristics with the crop they contaminate. Thus, similarly to crops deliberately introduced into the United Kingdom, most seed contaminants will have only a minor impact outside of a managed agricultural environment.

10.3. Fur farms

Four of the most harmful non-native mammals introduced in the UK originated from escapes from fur farms: American mink, grey squirrel, muskrat and coypu. While the coypu and muskrat have been successfully eradicated from the UK (Gosling and Baker, 1989), American mink and grey squirrel continue to cause economic and ecological problems. However, this potential source of non-native species will be consigned to the history books as of January 1 2003, when it will be illegal under the Fur Farming Prohibition Act 2000 to keep animals solely or primarily for slaughter for the value of their fur in England and Wales.

10.4. Horticulture

While some non-native species have been deliberately introduced into the wild e.g. snowberry (*Symphoricarpos albus*) often as cover for game birds, most result from deliberate introductions in parks and gardens from whence they escape. The majority (58%) of non-native plants naturalised in the UK result from garden escapes (Clement and Foster, 1994) and it is increasingly recognised that the composition of the UK non-native flora strongly reflects horticultural trends. Some of the most pernicious and invasive non-native plants are the result of garden escapes e.g. Japanese knotweed, rhododendron, giant hogweed (*Heracleum mantegazzianum*), Himalayan balsam (Table 1). Not only does horticulture contribute more non-native species than any other source, but also the species are often invasive, being both widespread and locally dominant. Conservative estimates indicate that British gardens, plant centres and nurseries grow at least fifty times as many plant species as are found in the entire native flora (RHS, 2000). Thus, even if only 10% of introductions establish successful garden escapes, this represents a sizeable number of potentially problematic species. Furthermore, the problems posed by non-indigenous species will increase in the future. The rapidly expanding market for ornamental plants (18% annual growth (MAFF, 2000)) and horticultural incentive

schemes e.g. EU Flower Promotion Fund will undoubtedly increase both the likelihood and diversity of non-indigenous garden escapes.

The horticulture trade is an important source of accidental introductions of agricultural pests e.g.

- The New Zealand flatworm (*Artioposthia triangulata*) is a terrestrial planarian which has become very widely distributed in garden centres, botanic gardens, nurseries and domestic gardens throughout Northern Ireland and Scotland. In Scotland, it has been recorded from less than 20 farms and these are mostly in the west.
- The tobacco whitefly (*Bemisia tabaci*), is a notifiable pest and subject to eradication in the UK. It is an effective vector of over 60 viruses from several groups, particularly geminiviruses. Many of these have been reported to cause economic damage to a large number of crops. Tobacco whitefly was first intercepted in the UK in 1987 on poinsettia cuttings and since then outbreaks have occurred annually, again mainly on poinsettia. It has also been intercepted on a wide range of other plant material including bedding plants such as *Lantana and Verbena* on finished pot plants such as *Ficus* species, ornamental citrus, and also on herb cuttings.
- The Colorado beetle (*Leptinotarsa decemlineata*) is not established in the UK and is a notifiable quarantine pest, whose introduction is prohibited under the EC Single Market Protected zone arrangements for Plant Health. In recent years, Colorado beetles have been intercepted on a wide range of plant produce including parsley from Italy, salad produce from France and Spain, and on potatoes from a number of other countries.

The evidence of accidental introductions of pest species implies that environmental pests are also likely to be introduced accidentally via horticultural trade. In many respects, these accidental introductions are probably the most serious source of potentially problematic non-native species.

10.5. Aquaculture

Although the number of the introductions is smaller, plants introduced into the natural environment from aquarium waste pose significant threats to the native biodiversity (Table 1). The introduction of non-native fish into UK freshwaters either deliberately e.g. Zander (*Stizostedion lucioperca*) or accidentally e.g. common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), red swamp crayfish (*Procambarus clarkii)* have resulted in dramatic habitat changes by increasing the turbidity of freshwaters, destroying macrophytes or predating native fish (Manchester and Bullock, 2000).

10.6. Forestry

One of the most marked changes in the British landscape since 1900 has been the expansion of the commercial forestry sector and the widespread planting of non-native conifers (Forestry Commission, 2000). To date, conifer plantations represent almost 6% of the land area of the British Isles , although the rate of expansion of commercial conifer plantations has declined in the last 10 years, over 5000 hectares of new conifer plantations continue to be established each year. Scotland has by far the highest cover of non-native conifer plantations in the British Isles (Table 2).

Many non-native conifers set seed and regenerate naturally in Britain and their invasive potential has recently been discussed by Peterken (2001).

Table 2. Most abundant non-native forestry trees (hectares) planted in the UK.

Species	Common Name	Total	England	Scotland	Wales
Picea sitchensis	Sitka spruce	692,000	80,000	528,000	84,000
Pinus contorta	Lodgepole pine	135,000	7,000	122,000	6,000
Larix kaempferi	Jap/Hybrid larch	111,000	33,000	56,000	22,000
Picea abies	Norway spruce	78,000	32,000	35,000	11,000
Pinus nigra	Corsican pine	46,000	41,000	2,000	3,000
Pseudotsuga menziesii	Douglas fir	45,000	24,000	10,000	11,000
Larix decidua	European larch	24,000	14,000	9,000	1,000

Larch is regularly found as self-sown individuals in semi-natural woodland, but it is never common, generally becomes established after felling, and seems unable to regenerate within undisturbed native woods. Nevertheless, its litter is nutrient rich, particularly in calcium and its ability to improve soils may disadvantage many moorland plants (Welch *et al.,* 2001). Norway spruce has been able to colonise ancient semi-natural Caledonian pine forest (e.g. Glen More Forest) and evidently could generate mixtures, which mimic present day Scandinavian forest types and interglacial British types. The long-term prospects for the main introductions from the Pacific Northwest, sitka spruce, lodgepole pine, Douglas fir and western hemlock (*Tsuga heterophylla*), remain uncertain. All these species can regenerate naturally, but they have not had time to spread far, and most mature stands are in 20th century afforestation scheme. Thus there has been insufficient time to witness significant invasion. Nevertheless, the evidence suggests that considerable invasion potential exists. For example, lodgepole pine is the most vigorous naturally regenerating introduced conifer in New Zealand, whose saplings threaten existing indigenous flora and fauna, visual landscape and land use values (Ledgard, 2001). The potential for lodgepole pine invasion has also been recognised in Sweden (Sykes, 2001) since lodgepole pine spreads more vigorously than other introduced conifers as it cones earlier, is capable of producing seed and saplings at higher altitudes, and has lighter seed allowing dispersal over wide areas. Successful invasion of native woodlands by non-native conifers may be restricted to the pine, birch and oak woods on strongly acid soils, yet could dramatically alter the species composition and function of these ecosystems.

10.7. Future Scenarios: Global Change, Globalisation and Agricultural Diversification

Global change is, in general, predicted to favour non-native invasive species (Dukes and Mooney, 1999). The spread of alien plants is likely to be facilitated by rising atmospheric CO_2 concentrations, warmer temperatures, greater nitrogen deposition, altered disturbance regimes and increased habitat fragmentation (e.g. Collingham *et al.,* 2000; Smith *et al.,* 2000; Mihulka and Pysek, 2001). Increased eutrophication of terrestrial and freshwater ecosystems resulting from intensive application of agricultural fertilizers is a nationwide signal detected in the recent Countryside Survey (Haines-Young *et al.,* 2000). Eutrophication favours plant communities dominated by a few tall, competitive plant species at the expense of species rich

communities. The successful invasive non-native plant species in the UK are often tall-growing competitive plants (Thomson *et al.,* 1995; Crawley *et al.,* 1996; Williamson and Fitter, 1996) that may take advantage of eutrophic conditions to spread more widely in the British Isles. Disturbance is widely recognised as a key driver of biological invasions (Mack *et al*., 2000). Arable fields are by their nature highly disturbed environments and present numerous opportunities for invasion by native and non-native species (hence the need for herbicide). However, collateral disturbance at field margins may pose a greater concern since it will facilitate invasions into herb-rich communities. Grazing also acts as a form of ecosystem disturbance that maintains open vegetation and creates microsites suitable for colonisation. Overgrazing has been held responsible for invasions of native and non-native weeds into pastures (Hobbs, 2001; Safford and Harrison, 2001). Hence non-native species that are currently localised or benign may become problematic in the future. Furthermore, the growth in international trade and commerce will continue to increase the movement of species between countries and continents, both deliberately and unintentionally. Thus, further non-native species introductions, a number of which will have economic or ecological impacts should be expected in the future.

The changing face of British agriculture will also contribute to the success of biological invasions as the market moves towards alternative agricultural production. Farmers are currently encouraged financially through the Rural Enterprise Scheme to diversify their farm businesses in order to improve their economic viability, particularly in rural areas that have experienced most difficulty in adjusting to agriculture's decline. Future alternatives include expanding the role of non-native species in UK agriculture either through the conversion of existing production to non-mainstream agricultural crops (e.g. industrial non-food crops, such as short rotation coppice for energy production, growing crops for pharmaceutical products, wildflower seed production,) and/or development of novel crops or livestock to provide products for new niche markets (e.g. new crops for fibre, keeping livestock such as wild boar, alpacas, ostriches, snails, worms etc.). Woodland is the major alternative land use to agriculture and will potentially expand the problems associated with forestry described above. While the overall environmental impact of the Rural Enterprise Scheme will be monitored, the risks involved in both deliberate and accidental introductions must also be assessed.

10.8. Practical Remedies

There have been relatively few successful control eradication programmes against non-native species. Control measures are generally not implemented until a species becomes a problem, by which stage they are very expensive and require extensive research into the ecological, economic and political aspects of management (Wadsworth *et al.,* 2000). Local control or suppression measures are carried out by national agencies and local authorities to reduce the impact of invasive non-native species in some areas. There is no effective national co-ordination of these measures at present. The success at eradicating coypu (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) (Gosling and Baker, 1989) must be balanced against the failure to manage American mink and rabbit (Manchester and Bullock, 2000). For other species, hitherto, the aim has generally been to seek local suppression rather than national eradication, though this approach may be reviewed in the future. The

direct costs of local control programmes can be high, for *Rhododendron ponticum* as much as £60,000 per hectare (Compton and Key, 1998) and cumulative costs for large areas such as Snowdonia National Park can reach as much as £45 million (Gritten, 1995). Faced with these potentially high costs, prevention is far better than cure. Comprehensive risk assessments are need for all non-native species introduced into the UK to prevent the introduction of problem species. Similarly, monitoring of established non-native species is required to identify potential outbreaks sufficiently early that control can be effective.

10.9. Legislative and Policy Perspectives

Member States of the European Union have a commitment *"to strictly control the introduction of non-indigenous species*" (Bern Convention on the Conservation of European Wildlife and Natural Habitats) and *eradicate those alien species which threaten ecosystems, habitats or species*" (UN Convention on Biological Diversity). Both the "Habitats" and "Birds" Directives of the European Union also contain provisions to ensure introductions do not prejudice the local flora and fauna (Hulme *et al.,* 2000). However, European legislation is restricted to: a) prevention of deliberate rather than accidental introductions; b) exemption of the major sources of accidental introductions e.g. forestry and agriculture species, biocontrol agents, introductions into zoological and botanical gardens; c) no commitment to eradicate or control established non-indigenous species. The European States also have a commitment *"to report the existence, outbreak and spread of plant pests and of controlling those pests*" (UN International Plant Protection Convention). Pests are clearly defined by the convention *of potential national economic importance to the country endangered thereby*". The "Plant Pests" Directive of the European Union provides lists of pest species that must be banned from being introduced into particular Member States.

In the United Kingdom, it is an offence to release or allow to escape any animal which is not ordinarily resident in, or not a regular visitor to, the UK. In addition, it is an offence to release or allow to escape a number of established non-native plants and animals (HMSO, 1981). While the UK has comprehensive regulations dealing with the introduction of non-native animal species, it has proved more difficult to formulate effective legislation to deal with non-native plants and other organisms. The Department of the Environment, Transport and the Regions has published guidelines *"The Regulation and Control of the Release of Non-native Animal and Plants into the Wild in Great Britai*n" (Department of the Environment, 1997) which explains the procedures needing to be followed before the release of a non-native species. Some legislative measures have been put in place to prevent the arrival of non-native species that might be expected to cause problems for agriculture, forestry or human health, though these do not extend effectively to prevent the arrival of invasive species that might be anticipated to cause problems for native biodiversity.
The UK Government initiated a fundamental review of non-native species policy early in 2001. Current initiatives by DEFRA are addressing the need to improve the means of preventing the arrival of non-native species and for ameliorating their effects if they become established. There is also considerable interest and concern among non-governmental conservation organisations on the issue of invasive non-native species and alternative ways of preventing or minimising their impacts on native biodiversity. However, those concerned about the effects of alien species

upon native biodiversity need to take into account the views and actions of other interests who wish to continue to import and release non-native species. Inevitably, there will continue to be conflicts of view between proponents for importation and release of alien species and those seeking to conserve indigenous biodiversity. Thus it is likely that introductions for agriculture, horticulture and forestry will be exempt from future legislation. However, future remedies currently focus on changes to UK legislative instruments:

- Update existing lists of invasive species for which release into the wild is an offence
- Prohibit sales of invasive species
- Establish in legislation a more precautionary approach to the release of non-native species
- Speed up the review process so responses to newly invading species can be more efficient
- Manage the control of invasive species at a national scale, possibly through a Lead Agency
- Include agricultural introductions within legislation

10.10. Research Priorities

The research approach should:

- Assess the impact of specific non-native species on ecosystem services e.g. biodiversity, N flux, hydrology etc. by comparing invaded/non-invaded ecosystems and the response of ecosystems following eradication of non-native species. This will facilitate assessments of economic costs and present a stronger basis for action.
- Identify the relative importance of ecosystem traits e.g. species richness, resource supply, proximity to man etc. that might influence their risk from invasion by non-native species. Such information will identify vulnerable ecosystems and assist in prioritisation of management efforts and limit introductions into such ecosystems.
- Examine these species:ecosystem interactions along natural environmental gradients to identify the extent to which climate, habitat disturbance and eutrophication influence the rate of invasion.
- Develop spatially explicit models, appropriately parameterised, to predict why invasions occur and how species spread within ecosystems and across landscapes.
- Test predictions through studies of ecosystem impacts along a chronsequence reflecting different periods since non-native species were introduced and/or carefully controlled introductions of non-indigenous or outbreak species within experimental mesocosms (where escape into the wider landscape is prevented).
- Use results to develop management guidelines in association with relevant stakeholders to prevent and/or control invasion where economically or environmentally appropriate.

10.11. Agriculture, Environment and Non-native Species

The review has highlighted that agriculture in its broadest sense plays an important role in introducing and/or facilitating introductions of non-native species into the

British Isles. While agriculture may be currently exempt from future non-native species policy, it should be emphasized that many economic pests of agriculture are introduced species. Two common grain contaminants, wild oat (*Avena fatua*) and field speedwell (*Veronica persica*), are significant agricultural weeds with annual costs of control running in to £100 million, whereas their environmental impact is minimal. Introduced deer e.g. sika and muntjac (*Muntiacus reevesi*) as well as grey squirrels are serious forest pests causing significant damage to broadleaved and conifer plantations. Canada geese (*Branta canadensis*) damage agricultural crops, such as cereals, oilseed rape, root crops and spring pastures. While the direct economic impacts of the New Zealand flatworm have not been estimated, should quarantine measures be established within the EU, they could severely hit UK horticultural exports. Horticultural imports may themselves introduce non-native pests e.g. tobacco whitefly or Colorado beetle. Clearly management of non-native species cuts across economic and environmental sectors and an inclusive, holistic approach should be adopted. Agriculturalists and environmentalists must work together if the future sustainability of UK agriculture is to be guaranteed.

10.12. Literature Cited

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Please see Appendix 5 for selected bibliography on non-indigenous species and biological invasions