Non-native species research requirements for delivery of the UK Biodiversity Action Plan

Report prepared for The Joint Nature Conservation Committee
By Just Ecology

Des Callaghan[1]

November 03

[1] **Contact:** The Old Wheelwrights, Ham, Berkeley, Gloucestershire, GL13 9QH. Tel: 01453 811780

Introduction

With increasing global trade and world travel, invasive non-native species[2] are a growing problem. The UK has international obligations to address non-native species issues, principally the Convention on Biological Diversity (CBD) and including the International Plant Protection Convention (IPPC), the Bern Convention on Conservation of European Wildlife and Habitats and the EC Habitats Directive. Within the UK BAP non-native species are identified as threatening factors within 17 (23%) Habitat Action Plans (HAPs) and 46 (12%) Species Action Plans (SAPs) (Table 1). Their cited impacts, and the frequency of citation, are competition (62%), habitat loss/degradation (18%), predation (12%) and disease (8%).

Research requirements to support the UK Biodiversity Action Plan (UK BAP) are varied, ranging from very specific needs for individual Species Action Plans (SAPs) or Habitat Action Plans (HAPs), to more generic needs regarding non-native species issues. The Biodiversity Research Working Group was established to identify and prioritise these latter research needs and convened five technical workshops to help accomplish this task. The five themes that were selected for the workshops were:

- Biodiversity and agriculture: focus on pastoral systems (grazing management and policy)
- Introductions, translocations and genetic conservation
- Coastal and marine issues
- Landscape ecology, habitat fragmentation and land use change scenarios
- Biodiversity monitoring and indicators

The second workshop took place on 18th November 1999, from which conclusions fell within three main themes (see Annex 1 for full report):

- Theme 1. Genetic conservation, translocations and the introduction of exotic, artificially selected or modified varieties. *Focus on plants used in agriculture (including agri-environment), ecological restoration, landscape and forestry.*
- Theme 2. Genetic conservation, translocations and the introduction of exotic, artificially selected or modified varieties. *Focus on exploited and exploitable species in aquatic environments, especially fish, shellfish and crustacea*
- Theme 3. Introduced and invasive species

BRWG (2001) analysed the outputs of the five technical workshops to develop six cross-cutting research programmes:

- Science for conservation of genetic and native species diversity
- Addressing the impacts of introduced species
- Understanding the roles of biodiversity in ecosystem function
- Science-based monitoring of biodiversity and evaluation of actions
- Science-based management of habitats and ecosystems
- Developing tools to optimise policies to favour biodiversity

---

[2] 'Non-native species' is considered synonymous with 'non-native species' and 'introduced species'. Following CBD (2003), 'Non-native species' refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution; it includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce. 'Invasive non-native species' means an non-native species whose introduction and/or spread threaten biological diversity. Following DEFRA (2003), non-native species excludes agricultural crops and genetically modified organisms.

An outline of each programme was developed within BRWG (2001), together with a list of possible research projects. The second of these programmes, 'Addressing the impacts of introduced species', was established to develop the scientific basis to address the most significant, negative impacts of non-native, translocated and purposely-bred and released species. The outline for this programme and 16 possible research projects included within BRWG (2001) are reproduced in Annex 2.

Since the publication of BRWG (2001) there have been a number of major developments and publications regarding non-native species and biodiversity conservation in the UK and internationally. In light of this, JNCC contracted Just Ecology to:

- Update non-native species research requirements for delivery of the UK BAP, identify any gaps in activity and develop proposals to fill those gaps accordingly.

Methods

Up-dating research needs

In order to update non-native species research requirements for delivery of the UK BAP, reference was made to a comprehensive set of recent policy documents (see Bibliography). From the recommendations and proposals included within these, a set of research actions needed to combat the problem of non-native species was compiled.

Each research action was then categorised within the Driving Forces-Pressure-State-Impact-Response (DPSIR) Framework (Figure 1). According to this systems analysis view, Driving Forces, such as technological development, lead to Pressure on the environment, such as Internet-based trade in unusual seeds, bulbs and plants. Consequently, the State of the environment changes, for example new non-native species become established, which leads to Impacts, such as competition with native species. This may elicit a societal Response, for example eradication of the invasive non-native and/or development of codes of conduct for internet-based trade in plant material categorised as invasive or potentially invasive. That feeds back on the Driving Forces, Pressures, State or Impacts directly.

After categorisation of the up-dated research actions, they were compared with the research actions outlined in the original non-native species research programme drafted within BRWG (2001). In addition, the up-dated actions were compared with recommendations contained within DEFRA (2003), since this is a particularly important recent policy document in the present context.

Assessment of research priorities

On 18th September 2003, the first meeting of the Non-native Species Sub-group of BRAG was held at The Royal Botanic Gardens, Edinburgh. At this meeting, the up-dated research actions were reviewed by the group and priorities for future action were identified. Priorities were assessed with consideration to:

- Time-scale – priority was given to actions that could be undertaken within the next five years;
- The CBD (2002) three-stage hierarchical approach (Guiding Principle 2):
  "1. Prevention is generally far more cost-effective and environmentally desirable than measures taken following introduction and establishment of an invasive non-native species.
  2. Priority should be given to preventing the introduction of invasive non-native species, between and within States. If an invasive non-native species has been introduced, early detection and rapid action are

crucial to prevent its establishment. The preferred response is often to eradicate the organisms as soon as possible (principle 13). In the event that eradication is not feasible or resources are not available for its eradication, containment (principle 14) and long-term control measures (principle 15) should be implemented. Any examination of benefits and costs (environmental, economic and social) should be done on a long-term basis."

Current activities and gaps

Current research activities regarding non-native species in the UK were reviewed via email circulars, internet searches and discussions held at the Non-native Species Sub-group Meeting. Key areas lacking current activity where then assessed.

Results

Up-dated research needs

An updated set of research actions needed to address the most significant, negative impacts of non-native species is included in Annex 3. The correspondence of these with the research projects originally identified by BRWG (2001) is shown in Table 2. This seems to show a bias of the BRWG (2001) research projects towards genetics and away from:

- evaluation of driving forces and pressures;
- improvement of taxonomy and nomenclature;
- impacts on human health, habitat composition, biodiversity structure and economies;
- development of contingency plans for non-established high risk non-natives;
- information transfer and integration of activities.

Some of these aspects, such as impacts on human health, economies and habitat composition, were included within recommendations from the original BRWG workshop (Annex 1).

Thirty-one research-related recommendations were included within DEFRA (2003) (Annex 3). These were all incorporated into the up-dated research actions identified within this document, except Recommendation 2.6 which concerns the possible creation of a list of low risk species for use in the horticultural industry (further consultation about this action is considered necessary). The up-dated research actions identified within this document include a number of areas of research that are seemingly excluded from DEFRA (2003):

- Monitoring and evaluating driving forces and pressures that give rise to non-native species;
- Improving taxonomy and identification of non-native species;
- Producing predictive models of the spread of non-native species;
- Conducting comparative studies of non-native species in their nature and non-native environments;
- Investing the impact of climate change on non-native species;
- Compiling registries of natives at risk, habitats at risk, invasion hotspots and high risk exports from the UK;
- Researching incentives that could reduce non-native species problems;
- Researching the use of native species to replace uses made of non-native species.

Some of these actions may arise from the implementation of recommendations included within DEFRA (2003), but this is not immediately apparent.

Assessment of research priorities

During the meeting of the Non-native Species Sub-group, there was general agreement that the following should be regarded as priorities for research action:

- Driving Forces and Pressures
    - Evaluation of economic driving forces and pressures
    - Evaluation of social driving forces and pressures
    - Evaluation of demographic driving forces and pressures
    - Evaluation of technological driving forces and pressures
    - Identification and understanding of pathways and vectors
- State
    - Improvement of taxonomy
    - Improvement of nomenclature
    - Audit of non-native species
    - Improvement of surveillance and monitoring activities
    - Conduct status reviews of non-native species
    - Compilation of distribution atlases
- Impacts
    - Investigation of health impacts
    - Investigation of biodiversity impacts
    - Investigation of economic impacts
    - Investigation of ecosystem service impacts
- Responses (generic)
    - Development of risk assessment system
    - Broad application of the risk assessment system to species and pathways, followed by more detailed application for select species and pathways
    - Integration of activities
- Responses (specific)
    - Development of action plans and detailed research needs for individual species and pathways
    - Development of economic incentives and disincentives
    - Development of codes of conduct
    - Develop use of natives species in place of non-natives
    - Development of control techniques

Current activities

Annex 5 provides a review of current, recent and planned research concerning non-native species in the UK. The aim was not to provide an exhaustive assessment, but rather to capture at least the main activities. These can be summarised as follows:

- Driving Forces
    - To be investigated at least partly through DEFRA's Horizon Scanning Programme
- Pressures
    - To be investigated at least partly through DEFRA's Horizon Scanning Programme
- State
    - Various monitoring, atlases, audits and status reviews being conducted for certain groups of species, but uncoordinated
- Impacts

    - Various species-specific work, largely concerning the impacts of non-natives (e.g. American Mink, Grey Squirrels and domestic cats) on certain native species (e.g. Water Voles, Red Squirrels and Otters)
- Responses (generic)
    - Development of risk assessment methods currently being undertaken by CEH as part of an EU project to assess large-scale risks; also a planned project funded by DEFRA to develop a standard risk assessment methodology for non-natives
- Responses (specific)
    - Various species-specific work largely related to development of control techniques, for example concerning Japanese Knotweed, North American Ruddy Duck and American Mink

Major gaps and next steps

During the meeting of the Non-native Species Sub-group, there was general agreement that the following are the major gaps that could be filled in the next 3-5 years:

- Development of a common terminology regarding non-native species, especially addressing when a species is considered non-native and/or invasive
- Compilation of a comprehensive and quantitative audit of non-native species in the UK, including information on distribution, population and impacts
- Review of monitoring schemes to identify key gaps and development of new schemes where needed
- Development of a risk assessment system
- Application of the risk assessment system, including an initial broad and rapid application to non-native species and major pathways, followed by more detailed assessments of certain species and pathways
- On-going species-specific research on impacts and mitigation
- Establishment of a web-based catalogue of active research projects concerned with ecology and/or control of non-native invasive species in the UK and territorial waters
- Development of a research conference concerning non-native species

Bibliography

BRWG (2001). *Science in action for biodiversity: a report of the Biodiversity Research Working Group 1998-2001*. DEFRA, Bristol, UK.

CBD (2003). *COP6 Decision VI/23 'Non-native species that threaten ecosystems, habitats or species'*.

CE & PE (2002). *European Plant Conservation Strategy: saving the plants of Europe.* Council of Europe, Strasbourg, France and Planta Europa, London, UK.

DEFRA (2002). *Working with the grain of nature: a biodiversity strategy for England.* DEFRA, Bristol, UK

DEFRA (2003). *Review of non-native species policy: report of the working group*. DEFRA, Bristol, UK.

EC (1998). *European Community Biodiversity Strategy*. European Commission, Brussels, Belgium.

EC (2001a). *Biodiversity Action Plan for the conservation of natural resources*. European Commission, Brussels, Belgium

EC (2001b). *Biodiversity Action Plan for agriculture*. European Commission, Brussels, Belgium

EC (2001c). *Biodiversity Action Plan for fisheries.* European Commission, Brussels, Belgium

EC (2001d). *Biodiversity Action Plan for development and economic cooperation.* European Comission, Brussels, Belgium

EC (2001e). *The sixth environment action programme.* European Commission, Brussels, Belgium.

EPBRS (2000). *Biodiversity research related to the 'Biology of Invasions': indicative list of topics of strategic importance.* European Platform for Biodiversity Research Strategy, Brussels, Belgium.

Genovesi, P. & Shine, C. (2002). *Draft European strategy on invasive non-native species*. Convention on the Conservation of European Wildlife and Habitats, Strasbourg, France.

NIBG (2002). *Northern Ireland biodiversity strategy*. Northern Ireland Biodiversity Group, Belfast, Ireland.

SBF (2003). *Towards a strategy for Scotland's biodiversity: biodiversity matters!* Scottish Biodiversity Forum, Edinburgh, UK.

UKBG (2001). *Sustaining the variety of life: 5 years of the UK Biodiversity Action Plan.* Report of the UK Biodiversity Group to the UK Government, the Scottish Executive, the National Assembly for Wales and the Northern Ireland Executive. Department of the Environment, Transport and the Regions, London, UK.

UKBP (2002). *The UK Biodiversity Action Plan: tracking progress*. DEFRA, Bristol, UK.

Annex 1. Recommendations from BRWG Workshop Theme 3

3.3 Recommendations

1. There is a need for a focal point and centre to coordinate activity (i.e. research, action) related to nonnative species.
2. There should be a balanced research programme to take forward all elements of the key issues identified by the workshop.
3. Research priorities should be driven by the:
    - degree of risk (known or perceived) posed by non-native species to UK biodiversity;
    - UK's international obligations (e.g. Ruddy Duck in relation to White-headed Duck).
4. The proposed research activities should be scoped and costed, considering different approaches to carrying out each area of work.

Although not considered strictly within the remit of the Biodiversity Research Support Project or the individual workshops, the participants of this session also recommended that:

- The key issues and topics identified should be considered in relation to overseas research funded by the Department for International Development (DFID).
- The scope of the research should include the UK's responsibilities to the Overseas Territories.

3.4 Key Issues

1. Review existing knowledge and experience (UK and other countries), encompassing:
    - Ecology
    - Policy and practice
    - Economics
    - Legislation
2. Which species are we/should we be concerned about and which should we take action on?
3. Understanding the process of invasion and how a species becomes a component of a native ecosystem.
4. Monitoring non-native species.
5. Categorisation of species according to their susceptibility to different approaches for control or eradication, and understanding how different circumstances may influence this susceptibility.
6. Identification and development of effective, target-specific, humane and socially acceptable methods for eradication or control.

3.5 Strategic topics requiring data and information

Topic 3.5.1 Database

It was noted that the database would be a source of data and information (with emphasis on information, as data on many species is not available or very patchy).

A database should be created that will provide a central point of data and information about non-native species.

The database should link to international databases.

The species for which data collation/collection are priorities:
1. Known problems species in the UK
2. (Consider) other species where there is a high risk of invasion to the UK

Develop criteria for identifying and prioritising species for data capture:
- Include an analysis of non-natives in relation to the Habitat and Species Action Plans.

The role of the National Biodiversity Network in data capture should be considered.

Encourage data collection by professional and volunteer sectors and provide guidance on this.

Topic 3.5.2 Decision support system
Develop criteria and protocols ("Decision Support System") to aid the decision-making process, e.g. to:
- define the threshold when change due to biological invasion becomes unacceptable (i.e. identify when and under what circumstances a species is or is may become a problem)
- produce a list of species ranked according to the threat they pose (create an alert system)*
- determine when to take action
- identify what to do (i.e. gather further information, monitoring, experimental research, policy modification, practical action).

*an initial list might be compiled via an expert meeting, but research could inform its future refinement.

Consider:
- the outcome of biodiversity risk assessments
- perceptions and attitudes
- the role of "natural" change (e.g. gradual accommodation of a species within a recipient ecosystem)
- economic issues
- human health impacts (e.g. malaria)

and determine how these should be accommodated within the decision-making process at all stages.

Characterise the range of perceptions concerning non-native species, and match these to evidence for adverse biodiversity impact, [using some representative case examples.]

Topic 3.5.3 Environmental accounting
Carry out economic evaluation of:
- proposals to commercially exploit non-native species
- existing species introduced for commercial exploitation incorporating environmental and social accounting.

Identify the economic costs of invasions, e.g. in relation to:
- Control/eradication measures

- Damage to commercially exploited natural resources (e.g. wild fish stocks used for sport angling)
- Ecosystem restoration
- Repairing/restoring other damage (e.g. power station intakes clogged by an invasive aquatic species).

Topic 3.5.4 Biodiversity risk assessment

Develop procedures and methods for screening samples of imports of:

- Exploited species (i.e. of commercial importance)
- Related commercial products (e.g. bird seed) in order to identify the role of different vectors and pathways for introducing species and inform the determination of future policy and practical action.

Improve current risk assessment procedures for biological control agents (ensuring that risks to biodiversity are fully addressed).

Undertake risk assessment of deliberate introductions for horticulture, forestry, agriculture & mariculture.

Identify places which are sinks or sources of non-native species (i.e. biotopes, specific localities).

Note: this is an approach that has been taken for the marine environment, where specific locations have been identified as sinks for invasive species (e.g. enclosed coastal waters with a significant amount of shipping movement, expulsion of ballast water and large numbers of introduced organisms).

Topic 3.5.6 Monitoring, and enhancing our understanding of the ecology of invasive species and the invasion process

Gain better knowledge of the biology and ecology of invaders.

Consider the incorporation of invasive species monitoring (and reporting) into existing or proposed long term monitoring projects, e.g.:

- Countryside 2000
- The Environmental Change Network
- Work of the Biological Records Centre.

Undertake periodic, random, stratified sampling of non-native species so as to identify long term changes (i.e. for a range of taxa in a particular location or habitat).

Build in a formal, periodic reporting procedure (i.e. on non-native species occurrences and biodiversity change associated with biological invasions).

Revisit sites where impacts have occurred in the past [to enable long term changes to be assessed].

Re-evaluate past research and observations using modern analytical approaches and recent knowledge.

Development of generic models to assess dispersal processes.

Experimental (mesocosms) studies to investigate invasive species impacts in selected biotopes, e.g. ponds pre and post-colonisation.

Carry out molecular studies of non-native species including time-series investigations, so as to identify:

- genetic changes as the invasion progresses
- adaptive variations within invading populations[3]
- species origin.

(Alder *Phythopthera* was noted as an example).

Identify post-invasion effects on the affected biotope, e.g.

- At community level
- In relation to species richness
- The population dynamics of the invader.

Topic 3.5.7 Identifying approaches for eradication or control
Review and evaluate generic approaches.

Classify species according to the feasibility of controlling them, and the levels and methods of control that are practical and feasible.

Undertake cost-benefit analysis of control/eradication proposals [see also "Environmental Accounting"].

Identify and develop methods for preventing invasions.

Evaluate existing policies and measures in order to inform the development of future policies/measures.

Topic 3.5.8 Informing the development of policies and measures
Assess the effectiveness of existing policy and legislation in relation to non-native species and UK biodiversity (policy analysis and evaluation).

[3] observation and experimentation to identify physiological and behavioural traits will need to accompany the use of molecular techniques in order to understand adaptive variation

Annex 2. Non-native species programme outlined within BRWG (2001)

Programme B. Addressing the impacts of introduced species

Derived from workshop projects labelled with the keywords 'non-native, translocated and purposely bred species'.

Key issues

To develop the scientific basis to address the most significant negative impacts of non-native, translocated and purposely-bred and released species, what ever they are and wherever they occur.

Drivers

An international responsibility to address the impacts of introduced species on UK biodiversity is driving the need for better information on: what we are trying to protect; the nature and scale of environmental damage, including economic impacts; the species, habitats and ecosystems currently and potentially at most risk; and how to manage and reverse environmental damage. Anticipated climate change may provide new opportunities for introduced species to thrive, perhaps causing new and greater problems.

Programme description

This research programme has been identified to address four main areas of information need:

(1) What we are trying to protect? Agree concepts regarding the goal/objectives for biodiversity conservation in relation to the threats posed by introduced species. Since the subject area is vast, develop a common framework for prioritising the introduced species and impacts to study.

(2) The nature and scale of environmental damage. Management strategies to address the impacts of introduced species may fail unless the significance of the impacts, and the mechanisms involved, are understood. Work to investigate the significance of impacts would include a review of existing knowledge and experience on the process of invasion and impacts, compiling a database of current information about actual/potential problem species, and ranking species according to threat posed. Improved monitoring and research on the ecology of introduced species is also needed and should include consideration of long-term adaptive change. Environmental accounts for introduced species, including loss of biodiversity benefits and services and costs to industry, are needed to evaluate the economics of new proposals for introductions. Research to understand impacts, both direct and indirect, undertaken at a variety of scales, would include impacts on genetical make-up within and between species and the functional and performance consequences of this on affected populations, species, habitats and ecosystems.

(3) The species, habitats and ecosystems at most risk. Here it is important to be armed with good information on the range of genetic variation represented in priority, native species (Programme A), and then to consider the potential, adverse, genetical impacts of contact with introduced species. It would then be possible to group species according to their vulnerability to genetic change from this source. Also, an approach to biodiversity risk assessment needs to be developed (Programme F) for screening imports of exploited species or related commercial products, in order to identify the role of

different vectors/pathways and sinks/sources for introduced species.

(4) How to manage and reverse environmental damage, including practical and policy responses. Work at a strategic level would include the development of a decision support system for defining thresholds beyond which to take action against introduced species and to determine what to do. Research to inform appropriate responses to observed/predicted effects is needed, and to evaluate options, including operational, educational, policy and economic responses (Programme F). At a practical level research needs include identifying approaches for eradication/control and classifying species according to the feasibility of control. This should be coupled with experiments to determine whether target species can be effectively removed, and how different circumstances may influence their susceptibility to control. The research should include recording the effects of control measures on other species, habitats and ecosystems, to understand the wider implications of taking action against introduced species. The ultimate aim would be to identify and develop effective, target-specific, humane and socially acceptable methods for eradication and control.

Further comments

The programme requires multi-disciplinary research including desk review, basic research at the genetic, species and ecosystem levels, risk assessment, including socio-economic evaluations, and the development of practical species conservation and management actions. Detailed methods and approaches will need to be defined and the programme costed in due course.

Research projects

1. *Removal of non-natives*. Experiments to determine whether invasive species can be effectively removed. Considerations include recruitment potential and landscape pattern/dynamics.
2. *Basic biology, database and monitoring*. Understanding the basic biology of introduced species: compiling a database of current information about actual and potential problem species, improved monitoring and researching the ecology of invasive species and invasions.
3. *Genetic vulnerability*. Improve current knowledge on 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.
4. *Genetic impacts*. Assessment of direct impacts through gene flow and introgression within-species, and gene flow between introduced and native species and hybridisation. Determination of functional/performance consequences for the population.
5. *Indirect impacts on species*. Assessing indirect impacts on native species, eg. on dependent/specialist herbivores, by altered competitive interactions, disease/pathogens etc. Determination of functional and performance consequences for the population.
6. *Functional impacts*. Assessing the ecological impacts of functional/performance consequences on affected species, on habitats, ecological processes and ecosystems.
7. *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 to do.

8. *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.
9. *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. Evaluation and analysis of policy and regulation needed also.
10. *Genetic conservation*. Research to develop a policy, strategy and guidelines for genetic conservation and, where needed, to review the regulatory framework, including wider countryside actions.
11. *Adaptation and climate change*. Investigate long-term adaptive changes amongst non-native species, eg. in relation to climate change, through monitoring genetic change and phenotypic indicators.
12. *Research prioritisation*. Development of a common framework for prioritising species to study, eg. in relation to conservation status, ecological importance, geographical distribution, genetic distinctiveness, commercial potential and focusing on fish and shellfish.
13. *Impacts of controlling diseases/parasites*. Investigate the effects of controlling introduced diseases/parasites on other species, at all relevant scales (individual, sub-population or population).
14. *Development of responses*. Research to inform appropriate responses to observed/predicted effects, and evaluate options, including operational responses, educational, policy and legislation, and economic.
15. *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. Identify sinks/sources of introduced species.
16. *Control techniques and feasibility*. Identify approaches for eradication/control. Classify species according to the feasibility of control and methods. Evaluate existing measures to inform future policy development.

Annex 3. Non-native species research recommendations from DEFRA (2003)

• Key Recommendation 2: Develop comprehensive risk assessment procedures to assess the risks posed by non-native species and identifying and prioritising areas for other prevention action.

Sub-recommendation 2.1:
Although it is clear that, for many taxa, there are no easy short cuts to risk assessments, further analysis of the attributes of species successfully invading Great Britain should be undertaken.

Sub-recommendation 2.2:
Plant health risk assessment standards and schemes should be used as a basis for constructing a general risk assessment scheme that can be applied to all non-native species. Plant health risk assessment procedures are widely applied and already recognised by the World Trade Organisation. Their use as a basis for generic risk assessments is likely to increase the speed with which they are accepted and adopted.

Sub-recommendation 2.3:
High priority should be given to developing and publishing a risk assessment scheme suitable for all non-native species. To foster best practice this would ideally be presented in the form of a manual supported by guidance, examples of best practice and a tool kit identifying, for example, suitable reference material. It is anticipated that priority for undertaking risk assessments would be afforded to potential or new introductions. A retrospective trawl through all long-established nonnatives is unlikely to be productive and hence is of lower priority.

Sub-recommendation 2.4:
In the light of consultation with interested parties outlined in the two subrecommendations (2.5 & 2.6) below, a list of problem species should be developed for priority action including licensing and even exclusion from Britain (a 'High Risk List'), a list of species where more evidence is required as to their potential to cause problems (an 'Medium Risk List') and possibly also a list of species assessed as not being known to cause problems (a 'Low Risk List')

Sub-recommendation 2.5:
Further consultation is needed with the horticultural industry and other interested parties to determine the extent to which it would be practicable to require risk assessments on all new imported and introduced plant taxa.

Sub-recommendation 2.6:
Further consultation is needed with the horticultural industry and other interested parties to determine whether the creation of lists of non-native species known and demonstrated to have no negative effects ('low risk' or 'harmless' lists) would be achievable and beneficial.

Sub-recommendation 2.7:
Comparative assessments should be undertaken of the risks of introducing non-native species to Great Britain by a variety of importation pathways, as a basis for prioritizing

resources to the detection, monitoring and management of non-native species entering Great Britain.

• Key Recommendation 3: Develop codes of conduct to help prevent introductions for all relevant sectors in a participative fashion involving all relevant stakeholders.

• Key Recommendation 5: Revise and update existing legislation to improve handling of invasive non-native species issues.

Sub-recommendation 5.1:
Reform legislation to: ensure plants and animals are treated equally in law; ensure the correct list of species are targeted with legislative action, which should include a ban on the sale of relevant species; define duty of care by legal underpinning for codes of conduct and incorporate into EIA legislation for risk assessment for major developments that could lead to unintentional introductions of problem invasive species; provide for suitable powers and responsibilities for enforcement where required.

Sub-recommendation 5.2:
Consideration should be given to identifying those circumstances where responsibility for management or its costs should lie with those responsible for the illegal introduction of the non-native species. Consideration should also be given to providing a legal basis for imposing fines on the 'polluter pays' principle.

• Key Recommendation 6: Establish adequate monitoring and surveillance arrangements for non-native species in Great Britain.

Sub-recommendation 6.1:
Work should be undertaken to classify the status of all macro-organisms in Great Britain. This is a key task to underpin work on non-native species. The Review Group notes that there is no clear view on the way in which criteria should be set, and recommends that further research is necessary to determine how these should be applied.

Sub-recommendation 6.2:
Measures to develop monitoring systems for non-native species should not be delayed while classification work is completed, since the need for monitoring will remain, even if the list of species and habitats which require monitoring may require further modification.

Sub-recommendation 6.3:
A group of experts should be formed to collate scientific information on those species which are considered to have the highest potential for arrival and establishment in Britain, and which may cause conflicts.

Sub-recommendation 6.4:
Britain should play a key role in supporting the development of international networks on invasive non-native species, in order to improve the flow of information about the impacts of invasive non-native species in climates similar to that in Britain.

Sub-recommendation 6.5:

Priority should be given to developing information exchange with Britain's principal trading partners, by air and sea. It may, for example, be useful to know which invasive non-native species are present in and around the source of major trading pathways.

Sub-recommendation 6.6:
The role of existing surveillance inspectors should be broadened to include all non-native species and it is suggested that, consideration should be given to putting in place surveillance of movements of non-native species within Britain, in tandem with enforcement and public awareness measures, for invasive species that are causing serious damage.

Sub-recommendation 6.7:
Priority should be given to developing specific mechanisms to monitor the arrival and establishment of marine/aquatic invasive non-native species around British ports.

Sub-recommendation 6.8:
A full audit should be undertaken to determine where the most significant 'gaps' lie in the capacity to monitor the spread of non-natives. In assisting the development of these schemes, it is suggested that priority should be accorded to those schemes covering taxa or habitats that are known to be vulnerable to invasion by non-native species.

Sub-recommendation 6.9:
Government should seek support the development of recording schemes for taxa that possess invasive qualities for which there is currently insufficient means to monitor their establishment and spread, through capacity building of appropriate NGOs or volunteers.

Sub-recommendation 6.10:
Government should encourage the organisers of all biological recording schemes to gather data on the status of non-native species.

Sub-recommendation 6.11:
Recommend the National Biodiversity Network is the obvious route through which data on non-native species from across Great Britain can be made available.

Sub-recommendation 6.13:
Support should be provided to enable biological recording schemes to produce, regular reviews of the status of non-native species.

Sub-recommendation 6.14:
Statutory conservation agencies and NGOs should collaborate to ensure that biological atlases include data collection on non-native species, and that government funding is available to support their production.

Sub-recommendation 6.15:
Resources should be directed towards monitoring the impacts of invasive non-native species on the most threatened species and habitats.

Sub-recommendation 6.16:
Control programmes should always include resources to monitor the population demography of the target species, and the effectiveness of control programmes. This

should continue beyond the end of management measures, in order to determine that further invasion has not occurred and that the problem has been resolved.

• Key Recommendation 7: Policies should be established with respect to management and control of invasive non-native species currently present or newly arrived in the wild, and operational capacity be developed to implement these policies.

Sub-recommendation 7.1:
A structured approach to assess the impact and management of individual invasive non-native species should be developed. This should include impact assessment, cost estimation and cost-benefit analyses to agreed criteria. The output should accommodate a range of management options from review through limitation to control. These methods should include economic, biodiversity, social, animal welfare and animal and human health considerations. These analyses should provide criteria from which to prioritise actions relating to different species.

Sub-recommendation 7.2:
Co-ordinated methods of risk assessment and control should be established with other countries and across sectoral groupings to assess future risks, limit spread and share expertise.

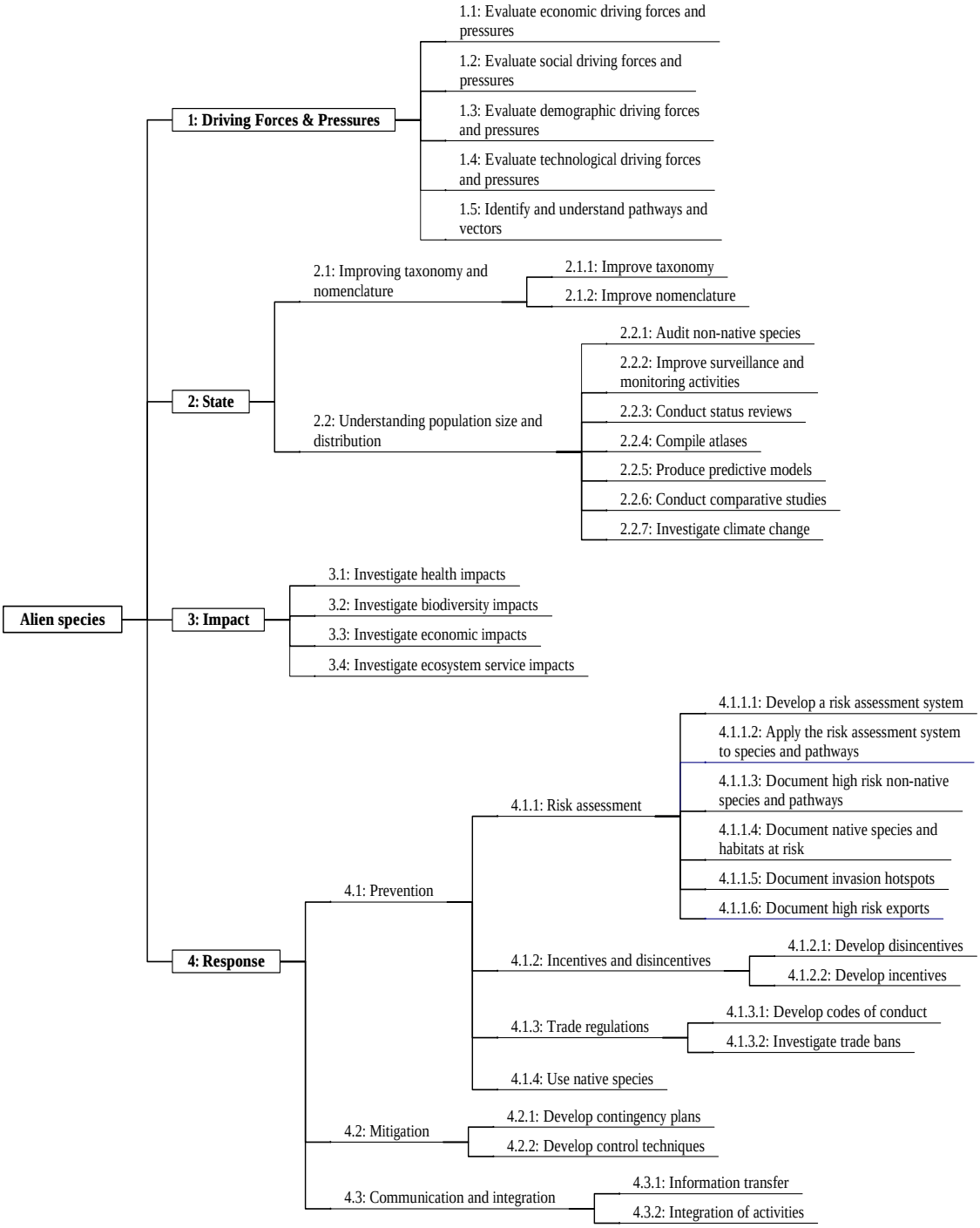
Sub-recommendation 7.3:
Individual agencies should be nominated to produce and implement management plans for dealing with particular invasive non-native species. Risk assessments and contingency plans should be prepared for species identified as likely to enter the country or to pose particular risks in advance of their arrival. Agencies should be empowered to act in advance of the species entering the country to ensure a rapid and co-ordinated response before the species becomes established. These agencies should also include a contingency capability to deal with the unexpected occurrence of species or species that cross existing sectoral responsibilities.

Sub-recommendation 7.4:
Strategic funding be should made available to support the development of novel control techniques for invasive non-native species and the establishment of centres of excellence for such methods.

Sub-recommendation 7.5:
Research should be conducted into the restoration of habitats or communities following the removal of invasive non-native species to restore their original biodiversity or economic value.

Sub-recommendation 7.6:
Methods of information transfer should be developed, through web-sites, email discussion groups, workshops and conferences, to disseminate information on effective control methods, both nationally and internationally

Annex 4. Up-dated non-native species research needs



1: Driving Forces & Pressures
1.1: Evaluate economic driving forces and pressures
Evaluate economic driving forces and pressures linked to the problem of non-native species, such as those associated with trade and financial subsidies

1.2: Evaluate social driving forces and pressures
Evaluate social driving forces and pressures linked to the problem of non-native species, such as trends in the desires and activities of humans

1.3: Evaluate demographic driving forces and pressures
Evaluate demographic driving forces and pressures linked to the problem of non-native species, such as trends in human population size, age structure and distribution

1.4: Evaluate technological driving forces and pressures
Evaluate technological driving forces and pressures linked to the problem of non-native species, such as e-commerce

1.5: Identify and understand pathways and vectors
Identify and understand pathways and vectors that give rise to non-native species

2: State
2.1: Improving taxonomy and nomenclature
2.1.1: Improve taxonomy
Improve taxonomic knowledge of non-native species where necessary

2.1.2: Improve nomenclature
Develop criteria for the classification of species according to their native/non-native and invasive/non-invasive status, and apply these to all macro-organisms in the UK

2.2: Understanding population size and distribution
2.2.1: Audit non-native species
Conduct a full, quantitative audit of non-native species, including distribution, population size and impacts

2.2.2: Improve surveillance and monitoring activities
Conduct a full audit of current monitoring and surveillance activities to identify key gaps in the capacity to detect and monitor the presence and distribution of non-native species, and fill key gaps

2.2.3: Conduct status reviews
Produce status reviews of non-native species

2.2.4: Compile atlases
Produce biological atlases that contain non-native species

2.2.5: Produce predictive models
Produce predictive models that describe the epidemiology of non-native species, including consideration of driving force, pressure, state, impact and response variables

2.2.6: Conduct comparative studies

Conduct comparative studies of non-native species within their native and non-native ranges, in particular concerning factors that limit population size and distribution

2.2.7: Investigate climate change
Investigate the impact of climate change on the characteristics of invasive non-native species and the vulnerability of habitats to invasion

3: Impact
Investigate ecosystem service impacts

3.1: Investigate health impacts
Investigate the impact of non-native species on the health of humans, crops, livestock and native species

3.2: Investigate biodiversity impacts
Investigate the impact of non-native species on biodiversity, including composition (gene-pools, species and habitats), structure and function

3.3: Investigate economic impacts
Investigate the economic impacts of non-native species

3.4: Investigate ecosystem service impacts
Investigate the impacts of non-native species on ecosystem services

4: Response
4.1: Prevention
4.1.1: Risk assessment
4.1.1.1: Develop a risk assessment system
Develop and publish a general risk assessment system that can be applied to all non-native species, pathways and receptor habitats

4.1.1.2: Apply the risk assessment system to species and pathways
Broadly apply the risk assessment system to species and pathways, followed by more detailed application for select species and pathways

4.1.1.3: Document high risk non-native species and pathways
Develop and regularly update an internet database of high risk non-native species and pathways

4.1.1.4: Document native species and habitats at risk
Develop and regularly update an internet database of priority native species and habitats that are at high risk from non-native species, including information on pathways, status, impacts and responses

4.1.1.5: Document invasion hotspots
Develop and regularly update an internet database of invasion hotspots, including information on driving forces, species and responses

4.1.1.6: Document high risk exports

Develop and regularly update an internet database of UK exports that could become invasive non-natives at their destination, including information on pathways, impacts and responses

4.1.2: Incentives and disincentives
4.1.2.1: Develop disincentives
Investigate disincentive measures to prevent non-native species problems, such as taxation and/or mandatory insurance for polluters

4.1.2.2: Develop incentives
Investigate incentive measures to prevent non-native species problems, such as subsidies for the use of native species in place of non-native species for the production of goods and services

4.1.3: Trade regulations
4.1.3.1: Develop codes of conduct
Develop codes of conduct to prevent introductions along high risk pathways where such codes are absent or inadequate

4.1.3.2: Investigate trade bans
Investigate the feasibility of trade bans as a means to reduce non-native species problems

4.1.4: Use native species
Investigate the potential use of native species in place of non-native species for the production of goods and services

4.2: Mitigation
4.2.1: Develop contingency plans
Develop contingency plans for future high risk non-native species that may enter the country

4.2.2: Develop control techniques
Review and evaluate techniques for the control and eradication of non-native species, and develop new techniques

4.3: Communication and integration
4.3.1: Information transfer
Develop methods for information transfer, including web-sites, e-mail discussion groups, workshops and conferences

4.3.2: Integration of activities
Integrate approaches to non-native species problems, particularly between the UK's principal trading partners and neighbouring countries

Annex 5. Current research activities concerning non-native species in the UK

Organisation: Oxford University
Contact person: David MacDonald
Research:

- Predictive modeling of alternative control strategies for mink on lowland rivers
- Field experiment on mink removal regarding effects on biodiversity
- Detailed interactions of mink and polecats
- Impacts of mink on water voles, terns, waterbirds and otters
- Impact of domestic cats on Scottish wildcats
- Competition between red squirrels and grey squirrels

Organisation: Cornwall County Council (in collaboration with Defra, Environment Agency, the South-West RDA, the Welsh Development Agency, British Waterways and Network Rail)
Contact person: Scott Sharples
Contractor: CABI Bioscience, Dick Shaw
Research:

- A four-year research project into the biological control of Japanese knotweed. The study will undertake the necessary research to establish whether biological control is a feasible method for the long-term, sustainable management of Japanese knotweed in the UK.

Organisation: DEFRA
Contact person: Christine Rumble
Research:

- Horizon Scanning – a new programme to improve the department's capability to anticipate and prepare for new risks and opportunities through the systematic study of new developments in science and society. In the first round of funding, six research projects were approved, including a scoping study to investigate the potential of alternative strategies for national biosecurity against introduced diseases, pests and non-native species.
- Standard Methodology to Assess the Risk Species Considered Possible Problem to the Environment - the ongoing review on problem species has confirmed the need for risk assessment of possible problem species to allow policy to be formulated within an established framework. Plant health risk assessment standards and schemes might be used as a basis for constructing a general risk assessment scheme that can be applied to all non-native species. This would contribute to the formulation of robust and consistent policy decisions across the range of species and enable the implications of the problems to be costed.

Organisation: Liverpool University
Contact person: Rob H Marrs
Research:

- Development of a web-based database on invasive species in the UK. Part-compleled and additional information being added as time and costs permit.

Organisation: The National Trust
Contact person: Simon Ford
Research:

- Control of Japanese Knotweed by using a stem injection method

Organisation: Imperial College
Contact person: Yvonne Buckley
Research:

- Population ecology of invasive plants - controlling *Echium*

Organisation: Universities Federation for Animal Welfare
Contact person: James K Kirkwood
Research:

- Humane methods of control of non-native species and in methods to resolve the animal welfare / conservation conflicts that can arise in controlling non-native species

Organisation: Paisley University
Contact person: B Tigar
Research:

- Dispersal of an invasive pest: tracing the origins of *Prostephanus truncatus* using stable isotope analysis, molecular genetics & trace element analysis

Organisation: Herpetological Conservation Trust
Contact person: Tony Gent
Research:

- Preliminary investigations of control of Salal (*Gaultheria shallon*) within heathland
- Preliminary investigations of control of Hottentot-fig (*Carpobrotus edulis*)

Organisation: English Nature
Contact person: ?
Research:

- Control of American Bullfrogs (*Rana catesbeiana*)

Organisation: NERC Centre for Population Biology
Contact person: Charles Godfray
Research:

- Studies of the population dynamics and community ecology consequences of plant invasions in the UK (in particular experimental work on non-natives in the genus *Conyza* and *Senecio aequidens*), and evolutionary comparisons of plants as invasives and endemics (e.g. *Cytisus*)
- Macroecological studies of the non-native components of different floras
- Experimental studies of the effects of non-native plants on ecosystem services and function: large scale manipulation experiments in the Argentinian wet pampas
- Models of the control of invasive plants by different management strategies (including insects and pathogens); theoretical studies in collaboration with experimental groups in the UK, New Zealand, Australia and South Africa
- Studies of the dynamics, ecology and ecological genetics of invasive insects in the UK, especially gall wasps and leaf miners
- Studies of the non-target effects of insect biocontrol agents of plants; the theory of biological control, the deliberate release of non-native organisms

Organisation: CSL - Wildlife Ecology and Management Group
Contact person: Niall Moore
Research:

- Carrying out a five-year eradication campaign on American mink in the Western Isles, Scotland and a control trial of ruddy ducks with the objective of a full eradication campaign for ruddy ducks in the UK beginning in 2004. Both of these campaigns have substantial research and modelling components built into them. These research components range from research into the basic ecology of the species, their impact on native fauna, spatial modelling and an assessment of their population dynamics, particularly as control proceeds.
- Compiling a database of UK offshore islands and the non-native terrestrial vertebrates that are present on each. Analysis will include assessing the factors influencing invasibility of island ecosystems, those factors influencing the occurrence of particular non-native species and an assessment of priorities for future management action.
- Examining the ecology of feral ferrets from the Western Isles and Shetland, looking at diet to assess impact on native fauna and modelling the population dynamics of the population. The group is also carrying out research into the newly-established population of feral wild boar in England, including monitoring spread within the main populations, modelling the potential for disease transmission and assessing management options. Data on distribution have been supplied to NBN.
- The group has carried out qualitative risk assessments on several vertebrate species perceived as posing a threat to agriculture and the environment. These have included Egyptian geese, ring-necked parakeets and feral wild boar.

Organisation: CSL - Plant Health Group
Contact person: Niall Moore
Research:

- The Group's mission is to provide the highest quality scientific consultancy and services based on research to (a) safeguard crops and the environment from invasive pests and diseases and to facilitate international trade in plants and planting material, and (b) to contribute scientific expertise, legislative experience and research excellence through the independent GM Inspectorate and its forensic research back up. The work of the Group is focused in the following main areas:
- Science consultancy support for international plant health policy.
- Pest and disease diagnosis to international standard in support of plant health legislation and commercially.
- Plant health risk analysis and management to deal with quarantine contingency issues.
- Research and development of diagnostics for laboratory and field use.
- Investigation of quarantine pest and disease biology to complete risk assessments.
- Provision of the GM Inspectorate for England and Wales and its supporting forensic research.

Organisation: Forestry Commission
Contact person: Steve Gregory
Research:

- Long-standing research programmes into the management of grey squirrels and large herbivores such as deer. Deer research makes no strong distinction between native and non-native species
- Research into the management of mammals also includes monitoring and "horizon scanning" to keep an eye on the behaviour of potentially troublesome species already in the UK or potentially so
- Maintenance of a substantial research effort on weed control for establishment and management of woodland (rhododendron has figured in the research)
- Research includes the examination of ecosystem functioning, which turns up threats by invasives from time to time
- Through the MONARCH project, investigation of species that may invade habitats as the climate changes
- A recently completed study of black poplar in Britain and Ireland in which one of the issues was potential introgression from introduced, related cultivars and hybrids
- With regard to Plant Health Regulation in GB related to forest trees, work is directed at the evidence base for risk assessment, at methods of monitoring and diagnosis, and at means of containment, control and eradication of pests (e.g. insects, fungi and nematodes)

Organisation: NERC Centre for Ecology & Hydrology
Contact person: Phil Hulme
Research:

- Coordination of the invasion module a major EU project assessing large scale risks. Over the next five years the project will developed integrated risk analysis toolkits that account for species traits, environmental hazards, ecosystem vulnerability and the costs of mitigation in their decision-making. In the UK, the work involves analysis of species databases, assessments of environmental drivers, estimates of impact and mitigation for a wide range of freshwater and terrestrial taxa. Parallel initiatives are being undertaken in several other European states to ensure complimentarity of the toolkits
- Several related projects are currently examining the spread and impact of monkeyflower, non-native gallwasps and exotic fish
- Non-native species have integrated into methods for Site Condition Monitoring of standing water habitats and in WFD approaches to macrophyte classification. Similarly, we are examining the occurrence of non-native plants within the Countryside Surveys and the new UK Plant Atlas to establish estimates of rate of change and habitat vulnerability.

Organisation: Centre for Environment, Fisheries & Aquaculture Science (CEFAS)
Contact person: Gordon H. Copp
Research:

- A 5-year Defra-funded contract examining the risks and impacts of non-native freshwater fishes, including both field research on issues related to introduction (means thereof, rates, etc.), establishment (life history traits and climate change in particular), dispersal (within river systems and across salinity barriers), impacts (interspecific interactions between native and non-native species, etc.) and the development of risk assessment protocols (derived from existing plant and plant pest protocols (i.e. the Weed Risk Assessment scoring system by Phelong et al. and the EPPO quarantine vetting protocol). These activities include associated

doctoral studies on small-bodied non-native fishes (sunbleak and topmouth gudgeon) in collaboration with CEH-Dorset, CEFAS-Weymouth, HIFI (Hull), and a Marie Curie post-doc expected to start in January 2004 on dispersal patterns in non-native fishes. This contract is also complemented by a NATO collaborative linkage grant for 2003-2004 to facilitate studies on use of life history traits as predictors of invasiveness (Slovak, Spanish, Canadian, Slovenian partners).

Organisation: Scottish Association for Marine Science
Contact person: Dr Elizabeth Cook & Dr Kate Willis
Research:

- Research into the ecology of Caprella mutica (The Skeleton Shrimp) and its impact on fisheries in Scotland. For further information see: www.sams.ac.uk/dml/projects/coastal/caprellid.htm

Organisation: Swansea County Council
Contact person: Sean Hathaway
Research:

- Research into the management and control of Japanese Knotweed.

Organisation: Natural History Museum, London
Contact person: Johannes Vogel
Research:

- Introgression and competition between the British and Spanish Bluebell;
- Identifying and cataloguing novel alien bryophyte and pteridophyte taxa and their mode(s) of introduction;
- consideration of life-history attributes, breeding system, ecology, etc. to produce better informed opinion as to native status for equivocal bryophyte and pteridophyte taxa;
- Ecology and genetic of the invasive bryophyte *Campylopus introflexus*;
- Identification of unrecognised insects received by the Ministry of Agriculture Central Science Laboratory;
- Watching brief on undescribed species in most insect genera (e.g. a recent whitefly discovery here on bay leaves imported from Colombia);
- Research into parasite ecology, specifically macroparasites of European eels *Anguilla anguilal*. Special emphasis on *Angillicola crassus*, a parasitic and potentially pathogenic nematode originally found in Japanese eels *Anguilla japonica*;
- Ecology and spread of Chinese Mitten Crab;
- Monitoring and recording taxa new to the British beetle fauna:
    - *Otiorhynchus armadillo* (Rossi) Curculionidae: Southern European pest newly established in Britain
    - *Otiorhynchus salicicola* Heyden Curculionidae: Southern European pest newly established in Britain
    - *Otiorhynchus aurifer* (Boh.) Curculionidae Southern European pest. Expanded range in England.
    - *Otiorhynchus crataegi* Germar Curculionidae. Southern European pest. Expanded range in England.
    - *Otiorhynchus setosulus* Herbst: Southern European non-pest. Expanded range in England.

    - *Tuponia brevirostris* Reuter (Hemiptera: Miridae): First British Record: Southern European non-pest species. Breeding.
    - *Chrysolina americana* (Linnaeus) Chrysomelidae: Southern European minor pest species: expansion of range in UK 2002.
    - *Nezara viridula* (L.) Southern Green Shield Bug. Hemiptera: Pentatomidae: First breeding record UK, cosmopolitan pest.
- Monitoring of the brackish water mussel *Mytilopsis leucophaeta* in the Thames Estuary
- Regular surveys of the Keyhaven-Lymington Lagoon system with monitoring of the local population of *Desdomona ornata* (Polychaeta; Sabellariidae
- Monitoring and recording of the only known alien pycnogonid in the UK, *Ammothea hilgendorfii*
- Monitoring sea water alien species during various routine surveys and monitoring work that forms part of NHMs commercial contract business

Organisation: University of Durham
Contact person: Professor B Huntley
Research:

- Researching a facility for modelling the spatio-temporal dynamics of ecological and environmental processes, including exploration of the dynamics of invasion of native communities by alien species.

Organisation: Marine Biological Association UK
Contact person: Dr SR Jenkins
Research:

- Susceptibility of marine algal communities to alien invasion: role of functional diversity.

Organisation: University of Birmingham
Contact person: Dr PG Angold
Research:

- Studentship: Hydrogeomorphological control of competitive interactions between native and alien plant species

Organisation: University of Lancaster
Contact person: Dr ND Paul
Research:

- Studentship: Mechanisms of tolerance in groundsel attacked by native and alien pathogens

Organisation: Loughborough University
Contact person: Dr Lois Child
Research:

- Ecology and control of invasive riparian plants, Japanese knotweed (*Fallopia japonica*), giant hogweed (*Heracleum mantegazzianum*), Himalayan balsam (*Impatiens glandulifera*), *Crassula helmsii* and *Azolla filiculoides*
- Distribution and regeneration potential of *Fallopia japonica* and *Fallopia x bohemica*
- Combination treatments for the management of Japanese knotweed (*Fallopia japonica*)
- Distribution surveys of Japanese knotweed in Swansea

- The Japanese Knotweed Manual
- Interactions between Japanese knotweed and environmental characteristics including soils
- Investigation of underground structures of Japanese knotweed
- 3-year postgraduate research into the mathematical modelling of the spatial spread of Japanese knotweed (*Fallopia japonica*) on a local scale in the UK using empirical data from the City and Council of Swansea as a benchmark. Research includes deterministic and stochastic models of aerial shoots and subterranean rhizomes. Eventually we hope to include various management techniques in the models to facilitate cost and effect appraisal.

Organization: School of Biological Sciences, University of Wales Swansea
Contact person: Dr Peter Dyrynda
Research:

- Studies on distributions and ecology of non-native marine seaweeds and invertebrates in selected docks, harbours, estuaries, lagoons and other coastal environments (this year at sites in the UK, mainland Europe and USA). Long term focus sites in the UK include Poole Harbour (18 year re-assessment completed recently) and the Fleet Lagoon.
- Authoring of educational marine biodiversity web sites. The following include some coverage of non-native species and their impacts: www.solaster-mb.org/mb; www.swan.ac.uk/biodiv/poole; www.swan.ac.uk/biodiv/fleet

Table 1. Citations of non-native species as threatening factors within the UK Biodiversity Action Plans

Action Plan	Threatening factor			
	Competition	Habitat loss	Predation	Disease
Upland oakwood	X			
Lowland beech and yew woodland	X	X		
Upland mixed ashwoods	X			
Wet woodland	X			X
Lowland calcareous grassland	X			
Lowland heathland		X		
Upland heathland				X
Mesotrophic lakes	X	X		
Eutrophic standing waters	X			
Chalk rivers		X		
Maritime cliff and slopes	X		X	
Machair			X	
Littoral and sublittoral chalk	X			
Coastal saltmarsh	X			
Mudflats	X			
Seagrass beds	X			
Sheltered muddy gravels	X	X		
Wilson's Pouchwort (*Acrobolbus wilsonii*)		X		
Ribbon-leaved Water-plantain (*Alisma gramineum*)	X			
Water Vole (*Arvicola terrestris*)			X	
Wild Asparagus (*Asparagus officinalis* ssp. *prostratus*)	X			
Freshwater White-clawed Crayfish (*Austropotamobius pallipes*)	X			X
Carder Bumblebee (*Bombus humilis*)	X			
Large Garden Bumblebee (*Bombus ruderatus*)	X			
Short-haired bumble-bee (*Bombus subterraneus*)	X			
Shrill Carder Bee (*Bombus sylvarum*)	X			
Dune Threadmoss (*Bryum mamillatum*)	X			
Long-leaved Threadmoss (*Bryum neodamense*)	X			
Sea bryum (*Bryum warneum*)	X			
Convergent Stonewort (*Chara connivens*)	X			
Lesser Bearded Stonewort (*Chara curta*)		X		
a Hoverfly (*Chrysotoxum octomaculatum*)		X		
Lundy Cabbage (*Coincya wrightii*)		X		
Vendace (*Coregonus albula*)	X		X	
Wild Cotoneaster (*Cotoneaster integerrimus*)	X			
Corncrake (*Crex crex*)			X	
Starfruit (*Damasonium alisma*)	X			
Ladybird Spider (*Eresus sandaliatus*)	X			
Pink Sea-fan (*Eunicella verrucosa*)	X		X	X
Spangled Water Beetle (*Graphoderus zonatus*)		X		
Grouped plan for river shingle beetles		X		
Grouped plan for tooth fungi	X			
Medicinal Leech (*Hirudo medicinalis*)		X		
Atlantic lejeunea (*Lejeunea mandonii*)	X			
Thatch Moss (*Leptodontium gemmascens*)	X			
Sunset Cup Coral (*Leptopsammia pruvoti*)	X			
Common Scoter (*Melanitta nigra*)	X		X	
Slender Naiad (*Najas flexilis*)	X			
Slender Thread-moss (*Orthodontium gracile*)	X			
Native Oyster (*Ostrea edulis*)	X			X
Grey Partridge (*Perdix perdix*)	X		X	X
Pillwort (*Pilularia globulifera*)	X			
Shetland Pondweed (*Potamogeton rutilus*)		X		
Three-lobed Water-crowfoot (*Ranunculus tripartitus*)		X		
Violet Crystalwort (*Riccia huebeneriana*)	X			
Shore Dock (*Rumex rupestris*)	X			
Red Squirrel (*Sciurus vulgaris*)	X			
Prostrate Feather-moss (*Sematophyllum demissum*)	X			
Ley's whitebeam (*Sorbus leyana*)	X			
Great Tassel Stonewort (*Tolypella prolifera*)	X			
Tadpole Shrimp (*Triops cancriformis*)			X	
Beaked Beardless-moss (*Weissia rostellata*)	X			
Knothole Moss (*Zygodon forsteri*)	X			

Table 2. Comparison between up-dated research actions and research projects identified within BRWG (2001).

Up-dated actions	1. Removal of non-natives	2. Basic biology, database and monitoring	3. Genetic vulnerability	4. Genetic impacts	5. Indirect impacts on species	6. Functional impacts	7. Decision support system	8. Cost-benefit analysis of proposed introductions	9. Scientific basis for management	10. Genetic conservation	11. Adaptation and climate change	12. Research prioritisation	13. Impacts of controlling diseases/parasites	14. Development of responses	15. Risk assessment	16. Control techniques and feasibility
1.1: Monitoring driving forces and pressures																
1.2.1: Evaluating economic and technological driving forces and pressures																
1.2.2: Evaluating social driving forces and pressures																
1.2.3: Evaluating demographic driving forces and pressures																
2.1: Monitoring status		X														
2.2.1: Improving taxonomy																
2.2.2: Improving nomenclature																
2.3.1: Surveying UK ports		X														
2.3.2: Auditing monitoring schemes																
2.3.3: Improving monitoring schemes		X														
2.3.4: Developing new monitoring schemes		X														
2.3.5: Conducting status reviews		X														
2.3.6: Compiling atlases		X														
2.3.7: Producing predictive models		X														
2.3.8: Conducting comparative studies		X														
2.3.9: Investigating climate change											X					
3.1: Monitoring impacts																
3.2: Human health impacts																
3.3.1.1: Impacts on gene-pool composition			X	X												
3.3.1.2: Impacts on species composition					X											
3.3.1.3: Impacts on habitat composition																
3.3.2: Impacts on biodiversity structure																
3.3.3: Impacts on biodiversity function				X	X	X										
3.4: Economic impacts																
4.1: Monitoring responses																
4.2.1.1: Risk assessment scheme								X	X						X	
4.2.1.2: High risk non-native species groups																
4.2.1.3: Registry of established high risk non-natives		X					X									
4.2.1.4: Registry of non-established high risk non-natives		X														
4.2.1.5: Registry of high risk pathways		X													X	
4.2.1.6: Registry of natives at risk		X	X													

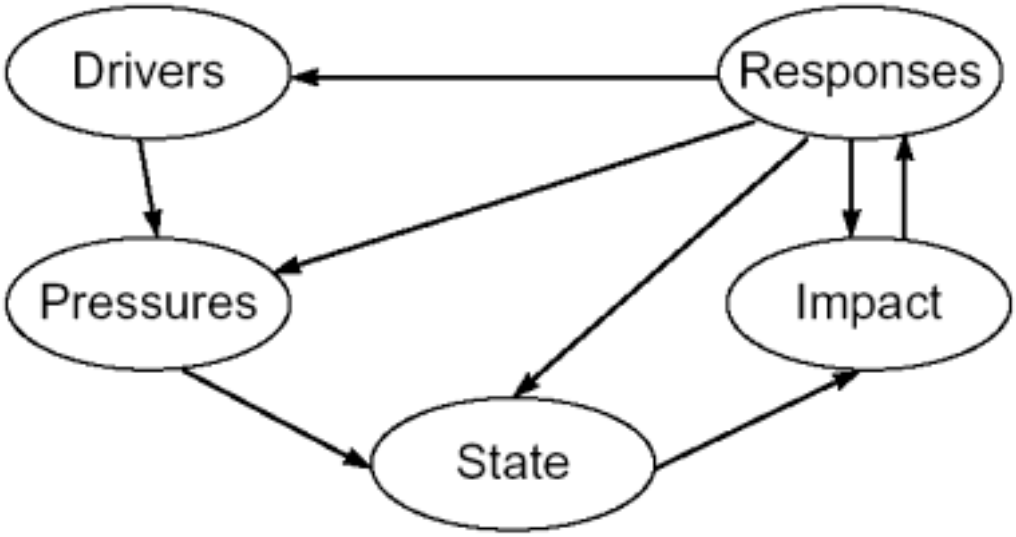
Up-dated actions	1. Removal of non-natives	2. Basic biology, database and monitoring	3. Genetic vulnerability	4. Genetic impacts	5. Indirect impacts on species	6. Functional impacts	7. Decision support system	8. Cost-benefit analysis of proposed introductions	9. Scientific basis for management	10. Genetic conservation	11. Adaptation and climate change	12. Research prioritisation	13. Impacts of controlling diseases/parasites	14. Development of responses	15. Risk assessment	16. Control techniques and feasibility
4.2.1.7: Registry of habitats at risk		X														
4.2.1.8. Registry of invasion hotspots															X	
4.2.1.9: Registry of high risk exports																
4.2.3.1: Disincentives														X		
4.2.3.2: Incentives														X		
4.2.4.1: Codes of conduct														X		
4.2.4.2: Trade bans														X		
4.2.5: Use of native species														X		
4.3.1: Decision support system							X		X			X		X		X
4.3.2: Contingency plans for future non-natives																
4.3.3.1: Review of control techniques													X			X
4.3.3.2: Development of control techniques	X								X				X	X		
4.3.4: Habitat resistance and recovery																
4.4.1: Information transfer																
4.4.2: Integration of activities																

Table 3. Comparison between up-dated research actions and research-related recommendations from DEFRA (2003).

Up-dated actions	2.1: Non-native species groups	2.2: Develop risk assessment scheme	2.3: Publish risk assessment scheme	2.4: High risk list	2.5: Risk assessments and horticulture	2.6: Low risk list and horticulture	2.7: High risk pathways	3: Develop codes of conduct	5.1: Trade bans, codes of conduct and EIAs	5.2: Polluter pays	6.1: Nomenclature	6.2: Monitoring population status	6.3: Identification of future non-natives	6.4: International networks	6.5: Networking trading partners	6.6: Surveillance inspectors	6.7: Monitoring at ports	6.8: Monitoring gaps	6.9: Development of recording schemes	6.10: Improving coverage of non-natives	6.11: National Biodiversity Network	6.13: Status reviews	6.14: Biological atlases	6.15: Monitoring impacts	6.16: Demography of controlled populations	7.1: Impact assessment and management	7.2: International coordination	7.3: Management and contingency plans	7.4: Novel control techniques	7.5: Restoration	7.6: Information transfer
1.1: Monitoring driving forces and pressures																															
1.2.1: Evaluating econ. and technol. driving forces/pressures																															
1.2.2: Evaluating social driving forces and pressures																															
1.2.3: Evaluating demographic driving forces and pressures																															
2.1: Monitoring status												X				X														
2.2.1: Improving taxonomy																															
2.2.2: Improving nomenclature											X																				
2.3.1: Surveying UK ports																	X														
2.3.2: Auditing monitoring schemes																		X													
2.3.3: Improving monitoring schemes																			X	X											
2.3.4: Developing new monitoring schemes																			X												
2.3.5: Conducting status reviews																						X									
2.3.6: Compiling atlases																							X								
2.3.7: Producing predictive models																															
2.3.8: Conducting comparative studies																															
2.3.9: Investigating climate change																															
3.1: Monitoring impacts																								X							
3.2: Human health impacts																										X					
3.3.1.1: Impacts on gene-pool composition																										X					
3.3.1.2: Impacts on species composition																										X					
3.3.1.3: Impacts on habitat composition																										X					
3.3.2: Impacts on biodiversity structure																										X					
3.3.3: Impacts on biodiversity function																										X					
3.4: Economic impacts																										X					

Up-dated actions	2.1: Non-native species groups	2.2: Develop risk assessment scheme	2.3: Publish risk assessment scheme	2.4: High risk list	2.5: Risk assessments and horticulture	2.6: Low risk list and horticulture	2.7: High risk pathways	3: Develop codes of conduct	5.1: Trade bans, codes of conduct and EIAs	5.2: Polluter pays	6.1: Nomenclature	6.2: Monitoring population status	6.3: Identification of future non-natives	6.4: International networks	6.5: Networking trading partners	6.6: Surveillance inspectors	6.7: Monitoring at ports	6.8: Monitoring gaps	6.9: Development of recording schemes	6.10: Improving coverage of non-natives	6.11: National Biodiversity Network	6.13: Status reviews	6.14: Biological atlases	6.15: Monitoring impacts	6.16: Demography of controlled populations	7.1: Impact assessment and management	7.2: International coordination	7.3: Management and contingency plans	7.4: Novel control techniques	7.5: Restoration	7.6: Information transfer
4.1: Monitoring responses																														
4.2.1.1: Risk assessment scheme		X	X																											
4.2.1.2: High risk non-native species groups	X																													
4.2.1.3: Registry of established high risk non-natives				X																										
4.2.1.4: Registry of non-established high risk non-natives				X	X								X																	
4.2.1.5: Registry of high risk pathways							X																							
4.2.1.6: Registry of natives at risk																														
4.2.1.7: Registry of habitats at risk																														
4.2.1.8. Registry of invasion hotspots																														
4.2.1.9: Registry of high risk exports																														
4.2.3.1: Disincentives										X																				
4.2.3.2: Incentives																														
4.2.4.1: Codes of conduct								X																						
4.2.4.2: Trade bans									X																					
4.2.5: Use of native species																														
4.3.1: Decision support system																										X		X		
4.3.2: Contingency plans for future non-natives																												X		
4.3.3.1: Review of control techniques																													X	
4.3.3.2: Development of control techniques																									X				X	
4.3.4: Habitat resistance and recovery																														X
4.4.1: Information transfer														X	X						X									X
4.4.2: Integration of activities																											X			

Figure 1. Driving Forces-Pressure-State-Impact-Response (DPSIR) Framework[1]



[1]For the purpose of categorizing research actions within this report, distinction between Drivers and Pressures was not considered necessary.