The UK risk assessment scheme for all non-native species

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Summary

1. A pest risk assessment scheme, adapted from the EPPO (European and Mediterranean Plant Protection Organisation) scheme, was developed to assess the risks posed to UK species, habitats and ecosystems by non-native taxa.

2. The scheme provides a structured framework for evaluating the potential for non-native organisms, whether intentional or unintentional introductions, to enter, establish, spread and cause significant impacts in all or part of the UK. Specialist modules permit the relative importance of entry pathways, the vulnerability of receptors and the consequences of policies to be assessed and appropriate risk management options to be selected. Spreadsheets for summarising the level of risk and uncertainty, invasive attributes and economic impact were created. In addition, new methods for quantifying economic impact and summarising risk and uncertainty were explored.

3. Although designed for the UK, the scheme can readily be applied elsewhere.

Key words: Alien, Invasive Attributes, Hazard identification, Pathways, Summarising Risks, Receptors, Uncertainty

1. Introduction

The Convention on Biological Diversity (CBD) guiding principles on invasive alien species (CBD 2004) and the European Strategy for Invasive Alien Species (Genovesi & Shine 2004) highlight the importance of risk assessment in non-native species policy. A review of non-

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native species policy in the UK (Defra 2003) also concluded that comprehensive, accepted risk assessment procedures were required to identify those species that pose the greatest threat and to set priorities for action. Surveys of existing non-native risk assessment techniques identified the European and Mediterranean Plant Protection Organisation (EPPO) pest risk assessment scheme (EPPO 1997, 2006) as suitable for application to taxonomic groups other than plants (e.g. fish; Copp et al. 2005b) and subsequently for the development of a generic scheme that could be applied to all non-native taxa. Although, like all schemes, its usability depends on the amount of information available, the EPPO scheme has a number of advantages. It has been under development since 1990, subjected to significant testing, provides a logical structure that separates the assessment of entry, establishment, spread and impacts and follows International Plant Protection Convention (IPPC) standards for pest risk analysis, PRA (FAO 2004) that are recognised by the World Trade Organisation Sanitary and Phytosanitary Agreement, WTO-SPS (WTO 1994).

Although the EPPO pest risk assessment scheme was originally designed to assess the risks posed by the unintentional entry of invertebrate and pathogen pests to cultivated plants, environmental impacts could also be considered (EPPO 1997). Clarification that the IPPC definition of a pest includes all species directly or indirectly injurious to plants (FAO 2006) together with attempts to determine the extent to which plant health regulations can assist the CBD in tackling the threat posed by invasive alien species led to a re-examination of the IPPC PRA standard (FAO 2004) and national PRA schemes to determine the extent to which they can be restructured for intentional introductions of non-native species, such as invasive plants. An IPPC standard on the introduction of beneficial organisms in which potential economic and environmental risks are considered has also been published (FAO 2005). Previous studies have shown that the assessment of invasion risks has common elements regardless of the taxon or the method of entry (Schrader & Unger 2003, Baker et al. 2005a). Thus, the aim of the present study was to adapt the EPPO protocols and to develop a generic risk identification and assessment framework with which to assess the risks posed by any non-native taxon to UK species, habitats and ecosystems.

2. Methodology

In the initial phase of development, the latest available draft of the EPPO pest risk assessment scheme (EPPO 2003) was reformatted into a table and circulated to experts who carried out trial risk assessments on 34 non-native species that are already present in the UK or that could enter intentionally or unintentionally. The species were selected from 12 different taxon-habitat combinations (Table 1) to ensure the scheme would be as generic as possible.

Following the trials, some protocols were modified or clarifications were provided, which in most cases were in the form of short, explanatory notes to aid interpretation of the questions. Two fundamental, post-trial changes were implemented to ensure that the scheme could be used to assess the risks posed by (a) non-native species from trophic levels other than herbivores and (b) intentional introductions. In the section of the scheme where the presence of particular host organisms is required for the successful establishment of the non-native organ-

Table 1: Non-native taxa used for testing and developing the UK risk assessment scheme.

Species	Taxon and Habitat
Giant hogweed *Heracleum mantegazzianum*	Terrestrial Plant
Himalayan balsam *Impatiens glandulifera*	Terrestrial Plant
Japanese knotweed *Fallopia japonica*	Terrestrial Plant
Water fern *Azolla filiculoides*	Aquatic Plant
Australian swamp stonecrop *Crassula helmsii*	Aquatic Plant
Floating pennywort *Hydrocotyle ranunculoides*	Aquatic Plant
Parrot's feather *Myriophyllum aquaticum*	Aquatic Plant
Curly waterweed *Lagarosiphon major*	Aquatic Plant
New Zealand flatworm *Arthurdendyus triangulatus*	Terrestrial Invertebrate
Western corn rootworm *Diabrotica virgifera virgifera*	Terrestrial Invertebrate
Asian longhorn beetle *Anoplophora glabripennis*	Terrestrial Invertebrate
Small hive beetle *Aethina tumida*	Terrestrial Invertebrate
Chrysanthemum stem necrosis virus	Plant pathogen
Rabies Lyssa Virus	Terrestrial vertebrate pathogen
Insect fungal pathogen: *Metarhizium anisopliae*	Terrestrial invertebrate pathogen
Insect fungal pathogen: *Metarhizium anisopliae* var. *Acridum*	Terrestrial invertebrate pathogen
Salmon parasite: *Gyrodactylus salaris*	Aquatic vertebrate pathogen
Crayfish plague: *Aphanomyces astaci*	Aquatic invertebrate pathogen
Sunbleak *Leucaspius delineatus*	Fish
Blageon *Leuciscus souffia*	Fish
Rainbow trout *Oncorhynchus mykiss*	Fish
Northern redbelly dace *Phoxinus eos*	Fish
Fathead minnow *Pimephales promelas*	Fish
Topmouth gudgeon *Pseudorasbora parva*	Fish
European catfish *Siluris glanis*	Fish
Ring-necked parakeet *Psittacula krameri*	Birds
Indian house crow *Corvus splendens*	Birds
American mink *Mustela vison*	Mammal
Wild boar *Sus scrofa*	Mammal
Skunk *Mephitis mephitis*	Mammal
Whitefly parasitoid: *Eretmocerus eremicus*	Biocontrol agent
Harlequin beetle *Harmonia axyridis*	Biocontrol agent
Predatory bug: *Macrolophus melanotoma*	Biocontrol agent
Predatory mite: *Amblyseius cucumeris*	Biocontrol agent

ism, this section was extended to include a requirement for suitable habitats (for non-native organisms), prey (for predators) or hosts (for parasites). In addition to suitable habitats, some organisms also require other species at critical stages in their life cycle (e.g. pollinators, seed dispersers or root symbionts for plants; mussel incubators for the eggs of fish such as bitterlings *Rhodeus* spp.), and this was also included in the scheme. For intentional pathways, a short cut can be made since entry is certain and a detailed pathway analysis is not needed unless other unintentional pathways also exist. The assessment therefore focuses on the extent to which the organism can spread from the intended habitat (e.g. garden ponds), and establish in unintended habitats (e.g. natural and semi-natural ponds and lakes).

Definitions in the field of invasion biology can cause problems, partly because of a lack of consensus between invasion biologists (Richardson et al. 2000) and partly from the disparity between definitions used by the CBD and

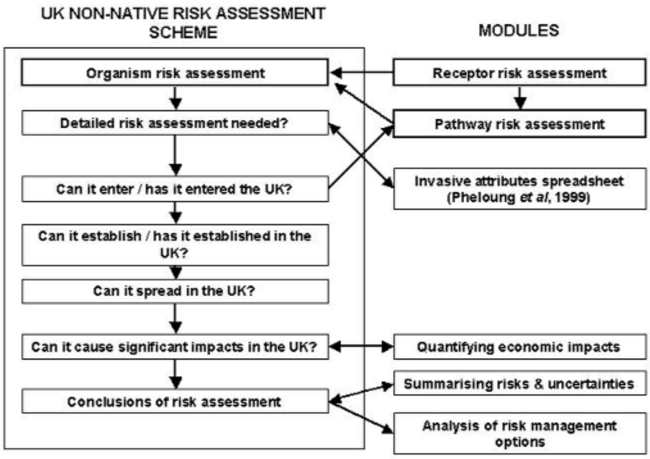

Fig. 1: Schematic representation of the UK non-native species risk assessment framework, its decision tree and its various modules.

the IPPC. Indeed, the IPPC does not use the term "alien" and does not differentiate between those species that can enter naturally or through man's agency. In the present scheme, which can be used for both methods of entry, "non-native" is considered synonymous to "alien" as per UK practice (Manchester & Bullock 2000, Copp et al. 2005a).

3. Description of the UK Non-Native Risk Assessment Scheme

The scheme (Fig. 1), which is available for download (Baker et al. 2005b), begins with Stage 1 in which a description of the reason for performing the risk assessment is required; the area at risk is defined and the relevance of earlier risk assessments is considered. The risk assessment itself (Stage 2) is divided into two sections (A, B). In Section A, organisms are screened via 14 questions to identify whether a detailed risk assessment (Section B) is warranted. Section A is particularly valuable when screening a large number of species that may be carried on a pathway. It is not normally necessary to conduct detailed risk assessments on species that are already considered to have reached the limits of their potential range outdoors or in protected conditions, e.g. glasshouses, but a study of possible further spread and additional impacts of widespread organisms under new management procedures, revised policies or climate change may still be required. If the answers to Section A questions lead the assessor to the conclusion that a detailed risk assessment is not warranted, then no further assessment is undertaken, though changes in the species' status may require a re-assessment. The species identified as high risk, and thus subject to assessment in Section B, must be taxonomically distinct, have invasive attributes, a potential for establishment and spread and the capability of causing unacceptable economic, environmental or social impacts in the area under consideration.

The detailed risk assessment scheme in Section B contains 51 questions that are designed to assess the potential for entry and establishment, the capacity for spread and the extent to which significant economic, environmental or social impacts may occur. The assessor is required to choose one of five levels of responses (with different words relating to very low, low, medium, high, very high risk) and one of three levels of uncertainty (low, medium, high), justifying these with a written, referenced comment. If any of the responses to the six key questions on impact are "massive" or "very likely", then the evaluation of a further six subsidiary questions may not be necessary. Guidance is provided on the procedures that should be adopted when information is particularly lacking or highly uncertain. Four examples of best practice have been included: a plant (Japanese knotweed, *Fallopia japonica*), an insect fungal pathogen (*Metarhizium anisopliae*), a fish (topmouth gudgeon, *Pseudorasbora parva*) and a bird (the Indian house crow, *Corvus splendens*). The scheme is currently provided as a spreadsheet template with a manual describing the procedures that should be followed (Baker et al. 2005b).

Three of the modules are designed to assist with the risk assessment by helping the assessor to determine whether the species has invasive attributes (Module 1), to quantify economic impacts (Module 4) and to summarise overall risk and uncertainty into low, medium or high categories (Module 5). Two of the modules provide a different perspective on non-native risk assessment, enabling the relative importance of entry pathways (Module 2) and the vulnerability of receptors (Module 3) to be assessed. Module 6 is a decision support scheme for selecting risk management measures, primarily to prevent entry. The modules can be accessed directly through icons embedded in the spreadsheet template.

3.1. The Invasive Attributes Spreadsheet (Module 1)

The spreadsheet created by Pheloung et al. (1999) for the Australian weed risk assessment (WRA), which has also been successfully adopted in Hawaii (Daehler et al. 2004), was obtained from the authors and adapted for freshwater fish (Copp et al. 2005b, 2005c), and subsequently for marine fish, marine invertebrates, amphibia and plants (http://www. cefas.co.uk/4200.aspx). These adapted versions of the Pheloung et al. (1999) WRA are essentially plug-ins, which are intended to provide the assessor with a less subjective means of determining whether an organism has invasive attributes when screening species in Section A of the scheme. These plug-ins may be used separately as decision-making tools to aid in the categorisation of non-native species in the implementation of non-native species policy.

For example, the version adapted for freshwater fish (FISK: Fish Invasive-ness Scoring Kit) is currently being subjected to a calibration and validation process as part of its use as a tool for categorizing non-native freshwater fishes under the *Import of Live Fish Act 1980* and related amendments. To this end, FISK has been enhanced (with permission from the original WRA authors) to include for each question a certainty assessment of the response as well as a rational reporting function in which the assessor must provide bibliographic and other background information to substantiate the response and certainty assessment (http://www. cefas.co.uk/4200.aspx).

3.2 Pathway Risk Assessment (Module 2)

This module can be used (a) to provide a rapid assessment of the risks associated with a pathway, (b) to generate a pathway risk assessment by consolidating data from a large number of risk assessments for non-native species associated with that pathway or (c) to help assessors identify potential non-native species entry pathways. Intentional pathways are categorised under four headings and unintentional pathways under a further ten headings. Two examples of pathway risk assessment were prepared: 1) the human-assisted introduction of non-native fish species into the UK and between water bodies, and 2) ship-assisted transfer of non-native avian species between other countries and the UK.

3.3 Receptor Risk Assessment (Module 3)

This module provides a rapid assessment to identify receptors that might be vulnerable to invasive non-native species and also to characterise in outline the nature and severity of the likely impacts. The receptors in this module primarily refer to those species, species groups, habitats or ecosystems that are potentially vulnerable to invasive non-native species, though other activities, such as angling, can also be studied. A list of the main habitats in the UK is provided and two receptor risk assessment examples have been prepared: 1) oak trees and oak woodland, and 2) slow-flowing water courses.

3.4 Economic Impact Assessment (Module 4)

This module is used to assess the potential economic impact of the non-native species being assessed. These questions are often the most difficult to answer, so a guide to the level of impacts has been provided for the five impact levels (minimal, minor, moderate, major, massive). This has been adapted to a 1-5 scale from risk management standards produced by Standards Australia & Standards New Zealand (2004). Four subjectively equivalent dimensions are given as examples for each level of magnitude: 1) monetary loss and response costs, 2) health impact, 3) environmental impact, and 4) social impact. For example, a monetary loss of up to £10,000 a year or an environmental impact of local, short-term population loss with no significant ecosystem effect

Table 2: Risk acceptability matrix used in the UK risk assessment scheme, based on weighted probabilities (Fig. 1). The 'negligible' outcomes are given in italics and the 'unacceptable outcomes are underlined.

Likelihood		**Uncertainty**				
		Minimal	**Minor**	**Moderate**	**Major**	**Massive**
Class	***P***	***P* = 0.1**	***P* = 0.50**	***P* = 0.20**	***P* = 0.15**	***P* = 0.05**
Very unlikely	0.1	*Negligible*	*Negligible*	Justifiable (low)	Justifiable (low-med)	Justifiable (med-high)
Unlikely	0.4	*Negligible*	Justifiable (low)	Justifiable (low-med)	Justifiable (med-high)	Justifiable (high)
Possible	0.3	Justifiable (low)	Justifiable (low-med)	Justifiable (med-high)	Justifiable (high)	<u>Unacceptable</u>
Likely	0.2	Justifiable (low-med)	Justifiable (med-high)	Justifiable (high)	<u>Unacceptable</u>	<u>Unacceptable</u>
Very likely	0.0	Justifiable (med-high)	Justifiable (high)	<u>Unacceptable</u>	<u>Unacceptable</u>	<u>Unacceptable</u>

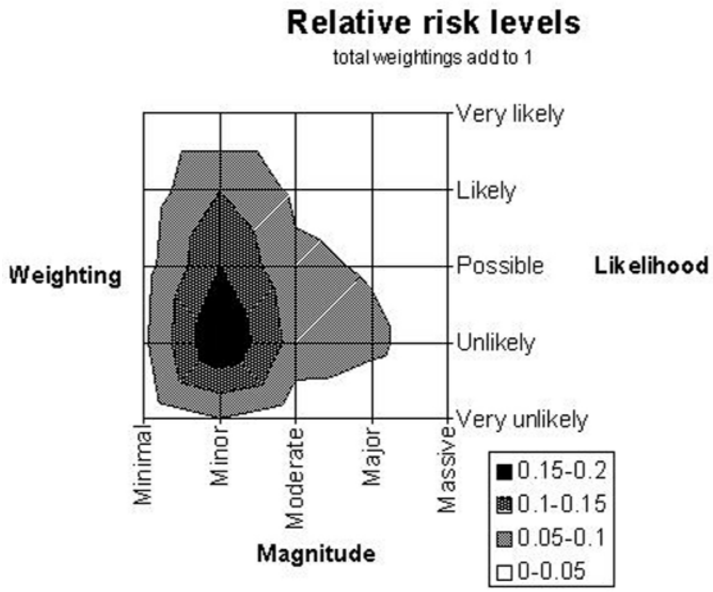

Fig. 2: Graphical representation of the uncertainty of the combined risk levels for the individual dimensions of likelihood and magnitude (Table 2), illustrating the extent of the uncertainty in each dimension whilst focussing on the most likely outcome expected.

would be recorded as 'minimal'. At the other end of the scale, 'massive' losses would be > £10 million a year or, when widespread, long-term population loss or extinction affecting several species with serious ecosystem effects are predicted. An additional table was also adapted from Standards Australia & Standards New Zealand (2004) to provide a 1-5 scale for the likelihood of the impacts occurring with a given frequency from 1 in 10,000 years (very unlikely) to once a year (very likely). The two tables can be combined in a matrix (Table 2) that takes uncertainty into account. An example of a method for determining the acceptability of the risk is provided in a graph that includes risk levels for the individual dimensions of likelihood and magnitude (Fig. 2). This can take into account the extent of the uncertainty in each dimension whilst focussing on the most likely potential outcome.

Eight additional questions are provided to quantify impacts over time, and as an example, the responses for the invasive fish species, topmouth gudgeon, are provided:

What is the total area (or other appropriate quantity) of resource? (This should include the entire area where the resource that could be affected by the organism is presen, for example the total area (ha) of wheat grown in the UK or the estimated surface area [km^2] of the river system)

What proportion of the above total is likely to be at risk from the organism? (If the spread of the organism is limited by climate or other factors, then the area at risk will be less than the total area)

What is the total annual value of the resource? (Annual values may be relatively simple to calculate for traded commodities (e.g. cereals, timber), though if the damage is occurring to a resource that has social or other environmental values, then an estimate of its value, e.g. the cost of replanting trees in parks or some sort of contingent value, may need to be used)

What proportion of the total value of the resource is at risk? (If the organism causes a 20 % reduction in yield then the figure will be 20 % of the total value of the crop, similarly if one in ten amenity trees are affected, then it will be 10 % of the total value)

How long will it take for the organism, taking into account various life-history stages where appropriate, to spread to the entire at risk area of the resource? (If a rate of migration or dispersal is known, then an estimate can be made of the time required to disperse throughout the entire at risk area)

Indicate the uncertainty of this estimate by giving a range of values. (If the rate of spread may be half this value then enter a value of 0.5, if it could be double a value of 2)

What is (are) the cost(s) of any control action(s) that are taken in areas where the organism is already established (or is a native pest subject to control measures in its native range)? (If the organism can be controlled by chemicals or other means, then use the costs available as a cost per unit area or other suitable measure)

What is the effectiveness of the control, i.e. the proportion of the damage prevented by the control actions(s)? (If chemical control reduces the damage by 90 %, then a figure of 0.9 should be entered)

3.5 Summarising Risks and Uncertainties (Module 5)

Elsewhere, the USDA (2000), CFIA (2001), Biosecurity Australia (2001) and EPPO (1997) have used three-, four-, six-, and nine-point scales, respectively. However, a 5-point ordinal scale, from 0 (very low) to 4 (very high), for responses to the questions in the scheme proved to be a reasonable compromise between parsimony and accuracy, and the use of an odd number allowed a mid-point score to be defined (see Holt 2005). Scores were averaged under each major heading (entry, establishment, spread, impact) as well as overall to obtain aggregate measures of risk. Summation or averaging has been used ubiquitously in similar schemes. In addition, a new approach was developed in which the scores were treated notionally as probabilities allowing a conditional probability that the species concerned posed a critical risk, given the set of scores assigned (Holt 2005). The calculation of probability is fundamentally different from averaging and overcomes the problem inherent in averaging that the effect of extreme scores tends to be underestimated (Zhu et al. 2000). Especially when uncertainty is high, many scores tend to be around the mid-point, and averaging tends to dilute the effect of the more extreme responses. The conditional probability calculation implicitly handles uncertainty better than averaging because mid-point scores have no effect on the outcome; by treating the five-point scores as probabilities, this method gives a progressively higher weight to scores as they diverge from the mid-point. The weighting is effectively logarithmic, because conditional probability is calculated from the product (as opposed to a sum) of the component likelihoods. For the four examples of best practice listed in Section 3, risk summaries based on the assessor's opinion, score averaging and conditional probability are compared (Table 3). The probability calculation provided better discrimination between these examples, and reflected the assessors' own judge-

Table 3: Risk assessment outcomes using the UK risk assessment scheme for non-native species based on the assessor's personal judgement, score averaging and conditional probability (as per Holt 2006). Underlined outcomes are those (score averages) that deviated from the assessors' judgements and the conditional probability methods, which agreed in all cases.

Case study	**Assessor**	**Score Averaging**	**Conditional Probability**
Topmouth gudgeon	High	Medium	High
Japanese knotweed	High	High	High
Indian house crow	Medium	Medium	Medium
Metarhizium anisopliae	Low	Medium	Low

ment of risk better than did score averaging. A subsequent application of the conditional probability method to a study involving 256 potential quarantine species (Holt et al. 2006) revealed that high and low risk cases were clearly separated and that discrimination was enhanced particularly for the more borderline cases, which arguably pose the greatest decision problem.

3.6 Risk Management (Module 6)

The risk management module of the present scheme was based on the scheme prepared by EPPO (2001) and provides a structured analysis of the strategies that can be undertaken to minimise the risks posed by an invasive non-native species or pathway. Measures to prevent or minimize entry, establishment, spread or impacts can be employed at: 1) the origin or in the exporting country, 2) the point of entry, or 3) within the importing country or invaded area. The scheme is structured on a scale of increasing stringency. Measures can be applied singly or in combination.

4. Discussion

The difficulties of assessing the risks posed by non-native species are widely recognised (Kolar & Lodge 2002, National Research Council 2002, Hulme 2003, Copp et al. 2005b, Gozlan et al. 2005, Rejmanek et al. 2005). Trait-based approaches work well for some taxa in some habitats (Pheloung et al. 1999, Daehler et al. 2004, Copp & Fox 2007) but not for others (Rosecchi et al. 2001, Kolar & Lodge 2002). Williamson (1999), for example, found no distinctive intrinsic attributes in the invasive non-native flora of the UK. The best predictors were propagule pressure and records of environmental impacts in other areas. However, there are many examples of species that have no significant impact in their native range but become invasive when they escape from biotic constraints or find vacant niches (Mack et al. 2000), though the validity of the 'vacant niche' concept is questionable (Herbold & Moyle 1986, Copp 2008). The base rate effect, where the probability of predicting an event accurately is dependent not only on the accuracy of the predictive system but also on the rarity of the event (Smith et al. 1999), adds to the problem.

Despite the stated difficulties, the need for such schemes is often mentioned. Lodge et al. (2006) have called for a more quantified scheme for risk assessment in the USA that could be applied to every species proposed for importation into the country and for risk analysis tools that are replicable, transparent, science-based and applied across all pathways and across all agency jurisdictions. In New Zealand, the ERMA (http://www.ermanz.govt.nz) manages a judicial review system for the introduction of any new organisms into New Zealand in which applicants for import provide a scientific and economic basis for importation that can be challenged by official or other public interests. Because of the legal basis of the public hearings and deliberations and the role of precedents in accepting risks, New Zealand's ERMA gives careful consideration to formalising risk estimates into consistent and comparable formats that can be used by assessors to justify decisions to refuse or allow introductions and release.

Recognising that there are no simple solutions, particularly for a generic scheme, the UK non-native risk assessment scheme concentrates on providing a framework that allows assessors to consider all the key elements of risk in a logical structure that follows established risk analysis procedures recognised by the IPPC and WTO-SPS. To maximise transparency, every score in the detailed section of the scheme is justified with a written comment. Modules, such as those described in this paper and others, exploring, for example, the suitability of the climate for establishment, can readily be added.

Although considerable progress has been made in constructing a generic non-native risk assessment scheme, a number of gaps and key areas for future work were identified to enhance its functionality and user-friendliness for both the risk assessor and the reader. The scheme also needs further testing with a wider range of intentional and unintentional entry pathways from different taxon/habitat combinations. Retrospective risk assessments for known invaders based on the knowledge available at the time of first detection may be useful in validating the scheme. To improve consistency, examples of each level of response for each question would be helpful. Once a large set of consistently produced risk assessments becomes available, additional techniques for summarising risk and uncertainty and prioritising non-native species, pathways and receptors for action can be explored.

Although developed in response to the UK strategy on non-native species (Defra 2003), all components of the scheme can easily be adapted to suit assessments at regional, continental or other national spatial scales including different biogeographic zones. The full scheme is available for download on the internet (Defra 2005).

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