Natural England Commissioned Report NECR053

Horizon-scanning for invasive non-native plants in Great Britain

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Foreword

Natural England commissions a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Invasive non-native species (INNS) are recognised as one of the main causes of global biodiversity loss and all current data shows that this is a problem which is increasing. Consequently there are a large number of agreements, conventions, legislation and strategies pertaining to INNS.

In May 2008 the GB Strategy for invasive non-native species was launched. One of the key elements of the strategy was a recognition of the need to prevent the introduction and/or spread of potentially invasive non-native species. Determining which species will become invasive is notoriously difficult, the best predictor being evidence of invasiveness elsewhere. To assist in the prioritisation and targeting of prevention work, Natural England sought a horizon-scanning exercise to identify non-native species that are most likely to become invasive in Great Britain in the future.

The aim of this report is to produce a list of potential new invasive non-native plant species in Great Britain using existing information on INNS. These might be species which are already here but are not established or species which are yet to arrive. It is envisaged that such a report will stimulate debate and help inform the targeting of resources.

For the purposes of this report a non-native species is a species introduced deliberately or accidentally by human action to an area lying beyond the limits of its current or former native range. An invasive non-native species is defined as a non-native species whose introduction and potential or actual capacity to spread is likely to pose a threat to biological diversity.

It is important for Natural England:

- to be informed of potential new invasive non-native species;
- to understand the challenges that new invasive non-native species may bring; and
- to consider appropriate responses to such species.

The purpose of this report is to help Natural England:

- **As the lead delivery body for the England Biodiversity Strategy** - develop a view on potential new invasive non native species in England and their impacts to biodiversity.
- Further contribute towards the **implementation of the Invasive Non-native Species Framework Strategy for Great Britain**.

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Further information
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Summary

- Invasive non-native species pose a significant threat to biodiversity in Britain. Dealing with the problems caused by invasive non-native species costs the British economy in excess of £2 billion annually. Often, the environmental damage they cause is irreversible.

- The *Invasive Non-Natives Species Framework Strategy for Great Britain* (*The Strategy*) recognises that the most cost-effective and least environmentally damaging approach to solving the problems caused by invasive non-native species is through prevention of introduction into the wild, rapid response and early intervention. This guiding principle, adopted by the Convention of Biological Diversity, is echoed in Natural England's position statement on invasive non-native species.

- Both *The Strategy* and Natural England call for a preventative approach to be adopted *vis-à-vis* invasive species. Such an approach may require potentially invasive non-native plants to be banned from sale, prohibited from being planted in the wild, or eradicated from known sites in the wild.

- A total of 1,867 non-native plant taxa (excluding marine species) were named in the 2005 audit of non-native species in England, and thousands more non-native plants are available to buy for use in gardens, landscaping and ponds. Yet invasive non-native plant species represent a small sub-set of our non-native flora, with the majority of non-native species unlikely to cause environmental damage now or in future. In order for preventative action to be proportionate, determining which taxa warrant preventative action and which do not is imperative.

- Predicting plant invasiveness cannot be done with complete accuracy: there will always remain the risks of false negatives – declaring a taxon to be low risk which then goes on to become invasive – and false positives – declaring a taxon to be higher risk when it does not become invasive. The potential for currently benign plants to become invasive as the climate changes adds to this challenge.

- When attempting to determine a plant's invasive potential, identifying characteristics such as smothering growth-forms and prolific seed production is useful but not fool-proof as plants often behave differently when removed from their usual biotic and abiotic constraints. Evidence of invasive behaviour in natural and semi-natural habitats elsewhere can also be indicative of potential invasiveness, but given the time lags associated with many plant invasion histories this is not, in itself, robust either. However, used in combination, and with the added consideration of pathways of introduction and spread within Britain, a broad level of risk posed by a particular taxon to natural and semi-natural habitats can be assigned with some confidence.

- The current mechanism for identifying potentially invasive plants in Britain involves a detailed Risk Assessment process that is both time- and resource-intensive. This renders it inappropriate to apply to large numbers of taxa.

- This project devised, trialled and implemented a rapid screening process designed to be applicable to larger numbers of plants. It is based on the Australian Weed Risk Assessment developed by Pheloung (1995; Pheloung, Williams & Halloy 1999), a process that has been well-received internationally as a tool for identifying invasive species. The screening consists of 22 questions that relate to current status in the UK, evidence of weed status outside of the UK, undesirable (invasive) traits, reproduction, dispersal mechanisms, and persistence attributes.

- The results of this screening process can be used to help prioritise resources by indicating (1) a shortlist of taxa for which more detailed assessment is considered imperative and/or prudent and (2) a much longer list of taxa for which such assessment is deemed currently unnecessary.

- The screening process is likely to be more susceptible to false negatives and false positives than both its progenitor and the more comprehensive Risk Assessment process used by the Non-Native Species Secretariat in Britain. To reduce the risk of false negative results the precautionary principle was applied. This is likely to increase further the occurrence of false positives.

- It is recommended that the taxa highlighted through this work as potentially posing an invasive risk are subject to more detailed assessment (where this has not already been commissioned). Moves to restrict taxa highlighted in this study through a ban on sale are not justifiable without further assessment of the risks they pose. It is highly recommended that more comprehensive assessments are conducted without delay.

- A total of 599 non-native plants of potential invasive concern were assessed, of which:

  - 92 are recommended for more detailed risk assessment as a matter of priority (ranked Critical);

  - 55 are highly recommended for more detailed risk assessment (ranked Urgent);

  - 72 are recommended for more detailed risk assessment (ranked Moderate Risk); and

  - 380 are identified as requiring no further assessment at present (ranked Low Risk).

- It is recommended that all plants screened are reviewed periodically to take account of emerging evidence and information, changes in climate and new horticultural varieties that become available which may, for example, be more frost-hardy than those currently available.

- Freshwater and terrestrial plants were included in this study. In light of the differences in invasion histories typical of freshwater and terrestrial systems, these two groups of species were treated differently. Invasions by non-native species in freshwater habitats tend to take place at a much faster rate than invasions in terrestrial habitats, in part due to the potential for rapid and widespread water-assisted dispersal in freshwater systems. In comparison, plant invasions in terrestrial habitats are typically quite slow, particularly if they involve woody species and/or highly fragmented habitats.

- Due to the speed of invasion in freshwater habitats, and the fact that many non-native invasive plants currently thought to be causing damage to the biodiversity of aquatic systems are ornamentals that have 'escaped over the garden wall', we decided that all commercially available non-native freshwater plants should be included in this study. The final screening was applied to 368 freshwater plants, over 90% of which are not currently known from the wild in Britain. In future it is recommended that *any* new aquatic taxa found to be on sale in Britain should be screened as soon as their existence is discovered. In addition, produce contaminants ('hitch-hikers') should also be identified and subject to rapid screening.

- Given the longer timeframe under which terrestrial invasions *tend* to occur and the tens of thousands of terrestrial species and varieties that are available to buy, the study looked only at terrestrial plants already established in the wild in Britain. In order to maintain a horizon-scanning function, the study focused on terrestrial neophytes recorded in the wild for fewer than 90 years and which are known to be increasing in distribution. The study also included established terrestrial neophytes on the list of the 100 fastest-spreading species since 2000, based on the results of the Local Change survey run by the Botanical Society of the British Isles, even if known from the wild for over 90 years. A small number of other species were included, including those that were the subject of consultation by Defra for inclusion on Schedule 9 of the Wildlife and Countryside Act, and those suggested for inclusion on Schedule 9 by members of the plant conservation consortium PlantLink. In total, 231 terrestrial plant taxa were screened.

- Of the freshwater plants assessed, 33 were ranked Critical (9%); 26 Urgent (7%); 60 Moderate Risk (16%); and 249 Low Risk (68%). Of the terrestrial plants assessed, 59 were ranked Critical (25.5%); 29 Urgent (12.5%); 12 Moderate Risk (5%); and 131 Low Risk (57%).

- Comprehensive Risk Assessments have been commissioned by the Non-Native Species Secretariat for 18 of the species screened in this study (at the time of submission): 13 of these were ranked Critical in the present assessment, 1 Urgent, 3 Moderate Risk and 1 Low Risk (giant salvinia *Salvinia molesta*). It is recommended that the remaining 201 Critical-, Urgent-, and Moderate Risk-ranked species should also be subject to full Risk Assessments.

- With the publication of the screening method, additional aquatic taxa found to be on sale in Britain and a wider scope of terrestrial plants can now be screened by third parties. As it requires less than 30 minutes to assess each plant, it is hoped that this screening process can be further developed into a tool that proves useful to land managers and the horticultural trades, as well as policy makers. We recommend that the Rapid Risk Assessment is developed further if it is to be used more widely by non-native invasive experts, particularly with regard to the weighting of questions and the handling of uncertainty.

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1 Introduction

1.1 Invasive non-native species are considered to pose a significant threat to biodiversity on a global scale (Wilson 1992; McNeely and others 2001). The environmental damage resulting from invasive non-native plants may be irreversible (Anderson and others 2004; Křivánek & Pyšek 2006). They can alter the species composition of a habitat and change its structure and function (Mack and others 2000; Hulme 2003; Hejda, Pyšek & Jarošik 2009). The spread of invasive non-native plants may also compromise the ability of natural and semi-natural habitats to provide essential ecosystem services (Anderson and others 2004; Millennium Ecosystem Assessment 2005).

1.2 Invasive plants compete with other plants – including vascular plants, bryophytes and lichens – for light, space and nutrients and have been observed to suppress native species in the UK (see, for example, Ratcliffe 1968; Pentecost 1987; Rothero 2005; Long & Williams 2007 on the impact of rhododendron *Rhododendron ponticum* and Dawson & Warman 1987; Langdon and others 2004 on New Zealand pigmyweed *Crassula helmsii*). In some cases the arrival and subsequent spread of invasive non-native plants has coincided with the local extinction of plant species of conservation concern (e.g. Putwain, Hatton & Haynes 2008). It is likely that documented observations relating to the detrimental impact of invasive plants would be more numerous but for the interventionist control measures taking place at many sites of botanical interest in the UK (Thomas & Dines 2010).

1.3 Invasive non-native plants also affect animals. For example, New Zealand pigmyweed *Crassula helmsii* is thought to have led to the loss of the Biodiversity Action Plan species great crested newt *Triturus cristatus* from a pond in a SSSI in Dorset (Defra 2010). Impacts of invasive non-native plants on birds in Britain have been documented by Goss-Custard & Moser (1988) and CEH (2005), whilst the potential impact of invasive floating aquatic plants has been illustrated by Boonman and others (1998) for bat foraging and Horváth & Kriska (2008) for semi-obligate aquatic insects.

1.4 The threats posed by invasive plants are considered so great that some freshwater habitats are being destroyed (that is, ponds are being filled in) by site managers upon the arrival of invasive aquatic plants as a preventative measure intended to minimise damage to the wider freshwater system.

1.5 In addition to the environmental damage caused by invasive non-native species, dealing with the problems they cause costs the British economy in excess of £2 billion annually (Defra 2007a). Much of this money is spent on containing spread and limiting further damage rather than eliminating the problem altogether, eradication now being considered unattainable for a number of already widespread invasive species.

1.6 The most cost-effective and least environmentally damaging approach to solving the problems caused by non-native invasive species is through prevention of introduction into the wild, rapid response and early intervention (Rejmánek 2000; Mack and others 2000). This hierarchical approach for invasive species action (whereby greatest priority is given to prevention), adopted by the Convention on Biological Diversity, has recently been carried through into relevant national policy and strategies (e.g. Defra 2008; Natural England 2009).

1.7 A preventative approach may require potentially non-native invasive plants to be banned from sale or prohibited from being planted in the wild. With 1,867 non-native plant taxa recorded from the wild in England in 2005 (Hill and others 2005) and over 70,000 more non-native plants available to buy for use in gardens, garden ponds and amenity and landscape planting (RHS 2009), the process of identifying potentially invasive taxa is challenging.

1.8 Only 66 (3.5%) of the 1,867 non-native plants in the wild in England in 2005 were considered to present an environmental problem by Hill and others (2005) and the vast majority of plant taxa used in the ornamental and horticultural trades are likely to pose no threat to semi-natural/natural habitats should they escape into the wild (see Williamson & Brown 1986, Williamson 1996). The inability to separate invasive from non-invasive non-native plants is a key hindrance to implementing an effective and proportionate preventative approach to invasive species (Manchester & Bullock 2000; Hulme 2006). Therefore, determining which species warrant preventative action, and which do not, is critical.

1.9 A number of risk-assessment processes have been developed, or are in the process of being developed, for non-native species across the globe in an effort to identify which species pose an invasive threat to a specific region or country (e.g. Pheloung 1995; Tucker & Richardson 1995; Pheloung, Williams & Halloy 1999; Copp Garthwaite & Gozlan 2005; Baker and others 2008; Randall and others 2008; van Wilgen, Richardson & Baard 2008; Mendoza Alfaro and others 2009). Risk assessments may then be used to approve or reject applications to import particular species or to intentionally plant them (for example in forestry). Many of these risk-assessment processes involve detailed assessments that take considerable resources to execute and Hulme (2006) warns that the investment required and the expense of risk assessments may ‘act against the net benefits of prevention’. The system currently in use in Great Britain take an average of over 19 hours to complete and cost at least £1,000 per species (Booy, White & Wade 2006). They are, therefore, inappropriate to apply to large numbers of species (Parrott and others 2009). Indeed (at the time of submission) just 32 plant species have been commissioned for these risk assessments, with ten completed (NNSS 2010).

1.10 Thus it is clear that there is a pressing need for a less resource-intensive method for assessing the invasive risk associated with non-native plants in Great Britain. Indeed, such a process was called for in the appraisal of the comprehensive British Risk Assessment scheme (see Booy, White & Wade 2006).

2 Aims & objectives

2.1 The aim of this work was to develop and implement a rapid screening system that could be used to identify plant taxa which may have the potential to become invasive in natural/semi-natural habitats in Britain.

2.2 Specific objectives were to:

- develop and trial a rapid risk assessment screening process that can be applied to large numbers of plant taxa;
- identify those non-native freshwater and terrestrial plants for which a rapid assessment of invasive risk would be desirable;
- use the screening process to determine a broad risk category for those plants; and
- use the findings to help prioritise resources for more detailed risk assessments where necessary.

3 Methodology

Rapid Risk Assessment screening process

3.1 The Australian Weed Risk Assessment developed by Pheloung (1995) and Pheloung, Williams & Halloy (1999) has already been adapted for application in the UK and forms part of the detailed risk assessment process currently used here (Baker and others 2008). In this study the UK-adapted Weed Risk Assessment was simplified from 49 to 21 questions, some of which were modified slightly to provide greater clarification.

3.2 Questions from the UK-adapted Weed Risk Assessment relating to agricultural weed status or impact on human interests (e.g. question numbers 3.02, 3.03, 4.07) were deleted in order to focus on identifying species with potential to damage natural and semi-natural habitats. Other questions were considered likely to be answered the same for all species (e.g. 8.05 biocontrol agents) and so had little relevance when the principal aim was to differentiate between taxa. As several questions were unlikely to have information available for the majority of taxa, some questions were combined (e.g. the original question on allelopathy was subsumed within the question relating to thicket/smothering/climbing growth habit).

3.3 Economic considerations were not included in the screening questions as they were seen as more pertinent to providing a context within which management or policy decisions would be made, rather than determining whether or not a plant poses a risk of invasiveness.

3.4 In order to trial the Rapid Risk Assessment and assess repeatability, 41 taxa were run through the process before the complete list of 599 taxa was screened. The trial taxa included hybrids, freshwater, terrestrial, native and known invasive plants to test the scheme's applicability to a wide range of plants, in a similar manner to the trials undertaken by Baker and others (2008) in the development of the more detailed UK risk assessment scheme. Of the 41 plants, 22 were screened separately by two or more experts allowing answers and scoring to be compared.

3.5 As a result of the trial some clarifications over questions were made and the scoring system altered to remove almost entirely the process of allocating a score of -1 for non-invasive attributes. The changes to the scoring system from the UK-adapted Australian Weed Risk Assessment process reflected the desire to adopt a precautionary approach whilst also eliminating question repetitions.

3.6 One additional question (Q1) relating to current spread in the UK was added. The 22 questions, listed in Table 1 (below), relate to:

- current status in the UK (Q1-3);
- evidence of weed status outside of the UK (Q4-6);
- undesirable (invasive) traits (Q7-10);
- reproduction (Q11–13);
- dispersal mechanisms (Q14–19); and
- persistence attributes (Q20-22).

3.7 Question 5 was misplaced in the 'Weed status outside of UK' whilst more appropriately it should sit in the 'Current status in the UK' section. The table outlines how the questions appeared to the assessors, but should be changed for future use of the scheme by third parties.

Table 1 List of questions in the Rapid Risk Assessment screening

Question Group	Q No.	Rapid Risk Assessment Question	Relation to UK-adapted Australian Weed Risk Assessment
UK status	1	What is its rate of spread in the UK?	**Additional question**
	2	To what climate is the species suited?	**Q 2.01 / Q 2.04**
	3	Is it an environmental weed in natural and valued habitats/designated sites?	**Q 3.04**
Weed status outside of UK	4	Has the species become naturalized where grown (globally)?	**Q 1.02**
	5	Does the species have a history of repeated cultivation (and associated introductions) in the UK?	**Q 2.05**
	6	Is the species naturalized beyond its native range?	**Q 3.01**
Invasive traits	7	Is it a congeneric weed?	**Q 3.05**
	8	Is it unpalatable to grazing animals (incl. for reasons of toxicity/spines/thorns)?	**Q 4.04 / Q 4.05**
	9	Can it tolerate a wide range of soil conditions (within the aquatic or terrestrial system)?	**Q 4.10**
	10	Does it have a climbing or smothering growth habit, and/or form dense thickets?	**Q 4.11 / Q 4.12**
Reproduction	11	Does/can it produce viable seed in the UK?	**Q 6.02**
	12	Does/can it reproduce by vegetative fragmentation?	**Q 6.06**
	13	What is its minimum generative time (years)?	**Q 6.07**
Dispersal mechanisms	14	Are propagules (likely to be) dispersed unintentionally (plants growing in heavily trafficked areas)?	**Q 7.01**
	15	Are propagules (likely to be) dispersed intentionally by people?	**Q 7.02**
	16	Are propagules (likely to be) dispersed as a produce contaminant?	**Q 7.03**
	17	Are propagules adapted to wind dispersal?	**Q 7.04**
	18	Are propagules water dispersed?	**Q 7.05**
	19	Are propagules bird/other animal dispersed?	**Q 7.06 / Q 7.07**
Persistence attributes	20	Does the species have prolific seed production?	**Q 8.01**
	21	Is there evidence that a persistent propagule bank is formed (>1yr)?	**Q 8.02**
	22	Does it tolerate or benefit from mutilation/cultivation/herbicides?	**Q 8.03 / Q 8.04**

3.8 Answers to the screening questions were based on information available in scientific journals and conference proceedings, weed/horticulture manuals, published Floras and plant databases, and other sources available from the internet. Expert opinion of the assessors was also accepted, given that for a large number of the species being screened there is little to no published material available.

3.9 The definitions and guidance notes provided to assessors, detailed in Table 2 (below), are based on the notes that accompany the UK-adapted Pheloung, Williams & Halloy (1999) assessment (Defra 1998).

Table 2 Scoring, definitions and notes, adapted from UK-adapted Pheloung, Williams & Halloy (1999) assessment (Defra 1998)

Q1 What is its rate of spread in the UK?

This is based on the Change Index as provided in the *New Atlas of the British and Irish Flora* (Preston, Pearman & Dines 2002) (henceforth referred to as *Atlas*) or the Spread Rate in hectads per year. Spread Rate is calculated by dividing the number of hectads in which the species has been recorded (according to the *Atlas*) by the number of years that the species has been recorded in the wild in the UK, based on date of first record in the wild.

For taxa for which there is no Change Index, the Spread Rate is used. Where both are available, the highest score is taken (reflecting a precautionary approach) unless a species is indicated in the *Atlas* as being under-recorded in the past. Such under-recording is likely to affect most conifers and shrubs, whose Change Index is therefore likely to over-emphasize the rate of spread (*ibid*). In these cases the lower score is used.

Correlation between Change Index and Spread Rate is poor. This is probably because the Change Index calculated in the *Atlas* is a measure of change in relation to the 'average species', it is not an absolute measure of change. Many non-native taxa are poorly recorded historically and cannot be regarded as 'average species'. Therefore, the thresholds for the Spread Rate scores are allocated so as to leave comparable proportions of species in each band as occurs using Change Index.

SCORE:	0 = change index : <+0.99	or hectad / year : < 2.99;
	1 = change index : +1 to +1.99	or hectad / year : 3 to 4.99;
	2 = change index : +2 to +2.99	or hectad / year : 5 to 11.99;
	3 = change index : +3 to +3.99	or hectad / year : 12 to 16.99;
	4 = change index : >+4	or hectad / year : >17.00
	? = DON'T KNOW	

Q2. To what climate is the species suited?

Take account of perennating organs, such that the hardiest part of the plant is considered.

SCORE: 0 = Tropical
1 = Subtropical (European hardiness zones Z11 to Z12)
2 = Warm temperate / Mediterranean (zones Z9 to Z10)
3 = Continental temperate (Z1 to Z8)

Q3. Is it an environmental weed in natural and valued habitats/designated sites?

Yes = grows in natural habitats and is being controlled there, OR has been found to be a pest in natural habitats (forms monocultures, reduces diversity, changes fire regime, is spreading rapidly, etc). Occurrence in natural environments *per se* is not sufficient to answer "yes". There is some flexibility and judgement here – award a 3 or use ½ points, for example, if the species occurs rarely but mainly on important plant sites. Rarely = c. 1-10 sites; Occasionally = c.11-50 sites; Frequent = c. 51-100 sites; Widely established = c. >100 sites.

SCORE: 4 = Yes: frequent in semi-natural habitats incl. Important Plant Areas /SSSIs etc
3 = Yes: occasionally in semi-natural habitats
2 = Yes: widely established but not usually in semi-natural sites
1 = Yes: rarely
0 = No, or mainly ruderal, disturbed, man-made habitats

Q4. Has the species become naturalized where grown (globally)?

Naturalized = species has become well established (widespread/common, and self-maintaining) in the wild flora of a new area/region. The following descriptions are NOT sufficient evident of naturalization: ‘occasional escape from cultivation’, ‘casual’, ‘apparently becoming naturalized around town X’, ‘sparingly naturalized around town Y’, ‘waif’. Almost all introduced species can occasionally be found in the wild but this does not indicate naturalization.

SCORE: 0 = Casual, not persistent / low spread
1 = Persistent but local (two or fewer countries)
2 = Noxious / notifiable weed in one or more country
? = Don’t know

Q5. Does the species have a history of repeated cultivation (and associated introductions) in the UK?

‘Introduction’ does not necessarily mean naturalized. Has the species been repeatedly grown (e.g. cultivated) or accidentally introduced to several regions that are clearly outside its native range? ‘Repeated introductions’ means records from at least three separate places. If introduction to a place was limited to a botanical garden (i.e. the species was not distributed to the public) it is not counted. For species that are widely cultivated or widely grown in horticulture, the answer is usually "yes".
SCORE: Yes = 2; No = 0; Don’t know = ?

Q6. Is the species naturalized beyond its native range?

Must be clearly outside of native range.

SCORE: 0 = No, or Yes: tropical / subtropical species
? = Don’t know
1= Yes: warm temperate / Mediterranean species
2 = Yes: continental temperate species

Q7. Is it a congeneric weed?

Yes = if any other species in the same genus is a weed / pest / subject to control measures (or meeting criteria for any category from above).

SCORE: 0 = No, or Yes: tropical / subtropical species
? = Don’t know
1= Yes: warm temperate / Mediterranean species
2 = Yes: continental temperate species

Q8. Is it unpalatable to grazing animals (incl. for reasons of toxicity/ spines/ thorns)?

Animals = livestock. (If no information, answer is "Don't know").

SCORE: Yes = 1; No = 0; Don’t know = ?

Q9. Can it tolerate a wide range of soil conditions (within the aquatic or terrestrial system)?

Wide = Grows well in at least two out of three of the main soil types (sand, clay, or silt), or under a wide range of nutrient conditions, or can tolerate a wide pH range (acid to alkaline). Consider within the system in which the plant grows – e.g. aquatic plants within the range of aquatic conditions.

SCORE: Yes = 1; No = 0; Don’t know = ?

Q10. Does it have a climbing or smothering growth habit, and/or form dense thickets?

Climbing habit includes all vines and woody lianas. 'Smothering' = physically pushing down or choking. Consider the species' competitiveness and the density it might achieve. Award ½ points if appropriate. Moderate = forming clumps or reaching 50% cover. Considerable = 90% cover, allelopathic species, eradication/out-competition of other species.

SCORE: No = 0; Don't know = ?; Slight = 1; Fair = 2; Moderate = 3; Considerable = 4

Q11. Does/can it produce viable seed in the UK?

No = only if direct evidence/reference for sterility/non production of seeds

SCORE: Yes = 1; No, or only very occasionally = 0; Don't know = ?

Q12. Does/can it reproduce by vegetative fragmentation

Yes = only if it spreads without seeds – includes rhizomes, stolons, root fragments, suckers, and these vegetative parts commonly survive without human cultivation.

SCORE: Yes = 2; No, or only very occasionally = 0; Don't know = ?

Q13. What is its minimum generative time (years)?

If plant can reproduce vegetatively, it is the time needed to do this (as this may be shorter than the time to seed production). If no direct reference available then contact people in the nursery business or in forestry.

SCORE: 1 = 1 year
0 = 2 or 3 years
-1 = 4+ years
? = Don't know

SCORES FOR THE REMAINING QUESTIONS:

1 = Yes
0 = No
? = Don't know

Q14. Are propagules (likely to be) dispersed unintentionally (plants growing in heavily trafficked areas)?

Consider the dispersal structure (or small seeds in muddy habitats) AND location where plants grow (heavily trafficked areas such as trail sides, road sides, farms). Does it have hooks or is it sticky? Consider any method by which it could get attached and hence be dispersed unintentionally by people. Also, consider possibility of movement to new areas unintentionally by environmental consultants, as well as by (e.g.) boats.

Q15. Are propagules (likely to be) dispersed intentionally by people?

Does it have any useful properties which might be a good reason for people to move it around? Horticultural, edible fruit, etc.

Q16. Are propagules (likely to be) dispersed as a produce contaminant?

'Produce' = any economic product (agriculture, forestry, horticulture).

Q17. Are propagules adapted to wind dispersal?

If no direct reference then answer based on the morphology of the seed/fruit. For example presence of pappus.

Q18. Are propagules water dispersed?
Answer 'yes' if any reproductive structure is known to be buoyant (e.g. pods), AND the structure is reasonably likely to come in contact with moving water.
Q19. Are propagules bird/other animal dispersed?
If no direct reference then consider the type of fruit. For example if it has small berries then probably = Yes. Also, consider seeds that may attach to animals, or are carried but not swallowed.
Q20. Does the species have prolific seed production?
Prolific seed production here is greater than 1000/m^2 viable seeds produced during one event/season of reproduction. If total per plant is given, estimate by dividing by the crown area of an average plant. Estimates can also be made based on seed size and type or fruit / number of seeds per fruit.
Q21. Is there evidence that a persistent propagule bank is formed (>1yr)?
Look for evidence of survival >1 year IN THE FIELD (not lab storage). Usually hard seeded legume seeds remain viable in the soil for >1 year. More than 1% of seeds must consistently remain viable >1 year under field conditions. Seeds with low viability after 1 year of lab storage are unlikely to meet this criterion.
Q22. Does it tolerate or benefit from mutilation / cultivation / herbicides?
Mutilation includes logging/lopping, vigorous regrowth from cut stumps; cultivation = ploughing the soil to cultivate the soil.

3.10 The maximum score possible is 38 points. One of four levels of risk was assigned to each taxon screened:

- Critical (red): taxa recommended for more detailed risk assessment as a matter of priority;
- Urgent (orange): taxa highly recommended for more detailed risk assessment;
- Moderate Risk (yellow): taxa recommended for more detailed risk assessment; and
- Low Risk (green): no further assessment is considered necessary at present.

3.11 Before thresholds between risk levels were drawn, the full range of taxa were scored and ranked according to score. A consensus of expert opinion was used to draw boundaries between the four categories as follows:

- Critical: >= 25 points;
- Urgent: 22-24.5 points;
- Moderate risk: 18-21.5 points; and
- Low risk: <=17.5 points.

3.12 As part of the risk categorisation stage, a further level of interpretation was given to the results based on expert opinion. At this point the answers to three questions were given added emphasis – **Q2, Q3, Q10** which relate to evidence of climatic suitability to the UK, invasive behaviour in valued habitats and climbing/smothering/thicket-forming growth habits – and two experts consulted to agree on the final categorisation for each taxon (Dr Trevor Dines and Andy Byfield). Potential worst-case scenarios, whereby unknown answers were scored as the maximum available, were also considered by these experts. For these reasons not all taxon scores correspond with their final risk categorisation.

Selection of species

3.13 Freshwater and terrestrial plants were included in this study. Marine species were not included.

3.14 A list of aquatic plants known to be on sale in the UK was compiled through searching online stock lists from major aquatic plant retailers. Major suppliers were asked to provide stock lists if these were not readily available online, but not all complied. A list containing 1,454 names was created. Native species (n = 108) were deleted from the list, along with bog garden species and taxa that would not survive in a truly aquatic environment (n = 442). Duplicate entries appearing as synonyms were also deleted where these were identified prior to the application of the screening questions. Taxa sold under genus name only were also excluded.

3.15 After such deletions 837 entities remained, of which over half were cultivars, varieties or other types of ‘infraspecific’ taxa. All remaining apparent species were put forward for screening. Of the cultivars, those with native ‘parent’ species were deleted as were those whose parents had already been put forward for screening. Of those remaining cultivars 44 were put forward for screening, with all parent types included. In total 440 taxa were put forward for further screening: the final figure of 368 arises from further duplications resulting from trade names and synonyms unknown at the outset of the project. Taxa were screened by experts at the Freshwater Biological Association and Plantlife. Guidance was given to limit the time spent on each taxon to 30 minutes.

3.16 For terrestrial plants the study identified neophytes (according to the *Atlas*) already established in the wild in Britain. Taxa were selected that had been established in the wild for less than 90 years (80 years at the point of data collection for the *Atlas*) and that also had a Spread Rate >= 0.5 hectads/year and/or a positive Change Index. The study also included 28 non-native established terrestrial neophytes from the list of the 100 fastest spreading species since 2000 – based on the results of the Local Change survey run by the Botanical Society of the British Isles (Braithwaite, Ellis & Preston 2006) – which had not already been included based on the original criteria. It also assessed 14 species which fulfilled neither criteria but were included in Defra’s recent consultation on additions to Schedule 9 of the Wildlife and Countryside Act (Defra 2007b) or recommended during that consultation for inclusion on Schedule 9 by plant experts from the plant conservation consortium PlantLink (PlantLink 2008). In total, 231 terrestrial plants were screened by Plantlife experts, again with a maximum of 30 minutes allocated per taxon.

4 Results & discussion

Taxa

4.1 **A total of 599 non-native plants were assessed, of which:**

- 92 are recommended for more detailed risk assessment as a matter of priority (ranked Critical – red);
- 55 are highly recommended for more detailed risk assessment (ranked Urgent – orange);
- 72 are recommended for more detailed risk assessment (ranked Moderate Risk – yellow); and
- no further assessment is considered necessary *at present* for the remaining taxa (ranked Low Risk – green).

4.2 The screening was applied to 440 aquatic plants. Of these, 190 assessments were terminated after Q2 at the point when assessors determined that the taxon was tropical. The assessments of all but two tropical taxa (*Myriophyllum aquaticum* and *M. propium*) were terminated in this way. Semi-tropical aquatic plants were fully screened as aquatic plants have demonstrated a large discrepancy between their native and non-native climatic ranges, with non-native ranges spanning a much greater climatic variation than one would have guessed from their often restricted native ranges (Cook 1985; Rejmánek 2000). In total 162 aquatic taxa were run through the entire 22 questions. A further 16 entities could not be identified, or no relevant information could be found relating to them due to the practice of applying trade names that are not botanically accepted, and the remaining entities were found to be trade names or synonyms and have been merged under one taxon entry.

4.3 The prominent tropical genera that were not fully screened were *Anubias*, *Cryptocoryne* and *Echinodorus*. The *Anubias* genus consists of about 20 species with a preference for a low light, low nutrient regime, and seems to be popular in the aquarium trade. Herbivorous fish find them unpalatable but they are slow growers (Crusio 1987). *Cryptocoryne* species are riverine and grow mainly in south-east Asia where they grow submerged in forest streams and wetlands and only occasionally flower. *Cryptocoryne* and *Echinodorus* species seem to attract a particular group of aquarists who rise to the challenge of growing them since some are very difficult to cultivate. Some *Echinodorus* species require reduced iron in the water which suggests they are used to growing in anaerobic conditions. Both genera, like several other large aquatic genera, consist of numerous trade names and many of the cultivars seem to have been developed without any detailed investigation of their parentage. There is great scope for mis-identification and mis-naming here. Although the popular *Aponogeton* genus is also largely tropical, the warm-temperate *Aponogeton distachyos* (here ranked Moderate Risk – yellow) has raised concern amongst some botanists. Little information about this genus was found.

4.4 Two tropical *Myriophyllum* were fully screened as relevant information was readily available. *Myriophyllum aquaticum* scored 28 points and is already a recognised invasive species in Britain, in spite of its seemingly incompatible climatic requirements. *Myriophyllum propium*, another taxon popularly traded, scored 15 points with ten questions remaining unanswered. Initial observations relating to *M. aquaticum* survival in winter (see the recently completed NNSS-commissioned full GB Risk Assessment for *M. aquaticum,* available from NNSS 2010 online) indicate that whilst emergent vegetation is susceptible to frost, submerged matter is able to survive substantial sub-zero overnight temperatures. The authors' field observations from, for example, the New Forest indicate that even a combination of the harshest British winters (ie 2008-9 and 2009-10) and herbicide treatments can be survived by *M. aquaticum*.

4.5 These two *Myriophyllum* cases cast substantial doubt on the soundness of the decision not to fully assess tropical aquatic species in the present study. Indeed, there may be a number of tropical taxa with submerged growth forms that might avoid extreme winter cold, and so be able to present an invasive threat to Britain, by living wholly under water. In a similar fashion, tropical montane species may also, perhaps, persist in cooler climates. Although information on many tropical taxa was difficult to obtain, it is recommended that tropical submerged and montane taxa are identified and subjected to further scrutiny.

4.6 Only 25 of the freshwater taxa assessed in the present study have been recorded in the wild for more than ten years (i.e. recorded before 1999 and thus have an entry in the *Atlas*), with a small number having been recorded from the wild for the first time since then (e.g. water-lettuce *Pistia stratiotes* and the water primroses *Ludwigia uruguayensis* (= *grandiflora*), *Ludwigia peploides*, *Ludwigia* x *kentiana*) (Preston, Pearman & Dines 2002; BSBI 2010 online). Thus the freshwater screening can be considered, for the most part and notwithstanding the submerged/montane tropical taxa oversight, a preventative exercise.

4.7 **Of the 368 aquatic plant entries:**

- 33 were ranked Critical (9%), of which 11 have *Atlas* entrances;
- 26 were ranked Urgent (7%), of which five are in the *Atlas*;
- 60 were ranked Moderate Risk (16s%), of which four are in the *Atlas*; and
- 249 were ranked Low Risk (68%), of which five are in the *Atlas.*

4.8 **Of the 231 terrestrial plants screened:**

- 59 were ranked Critical (25.5%);
- 29 were ranked Urgent (12.5%);
- 12 were ranked Moderate Risk (5%); and
- 131 were ranked Low Risk (57%).

4.9 See Tables 3-6 below for listings of Critical, Urgent and Moderate Risk taxa. Complete screening scores for all assessed taxa are provided in Appendix 1. In some cases the name listed is a trade name/ name under which a plant is sold rather than a fully-recognised botanical name.

Table 3 Critical-ranked freshwater taxa

Latin name	Common name
Azolla caroliniana	Carolina mosquito fern
Azolla filiculoides	Water fern
Cabomba caroliniana	Carolina water-shield
Crassula helmsii	New Zealand pygmyweed
Egeria densa	Large-flowered waterweed
Elodea callitrichoides	South American waterweed
Elodea canadensis	Canadian waterweed
Elodea nuttalli	Nuttall's waterweed
Equisetum scirpoides	Dwarf horsetail
Glossostigma diandrum	
Houttuynia cordata	Lizard tail
Hydrocotyle ranunculoides	Floating pennywort
Hydrocotyle sibthorpioides	Lawn marsh-pennywort
Juncus ensifolius	Swordleaf rush
Lagarosiphon major	Curly Waterweed
Lagarosiphon muscoides	
Limnobium spongia	American spongeplant
Ludwigia grandiflora	Water primrose

Latin name	Common name
Ludwigia peploides	Floating primrose willow
Ludwigia repens	Creeping primrose willow
Micranthemum umbrosum	Shade mudflower
Myriophyllum aquaticum	Parrot's-feather
Myriophyllum elatinoides	New Zealand watermilfoil
Oenanthe javanica 'Flamingo'	
Orontium aquaticum	Golden club
Peltandra virginica	Green arrow arum
Rotala rotundifolia	
Sagittaria latifolia	Duck-potato
Sagittaria sagittifolia subsp. *leucopetala*	
Saururus cernuus	Lizards tail
Typha gracilis	Slender cattail
Typha laxmannii	
Typha minima	

Table 4 Critical-ranked terrestrial taxa

Latin name	Common name
Acaena novae-zelandiae	Pirri-pirrri-bur
Ailanthus altissima	Tree-of-heaven
Allium triquetrum	Three-cornered garlic
Buddleja davidii	Butterfly-bush
Cardamine raphanifolia	Greater cuckooflower
Chamaecyparis lawsoniana	Lawson's cypress
Cortaderia richardii	Early pampas-grass
Cotoneaster bullatus	Hollyberry cotoneaster
Cotoneaster conspicuus x dammeri (C. x suecicus)	Tibetan cotoneaster
Cotoneaster dammeri	Bearberry cotoneaster
Cotoneaster dielsianus	Diels' cotoneaster
Cotoneaster frigidus x salicifolius (C. x watereri)	Tree cotoneaster
Cotoneaster hjelmqvistii	Hjelmqvist's cotoneaster
Cotoneaster horizontalis	Wall cotoneaster
Cotoneaster lacteus	Late cotoneaster
Cotoneaster microphyllus agg.	Small-leaved cotoneasters
Cotoneaster prostratus	Procumbent cotoneaster
Cotoneaster rehderi	Bullate cotoneaster
Cotoneaster salicifolius	Willow-leaved cotoneaster
Cotoneaster simonsii	Himalayan cotoneaster
Cotoneaster sternianus	Stern's cotoneaster
Crocosmia paniculata	Aunt-Eliza

Latin name	**Common name**
Crocosmia pottsii	Pott's montbretia
Crocosmia x crocosmiiflora	Montbretia
Cyperus eragrostis	Pale galingale
Disphyma crassifolium	Purple dewplant
Euphorbia amygdaloides subsp.*robbiae*	
Fallopia baldschuanica	Russian-vine
Fallopia japonica x sachalinensis (F. x bohemica)	
Hedera colchica	Persian ivy
Hyacinthoides hispanica x non-scripta	Spanish bluebell
Lamiastrum galeobdolon subsp.*argentatum*	Variegated yellow archangel
Laurus nobilis	Bay
Ligustrum ovalifolium	Garden privet
Lonicera japonica	Japanese honeysuckle
Lonicera nitida	Wilson's honeysuckle
Persicaria campanulata	Lesser knotweed
Persicaria wallichii	Himalayan knotweed
Petasites japonicus	Giant butterbur
Picea sitchensis	Sitka spruce
Pinus nigra	Austrian pine, Corsican pine
Prunus lusitanica	Portugal laurel
Pseudosasa japonica	Arrow Bbamboo
Pyracantha coccinea	Firethorn
Pyracantha rogersiana	Asian firethorn
Quercus cerris	Turkey oak
Quercus ilex	Evergreen oak
Quercus rubra	Red oak
Rhododendron ponticum x R. maximum	Rhododendron hybrid
Ribes odoratum	Buffalo currant
Robinia pseudoacacia	False-acacia
Rosa multiflora	Many-flowered rose
Rosa rugosa	Japanese rose
Rubus cockburnianus	White-stemmed bramble
Rubus tricolor	Chinese bramble
Sasa palmata	Broad-leaved bamboo
Sasaella ramosa	Hairy bamboo
Sorbaria sorbifolia	Sorbaria
Yushania anceps	Indian fountain-bamboo

Table 5 Urgent-ranked taxa

Latin name	**Common name**
Acorus calamus	Sweet flag
Alnus cordata	Italian alder
Alstroemeria aurea	Peruvian lily
Ampelodesmos pliniana	
Arundo donax	Giant reed
Buddleja globosa	Orange-ball-tree
Cardamine corymbosa	New Zealand bitter-cress
Ceratochloa carinata	California brome
Cornus alba	White dogwood
Cortaderia selloana	Pampas-grass
Cotoneaster conspicuus	Tibetan cotoneaster
Cotoneaster divaricatus	Spreading cotoneaster
Cotoneaster franchetii	Franchet's cotoneaster
Cotula coronopifolia	Buttonweed
Cyperus albostriatus 'Variegatus'	
Cyperus rotundus	Purple nut sedge
Echium pininana	Giant viper's-bugloss
Erigeron karvinskianus	Mexican fleabane
Gaultheria mucronata	Prickly heath
Geranium endressii x versicolor (G. x oxonianum)	French crane's-bill
Gunnera tinctoria	Giant-rhubarb
Iris orientalis	Turkish iris
Juncus xiphioides	Iris-leaved rush
Kniphofia uvaria	Red-hot-poker
Kniphofia x praecox	Greater red-hot-poker
Lemna minuta	Least duckweed
Lonicera pileata	Box-leaved honeysuckle
Lupinus arboreus	Tree lupin
Lupinus arboreus x polyphyllus (L. x regalis)	Tree lupin
Myriophyllum het	Western milfoil
Myriophyllum hippuroides	
Myriophyllum pinnatum	
Myriophyllum propinquum	
Myriophyllum propium	
Myriophyllum 'Red Stem'	
Nymphaea tetragona	Pygmy water Lily
Oxalis latifolia	Garden pink-sorrel
Parthenocissus quinquefolia	Virginia-creeper
Pinus contorta	Lodgepole pine
Pontederia cordata	Pickerelweed

Latin name	Common name
Rosa ferruginea	Red-leaved rose
Sagittaria graminea	Grassy arrowhead
Sagittaria subulata	Narrow-leaved arrowhead
Sagittaria teres	Slender arrowhead
Salvinia natans	
Spiraea douglasii x salicifolia (S. x pseudosalicifolia)	Lange's spiraea
Symphoricarpos microphyllus x orbicularis (S. x chenaultii)	Snowberry
Thalia geniculata	
Thuja plicata	Western red-cedar
Trapa natans	Water chestnut
Utricularia gibba	Humped bladderwort
Vallisneria americana	
Vallisneria asiatica	
Vallisneria spiralis	Tape grass
Viburnum rhytidophyllum	Wrinkled viburnum

Table 6 Moderate Risk taxa

Latin name	Common name
Acorus gramineus 'Pusillus'	Miniature sweet-flag
Alchemilla mollis	Garden lady's-mantle
Alisma parviflora	American water-plantain
Alocasia cucullata	Chinese taro
Aponogeton distachyos	Cape-pondweed
Bacopa caroliniana	Giant babies tears
Bacopa rotundifolia	Disk water-hyssop
Berberis thunbergii	Thunberg's barberry
Blyxa aubertii	Bamboo plant
Calla palustris	Bog arum
Caltha leptosepala	White marsh-marigold
Caltha palustris subsp. *polypetala*	Giant kingcup
Caltha palustris var. *barthei*	
Caltha palustris var. *radicans*	
Campanula poscharskyana	Trailing bellflower
Cardamine lyrata	Chinese ivy
Cardamine macrophylla	
Carex muskingumensis	Musk sedge
Cymbalaria pallida	Italian toadflax
Cyperus haspan L.	
Cytisus striatus	Hairy-fruited broom
Echinodorus argentinensis	

Latin name	**Common name**
Echinodorus berteroi	Upright burhead
Echinodorus cordifolius	Creeping burhead
Echinodorus parviflorus	
Echinodorus tenellus	Pygmy chain sword
Echinodorus uruguayensis	
Eichhornia crassipes	Water hyacinth
Eleocharis dulcis variegated	Chinese water-chestnut
Equisetum hyemale var. *affine*	
Equisetum japonicum	
Equisetum ramosissimum var. *japonicum*	Branched horsetail
Erigeron glaucus	Seaside daisy
Eriocaulon cinereum	Ashy pipewort
Eusteralis stellata	
Glossostigma elatinoides	
Gratiola officinalis	Hedge hyssop
Gymnocoronis spilanthoides	Senegal tea plant
Hydrocotyle verticillata	Whorled marsh-pennywort
Hygrophila lacustris	Gulf swampweed
Hygroryza aristata	
Iris laevigata	Japanese water iris
Kerria japonica	Kerria
Lindernia grandiflora	Blue moneywort
Ludwigia ovalis	
Ludwigia x kentiana (L. palustris x L. repens)	Hampshire-purslane
Lysichiton americanus	American skunk-cabbage
Lythrum virgatum 'Dropmore Purple'	Purple loosestrife 'Dropmore Purple'
Marsilea hirsuta	Rough water clover
Mayaca fluviatilis	Green mayaca
Nuphar japonicum	
Nymphaea odorata	Fragrant water lily
Nymphaea odorata subsp. *tuberosa*	
Nymphaea pubescens	Purple water lily
Nymphoides aquatica	Banana plant
Parthenocissus inserta	False virginia-creeper
Pistia stratiotes	Water lettuce
Proserpinaca palustris	Mermaid weed
Rhododendron luteum	Yellow azalea
Rhus typhina	Stag's-horn sumach
Rosa 'Hollandica'	Dutch rose
Sagittaria platyphylla	
Samolus valerandi ssp. *parviflorus*	Water pimpernel
Saururus chinensis	

Latin name	Common name
Schoenus pauciflorus	
Spiraea alba x salicifolia (S. x rosalba)	Billard's bridewort
Thalia dealbata	
Trichocoronis rivularis	
Typha shuttleworthii	
Utricularia sandersonii	
Vallisneria natans var. *natans*	
Vallisneria tortifolia	

4.10 The difference in selection processes between freshwater and terrestrial taxa for inclusion in the Rapid Risk Assessment screening reflects the nature of invasion histories for freshwater and terrestrial systems. As the original UK-adapted Weed Risk Assessment allocates five points to a species just for being aquatic, the greatest score possible from a single question in the assessment (and as opposed to a maximum of one point available for certain types of terrestrial species) (Defra 2008 online), the differing approach seems justifiably precautionary.

4.11 Freshwater systems appear to be particularly susceptible to colonisation by invasive non-native plants (Zedler & Kercher 2004). Moreover, invasions by non-native species in freshwater systems tend to take place at a much faster rate than invasions in terrestrial habitats. The potential for rapid (and widespread), water-assisted dispersal of propagules through the aquatic habitat, availability of surplus nutrients (for example through pollution), ‘empty’ space in the water column and high levels of disturbance (e.g. in the draw-down zone) are all likely to contribute to the high ‘invasibility’ of freshwater habitats.

4.12 Invasions in terrestrial habitats, by comparison, are often slower not least because the ‘invader’ may be a woody species that takes considerable time to establish. Where lag phases of terrestrial species have been examined, typically over 100 years pass between first records in the wild and the recognisable display of invasive behaviour and spread by a species (Kowarki 1995). Moreover, initial establishment in a number of terrestrial habitats is more likely to require a serendipitous timing of disturbance with the arrival of an invasive species’ propagules than are freshwater systems.

4.13 Rather than seek to determine which of the tens of thousands of terrestrial plants available to gardeners and landscapers merited inclusion in the study, the approach taken was to identify already established terrestrial species which have been seen to be increasing in the wild in recent years. In this way, terrestrial species may be identified that are on the cusp of becoming invasive in Britain.

4.14 Even though the terrestrial plants included in the study are already present in the wild, for a number of taxa early detection may still enable ‘offensive strategies’ (i.e. eradication) to be undertaken rather than requiring ‘[retreat] to defensive strategies with their long-term financial commitments’ (Rejmánek 2000). Half of the terrestrial taxa screened were recorded in the most recent date-class (1987-99) from 70 or fewer 10km squares (hectads) (Preston, Pearman & Dines 2002). Rapid response strategies may still be viable for a number of these taxa. Around 50 taxa were already recorded from 200 or more tetrads in the *Atlas* and different management approaches, beginning with containment, may be required for these. The purpose of the Rapid Risk Assessment is to prioritise plants for further, fuller risk assessments. The outcome of the detailed risk assessments would help determine whether or not a species requires a management plan and the objective (control or eradication, for example) of such a plan. Some species screened, like Sitka spruce *Picea sitchensis*, are used commercially and economic considerations may heavily influence any potential management recommendations.

4.15 Mapping resolution can affect the perception of the extensiveness of an invasion and rate of spread (Hulme 2003). The rate of increase in the wild for assessed taxa is based on records mapped at 10km square (hectad) resolution - this was the finest resolution that was easily available and manageable for such large numbers of taxa. It is possible that this resolution could lead to overestimating the distribution of a taxon (see Pearman & Walker 2009). Since this would affect the score of just one of the 22 questions (though admittedly one with a high maximum score of four points) this is unlikely to play a pivotal role in determining whether or not a taxon was deemed invasive. However, if a taxon is identified as invasive and yet is only found in a limited number of locations within each $10km^2$, effective control may be more achievable than its $10km^2$ distribution would initially suggest.

4.16 The speed of invasion in freshwater systems, coupled with the acknowledgement that the majority of non-native invasive freshwater plants causing damage to the wider environment are ornamental aquatic plants that have 'escaped over the garden wall', led to any non-native freshwater plant known to be on sale in Britain to be included in this study. As the number of aquatic plants available commercially is far smaller than that for terrestrial species, this was considered more feasible than a similar approach for terrestrial species (even though ornamental terrestrial plants are also a major source of invasive terrestrial species in the wild – see Hill and others 2005).

4.17 However, the initial list of 1,454 names cannot be considered a comprehensive list of all freshwater species and taxa on sale in Great Britain. Since plants are now available via internet mail order, making a comprehensive list of plants with the potential to enter Britain may no longer be realistic. Produce contaminants ('hitch-hikers') add to this problem as a number of plant species in Britain, or likely to arrive here, are not intentionally imported. A number of aquatic plants are sold identified to genus level only and some appear not to be identified at all, for example plants simply sold as 'mixed oxygenators'. It is likely that expert analysis would be required to identify many of these entities to species/taxa level. This was incongruous with the task in hand – performing a rapid risk assessment for large numbers of taxa – and so these entities were excluded from assessment. Meanwhile, the widespread use of misnomers (as well as synonyms) compounds the task of identifying exactly what is available to purchase here.

4.18 As the compilation of a comprehensive list of freshwater plants traded in Britain was not achieved in this project, it is strongly recommended that *any* freshwater non-native plant found to be traded in Britain is risk-assessed for its invasive potential. Furthermore, produce contaminants (such as *Spirodela (Landoltia) punctata, Lemna valdiviana* and others, pers. comm. Richard Lansdown, March 2009) should also be identified and assessed. Marine plant commodities must also be subject to assessment.

4.19 Predicting plant invasiveness cannot be done with complete accuracy: there will always remain the risks of false negatives and false positives (Daehler & Denslow 2007). The potential for currently benign plants to become invasive as the climate changes adds to this challenge. Rejmánek (2000) suggests that a number of invasive species will benefit from expected global trends associated with climate change such as atmospheric nitrogen fertilization, CO_2 rises and climate extremes. However, Hulme (2003; 2009) expects that the relationship between climatic changes and non-native species in the UK will be less predictable and complicated by, for example, interactions between species and changes in land-use.

4.20 The recently observed increased competitive ability in New Zealand willowherb *Epilobium brunnescens* demonstrates this complexity. *E. brunnescens* has benignly occupied niches alongside native plants in Snowdonia for many years. Now the average snowline has increased from 100m above sea level in the 1980s to 800m today, and the native Snowdon lily *Lloydia serotina* is flowering three weeks earlier than it used to. The once benign non-native plant may now, as a result of climatic changes, have a significant impact on rare British plants and their associated disappearing habitats (Thomas & Dines 2010). This species may also be having an impact on rare/scarce communities in uplands in England too (pers. comm. Simon Leach, October 2010).

4.21 For these reasons, it is recommended that all plants screened in this study are reviewed periodically to take account of emerging evidence, changes in climate and the emergence of new horticultural varieties and cultivars that may be more frost-hardy than the taxa screened here.

Scheme assessment

4.22 It has been possible to assess the scoring process against known invasive species. Thirty of the 'new' plant species added to Schedule 9 of the Wildlife and Countryside Act in April 2010 were assessed as part of this Rapid Risk Assessment, and of these the scores of 17 would place them in either Critical (red) or Urgent (orange) categories (see Table 7, below). Of some concern was the fact that the remaining 13 species assessed fell into the Moderate Risk (yellow) and Low Risk (green) categories, based on the score allocated.

4.23 The Low Risk scoring species were giant salvinia *Salvinia molesta* and giant-rhubarb *Gunnera tinctoria*. Evidence from western Britain and Ireland of *G. tinctoria*'s invasive behaviour led to this species being re-ranked to Urgent. *Salvinia molesta* is considered a tropical species with no known hardy varieties available to date and so was terminated in the Rapid Risk Assessment at Q2. Although this species has a far wider climatic distribution in its non-native range compared to its restricted native range, it has had less success in exploiting habitats north of 30° (Rejmánek 2000) and in the opinion of the authors would not be able to survive here at present due to short growing seasons, lower average temperatures and the incidence of frost. The full risk assessment for this species, commissioned by the Non-Native Species Secretariat is still in progress at the time of submission and so its findings cannot be compared with the output of the Rapid Risk Assessment.

4.24 After expert opinion was taken into account (but before the Defra announcement), 23 new Schedule 9 species were ranked Critical, two Urgent, four Moderate Risk and one Low Risk (see 3.12 above and section 4.56 below for details of secondary assessment using expert opinion).

Table 7 Scores of plants newly listed on Schedule 9 of the Wildlife and Countryside Act

Species	Score	Appropriate rank based on score alone	Final rank allocated
Allium triquetrum	24		
Azolla filiculoides	29		
Cabomba caroliniana	22		
Cotoneaster bullatus	20		
Cotoneaster horizontalis	30		
Cotoneaster microphyllus agg.	21		
Cotoneaster simonsii	20.5		
Crassula helmsii	30		
Crocosmia x *crocosmiiflora*	25.5		
Disphyma crassifolium	20.5		
Eichhornia crassipes	18		
Elodea callitrichoides	19		
Elodea canadensis	28		
Elodea nuttalli	30		
Fallopia japonica x *sachalinensis*	26		
Gunnera tinctoria	14		
Hydrocotyle ranunculoides	27.5		
Lagarosiphon major	28		
Lamiastrum galeobdolon subsp.*argentatum*	31		
Ludwigia grandiflora	29		
Ludwigia peploides	19		
Myriophyllum aquaticum	28		

Species	Score	Appropriate rank based on score alone	Final rank allocated
Parthenocissus inserta	20		
Parthenocissus quinquefolia	22		
Pistia stratiotes	20		
Rhododendron ponticum x *R. Maximum*	21		
Rhododendron luteum	20		
Rosa rugosa	24		
Sagittaria latifolia	26		
Salvinia molesta	Screening terminated		

Critical (red); Urgent (orange); Moderate Risk (yellow); Low Risk (green)

4.25 Thus, based on the final rankings allocated, the Rapid Risk Assessment screening may be considered to have been largely successful in identifying plants now considered invasive as presenting an invasive risk. Although this is how many other risk assessment systems have been appraised (e.g. Pheloung 1995; Daehler & Denslow 2007), this may not be considered sufficient evidence of the effectiveness of the screening process due to the role of expert opinion in determining the risk ranks assigned to each species.

4.26 The preventative approach to dealing with invasive non-native plants in Britain requires a rapid risk assessment capable of highlighting previously unknown or unsuspected potential invaders, yet the effectiveness of a screening process (this or any other) to that effect cannot be determined until a number of screened species not already considered to be invasive at the time of assessment become invasive. Baker and others (2008) suggest conducting a retrospective risk assessment for a species now known to be invasive in Britain *based on evidence available before it became invasive* provides a reasonable means for testing the efficacy of a risk assessment process. This has not been done to date for this Rapid Risk Assessment and may be considered a useful technique, although hindsight may make it difficult to simulate realistic contemporary expert opinion.

4.27 Meanwhile, the progenitor of the Rapid Risk Assessment process has been subjected to much greater levels of scrutiny and this may offer some insight into the likelihood of the screening process performing well at identifying potentially invasive plants.

Approaches to risk assessment

4.28 Out of the numerous risk assessment systems and approaches developed to assess potential invasiveness of non-native species, the Australian Weed Risk Assessment of Pheloung (1995, Pheloung, Williams & Halloy 1999) is considered to have a high rate of correct invasive identification. As such it has been adapted for use in other areas of the world, including temperate regions, where it has also performed with reasonable to high levels of success (Daehler & Carino 2000; Jefferson, Havens & Ault 2004; Křivánek & Pyšek 2006; Gordon, Fox & Stocker 2006; Daehler & Denslow 2007). It was also adapted for use in the risk assessment system trialled in Britain (Baker and others 2008, Defra 2008 online).

4.29 What makes a risk assessment for invasiveness 'successful' has been much debated and no clear guidelines emerge. For example, concentrating on species traits has met with patchy success (e.g. Alpert, Bone & Holzapfel 2000) or requires assessment on a habitat-specific basis (Lloret and others 2005), perhaps because no single suite of traits for invasiveness exists (Heger & Trepl 2003; Hulme 2006). Moreover, such a focus may risk increasing the rate of false positives (declaring a species to be invasive when it is not/does not become invasive) (Rejmánek 2000). Meanwhile, the importance of evidence of environmental impacts/invasive behaviour elsewhere has been considered critical (e.g. Reichard & Hamilton 1997; Rejmánek 2000), yet also cited as a reason for poor predictive results of one risk assessment system that emphasised the importance of such evidence (Křivánek & Pyšek 2006).

4.30 Despite this, attempts to produce rapid assessments with a small number of questions have been reasonably successful in some applications (see Reichard & Hamilton 1997; Caley & Kuhnert 2006). Caley & Kuhnert (2006) reduced the original 49-question Australian Weed Risk Assessment to just four questions (intentional human dispersal of propagules, evidence of naturalisation beyond native range, evidence of being a weed elsewhere, high level of domesticity), although Daehler & Denslow (2007) warn of potential quirks in the original dataset that could have led to their success. Reichard & Hamilton's (1997) scheme, designed for application in North America, consisted of seven questions and performed well in the area for which it was designed but the small number of questions was considered central to its limited application success elsewhere (Křivánek & Pyšek 2006). Using a small number of questions may be considered to add bias into the risk assessment process, particularly as a definitive set of conditions for predicting invasiveness has not been established. In contrast, however, some consider the Australian Weed Risk Assessment to be over-fitted, whereby its extensive questions and complexity compared to the amount of data available may limit its predictive power (see Booy, White & Wade 2006). (It is possible that the less extensive version of the Weed Risk Assessment trialled in this project could be absolved from this flaw.)

4.31 Sufficient evidence and information is unlikely to exist for exhaustive assessments to be completed for more than a handful of species (that are anyway already identified as being invasive elsewhere). Indeed, Anderson and others (2004) suggest that the empirical evidence ideally needed to carry out comprehensive risk assessments for potentially invasive species is likely to 'persistently outstrip [information] supply'. Meanwhile, Wilby (2007) stresses that in waiting for 'proof' of invasiveness in Britain the opportunity to implement effective eradication of invasive non-native aquatic plants may be lost. Taylor and others (2007) similarly warn against taking no management action against invasive plants whilst 'hypothesising that [invasive plants...] may one day become innocuous'.

4.32 As the intention for the Rapid Risk Assessment process was to screen species about which there may be little to no information on species' traits, let alone evidence of invasiveness elsewhere, a broad suite of questions was considered necessary to reduce bias. Inevitably the answers to many questions would be unknown and with a small initial suite of questions this could have left invasive risk categories to be assigned based on minimal considerations. The apparent validity of risk assessments with few questions (at least when they are applied to the geographic areas and taxa forms for which they were developed) suggests that an assessment consisting of 22 questions is not so simplified / biased as to be rendered futile, even if a number of questions remain unanswered.

Screening questions and weightings

4.33 The inclusion and exclusion of specific questions raises further issues. For example, Křivánek & Pyšek (2006) express concern over the inclusion of questions relating to congeneric weeds. Although their concern was in the context of a seven-question risk assessment (and so more likely to produce significant bias in the risk assessment process than in this 22-question scheme), it may, nonetheless, be considered a weakness of the Rapid Risk Assessment that taxonomic affiliation is considered so crudely. A species in a large genus with just one known invasive species will be penalised as much as one in a small genus with several other invasive species, yet the risk could clearly be considered different in these cases. Meanwhile, Rejmánek (2000) warns that making conclusions based on a lack of invasive history (or under-representation) in a plant family can be dangerous too, citing the now invasive *Cinchona pubescens* (Rubiaceae) in Galápagos.

4.34 The use of spread rate/year from the time of first record in the wild introduces a second issue over choice of resolution. Calculating the rate of increase between the two *Atlas* distributions in 1986 and 1999 would have caused 21 taxa to score three or four points more on Q1 than using spread rate from the date of first record in the wild. A difference of two points would have been seen in a further 55 taxa. Thus potential lag phases could have diluted the signal of recent rapid growth in the current system. The time resolution used should be reconsidered in any development of this screening system.

4.35 Recognising that the majority of invasive plants affect human-dominated rather than (semi-)natural habitats (Clement & Foster 1994; Crawley, Harvey & Purvis 1996; Chytrý and others 2005), the Rapid Risk Assessment screening makes the assumption that it is important to distinguish between taxa that will thrive in human-dominated habitats and those that will spread into (semi-) natural areas. However, this assumes that taxa currently only in urban habitats are not going to spread elsewhere. Given that urban habitats may provide refugia for invasive non-native species and offer a launch pad for future invasion (particularly as humans are often crucial agents in the movement of species in to the wild), this may be considered a further weakness of the rapid screening system (see Pyšek, Jarošik & Kucera 2002; Hulme 2003). The spread of species like Variegated yellow archangel *Lamiastrum galeobdolon* subsp *argentatum*, or Spanish bluebell *Hyacinthoides hispanica* from 'urban' or otherwise 'unnatural' woodland into semi-natural habitats is a good case in point. Moreover, other interest groups may be more concerned by invasive species that occupy these human-dominated habitats than those likely to affect (semi)-natural areas. For example, the invasive non-native plant Japanese knotweed *Fallopia japonica* has had little impact on sites of botanical interest in the UK (see Preston & Walker 2009), but continues to be a considerable concern for construction and transport industries. Where invasive potential *per se* is of interest, it may be possible to utilise an amended version of the Rapid Risk Assessment, although in adding extra questions the scheme's speed may be compromised.

4.36 Three questions are included relating to seed production (Q11, Q20, Q21), yet the matter of whether or not seeds establish freely under British conditions is not addressed. The wording of Q11 (ability to produce seed here) and Q20 (prolific seed production) would benefit from revision in any developments of the screening process. The paucity of information in this area for aquatic plants should be considered during the revision.

4.37 Invasive behaviour in natural and semi-natural habitats elsewhere has been considered one of the most important considerations in assessing the invasive potential of a species. However, given the time lags associated with many plant invasion histories this is clearly not a fool-proof approach. Assessing characteristics such as smothering growth forms and prolific seed production is also not fool-proof, as plants often behave differently when removed from their usual biotic and abiotic constraints (Mack and others 2000).

4.38 In spite of these issues, used in combination, and with the added consideration of pathways of introduction and spread within Britain, we consider it possible to assign a broad level of risk posed by a particular species to natural and semi-natural habitats.

4.39 In so doing, however, the different aspects of an invasion – likelihood of species' establishment, potential impacts and likely spread – must be weighted. Weighting is a key consideration in the development of a risk assessment process, although Pheloung (1995) considers weighting questions to be subjective. Yet, since no universally accepted set of criteria exists to determine a species' invasiveness, the choice of questions to include and exclude from a screening system already contains a level of weighting or subjectivity. Furthermore, a lack of weighting equates to equal weighting for each question.

4.40 The non-native risk assessment process adopted by the GB Non-Native Species Secretariat has unequal numbers of questions relating to establishment, impacts, entry and spread, in effect weighting these key aspects of invasion differently. Meanwhile, in sections containing several questions individual questions may have less bearing on that area of the risk assessment than questions in shorter sections (see Booy, White & Wade 2006). The scheme has been criticised for question repetition, particularly as it was assumed that the repetition served as a means to achieve weighting (*ibid*). As repetition is incongruous with speed questions were weighted in the Rapid Risk Assessment.

4.41 Questions relating to rate of spread in the UK (Q1) , climatic suitability (Q2), evidence of 'weediness' in natural and valued habitats (Q3) and climbing/smothering/thicket growth traits (Q10) were allocated maximum scores of three or four points, five questions had a possible top score of two and the remaining 13 questions scored one point each. Plants suited to continental temperate climates scored more highly than plants of warm temperate, semi-tropical and tropical species in three questions (Q2, Q4, Q7), even though there was only one question directly related to climate.

4.42 As the importance of human-mediated transport, especially for long distance dispersal events, is becoming more apparent (e.g. Hodkinson & Thompson 1997) this means of dispersal was, in effect, weighted by asking three questions pertaining to it (Q14, Q15, Q16) rather than one. Three other questions on wind-, water- and animal-assisted dispersion were also separated out. This may be considered weighting by repetition as it would be possible to group Q14-19 into one question with one point awarded for each method by which a plant may be dispersed. This method would not preserve potentially useful 'unknown' and 'no' answers, however, and so was not chosen.

4.43 The effects of the scheme's weighting on the outcomes of the screening process have not been analysed in depth. It is recommended that, should there be merit in developing the Rapid Risk Assessment further, this area is afforded greater attention.

False negatives and positives

4.44 As it is less comprehensive than the full Weed Risk Assessment on which it is based, the Rapid Risk Assessment screening process is likely to be more susceptible to false negatives – declaring a species to be non-invasive which later becomes invasive – and false positives – declaring a species to be high risk which does not prove invasive – than its progenitor.

4.45 As non-native plants become invasive at a low base rate, high levels of false positive results may be considered to render a risk assessment process futile (Smith, Lonsdale & Fortune 1999). This assertion is based on the notion that for a risk assessment with accuracy below 85% the costs of introducing an invasive species need to outweigh the costs of not introducing a benign species by eight-fold in order for the assessment process to be of value. Using this argument, many invasive species risk assessments should be ignored, including Pheloung's Australian Weed Risk Assessment and (almost certainly) the Rapid Risk Assessment.

4.46 However, Keller, Lodge & Finnoff (2007) challenge this notion and argue that Pheloung's assessment is sufficiently accurate as to have net economic benefits. This was the case even when the damage done by invasive plants was costed low and the value of the species to ornamental trades costed high. Moreover, the study did not include the non-market costs of invasive species such as threats to biodiversity as a result of the introduced species itself or the diseases it may harbour, reduced amenity uses of habitats or even the voluntary labour given to clearing invaded areas. Hence, it is possible that the true value of the Australian Weed Risk Assessment has still been underestimated.

4.47 Other challenges to the low base rate/high predictive power requirement may also exist. As ecosystem services provided by natural and semi-natural habitats are audited, it is likely that the true value of detecting invasive species will be better understood and elevated accordingly, tipping the balance in favour of rejecting potentially benign species rather than risking accepting them. The low base rate of species invasions, currently based on Williamson's 'tens rule', developed in relation to terrestrial species behaviour up until the 1980s, may also be challenged. The base rate of invasion for non-native aquatic plants is likely to be greater than that for terrestrial species. Climate change may increase the base rate of species invasions too, not least as a result of increased habitat disturbance. Calculations of a base rate of invasion may be suppressed by the lag phases of introduced species. The higher rates of spread achieved by 87% of the terrestrial species screened in this project post-1986 compared to pre-1986 serve as a reminder that the ten's rule is a hypothesis based on contemporary evidence from the 1980s, and should be revisited rather than treated as a constant (Hulme 2003).

4.48 Whilst acknowledging the low base rate issue, in this screening project it was considered more important to reduce the risk of false negative results than false positive results. Reducing false positives was considered more appropriate for assessments that influence policy making and management decisions than a broad screening process. In order to reduce the risk of false negative results the precautionary principle was applied.

4.49 Although this will increase further the number of false positive results, the precautionary principle has been used elsewhere in risk assessment processes, including the USA's Animal and Plant

Health Inspection Service (for deliberate introduction of species), where uncertainty can be a reason for a high risk status (Daehler & Denslow 2007). Others (e.g. Pheloung 1995; Manchester & Bullock 2000) also acknowledge that there is a legitimate place for the precautionary approach in invasive risk assessment schemes, and this principle has been adopted in relevant England and GB invasive non-native species policy (Defra 2008; Natural England 2009). As the damage done to (semi-)natural habitats and ecosystem services by invasive species may be irreversible, applying the precautionary principle in an initial screening system (whereby all species of 'concern' should be subject to further assessment before any restrictive measures on their use are taken) can be considered justified.

4.50 The precautionary principle was applied at four stages of the Rapid Risk Assessment screening process. First some of the original questions were altered – for example, the definition of 'prolific seed/propagule production' is >2000/m^2 in the original UK-adapted Weed Risk Assessment (Defra 2008 online) but was reduced to >1000/m^2 for the Rapid Risk Assessment. In the original Pheloung assessment, positive 'non-invasive' attributes of a plant could reduce a species' score, making the system more flexible and less likely to penalise non-invasive species (Pheloung 1995). In the rapid assessment, all but one negative scoring possibility was removed (and even then in the remaining question the score could be reduced by just one point and would, most likely, mainly affect woody species). In cases of uncertainty over question answers a worst-case scenario was considered whereby each taxon was given a potential score based on each of the unknowns being answered so as to score most highly. This was considered alongside the actual score given to a taxon based on available information when expert opinion was used to assign a risk rank. Finally, in some cases where taxa achieved a relatively low score yet were thought by experts to still *potentially* pose a threat, they might be recommended for a full risk assessment and be placed in a higher ranking category than their score would dictate.

4.51 Within those taxa nominally scored in the Moderate Risk and Low Risk categories, 44 were upgraded to Critical and a further 31 moved to the Urgent category. These were typically taxa that belonged to 'problem' genera (e.g. *Buddleja*, *Cotoneaster*, *Ludwigia*, *Myriophyllum* and *Sagittaria*) or families (e.g. *Yushania anceps*); and/or were already known to pose a significant threat to key botanical sites in north-west Europe (e.g. *Disphyma crassifolium*, *Quercus ilex*, *Rhododendron ponticum* and hybrids, and *Robinia pseudoacacia*).

4.52 In contrast, within the category for nominally Critical risk taxa (i.e. scoring >=25) expert opinion suggested that just two species would not pose a major threat to semi-natural vegetation or rarer species and were downgraded to the Moderate Risk category (*viz*. *Gymnocoronis spilanthoides* and *Nymphaea odorata*). Amongst the nominally Urgent risk taxa (ie scoring 22 – 24.5), only five species were downgraded to the Low Risk category on expert opinion (*Campanula portenschlagiana*, *Hyacinthus orientalis*, *Physalis peruviana*, *Scilla sibirica*, and *Stachys byzantina*), and eight taxa to the Moderate category. These downgrades were typically because the taxon was thought to have a low competitive ability (e.g. *Hyacinthus orientalis*), was not thought to have a smothering habit, was confined to artificial habitats or was a relatively small annual.

4.53 Given the low scores for a number of known invasive plants (Table 7, above) and the small number of plants downgraded in rank as a result of expert opinion compared to those upgraded, there may be merit in lowering the threshold for the Urgent rank category.

4.54 In adopting a precautionary approach the risk of false positives is heightened. This would be compounded if the Urgent category threshold was lowered. Therefore, it is highly recommended that potentially 'risky' taxa are subject to more detailed assessment before any management or policy decisions about the taxon in question are taken. Indeed, moves to restrict taxa highlighted in this study through a ban on sale should be considered unjustifiable without further and fuller assessment of the risks an individual taxon poses. However, it is recommended that these more comprehensive assessments are conducted without delay.

4.55 The inevitable trade-off between including 22 questions and requiring an assessment to be rapid (and so applicable to large numbers of taxa) has been made in the certainty with which the questions are answered and the transparency of answers. The comprehensive risk assessment process used in Britain requires a written statement to accompany all answers given (Baker and others 2008). Although desirable, it is recognised that such a process requires substantial effort (see Booy, White & Wade 2006) and hence is not compatible with a rapid screening system. However, it should be recognised that even when such apparent transparency is required in a system, this may not guarantee impartiality. Indeed, 22% of assessors trialling the comprehensive risk assessment for non-native species in Britain acknowledged that their approach to the assessment was non-neutral (*ibid*). Moreover, although written statements are required, many are not substantiated by published evidence (see NNSS 2010 online).

Secondary assessment using expert opinion

4.56 The decision to incorporate expert opinion in categorising the risk associated with screened taxa may be considered to further hinder transparency. However, without expert opinion the task of screening volumes of taxa about which little may be known would not be possible. Although expert opinion has been used to ‘test’ other invasive risk assessment systems (e.g. Pheloung 1995; Daehler & Denslow 2007), in the Rapid Risk Assessments expert opinion could not be formed from experience of the individual taxon in question in a number of cases and particularly amongst the aquatic plants. Repeatability of expert opinion, therefore, becomes a key feature in the efficacy of the system.

4.57 The opinions of two experts were independently sought at the risk categorisation stage (Dr Trevor Dines and Andy Byfield). Of 207 taxa where expert opinion was sought, both experts returned the same answer in a five point risk rank (species likely to pose ‘very high’, ‘high’, ‘medium’, ‘low’, ‘very low’ invasive risk to (semi-)natural sites) for 91 taxa and an adjacent risk rank for 81 others. There was a difference of 2 ranks for 29 taxa and a difference of three ranks for six taxa. For the 35 taxa where expert opinion differed significantly, the precautionary principle was applied and all taxa that either expert considered to present a ‘high’ (or ‘very high’) invasive risk were ranked so as to recommend more comprehensive analysis. Contradictory opinions were most likely for taxa where one or both experts had little/no knowledge or experience, but a consensus or near consensus for 83% of taxa may be considered to demonstrate a reasonable level of repeatability, particularly given the screening rather than decision-making nature of the assessment scheme.

4.58 As the potential invasiveness of a species does not necessarily equate to its potential impact on (semi-)natural sites (Rejmánek 2000; Ricciardi & Cohen 2007), the use of expert opinion may be considered further justified in the Rapid Risk Assessment process. For example, Italian toadflax *Cymbalaria pallida* and adria bellflower *Campanula portenschlagiana* both score highly in the screening process and, using the suggested scoring thresholds, sit at the top and bottom end of the Urgent (orange) rank range. However, as wall specialists, their rapid spread in the wild and ability to cause significant damage to (semi-)natural habitats was considered highly unlikely, and hence their final rank was lowered. An unnecessarily high risk rank could have been avoided by the addition of further questions in the screening process (or a terminator question), but scheme simplicity would be compromised if all such quirks were pre-empted.

4.59 With the opposite effect, red oak *Quercus rubra* was ranked Critical after expert opinion was taken into account, even though its score was 19 (a score that would suggest a Moderate Risk/yellow rank). Interestingly, Reichard & Hamilton’s (1997) Europe-adapted risk assessment decision tree also failed to recognise this species as invasive in central Europe, despite it being already considered a pest species in the Czech Republic (Křivánek & Pyšek 2006).

Managing uncertainty in the risk assessment process

4.60 The final central feature of a risk assessment process is the manner in which it handles uncertainty. In this rapid screening assessment uncertainty was handled crudely: worst-case scenario scores were taken into consideration where answers to questions were unknown. The use of uncertainty scales (see Baker and others 2008) might well merit consideration if this rapid screening scheme is to be developed further.

4.61 Uncertainty is a much greater issue for the aquatic plants screened than the terrestrial taxa. Just 38 terrestrial taxa had a ‘Don’t Know’ answer to one of the 22 screening questions of which only nine had more than one question answered as ‘Don’t Know’. Uncertainty in the aquatic scores is far greater, with just nine taxa having one or no unanswered questions. Some of the aquatic cultivars, especially of the largely tropical genera but also several temperate taxa, were scored as the type variety since there was insufficient information on the cultivar or variety itself. Information was almost entirely absent for many aquatic plants with respect to sexual reproduction (seed produced, their dispersal and factors of germination). Thus the risk of false positives is considerably greater amongst the aquatic than the terrestrial taxa. Given the speed with which damage can be done by invasive plants to aquatic systems it was considered prudent to accept false positives over false negatives.

4.62 Ideally, for a risk assessment process to be useful the number of species falling into a ‘further assessment required’ category should be limited (Pheloung 1995); otherwise, screening systems can merely create a ‘greylist’ of species, devoid of proactive application (Hulme 2006). Whilst thresholds for risk categories can be adjusted easily, thereby reducing the number of species for which further assessment is required, there is an inevitable trade-off between increased detection of species with some potential risk of invasiveness and misclassification of genuinely benign species (Pheloung 1995).

4.63 Rather than adjusting category thresholds, Daehler and others (2004) attempted to solve this issue by creating a supplementary ‘key question decision-tree’ for species otherwise scored as ‘further assessment required’, and in so doing reduced the proportion of false positives (Daehler & Denslow 2007). Křivánek & Pyšek (2006) found that combining the Australian Weed Risk Assessment and Daehler and others (2004) decision-tree led to 100% of invasive species in their central Europe study area being identified, much higher predictive results than the Australian assessment alone. A secondary screen also proved useful when the Australian system was applied in Florida (Gordon, Fox & Stocker 2006).

4.64 The very purpose of the Rapid Risk Assessment is to recommend taxa for which it would be desirable to acquire greater levels of information, but with one third of the taxa screened recommended for further examination, it remained crucial to be able to prioritise within the ‘further assessment’ category in order to avoid an unconstructive greylist scenario.

4.65 Although there were often high levels of uncertainty amongst the freshwater plants screened, taxa whose scores placed them near or in the ‘assess further’ categories were then subject to a key question mini-assessment. Three questions (Q2, Q3, Q10) relating to evidence of climatic suitability to temperate areas, invasive behaviour in valued habitats and climbing/smothering/thicket-forming growth habits were used. Not only were these questions considered crucial to determining invasive risk to (semi-)natural habitats, but they were also reasonably devoid of uncertainty. Only eight of the 1,176 answers for non-tropical taxa were ‘Don’t know’. As a result of the secondary assessment, taxa could be assigned as being of little invasive concern (at present), and those falling within the ‘greylist’ were separated into three tiers relating to the urgency with which additional assessments are considered necessary.

4.66 The three questions used in this secondary screen were already heavily weighted in the scoring system and the impact of this effective double weighting on the results has not been examined.

Application

4.68 The Rapid Risk Assessment system is not sufficiently robust to be able to be used as a screening test by bio-controllers or horticultural producers, importers or wholesalers as the method for dealing with uncertainty is not sufficiently developed. However, it may be desirable to produce a simplified checklist that could be used by the horticultural trades in a system of voluntary self regulation, as has been done in Hawai’i (see Daehler & Denslow 2007), or by land managers.

4.69 The Rapid Risk Assessments completed to date make no consideration as to the volumes of specific plants in the horticultural/aquatics trades, nor their commercial value. As propagule pressure and likelihood of introduction and establishment in the wild are likely to be greater for species that are widely sold compared to those with low volumes of trade such information should be taken into account when more comprehensive risk assessments are conducted.

4.70 The commercial value of each species may be regarded as an important consideration that influences management decisions, but this consideration is not in itself related to invasive risk. It is recommended that where commercial interests are considered in decision making, the volume and value of trade are decoupled so that the invasive risk and nature of likely economic costs can be better understood. For example, a species with a high commercial value may reflect a high volume of cheap units (plants) or low volume of expensive units. The former may affect more businesses, but to a small extent, whilst generating a large propagule pressure. The latter may affect fewer businesses, but losses incurred to individual businesses may be greater, for example. Establishing the relative size of the market of particular species may be indicative of propagule pressure, but cannot guarantee that less frequently traded species will not be released as anthropogenic species introduction pathways can be difficult to predict (Kowarik 2003). Nonetheless, widely-available taxa such as *Lagarosiphon major* (sold as *Elodea crispa*) may be considered more likely to be repeatedly introduced into the wild than less popular plants.

4.71 It should be noted that the recommendation for further analysis can speed up the process by which species are given the ‘all clear’ for continued unrestricted use in the ornamental or landscaping trades, as well as the process through which such use may be restricted. Recent proposals for legislative changes to Schedule 9 of the Wildlife and Countryside Act (1981) might have led to nearly all *Cotoneaster* and *Crocosmia* species being made illegal to plant or otherwise cause to grow in the wild (Defra 2007b). The recommendation for species in these genera to be subject to more detailed risk assessment would seem both prudent, in terms of potential invasive threat to (semi-) natural habitats, and rational, in light of these suggestions of blanket restrictions.

5 Conclusions

5.1 This project set out to devise a rapid form of invasive risk assessment for non-native plants that enter Britain, are grown here or are already present in the wild.

5.2 In spite of efforts to base the screening system on a risk assessment scheme that has been well-received internationally, apply appropriate weighting to questions, and consider the role of uncertainty, in essence, expert opinion has still been central to the assessment of potential invasiveness of individual species. In an arena where demand for information about taxa will consistently outstrip supply, the use of expert opinion is almost inescapable.

5.3 Taxa highlighted through the screening process cannot, at this stage, be described as Britain's next invasive plants. The Rapid Risk Assessment scheme has adopted the precautionary principle and so is likely to generate a considerable number of false positive results.

5.4 However, the process has provided a horizon-scanning service which can be used to help prioritise resources by recommending a shortlist of plants for which more detailed assessment is considered imperative and/or prudent. Within the 218 taxa recommended for further assessment are three clear tiers of urgency with which such investigation is deemed necessary.

5.5 The need for a resource-efficient risk assessment with proven high predictive power in screening large numbers of non-native aquatic and terrestrial plants remains unabated. It is hoped that the results of this project will facilitate the development of such a system. With the publication of the screening method, additional aquatic taxa found to be on sale in Britain and a wider scope of terrestrial plants can now be screened by third parties. Further development of this risk assessment scheme should give greater consideration to the relative weighting of questions and the handling of uncertainty.

6 References

AKYALCIN, H., OZEN, F., & DULGER, B. 2006. Anatomy, Morphology, Palynology and Antimicrobial Activity of *Amsonia orientalis* Decne. (*Apocynaceae*) Growing in Turkey. *International Journal of Botany,* 2 (1), 93-99.

ALPERT, P., BONE, E., & HOLZAPFEL, C. 2000. Invasiveness, invisibility and the role of environmental stress in the spread of non-native plants. *Perspectives in Plant Ecology, Evolution and Systematics,* Vol. 3/1, 52-56.

ANDERSON, M.C., ADAMS, H., HOPE, B., & POWELL, M. 2004. Risk Assessment for Invasive Species. *Risk Analysis,* Vol. 24(4), 787-793.

Aquarium-gardening.com [online]. URL: **http://aquarium-gardening.com** [Accessed December 2008].

Aquatic Quotient [online]. URL: **www.aquaticquotient.com/** [Accessed November 2008].

BAKER, R.H.A., BLACK, R., COPP, G.H., HAYSOM, K.A., HULME, P.E., THOMAS, M.B., BROWN, A., BROWN, M., CANNON, R.J.C., ELLIS, J., ELLIS, M., FERRIS, R., GLAVES, P., GOZLAN, R.E., HOLT, J., HOWE, L., KNIGHT, J.D., MACLEOD, A., MOORE, N.P., MUMFORD, J.D., MURPHY, S.T., PARROTT, D., SANSFORD, C.E., SMITH, G.C., ST-HILAIRE, S. & WARD, N.L. 2008. The UK risk assessment schemes for all non-native species. In: *Neobiota – From Ecology to Conservation: The 4th European Conference of the working group NEOBIOTA on Biological Invasions, 27-29 September 2006, Vienna, Austria, pp.46-57.*

BASTMEIJER, J.D. [online] *The crypts pages*. URL: **http://www.xs4all.nl/~crypts/Cryptocoryne/index.html** [Accessed November 2008].

BOONMAN, A. M., BOONMAN, M., BRETSCHNEIDER, F., & VAN DER GRIND, W. A. 1998. Prey detection in trawling insectivorous bats: duckweed affects hunting behaviour in Daubenton's bat, *Myotis daubentonii*. *Behavioral Ecology and Sociobiology.* 44, 99-107.

BOOY, O., WHITE, V., & WADE, M. 2006. *Non-Native Organism Risk Assessment Scheme: Trialling and Peer Review.* Report for Scottish Executive. Report reference: FF/05/22 / Jpp1216-R-002a. Cambridgeshire: RPS Ecology.

BRAITHWAITE, M.E., ELLIS, R.W., & PRESTON, C.D. 2006. *Change in the British Flora 1987-2004*. London: Botanical Society of the British Isles.

BSBI. 2010. [online] *BSBI Map Scheme: Hectad Maps.* URL: **http://www.bsbimaps.org.uk/atlas/main.php** [Accessed February 2010].

CALEY, P., & KUHNERT, P.M. 2006. Application and evaluation of classification trees for screening unwanted plants. *Austral Ecol.,* 31, 647-655.

CANTER-LUND, H., & LUND J. W. G. 1995. *Freshwater Algae: Their Microscopic World Explored*. Bristol: Briopress Ltd.

CEH. 2005. *Relationship between Tree Mallow (Lavatera arborea) and Atlantic Puffin (Fratercula arctica) on the island of Craigleith, Firth of Forth (Forth Islands Special Protection Area).* Scottish Natural Heritage Commissioned Report No. 106 (Purchase order no. 7125)

CEH. 2007. *Development of eradication strategies for Ludwigia species*. Defra Research Project Report PH0422. URL: **http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=1&ProjectID=14763** [Accessed December 2008].

CENTRE FOR AQUATIC PLANT MANAGEMENT. 2004a. [online] *Information Sheet 7: Canadian Waterweed.* CEH. URL: **http://www.ceh.ac.uk/sci_programmes/documents/CanadianPondweed.pdf** [Accessed December 2008].

CENTRE FOR AQUATIC PLANT MANAGEMENT. 2004b. [online] *Information Sheet* Lagarosiphon major, *Curly water Thyme, Curly Waterweed*. CEH. URL: **http://www.ceh.ac.uk/sci_programmes/documents/CurlyWaterThymeCurlyWaterWeed.pdf** [Accessed December 2008].

CHYTRÝ, M., PYŠEK, P., TICHÝ, L., KNOLLOVÁ, I. & DANIHELKA, J. 2005. Invasions by alien plants in the Czech Republic: a quantitative assessment across habitats. *Preslia*, 77, 339-354.

CLEMENT, E.J., & FOSTER, M.C. 1994. *Alien plants of the British Isles.* London: Botanical Society of the British Isles.

COOK, C.D.K., & URMI-KÖNIG, K. 1983. A revision of the genus *Limnobium* including *Hydromystria* (Hydrocharitaceae). *Aquatic Botany*, 17, 1-27.

COOK, C.D.K. 1985. Range extension of aquatic vascular plants species. *Journal of Aquatic Plant Management,* 23, 1-6.

COPP, G.H., GARTHWAITE, R. & GOZLAN, R.E. 2005. *Risk identification and assessment of non-native freshwater fishes: concepts and perspectives on protocols for the UK*. Sci. Ser. Tech Rep., Lowestoft: Cefas. 129: 32pp.

CRAWLEY, M.J., HARVEY, P.H., & PURVIS, A. 1996. Comparative ecology of the native and alien floras of the British Isles. *Philos. Trans. R. Soc. London Biol. Sci.,* 351, 1251-1259.

CROSSLEY, M.N. (2002) 'The Effects of Water Flow, pH and Nutrition on the Growth of the Native Aquatic Plant, Aponogeton elongatus' MPhil Thesis, University of Queensland, Gatton. URL: **http://viewimages.aquaria.net/plants/Aponogeton/.pdf/crossley_2002_thesis.pdf** [Accessed November 2008].

CRUSIO 1987. De gattung Anubias. *Aqua-planta, Sonderheft,* 1, 1-44.

DAEHLER, C. C., & CARINO, D. A. 2000. Predicting invasive plants: prospects for a general screening system based on current regional models. *Biological Invasions,* 2, 92-103.

DAEHLER, C. C., DENSLOW, J.S., ANSARI, S., & KUO, H. 2004. A risk assessment system for screening out invasive pest plants from Hawai'I and other Pacific Islands. *Conservation Biology,* 18, 360-368.

DAEHLER, C. C., & DENSLOW, J.S. 2007. The Australian weed risk assessment system: Does it work in Hawai'i? Would it work in Canada? In CLEMENTS, D.R., & DARBYSHIRE, S. J. (Eds). *Invasive plants: Inventories, strategies and action. Topics in Canadian Weed Science*, Volume 5. Sainte Anne de Bellevue: Québec: Canadian Weed Science Society. pp: 9-24.

DAWSON, F.H., AND WARMAN, E.A. 1987. *Crassula helmsii* (T. Kirk) Cockayne: Is it an Aggressive Alien Aquatic Plant in Britain? *Biological Conservation,* 42, 247-272.

Defra. 2007a. [online] Defra consults on further protection for UK wildlife from non-native species News release 408/07. URL: **http://nds.coi.gov.uk/content/detail.aspx?NewsAreaId=2&ReleaseID=328891&SubjectId=16&AdvancedSearch=true** [Accessed May 2010].

DEFRA. 2007b. *Consultation on: (1) The Review of Schedule 9 to the Wildlife and Countryside Act 1981 and (2) The Ban on Sale of Certain Non-native Species.* Defra.

DEFRA. 2008. *The Invasive Non-native Species Framework Strategy for Great Britain*. Defra.

DEFRA. 2008. [online] '*UK plant pheloung spreadsheet.xls'*. No longer accessible from Defra website. Originally accessed January 2008.

DEFRA. 2010. [online] *Weeding our water invaders.* News release 34/10. URL: **http://www.defra.gov.uk/news/2010/100224a.htm** [Accessed March 2010].

GORDON, D.R., FOX, A.M., & STOCKER, R.K. 2006. *Testing a predictive screening tool for reducing introduction of invasive plants to Florida.* Final report to USDA APHIS-PPQ Contract 05-8100-1078-CA.

GOSS-CUSTARD, J. D., & MOSER, M. E. (1988) Rates of change in the numbers of Dunlin *Calidris alpina* wintering in British estuaries in relation to the spread of *Spartina anglica. Journal of Applied Ecology,* 25, 95-109.

EVERGREEN [online] *Invasive Plant Profile Dead Nettle, Yellow Lamium* Lamiastrum galeobdolon URL: **http://www.evergreen.ca/docs/res/invasives/deadnettle_factsheet.pdf** [Accessed December 2008].

Floridata [online]. *Alpinia zerumbet* URL: **www.floridata.com/ref/A/alpi_zer_var.cfm** [Accessed November 2008].

Hawaiian Ecosystems at Risk Project [online]. URL: **www.hear.org** [Accessed December 2008].

HEGER, T., & TREPL L. 2003. Predicting biological invasions. *Biological Invasions,* 5, 313-321.

HEJDA, M., PYŠEK, P., AND JAROŠIK, V. 2009. Impact of invasive plants on the species richness, diversity and composition of invaded communities. *Journal of Ecology*, 97, 393-403.

HILL, M., BAKER, R., BROAD, G., CHANDLER, P. J., COPP, G. H., ELLIS, J., JONES, D., HOYLAND, C., LAING, I., LONGSHAW, M., MOORE, N., PARROTT, D., PEARMAN, D., PRESTON, C., SMITH, R. M., & WATERS, R. 2005. *Audit of non-native species in England*. English Nature Research Report 662.

HODKINSON, D.J., & THOMPSON, K. 1997. Plant dispersal: the role of man. *Journal of Applied Ecology,* 34, 1484-1496.

HORVÁTH, G., & KRISKA, G. 2008. Polarization Vision in Aquatic Insects and Ecological Traps for Polarotactic Insects. In LANCASTER, J. & BRIERS, R. A. (eds) *Aquatic Insects: Challenges to Populations* CAB International. pp 204-229.

HOSHOVSKY, M. [online] Element Stewardship Abstract for *Arundo Donax* Giant Reed. The Nature Conservancy. URL: **http://www.invasive.org/gist/esadocs/documnts/arundon.pdf** [Accessed November 2008].

HULME, P. E. 2003. Biological invasions: winning the science battles but losing the conservation war? *Oryx,* 37(2), 178-193.

HULME, P.E. 2006. Beyond control: wider implications for the management of biological invasions. *Journal of Applied Ecology,* 43, 835-847.

HULME. P. E. 2009. Recent roles of life-form, land use and climate in recent dynamics of alien plant distributions in the British Isles. *Weed Research,* 49, 19-28.

HUXLEY, A. GRIFFITHS, M & LEVY, M. (Eds). 1992. *The New RHS Dictionary of Gardening*. MacMillan Press.

JACOBSEN, N. 1977. Chromosome numbers and taxonomy in Cryptocoryne (Araceae). *Bot. Notiser,* 130, 71-87.

JEFFERSON, L., HAVENS, K., & AULT, J. 2004. Implementing invasive screening procedures: The Chicago Botanic Garden model. *Weed Technology*, 18, 1434-1440.

KELLER, R. P., LODGE, D.M., & FINNOFF, D.C. 2007. Risk assessment for invasive species produces net bioeconomic benefits. *PNAS*, 104(1), 203-207.

KOWARIK, I. 1995. Time lags in biological invasions with regard to the success and failure of alien species. In. Pyšek, P., Prach, K., Rejmánek, M., & Wade, M. (eds) *Plant Invasions: general aspects and special problems*. Amsterdam: SPB Academic Publishing. pp.15-38.

KOWARIK, I. 2003. Human agency in biological invasions: secondary releases foster naturalisation and population expansion of alien plant species. *Biological Invasions,* 5, 293-312.

KŘIVÁNEK, M., & PYŠEK, P. 2006. Predicting invasions by woody species in a temperate zone: a test of three risk assessment schemes in the Czech Republic (Central Europe). *Diversity and Distributions,* 12, 319-327.

LANGDON, S.J., MARRS, R.H., HOSIE, C.A., MCALLISTER, H.A., NORRIS, K.M., AND POTTER, J.A. 2004. *Crassula helmsii* in U.K. Ponds: Effects on Plant Biodiversity and Implications for Newt Conservation. *Weed Technology,* 18,1349-1352.

LES, D.H., JACOBS, S.W.L., TIPPERY, N.P., CHEN, L, MOODY, M. L., & WILSTERMANN-HILDEBRAND, M. 2008. Systematics of *Vallisneria* (Hydrocharitaceae) *Systematic Botany,* 33(1), 49-65.

LLORET, F., MÉDAIL, F., BRUNDU, G., CAMARDA, I., MORAGUES, E., RITA, J., LAMBOURNE, P. & HULME, P. E. 2005 Species attributes and invasion success by alien plants in Mediterranean islands. *Journal of Ecology,* 93, 512-520.

LONG, D., & WILLIAMS, J. 2007. *Rhododendron ponticum: impact on lower plants and fungi communities on the west coast of Scotland. Working towards protecting internationally important bryophyte and lichen communities from Rhododendron ponticum invasion*. Scottish Natural Heritage, Project no. 19412.

LOWDEN, R. M. 1982. An approach to the taxonomy of *Vallisneria* L. (Hydrocharitaceae) *Aquatic Botany,* 13, 293-298.

MCNEELY, J.A., MOONEY, H.A., NEVILLE, L.E., SCHEI, P. AND WAAGE J.K. (eds) 2001. *A Global Strategy on Invasive Alien Species.* Gland, Switzerland, and Cambridge, UK: IUCN.

MACK, R.N. SIMBERLOFF, D., LONSDALE, W.M., EVANS, H., CLOUT, M. & BAZZAZ, F. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications,* 10, 689-710.

MANCHESTER, S.J., & BULLOCK, J.M. 2000. The impacts of non-native species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology,* 37, 845-864.

MENDOZA ALFARO, R.E., CUDMORE, B., ORR, R., FISHER, J.P., CONTRERAS BALDERAS, S., COURTENAY, W.R., OSORIO, P.K., MANDRAK, N., ÁLVAREZ TORRES, P., ARROYO DAMIÁN, M., ESCALERA GALLARDO, C., GŰEVARA SANGUINÉS, A., GREENE, G., LEE. D., ORBE-MENDOZA, A., RAMÍREZ MARTÍNEZ, C. & STABRIDIS ARANA, O. 2009. *Trinational Risk Assessment Guidelines for Aquatic Alien Invasive Species*. Commission for Environmental Cooperation Project Report, Montreal, Canada.

MILLENNIUM ECOSYSTEM ASSESSMENT. 2005. *Ecosystems and Human Well-Being: Wetlands and Water Synthesis.* Washington, D.C.: World Resources Institute.

Natural Aquariums [online] URL: **http://naturalaquariums.com/** [Accessed November 2008].

NATURAL ENGLAND. 2009. *Natural England's Draft Policy on Invasive Non-native Species*. URL: **http://www.naturalengland.org.uk/Images/inns_tcm6-10495.pdf** [Accessed April 2010].

NON-NATIVE SPECIES SECRETARIAT. 2010. [online]. Risk Assessments. URL: **https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?pageid=216** [Accessed May 2010].

PADGETT, D.J. 2007. A monograph of *Nuphar* (Nymphaeaceae) *Rhodora,* 109, 1-95.

PARROTT, D., ROY, S., BAKER, R., CANNON, R., EYRE, D., HILL, M., WAGNER, M., PRESTON, C., ROY, H., BECKMANN, B., COPP, G.H., EDMONDS, N., ELLLIS, J., LAING, I., BRITTON, J.R., GOZLAN, R.E., & MUMFORD, J. 2008. *Horizon scanning for new invasive non-native animal species in England.* Natural England Contract No. SAE03-02-189.

PENTECOST, A. 1987. The Lichen Flora of Gwynedd. *The Lichenologist*, 19, 97-166.

PEARMAN, D., AND WALKER, K. 2009. Alien plants in Britain – a real or imagined problem? *British Wildlife,* 21(1), 22-27.

PHELOUNG, P.C. 1995. *Determining the weed potential of new plant introductions to Australia.* Australian Weeds Committee Commissioned Report.

PHELOUNG, P.C., WILLIAMS, P.A., & HALLOY, S.R. 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management*, 57(4), 239-251.

PLANTLINK. 2008. Unpublished. Plant Link UK and Plant Link Cymru Response to Defra's *Consultation on: (1) The Review of Schedule 9 to the Wildlife and Countryside Act 1981 and (2) The Ban on Sale of Certain Non-native Species*. Available from Plantlife International.

Plants for a Future [online] *Nymphaea tuberosa* – Paine. URL: **http://www.pfaf.org/database/plants.php?Nymphaea+tuberosa** [Accessed November 2008].

PRESTON, C.D., PEARMAN, D.A. & DINES, T.D. 2002. *New Atlas of the British and Irish Flora*. Oxford: Oxford University Press.

PUTWAIN, P.D., HATTON, K.J. AND HAYNES, G.M. 2008. A survey of the marginal and accessible submerged vegetation of Llyn Helyg, with particular attention to Pillwort (*Pillularia globulifera*) and Australian Swamp Stonecrop (*Crassula helmsii*). A report for NewWildlife Limited.

PYŠEK, P., JAROSIK, V., & KUCERA, T. 2002. Patterns of invasion in temperate nature reserves *Biological Conservation,* 104, 13-24.

PYŠEK, P. SÁDLO, J., & MANDÁK, B. 2002. Catalogue of alien plants of the Czech Republic *Preslia,* 74, 97-186.

QUEENSLAND GOVERNMENT [online] URL: **www.dpi.qld.gov.au/** [Accessed November 2008].

QUESTER, C. [online] URL: **www.echinodorus-online.de** [Accessed November 2008].

RANDALL, J.M., MORSE, L.E., BENTON, N., HIEBERT, R., LU, S. & KILLEFFER, T. 2008. The Invasive Species Assessment Protocol: A Tool for Creating Regional and National Lists of Invasive Nonnative Plants That Negatively Impact Biodiversity. Invasive Plant Science and Management, *1(1), 36-49.*

RANDALL, K. [online] *The Aponogeton*. Aquarium Frontiers article series. URL: **http://web.archive.org/web/20010211193724/http://www.animalnetwork.com/fish2/aqfm/1999/june/aquatic/default.asp** [Accessed November 2008].

RATAJ, K. 1969. Contribution to the knowledge of *Echinodorus macrophyllus* (KUNTH) MICH. and *E. scaber* RATAJ from tropical America. *Folia Geobotanica,* 4(4), 435-442.

RATCLIFFE, D. A. 1968. An ecological account of Atlantic bryophytes in the British Isles. *New Phytologist*, 67, 365-439.

REICHARD, S.H., & HAMILTON, C.W. 1997. Predicting invasions of woody plants introduced into North America. *Conservation Biology,* 11, 193-203.

REJMÁNEK, M. 2000. Invasive plants: approaches and predictions. *Austral Ecology,* 25(5), 497-506.

RHS (2009) *RHS Plant Finder 2009-2010.* London: Dorling Kindersley.

RICCIARDI, A., & COHEN, J. 2007. The invasiveness of an introduced species does not predict its impact. *Biological Invasions,* 9, 309-315.

ROOK, E.J.S. [online] *Utricularia gibba*. URL: **http://www.rook.org/earl/bwca/nature/aquatics/utriculariagib.html** [Accessed November 2008].

ROTHERO, G. P. 2005. Oceanic bryophytes in Atlantic Woodlands. *Botanical Journal of Scotland,* 57, 135-140.

RUZEK, K.V. (online) Master Index of Freshwater Fishes (Aquatic Plant Index) URL: **www.webcityof.com/** [Accessed November 2008].

SMITH, C.S., LONSDALE, W.M., & FORTUNE, J. 1999. When to Ignore Advice: Invasion Predictions and Decision Theory. *Biological Invasions,* 1(1), 89-96.

TAYLOR, I, LEACH, S., COX, J., CLARKE, S & WATERS, R. 2007. Letter: 'Invasive plants.' *British Wildlife,* 18(6), 454.

The University and Jepson Herbaria [online] University of California, Berkeley. URL: **http://ucjeps.berkeley.edu/** [Accessed November 2008].

The Wild Flower Society [online] London June 30th to July 2nd Meeting Report. URL: **http://www.thewildflowersociety.com/wfs_report_menus/wfs_london_2006/london_pages/london_page_2.htm** [Accessed November 2008].

THOMAS, S., & DINES, T. 2010. Non-native invasive plants in Britain – a real, not imagined, problem. *British Wildlife,* 21(2), 177-183.

TUCKER, K.C. & RICHARDSON, D.M. 1995. An expert system for screening potentially invasive alien plants in South African fynbos. *Journal of Environmental Managements,* 44, 309-338.

UNITED STATES GEOLOGICAL SURVEY [online] Non-indigenous Aquatic Species. URL: **http://nas.er.usgs.gov/** . [Accessed November 2008, May 2010].

USDA [online] *Bacopa rotundifolia* (Michx.) Wettst. URL: **http://plants.usda.gov/java/nameSearch?keywordquery=Bacopa+rotundifolia&mode=sciname&submit.x=0&submit.y=0** [Accessed November 2008].

VAN WILGEN, N.J., RICHARDSON, D.M., & BAARD, E. H. W. 2008. Alien reptiles and amphibians in South Africa: towards a pragmatic management strategy. *South African Journal of Science,* 104(1-2), 13-20.

WEED SOCIETY OF QUEENSLAND [online] Thalia (*Thalia geniculata*) URL: **http://www.wsq.org.au/weedsinfocus.htm** [Accessed November 2008].

WILBY, N. J. 2007. Managing invasive aquatic plants: problems and prospects. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 17, 659–665.

WILLIAMSON, M. H., & BROWN, K.C. 1986. The analysis and modelling of British invasions. *Phil. Trans. R. Soc. Lond. B.*, 314, 505-522.

WILLIAMSON, M. 1996. *Biological Invasions*. London: Chapman & Hall.

WILSON, E. O. 1992. *The diversity of life*. Cambridge, USA: Belknap Press.

WOODELL, S. R. J., & KOOTIN-SANWU, M. 1971. Intraspecific variation in *Caltha palustris. New Phytologist*, 70, 173-186.

ZEDLER, J.B., & KERCHER, S. 2004. Causes and Consequences of Invasive Plants in Wetlands: Opportunities, Opportunists, and Outcomes. *Critical Reviews in Plant Sciences,* 23(5), 431-452.

Appendix 1 Taxa scores

Complete screening scores for all plants assessed are provided at the following link: **click here for further details**.