Assessment of alien invasive aquatic weeds in the UK

Sarah Clarke and Jonathan R. Newman
Institute of Arable Crops Research, Centre for Aquatic Plant Management, Broadmoor Lane, Sonning, Reading RG4 6TH, UK

Summary All the aquatic weeds present in the UK are derived from horticultural trade sources within the UK and Europe. Changes in the supply of plants to the general public in the last 50 years have altered the way in which natural ecosystems are threatened by new species, and the rate at which invasion takes place. Currently there are no means of assessing the potential of species new to the UK to become weeds.

This paper examines ecological and cultural influences on the reasons for success of alien invasive weed species in the UK, presents data on attempts to determine weedy traits and provides information on development of control techniques in the light of current European Union legislation on pesticide use in water.

Keywords Risk assessment, *Hydrocotyle*, *Myriophyllum*.

INTRODUCTION

Alien invasive species are accepted as the second biggest threat to biodiversity after loss of habitat. The aquatic environment in the UK currently suffers from several aquatic and riparian species that have contributed to a rapid decline in biodiversity at several sites. These species caused drowning of livestock, prevention of recreation, sailing, fishing and other watersport activities, increased eutrophication and sedimentation in rivers and other subtle ecological interactions.

The species are escapees from introductions by the horticultural trade for ornamental garden pond or tropical aquarium planting. It is hypothesised that the increase in availability of alien species by this route has lead to the establishment of a higher proportion of alien species in recent years than would be expected. Table 1 lists the species that pose the greatest threat to aquatic ecosystem stability in the UK.

The UK and Europe as a whole are way behind Australia, New Zealand and North America in controlling the introduction and sale of non-native species. A recent review by the Department of Food and Rural Affairs (DEFRA) in the UK on non-native species policy identified three main areas for action: prevention, remedy and control, and risk assessment. Prevention and risk assessment are two sides of the same coin in aquatic plant risk, for there is no point in preventing the entry of a species if it does not pose a risk. At the moment there is no adequate risk assessment for introduction of any plant species by the horticultural trade to Europe, apart from a certificate that states the plant material is free of pests and diseases, termed a phytosanitary certificate. This is a continuation of the plant hunting mentality of old, typified by the Victorian adventurers. The effect of new dominant plant species on other plants, animals, invertebrates, fish and birds is largely unknown. This lack of understanding is not just related to the presence of the species in the ecosystem, but how the presence of that species affects ecosystem processes essential for sustaining trophic interactions and energy cycling within and through the system.

One of the major difficulties of predicting which species will become weeds is the lack of information on a particular species in a new environment. For agricultural weeds it is possible to generalise that if a species is a weed in its native range then it will also be a weed in its introduced habitat. This is not the case with so called environmental weeds. Much less research has been done on weeds of non-agricultural importance for obvious economic reasons, and now that the majority of agricultural weeds can be controlled, attention has turned to environmental weed problems. This paper examines the usefulness of one characteristic for predicting potential invasiveness.

MATERIALS AND METHODS

The hypothesis under test was that relatively high leaf water content would be a good predictor of invasiveness. The most problematic alien invasive species are amphibious, having the ability to grow both in and out of the water. High leaf water potential may confer

Table 1. Date of introduction and observation of aquatic weed species in the UK ecosystems.

Species	Date of introduction	Date of observation
Elodea canadensis	1820	1847
Crassula helmsii	1911	1956
Lagarosiphon major	1920	1944
Myriophyllum aquaticum	1960	1975
Hydrocotyle ranunculoides	1989	1991
Ludwigia grandiflora	1995 ?	2000
Myriophyllum brasiliensis	2000	?

an advantage over other species because of enhanced metabolite transport, water use efficiency, stem rigidity or other advantages associated with this habitat niche area.

Five species of plants were tested: *Hydrocotyle vulgaris* and *Myriophyllum spicatum* as UK natives, two alien invasive species, *Hydrocotyle ranunculoides* and *Myriophyllum aquaticum* and one non-native species of unknown characteristics, *Myriophyllum brasiliensis.*

These plants were grown outdoors in 450 L glass-fibre ponds with high and low nutrient conditions from June onwards. Four replicate ponds per treatment containing five replicate plants were used. All species were planted in 9 cm diameter 0.37 L plastic pots. All pots were placed with the water surface at the soil surface to maintain complete saturation of the soil during the experiment except *M. spicatum* which was grown completely submerged. For the high nutrient level treatment, plants were transplanted into sandy-loam soil mixed with Osmocote® slow-release fertiliser granules at 3.3 g L^{-1}, and the surface covered with 0.5 cm horticultural-grade sand. Plants were grown in water from a natural borehole water source. This water contained 21 mg L^{-1} NO_3 and 0.28 mg L^{-1} PO_4, a ratio of 75:1. For low nutrient level treatments, plants were planted into horticultural-grade sand and placed in tanks filled with tap-water. Tap water contained less than 4.1 mg L^{-1} NO_3 and 0.04 mg L^{-1} PO_4, a ratio of about 10:1. Initial dry weight measurements were taken from an additional 10 plants for each treatment.

The leaf water content of the plants was measured after six weeks growth by collecting a single leaf from each plant, measuring the wet weight, before drying at 60°C for three days to determine the dry weight. The leaf water content of each leaf was then determined by subtracting the dry weight of the leaf from the wet weight, and converted into a percentage value by dividing this figure by the wet weight and multiplying by 100. Mean growth was determined by subtracting mean initial dry weight for the species from final dry weight values.

RESULTS

Approximately half of the *H. vulgaris* failed to grow under the experimental conditions described. *H. ranunculoides* plants had grown entangled at the high nutrient condition and were impossible to separate when harvesting, all of the growth data for this species had to be collected by tank rather than by plant. In order to analyse this data, all other growth data also was summed into values per tank

Due to an unbalanced nature of the row and column design, the method of Residual Maximum Likelihood (REML) was used to fit the design and treatment factors models for the percentage LWC and growth data. The model is given in Newman *et al.* (2002). The means for the treatments are given Table 2, and take account of variation due to the experimental design. In the model, the interaction term species.nutrient was not quite significant ($P = 0.081$) at the 5% level. Therefore, although it may be concluded that the effect of the nutrients caused a similar response for each species, there is some indication that the species reacted differently to a change in nutrient level. However, the two main effects of species and nutrient were highly significant ($P < 0.001$). Table 2 shows that a higher LWC was attained at the high nutrient level for all species. *M. brasiliensis* and *H. vulgaris* had the overall highest LWC irrespective of nutrient content. It is clear however, that *M. spicatum* shows a much greater reduction in LWC at low nutrient levels than the other species.

For growth data there was no replication at the row.column level (Newman *et al.* 2002). In this model, the interaction term species.nutrient was significant, indicating that the growth response of the species tested did react significantly differently to nutrients. The data in Table 3 show *H. ranunculoides* and *M. aquaticum* grow similarly at both nutrient levels. However, *M. brasiliensis* has significantly lower growth at high nutrient than these two, whereas *M. spicatum* exhibited poor growth in comparison with all other species.

The effect of nutrient concentration and substrate type can be clearly seen in Figure 1.

Although M. *brasiliensis* maintains a high %LWC, it shows low growth in comparison with

Table 2. Mean leaf water content (%).

Species	High nutrient	Low nutrient
H. ranunculoides	76.19	71.91
H. vulgaris	82.81	79.19
M. aquaticum	80.39	74.50
M. brasiliensis	87.78	80.58
M. spicatum	73.78	55.20

Table 3. Mean growth over six weeks.

Species	High nutrient	Low nutrient
H. ranunculoides	98.52	7.54
H. vulgaris		
M. aquaticum	98.23	7.01
M. brasiliensis	56.03	6.15
M. spicatum	3.55	0.13

H. ranunculoides and *M. aquaticum* that have high %LWC. However, low %LWC for *M. spicatum* appears to be reflected in low growth for this species. Therefore, %LWC is not a clear indicator of growth for all species.

DISCUSSION

There are about 3500 alien plant species in Great Britain (excluding grasses) (Clement and Foster 1994). There are about 240 aquatic and riparian species and subspecies, and most aquatic nursery catalogues list between 130 and 180 species and varieties. If the Tens Rule (Williamson 1993) is followed, then 10% of those introduced should become established, and 10% of those will become problems, leading to an estimate of about 0.1% of introduced species becoming problems. The figure for aquatics is probably greater than this as there are about 200 species listed in trade catalogues, with about 60% being non-native to the UK, and at least 10 species that are invasive or will become invasive with time, a figure of about 8% of non-native species sold. This factor is high because of the association with the intense anthropogenic influence on aquatic plant distribution in the UK and other countries with a well developed garden centre network.

A recent paper by Lansdown (2002) lists over 20 species of aquatic plant that are currently sold by aquatic garden centres and that have been observed growing in natural habitats. While not all of these are invasive at the moment, some species may be in the lag phase of invasiveness as recent introductions, and others may never become invasive. Of greater concern is the possibility of genetic mixing of native species of the same genus with the introduced species. The effects of this are largely unknown and not investigated in sufficient detail in terms of loss of fitness.

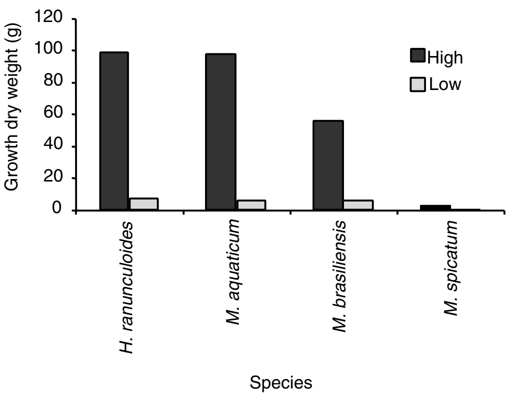

Figure 1. Effect of nutrient status on observed growth after six weeks.

The large number of unknowns associated with non-native species requires attempts to be made to assess which species are likely to be the worst offenders, the most logical step being the implementation of a risk assessment process. Although risk assessment for non-native species is common elsewhere in the world, the UK and Europe generally, do not have effective assessment measures for non-agricultural weeds. Risk assessment measures should be simple, easy to implement and easily understandable by the non-specialist. For these reasons we concentrated on a simple plant trait. While there was some success in associating invasive potential with leaf water content, the technique is not fool proof enough to be adopted as a stand-alone test, and other measures will be investigated further in order to develop a suite of measures that give a more accurate level of prediction.

The implications of our experiments for the species tested are discussed below. Figure 1 clearly shows the ability of the alien invasive macrophytes *H. ranunculoides* and *M. aquaticum* to utilise the nutrients available to produce very rapid growth. The relatively low growth rate at the low nutrient condition is probably comparable with most non-invasive plants, but the growth rate shown at the higher nutrient condition is dramatically different from that shown by the native plant, *M. spicatum*.

The comparison between the growth of these species at low and high nutrient conditions also shows how a seemingly innocuous plant in a garden centre can cause so much havoc when released into the wild. It is worth noting that although the growth of *M. brasiliensis* at the higher nutrient level was significantly lower than that of both *M. aquaticum* and *H. ranunculoides*, it still shows the same potential to grow much faster at high nutrient levels. Therefore its introduction to any new environment should be regarded with the same caution as the known invasive species. This supports the precautionary approach in limiting the supply of all non-native *Myriophyllum* species in the UK.

Table 2 shows the leaf water content of the alien invasive plants tested is relatively stable despite changing nutrient conditions. However, the significant rise in leaf water content shown by *M. spicatum* at the higher nutrient condition suggests that this trait is not stable in all macrophytes, and it would need further species testing to find how useful the trait is in this respect. Also the high leaf water content of the non-invasive *H. vulgaris*, higher than that of the invasive plants, suggests that the structure and typical habitat of the plant also heavily influence this trait. *H. vulgaris* is a rather succulent plant, which immediately suggests a high leaf water content. Similarly, *Crassula helmsii*, the species found in previous Centre for Aquatic Plant

Management (CAPM) work to have the highest leaf water content of all of the plants tested is also of a succulent nature. *H. vulgaris* is an emergent rather than a floating or submerged plant, found on muddy banks and flushes rather than in standing or flowing water. The typical habitat of the plant could therefore play a role in determining the leaf water content. This could also explain why *M. spicatum* fared so poorly in comparison with the other plants tested for leaf water content, as it is the only fully submerged species.

In hindsight, it may have been a more useful experiment to concentrate on testing the leaf water content of invasive and non-invasive plants of similar growth forms and habitats, instead of comparing alien and native species of the same genus. However this in itself has difficulties, as the species of invasive aquatic plants that cause the most problems in the UK tend to be floating plants, growing emergent or rooted at the bank, and floating out over the water surface, using a dense mat of floating roots to take up nutrients. There are few, if any, native plants that exhibit this growth form, and the growth form in itself may contribute significantly to the success of the plants, as it enables them to colonise an otherwise vacant niche.

Therefore it is concluded that the usefulness of leaf water content as an indicator of potential invasiveness may be limited. However, further tests using a wider range of native plants growing in different habitats may allow prediction of a typical range of leaf water content for plants of similar growth form, growing in discrete habitats. If it was possible to detect this, and invasive plants in these habitats did indeed have higher than average leaf water content, then the trait could still prove a valuable addition to any suite of traits used for predicting invasiveness.

The critical importance of risk assessment in the determination of potential invasiveness will lead to development of measurement of other plant traits that may prove useful in refining current assessment techniques.

ACKNOWLEDGMENTS

The Centre for Aquatic Plant Management is part of the BBSRC funded Institute of Arable Crops Research and receives funding from the Environment Agency, British Waterways, Regional Flood Defence Committees and Internal Drainage Boards.

REFERENCES

Lansdown, R.V. (2002). Alien aquatic plants in garden centres. *Botanical Society of the British Isles News* 89, 50-51.

Newman, J.R., Grieve, N. and Clarke, S. (2002). IACR-Centre for Aquatic Plant Management Annual Report 2001. (Long Ashton Research Station, Bristol).

Williamson, M. (1993). Invaders, weeds and the risk from genetically modified organisms. *Experientia* 49, 219-24.