EUPHRESCO Final Report

Project Title
Decision Support Systems for **C**ontro**L** of **A**lien **I**nvasive **M**acrophytes

Project Duration:

Start date:	08/03/09
End date:	01/07/11

1. Research Consortium Partners

Coordinator – Partner 1			
Organisation	Plant Protection Service		
Name of Contact *(incl. Title)*	Dr J.L.C.H. van Valkenburg	**Gender**:	Male
Job Title	Project Manager PD FES Consortium Invasive Plant Species		
Postal Address	P.O. Box 9102, 6700 HC Wageningen, The Netherlands		
E-mail	j.l.c.h.van.valkenburg@minlnv.nl		
Phone	(31)317-496730		

Partner 2			
Organisation	Plant Research International, Wageningen UR		
Name of Contact *(incl. Title)*	Dr L.A.P. Lotz	**Gender**:	Male
Job Title			

Postal Address	P.O. Box 616, 6700 AP Wageningen
E-mail	bert.lotz@wur.nl
Phone	(31)317-480556

Partner 3			
Organisation	Aquatic Ecology and Water Quality Management Group, Wageningen UR		
Name of Contact *(incl. Title)*	Dr R.M.M. Roijackers	**Gender**:	Male
Job Title			
Postal Address	P.O. Box 47, 6700 AA Wageningen		
E-mail	Rudi.Roijackers@wur.nl		
Phone	(31)317-484419		

Partner 4			
Organisation	Centre for Ecology and Hydrology		
Name of Contact *(incl. Title)*	Dr J.R. Newman	**Gender**:	Male
Job Title	Head Aquatic Plant Management Group		
Postal Address	CEH Wallingford. MacLean Building, Wallingford, OX10 8BB, United Kingdom		
E-mail	jone@ceh.ac.uk		
Phone	+44 1491692556		

Please make as many copies of this table as necessary.

Executive Summary

Project Summary

Please provide a summary suitable for web publication and which is understandable to the intelligent non-scientist.

Include: Title, main objectives, appropriate Methods, Results and Conclusions. (max. 2 pages)

EUPHRESCO – DeCLAIM : A Decision Support System, for Control of Alien Invasive Macrophytes

This report contains the result of a research programme on four invasive aquatic macrophytes, *Cabomba caroliniana* (Fanwort), *Hydrocotyle ranunculoides* (Floating pennywort) , *Myriophyllum aquaticum* (Parrott's feather) and *Ludwigia grandiflora* (Water primrose). The collaborative project was intended to generate a prototype decision support system for optimising control measures for these species, considered to be the four most troublesome invasive alien aquatic weeds at present in the UK and NL. A further reason for selecting these species is that they are widely sold in the horticultural trade and are therefore the number of invaded sites is likely to increase in the short term.

C. caroliniana, was selected as a representative of the Myriophyllids growth form, representing 35% of the import volume of aquarium plants in The Netherlands. In 2009 it is found at three sites in The Netherlands, posing serious problems at one. It has been present at two sites in the UK recent past and was collected from one site again in autumn 2011.

H. ranunculoides, was selected as a representative of the Stratiotids *s.l.* growth form, is at present the most troublesome invasive alien aquatic weed in the United Kingdom and The Netherlands, and is showing increased distribution in neighbouring countries, including Belgium and Germany as well as in Australia, Uganda and Zimbabwe.

A second representative of the Stratiotids *s.l.* growth form, *L. grandiflora*, has proven to have a severe detrimental ecological impact in France and is gaining importance in The Netherlands. In the UK promising management strategies have already been developed using and the infestation in the wild has responded well to rapid application fo control measures.

The third representative of the Stratiotids s.l growth form is *M. aquaticum.* This species has been sold extensively by the aquatic nursery trade as an ornamental species for domestic ponds. It is now present in many natural lowland static water sites in the UK. The species is still very popular in The Netherlands, and the number of occurrences is increasing.

The project was divided into several work packages in order to prioritise the order in which data were derived and used in the project. The first stage was to collect all published data on the individual species, in order to gain information on various physiological parameters of the species to put into the model CHARISMA, a model that predicts biomass of a species given both physiological and environmental data. We found that although the species were relatively common in the UK and the Netherlands, data on physiology were not widely available and we had to estimate some of the more important model parameters to get a realistic output. This is an area of possible experimental error and can only be corrected by actual field and laboratory measurements on net photosynthetic rate, light compensation point, biomass production related to nutrient availability and other indices, including shoot to root ratios, leaf area indices etc.. The literature survey also provided information on the native range of the species from which we were able to derive optimum environmental conditions for growth in Europe and the effect of any management techniques already in use. The literature survey also produced information on the main reproductive strategies, either by vegetative means such as fragmentation, or by seed production, or a combination of both. Most species have very effective reproductive strategies using vegetative fragmentation and seed production in both countries was considered to be relatively unimportant.

Stage two of the project involved an assessment of the areas at risk of colonisation by the four species in both countries. For the Netherlands it was assumed that if the site of an occurrence shared both physical and chemical characteristics, then it should be classed as at risk. The low altitudes and low slopes of most watercourses in the Netherlands create a situation in which the whole country can be considered at risk. For the UK, we used the elevation data for known occurrence and plotted an area at risk based on this altitude plus 100m, to account for any unknown sites. This produced different maps for each species as some had been found at higher altitudes than others. We do not consider this to be as accurate as possible and the integration of temperature data, especially a day degree index could improve the prediction of at risk areas for each species in the UK. This is an important topic for inclusion in future work.

The third area of work was to assess current methods of control and to develop or optimise new techniques. This was carried out in conjunction between all four project partners. Considerable improvements in the management of *C. caroliniana* were made during this project and have been implemented by water boards in the Netherlands. A consistent approach to management of *H. ranunculoides* has been adopted in this project and the approaches to management of the two other species have been shown to be effective in the current regulatory conditions.

The spatially explicit model CHARISMA was developed for two native macrophytes species in the Netherlands and was used in this project to model growth and biomass accumulation of the four non-native invasive macrophyte species. Some of the input parameters used in the original model were not valid for the new species, and estimates or adjustments had to be made. However, for three out of four of the new species, the predictions of biomass and dominance were quite accurate and the model could be developed for these species without excessive modification. The only species that did not comply well with the model was *C. caroliniana*, but only in the degree of overwintering biomass required for dominance in the following season. This is probably due to a lack of any data for physiological characteristics of this species in winter in Europe and this data gap should be addressed for this species and others in order to accurately model the behaviour of other species in European conditions.

The main objective of this project was to produce a draft Decision Support System that could be used by field operatives and office based managers to identify the species accurately, and to enable a rapid risk assessment to be made in the field that could be reported in a consistent manner, enabling a rapid response to be made against the species with the aim of preventing further spread and eventually eradication the species from the affected watercourse. In order to make the response to aquatic non-native species consistent and proportionate a pictorial field and office guide has been produced that provides descriptive photographs of characteristic features, areas at risk, typical habitat types, and available management techniques. We have deliberately left out costs of management as these vary within each country and certainly between countries. In addition, each species chapter will be made available at www.declaim.eu . The DSS was submitted to the Non Native Species Secretariat in the UK for comment before being used by managers. In the Netherlands the DSS was submitted to representatives of various water boards that are actively involved in trials to control invasive macrophytes. The comments received were positive and helpful and led to developments in the current version.

2. Report

This report is to provide EUPHRESCO and others with the outputs of the research project to allow EUPHRESCO to publish details of the outputs.
This report does not preclude contractors from publishing results in scientific journals or elsewhere. Also, this report does not release research partners from any national reporting obligations required by national contracts.

The report should be in Arial Font size 12 for normal text and size 14 bold for headings. It should consist of maximal 20 pages.

The report to EUPHRESCO should include:

- **Objectives and tasks of the project**, as stated in the work plan, with degree of achievement

*Analyse from literature what the (a)biotic factors are that characterize the habitats of *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Myriophyllum aquaticum* and *Ludwigia grandiflora.*
100% achieved
*Identify from existing databases the locatities at risk in the Netherlands and UK. 100% achieved
*Review ecological literature on the life cycle of all 4 species to come to a preliminary parameterization for the CHARISMA mode. Gaps in published literature will be identified and wherever possible remedied. 100% achieved
*Field test of management options on *Cabomba caroliniana* to be carried out in Loosdrecht100% achieved
*Develop a prototype Decision Support System (DSS) and disseminate this DSS for review amongst relevant institutions involved in the management of surface water in NL and UK 100% achieved
*Translate the research findings and the feedback on the prototype DSS to actively promote the results to water boards in the UK and NL as well as relevant international networks such as EPPO 100% achieved

- **Methods used and Results obtained**, including statistical analysis (if appropriate)

*Literature on the four species has been collected and this literature has been summarized in order to extract data on growth and reproduction that is needed for the modelling of these species. The references are integrated in the State-of –the-Art June 2011 ‘chapters’.
*An inventory has been made of the localities where the four species are observed in The Netherlands and UK. For *C. caroliniana* this resulted in a characterization of its habitat and thus of the habitats at risk.
*Based on the actual distribution and published data, river and wetland types at risk have been identified for *H. ranunculoides* (slow flowing riverine systems and static ponds) *L. grandiflora* (primarily static ponds, or very slow flowing small ditch systems) and *M. aquaticum* (shallow, nutrient rich water at the margins of ponds, lakes, canals and streams).
*Resulting from the literature survey on the life cycle of *C. caroliniana* the model CHARISMA was used to predict the growth and production cycle of this species. Extra field measurements were made to improve the parameterisation for *C. caroliniana*
*Adaptations have been made to the model CHARISMA to accommodate the differing growth form of the three species representing the Stratiotids s.l. growth form.,
*In order to have more precise data for the modelling in CHARISMA, field visits have been made to collect plant material and abiotic data on all four species.
*Field experiments have been set up in NL in order to investigate different management options for *C. caroliniana*. The four options are 1) conventional management (dredging), 2) covering the stand with dark foil, 3) using a new dredging method (resuspending sediment material by using a jet stream) and 4) covering the sediment with foil. These experiments lasted for over one year. In each of the experimental plots several enclosures have been placed to exclude the inflow of plant fragments.

*Field-testing of various methods have been undertaken in the UK, although mechanical control has not been practiced on *L. grandiflora*. Data from other organisations experiences have been collated into the final report.

- **Discussion of results and their reliability**

Range

In its native range, *Cabomba caroliniana* (Fanwort) is restricted to clear and acidic low nutrient-content waters. In South America the species is present in Brazil, Paraguay, Uruguay and Argentina and in North America in the southeast along the Gulf and Atlantic coast. *Cabomba caroliniana* is an invasive species in the UK and the Netherlands, where the species has been recorded since the 1990s. In contrast to its native habitat in the Netherlands the species is found in nutrient-rich water with often poor visibility. It is considered an invasive species in various States of the United States and Canada, China, Japan, Malaysia, India, New Guinea and Australia. In Europe the species is also reported in France and Hungary.
In its native range, *Hydrocotyle ranunculoides* (Floating pennywort) occurs in, and at the margins of, slowly flowing, warm and nutrient rich water in Argentina, Brazil and Paraguay, also in southern states of the USA. *H. ranunculoides* is an invasive aquatic weed in North Western Europe and several other countries worldwide, including Chile, Australia and Uganda. In Europe, it is found in and around canals, lakes, rivers, streams, ditches, and garden ponds.
In its native range *Ludwigia grandiflora* (Water Primrose) in South America is reported in wetlands in the transition zone-between aquatic and terrestrial environments. In North America, the species has been introduced and is spread across various States, but there are few occurrences reported. In the UK it has been noted as a pest species since the middle of the 1990s (Newman *et al*., 2000). In 2010 there were 13 sites under management (Renals, 2010), but there are likely to be many more occurrences due to extensive planting in garden and ornamental ponds which are classed as unreported. In The Netherlands it is reported throughout the country except in the Waddenzee Islands. The number of sites remains relatively low, and local abundance varies (Luijten & Odé, 2007). The first report of invasive behaviour was in 2000. *L. grandiflora* is widespread in France as well as in Belgium, Germany, Ireland, Italy, the Netherlands, Spain and the UK where invasion is at an early stage.
Myriophyllum aquaticum occurs in South America along the margins of tropical and subtropical rivers and streams, and also in wet areas. It is found in freshwater lakes, ponds, streams and canals, and appears to be adapted to high nutrient environments. *M. aquaticum* does well in good light and slightly alkaline conditions. Almost all plants are female, and male plants are unknown outside of South America. *M. aquaticum* has been introduced for use in indoor and outdoor aquaria and is also a popular aquatic garden plant. It has escaped cultivation and spread via plant fragments and intentional plantings. The species continues to be supplied via trade and its range and density within existing territories is predicted to increase in the short to medium term.

Growth characteristics

C. caroliniana has a relatively low photosynthetic rate, a high light compensation point, and a high fraction of light reduced by epiphytes colonisation of its highly dissected leaves.
In an aquatic environment *H. ranunculoides* forms floating mats, in riparian vegetation it behaves as a helophyte. Growth in North Western Europe starts in early spring from small plants or fragments when air and water temperatures rise. They grow slowly in spring and form small, up

to 10 cm^2 large leaves, which mostly float on the surface water (Hussner & Lösch, 2007). With increasing temperatures, photoperiod and light intensity, leaves grow larger and petioles reach a height of up to 40 cm above water level (EPPO, 2006). The growth rate of *H. ranunculoides* is highest in June and July. The stems root freely from nodes at about 4-15 cm intervals. With decreasing temperatures and light availability in autumn, smaller leaves are develop and some of the leaves die due to night frost. At this time plants will form floating and submerged leaves. The latter are able to survive the low water temperatures during the winter (Hussner & Lösch, 2007). From these small submerged plants and leafless overwintering stolons plants will grow out again in spring.

L. grandiflora has a highly variable morphology depending on abiotic conditions (Lambert *et al*., 2009), especially the leaf shape and stem size. Three morphological forms are distinguished according to ecological conditions, a prostrate small leaved form; an actively growing creeping form in the first step of development or in static or slow flowing waters and; an erect form at later stages, in favourable ecological conditions, usually in shallow waters. Furthermore it forms two kinds of roots: those for substrate anchorage and nutrient absorption; and adventitious roots, which occur at the stem nodes and can absorb atmospheric oxygen. The adventitious roots allow the plant to tolerate anaerobic sediment conditions.

M. aquaticum is a bright or glaucous green perennial freshwater herb. It exhibits two different leaf forms (heterophyllous) depending on whether it is growing as a submerged plant or as an emergent. It is characterised by emergent feather-like leaves which are arranged around the stem in whorls of four to six. The submerged leaves are 1.5 to 3.5 cm long and have 20 to 30 divisions per leaf. The emergent leaves are 2 to 5 cm long and have 6 to 18 divisions per leaf. The emergent leaves are stiffer than the submerged leaves. Rhizomes function as a support structure for adventitious roots and provide buoyancy for emergent growth during the summer. *M. aquaticum* exhibits a creeping emergent life form (*sensu* Rejmánková 1992). The apical tips are the most physiologically active and productive parts of the plant, but extension of the emergent stem forces older parts underwater where emergent leaves die and adventitious roots and submerged leaves form at the submerged nodes. Dense mats up to 40 cm thick form at the surface of nutrient rich lakes, with stem densities of up to 1,500 stems m^{-2} (Sytsma & Anderson, 1993a)

Areas at risk

We can consider all shallow slow flowing and still waters in the Netherlands to be potentially at risk for all four species. For the UK we have indicated a temperature related altitudinal maximum for areas to be at risk, although these areas will be better defined with increased temperature data input.

Reproductive strategy

In cold temperate climates, *C. caroliniana* overwinters mainly vegetatively and the main mode of spread is by plant fragments. Buoyant fragments can be carried over long distances. One single stem node can produce a new plant. Fragments rarely can survive exposure in air for more than 24 hours. However, they can stay moist and survive for weeks in mud, even under hot and dry conditions. *Cabomba* flowers but does not set viable seed in the Netherlands or the UK.

The species reproduces primarily by vegetative reproduction in Europe though spread by seed has been observed through sewage treatment works (*e.g.* Pevensey Levels). It can regenerate from small stolon fragments which must contain at least one node. It flowers in July–October in its native and introduced range. Flowers are white in colour, small and held above the water in the axes of stolons and petioles on 5 – 15 mm stems, with a group of 5 – 15 individual flowers in an umbel. Although establishment by seed is suspected at Pevensey Levels (UK), the production of viable seeds in this site has not yet been observed. Seeds do form, but seem not to mature, remaining white in colour rather than the brown of mature seeds in the Americas. This is probably due to cold temperatures at the time when seeds should mature in autumn. Vegetative reproduction is thought to be favoured in both flowing conditions at the edge of the mat, and during late November through to January when the plants start to decompose and small fragments are produced in very large numbers. The regenerative capacity of nodal material under favourable conditions is close to 100%, and colonisation is inevitable in suitable habitats (Newman, unpubl.). With decreasing temperatures and light availability in autumn, smaller leaves develop and some of the leaves die due to night frost. At that time plants form floating and submerged leaves. The latter are able to survive the low water temperatures during the winter. From these small submerged plants and leafless overwintering stoloniferous plants will grow out again in spring.

In the introduced range in Europe, *L. grandiflora* probably relies mainly on vegetative propagation. It overwinters as standing visibly dead vegetation and the main mode of spread is by fragmentation during autumn and winter. Nodal material probably survives longer at colder temperatures and provides numerous viable propagules. Buoyant fragments can be carried over long distances. One single stem node can produce a new plant. Plants may die back considerably as a result of frost but regrow from basal parts.

The importance of seed production to the overall reproductive strategy of *L. grandiflora* in Northern Europe has not been investigated. However, Ruaux *et al.* (2009) compared various characteristics of seeds of both *L. peploides* and *L. grandiflora* from nine populations. They found that seeds of *L. grandiflora* were buoyant for approximately 12 weeks; that seed populations were approximately 47% viable and that temperatures of 4℃ did not affect % seed viability. Freezing of seeds under water reduced viability by about 50%, resulting in a total potential viability of about 25% of all seeds produced under northern European conditions (freezing temperatures in winter). Dandelot (2004) estimated that seed production in by *L. grandiflora* in western France was approximately 10,000 m^{-2}, giving a potential viable seed number production of close to 2,500 m^{-2} The study thus suggests that sexual reproduction is an important additional mechanism for winter survival and spread of *L. grandiflora*, and given the long buoyancy period, especially over long distances.

In South America there are both male and female plants of *M. aquaticum*, but in the introduced range only female plants have been found, limiting reproduction to vegetative means. The importance of sexual reproduction in the natural habitat may be limited, as conditions are relatively stable, with long distance transport of propagules achieved by vegetative means.

CHARISMA

The CHARISMA model is an individual-based and spatially explicit model in which individual plants and overwintering structures are positioned on grid cells. This allows modelling spatial ecological processes such as seed or tuber dispersal. CHARISMA allows modelling of 3D competition for light and nutrients between two or more aquatic plant species. CHARISMA was run twice to simulate the growth with and without competition from other macrophytes. Model parameters were derived from literature or estimated. Simulations with the CHARISMA model indicated that the percentage of overwintering biomass of *C. caroliniana* is a crucial factor that

can completely modify the dynamics of the aquatic plant community. In competition with *Chara aspera* and *Potamogeton pectinatus* it was shown that *C. caroliniana* was not able to establish successful populations after 10 years when grown from a wintering fraction of 0.50. However, with a wintering fraction of 0.75. *C. caroliniana* is able to establish and grow for the whole length of the time series. However, *Potamogeton pectinatus* dominates after 20 years. With a wintering fraction of 0.90 *C.caroliniana* completely out competes the other species and dominates the macrophyte community. However, actual field observations do not corroborate the outcome of the simulations, with *Cabomba* dominating from very small overwintering biomass. This implies that other physiological factors may confer dominance on this species in European habitats.
Only a hand full of scientific articles describe the characterization of the growth conditions for *H. ranunculoides* in more detail and make an effort to quantify the growth under these conditions. In those studies, the leaf area index (LAI), total dry weight, dry weight of leaves, petioles, shoots and roots, the total shoot length, the number of nodes, the total number of leaves and the average leaf size between naturally occurring stands in habitats with low and high nutrient levels. It was concluded that with increasing nutrient content of the soil, all these parameters were higher than for stands in a habitat with a lower nutrient contents of the soil. In an aquatic environment the species forms floating mats, in riparian vegetation it behaves as a helophyte. CHARISMA accurately predicts growth patterns and biomass accumulation when in an unmanaged state, with annual biomass maxima c. 1,200 g dry weight m^{-2}. However, it was not possible to model the effects of management using this system in this project; as a result biomass maxima may occur on more than one occasion per year, resulting in peak release of vegetative fragments on a more regular basis, especially if plant material is cut, releasing fragments at optimal times of the year for regrowth and colonisation, rather than natural fragmentation which tends to occur in fast flowing environments and in the winter, both less suitable for rapid regrowth.
In simulations without competition, *L. grandiflora* grows to densities up to 700g m^{-2}. This value is very close to 652g m^{-2}, the averaged biomass (dry weight) measured in the field of *L. peploides* collected from California (Rejmánková 1992). Simulations of the growth of *L. grandiflora* with two competing species, *Chara aspera* and *Potamogeton pectinatus* over a 10 year period. *L. grandiflora* outcompeted the other species and dominated the macrophyte community. This tends to suggest that if left unmanaged, *L. grandiflora* will dominate the macrophyte community after only a few years.
Considering the relatively high photosynthetic rate 0.01/h shown by *M. aquaticum* the species is predicted to grow to densities of around 400 g dry weight /m^2. This value is within the range of 219-969 g/m^2 from data collected in the field in September 2009 (Roijackers & van Valkenburg). The same simulation was run again to attempt to reach these higher observed biomass values with less biomass allocated to roots and rhizomes and more to photosynthetic structures. The predicted biomass values then reached more than 600 g/m^2. Competition simulations showed that *M. aquaticum* outcompetes other species and rapidly dominates the macrophyte community from the first growing season onwards. Further optimisation of this model may be possible using data collected during this study, and a better understanding of the relative contribution of each component part of the plant will also lead to better data input. It may be that iterations of the model should be run to predict biomass accumulation in different seasons.

Management

In field experiments, lasting for over one year, several management techniques were studied.

Blocking the sunlight will kill all underwater vegetation. It is to be expected that after re-exposing the water column to sunlight, dependent on the inflow of fragments *C. caroliniana* can re-enter. Coverage of the sediment did not result in a suppression of *Cabomba*, as plants colonized the new sediment on top of the geotextile. Regular dredging will not result in a permanent removal of this macrophyte. Even if dredging is applied twice a year, it will just result in a temporary decrease of the plant's biomass. The major cause of the excessive growth of *C. caroliniana* is the influx of fragments and the weak competition by other water plants, as shown by cage experiments. A new technique, in which the loose sediments together with the rooted macrophytes are vigorously re-suspended through a water jet stream, turned out to be quite successful. This technique can still be improved, particularly in the collecting and removal of the re-suspended plant material. Experiments with the cages indicated that the inflow of plant fragments is the major route for recolonization by *C. caroliniana*. Particularly in the ditches where the shoreline vegetation consists of reed, shrubs and trees, it will be difficult to remove the fragments completely.

Mechanical control is the main method of management of *H. ranunculoides*, with cutting and removal of large floating mats the most common operation. This has been shown to produce benefits over time with regular maintenance, resulting in a much reduced final biomass in Dutch canal systems. In UK situations, mechanical control has probably perpetuated the presence of the plant in several locations, primarily as a result of the timing of cutting and release of vegetative fragments at optimum times for regeneration of fragments. In studies on the comparison between mechanical and chemical costs, herbicides are approximately 50% cheaper than mechanical control, and result in a better overall reduction in plant biomass in the following year. Novel techniques using hydrogen peroxide, flame throwers, adjuvants and combined mechanical and chemical techniques all show promise. Methods using heat and hydrogen peroxide have been tested in greenhouses during the project in the Netherlands. The prospects for flame weeding are positive, as a result of which one of the Belgian waterboards will test this control option under practical conditions in the growth season and investigate the optimal timing of application in relation to growth stage. Trials using herbicides and adjuvants in combination with mechanical control are ongoing in the UK. It appears that site requirements and conditions govern the choice of technique and optimisation of those techniques in particular situations will still require up to date advice based on experience.

Effective management of *L. grandiflora* for eradication is relatively difficult. Mechanical removal tends to create viable fragments which can spread to new areas or recolonise existing managed sites. Even complete removal does not often eradicate the species because of the high propagule pressure created by large numbers of viable overwintering seeds. Chemical control using aquatic approved formulations of glyphosate and the adjuvant TopFilm™ at a rate of 800 mL ha^{-1} were more successful than glyphosate formulations alone (Defra, 2007). 2,4-D amine carries a label recommendation for treatment of *Ludwigia peploides*, but while successful in the USA, no studies have been carried out in Europe using this herbicide. Retreatment and continuous monitoring is recommended for successful management of *Ludwigia* species.

Effective management of *M. aquaticum* for eradication is relatively difficult. Mechanical control tends to remove very large amounts of material in a relatively short period of time, but due to the rapid regeneration of fragments of leaves, shoots and roots, recolonisation is inevitable within weeks. Continuous efforts should be made to remove plants as soon as they reappear after mechanical control to prevent reinfestation and dominance of the habitat. Chemical control using various herbicides and combinations of herbicides have shown that single herbicides are not usually effective unless applied with adjuvants, and that combinations of herbicides with different modes of action are required to achieve 100% control of this species.

Decision Support System

The main objective of this project was to produce a support system that could be used by field operatives and office based managers to identify the species accurately, and to enable a rapid risk assessment to be made in the field that could be reported in a consistent manner, enabling a rapid response to be made against the species with the aim of preventing further spread and eventually eradication the species from the affected watercourse. In order to make the response to aquatic non-native species consistent and proportionate a pictorial field and office guide has been produced that provides descriptive photographs of characteristic features, areas at risk, typical habitat types, and available management techniques. We have deliberately left out costs of management as these vary within each country and certainly between countries. In addition, each species chapter will be made available at www.declaim.eu and www.q-bank.eu/plants. The DSS was submitted to the Non Native Species Secretariat in the UK for comment before being used by managers. In the Netherlands the DSS was submitted to representatives of various water boards that are actively involved in trials to control invasive macrophytes The comments received were positive and helpful and led to developments in the current version.

- **Main conclusions,** including:

  - The expected benefits and usability of results (technology transfer)

The findings of the literature survey, desk studies, field trials and consultation of stake holders regarding all four species has been translated in a user oriented Decision Support System addressing the surveyor in the field as well as the manager and ecologist at the office. Field cards to assist identification of the species and the risk level for the surveyor are supplemented with an office guide providing further information to assist identification and risk assessment as well as providing management options. For a complete overview of all aspects of ecology and management as well as full bibliography a State-of –the-Art document is provided for each species. Field cards and office guides are available in English and Dutch, whereas the State-of-the-Art document is in English only. All products can be found http://www.declaim.eu/ and at http://www.q-bank.eu/Plants/ under the header ‘control’.

  - Implication for stakeholders and policy

This work has shown that control methods can be optimised for all four species, saving time and resource effort on inappropriate management activities. The policy implications of this project include the importance of rapid risk assessment protocols, the value of expert opinion, gap analysis work to identify both scientific and trade knowledge gaps. The main benefit of this project is that it has established a standard method of reporting on invasive species ecology and management in the two countries which could be extended to European policy frameworks.

  - Recommendations for future work (on the activities or other steps that may be taken to further develop, disseminate or to uptake the results of the project)

The EUPHRESCO-DeCLAIM project, part of the EUPHRESCO I programme, has made an effort to promote the exchange of knowledge and ideas concerning the management options for four non native invasive aquatic plants posing problems in both the UK and NL(*Cabomba*

caroliniana, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *Myriophyllum aquaticum*).
Based on the outcome of this project new ideas for future activities have come up.
These ideas can be grouped under three themes.
Deepening knowledge on any of the four species by addressing questions raised during the project
Widening the scope by incorporating other EU countries to address and investigate differences in habitat and management techniques applied
Widening the scope by addressing other species that can be considered emerging risks.

We could envisage the following projects

- More detailed research on the ecology of *Cabomba caroliniana* to explain its competitiveness that contradicts the present physiological knowledge on the species.
- More detailed research on the importance of seed production to the overall reproductive strategy of *L. grandiflor*a in Northern Europe.
- Research on *Myriophyllum heterophyllum* a species that accidentally was subjected to the same management trials as *Cabomba caroliniana* and responded very well to one of the techniques. This species is spreading at an alarming rate in the Netherlands but is reported to be no longer present in the UK.
- Research on *Egeria densa* and *Lagarosiphon major*, emerging invaders for the UK and to a lesser extent the Netherlands posing serious problems for local drainage boards. Some management trials have recently started in Ireland and the Netherlands.
- Translating the findings of EUPHRESCO DeCLAIM project to other EU countries for the four species addressed.

- Papers, other publications and dissemination activities done.

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- References (see individual State-of-the-Art documents)

- Possible Appendices: problems encountered, delays and corrective actions taken (if any), publications and (planned) dissemination activities, and possibly terms and definitions, abbreviations, protocols.
  - Field card for *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *Myriophyllum aquaticum*
  - Veldkaart voor *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *Myriophyllum aquaticum*
  - Risk assessment sheet
  - Risicokaart
  - Office guide for *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *Myriophyllum aquaticum*
  - Handleiding voor *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *Myriophyllum aquaticum*
  - State-of-the-Art for *Cabomba caroliniana*, *Hydrocotyle ranunculoides*, *Ludwigia*

grandiflora, *Myriophyllum aquaticum*
- Bibliography for *Cabomba caroliniana*

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