EUPHRESCO DeCLAIM Final report

A State-of-the-art June 2011

Myriophyllum aquaticum (Vell.) Verdcourt

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This report contains the result of research on *Hydrocotyle ranunculoides* and was part of a larger project EUPHRESCO DeCLAIM (Decision Support Systems for ControL of Alien Invasive Macrophytes). A project initiated to generate a prototype decision support system for optimal control measures for the four most troublesome invasive alien aquatic weeds at present in the UK and NL.

Cabomba caroliniana, a representative for the Myriophyllids growth form, representing 35% of the import volume of aquarium plants in The Netherlands. In 2009 it was found at three sites in The Netherlands, posing serious problems at one.

Hydrocotyle ranunculoides, a representative for 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 as well as in the Australia, Uganda and Zimbabwe.

A second representative for the Stratiotids *s.l.* growth form, *Ludwigia grandiflora*, has demonstrated significant detrimental ecological impact in France and is gaining importance in The Netherlands. In the UK early intervention management strategies using herbicides have been developed and deployed (DEFRA website).

A third representative of the Stratiotids *s.l* growth form is *Myriophyllum 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 infestations is increasing.

The overall project was a joint effort between four partners.

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1. Executive Summary

- **Range:** *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 best 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:** *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. Similar species visually are *Cabomba caroliniana* (when submerged), *Myriophyllum robustum, Myriophyllum heterophyllum, Myriophyllum verticillatum, Hottonia palustris and Hippuris vulgaris.* 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 the UK we have indicated a temperature related altitudinal maximum for areas to be at risk, based on current observations plus 100m to account for possible unreported sites.

- **Reproductive Strategy:** In South America there are both male and female plants, 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:** 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:** Effective management of this species 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[1]. 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 waterboards that are actively involved in trials to control invasive macrophytes. The comments received were positive and helpful and led to developments of the current version.

[1] This domain is not hosted within any of the project organisations and should be migrated to a partner organisation web site as soon as possible.

2. Habitat requirements and areas at risk

2.1. Objectives

- Analyse from literature what the (a)biotic factors are that characterize the habitat of *Myriophyllum aquaticum*.
- These (a) biotic factors will be used to identify in existing databases (STOWA-databases on ditches, streams, canals, lakes and ponds for The Netherlands; MTR, SNIFFER, LEAFPACS and existing CEH databases for the UK) localities at risk.
- Using these data maps of "at risk areas" of The Netherlands and the UK will be produced

2.2. Literature Analysis of Growth conditions

In its' native range of floodplain swamps and water margins in South America, little is known about nutrient requirements, although the most characteristic feature of these habitats is that they are slow flowing or static, often shallow waterbodies, with little or no substantial shading, allowing access to nearly full sunlight. The requirement for relatively high dissolved nutrient concentrations in introduced ranges implies that the native habitat should also be at least mesotrophic.

Nutrient supply

It is not known if the species needs to be rooted in sediment for growth, but the presence of floating rafts of vegetation in such areas would indicate that this is not always necessary. The importance of sediment for nutrient supply in the introduced range is less important than water column nutrient supply as Sytsma & Anderson (1993a) showed that only 2% of water transpired by *M. aquaticum* was derived from soil interstitial water supply, implying that the majority (98%) of water and associated nutrients required for mass transport of nutrient into the plant enters through adventitious roots, which also have the highest relative growth rate (RGR) of any part of the plant compared to the RGR of sediment roots having a RGR of close to zero. The thick cuticularisation of sediment roots reduces the ability of water to enter (Kimbel, 1973, Sytsma & Anderson, 1993a) and reduces their function to one of exclusive anchorage to the sediment. When adventitious roots come into contact with the sediment surface they can also act as a route of nutrient entry to the plant.

Most authors agree that *M. aquaticum* only grows to nuisance levels in nutrient rich water. This observation has been summarised by work in Wersal & Madsen (2011) who showed that the biomass yield of *M. aquaticum* was a quadratic function of tissue nutrient content, and that yield was positively correlated with nitrogen but negatively correlated with phosphorus content of the water. The critical tissue nutrient concentrations required for nuisance growth are 1.8% N and 0.2% P, which can only be achieved in water with relatively high dissolved nutrient concentrations, especially when

N:P ratios were high (high N, Low P), and when Nitrogen concentrations were above 1.8 mg L^{-1}. Sediment phosphorus is thought not important for development of the plant as 80% of the phosphorus is found in emergent shoot tissues, implying that all the phosphorus needs of the species are met by water column nutrient supply (Sytsma & Anderson, 1993b).

2.3. Areas at Risk

Databases in the UK and NL could not provide the detailed information we had hoped for. Previous studies in France and the wide distribution in the Netherlands already revealed the wide tolerance of *M. aquaticum* for abiotic factors. Therefore we can consider all shallow slow flowing and still waters in the Netherlands to be potentially at risk. For the UK we have indicated a temperature related altitudinal maximum to be at risk.

Figure 1. Known and Potential Distribution range of *M. aquaticum* in the UK.

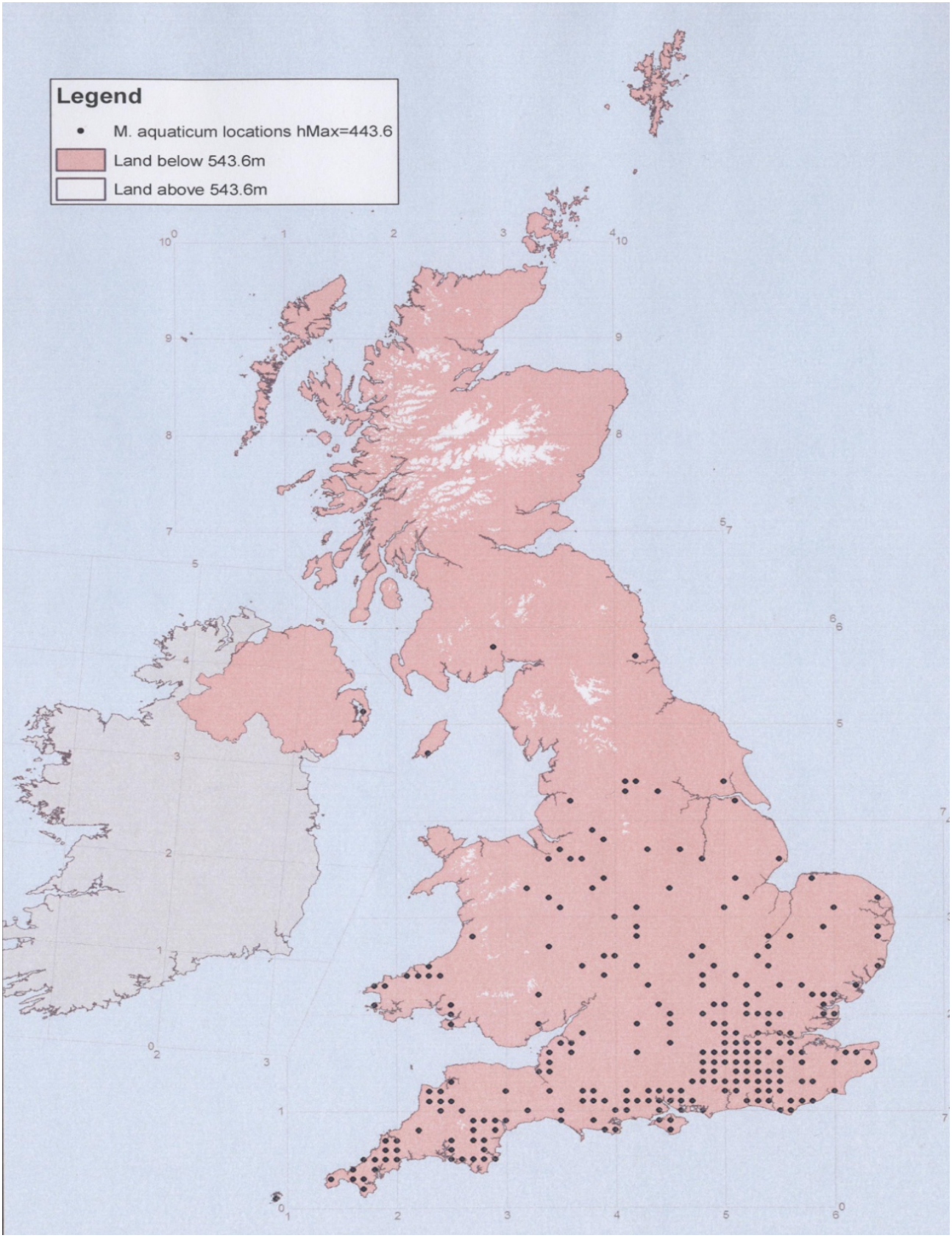
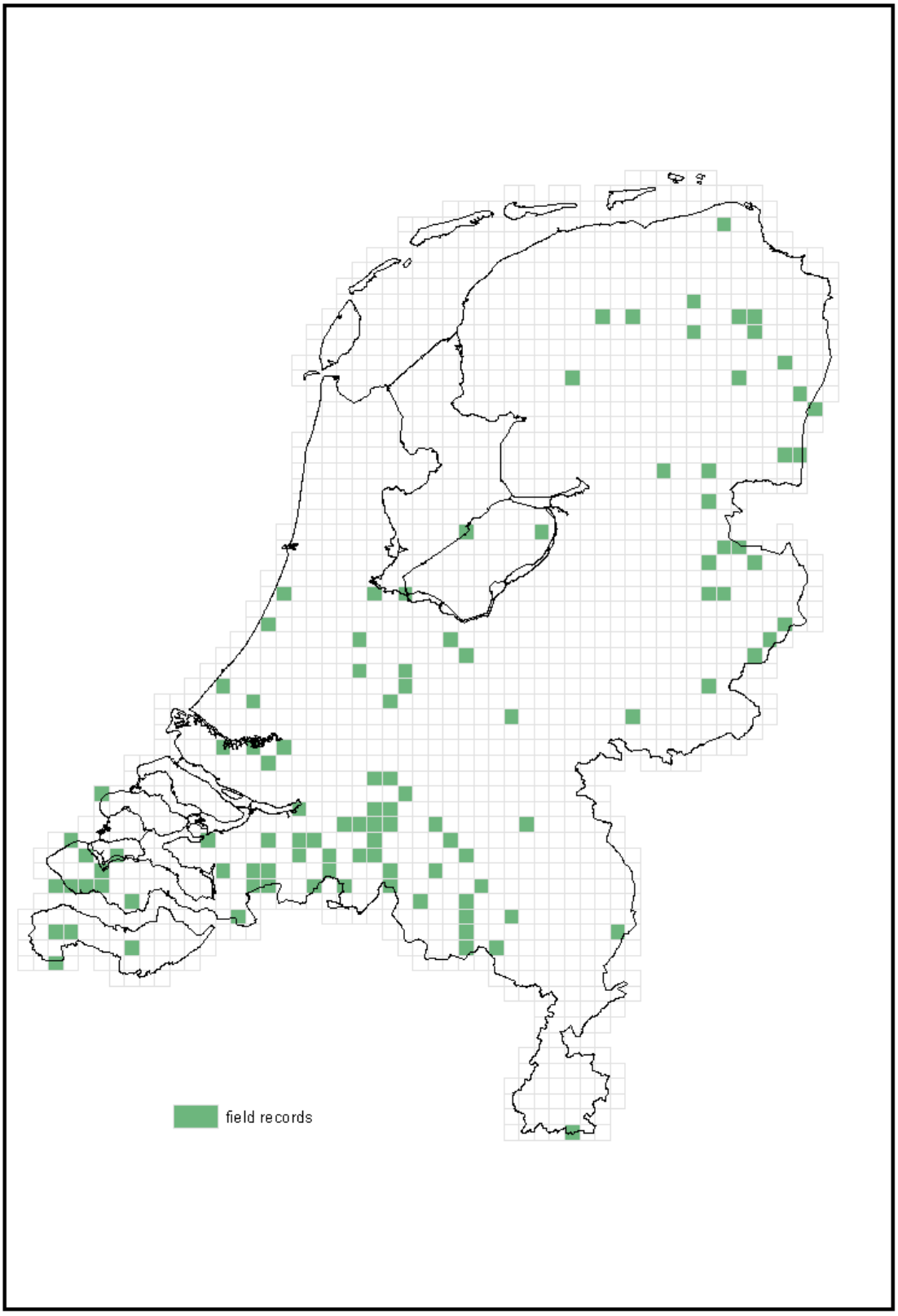


Figure 2. Known Distribution of *M. aquaticum* in the Netherlands (2011)



3. Ecology and Growth Modelling using CHARISMA

3.1. Objectives

- Review ecological literature on the life cycle of *Myriophyllum aquaticum*.
- Based on the available information come to a preliminary parameterization of the individual based macrophyte model CHARISMA (Van Nes *et al*. 2003).
- Gaps in published literature will be identified and attempts to gain information required for CHARISMA will be made.

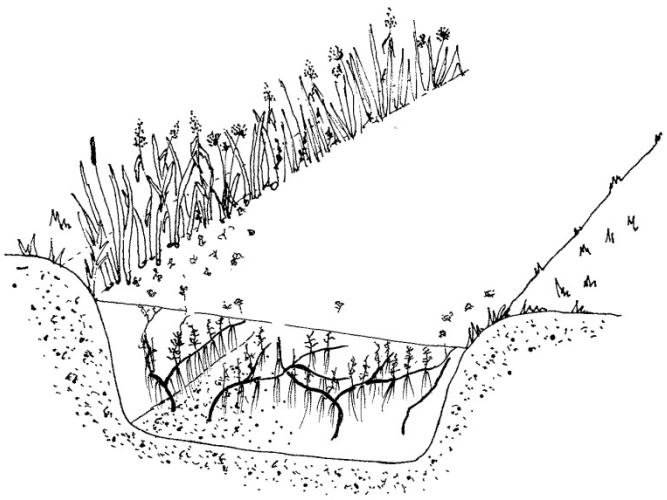
3.2. Life Cycle

The contribution of submerged leaves to net carbon gain is very low, and Salvucci & Bowes (1982) suggest that submerged leaves possess a large internal resistance to CO_2 fixation. The light saturated rate of oxygen evolution of submerged leaves is some 8 times lower than for emergent leaf material, and photosynthesis is not fully active in emergent leaves until full sunlight is reached (2000 µE $m^{-2}s^{-1}$), while it is saturated at about 10% full sunlight in submerged leaves. Published rates of photosynthesis at non-limiting light and CO_2 levels range from 18 µmol O_2/mg Chl h^{-1}) in submerged leaves (Salvucci & Bowes, 1981) to 125 µmol O_2/mg Chl h^{-1} in emergent leaves at low external oxygen concentration. Hussner (2009) gives a photosynthetic rate for *M. aquaticum* shoots of 400 µmol O_2/mg g^{-1} dw h^{-1}, equivalent to about 65 µmol O_2/mg Chl h^{-1} on a leaf chlorophyll basis (6.1 mg Chl g^{-1} dw). Hussner (2009) also noted that photosynthesis of emergent shoots was saturated at 900 µE $m^{-2}s^{-1}$, or about half full sunlight. It is not clear if this was due to adaptation to northern European climate and conditions, or if it may have been a consequence of growth conditions prior to collection (e.g. if collected from shady conditions the light compensation point might have been lower).

Emergent leaves of *M. aquaticum* have anomocytic stomata (lacking guard cells) (Sutton & Bingham, 1973), a thick waxy cuticle and narrow nearly cylindrical leaflets, typical of plants form xeric habitats usually associated with reducing transpiration. These adaptations allow biomass accumulation with water use efficiency similar to terrestrial C-4 plants (Sytsma & Anderson, 1993a). The benefits of emergent leaf forms to aquatic macrophytes in terms of CO_2 assimilation are obvious, but the trade off required in terms of maintaining hydrostatic pressure in the absence of lignifications or secondary structures (as in *M. aquaticum)* are less clear, and these leaf adaptations reducing transpiration rates in physiologically active leaves are probably associated with maintenance of adequate leaf turgor and water content for

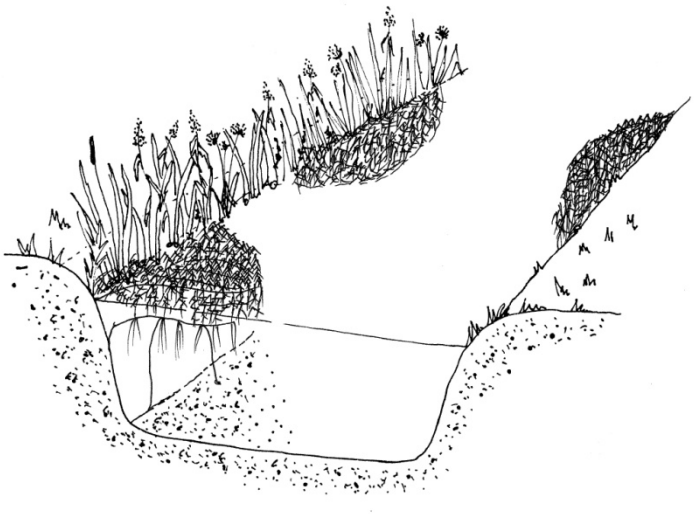
physiological processes to work effectively. This potential weakness could be utilised in control techniques.

3.2.1. Life cycle diagrams



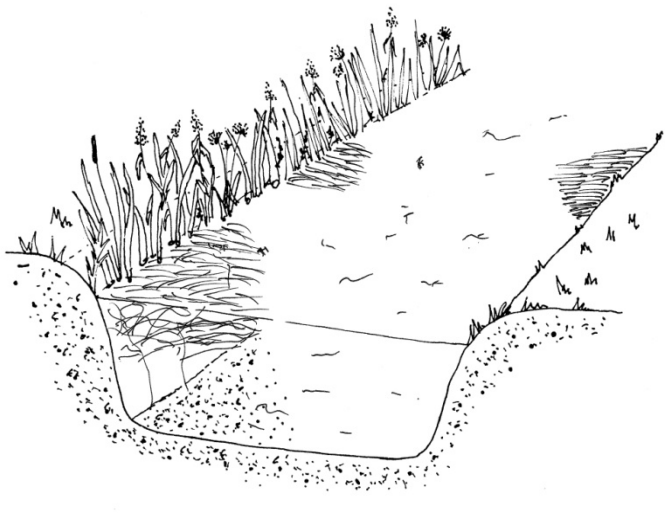
***Myriophyllum aquaticum* in Spring**

In spring, when water temperatures rise above 10°C, adventitious roots develop at individual stolons usually with two or three roots per node. Submerged shoots develop only after these roots have formed (see below). New submerged type shoots start to develop from nodes on overwintering stolons. The stems and leaves are red in colour due to pigmentation to absorb excessive UV light. There are no obvious signs of emergent material at this time, and emergent leaves start to appear once all signs of frost have past, usually in mid to late May



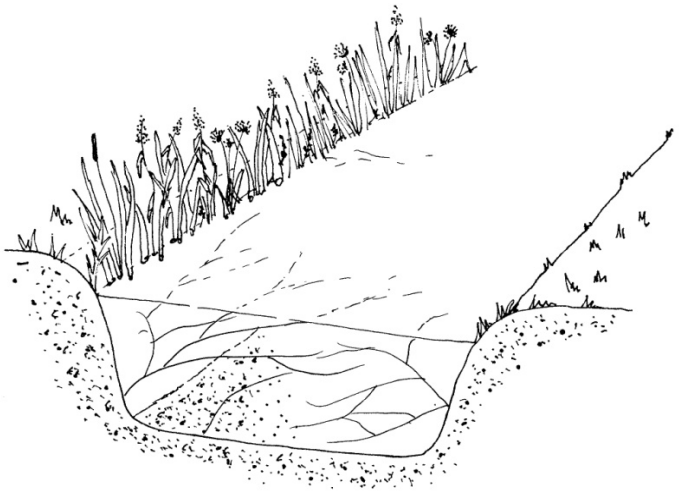
***Myriophyllum aquaticum* in Summer**

By early June, the emergent leaves have formed and dense carpets of plant material grow close to the bank, with mounds appearing to spread outwards. The most active growth occurs at the apical tips of the plant, so the edges of the mat and the top surface of the mat tend to reach out into the water, followed by submersion of older stems which then grow more adventitious roots and more shoots which eventually become emergent, maintaining the apparent health of the mat.



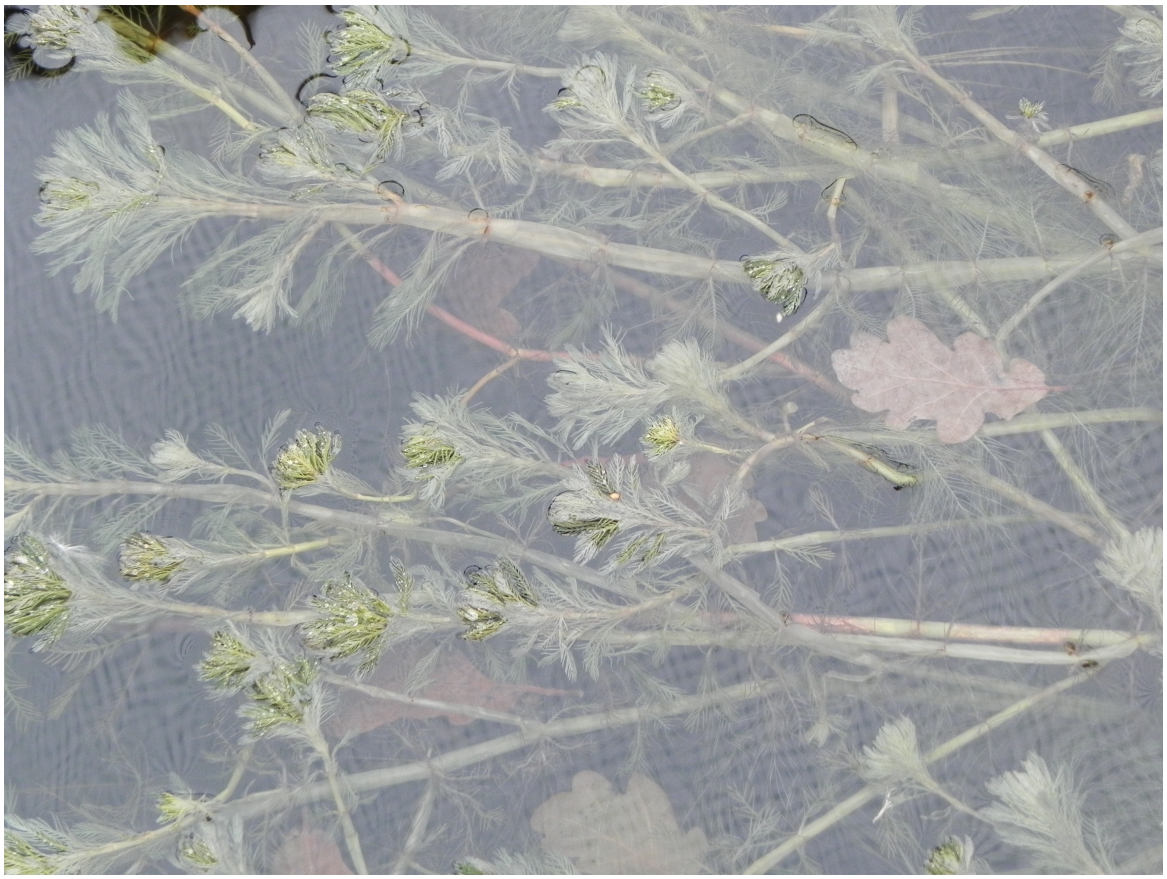
***Myriophyllum aquaticum* in Autumn**

With shorter days and colder nights, the growth rate declines and mats start to fragment, causing viable propagules to be spread within and between systems. Fragmentation in autumn, when the plant still retains the capacity to regenerate rapidly, is considered to be the most important time for vegetative spread. The underside of the dense mat will become senescent and start to die back, leaving only the stolons intact under the water. These survive through autumn and over winter and form the basis for new growth in the next spring period, when the material above the inactive stolon has rotted away.



***Myriophyllum aquaticum* in Winter**

After the first frost, emergent leaves collapse because of damage to cell membranes that cause irreversible loss of turgor. The plant overwinters as submerged stems and stolons. Fragments released in autumn overwinter on the sediment surface and grow again in spring.



3.3. CHARISMA model development

The objective of this work package is to review ecological literature on the life cycle of *M. aquaticum* and based on the available information come to a preliminary parameterization of the individual based macrophyte model CHARISMA (Van Nes *et al*. 2003). Gaps in published literature will be identified and attempts to gain information required for CHARISMA will be made.

The basis of this spatially explicit model is the seasonal cycle. Plants can survive the winter as shoots and as different types of overwintering structures. At a pre-set day in spring, growth is initiated and the plants get a certain amount of energy from the overwintering structures and an increasing amount from primary production. At a pre-set age, the macrophytes start allocating a part of their biomass to overwintering structures. At the end of the growing season, this part of the plants is transformed into biomass and the plants die off.

We used the literature review to parameterize the model CHARISMA. The model has been parameterized for *Potamogeton pectinatus, P. perfoliatus* and *Chara aspera* (Van Nes *et al*. 2002, 2003; Coops *et al*. 2002). These parameter sets will be used as basis. In discussion with partners we will come to a preliminary parameterization of the model. For *Myriophyllum*, that has a different growth form, similar to *Hydrocotyle*, the aim will be to come to an appropriate design of the model.

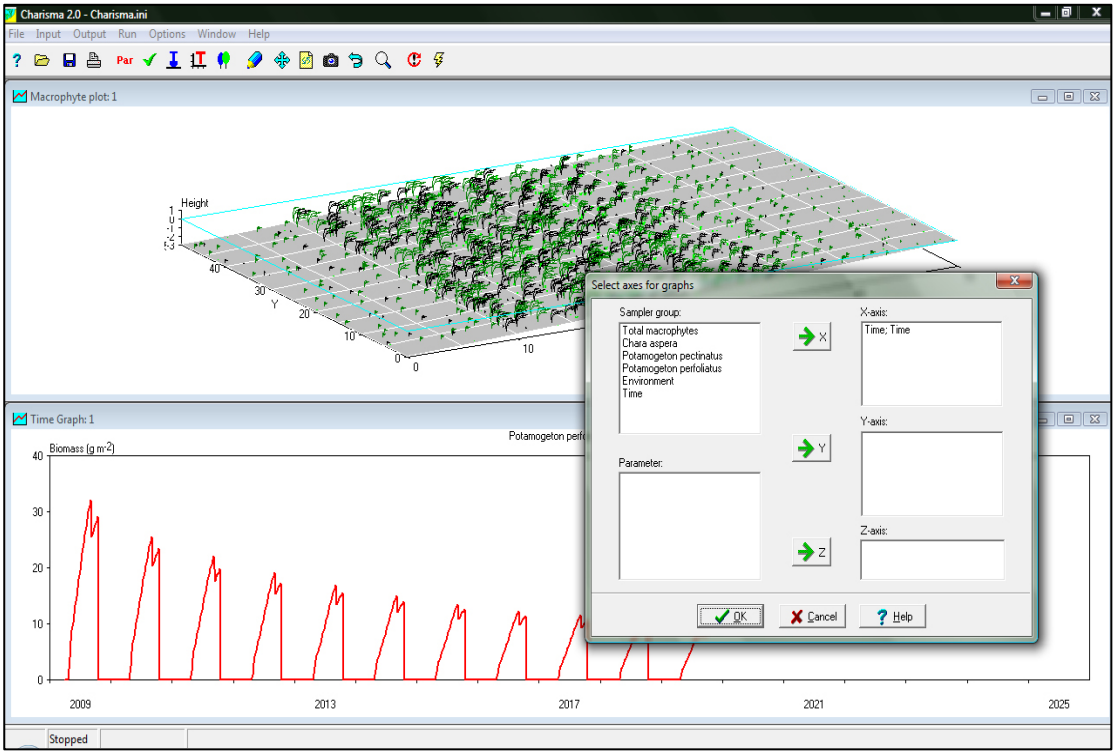
For several growth parameters insufficient parameter values are available in literature to run the CHARISMA model accurately. Most papers only give a general description of favourable or unfavourable conditions for *M. aquaticum* growth. To be able to further adapt the model CHARISMA to accommodate for *M. aquaticum* growth, this information should be obtained from experimental work.

3.3.1. The CHARISMA model

The CHARISMA model is an individual-based and spatially explicit model in which individual plants and overwintering structures are positioned on grid cells (Figure 3). 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.

The model is based on a seasonal cycle. Plants survive the winter as shoots or overwintering structures. In the spring, growth is initiated from the energy from the overwintering structures. At the beginning of the summer, primary production and respiration determine plant growth. In the fall, individual plants start allocating biomass to overwintering structures. At the end of the growing season, shoot biomass is transferred to overwintering structures and the plants die off.

Figure 3: Diagram of CHARISMA model grid cells



3.3.1.1. Growth form

The weight of plants is determined by a fixed root/shoot ratio. Part of the biomass during the growing season will be allocated to reproductive organs. The length of young shoots increases underwater proportionally with biomass. After reaching the water surface, there is a proportional increase of the biomass over the whole length of the plant. Optionally, a fraction of the biomass can be allocated to spread just under the water surface.

3.3.1.2. Growth rate and mortality

The daily growth rate depends mainly on the gross photosynthesis rate and the respiration rate. Mortality can be caused by high plant densities, wave damage, grazing, or seasonal die-off. In the specific case of *M. aquaticum*, tissue behind the apical stems becomes senescent or submerged, altering the functionality of the plant (Sytsma & Anderson, 1993a), and affecting the ability of the model to accurately represent a real life plant.

3.3.1.3. Environmental variables

The CHARISMA model allows you to modify a wide array of environmental variables such as light levels, temperature, turbidity, bicarbonate concentrations in the water

and water levels (figure 4).Model parameters, including comments on significant gaps

An exhaustive list of all the parameters that can be adjusted In CHARISMA is presented in the annex 1. Table 2 presents the different parameters that have been adjusted specifically for modelling the life cycle of *M. aquaticum*

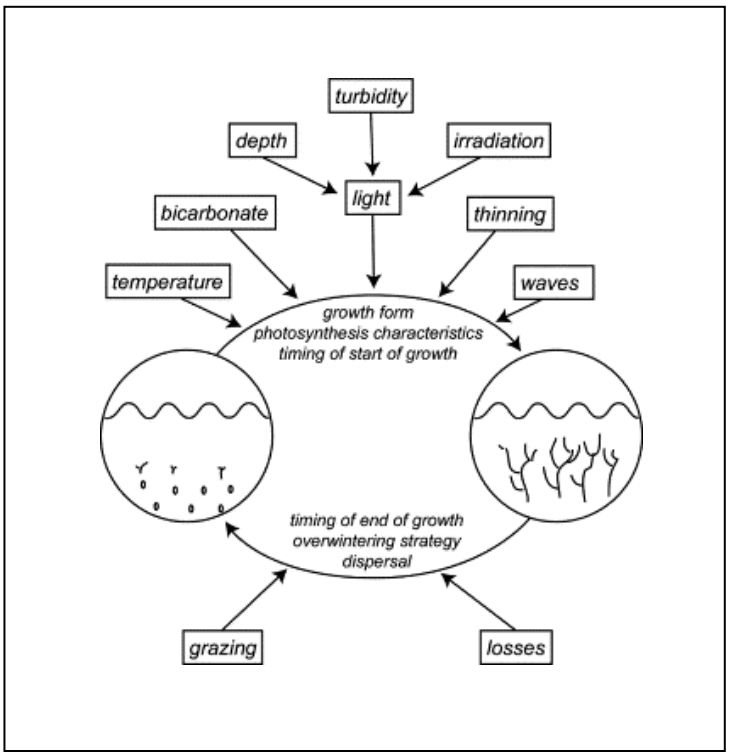


Figure 4. Seasonal cycle and environmental variables in the CHARISMA model

3.3.2. Summary of available data for CHARISMA variables

Table 1 contains the different parameters that have been adjusted specifically for modeling the life cycle of *Myriophyllum aquaticum.*

The P_{Max}, the maximal gross photosynthetic rate at the plant top at 20°C in the absence of light limitation, has been adjusted for *M. aquaticum* to 0.01/h, based on measurements of 400 µmol of CO_2 h^{-1} g^{-1} dry weight (Hussner 2009). The light compensation point (hPhotoLight) was fixed at the default value (52 µE $m^{-2}s^{-1}$), as well as the plant K (0.02 m^2/g). The respiration rate was fixed at 0.0025/day (calibrated).

The average root/shoot ratio has been determined from data from Hussner *et al.* (2009) and data collected in the field in September 2009 by Rudi Roijackers and Johan van Valkenburg. It ranges from 8% (Hussner *et al.* 2009) to 32% (data collected).

Production of male plants is unknown outside South America. Therefore there is no seed production. All parameters related to sexual reproduction (seed and flower production) production have thus been fixed to zero.

From Hussner *et al.* (2009), we calculated the dry weight of single shoot segments of 10cm (as a standard length) to be 0.19g, which is considered the weight of regeneration fragments (or rhizome fragments). In CHARISMA, regeneration fragments (any vegetative wintering structure) will be considered as a tuber. Thus 0.19g will be considered the average TuberBiomass in the model. 0.19g will also be considered as the ''frond weight'' (WeightFond) as *M. aquaticum* (similarly to *Hydrocotyle ranunculoides* and *Ludwigia grandiflora*) is modeled as a floating plant in CHARISMA, which was based on *Lemna* species (default floating species). Although it also forms submerged leaves, *M. aquaticum* – as well as *H. ranunculoides* and *L. grandiflora*— is mainly found in its floating form in Europe (Hussner *et al.* 2009). Field measurements (Roijackers & van Valkenburg, September 25th 2009) from two sites in the Netherlands colonised by *M. aquaticum* confirms the absence of coverage (0%) of its submerged form versus 75-100% of its floating form.

The fraction of biomass allocated to tuber (TuberFraction) has been defined as the rhizome fraction, which for *M. aquaticum* is defined as old emergent stems that have been pushed underwater by elongation of the aerial stems. Moreover, rhizomes are more dense and rigid than submersed stems (Sytsma and Anderson 1993b). The tuber fraction has been estimated to vary from 20 % (collected data 2009) to 95% in deeper waters – 1.5m (Sytsma and Anderson 1993b).

The germination day of the overwintering rhizomes (TuberGerminationDay) has been fixed to April 1st. *M. aquaticum* does not store phosphorus or carbon in its rhizomes as oppose to tubers which release only a proportion of their biomass everyday for the production of shoots. Therefore 100% of the biomass of the

rhizomes (cTuber=1) turns into photosynthetic shoots on April 1st. Because *M. aquaticum* is producing rhizomes all summer (as a structure for buoyancy for emergent shoots), we decided to set the age of the plant when it starts to make overwintering structures on April 1st as well (at age=1 day). The end of the production of rhizomes, October 1st (at age 182 days=6 months, May-October), is also the end of the growing season (reproDay) which represents the day when tubers (here rhizomes) are dispersed. We also decided for the duration of the simulations not to have any import of fragments (tuber import=0).

Table 1. Summary of parameters used for CHARISMA modelling of *M. aquaticum* growth

Parameter	value	remarks
light		
PMax	0.01/h	
hPhotoLight	52 µE $m^{-2}s^{-1}$	default
half saturation light intensity (PAR)		
PlantK	0.02 m2/g	default
Resp20	0.0025 /day	calibrated
reproduction		
ReproDay	Day#274	#day of dispersal (seeds and tubers): October 1st
SeedGerminationDay	0	
Seed Germination	0	
Seed Mortality	1	
Seed fraction	0	
Seed Biomass	0	
SeedsStartAge	0	
SeedsEndAge	0	
SeedImport	0	
tuberfraction	0.20-0.95	
TuberGerminationDay	Day#92	April 1st
Tuberbiomass	0.19g	weight of one fragment
TuberImport	0	
cTuber	1	
TuberStartAge	1	
TuberEndAge	182	
maxWeightLen ratio	n	
RootShootRatio	0.08-0.32	
MaxLenght	N	
Weight Fond	0.19g	

3.3.3. Results

After adjusting in the model all the required parameters, we ran simulations of the growth of *M. aquaticum* over time with and without other competing species (*Chara aspera, Potamogeton pectinatus*).

The aim of the first set of simulations was to understand better the growth patterns of *M. aquaticum* alone without competition. We first used the following extreme values: a root:shoot ratio of 0.32 and a tuber fraction of 0.95. Considering its relatively high photosynthetic rate 0.01/h (but moderate in comparison to for example *Hydrocotyle ranunculoides*, 0.088/h), the species can grow to densities around 400g/m^2 (figure 5a). This value is within the range of 219-969 g/m^2 from the data collected on the field in September 2009 (Roijackers & van Valkenburg). However, we wanted to see if we can approach the higher range limit considering the simulated values were **without** competition. We ran again the same simulations but this time with a root:shoot ratio of 0.08 and a tuber fraction of 0.20, which means less biomass allocated to roots and rhizomes and more on photosynthetic structures. The values then rise up to more than 600g/m2 (figure 5b).

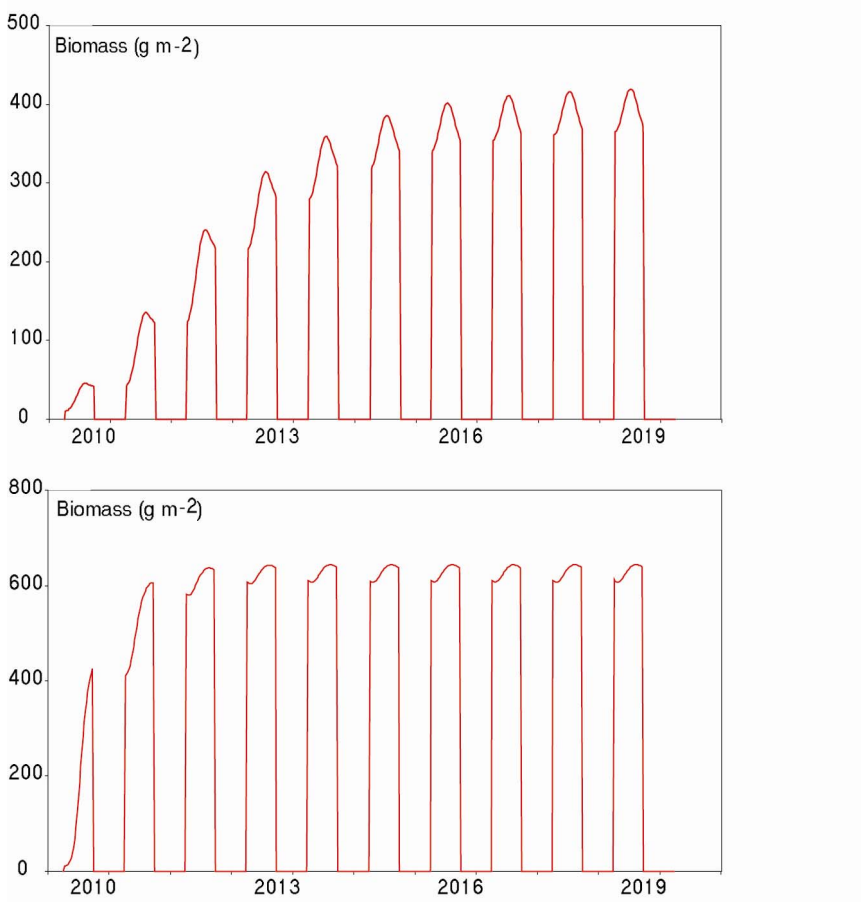


Figure 5. Simulations of the growth of *Myriophyllum aquaticum* over ten years without competition. a) with a root:shoot ratio of 0.32 and a tuber fraction of 0.95. b) with a root:shoot ratio of 0.08 and a tuber fraction of 0.20.

We then performed simulations of the growth of *M. aquaticum* with two competing species, *Chara aspera* and *Potamogeton pectinatus* on a 10 years period. We can see that *M. aquaticum* outcompetes the other species and dominates the macrophyte

community from the first growing season. This leads to extinction of *Chara aspera* and *Potamogeton pectinatus* in the second growth year (Figure 6).

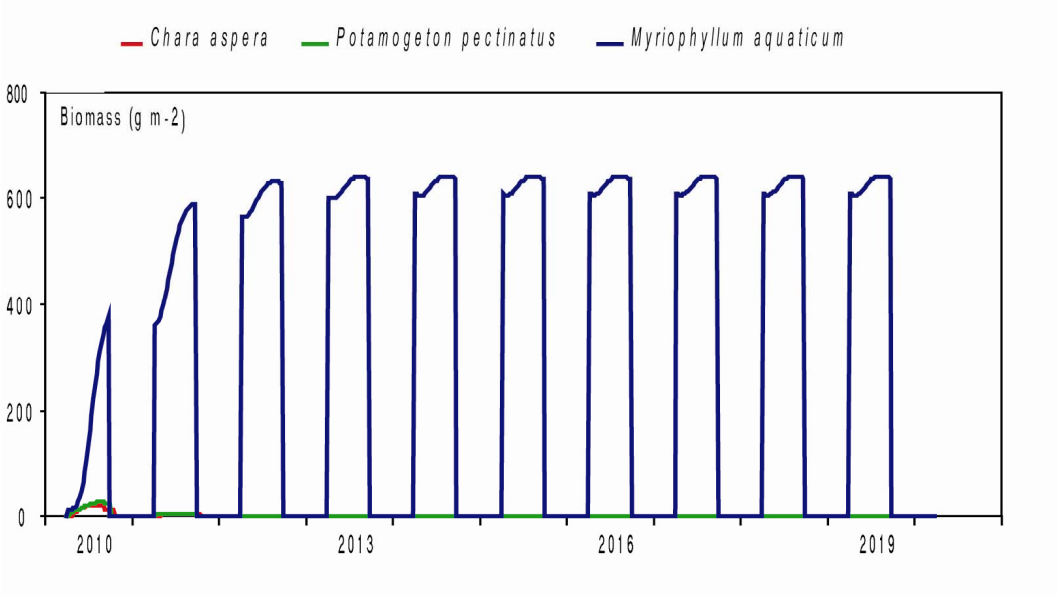


Figure 6. Simulations of the growth of *Myriophyllum aquaticum* with competition by *Chara aspera* and *Potamogeton pectinatus* over ten years.

3.4. Discussion

CHARISMA predicts reasonably accurately the dominance of *M. aquaticum* in invaded habitats. The accuracy may be increased by reducing the propagule weight, as work undertaken by Jacot Guillarmod (1979) showed that all parts of the plant were equal in their ability to regenerate new plants, and that a fragment as small as 0.5 cm with a node could produce a viable new plant. The figure of 0.19g used for tuberbiomass could have been reduced by a factor of 10/0.5 (20) to 0.085g. Future work will include data from recent collections in the Netherlands and the UK to optimise the model data set. The limited amount of physiological data used in this model may have limited the predicted biomass accumulation, and again these data will be used in future iterations.

Wersal *et al.* (2011) studied seasonal biomass and starch allocation patterns in *M. aquaticum* between January 2006 and December 2007. These data were not available at the time of the model iteration, but, water temperature, water depth, light irradiance, light transmittance, pH, and conductivity were recorded during biomass harvests. Overall, few significant relationships were observed between the environmental factors tested and seasonal biomass. Stolons accounted for 40-95% of total biomass followed by emergent shoot, submersed shoot, and root biomass. Percent starch in plant tissues was positively related to water temperature. Starch allocation was greatest in stolons where up to 16.3% of total starch was stored. Submersed shoots stored 0.6-11.0% of total starch followed by emergent shoots (0.4-7%). Reduced biomass and starch storage occurred from October to March in

both 2006 and 2007, reflecting the lower photosynthetic activity and carbon assimilation when emergent leaf material was absent. A replication of this study under European conditions, where seasonal differences in environmental variables could provide information on the importance of stolons as overwintering structures.

4. Management

4.1. Objectives

The objective of this work package is to derive from the results of Work packages 2 and 3 new practical control options that can be tested by water boards and other bodies involved in management of surface water.

Since chemical weed control in an aquatic environment is extremely restricted in the Netherlands and because the results should be of practical use for both NL and UK, and other EU countries, the practical control options will focus on prevention and non-chemical methods. Data on suitable habitat characteristics and life cycle will be used to:

- Indicate how and when in the season the colonization of *M. aquaticum* can be prevented or markedly restricted by influencing the growth requirements (substrate, light conditions and other environmental characteristics that result from Work package 2)

- Conceptualize physical control options that combine a very high control efficacy with a minimum dispersal of vegetative parts of the aquatic weed. The current mechanical control options generally strongly induce further vegetative reproduction.

4.2. Environmental Control

Reducing nutrients, especially nitrogen is likely to reduce the vigour of this species, the critical value being approximately 1.8 mg/L N below which the species is stunted (Sytsma & Anderson, 1993d). Reducing water column phosphate does not appear to limit growth.

Reducing light will decrease the net photosynthetic gain by the plant, and field observations show that growth is severely limited by even low levels of shade.

There is some evidence to suggest that *M. aquaticum* does not grow well in water deeper than 50 cm, especially if the adventitious roots cannot come into contact with the sediment surface to enable enhanced nutrient uptake (Sytsma & Anderson, 1993b, 1993c). Deepening channels or the margins of lakes and ponds may reduce regrowth once other control activities have taken place.

4.3. Non Chemical Control

Effective management of this species 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. Figures for biomass accumulation of up to 969 g/m^2 (dry weight) from the data collected in the field in September 2009 (Roijackers & van Valkenburg) indicate that substantial amounts of biomass could be collected from small areas, up to 970 Kg wet weight from 100 m^{-2} and consideration should be given to disposal methods before attempting mechanical removal. Removal to dry bunded areas is acceptable for temporary storage, but deep burial or drying and burning are considered more effective long term disposal options.

Many aquatic plants have the ability rapidly to colonise waterbodies using vegetative growth, but species in the genus *Myriophyllum* have inherently high capacities for rapid axillary branching and adventitious shoot production (Kane *et al*., 1991) and can form new plants from fragments of root, shoot or leaves (Hagemann, 1982, Lacroix & Jeune, 2009, Lacroix & Bourque, 2011). This ability has enabled rapid spread within aquatic systems once introduced, as natural fragmentation occurs in autumn and winter, spreading vegetative fragments within and between waterbodies. Work on minimum fragment size shows that a 0.5 cm stem fragment with a node is capable of forming a new plant (Jacot Guillarmod, 1979) and given that every node has an equal ability to form new plants (Kane *et al*., 1991) this represents a huge inherent propagule pressure and the base of the success of this species in introduced ranges.

4.4. Chemical Control

Research into the control of *M. aquaticum* using herbicides has been carried out in the UK, New Zealand and in the USA. In the UK, good control of the species was obtained using glyphosate at 1.9 kg a.i per hectare with the adjuvant TopFilm at 600 mL per hectare; and also using 2,4-D amine at 450 g a.i. per hectare (Newman JR, unpubl.). In the USA, combinations of Carfentrazone ethyl and 2,4-D amine give 100% control (Gray *et al.*, 2007) , as does triclopyr (Hofstra *et al*., 2006) and imazapyr and imazamox to some extent (Wersal & Madsen, 2007) and there is some evidence that flumioxazin gives partial control after one application (Richardson *et al.*, 2008). It is evident 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. In some sensitive areas including peat bogs, chemical control is the only effective method of control as uprooting the plant damages the peat. Application of herbicide kills the *Myriophyllum* and allows native bog plants to recover from the seed bank (Forestry Commission, 2008).

A feature of this species is the rigid emergent stems that are required for the observed high photosynthetic rates of carbon assimilation. Consideration should be given to using environmentally benign chemicals that either weaken or destroy the waxy cuticle in order to kill the emergent material. This would have a similar effect to that caused by air frost in late autumn, when emergent stems collapse due to cell damage and loss of turgor.

4.5. Biological Control

Insect Pests

Cilliers (1999a, 1999b and in Morris *et al.*, 1999) reports that *Lysathia* n. sp. fed exclusively on *M. aquaticum*, with some variation in intensity due to temperature and flooding. Emergent shoots were often totally bare of leaves and some growing tips died back. Shoots were also thinner and smaller after colonisation. Plants that were heavily attacked showed new growth after three weeks. Full recovery took approximately six weeks. *Lysathia* n. sp. tended to migrate from heavily damaged plants to areas where food was more plentiful (C.J. Cilliers, unpubl. obs.). The number of shoots m^{-2} increased because each shoot, when damaged, usually sprouted 1–4 new shoots.

Oberholzer *et al*. (2007) reported on studies with the weevil *Listronotus marginicollis* for control of *M. aquaticum* in South Africa. Cordo & DeLoach (1982) tested *L. marginicollis* in no-choice trials on leaf discs of 43 test species in 22 families in the country of origin, Argentina. The insect showed a strong preference for *M. aquaticum*, only feeding lightly on *Limnobium stoloniferum,* causing damage to leaves and stems. This weevil is most effectively used in combination with the previous *Lysathia* sp.

Fungal Pathogens

Bernhardt & Duniway (1984) reported severe damage to underwater roots and stems of *M. brasiliense* causing frequently wilted and collapsed tissues caused by rot when infected with *Pythium carolinianum*. Plants grown in controlled field conditions inoculated with the pathogenic isolate produced significantly less biomass and fewer shoots than did uninoculated controls.

Herbivory

Parker *et al.* (2007) showed that beaver (*Castor canadensis*) herbivory reduced the abundance of the *M. aquaticum* by nearly 90%. Catarino *et al.* (1997) found that young grass carp (<2 yrs) did not consume *M. aquaticum*, but older fish were less selective and if the species were dominant it is likely that it would be eaten. Qiu *et al.* (2009, 2010a, 2010b & 2011) showed that Apple snails (*Pomacea canaliculata*), a voracious aquatic macrophyte herbivore fed *M. aquaticum* had very low survivorship, grew very little and did not reproduce.

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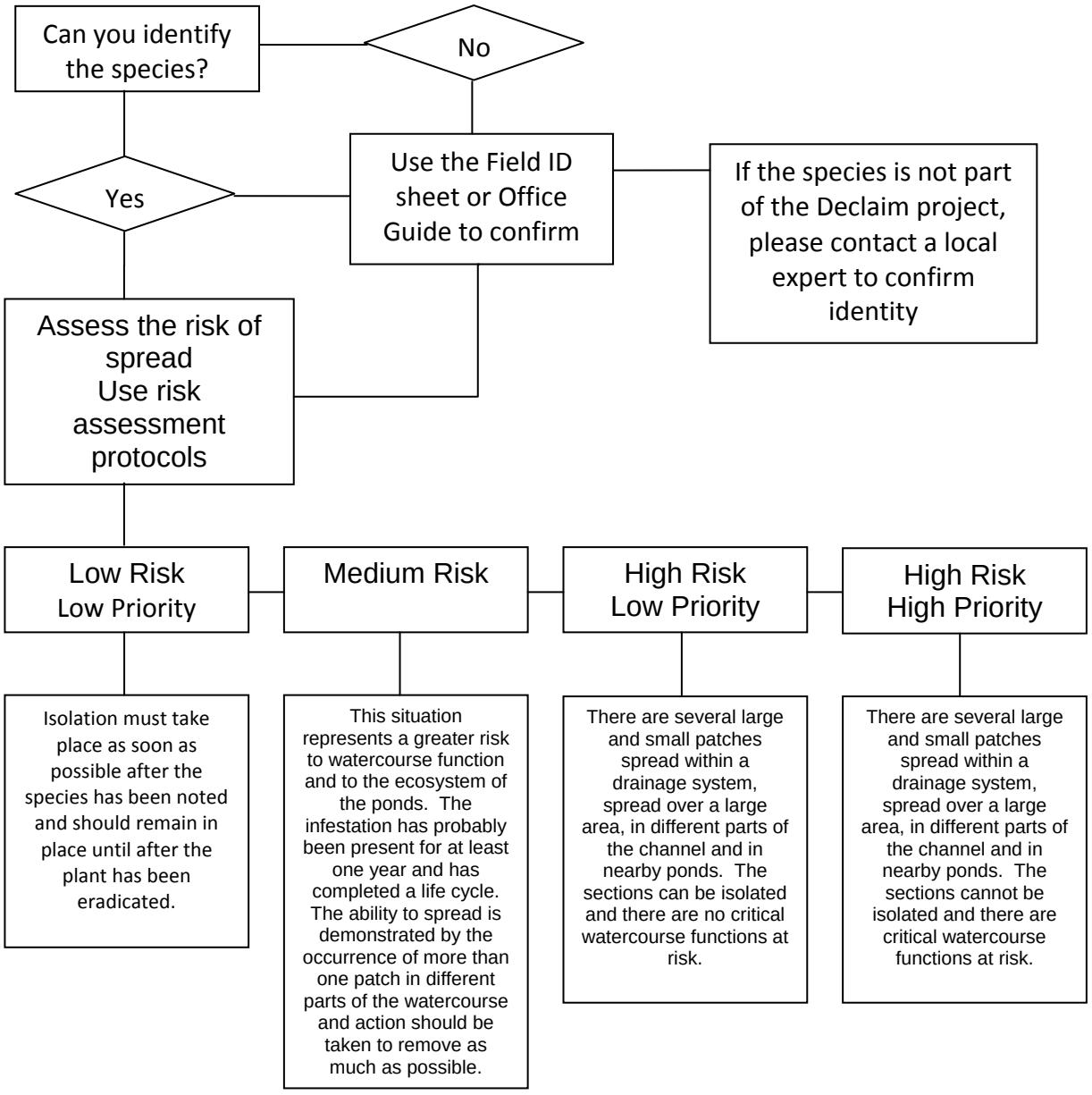
5. Decision Support System

5.1. Objectives

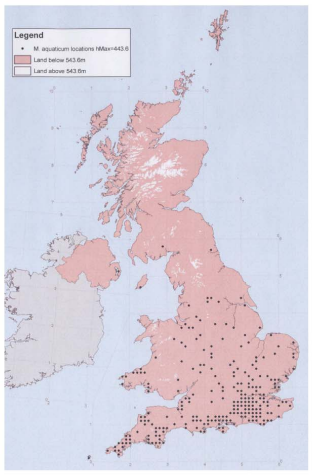
The objective of this work package is to derive from the current practices in aquatic weed management and from the results of Work packages 2, 3 and 4 a prototype DSS. This DSS will be disseminated amongst bodies involved in water management for review.

The DSS will permit the application of best practice derived from fundamental understanding of the ecology and growth strategy of the species in question, and the application of existing management techniques to achieve optimum control.



5.2. Information for use in the field

5.2.1. Identification



Areas at Risk of Colonisation in the UK Areas at risk are suitable habitats below about 550 m. The species has been found at a maximum altitude of 443m and can therefore tolerate prolonged cold winter conditions by lying dormant under ice. Cold weather tendds to increase fragmentation increasing rates of spread. Proximity to existing populations will increase the likelyhood of spread to new areas.

Myriophyllum aquaticum
(Parrot's-feather)

Field Recognition Guide

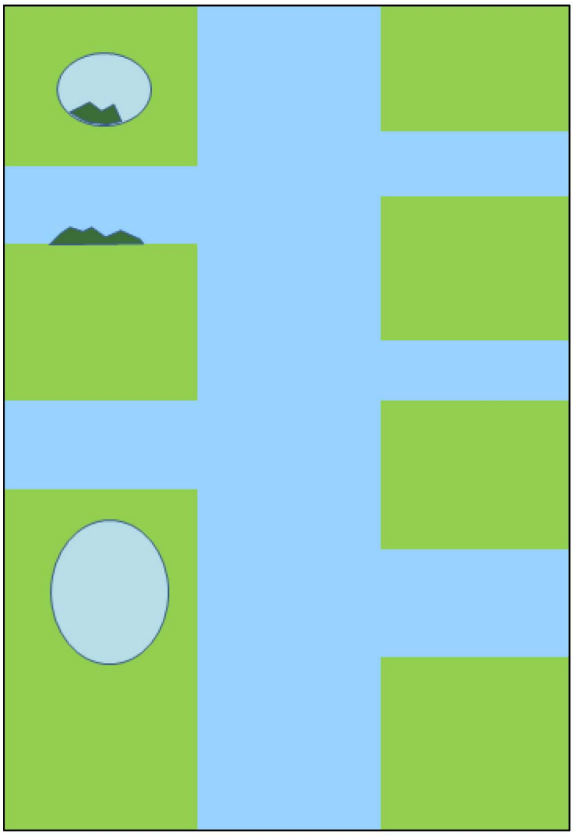
Preferred habitat: shallow (usually <50cm), nutrient rich water at the margins of ponds, lakes, canals and streams.

Key features: two types of leaves, submerged: flaccid highly dissected leaves in a whorl of 4 – 6 around stem, 2 – 5 cm long and emergent: rigid, with 6 – 18 divisions per leaf, 3 – 5 cm long on stems that can reach 30cm above the water surface. White flowers in leaf axils from June.

Reporting: please inform the Non Native Species Secretariat at www.nonnative species.org giving grid reference, extent of infestation, photograph and date of observation, and the Biological records centre at http://www.brc.ac.uk/contact.htm

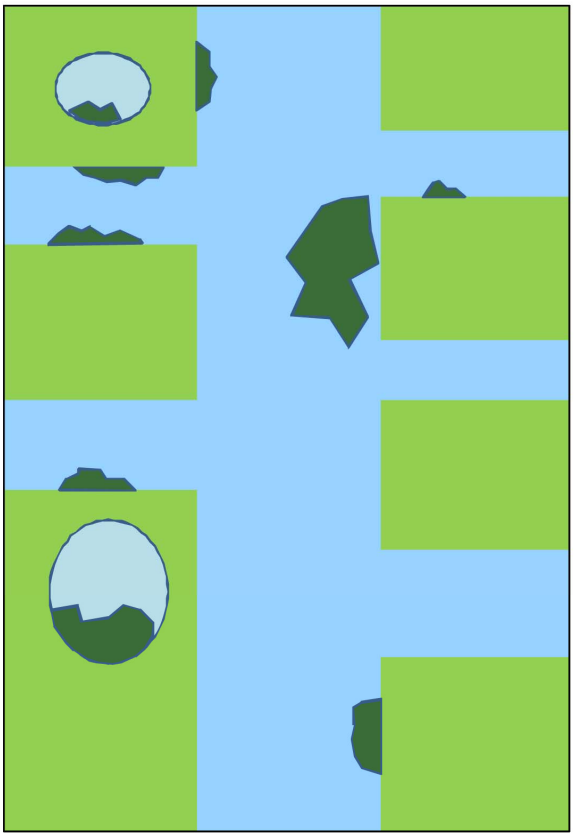
Further action: Assess the risk of the population you have observed using the risk assessment sheet provided in this pack.

5.2.2. Risk assessment



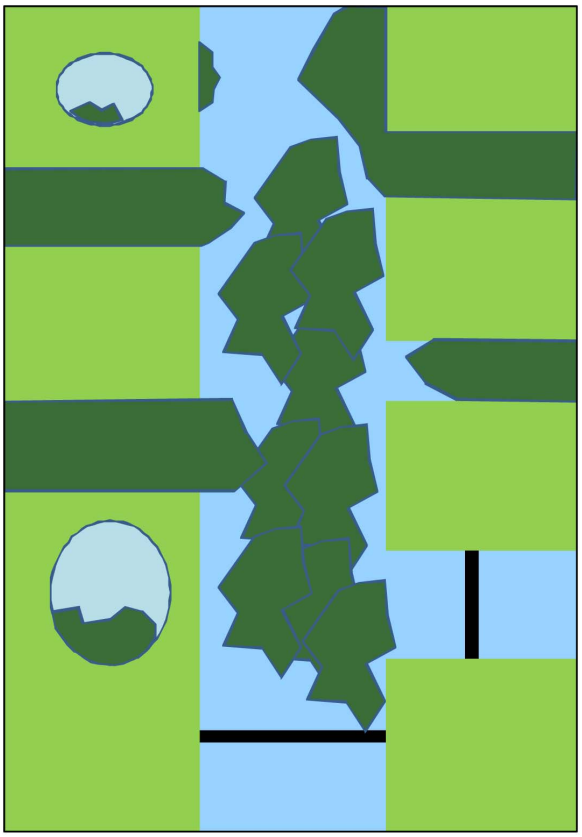
LOW RISK
The occurrence is limited to a few square metres at one location.
ACTION:

1. Inform appropriate manager, authority, national organisation
2. Arrange for removal by manual / hand picking.
3. Ensure no fragments get out of the side channel into the main river, or spread to nearby ponds.



MEDIUM RISK
There are several small patches of less than ten square meters spread within a short distance, but in different parts of the channel and in nearby ponds.
ACTION:

1. Inform appropriate manager, authority, national organisation
2. Arrange for removal by manual / hand picking.
3. Ensure no fragments spread form the small patches by isolating side channels or retaining patches in large channels by using floating barriers etc.
4. Monitor for regrowth at 4 week intervals

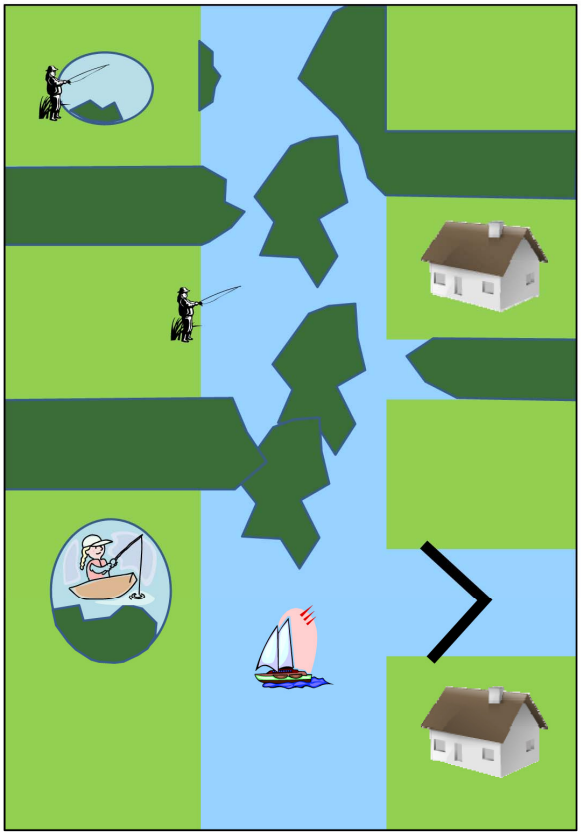


HIGH RISK – LOW PRIORITY

There are several large and small patches spread within a drainage system, spread over a large area, in different parts of the channel and in nearby ponds. The sections can be isolated and there are no critical watercourse functions at risk.

ACTION:

1. Inform appropriate manager, authority, national organisation
2. Arrange to isolate the section from water movement for as long as possible.
3. Arrange for treatment by manual / hand picking of small patches, mechanical removal of large patches followed by hand picking or by herbicide treatment
4. Ensure no fragments spread form the small patches by isolating side channels or retaining patches in large channels by using floating barriers etc.
5. Monitor for regrowth at 4 week intervals



HIGH RISK AND HIGH PRIORITY

There are several large and small patches spread within a drainage system, spread over a large area, in different parts of the channel and in nearby ponds. The sections cannot be isolated and there are critical watercourse functions at risk.

ACTION:

1. Inform appropriate manager, authority, national organisation
2. Arrange for removal by manual / hand picking and by any means possible. Try to contain each patch to prevent fragmentation and spread.
3. Protect pumps, sluices and other structures from becoming blocked by vegetation.
4. Ensure no fragments spread form the small patches by isolating side channels or retaining patches in large channels by using floating barriers etc.
5. Monitor for regrowth at 4 week intervals

5.3. Information for use in the Office

This information is produced as a separate document, both in printed form and in PDF form for access via the website http://www.q-bank.eu/Plants/ . Scroll for header: Control

Myriophyllum aquaticum (Vell.) Verdcourt

A guide to Identification, Risk Assessment and Management

© Jonathan Newman

Background and Ecology

What is it?

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. Similar species visually are *Cabomba caroliniana* (when submerged), *Myriophyllum robustum*, *Myriophyllum heterophyllum*, *Myriophyllum verticillatum*, *Hottonia palustris* and *Hippuris vulgaris*. 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* Rejmankova 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 1500 stems m^{-2} (Sytsma & Anderson, 1993a)

Where does it grow?

This species grows rooted in the mud of stagnant to slow flowing water, including, lakes, ponds, canals, and ditches. The species was introduced to natural watercourses in the Netherlands and the UK via discarded or deliberately planted aquarium plants (Brunel, 2009, Van Valkenburg & Pot, 2008).

In Europe naturalised populations comprise exclusively female plants, only vegetative propagation by detached (parts of) rhizomes or stems is possible

Identification

Morfological description:

Q-Bank (www.q-bank.eu) describes *M. aquaticum* as a creeping perennial with stoloniferous submerged stems with weakly trailing, glaucous emergent stems, rooting freely from lower nodes, glabrous. Submerged leaves in whorls of (4-) 5-6, without stipules, flaccid, usually much longer than internodes, oblanceolate in outline, rounded at apex, pectinate, with 25-30 linear pinnae up to 0.7 cm long, the lower leaves usually decaying rapidly. Emergent leaves glaucous and densely covered by translucent hemispherical glands, flaccid, usually much longer than internodes, in whorls of (4-) 5-6, erect near apex, spreading in lower parts, narrowly oblanceolate in outline, rounded at apex, pectinate, with (18-) 24-36 pinnae in the upper 80% (lower 5-7 mm of rachis naked), pinnae linear to subulate, 4.0-5.5 mm long, 0.3 mm wide, tips very apiculate, slightly in curved. Numerous hydathodes at base of leaves, 0.5-1 mm long.

Plants dioecious, male much less common than female throughout introduced range. In Europe exclusively female flowers (but in Germany there are also plants with male flowers in culture). Inflorescence is an indeterminate spike with white flowers singly borne in axils of upper emergent leaves, subtended by 2 bracteoles subulate, 1.2 - 1.5 mm long with (1-) 2 short teeth in the lower-third. Male flowers tetramerous, sessile at first, with pedicels to 4 mm long usually developing at anthesis; sepals 4, ovate-deltoid, very weakly denticulate, smooth; petals weakly hooded and keeled; stamens 8; styles 0. Female flowers tetramerous, on pedicel 0.2-0.4 mm long; sepals 4, white, deltoid, denticulate with one to several small teeth on each margin, smooth (first persisting, erect, withering at maturity); stamens 0; styles clavate, very short, stigmas subsessile, oblong, recurved, persistent.

.

Myriophyllum aquaticum: Distinguishing Features

General Appearance	Emergent Leaf Canopy	Flowers in leaf axils
Emergent Stem details	Leaflet Detail	Submerged leaf and Stem
Submerged red stems in spring	Submerged adventitious roots	Details of flower

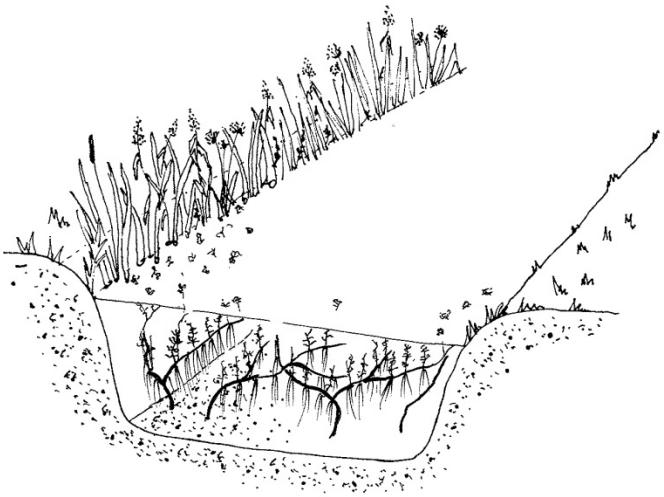
Not to be confused with: other *Myriophyllum* species

Myriophyllum heterophyllum	*Myriophyllum robustum*	*Myriophyllum verticillatum*
General Appearance	General Appearance	General Appearance
Heterophylly	Heterophylly	Produces turions (specialised Leaf Buds)
Emergent Leaf Detail	Emergent Leaf Detail	Emergent Leaf and Flower Detail

Not to be confused with: other species

Hippuris vulgaris	*Cabomba caroliniana*	*Hottonia palustris*
General Appearance	General Appearance	General Appearance
Heterophylly	Submerged Leaf detail	Submerged Leaf detail
Emergent Leaf Detail	Emergent Leaf Detail and flower	Emergent Leaf Detail
		Pictures Patrizio Ferrari and Andrea Moro

Life cycle

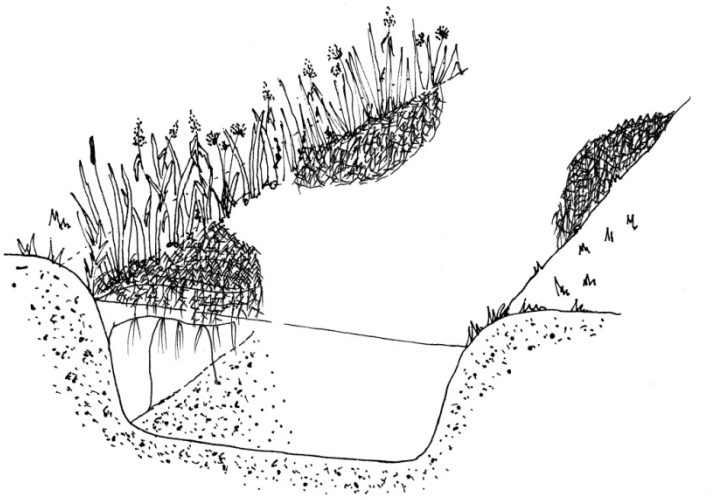


***Myriophyllum* in Spring**

In spring, when water temperatures rise above 10°C, adventitious roots develop at individual stems/stolons usually with two or three roots per node. Submerged shoots develop only after these roots have formed (see below). New submerged type shoots start to develop from nodes on over wintering stolons. The stems and leaves are red in colour due to pigmentation to absorb excessive UV light. There are no obvious signs of emergent material at this time, and emergent leaves start to appear once all signs of frost have past, usually in mid to late May.

Management Restrictions: There are restrictions on mowing, dredging re-profiling and cutting between the middle of March and the end of May, and in addition these activities are not recommended between June and the middle of July.

Action: Cover with opaque floating material, or use dyes in still water.

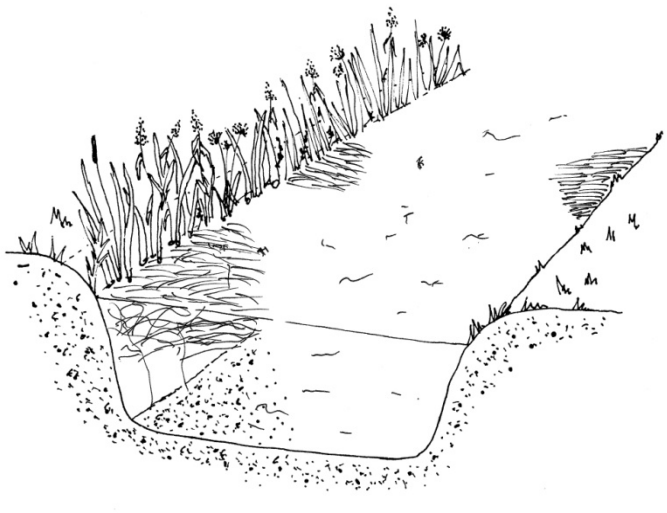


***Myriophyllum* in Summer**

By early June, the emergent leaves have formed and dense carpets of plant material grow close to the bank, with mounds appearing to spread outwards. The most active growth occurs at the apical tips of the plant, so the edges of the mat and the top surface of the mat tend to reach out into the water, followed by submersion of older stems which then grow more adventitious roots and more shoots which eventually become emergent, maintaining the apparent health of the mat.

Management restrictions: There are no restrictions on mowing, dredging re-profiling and cutting should only be undertaken after the middle of July. Please be aware that cutting has no long term effect on this species and may assist spread

Action: Spray with herbicide with the addition of an adjuvant, or remove mechanically to the bank and dispose of by burial or drying and burning.

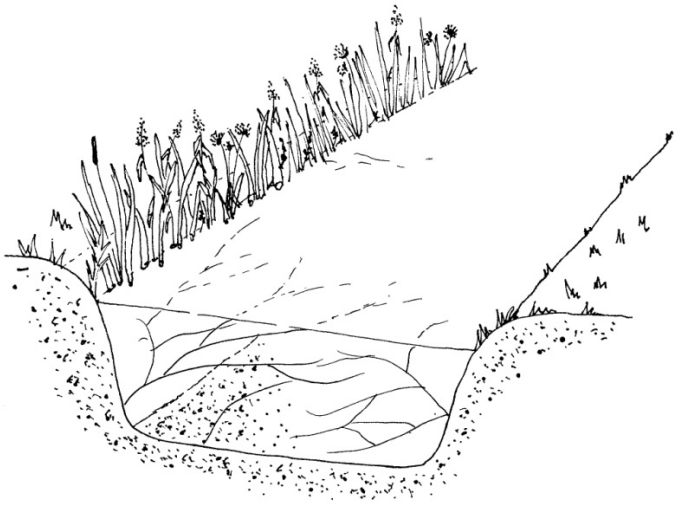


***Myriophyllum* in Autumn**

With shorter days and colder nights, the growth rate declines and mats start to fragment, causing viable propagules to be spread within and between systems. Fragmentation in autumn, when the plant still retains the capacity to regenerate rapidly, is considered to be the most important time for vegetative spread. The underside of the dense mat will become senescent and start to die back, leaving only the stolons intact under the water. These survive through autumn and over winter and form the basis for new growth in the next spring period, when the material above the inactive stolon has rotted away.

Management Restrictions: No applicable

Action: remove mechanically, being careful to restrict the release of fragments. Pull by hand in small infestations.



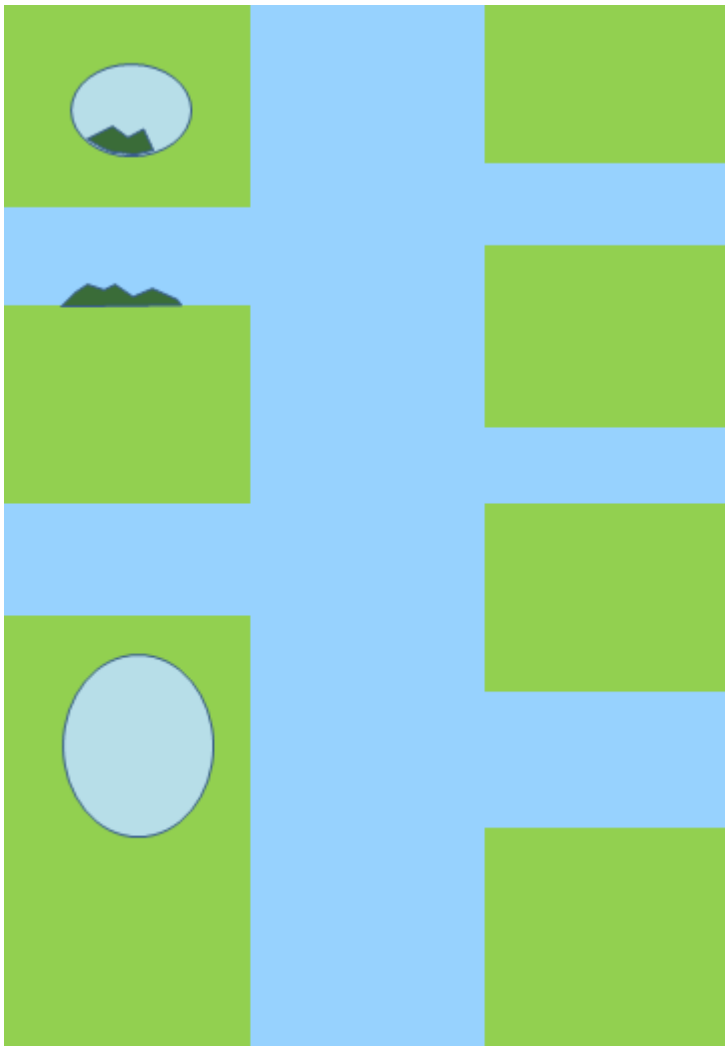
***Myriophyllum* in Winter**

After the first frost, emergent leaves collapse because of damage to cell membranes that cause irreversible loss of turgor. The plant overwinters as submerged stems and stolons. Fragments released in autumn overwinter on the sediment surface and grow again in spring.

Management Restrictions: There are restrictions on re-profiling the wetted channel and on weed cutting.

Action: There is little that can be done to control this species during winter apart from mechanical removal or dredging of the habitat. The best option would be to prepare for spring by covering with opaque floating material, or use dyes in still water.

Risk Assessment

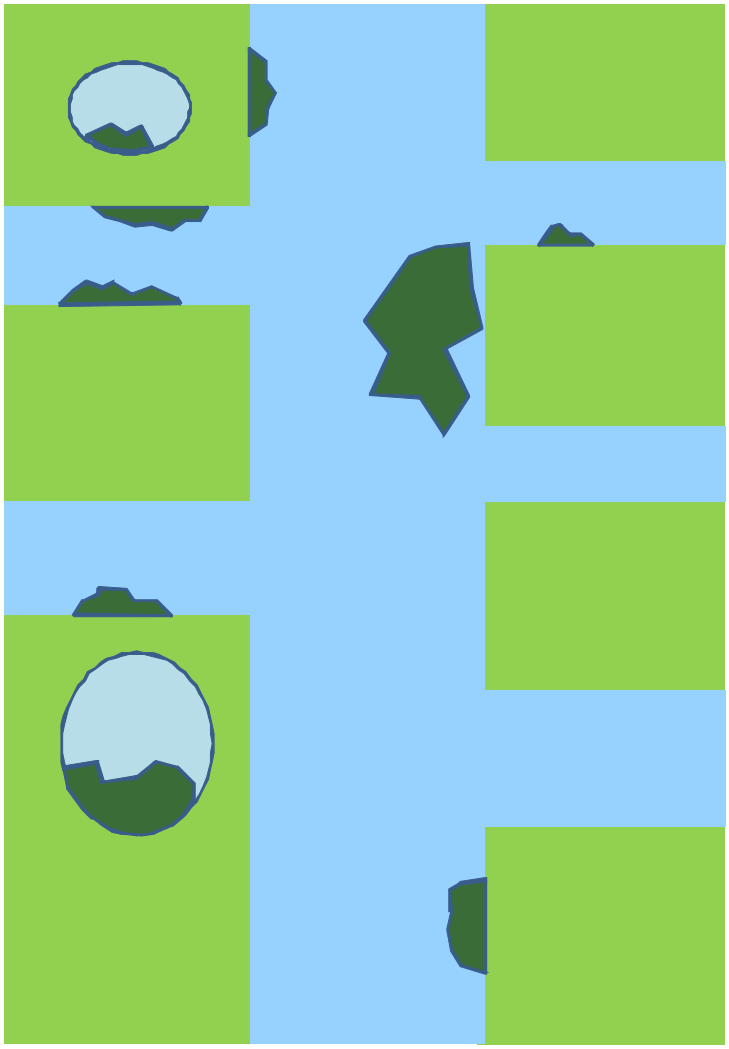


Low Risk High Priority

The occurrence of an invasive species in a new area should always be a case of low risk, because the isolated presence of a small amount of biomass does not present a risk to watercourse function or ecology. However, it should be a high priority to remove or isolate the infested area and to eradicate the species from the area as soon as possible.

In the situation described in the diagram to the left, eradication from the pond would be relatively easy. The patch in the channel should be isolated from the rest of the ditch network and removed as soon as possible. The isolation can take the form of a temporary dam, weighted net or other structure that does not represent a flood risk.

Isolation must take place as soon as possible after the species has been noted and should remain in place until after the plant has been eradicated, and probably for at least 1 year after no more plants have been observed in the area. This is to ensure that a re-occurrence does not occur, caused either by fragmentation of upstream patches, or by deliberate planting.

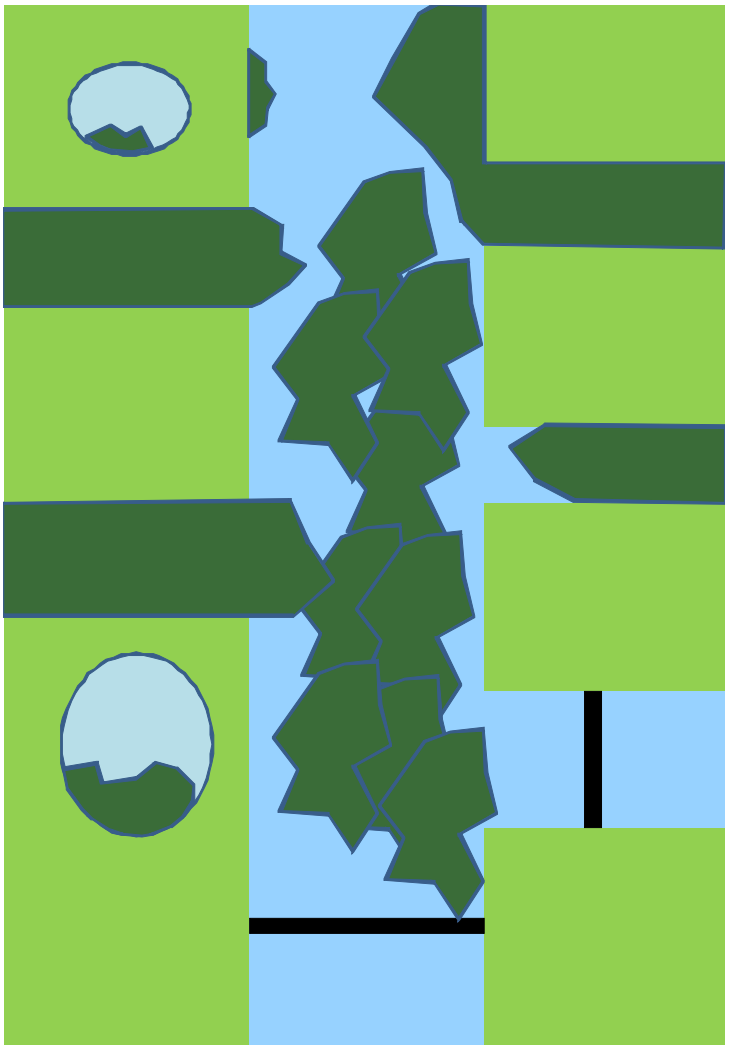


Medium Risk

There are several small patches of less than ten square meters spread within a short distance, but in different parts of the channel and in nearby ponds.

This situation represents a greater risk to watercourse function and to the ecosystem of the ponds. The infestation has probably been present for at least one year and has completed a life cycle. The ability to spread is demonstrated by the occurrence of more than one patch in different parts of the watercourse and action should be taken to remove as much as possible.

Sections of the watercourse that can be isolated must be isolated immediately. Removal of as much as possible of all the patches should be undertaken within 6 months of the first observation. A management plan for removal and eradication of the species could be used to prioritise resources for future observation and monitoring and immediate removal.



High Risk – Low Priority

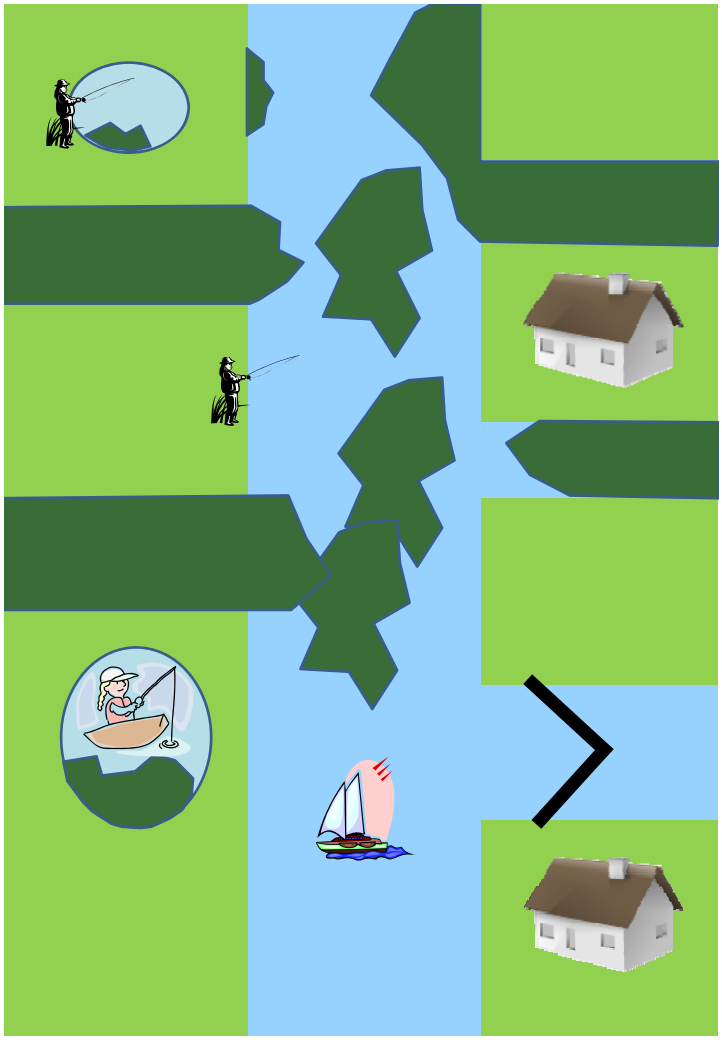
There are several large and small patches spread within a drainage system, spread over a large area, in different parts of the channel and in nearby ponds. The sections can be isolated and there are no critical watercourse functions at risk.

This situation represents perhaps an agricultural drainage network with no pumps, sluices, weirs or risk of flooding to populated areas. The infested section is either contained within an isolated section of watercourse, or can be easily contained.

The spread within this section can be easily monitored and a strategy for eradication or reduction can be implemented as and when resources are available.

Consideration should be given to the impact of the non-native species on the ecology of the drainage network, in terms of angling, bird and invertebrate populations.

Careful disposal of the biomass removed from the watercourse is required to prevent reinfestation of the cleared channel, or any channels along the transport route to the disposal site.



High Risk and High Priority

There are several large and small patches spread within a drainage system, spread over a large area, in different parts of the channel and in nearby ponds. The sections cannot be isolated and there are critical watercourse functions at risk.

This is a situation that should be rare, and results often from inappropriate management of small infestations, the presence of a very aggressive species, or as a result of favourable environmental conditions resulting in rapid spread within a system in less than one year.

Navigation functions are at risk, both from an inability to navigate and because movement of boats and ships will transport fragments of the species elsewhere in the network.

Fishing may be prevented by excessive growth of the target species.

Sluices, locks, weirs, pumps and other critical watercourse management structures may be at risk.

There is a serious risk of flooding of houses and commercial property as a result of the presence of this species.

Rapid and immediate management should take place to reduce the biomass of the target species. Sections, once cleared should be isolated to prevent further spread, and in the main channel a follow up maintenance operation should be undertaken, usually involving manual removal of fragments. Consideration should be given to educational notices and public awareness campaigns in the local are to encourage reporting of additional sites not normally monitored by the responsible authorities.

6. Bibliography

All the references consulted in the preparation of this document are listed below, but not all are cited in the text, some being background information or related information on physiological capacities of *M. aquaticum.*

Anawar, H., Garcia-Sanchez, A., Kul Alam, M. T., and Rahman, M. M. (2008), "Phytofiltration of Water Polluted with Arsenic and Heavy Metals," *International Journal of Environment and Pollution*, 33, 292-312.

Armellina, A. A. D., Bezic, C. R., and Gajardo, O. A. (1999), 'Submerged macrophyte control with herbivorous fish in irrigation channels of semiarid Argentina', *Hydrobiologia,* 415, 265-69.

Arts, G. H. P., Belgers, J. D. M., Hoekzema, C. H., and Thissen, J. T. N. M. (2008), "Sensitivity of Submersed Freshwater Macrophytes and Endpoints in Laboratory Toxicity Tests," *Environmental Pollution*, 153, 199-206.

Barreto, R., Charudattan, R., Pomella, A., and Hanada, R. (2000), "Biological Control of Neotropical Aquatic Weeds with Fungi," *Crop Protection*, 19, 697-703.

Bernhardt, E. A. and Duniway, J. M. (1984), 'Root and Stem Rot of Parrotfeather (*Myriophyllum brasiliense*) Caused by *Pythium-Carolinianum'*, *Plant Disease,* 68 (11), 999-1003.

Best, E. P. H., Woltman, H., and Jacobs, F. H. H. (1996), 'Sediment-related growth limitation of *Elodea nuttallii* as indicated by a fertilization experiment', *Freshwater Biology,* 36 (1), 33-44.

Bhadra, R., Spanggord, R., Wayment, D., Hughes, J., and Shanks, J. (1999), Characterization of Oxidation Products of Tnt Metabolism in Aquatic Phytoremediation Systems of *Myriophyllum aquaticum*, *Environmental science & technology*, 33, 3354-3361.

Bhadra, R., Wayment, D., Hughes, J., and Shanks, J. (1999), Confirmation of Conjugation Processes During TNT Metabolism by Axenic Plant Roots," *Environmental science & technology*, 33, 446-452.

Bianchini, I., Cunha-Santino, M. B., and Panhota, R. S. (2011), 'Oxygen uptake from aquatic macrophyte decomposition from Piraju Reservoir (Piraju, SP, Brazil)', *Brazilian Journal of Biology,* 71 (1), 27-35.

Borth, W., Fukuda, S., Hamasaki, R., Hu, J., and Almeida, R. (2006), "Detection, Characterisation and Transmission by *Macrosteles* Leafhoppers of Watercress Yellows Phytoplasma in Hawaii," *Annals of Applied Biology*, 149, 357-363.

Bromilow, R. H., de Carvalho, R. F., and Greenwood, R. (2007), 'Uptake and translocation of non-ionised pesticides in the emergent aquatic plant parrot feather *Myriophyllum aquaticum'*, *Pest Management Science,* 63 (8), 798-802.

Cardwell, A. J., Hawker, D. W., and Greenway, M. (2002), 'Metal accumulation in aquatic

macrophytes from southeast Queensland, Australia', *Chemosphere,* 48 (7), 653-63.

Carvalho, E. M. and Graca, M. A. S. (2007), 'A laboratory study on feeding plasticity of the shredder *Sericostoma vittatum* Rambur (Sericostomatidae)', *Hydrobiologia,* 575, 353-59.

Catarino, L. F., Ferreira, M. T., and Moreira, I. S. (1997), 'Preferences of grass carp for macrophytes in Iberian drainage channels', *Journal of Aquatic Plant Management,* 35, 79-83.

Chilton, E. W. and Magnelia, S. J. (2008), 'Use of an Incremental Triploid Grass Carp Stocking Strategy for Maintaining Vegetation Coverage in a Riverine Texas Reservoir', *Balancing Fisheries Management and Water Uses for Impounded River Systems,* 62, 543-55.

Cilliers, C. J. (1999a), 'Biological control of parrot's feather, *Myriophyllum aquaticum* (Vell.) Verdc. (Haloragaceae), in South Africa', *African Entomology Memoir No. 1. Biological control of weeds in South Africa (1990–1998) pp 113 - 118*

Cilliers, C. J. (1999b), *'Lysathia* n.sp (Coleoptera : Chrysomelidae), a host-specific beetle for the control of the aquatic weed *Myriophyllum aquaticum* (Haloragaceae) in South Africa', *Hydrobiologia,* 415, 271-76.

Collins, B. S., Sharitz, R. R., and Coughlin, D. P. (2005), 'Elemental composition of native wetland plants in constructed mesocosm treatment wetlands', *Bioresource Technology,* 96 (8), 937-48.

Cruz-Uribe, O. and Rorrer, G. L. (2006), 'Uptake and biotransformation of 2,4,6-trinitrotoluene (TNT) by microplantlet suspension culture of the marine red macroalga *Portieria hornemannii*', *Biotechnology and Bioengineering,* 93 (3), 401-12.

Dorn, P. B., Rodgers Jr, J. H., Gillespie Jr, W. B., Lizotte Jr, R. E., and Dunn, A. W. (1997), "The Effects of a C 12–13 Linear Alcohol Ethoxylate Surfactant on Periphyton, Macrophytes, Invertebrates and Fish in Stream Mesocosms," *Environmental toxicology and chemistry*, 16, 1634-1645.

Emerine, S.E., R. J. Richardson, S. L. True, A. M. West and R. L. Roten (2010), 'Greenhouse Response of Six Aquatic Invasive Weeds to Imazamox', *Journal of Aquatic Plant Management,* 48, 105-11.

Estebenet, A. L. (1995), 'Food and Feeding in *Pomacea canaliculata* (Gastropoda, Ampullariidae)', *Veliger,* 38 (4), 277-83.

Fang, L., Wong, P.K., Lin, L., Lan, C.Y., and Qiu, J.W. 2010. Impact of invasive apple snails in Hong Kong on wetland macrophytes, nutrients, phytoplankton and filamentous algae. Freshwater Biol. 55(6):1191-1204.

Ferreira, M. T., Catarino, L., and Moreira, I. (1998), 'Aquatic weed assemblages in an Iberian drainage channel system and related environmental factors', *Weed Research,* 38 (4), 291-300.

Gao, J., Garrison, A. W., Hoehamer, C., Mazur, C., and Wolfe, N. L. (2000), "Uptake and Phytotransformation of Organophosphorus Pesticides by Axenically Cultivated Aquatic Plants," *Journal of Agricultural and Food Chemistry*, 48, 6114-6120

Gettys, L. A., W. T. Haller, C. R. Mudge and T. J. Koschnick, (2008), 'Effect of temperature and

feeding preference on submerged plants by the island apple snail, *Pomacea insularum* (d'Orbigny, 1839) (Ampullariidae)', *Veliger,* 50 (3), 248-54.

Gray, C. J., Madsen, J., Wersal, R., and Getsinger, K. (2007), "Eurasian Watermilfoil and Parrotfeather Control Using Carfenfrazone-Ethyl," *Journal of Aquatic Plant Management*, 45, 43-46.

Gujarathi, N. P., Haney, B. J., and Linden, J. C. (2005), 'Phytoremediation potential of *Myriophyllum aquaticum* and *Pistia stratiotes* to modify antibiotic growth promoters, tetracycline, and oxytetracycline, in aqueous wastewater systems', *International Journal of Phytoremediation,* 7 (2), 99-112.

Hannink, N. K., Rosser, S. J., and Bruce, N. C. (2002), 'Phytoremediation of explosives', *Critical Reviews in Plant Sciences,* 21 (5), 511-38.

Hitchcock, D. R., McCutcheon, S. C., and Smith, M. C. (2003), 'Using rotifer population demographic parameters to assess impacts of the degradation products from trinitrotoluene phytoremediation', *Ecotoxicology and environmental safety,* 55 (2), 143-51.

Hoehamer, C. F., Wolfe, N. L., and Eriksson, K. E. L. (2006), 'Differences in the biotransformation of 2,4,6-trinitrotoluene (TNT) between wild and axenically grown isolates of *Myriophyllum aquaticum'*, *International Journal of Phytoremediation,* 8 (2), 107-15.

Hofstra, D. E., Champion, P. D., and Dugdale, T. M. (2006), 'Herbicide trials for the control of parrotsfeather', *Journal of Aquatic Plant Management,* 44, 13-18.

Höss, S., Ahlf, W., Fahnenstich, C., Gilberg, D., Hollert, H., Melbye, K., Meller, M., Hammers-Wirtz, M., Heininger, P. and Neumann-Hensel, H. (2010), 'Variability of sediment-contact tests in freshwater sediments with low-level anthropogenic contamination - Determination of toxicity thresholds', *Environmental Pollution,* 158 (9), 2999-3010.

Hughes, J. B., Shanks, J., Vanderford, M., Lauritzen, J., and Bhadra, R. (1996), Transformation of TNT by Aquatic Plants and Plant Tissue Cultures, *Environmental science & technology*, 31, 266-271.

Hussner, A. (2009), 'Growth and photosynthesis of four invasive aquatic plant species in Europe', *Weed Research,* 49 (5), 506-15.

Hussner, A. and Losch, R. (2005), 'Alien aquatic plants in a thermally abnormal river and their assembly to neophyte-dominated macrophyte stands (River Erft, Northrhine-Westphalia)', *Limnologica,* 35 (1-2), 18-30.

Hussner, A., Meyer, C., and Busch, J. (2009), 'The influence of water level and nutrient availability on growth and root system development of *Myriophyllum aquaticum'*, *Weed Research,* 49 (1), 73-80.

Hussner, A., Van de Weyer, K., Gross, E., and Hilt, S., (2010), 'Comments on increasing number and abundance of non-indigenous aquatic macrophyte species in Germany', *Weed Research,* 50 (6), 519-26.

Jacot Guillarmod, A. (1979) 'Water weeds in Southern Africa', *Aquatic Botany,* 6, 377-91.

Jeune, B. (1977), 'Activity of Generative Centers inside Leaf of "*Myriophyllum aquaticum* (Vell.) Verde. (*Myriophyllum brasiliense*-Camb.)', *Adansonia,* 16 (4), 493-507.

Kane, M. E. and Gilman, E. F. (1991), 'In vitro-Propagation and Bioassay Systems for Evaluating Growth-Regulator Effects on *Myriophyllum*-Species', *Journal of Aquatic Plant Management,* 29, 29-32.

Kane, M. E., Gilman, E. F., and Jenks, M. A. (1991), 'Regenerative Capacity of *Myriophyllum aquaticum* Tissues Cultured Invitro', *Journal of Aquatic Plant Management,* 29, 102-09.

Kane, M. E., Mcconnell, D. B., and Sheehan, T. J. (1988), 'In vitro Regeneration Studies on Ornamental Aquatic Plants – *Myriophyllum aquaticum and Limnophila indica'*, *Hortscience,* 23 (3), 780-80.

Kane, M.E., McConnell, D., Sheehan, T., and Dehgan, B. (1988) A Laboratory Exercise to Demonstrate Direct Shoot Organogenesis Using Stem Internodes of Parrot-Feather (*Myriophyllum aquaticum*)', *Hortscience,* 22 (5), 1060-60.

Knuteson, S. L., Whitwell, T., and Klaine, S. J. (2002), 'Influence of plant age and size on simazine toxicity and uptake', *Journal of Environmental Quality,* 31 (6), 2096-103.

Lacroix, C. and Bourque, L. (2011), 'Lobe-generating centres in the simple leaves of *Myriophyllum aquaticum*: evidence for KN1-like activity', *Annals of Botany,* 107 (4), 639-51.

Lacroix, C. R. and Jeune, B. (2009), 'A quantitative analysis of leaf growth parameters in *Myriophyllum aquaticum* (Haloragaceae)', *Botany-Botanique,* 87 (9), 807-20.

Larson, S. L., Jones, R. P., Escalon, L., and Parker, D. (1999), 'Classification of explosives transformation products in plant tissue', *Environmental Toxicology and Chemistry,* 18 (6), 1270-76.

Lizotte Jr, R. E., Dorn, P. B., Steinriede Jr, R. W., Wong, D. C. L., and Rodgers Jr, J. H. (2002), 'Ecological effects of an anionic C12-15 AE-3S alkylethoxysulfate surfactant in outdoor stream mesocosms', *Environmental Toxicology and Chemistry,* 21 (12), 2742-51.

Madsen, J. D. and Wersal, R. M. (2007), 'Comparison of imazapyr and imazamox for control of parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc.)', *Journal of Aquatic Plant Management,* 45, 132-36.

Madsen, J. D. and Wersal, R. M. (2011), 'Influences of water column nutrient loading on growth characteristics of the invasive aquatic macrophyte *Myriophyllum aquaticum* (Vell.) Verdc.', *Hydrobiologia,* 665 (1), 93-105.

Medina, V. F., Larson, S. L., Agwaramgbo, L., Perez, W., and Escalon, L. (2004), Treatment of Trinitrotoluene by Crude Plant Extracts," *Chemosphere*, 55, 725-732.

Medina, V. F., Larson, S. L., and McCutcheon, S. C. (2002), 'Evaluation of continuous flow-through phytoreactors for the treatment of TNT-contaminated water', *Environmental Progress,* 21 (1), 29-36.

Medina, V., Larson, S., Bergstedt, A., and McCutcheon, S. (2000), 'Phyto-removal of trinitrotoluene from water with batch kinetic studies', *Water Research,* 34 (10), 2713-22.

Monteiro, A. and Moreira, I. (1990), 'Chemical Control of Parrotfeather (*Myriophyllum aquaticum*)', *8th International Symposium on Aquatic Weeds*, 163-64.

Moreira, I., Ferreira, T., Monteiro, A., Catarino, L., and Vasconcelos, T. (1999), 'Aquatic weeds and their management in Portugal: insights and the international context', *Hydrobiologia,* 415, 229-34.

Morris, M. J., Wood, A. R., and den Breeyen, A. (1999), 'Plant pathogens and biological control of weeds in South Africa: a review of projects and progress during the last decade', *African Entomology Memoir No. 1. Biological control of weeds in South Africa (1990–1998)*, pp129-37.

Murakoshi, I., Matsumoto, M., Soeda, Y., and Saito, K. (1989), "Removal of Pollutants in Lakes by the Aquatic Plant *Myriophyllum brasiliense*," *EISEI KAGAKU.*, 35, 32.

Murakoshi, I., Matsumoto, M., Soeda, Y., and Saito, K. (1989), 'Removal of Nutrient Salts and Phenol by Aquatic Plant *Myriophyllum brasiliense'*, *Eisei Kagaku-Japanese Journal of Toxicology and Environmental Health,* 35 (2), 147-51.

Murphy, K. J., Dickinson, G., Thomaz, SM, Bini, LM, Dick, K., Greaves, K.,Kennedy, MP,Livingstone, S.,McFerran, H. and Milne, JM (2003), 'Aquatic plant communities and predictors of diversity in a sub-tropical river floodplain: the upper Rio Parana, Brazil', *Aquatic Botany,* 77 (4), 257-76.

Nimptsch, J. and Pflugmacher, S. (2005), 'Substrate specificities of cytosolic glutathione-S transferases in five different species of the aquatic macrophyte *Myriophyllum'*, *Journal of Applied Botany and Food Quality-Angewandte Botanik,* 79 (2), 94-99.

Nuttall, P. M. (1985), 'Uptake of Phosphorus and Nitrogen by *Myriophyllum aquaticum* (Velloza) Verd Growing in a Waste-Water Treatment System', *Australian Journal of Marine and Freshwater Research,* 36 (4), 493-507.

Oberholzer, I. G., Mafokoane, D. L. and Hill, M. P., (2007), 'The biology and laboratory host range of the weevil, *Listronotus marginicollis* (Hustache) (Coleoptera : Curulionidae), a natural enemy of the invasive aquatic weed, parrot's feather, *Myriophyllum aquaticum* (Velloso) Verde (Haloragaceae)', *African Entomology,* 15 (2), 385-90.

Orr, B. K. and Resh, V. H. (1992), 'Influence of *Myriophyllum aquaticum* Cover on Anopheles Mosquito Abundance, Oviposition, and Larval Microhabitat', *Oecologia,* 90 (4), 474-82.

Parker, J. D., Caudill, C. C., and Hay, M. E. (2007), 'Beaver herbivory on aquatic plants', *Oecologia,* 151 (4), 616-25.

Pavlostathis, S. G. and Jackson, G. H. (2002), 'Biotransformation of 2,4,6-trinitrotoluene in a continuous-flow *Anabaena* sp system', *Water Research,* 36 (7), 1699-706.

Peltre, MC, Dutartre, A., Barbe, J., Haury, J., Muller, S. and Ollivier, M. (2002), 'Aquatic plant proliferations in France: biological and ecological features of the main species and favourable environments. I. Synthesis of a bibliographic survey.', *Bulletin Francais De La Peche Et De La Pisciculture,* (365-66), 237-58.

Peterson, M. S., Fitzpatrick, J. F., and VanderKooy, S. J. (1996), 'Distribution and habitat use by dwarf crayfishes (Decapoda: Cambaridae: Cambarellus)', *Wetlands,* 16 (4), 594-98.

Pilon-Smits, E. A. H., De Souza, MP, Hong, G., Amini, A., Bravo, RC, Payabyab, ST and Terry, N. (1999), 'Selenium volatilization and accumulation by twenty aquatic plant

species', *Journal of Environmental Quality,* 28 (3), 1011-18.

Pine, R. T. and Anderson, L. W. J. (1991), 'Plant Preferences of Triploid Grass Carp', *Journal of Aquatic Plant Management,* 29, 80-82.

Planojevic, I Teodorovi , I., Bartova, K., Tubi , A., Jurca, T., Kopf, W., Machat, J., Blaha, L. and Kovaevi , R. (2011), 'Wastewater canal Vojlovica, industrial complex Pancevo, Serbia - preliminary ecotoxicological assessment of contaminated sediment', *Journal of the Serbian Chemical Society,* 76 (3), 459-78.

Podlipna, R., Nepovim, A., Soudek, P., Vágner, M., and Van k, T. (2007), "Soapwort Oxidoreductase Is Involved in Trinitrotoluene Detoxification," *Biologia Plantarum*, 51, 367-371.

Polomski, R.F., Taylor, M.D., Bielenberg, D.G., Bridges, W.C., Klaine, S.J. and Whitwell, T. (2009), 'Nitrogen and Phosphorus Remediation by Three Floating Aquatic Macrophytes in Greenhouse-Based Laboratory-Scale Subsurface Constructed Wetlands', *Water Air and Soil Pollution,* 197 (1-4), 223-32.

Qian, J. H., Zayed, A., Zhu, Y. L., Mei, Y., and Terry, N. (1999), 'Phytoaccumulation of trace elements by wetland plants: III. Uptake and accumulation of ten trace elements by twelve plant species', *Journal of Environmental Quality,* 28 (5), 1448-55.

Qin, Song Yan, Qi Xing Zhou, Jin Xi Zhou and Ya Qi Duan (2011), 'Algae Growth Inhibition by the Combination of Emergent Plant and Submerged macrophytes', *Environmental Biotechnology and Materials Engineering, Pts 1-3,* 183-185, 1349-53.

Qiu, J. W. and Kwong, K. L. (2009), 'Effects of macrophytes on feeding and life-history traits of the invasive apple snail Pomacea canaliculata', *Freshwater Biology,* 54 (8), 1720-30.

Qiu, J. W., Chan, M. T., Kwong, K. L., and Sun, J. (2011), 'Consumption, Survival and Growth in the Invasive Freshwater Snail *Pomacea Canaliculata*: Does Food Freshness Matter?', *Journal of Molluscan Studies,* 77, 189-95.

Rejmankova, E. (1992), 'Ecology of Creeping Macrophytes with Special Reference to *Ludwigia peploides* (Hbk) Raven', *Aquatic Botany,* 43 (3), 283-99.

Richardson, R. J., Roten, R., West, A., True, S., and Gardner, A. (2008), 'Response of Selected Aquatic Invasive Weeds to Flumioxazin and Carfentrazone-ethyl', *Journal of Aquatic Plant Management,* 46, 154-58.

Riis, T., Biggs, B. J. F., and Flanagan, M. (2003), 'Seasonal changes in macrophyte biomass in South Island Lowland Streams, New Zealand', *New Zealand Journal of Marine and Freshwater Research,* 37 (2), 381-88.

Riis, T., Biggs, B. J. F., and Flanagan, M. (2004), 'Colonisation and temporal dynamics of macrophytes in artificial stream channels with contrasting flow regimes', *Archiv Fur Hydrobiologie,* 159 (1), 77-95.

Rodríguez, C. T. C., Amaya-Chávez, A., Roa-Morales, G., Barrera-Díaz, C. E., and Ureña-Núñez, F. (2010), "An Integrated Electrocoagulation-Phytoremediation Process for the Treatment of Mixed Industrial Wastewater," *International Journal of Phytoremediation*, 12, 772-784.

Rosa, C.S., Antunes, R.D., Pitelli, R.A. and Pitelli, R.L.C.M. (2009), 'Comparative Evaluation of

Water Losses by Evapotranspiration in Mesocosms Colonized by Different Aquatic Weeds', *Planta Daninha,* 27 (3), 441-45.

Sabbatini, M. R., Murphy, K. J., and Irigoyen, J. H. (1998), 'Vegetation-environment relationships in irrigation channel systems of southern Argentina', *Aquatic Botany,* 60 (2), 119-33.

Saito, K., Matsumoto, M., Sekine, T., Murakoshi, I., Morisaki, N. and Iwasaki, S.1989), 'Inhibitory Substances from *Myriophyllum brasiliense* on Growth of Blue-Green-Algae', *Journal of Natural Products,* 52 (6), 1221-26.

Salvucci, M. E. and Bowes, G. (1982), 'Photosynthetic and Photorespiratory Responses of the Aerial and Submerged Leaves of *Myriophyllum brasiliense'*, *Aquatic Botany,* 13 (2), 147-64.

Schoenmuth, B. W. and Pestemer, W. (2004), 'Dendroremediation of trinitrotoluene (TNT) - Part 1: Literature overview and research concept', *Environmental Science and Pollution Research,* 11 (4), 273-78.

Solarz, S. L. and Newman, R. M. (2001), 'Variation in hostplant preference and performance by the milfoil weevil, *Euhrychiopsis lecontei* Dietz, exposed to native and exotic watermilfoils', *Oecologia,* 126 (1), 66-75.

Stesevic, D., Feiler, U., Sundic, D., Mijovic, S., Erdinger, L., Seiler, T.B., Heininger, P. and Hollert, H. (2007), 'Application of a new sediment contact test with *Myriophyllum aquaticum* and of the aquatic *Lemna* test to assess the sediment quality of Lake Skadar', *Journal of Soils and Sediments,* 7 (5), 342-49.

Subramanian, M., Oliver, D. J., and Shanks, J. V. (2006), 'TNT phytotransformation pathway characteristics in *Arabidopsis*: Role of aromatic hydroxylamines', *Biotechnology Progress,* 22 (1), 208-16.

Sytsma, M. D. and Anderson, L. W. J. (1993a), 'Transpiration by an Emergent Macrophyte - Source of Water and Implications for Nutrient Supply', *Hydrobiologia,* 271 (2), 97-108.

Sytsma, M. D. and Anderson, L. W. J. (1993b), 'Biomass, Nitrogen, and Phosphorus Allocation in Parrotfeather (*Myriophyllum aquaticum*)', *Journal of Aquatic Plant Management,* 31, 244-48.

Sytsma, M. D. and Anderson, L. W. J. (1993c), 'Criteria for Assessing Nitrogen and Phosphorus Deficiency in *Myriophyllum aquaticum'*, *Journal of Freshwater Ecology,* 8 (2), 155-63.

Sytsma, M. D. and Anderson, L. W. J. (1993d), 'Nutrient Limitation in *Myriophyllum aquaticum'*, *Journal of Freshwater Ecology,* 8 (2), 165-76.

Tur, N. M., Robles, S. S. T., and Peter, G. (2009), 'About the Typification of *Myriophyllum aquaticum* (Haloragaceae)', *Novon,* 19 (1), 127-29.

Turgut, C (2006), 'The growth stability and sensitivity of parrot feather to a reference toxicant (3,5-dichlorphenol) throughout a 1-year period', *Fresenius Environmental Bulletin,* 15 (5), 462-64.

Turgut, C. (2005), 'Uptake and modeling of pesticides by roots and shoots of parrotfeather (*Myriophyllum aquaticum*)', *Environmental Science and Pollution Research,* 12 (6),

342-46.

Turgut, C. (2007), 'The impact of pesticides toward parrot feather when applied at the predicted environmental concentration', *Chemosphere,* 66 (3), 469-73.

Turgut, C. and Fomin, A. (2002), 'Sensitivity of the rooted macrophyte *Myriophyllum aquaticum* (Vell.) Verdcourt to seventeen pesticides determined on the basis of EC50', *Bulletin of Environmental Contamination and Toxicology,* 69 (4), 601-08.

Turgut, C. and Fomin, A. (2001), 'Establishment of standardized growth conditions of *Myriophyllum aquaticum* (Vell.) verdcourt for testing sediment toxicity', *Journal of Applied Botany-Angewandte Botanik,* 75 (1-2), 80-84.

Turgut, C. and Fomin, A. (2002), 'The ability of *Myriophyllum aquaticum* (Vell.) verdcourt in the uptake and the translocation of pesticides via roots with a view to using the plants in sediment toxicity testing', *Journal of Applied Botany-Angewandte Botanik,* 76 (1-2), 62-65.

Vanderford, M., Shanks, J. V., and Hughes, J. B. (1997), 'Phytotransformation of trinitrotoluene (TNT) and distribution of metabolic products in *Myriophyllum aquaticum*', *Biotechnology Letters,* 19 (3), 277-80.

Vanek, T., Gerth, A., Vakrikova, Z., Podlipna, R., and Soudek, P. (2007), "Phytoremediation of Explosives," *Advanced Science and Technology for Biological Decontamination of Sites Affected by Chemical and Radiological Nuclear Agents*, 209-225.

Vila, M., S. Pascal-Lorber, E. Rathahao, L. Debrauwer, C. Canlet, and F. Laurent (2005), 'Metabolism of [C-14]-2,4,6-trinitrotoluene in tobacco cell suspension cultures', *Environmental Science & Technology,* 39 (2), 663-72.

Wang, C. Y. and Hughes, J. B. (2001), 'Phytotransformation of TNT in *Myriophyllum aquaticum:* A complex pathway through hydroxylamino intermediates', *Phytoremediation, Wetlands, and Sediments,* 6 (5), 85-93.

Wang, C., Lyon, D. Y., Hughes, J. B., and Bennett, G. N. (2003), 'Role of hydroxylamine intermediates in the phytotransformation of 2,4,6-trinitrotoluene by *Myriophyllum aquaticum'*, *Environmental Science & Technology,* 37 (16), 3595-600.

Wen, L. and Recknagel, F. (2002), 'In situ removal of dissolved phosphorus in irrigation drainage water by planted floats: preliminary results from growth chamber experiment', *Agriculture Ecosystems & Environment,* 90 (1), 9-15.

Wersal, R. M., Cheshier, J.C., Madsen, J.D. and Gerard P.D. (2011) . 'Phenology, Starch Allocation, and Environmental Effects on *Myriophyllum aquaticum'*, *Aquatic Botany,* In Press, Accepted Manuscript.

Wilson, P. C., Whitwell, T., and Klaine, S. J. (2001), 'Metalaxyl toxicity, uptake, and distribution in several ornamental plant species', *Journal of Environmental Quality,* 30 (2), 411-17.

Wilson, P. C., Whitwell, T., and Klaine, S. J. (2001), 'Simazine toxicity and uptake by parrotfeather', *Journal of Aquatic Plant Management,* 39, 112-17.

Wong, P.K.,Yan Liang, Nga Ying Liu and Jian-Wen Qiu (2010b), 'Palatability of macrophytes to the invasive freshwater snail *Pomacea canaliculata*: differential effects of multiple plant traits', *Freshwater Biology,* 55 (10), 2023-31.

Xie, D., Yu, D., Yu, L. F., and Liu, C. H. (2010), "Asexual Propagations of Introduced Exotic Macrophytes *Elodea nuttallii, Myriophyllum aquaticum, and M. propinquum* Are Improved by Nutrient-Rich Sediments in China," *Hydrobiologia*, 1-11.

Yu, D., et al. (2002), 'Taxonomic revision of the genus *Myriophyllum* (haloragaceae) in China', *Rhodora,* 104 (920), 396-421.