Title:	Control of aquatic weeds in nurseries and water storage systems: a literature review
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Section One:
Practical Section for Growers

1.1 Objectives and Background.

The main environmental factors regulating aquatic weed growth are the supply of light and nutrients. Both of these resources are likely to be found in great abundance in aquatic plant growth tanks and in water storage reservoirs, thus providing the potential for rapid and persistent aquatic weed growth.

The growth of floating-leaved weeds in aquatic nurseries may inhibit the growth of cultivated plants by forming dense mats, obscuring light and causing de-oxygenation of the water. They also compete for nutrients and may harbour pests and diseases. Also, excessive growth of aquatic weeds in water storage systems can reduce both the quality and quantity of water available to growers. Persistent weed growth can also block pumps and filters.

The first stage of this project was implemented to assess the scale and type of aquatic weed problem faced by UK nursery growers. This took the form of a survey questionnaire being sent to all HDC growers. The second stage of the project used the collated responses from the survey as the basis for a review of the techniques suitable for the control of aquatic weed species identified as being problems in aquatic plant nurseries.

The overall aim of the project is to review techniques of aquatic weed control suitable for use in aquatic plant nurseries and, hence, to promote their correct implementation by growers. The project highlights situations where effective management practices are lacking and where research into new techniques would be advantageous.

1.2 Summary of Survey Results.

To assess the scale of the aquatic weed problem experienced in the Horticultural Industry, and to identify the main problem species, an industry survey was undertaken with 537 questionnaires circulated to HDC growers.

Of the 202 returned questionnaires, 28 growers (13.9% of those who replied) experienced problems with the growth of aquatic weeds in their nursery. The most common aquatic weed in water storage systems is *Cladophora* spp.(Blanket Weed). This commonly interferes with the irrigation and water distribution system by clogging filters, pumps and spray nozzles. It also aids the spread of diseases and produces foul odours on decomposition. *Lemna* spp. (Duckweeds) are the second most common aquatic weed in nursery water storage systems. Others include: *Spirogyra* spp. and other unidentified algae, *Elodea canadensis* (Canadian Pondweed), *Myriophyllum* spp. (Water-milfoils), *Potamogeton natans* (Broadleaved Pondweed) and Reeds.

In nurseries where aquatic weeds were reported in plant growth tanks, *Cladophora* (Blanket Weed) was again the most common species (100% of reported cases). Other aquatic weeds included *Lemna* spp.(Duckweeds), *Azolla filiculoides* (Water Fern) and *Elodea canadensis* (Canadian Pondweed).

A literature search was undertaken to identify work relevant to the control of aquatic plants in nursery water storage systems and aquatic plant growth tanks. Searches were made on Current Contents Diskette and BIDS (Bath Information and Data Systems) at the University of Reading and Long Ashton Research Station (University of Bristol). Of over 1200 references found on the control of aquatic weeds many were applicable either to the control of exotic species of weeds or biological control in tropical locations. Those references appropriate to the control of weeds in UK conditions were much more limited in number. Only one reference was directly relevant to the control of aquatic plants in the horticultural industry (Control of Submersed Weeds by Grass Carp in Waterlily Production Ponds, Santha, Martyn, Neill & Strawn, 1994).

All techniques suitable for the control of those aquatic weed species highlighted by the survey are reviewed in the following sections.

1.3 Weed Control Techniques: Action Points for Growers.

1.3.1 Control of Algae with Barley Straw.

•The application of barley straw to water storage reservoirs, lakes and growth tanks offers an environmentally friendly and cost effective method of algal control.

•Straw is best held in nets, cages or bags and should be loose enough for water to circulate through it easily.

•The straw should be supported by floats so that it does not sink more than 1 metre below the water surface.

•Applications of straw should be spread at equidistant intervals over the surface to insure an even spread of anti-algal activity.(see table 1)

•It is usual to apply straw at rates between 15 and 25 g/m^2 but rates of up to 50 g/m^2 should be used in heavily infested or muddy waters.

•Straw should be applied twice each year, preferably in early spring before algal growth starts, and again in autumn.

•Table 1 should be used to calculate the correct application rate.

Table 1.
Steps in Calculating the appropriate straw application rate to control algae in water.

	Decision Step	Calculated Example
1.	Estimate the surface area of the lake/tank.	1.5 ha (15,000 m^2)
2.	Decide on the dose rate of straw. 15 g/m^2 in water with little algae or mud to 25-50 g/m^2 for heavily infested and/or muddy water.	25 g/m^2
3.	Multiply the water area (in m^2) by the quantity of straw required per m^2 to obtain total quantity of straw required.	15,000x25 = 375,000 375,000 ÷ 1000 = 375kg
4.	To calculate the number of bales to be purchased divide the total weight of straw by the weight of bales. (Small rectangular bales normally weigh about 20kg, weights should be checked for other sizes of bales).	375kg ÷ 20kg = 19 bales
5.	Decide on the weight of straw to be placed in each net. (Bear in mind that less straw in more nets will aid the distribution of the chemical). Nets should normally contain between 1kg (in small waterbodies) and 40kg (in large reservoirs).	25kg
6.	Calculate the number of nets required. Divide the total quantity of straw (3) by the weight in each net (5).	375kg ÷25kg = 15 nets
7.	Calculate the area of water which will be treated by each net at the dose rate decided in (2) above.	25kg ÷25 g/m^2 =1000 m^2
8.	Calculate the diameter of a circle with an area of the size calculated in (7) above using πr^2 to calculate radius (r) The diameter is r x 2	$\pi r^2 = 1000$ $r = \sqrt{1000 \div 3.142}$ r =17.85m r x 2 = 35.7m
9.	Decide on the most appropriate placement of the nets of straw so that each one is 35m from its neighbour and 18m from the bank.	Usually a regular square grid pattern with centres at 35m.

1.3.2 Control of Algae with Chemicals.

•If quick control of an algal infestation is necessary, the use of chemical herbicides may be considered.

•Herbicides are often useful as a first step and can be followed by long term algal management using, for example, barley straw to prevent further growth of algae.

•***Professional herbicides that kill algae are non selective and will kill other desirable vegetation.*** They are not suitable for use in aquatic plant production ponds or water storage reservoirs or tanks that are being used for irrigation.

•***Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.***

•**Turbutryn** is suitable for treating *Cladophora glomerata, Enteromorpha intestinalis, Rhizoclonium* species, *Spirogyra* species (all of which are susceptible). *Vaucheria dichotoma, Enteromorpha intestinalis* and *Vaucheria sessilis* are moderately resistant.

•Turbutryn can be supplied in a granular formulation containing 1% active ingredient and should be spread evenly over the water surface. Susceptible algae should be treated with 5 kg per 1000 m^3 of water and moderately resistant algae with 10 kg per 1000 m^3.

•Turbutryn should be applied early in the growing season and is only effective in static water or where flow is less than 1 metre in 3 minutes (effectively static).

•Turbutryn should not be applied to more than one quarter of the whole water body at any one time. The remaining sections should be left for a minimum of 14 days before they in turn are treated over 6-8 week period.

•Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted.

•**Diquat** is suitable for treating *Cladophora glomerata*, *Enteromorpha intestinalis* and *Spirogira* species which are all moderately susceptible to its application.

•Diquat, supplied as a liquid formulation containing 20% active ingredient, can be applied with or without dilution by surface spray or subsurface injection (by trailing a nozzle below the water surface) at 5 litres per 1000 m^3 of water.

•Diquat should be applied in the spring when rapid algal growth occurs but may only be used in static waters or where the flow is less than 90 metres per hour. Not more than 25% of the water body should be treated at any one time.

•Diquat is rapidly absorbed by plants and mud and, therefore, should not be applied to waters containing large amounts of suspended sediment.

•Product guidelines should always be followed. Growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted.

1.3.3 Control of Duckweeds (*Lemna* species).

•Duckweeds(*Lemna minuta, Lemna minor, Lemna gibba* and *Lemna trisulca*) are small free-floating plants which often form dense mats on the surface of still and slow flowing eutrophic (nutrient rich) waters. Duckweeds grow rapidly and quickly colonise and re-infest suitable waters. Often it is necessary to remove the plant continuously to maintain relatively clear waters. The best control options are:-

•Remove as much weed as possible by mechanical means ensuring that any remaining weed forms a layer only one leaf thick.

•Spray any remaining weed with glyphosate. Spot treat any re-infestation.

•Product guidelines should always be followed, growers should pay particular attention to the list of susceptible species to avoid any unwanted damage to crop plants.

•Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.

•Increase the population of other floating leaved aquatic plants in the water to compete against the *Lemna* spp. and reduce the intensity of future infestations.

•Increase the disturbance of the water surface with fountains or by increasing the flow rate with a pump.

•Complete control is often not possible so careful monitoring of the water body is required to detect regrowth and allow remedial action before the problem reaches nuisance proportions.

1.3.4 Control of Water Fern (*Azolla filiculoides*).

•*Azolla filiculoides* is a floating fern which reproduces both vegetatively and sexually. Germinating spores can give rise to dense infestations and are the main method of overwintering. The best control options are:-

•Physically remove as much of the plant as possible early in the season (e.g. May/June) before sporulation has occurred.

•Treat any remaining plants with glyphosate or diquat.

•Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

•Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.

•Removing *Azolla filiculoides* after sporulation will not prevent re-infestation.

1.3.5 Control of Canadian Pondweed (*Elodea canadensis*) and Nutall's Pondweed (*Elodea nutallii*).

•*Elodea canadensis,* a native of North and South America, is a pest in many regions of the world. It grows from stolons and has vertical, narrow, sparsely branched stems with leaves in whorls of three. It does not reproduce by seed in the U.K. and relies on vegetative reproduction for its spread.

•Where *Elodea canadensis* occurs in mixed stands it should be controlled by mechanically removing as much of the plant material as possible followed by spot treatments with dichlobanil or diquat to the remaining infestations.

•In mono-specific stands of *Elodea canadensis* in still waters, turbutryn should be applied after thorough mechanical removal.

•If mechanical removal is not possible the following herbicides can be used; dichlobanil, turbutryn or diquat depending on conditions. Be sure to read the guidelines for use and application to decide on the most appropriate chemical.

•Approved products containing dichlobenil are granular formulations and should generally be used in shallow or small water bodies. The slow release formulation can give some degree of localised control on larger water bodies if used carefully. Terbutryn comes as a granule formulation, it will kill all submerged vegetation and can only be used in still water. Diquat is available as a liquid, which can be applied as a spray to the water surface or directly by subsurface injection, or a viscous gel which can be applied in flowing water or used for more localised control in still or slow flowing water bodies. Diquat is not effective in muddy water.

•All these herbicides are non-specific and cannot be used in aquatic plant production tanks except when weeds have excluded the desired species. Application of any of these herbicides to water storage reservoirs may result in damage to irrigated plants. They should only be applied when the reservoir can be removed from use for a period long enough to allow dissipation of residues (see manufacturers guidelines).

•Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

•Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.

•The same measures apply to the control of *Elodea nutallii* (Nutall's Pondweed).

1.3.6 Control of Spiked Water-milfoil (*Myriophyllum spicatum*).

•*Myriophyllum spicatum* (Spiked Water-Milfoil) is characterised by groups of four feathery leaves arranged around a circular reddish coloured stem. This submerged plant commonly grows in lakes, ponds and ditches often in dense mono-specific stands, but is not found in faster flowing water.

•Where *Myriophyllum spicatum* occurs in mixed stands it should be controlled by removing as much of the plant material as possible using mechanical methods followed by spot treatments of remaining plants with dichlobenil or diquat alginate. (Diquat alginate can also be used in flowing water).

•In mono-specific stands of *Myriophyllum spicatum* in still waters terbutryn should be applied after thorough mechanical weed removal.

•If physical removal is not possible the following herbicides can be used; dichlobenil, diquat, diquat alginate or terbutryn depending on conditions. Be sure to read the guidelines for use and application to decide on the most appropriate chemical.

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•All these herbicides are non-specific and cannot be used in aquatic plant production tanks except when weeds have excluded the desired species. Application of any of these herbicides to water storage reservoirs may result in damage to irrigated plants. They should only be applied when the reservoir can be removed from use for a period long enough to allow dissipation of residues (see manufacturers guidelines).

•Chemical control will give effective eradication of the plant for between 2 and 3 years. Regular inspections should be made and any re-infestation given spot treatments to prevent extensive regrowth.

•Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

•Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.

1.3.7 Control of Broadleaved Pondweed (*Potamogeton natans*).

•*Potamogeton natans* is commonly found in static or slow flowing waters up to 1.5 metres in depth. The leaves of this plant can form a dense surface cover over the water which tends to interfere with recreational activities, such as boating or fishing, and can impede flow.

•Although cutting provides only short-term control of *Potamogeton natans*, it is probably the only suitable method for use in aquatic plant tanks. Cutting as late in the season as possible will reduce regrowth.

•Dredging to remove the plant's rhizomes is the only method that offers long term control. It is the most suitable method for use in water storage reservoirs, if chemical control is undesirable. Dredging the sediment to a depth in excess of 2 metres from the water surface will discourage re-colonisation.

•If chemical control is acceptable then dichlobenil, (in slow release formulation), should be applied early in the spring, before the floating leaves have formed. The chemical is not specific and will kill most or all of the other submerged plants present. It cannot be used in aquatic plant production tanks to give specific control and should only be used in water storage reservoirs when the reservoir in question can be taken out of use for an appropriate time.

•Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

•Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.

1.3.8 The Control of Reeds, Rushes and Sedges.

•Reeds, rushes and sedges are perennial plants which grow in or near static or flowing water and on marshy ground. Once the plants are established in shallow water they trap silt around the roots and shoots. This can impede or divert water flow and allow further spread of the plants into water previously too deep to sustain them.

•Normally, foliar application of glyphosate will provide cost effective control of Reeds, rushes and sedges.

•Glyphosate should be applied in mid to late summer (August or September) when it will give control for 2-3 years. Control can be localised by careful direction of the spray so that predetermined areas of emergent weed can be preserved.

•Product guidelines should always be followed. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

•Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters.

1.4 Anticipated Practical and Financial Benefits.

Currently, without effective guidelines many growers will be unaware of, or unsure about, practical management techniques which are available to them. The provision of a review of techniques of aquatic weed control suitable for use in nurseries should increase the knowledge of 'Best Management Practices' for growers and encourage their correct implementation.

Any improvement in the efficiency of the control of aquatic weeds in nurseries will reduce labour and chemical costs significantly. Reduced aquatic weed growth in water storage reservoirs may reduce the frequency of blockages of pumps and filters, halting water supplies and damaging pumping equipment. Improved aquatic weed management will enhance the productivity of crop plants in aquatic growth tanks and increase the value of the saleable product, as plants are not contaminated with weeds. Any reduction in the contamination of crop plants will also inhibit the spread of unwanted weed species, especially exotic introduced species, to public waters and will therefore reduce national weed control costs and enhance the environment.

Section Two:
Science Section

2.1 Survey of H.D.C. Levy Payers.

A postal survey of H.D.C. levy payers was made to assess the scale of the problem experienced in the Horticultural Industry and to identify problem weeds. At the beginning of February 1997 a questionnaire (Appendix 1) was distributed (together with a stamped return envelope) to 537 registered horticultural growers.

2.1.1 Survey Results

Of the 537 questionnaires circulated, 202 were returned, representing a response rate of 37.6%. Of these, 28 growers (13.9% of replies) reported problems with aquatic weeds. (Table 2.1.1).

Table 2.1.1 Analysis of returned questionnaires. 1: General Aquatic Weed Problems.

	Number (and%) of returned questionnaires
No aquatic weed problem.	174/202 (86.1%)
Aquatic weed problem.	28/202 (13.9%)
Total replies.	202/202 (100%)

Similarly, 13.4% of H.D.C. growers experience problem growth of aquatic weeds in their water storage systems and 2.5% experience growth of aquatic weeds in their aquatic plant growth tanks.(Table 2.1.2).

Table 2.1.2. Analysis of returned questionnaires. 2: Aquatic weed problems in storage or growth tanks.

	Number (and %) of returned questionnaires
Weeds in storage reservoirs.	23/202 (11.4%)
Weeds in storage res. & aquatic plant tanks.	4/202 (2%)
Weeds in aquatic plant tanks.	1/202 (0.5%)
Total	28/202 (13.9%)

Although only a very small proportion of responding growers have aquatic weed problems in their aquatic plant tanks, the figure of 2.5% actually represents 100% of those respondents who claimed to be either an aquatic nursery grower (1) or a combined aquatic and terrestrial nursery grower (4). (refer to table 2.1.3)

Table 2.1.3 Analysis of returned questionnaires. 3: The number and type of growers who experience Aquatic Weeds.

	Number of returned questionnaires	Number (and%) with aquatic weed problems.
Terrestrial Plant Nursery	197	23 (11.7%)
Terrestrial and Aquatic Plant Nursery	4	4 (100%)
Aquatic Plant Nursery	1	1 (100%)

It is important to note that on the whole the vast majority of growers contacted did not experience an aquatic weed problem because they were not aquatic specialists or they did not have any form of water storage facility. This point added to the fact that only a very small number of aquatic nurseries are represented in the survey indicates that the information gained from results has a very low significance and should only be treated as a guide.

Water Storage Systems.

The most common weed encountered by H.D.C. growers in their water storage systems was *Cladophora* spp. which was identified in 48% of returns. In 38.5% of cases where the growth of *Cladophora* was reported, interference with the irrigation and water distribution system by clogging filters, pumps and spray nozzles had occurred.

Duckweeds (*Lemna* spp.) are the second most common type of aquatic weed (25.9% of reported cases) experienced in nursery water storage systems. Duckweeds, like algae, interfere with water distribution systems by blocking filters and nozzle heads. Other species of algae (including those which were unidentified) make up a large proportion of reported weeds (18.5%). The breakdown of reported weeds can be seen in table 2.1.4 below.

Table 2.1.4 Analysis of returned questionnaires. 3: Species of aquatic weeds experienced by Growers in nursery water storage systems.

Species of Aquatic Weed.	Number (and%) of total replies identifying a weed problem.
Cladophora	13(48%)
Spirogyra	2 (7.4%)
Unidentified algae	3 (11.1%)
Lemna spp.	6 (25.9%)
Elodea canadensis	1(3.7%)
Potamogeton natans	1(3.7%)
Myriophyllum spp.	1 (3.7%)
Typha augustifolia	1 (3.7%)
Unknown weed	2 (7.4%)
Total	27(100%)

Aquatic Plant Growth Tanks.

Where the growth of aquatic weed was reported in growth tanks *Cladophora* was, once again, the most common (100% of reported cases) species. Other reported weeds included *Lemna* spp. and *Elodea canadensis*. As only few aquatic plant nurseries responded to the questionnaire, other aquatic nurseries were contacted individually to assess their experiences of aquatic weed problems. The most common aquatic weeds regularly causing problems included species of Duckweeds (*Lemna minor, Lemna minuta, Lemna gibba and Lemna trisulca*), species of algae (particularly *Cladophora*), the Water Fern (*Azolla filculoides*), Canadian Pond Weed (*Elodea canadensis*) and Water Milfoil (*Myriophllum spicatum*).

The proliferation of aquatic weeds in the growth tank environment directly competes with, and reduces the amount of light and nutrients available to, the plants being cultivated. Some species of algae (for example *Cladophora*) often grow on the leaves of the cultivated species, smothering and eventually killing leaves, reducing the growth and size of plants and sometimes killing the whole plant. The potential reduction in saleable plants could be significant. Reduced productivity is not the only problem experienced by aquatic plant growers. Before sale, plants and their containers which are covered in weed (particularly *Lemna* spp., algae e.g. *Cladpohora,* and *Azolla filculoides*) will require thorough expensive cleaning, by hand, to increase the aesthetic quality of the product and reduce the possibility of unwanted contamination of customers tanks, ponds and lakes with aquatic weeds.

2.2 Aquatic Weed Control.

2.2.1 Introduction.

An aquatic weed may be defined as 'an aquatic plant (or group of plants) which is not desired by the manager(s) of the water body where it occurs, either when growing in abundance or when interfering with the growth of crop plants or ornamentals' (Pieterse, 1990). In aquatic environments, such as lakes and rivers, excessive growth of aquatic plants can create problems by impeding flow (increasing flood risk), interfering with recreational activities (such as boating or fishing) or inhibiting the growth of native species of aquatic plant. In both aquatic and terrestrial nurseries the excessive growth of aquatic plants can block irrigation systems by impeding flow, clog pumps and block filters. It will also compete with crop aquatic plants for light and nutrients.

Aquatic weeds are divided into five categories according to their growth form:

Emergent Weeds

These are rooted plants whose stems and leaves are exposed above the surface. They include reeds and broadleaved plants. Examples include Common Reeds (*Phragmites* spp.), Bulrushes (*Typha* spp.), Common Club Rush (*Schoenoplectus lacustris*), Reed Sweet Grass (*Glyceria maxima*) and Water Plantain (*Alisma plantago-aquatica*).

Floating Weeds

Many aquatic plants have leaves that float on the surface. They may be free floating e.g. Duckweed (*Lemna* spp.), Frogbit (*Hydrocharis morsus-ranae*) and Water Fern (*Azolla filiculiodes*) or rooted e.g. Yellow Water Lily (*Nuphar lutea*), Fringed Water Lily (*Nymphoides peltata*) and Water Starworts (*Callitriche* spp.).

Submerged Weeds

These plants are mostly submerged (although flowers and occasionally leaves reach the surface) and rooted in the sediment. Examples include Water Crowfoot (*Ranunculus* spp.) Canadian Pond Weed (*Elodea canadensis*) and Water Milfoils (*Myriophyllum* spp.). Some submerged weeds are free floating, just below the surface e.g. Ivy-leaved Duckweed (*Lemna trisulca*).

Algae

Algae may grow as filaments, often forming a scum on the water surface, slime on surfaces, or characteristic entangled mats known as 'blanket weed' or 'cott'. They include *Cladophora* spp., *Spirogira* spp. and *Hydrodictyon* spp. Unicellular species may bloom during the summer months and on occasion form surface scums (some of which are toxic). Examples include *Microcystis aeruginosa* and *Anabaena flos-aquae.*

Depending on the type of aquatic weed and the environment in which it is growing, weeds can often be controlled by a variety of techniques. These techniques can be described under the broad headings of physical (including mechanical techniques), chemical, biological and environmental control.

2.2.2 Physical or Mechanical Control.

Hand pulling, raking or cutting vegetation represent the most traditional forms of aquatic weed management. Such techniques have been employed for centuries using scythes, sickles, hooks, rakes and chain scythes to cut and remove vegetation from rivers, drainage channels and lakes. The large scale use of hand cutting and physical removal of aquatic weed in Europe and the developed world is becoming ever more infrequent as the costs of manual labour become more expensive. There are however exceptions; manual techniques are still commonplace where highly selective plant removal is needed, for instance in nature reserves (Brookes, 1981; Lewis and Williams, 1984), fisheries (Philipose, 1968; Ramaprabhu, Ramachandran and Reddy, 1982) including the salmonid fisheries of UK chalk streams (Ham, Wright and Berrie, 1982) and in aquatic nurseries (Santha, Martyn, Neill and Strawn, 1994). The continued use of manual removal techniques in developed countries is more likely to be undertaken in conjunction with, or as a follow up to, chemical or mechanical control operations to achieve more complete aquatic weed management (Ruiz-Avila and Klemm, 1996). Manual techniques remain an important means of weed control in countries where labour is readily available and cheap (Ramaprabhu *et al*, 1982).

Currently large scale weed cutting operations are more likely to be undertaken using specialised mechanical equipment developed to cut and remove aquatic plant material by boat, barge or from the bank. Reviews of machines are provided by Bagnall (1981), Canellos (1981), Ramay (1982) and Gopal (1987). The wide range of machinery includes weed cutting and weed harvesting boats and bank operated equipment (such as tractors with mowing buckets and excavators) which can be used in lakes, rivers and ditches, or more specialised machines such as the 'spider' which is used exclusively in drainage ditches and small channels (Hemmings 1997). Dredging, although not normally employed purely for the purpose of weed control, is also regarded as a method of physical control of aquatic weeds. Mechanical cutting and harvesting may be economically viable only in the largest of nursery water storage reservoirs if emergent or rooted weed problems become particularly severe. Cutting is not an effective management technique for the control of free floating weeds or algae (both unicellular and filamentous).

With any physical weed cutting programme the regrowth of cut plant material is often rapid. This usually necessitates frequent recutting in order to maintain relatively clear water throughout the summer months. In practice the cost of operation often limits the number of cuts per season and alternative methods which produce longer lasting control are sought (Barrett *et al* 1990).

2.2.3 Chemical Control.

A range of herbicides has been developed to control aquatic weeds. The careful use of these herbicides at appropriate times of the year can give effective control of a wide variety of aquatic plants. Emergent or floating leaved aquatic weeds may be treated by foliar spray, (e.g. glyphosate) in a similar fashion to terrestrial weeds, thus allowing selective or more widespread applications, typically with hand held applicators. Submerged weeds and algae can be treated by the application of specifically formulated herbicides, directly to water. A good example is diquat-alginate, a viscous gel formation designed to stick to aquatic weeds underwater.

Only herbicides currently approved under the Control of Pesticides Regulations (1986) for use in water may be used to treat aquatic weeds. A summary table of the approved herbicides for the control of groups of plants found in or near water is shown in Table 2.2.3.

Table 2.2.3: Herbicides suitable for the control of the main groups of weed found in or near watercourses.

	Asulam.	2,4-D Amine.	Dalapon/Diclobanil Mix.	Dichlobenil.	Diquat.	Diquat Alginate.	Fosamine ammonium.	Glyphosate.	Maleic hydrazide.	Terbutryn.
Trees & shrubs on bank							✓	✓		
Bracken & docks	✓		✓					✓		
Broad-leaved weeds on banks		✓	✓					✓		
Grasses on banks			✓					✓	✓	
Reeds & sedges								✓		
Floating-leaved plants				✓				✓		
Free-floating plants					✓			✓		✓
Submerged weeds				✓	✓	✓				✓
Submerged weeds (flowing water)						✓				
Algae (blanket weed or cott)						✓				✓

Adapted from 'Guidelines for the use of herbicides on weeds in or near watercourses and lakes' (MAFF1995). A list of professional products, approved for use in or near water can be found in Appendix 2. The list also contains details of relevant marketing companies and MAFF registration numbers for individual products.

It should be noted that, in the UK the agreement of the relevant water authority is required before using a herbicide in or near 'controlled waters'(this includes rivers, canals, most lakes and ponds, reservoirs, estuaries, coastal waters and ground water.) In England and Wales this means contacting the local office of the Environment Agency (EA), in Scotland the Scottish Environmental Protection Agency (SEPA) and in Northern Ireland the Department of the Environment (DOE(NI)) (MAFF, 1995).

Before implementing any weed control programme it is important to consider both the aims of the treatment and the effects that the treatment may have on the functions of the water body. With herbicides the treatment may affect both local and downstream functions of the water body by direct toxicity and the death and decomposition of plant material. This is especially important if water is abstracted for irrigation or potable supply.

When considering application of herbicides to water storage reservoirs in aquatic or terrestrial nurseries it is particularly important to take note of the statutory irrigation interval. Herbicides approved for use in water have an irrigation interval, during which they may damage crops if the treated water is abstracted and used to irrigate. This interval may last between a few days and a few weeks depending on the product. For example, terbutryn has an irrigation interval of 7days and dalapon, 5 weeks.

A reduction in the amount of herbicide applied in or near water is always desirable to reduce both the cost and the effects on the surrounding environment. When chemical control is necessary, employment of localised or selective treatments is always more advantageous than widespread applications. Large scale weed eradication schemes may result in the colonisation of the area with an aquatic weed which could prove more troublesome than the original species. Ideally, weed stands situated in areas where they do not cause many problems, e.g. away from water filtration equipment or along the margins of the water body, should be left untreated.

It is always important to read the product label or leaflet accompanying the herbicide product and adhere to the guidelines. Failure to do so may result in a mis-timed or incorrect application, the consequences of which may include lack of weed control, contamination of water supplies or a loss of irrigated crops (Bowmer *et al*, 1976; Bryan and Hellawell, 1980).

Herbicide treatments can be broadly separated by the type of weed to be treated. All emergent reeds, rushes and most floating leaved plants can be controlled by foliar spray of glyphosate. Exceptions include Amphibious Bistort (*Polygonum amphibium*), Broadleaved Pondweed (*Potamogeton natans*), Duckweed (*Lemna minuta*) and Fringed Water Lily (*Nymphoides peltata*). These plants (with the exception of *Lemna*) are best controlled by the early season application of dichlobenil. *Lemna* can be controlled by diquat or by 2,4-D Amine. Most submerged rooted plants can be controlled by dichlobenil, diquat or terbutryn. Most algae can be controlled by terbutryn or diquat. Approved professional products are listed in Appendix II.

The timing of application of any herbicide can have a major influence on its effectiveness. Thus, glyphosate, which controls a wide range of emergent and floating leaved plants (Barrett, 1974,1976,1985; Evans 1978; Barrett and Gibson 1990; Smith et al 1993) has been shown to give long term control of emergent reeds and rushes if its use is restricted to late summer, i.e. late August or September (Caffrey, 1996). This can reduce the need for repeated chemical control (and hence the amount of chemical used) or for other control practices. Many other species of aquatic weed are more susceptible to chemical treatment at particular times of the year or stages in their life cycle. The product label, specific weed control handbooks or other sources of information, such as the CAPM information sheet series, should be consulted to ensure the best times for chemical weed control operations. Unfortunately many weed problems develop so rapidly that little or no warning of it is seen. It is then often too late in the season for herbicides to be effective, leading to a delay in up to a year before the timing of chemical treatment can give adequate control.

2.2.4 Biological Control

The biological control of aquatic weeds may be defined as 'activities aimed at decreasing the population of an aquatic weed to acceptable levels by means of a living organism or virus', Pieterse (1990). In practice, this means using selective organisms which attack one or only a few target species of aquatic weed, or non-selective species which attack all, or nearly all weeds. The introduction of other plant species to out compete target weeds for necessary light and nutrients is also regarded as a biological control technique.

Classical biological control focuses on introduced species of weed and involves the introduction of an organism which attacks the weed in its native habitat into the region where the plant has become a nuisance. Such 'biocontrol' agents have been successful in controlling some species of particularly problematical aquatic weeds overseas. Examples include the control of Alligator Weed (*Alternanthera philoxeroides*) with the Chrysomelid beetle *Agasicles hygrophila* which has been successful in the USA and Australia (Coulsdon, 1977; Julien, 1981); the control of Salvinia (*Salvinia molesta*) with the weevil *Cyrtobagous salviniae* in Australia (Room, Forno & Taylor, 1984; Forno, 1985,1987), Papua New Guinea (Room & Thomas, 1985) and India (Joy *et al,* 1985); and the control of Water Hyacinth (*Eichhornia crassipes*) with the weevil *Neochetina eichhorniae*, among other control agents, in the Sudan (Beshir & Bennett, 1984).

The microbial herbicide strategy focuses on the control of indigenous weed species and uses indigenous microbial pathogens of that weed. They are applied in the same way as chemical herbicides as an 'inundative inoculum' and it is generally accepted as necessary to apply them with the same frequency as herbicides. Many potential agents for use in this strategy have been investigated (Charudattan, 1991) but, as yet, none is available for practical use.

Biological controls using microorganisms or phytophagous insects have not yet been developed for species of aquatic weed common in the in the UK. Restrictions on the import of exotic species of insects and fungi necessitates painstaking and expensive research under quarantine conditions before a biocontrol agent can be released into the environment. This often prevents the investigation of potential biocontrol agents beyond the preliminary stages. The development of mycoherbicides for aquatic weeds has also been limited by funding and a hesitancy of the industrial sector to support and then market a product that is likely to be restricted in its effect (i.e. it only attacks one aquatic weed), Forno & Cofrancesco, (1993). Biological control therefore remains limited in the UK.

Some biological control agents, in the broadest sense, include sheep and cattle which may be used to control bank side and emergent vegetation. Cattle have also been used in shallow streams where grazing and trampling helps to control submerged weed, Barrett *et al* (1990). Waterfowl can help to control some floating and submerged weed by grazing. It is, however, unlikely that they can be kept in such numbers, or restricted to certain areas, as to provide an adequate degree of control.

The use of Grass Carp (*Ctenopharyngodon idella*), a herbivorous fish, as a biological control agent is an option in enclosed waters. Regarded as a non-selective control agent (Van der Zweerde, 1990), the grass carp consume a variety of floating and submerged weeds as well as algae. Under the Wildlife and Countryside Act 1981 a licence for its use is required from the Ministry of Agriculture Fisheries and Food, in addition to a permit from the Environment Agency (in England and Wales) or SEPA (in Scotland).

Good aquatic weed control can be achieved by grass carp in drainage canals (van der Eijk, 1978; Riemans, 1981). The biological control strategy is often cheaper than conventional maintenance (mainly mechanical), (de Vries, 1987; Willems, 1981).

Although previously described as a non selective control agent, studies on the feeding habits of grass carp (e.g. Pine and Anderson, 1991), have revealed food preferences and led to the use of grass carp for more selective weed control. For example Santha, Martyn, Neill & Strawn (1994) found that, with careful management, grass carp can be used to control submerged aquatic weeds in waterlily production ponds. A more detailed review of the potential use of grass carp in aquatic nurseries can be found in section 2.3.8.

Some species of native fish can also help to control aquatic weeds. Bottom feeders such as carp and bream can reduce aquatic weed growth by pulling up small plants during feeding and by stirring up sediment. The resulting turbid waters inhibit future growth of submerged and some floating aquatic weeds.

The use of barley straw for controlling algae (see section 2.3.1.2.) can also be regarded as a biological control technique. Straw can be applied to water by a variety of techniques usually involving the use of netting or cages together with floats to suspend loosely packed straw close to the surface where it remains most active. Its application at doses of between 15 to 50 g/m^2, to fresh waters has resulted in the inhibition of filamentous and unicellular algal growth in a wide variety of locations. It is thought that the barley straw effect arises from its decomposition under aerobic conditions releasing algal inhibitors (Welch *et al.*,1990; Gibson *et al.*,1990; Ridge & Pillinger, 1996). The method is now widely regarded and used as an effective means of controlling nuisance algae (Ridge & Barrett, 1992; Newman & Barrett, 1993). Barley straw, typically, becomes effective after 1 month in well aerated water and remains active against a wide range of green algae and cyanobacteria for at least 6 months (Ridge & Pillinger, 1996).

2.2.5 Environmental Control.

Environmental control involves altering the local environmental conditions to inhibit the growth of aquatic weeds and algae. Environmental factors that offer the greatest scope for manipulation include light intensity, nutrient levels and the depth of water.

Reducing the amount and quality of light available for plant growth can be achieved by shading the water surface with trees planted on the bank. Narrow watercourses or small ponds (including small water storage reservoirs) can be more effectively shaded than large ones, particularly if trees are planted along the south side of the water body. The light intensity within a pond, lake or storage reservoir can also be reduced by stocking with bottom feeding fish such as carp and bream. They increase the turbidity of the water by stirring up the sediment and can, therefore, limit the growth of aquatic plants. This may, however, increase the likelihood of unicellular algal blooms. The complete exclusion of light may be an option in small purpose built storage reservoirs where the construction of a cover would eliminate the need for aquatic weed control in the future.

A reduction in the concentration of nutrients entering a water body can limit the amount of aquatic plant growth. As methods of nutrient removal (e.g. phosphate stripping) are expensive their use is usually restricted to sewage treatment works where a high degree of nutrient reduction is necessary to comply with EC Directives on waste water quality. Alternatives to removing or 'stripping' nutrients include the diversion of any agricultural, industrial or sewage effluents away from or around the water body using bypass channels, diverting inflows through constructed reed bed or other planted systems which may absorb or 'filter out' a proportion of the nutrients and encouraging the growth of riparian vegetation which may help reduce the concentration of nutrients entering the water body via shallow groundwater flow or surface run-off from adjacent agricultural areas.

Alteration of the water level by draining the pond, lake or reservoir can be used to control aquatic plants. This technique often referred to as 'drawdown' controls plants by dehydration. It should be noted, however, that in deeper water bodies drawdown can enable weeds to establish themselves at depths beyond their normal limit thus extending the weed problem to a location where it may not normally exist.

2.3 Summary of Control Methods.

2.3.1 The Control of Algae.

Filamentous algae represent the most commonly described type of aquatic weed experienced by H.D.C. growers. *Cladophora glomerata* (Blanket weed) was reported most frequently with *Spirogyra* spp. also being described. Other species of filamentous algae that regularly cause problems in the U.K. include *Vaucheria dichotoma* (Cott) and *Rhizoclonium* spp. The persistent growth of filamentous algae causes problems for both aquatic and terrestrial plant nurseries. Growth in storage reservoirs can interfere with irrigation systems by blocking filters, pumps and nozzle heads and proliferation in aquatic growth tanks can reduce the size and quality of crop plants.

Unicellular algae can also interfere with the maturation of crop plants in aquatic nurseries due to light intensity reduction by blooms. Blooms of unicellular cyanobacteria, such as *Anabaena flos-aquae,* or *Microcystis aeruginosa,* may also pose a health risk to nursery workers as decomposing cells release toxins which are irritating to the skin and potentially harmful if consumed. Unicellular algae may be problematic in water storage reservoirs when severe blooms of green algal species cause de-oxygenation of the water resulting in fatalities among resident fish populations. Toxic cyanobacterial blooms will become hazardous to humans and livestock frequenting the reservoir or surrounding bank-sides. Blooms of unicellular algae in the water reservoir will lead to problems in the plant growth tanks they feed and can, like filamentous forms, produce blockage of irrigation nozzles and pumps. Spillage of water containing algae on concrete pathways can result in dangerous and slippery growth.

Many species of filamentous and unicellular algae are susceptible to herbicides but these are usually unacceptable in aquatic growth tanks, where crop plants may be affected, or in water storage reservoirs where the water is required for crop irrigation. No herbicides have been developed for the specific control of unicellular or filamentous algae or cyanobacteria.

2.3.1.1 Physical Control.

Algae are often very difficult to control. Traditional forms of physical and mechanical removal can help reduce problems with filamentous algae but offer only a short respite. They require frequent repetition to provide clear water over the summer months.

2.3.1.2 Control of Algae with Barley Straw.

A novel effective method of controlling many unicellular and filamentous species of algae which involves the application of barley straw to water has been developed by the Centre for Aquatic Plant Management. It offers a cheap and environmentally friendly method of controlling algal growth and is highly suitable for use in nursery water storage reservoirs and aquatic growth tanks where the use of herbicides is undesirable. The use of barley straw has been tested in a wide range of situations and has no known undesirable side effects and it does not appear to have any inhibitory effect on the growth of macrophytes. Indeed the reduction in algal growth will only improve the size and quality of crop aquatic macrophytes.

How to Apply Straw.

The anti-algal effects of barley straw are produced when it rots under aerobic conditions. Therefore, it is not appropriate to put the straw into water as compact masses such as bales. The straw should be packed loosely into a netting container of some sort with a float and then anchored in the water body so that the straw is kept close to the surface. The size of the container used will be determined by the size of the water body to be treated, its function and economic considerations. Ideally, any water body is best treated with many small containers spaced at 60 m intervals throughout the water surface area, those nearest the bank being no more than 30 m from the bank. This ensures the most even distribution of the active ingredient throughout the water. Clearly this may not be feasible if the water body is used for fishing or boating where fewer larger containers may be more practical. Whatever size of container used one or more should be sited near to any inflow to the water body.

Various netting containers are possible. Individual netting sacks, for example onion sacks, each containing a small quantity of straw together with a float (e.g a sealed empty plastic bottle) are suitable for treating smaller water bodies or tanks. Larger water bodies, such as irrigation reservoirs, can be treated with a large straw 'sausage' made with the tubular netting normally sold for wrapping Christmas trees. Using a tree wrapping machine tubular netting can be filled to construct straw 'sausages' up to 20 m long containing up to 50 kg of straw. In addition to straw air filled bottles or small barrels should be incorporated within the netting at regular intervals. This will give the straw sausage some buoyancy and ensure that the straw remains suspended in the top layers of the water column where oxygen concentration is highest. It is advisable that the floats are tied in position with string or by knotting the netting to ensure that all the floats do not move together. Once constructed the straw sausages float well and can be towed behind a boat or dragged into position where they should be anchored by polypropylene rope to concrete blocks or bricks. Long 'sausages' are best anchored at one end only so they can swing around freely and offer minimum resistance to wind and currents. Alternatively, steel wire mesh gabions (cages), which can be produced in various sizes, can be filled with straw, floated and anchored into position. They offer a reusable straw application method and can be refilled with straw as and when necessary.

The steps involved in the calculation of the dose rate and application of straw are described in table 2.3.1.2 overleaf.

How much Straw to Apply.

The most important measurement in calculating the quantity of straw required is the surface area of the water. In still waters such as lakes, tanks and reservoirs the minimum quantity of barley straw required is 15 g straw m^{-2} of water surface. In practice the optimum dose seems to be between 15 and 25 g m^{-2}. This seems to be equally effective against unicellular species, which are relatively sensitive, and the more resistant filamentous species. When a water body with a history of severe algal problems is first treated a higher dose is usually required; quantities of up to 50 g m^{-2} have been applied. Once the algal problem has been controlled, and repeat additions of straw are being made to prevent a recurrence of the problem, the dose rates can steadily be reduced.

Table 2.3.1.2: Calculating the Amount of Barley Straw required.

	Decision Step	Calculated Example
1.	Estimate the surface area of the lake/tank.	1.5 ha (15,000 m^2)
2.	Decide on the dose rate of straw. 15 g/m^2 in water with little algae or mud to 25-50 g/m^2 for heavily infested and/or muddy water.	25 g/m^2
3.	Multiply the water area (in m^2) by the quantity of straw required per m^2 to obtain total quantity of straw required.	15,000x25 = 375,000 375,000 ÷ 1000 = 375kg
4.	To calculate the number of bales to be purchased divide the total weight of straw by the weight of bales. (Small rectangular bales normally weigh about 20kg, weights should be checked for other sizes of bales).	375kg ÷ 20kg = 19 bales
5.	Decide on the weight of straw to be placed in each net. (Bear in mind that less straw in more nets will aid the distribution of the chemical). Nets should normally contain between 1kg (in small waterbodies) and 40kg (in large reservoirs).	25kg
6.	Calculate the number of nets required. Divide the total quantity of straw (3) by the weight in each net (5).	375kg ÷25kg = 15 nets
7.	Calculate the area of water which will be treated by each net at the dose rate decided in (2) above.	25kg ÷25 g/m^2 =1000 m^2
8.	Calculate the diameter of a circle with an area of the size calculated in (7) above using πr^2 to calculate radius (r) The diameter is r x 2	$\pi r^2 = 1000$ $r = \sqrt{1000 \div 3.142}$ r =17.85m r x 2 = 35.7m
9.	Decide on the most appropriate placement of the nets of straw so that each one is 35m from its neighbour and 18m from the bank.	Usually a regular square grid pattern with centres at 35m.

Although straw can be applied at any time of the year it is much more effective if applied before algal growth takes place. Therefore, straw is best applied in autumn, winter or very early in the spring when the water temperature is low. The straw will usually become active about one month after application and will continue to inhibit algal growth for around 6 months. Rapid algal growth can take place once the straw has rotted away so it is important apply more straw at least every 6 months and always before the previous treatment has completely decomposed.

It is advisable to place the new straw application in the water body at least one month before removing the old straw to avoid an interval when no anti-algal chemicals are being produced.

The use of barley straw cannot be guaranteed to control algae in all situations. It is a biological process which is not fully understood at present. Therefore, factors which may influence the efficacy of barley straw are not fully understood or documented. However, where 'failures' have occurred they are most likely due to the following factors:

1. Not enough straw.

2. Straw too tightly packed.

3. Too much sediment in the water.

4. Incorrect timing of application.

5. Incorrect application method.

6. Water draw-down leaving straw out of the water.

2.3.1.3 Chemical Control of Algae.

Herbicides can be used to control algae, especially filamentous forms, if a rapid effect is required. The control achieved is, generally, only temporary. All herbicides approved for use in water and which control algae also control macrophyte species. Their use removes the macrophytes, an addition to algae, so creating an ecological void which is often rapidly exploited by algae. Thus, the algal problem is exacerbated and the need for repeated chemical treatment is established. This can, in turn, lead to the development of herbicide resistance in some algal species.

Herbicide use can, however, be beneficial as the first stage in a management regime involving the use of barley straw and the re-establishment of submerged and floating plant communities which will inhibit the future regrowth of algae.

It must be emphasised that the professional herbicides which kill algae are non selective and will kill other desirable vegetation. ***They must not be used in aquatic plant growth tanks which are in active use or in water storage reservoirs which are supplying water to growth tanks or for irrigation of crop plants.*** Guidelines supplied with the products on irrigation intervals and plant introduction times should always be followed to avoid any damage to crop plants. A list of professional products suitable for use in water is available in Appendix II.

Terbutryn.

Terbutryn will kill most submerged vegetation. The following species of algae are susceptible to treatment with terbutryn:

Susceptible: *Cladophora glomerata*
Enteromorpha intestinalis
Rhizoclonium species
Spirogira species

Moderately resistant: *Vaucheria dichotoma*
Vaucheria sessilis

Terbutryn is supplied in a granular formulation and should be spread evenly over the water surface. Susceptible algae should be treated at an application rate of 5 kg per 1000 m^3 of water and moderately resistant algae at 10 kg per 1000 m^3. The product should be applied early in the growing season. If dense weed growth is present the product should only be used on one quarter of the whole water body at one time. The remaining sections should be left for a minimum of 14 days before they in turn are treated. The entire lake should be treated within a 6-8 week period to ensure control. Terbutryn is only effective in static water or in watercourses where the flow is less than 1 metre in 3 minutes (effectively static). If there is any observable flow then it should be stopped for at least 7 days. Water treated with this product may be used for irrigation of crops and livestock 7 days after treatment.

After treatment with terbutryn growth ceases almost immediately and signs of death are evident after 2-4 weeks. Regrowth will not occur for at least 3-4 months. Terbutryn works by inhibition of photosynthesis. It does not, however, interfere with respiration and can therefore result in dropping dissolved oxygen levels in the treated waters which may become harmful to fish and other animals. It is very important not to treat the entire water body at one time to allow fish and invertebrates to seek shelter in unaffected locations.

Diquat.

Diquat will kill many submerged vascular plants and floating plants (including duckweeds) as well as some species of algae. The following species of algae are moderately susceptible to treatment with diquat:

Moderately susceptible:	*Cladophora glomerata*	**Resistant:**	*Vaucheria dichotoma*
	Enteromorpha intestinalis		*Vaucheria sessilis*
	Spirogira species		

Diquat as 'Reglone' is a liquid formulation, containing 20% active ingredient, it can be applied with or without dilution by surface spray or subsurface injection (by trailing a nozzle below the water surface) at a rate of 5 litres per 1000 m^3 of water. It should be applied in the spring when rapid algal growth occurs but may only be used in static waters or where the flow is less than 90 metres per hour. Not more than 25% of the water body should be treated at any one time. Diquat is rapidly absorbed by plants and mud and therefore should not be applied to watercourses containing a large amount of suspended sediment.

Plants become yellow within 2-4 days after treatment with Diquat and will begin to sink and decay within 1-2 weeks Diquat persists for a few days only and algal growth will return later in the season.

2.3.1.4 Environmental Control.

Algae, like aquatic macrophytes, can be controlled by shading. Although unsuitable in aquatic plant growth tanks, where high light intensities are necessary for the production of crop plants, it is an option that should be considered on water storage reservoirs. In these locations shading can be achieved by planting trees along the south side of the water body. A second option involves the complete exclusion of light, this may be an option on small purpose built storage reservoirs where the construction of a cover would eliminate the need for aquatic weed control in the future.

2.3.2 The Control of Duckweeds (*Lemna* spp.).

Duckweeds are small free floating plants which often form dense mats on the surface of still and slow flowing, eutrophic (nutrient rich), waters. Duckweeds are the second most common species of aquatic weed experienced in growth tanks and water storage reservoirs. Duckweed leaves are small, often not exceeding 5mm in length and are either single (*Lemna minuta* and *Lemna gibba*) or in groups of two or three (*Lemna minor*). *Lemna trisulca* has a more complex branched structure and is the only submerged species of duckweed. The leaves of *Lemna gibba* are swollen.

Duckweeds reproduce mainly vegetatively which permits a very rapid growth rate and high efficiency at colonising and re-infesting suitable waters. Thus, it may be necessary to continuously remove the plant to maintain relatively clear waters.

2.3.2.1 Physical Control.

Physical removal of *Lemna* spp. is possible in small tanks by dragging a floating boom over the water surface to the collect the weed at the point where it can be removed and disposed of. On large water storage reservoirs harvesting machines can be employed to remove *Lemna* spp if the problem is particularly bad. It is impossible to remove every plant by physical means and the regrowth of *Lemna* spp. is inevitable. Despite this, physical methods of removal are rapid and the effect can last for a reasonable length of time.

2.3.2.2 Chemical Control.

Lemna spp. are susceptible to herbicides containing 2,4-D amine, diquat, terbutryn or glyphosate (Refer to appendix II for a list of professional products). 2,4-D amine, diquat, terbutryn are all non specific herbicides affecting a range of macrophytes as well as algae. They are, therefore, unsuitable for use in aquatic plant production tanks or associated water reservoirs. *Lemna* spp. with the exception of the submerged species, *Lemna trisulca*, are susceptible to applications of glyphosate. Glyphosate is applied as a foliar spray and kills only those plants that the spray touches. It will kill waterlilies and all emergent reeds, rushes and grasses but with care to avoid drift onto important plants, glyphosate can be applied selectively in aquatic growth tanks and water storage reservoirs. It is not advisable to use glyphosate on thick mats of duckweed as only the top layers will be killed and regrowth will be rapid. The spot application of glyphosate does remain the best option for single layered and small infestations.

Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters. Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

2.3.2.3 Biological Control.

Grass carp will eat *Lemna* species. The potential for use of grass carp in aquatic nurseries is discussed in section 2.3.8.

2.3.2.4 Environmental Control.

The use of deep shade has been successful in reducing the amount of duckweed growth and may be an option on storage reservoirs if a protective cover can be constructed. It is not an option in aquatic plant growth tanks. Duckweeds do not compete well with other floating leaved plants such as waterlilies so increasing their population in the lake, reservoir or tank can reduce *Lemna* to acceptable levels. Duckweeds prefer still waters and their growth can be inhibited by disturbing the water surface by increasing the flow rate through the water body or agitating the surface with a hose or fountain.

2.3.3 The Control of Water Fern (*Azolla filiculoides*).

Azolla filiculoides is a species of aquatic fern found in Britain. The most characteristic feature of this plant is the red colouration taken on in the autumn opposed to its usual green colour. It reproduces both vegetatively and sexually by producing spores. Germinating spores which can give rise to dense infestations, are the main method of overwintering. Spore production usually is a result of stress when the plants form dense mats. Controlling or harvesting an infestation of *Azolla filiculoides* after sporulation will not prevent re-infestation as new plants will emerge the following year.

2.3.3.1 Physical Control.

Physical control of *Azolla filiculoides* is best achieved in tanks and reservoirs by dragging a boom over the water surface to concentrate the plants at one site followed by removal with a rake or bucket. The efficiency of removal is often improved by fitting a fine meshed netting to the bucket or rake to prevent fronds from escaping. If spores have already been released in the current or previous year it may be necessary to carry out repeated control operations until all spores have germinated and subsequently been controlled.

2.3.3.2 Chemical Control.

Herbicides are the most effective form of control. The floating fronds can be controlled with diquat or glyphosate. (Refer to appendix II for a list of professional products). Glyphosate will only kill those fronds which come into contact with the spray (although if the spray drifts it will kill any emergent or floating weeds which it contacts). Repeated applications are often necessary to kill any surviving fronds. Diquat will kill floating fronds when sprayed onto *Azolla filiculoides*. But, as with Glyphosate, a second application will often be required to ensure full control. This is best undertaken when winds or currents collect the floating fronds together.

Herbicides are best applied before complete surface cover has developed. When this is not possible repeat applications are usually necessary to kill surviving plants.

Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters. Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

2.3.3.3 Biological Control.

There are no known biological control agents suitable for the control of *Azolla filiculoides*.

2.3.3.4 Environmental Control.

Azolla filiculoides can be controlled by dense shade but this not applicable for use in aquatic growth tanks. An option suitable for use on small purpose built storage reservoirs is the construction of protective covers. The exclusion of light would inhibit the growth of aquatic plants and algae, including Azolla filiculoides, and would eliminate the need for aquatic weed control in the future.. Shading with trees around the southern shores of larger storage reservoirs may also be an option.

2.3.4 The Control of Canadian Pondweed (*Elodea canadensis*).

Elodea canadensis is native to North and South America where it occurs in lakes, canals and slow flowing water bodies. It has spread around the globe and is now a pest in many regions of the world. It grows from stolons and has vertical, narrow, sparsely branched stems with leaves in whorls of three. It does not reproduce by seed in the U.K. and relies on vegetative reproduction for its spread.

2.3.4.1 Physical Control.

Cutting *Elodea canadensis* will give control for short periods (1-2 months) during the summer. Most methods of physical control are appropriate depending on the size of the water body. Cutting and removal by hand or raking is suitable in smaller tanks, whereas chains, weed buckets, weed boats or dredging are all more appropriate for use in larger water storage reservoirs.

2.3.4.2 Chemical Control.

Elodea canadensis is susceptible to terbutryn, dichlobenil and diquat applied in the spring before the plant is fully grown. (Refer to appendix II for a list of professional products). The only product containing terbutryn that is approved for use in water is Clarosan 1FG. It comes as a granule application, will kill all submerged vegetation and can only be used in still water. Approved products containing dichlobenil (Casoron G and Casoron GSR) are both granule formulations. Only Casoron G should be used in shallow and/or small water bodies. The slow release formulation can give some degree of localised control on larger water bodies if used carefully. The flow limitation of these products is 1.5 metres per minute. The approved products containing diquat are Reglone and Midstream. Reglone is supplied as a liquid which can be applied as a spray to the water surface or directly by subsurface injection. Midstream is a viscous gel formulation which can be applied in flowing water or used for more localised control in still or slow flowing water bodies. Diquat is not effective in muddy water.

None of these chemical applications are species specific and they will kill most if not all of the submerged plants in the treated area. Therefore, they cannot be used in aquatic plant production tanks. Their use in water storage reservoirs should only be undertaken when absolutely necessary and at a time when the water is not being used to supply other tanks or irrigate to crops.

Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters. Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

Chemical treatment will give effective control of the plant for between 2 and 3 years. Regular inspections should be made to check for re-infestation and spot treatments should be applied to prevent further spread.

2.3.4.3 Biological Control.

Grass carp could be considered as an appropriate biological control technique for *Elodea canadensis.* Common carp, and other bottom feeding fish, which create turbid water can be effective in preventing regrowth of *Elodea canadensis* after physical removal or chemical treatment.

2.3.4.4 Environmental Control.

Elodea canadensis, like most submerged species of aquatic plants, can be controlled by shading. This can be best achieved by planting trees along the south side of water bodies. The construction of protective covers over small water storage reservoirs will prevent the growth of aquatic plants by excluding light.

2.3.5 The Control of Spiked Water-milfoil (*Myriophyllum spicatum*).

Myriophyllum spicatum (Spiked Water-Milfoil) is a submerged aquatic macrophyte characterised by groups of four feathery leaves arranged around a circular reddish coloured stem. The plant commonly grows in lakes, ponds and ditches often in dense mono-specific stands, but is not found in faster flowing water. It reproduces by seed and by vegetative growth and any control strategies should take this into account.

2.3.5.1 Physical Control.

Cutting can be effective in the short term (usually giving 1-2 months control during the summer). If a large amount of material is cut then it should be removed from the water body to avoid de-oxygenation caused by rotting. Any of the common physical or mechanical means of control (including removal by hand, raking, cutting with scythes and chains or using a weed bucket, boat or dredger) are suitable depending on the size of the water body.

Dredging provides the most effective means of removal and control.

2.3.5.2 Chemical Control.

Myriophyllum spicatum, like *Elodea canadensis,* is susceptible to terbutryn, dichlobenil or diquat if the chemical is applied in the spring before the plant is fully grown. (Refer to appendix II for a list of professional products). The only terbutryn product that is approved for use in or near water is Clarosan 1FG. It is a granular formulation that will kill all submerged vegetation and can only be used in still water. Approved products containing dichlobenil are Casoron G and Casoron GSR and are also granules. Casoron G should be used in shallow and/or small water bodies whereas Casoron GSR may be used to give some degree of localised control in larger water bodies if applied carefully. The flow limitation of these products is 1.5 metres per minute. The approved products containing diquat are Reglone and Midstream. Reglone is a liquid which can be applied as a spray to the water surface or directly by subsurface injection. Midstream is a viscous gel which has been designed for application into flowing water and to enable more localised control in still or slow flowing water bodies. Diquat is not effective in muddy water.

None of these chemical applications are species specific and they will kill most if not all of the submerged plants in the treated area. Therefore, they should not be used in aquatic plant production tanks. Their use in water storage reservoirs should only be undertaken at a time when the water is not being used to supply other tanks or to irrigate crops.

Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters. Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

Chemical treatment will give effective control of the plant for between 2 and 3 years. Regular inspections should be made to check for re-infestation, which would allow spot treatments to be applied thus preventing extensive regrowth.

2.3.5.3 Biological Control.

Grass carp do eat *Myriophyllum spicatum* and can, therefore, be considered as an appropriate biological control technique. As with *Elodea canadensis,* it may be worth considering the introduction of some common carp or other bottom feeding fish into the reservoir or storage tank. These fish tend to create turbid water and can be effective in preventing regrowth of *Myriophyllum spicatum* after physical removal or chemical treatment.

2.3.5.4 Environmental Control.

Shade will control the growth of *Myriophyllum spicatum.* Although shading is not an option in the growth tank environment it may be considered for use on water storage reservoirs. This is best achieved by planting trees on the south side of the water storage reservoir or lake. A second option is to construct protective covers which will prevent light from reaching the water surface.

2.3.6 The Control of Broadleaved Pondweed (*Potamogeton natans*).

Potamogeton natans is commonly found in static or slow flowing waters up to 1.5 metres in depth. It has rhizomes buried in the mud from which leaf and flower stalks grow up each spring. The leaf stalks produce flat blades which float on the surface and can form a dense surface cover over the water interfering with recreation (such as boating or fishing) and impeding flow.

2.3.6.1 Physical Control.

Cutting will provide only short term control of *Potamogeton natans*. At the most this control will last for one season. It is best to cut as late in the season as possible to reduce the risk of regrowth. Because *Potamogeton natans* grows up each year from its rhizomes dredging is the only (physical) method that can achieve long term control.

2.3.6.2 Chemical Control.

Unlike other species of floating plant *Potamogeton natans* is not susceptible to foliar application of glyphosate.

Potamogeton natans can be controlled with dichlobenil as Casoron early in the spring when growth is just starting (well before the floating leaves have formed). (Refer to appendix II for a list of professional products). Once the leaves are at the surface the growth rate of the plant slows down and Casoron is no longer effective. Cutting of the floating leaves will stimulate the growth of new leaves and if herbicide is applied at the same time increase the uptake of the chemical. Despite this, treatment is most effective early in the growth season. Casoron can only be applied in static waters, or those with a flow rate no greater than 1.5 metres per minute.

Diquat alginate (as Midstream) can be used in static or flowing waters with a low calcium content. This herbicide should be applied when floating leaves are starting to appear. It is not suitable where water bodies have a high sediment load or the plants are covered in silt or epiphytes.

These chemicals are not species specific and will kill most if not all of the submerged plants in the treated area. Therefore, they should not be used in aquatic plant production tanks. Their use in water storage reservoirs should only be undertaken at a time when the water is not being used to supply other tanks or to irrigate crops.

Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters. Product guidelines should always be followed, growers should pay particular attention to specific instructions regarding irrigation intervals and periods of time that should pass before re-introduction of aquatic plants is permitted. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

2.3.6.3 Environmental Control.

Potamogeton natans is susceptible to shading which can be created by planting trees around the southern shores of the reservoir or lake. A second option, suitable for use on small purpose built reservoirs, is to construct protective covers which will prevent light from reaching the water surface.

Potamogeton natans does not grow in deep water so dredging the tank or reservoir to a depth of over 2 metres is likely to inhibit its return.

2.3.7 The Control of Reeds, Rushes and Sedges.

Reeds, rushes and sedges are perennial plants which grow in or near static or flowing water and on marshy ground. If they grow in water it is usually at a depth of no more than 1 metre. Although some species reproduce by seed the main method of spread is by growth from the rhizomes. Once the plants are established in shallow water they trap silt around the roots and shoots. This can impede or divert water flow and allow further spread of the plants into water previously too deep to sustain them.

2.3.7.1 Mechanical Control.

These plants can be cut and removed by a variety of techniques including hand cutting or by weed cutting buckets or boats. The choice of method is usually dependent on the area involved and factors such as the depth of water and ease of access.

Cutting only removes the emergent shoots and new shoots will emerge from the buried rhizomes. It is advisable to delay cutting until late July and August to prevent the need for a second cut during the growth season. Cutting earlier in the year will also disturb waterfowl which tend to use emergent reeds, rushes and sedges to nest and reproduce between May and early July.

Dredging removes the rhizomes as well as the emergent shoots and so produces longer lasting control. It is, generally, too expensive to be used purely as a method of weed control. When it is anticipated that a reservoir or tank infested with rushes, reeds and sedges will require dredging it is advantageous to spray the emergent leaves with glyphosate before commencing. The herbicide will kill the rhizomes and prevent their growth on land on which the dredgings may be spread.

2.3.7.2 Chemical Control.

Reeds, rushes and sedges are all susceptible to the herbicide Glyphosate. (Refer to appendix II for a list of professional products). This herbicide is applied as a foliage spray directly on to the plants that require control. The herbicide is translocated into the rhizomes therefore killing the whole plant. Control will last for several seasons. As only the plants on to which the spray is directed are controlled, localised treatment of selected areas or individual reed beds can be achieved.

Glyphosate is a slow acting herbicide and plants which are sprayed late in the season show no obvious symptoms but appear to die back naturally in the autumn at the same time as the other plants. However, treated plants will not regrow the following spring.

Agreement must be obtained from the local Environment Agency office before application of herbicides in, on or near controlled waters. Product guidelines should always be followed. They should also examine the list of susceptible species to avoid any unwanted damage to crop plants.

2.3.7.3 Biological Control.

Cattle, and to a lesser extent sheep, graze on some types of rushes and reeds. Livestock can be used for biological control on large banks of a water storage reservoir where they will provide a cost effective form of managing grasses and terrestrial plants as well as bankside rushes and reeds. However, livestock can damage banks and trees and will require fencing in.

2.3.7.4 Environmental Control.

Because most emergent weeds are limited to water less than 1 metre deep it is sometimes possible to control them either raising the water level or by dredging. Where dredging becomes necessary in areas where emergent weeds become a problem, the creation of a steep bank descending immediately into the water of more than 1 metre in depth will limit the growth of these plants to a narrow fringe on the bank.

2.3.8 The Potential for using Grass Carp in Aquatic Growth Tanks.

The use of herbivorous grass carp (*Ctenopharyngodon idella*), is an option for the biological control of aquatic weeds in enclosed waters. Grass carp are inefficient digesters of food and, hence, good biological control agents as they must consume large quantities of plant material to obtain adequate nutrition.

Although described as non-selective control agents grass carp prefer soft tissued aquatic plants, filamentous algae and duckweeds (*Lemna* spp.)(Van der Zweerde, 1990). Detailed studies on the feeding habits of grass carp (Pine and Anderson, 1991), have revealed marked plant preferences. Their general dislike of fibrous species of aquatic plants has led to investigation of grass carp as suitable for use in aquatic nurseries.

Santha, Martyn, Neill and Strawn (1994) investigated the use of grass carp in the management of submersed aquatic weeds in a commercial waterlily production facility in Texas USA. Their experiment in a large pond lasted a year and used sixteen 7 m x 7.5 m enclosures each containing six waterlily plants (the tropical waterlily hybrid 'Robert Strawn' and the hardy waterlily hybrid 'Attraction'). Three different treatment methods (one grass carp per enclosure, two grass carp per enclosure, manual harvesting) and an untreated control were monitored for weed growth and effects of weed control on the growth of the two waterlily types.

Aquatic weed biomass, waterlily leaf surface area and waterlily flower production were measured each month for each enclosure. Waterlily plants growing in the untreated control had significantly lower leaf area than those in any of the other treatments. These control plants were fairly small with a leaf area of 0.162 m^2 one year after the experiment began. The average leaf area per plant in the manual harvest treatment, one carp and two carp treatments were 0.289m^2, 0.202m^2 and 0.238m^2 respectively. The grass carp stocking densities of 188 carp/ha and 376 carp/ha resulted in the complete elimination of submerged aquatic weeds and algae in 60 and 40 weeks respectively. Although weed harvesting appeared to result in greater waterlily plant growth this was not significantly different from the growth in the two carp treatments. Unlike the grass carp treatments this technique never resulted in complete weed control.

Manual harvesting techniques are naturally highly labour intensive and significantly more expensive than using grass carp. During the above experiment, 3 man hours per enclosure per month were required to remove weeds manually. This equates to 571 man hours/ha per month giving an estimated cost of $2,484/ha per month (or$29,806/ha per year), using $4.35 per man-hour (the minimum wage). Grass carp were purchased for $3 per fish and, so, effective weed control with grass carp would, theoretically, cost $564/ha per year at a stocking density of 188 carp/ha. This fish density, which controlled all weeds in 1 year, would produce savings of $29,242/ha per year. At the higher stocking density, savings would be $28,678/ha/year. Survival of the fish from year to year would increase this saving.

Although waterlily plants in enclosures were not damaged by the grass carp while aquatic weeds were present following weed elimination some plants were destroyed. Thus, removal, or reduction in the number of grass carp would be necessary when weed control was established. In practice this would require frequent monitoring of production ponds to avoid damage to crop waterlilies and so would increase control costs.

While the results clearly indicate that, under supervision, grass carp may successfully control aquatic weeds in waterlily production ponds, great care must be exercised. The feeding habits of grass carp may change under differing environmental conditions and degrees of stress. It is, therefore, essential to monitor carefully any introductions of grass carp to waterlily production ponds under UK conditions. As grass carp have been shown to have plant preferences (Pine and Anderson, 1991) it may be possible to use grass carp, at lower stocking densities, for the control of aquatic weeds in the growth tanks of plants such as *Myriophyllum spicatum* (Spiked Watermilfoil) and *Myriophyllum aquaticum* (Parrots Feather) that they dislike. This requires confirmation by detailed experimentation.

A licence for their use is required under the Wildlife and Countryside Act 1981 from the Ministry of Agriculture Fisheries and Food in addition to a permit from the Environment Agency (in England and Wales) or SEPA (in Scotland).

Section Three:
Future research.

3.1 Areas for future research.

•Although the use of barley straw is an effective, environmentally benign, method of algal control new methods of algal control should be developed.

Hydrogen peroxide. H_20_2 has been used successfully as a method of controlling blue-green algae in large reservoirs. Drip feeding of H_20_2 into inlet systems to maintain a concentration in the water of 2 ppm could be established as a method of algal control in small systems. Complicated feedback monitoring and measurement would be required to control the concentration of H_20_2 in the system. Further research is required to examine the effects of low doses of H_20_2 on submerged macrophytes and on filamentous algae.

Magnetic treatment of algae. Recent research has shown that domestic systems which claim to reduce scale by electronic means can affect the growth of filamentous algae in recirculating systems. The life time of the effect may be sufficient for adequate control to be achieved in small delivery systems. The diameter of the pipe feeding the water would have to be restricted and so this system would not work where the water is taken from a spring source or large diameter pipe (greater than 10cm). The effects of this 'magnetised water' on other aquatic plants and nursery crop plants requires investigation, although it has already been reported that it can increase yields of crop plants (Steadman, 1996). Further research is necessary to determine the mode of action and optimum application methods.

•Novel methods of treating duckweeds *(Lemna* spp.*)* are required. Their susceptibility to surface disturbance and factors determining their uptake of herbicides requires investigation.

•The possible use of grass carp for aquatic weed control in waterlily production ponds has been discussed. It is advisable to determine feeding habits and plant preferences under UK conditions to assess the viability of using grass carp in UK nurseries.

•Investigation of the use of grass carp in production ponds for fibrous aquatic plants other than waterlilies would be advantageous.

Questionnaire on the growth and control of Aquatic weed in nurseries and water storage reservoirs

Please return the completed questionnaire in the enclosed stamped and addressed envelope.
Any information collected in this questionnaire will be treated in the utmost confidence.

A. Your Nursery

1. Address of your Nursery: ______________________

____

____

____

____

2. Please tick the box which best describes your nursery.

Aquatic Plant Nursery ☐
Aquatic and Terrestrial Plant Nursery ☐
Terrestrial Plant Nursery ☐

3. Do you experience problems with the growth of Aquatic Weeds?

Yes ☐ Go to section B
No ☐ Please return the questionnaire.

B. Problems with Aquatic Weeds.

1. Where do you experience problems with the growth of Aquatic Weeds?

In Aquatic plant growth tanks and ponds ☐ Complete section C.
In Nursery water storage systems ☐ Complete section D.

C. Aquatic Weeds in growth tanks and ponds.

1. Which species of aquatic weeds do you experience problems with?

Species of weed	Frequency of problem	Period of problem
e.g. *Cladophora*	e.g. Every Year	e.g. May-September

2. What area of your growth tanks/ponds is affected by the growth of aquatic weed? (in m^2)

___

3. Does this weed growth affect the quality of your product?

Yes ☐
No ☐

If so in what way?

___

___

___

4. Have you attempted to control or treat these weeds?

Yes ☐ Go to the next question
No ☐ Go to section D

5. Which weeds have you treated? (please complete the table)

Name of weed	Treatment method(s)	Did it work?

6. Can you give an indication of the annual costs of treating each species of weed, including the estimated costs of labour, equipment and chemicals. Detailed cost figures are not required. Please estimate to the nearest £100. (please complete the table)

Name of weed	Estimate of manhours required (hours)	estimated cost of equipment purchased (£)	estimated cost of chemicals purchased (£)	**Total (£)**

D. Aquatic weeds in water storage systems.

1. What type of water storage system do you have?
(e.g. ponds/ tanks/ reservoirs/covered/uncovered)

____

2. What is the approximate volume of this system?

____

3. What type of water distribution system do you have?
(e.g. pipes/flowing channels etc)

____

4. Do you have problems with Aquatic weed growth in the distribution pipes/channels as well as in the water storage system?

Yes ☐
No ☐

5. Which species of aquatic weeds do you experience problems with and in what location?

Species of weed	**Frequency of problem**	**Period of problem**
e.g. *Cladophora*	e.g. Every Year	e.g. May-September

6. Does aquatic weed growth affect the quality of your water supply?

Yes ☐
No ☐

If so in what way?

____

____

____

7. Have you attempted to control or treat these weeds?

Yes ☐ Go to the next question
No ☐ Go to section E

8. Which weeds have you treated? (please complete the table)

Name of weed	**Treatment method(s)**	**Did it work?**

9. Can you give an indication of the annual costs of treating each species of weed, including the estimated costs of labour, equipment and chemicals. Detailed cost figures are not required. Please estimate to the nearest £100. (please complete the table)

Name of weed	Estimate of manhours required (hours)	estimated cost of equipment purchased (£)	estimated cost of chemicals purchased (£)	**Total (£)**

E. Future problems with aquatic weeds

1. Are there any species that you think may become a problem in the future?

____

____

F. Techniques suitable for controlling aquatic weeds in nurseries.

1. Would you benefit from the provision of a report reviewing techniques suitable for controlling aquatic weeds in nurseries?

Yes ☐
No ☐

Thank you for your participation, please return the completed form in the stamped and addressed envelope provided.

Appendix 2

Approved Professional Products for Use On or Near Water.

Active Ingredient	Product Name	MAFF Number
Asulam	Asulox	06124
2,4-D Amine	Atlas 2,4-D	03052, 07699
	Dormone	05412
	MSS 2,4-D Amine	01391
	Agricorn 2,4-D	07349
Dalapon/Dichlobenil Mix	Fydulan	06823, 00958
Dichlobenil	Casoron G	00448,06854,07926,08065
	Casoron GSR	00451,06856,07925
Diquat	Reglone	04444,06703
	Levi	07845
Diquat Alginate	Midstream	01348,06824,07739
Fosamine ammonium	Krenite	01165
Glyphosate	Barclay Gallup Amenity	06753
	Clayton Swath	06715
	Danagri Glyphosate 360	06955
	Glyfos	07109
	Glyfos 480	08014
	Glyfos Proactive	07008
	Glypher	07677, 07968
	Glyphogan	05784
	Helosate	06499
	Mon 44068 Pro	06815
	Mon 55276	06949
	MSS Glyfield	08009
	Roundup	01828, 03947
	Roundup Biactive	06941
	Roundup Biactive Dry	06942
	Roundup Pro	04146
	Roundup Pro Biactive	06954
	Spasor	03436,07211
	Spasor Biactive	07651
	Stetson	06956
Maleic hydrazide	Regulox K	05405
Terbutryn	Clarosan 1FG	03859
	Algae Kit	04545
	Blanc-kit	04546

Professional Products and their Marketing Companies.

Product Name	Marketing Company	Reg. No
Agricorn 2,4-D	Farmers Crop Chemicals Ltd	MAFF 07349
Algae Kit	Ciba Agriculture	MAFF 04545
Asulox	Rhone-Poulenc Agriculture	MAFF 06124
Atlas 2,4-D	Atlas Interlates Ltd	MAFF 03052
Atlas 2,4-D	Atlas Crop Protection	MAFF 07699
Barclay Gallup Amenity	Barclay Chemicals (UK) Ltd	MAFF 06753
Blanc-Kit	Intercel (UK)	MAFF 04546
Casoron G	Imperial Chemical Industries Plc	MAFF 00448
Casoron G	Zeneca Professional Products	MAFF 06854
Casoron G	Miracle Professional	MAFF 07926
Casoron G	Zeneca Crop Protection	MAFF 08065
Casoron GSR	Imperial Chemical Industries Plc	MAFF 00451
Casoron GSR	Zeneca Professional Products	MAFF 06856
Casoron GSR	Miracle Professional	MAFF 07925
Clarosan 1FG	Ciba Agriculture	MAFF 03859
Clayton Swath	Clayton Plant Protection (UK) Ltd	MAFF 06715
Danagri Glyphosate 360	Danagri ApS	MAFF 06955
Dormone	Rhone-Poulenc Amenity	MAFF 05412
Fydulan	Imperial Chemical Industries Plc	MAFF 00958
Fydulan	Zeneca Professional Products	MAFF 06823
Glyfos	Cheminova Agro (UK) Ltd	MAFF 07109
Glyfos 480	Cheminova Agro (UK) Ltd	MAFF 08014
Glyphos Proactive	Nomix-Chipman Ltd	MAFF 07800
Glypher	Nufarm UK Ltd	MAFF 07677
Glypher	Pan Britannica Industries Ltd	MAFF 07968
Glyphogan	Makhteshim-Agan (UK) Ltd	MAFF 05784
Helosate	Helm AG	MAFF 06499
Krenite	Dupont (UK) Ltd	MAFF 01165
Levi	Phoenix Scientific Innovation UK Ltd	MAFF 07845

Product Name	**Marketing Company**	**Reg. No**
Midstream	Imperial Chemical Industries Plc	MAFF 01348
Midstream	Zeneca Professional Products	MAFF 06842
Midstream	Miracle Professional	MAFF 07739
Mon 44068 Pro	Monsanto Plc	MAFF 06815
Mon 55276	Monsanto Plc	MAFF 06949
MSS 2,4-D Amine	Mirfield Sales Services	MAFF 01391
MSS Glyfield	Mirfield Sales Services	MAFF 08009
Reglone	ICI Agrochemicals	MAFF 04444
Reglone	Zeneca Crop Protection	MAFF 06703
Regulox K	Rhone-Poulenc Amenity	MAFF 05405
Roundup	Monsanto Plc	MAFF 01828
Roundup	Schering Agrochemicals Ltd	MAFF 03947
Roundup Biactive	Monsanto Plc	MAFF 06941
Roundup Biactive Dry	Monsanto Plc	MAFF 06942
Roundup Pro	Monsanto Plc	MAFF 04146
Roundup Pro Biactive	Monsanto Plc	MAFF 06954
Spasor	Rhone-Poulenc Environmental Products	MAFF 03436
Spasor	Rhone-Poulenc Amenity	MAFF 07211
Spasor Biactive	Rhone-Poulenc Environmental Products	MAFF 07651
Stetson	Monsanto Plc	MAFF 06956

Adapted from: Pesticides 1997, Pesticides approved under The Control of Pesticides Regulations 1986 (Anon, (MAFF/HSE), 1997).

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