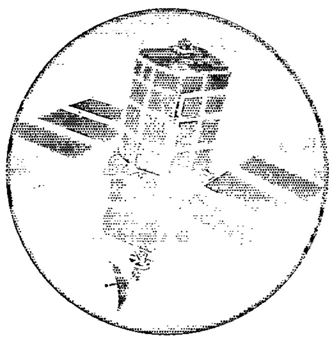
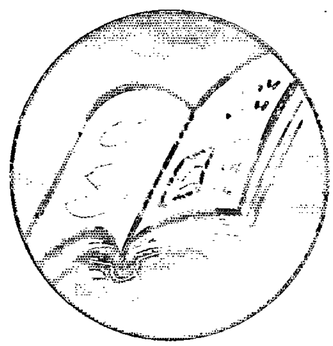
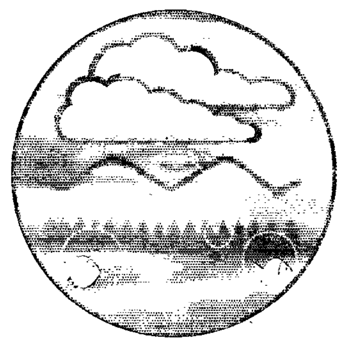
Aquatic Weed Control Operation
Best Practice Guidelines

Research and Development

Technical Report
W111

ENVIRONMENT AGENCY

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Aquatic Weed Control Operation
Best Practice Guidelines

R&D Technical Report W111

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Research Contractor:
IACR Long Ashton Research Centre
Centre for Aquatic Plant Management

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Statement of use
This document is to be used by the EA as a source of advice and information on the control and management of aquatic weeds. The document contains advice on the best practice options for the control of individual weed species and communities of weeds using mechanical, chemical, biological and environmental methods of control.

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FOREWORD

In prehistoric times, when man was a hunter-gatherer and tried to catch fish, he must have known that water weeds could be a nuisance; anglers still complain about weed growth. Agriculture and urbanisation have exacerbated the problems caused by water weeds, so that flood defence is now the major reason why weed control is necessary in many of our rivers. If the channels were not kept clear and the weeds controlled, most of the Grade 1 agricultural land in England would flood regularly with enormous loss of crops, livestock and livelihood, if not lives, of the people living and working in the country. Many low-lying towns and cities would also flood with incalculable social and economic costs. The fact that flooding caused by, or exacerbated by, excessive weed growth occurs only rarely shows that the estimated £5 million, spent annually by the Environment Agency on weed control, is well justified. It is likely that this cost is an underestimate because weed growth can cause banks to erode, silt to deposit, water quality to deteriorate and safety to be jeopardised. All these incur costs to the Environment Agency which are not always attributed to weed growth. Thus, the true cost of managing watercourses to prevent or repair the damaging results of weed growth may be far higher.

In 1982 the Aquatic Weeds Section of the Weed Research Organisation undertook a survey, within the Water Authorities and Internal Drainage Boards, of the extent of aquatic weed problems. The survey showed that most water managers considered that weed problems had increased over the previous 10 years. Less weed could be tolerated because more use was being made of the water and waterspace and more weeds were growing in the channels. If a similar survey were to be carried out in 1998, it would probably produce the same result and might also show that, not only have weed problems continued to increase, but that the species involved have changed. For example, problems caused by algae, particularly blooms of blue green algae, which increased suddenly around the start of the drought in 1989 and 1990, are more common. What is perhaps, more worrying, is that these blooms of blue green algae appear to be continuing, even though rainfall has subsequently returned to normal levels. Other weed problems have also changed. It seems likely that emergent weeds also benefited from the reduced water levels following the drought and spread into water which was previously too deep. Plants which were once considered rare or uncommon, such as the Water Fern (*Azolla filiculoides*), or Fringed Water-lily (*Nymphoides peltata*), are regularly reported as causing serious weed problems.

Irrespective of the reason why these changes have occurred, when a new weed problem arises management practices and methods of weed control must be reviewed. Control techniques which have worked well in the past may become inappropriate. New management practices may need to be introduced or old ones extensively modified. Even where the situation remains unchanged, management practices need to be reviewed periodically to ensure that they are providing the optimum level of service required for a particular watercourse. This document aims to supply the water manager with a set of Guidelines which allows him to select the most cost effective and environmentally acceptable form of weed control.

In preparing these Guidelines, many people have contributed their time and expertise. In particular, we would like to thank Lesley McGillivrey, who, in the early stages of the project, visited every Region in the Environment Agency to collect data and results from engineers, biologists, fishery and conservation officers. Special thanks are also due to all those officers in the Environment Agency, IDBs and British Waterways who gave their valuable time to answer questions and to contribute in many ways to the information presented here. Joe Caffrey of the Central Fisheries Board, staff of the Office of Public Works in Ireland and staff of the Fleverwaard Watershap in the Netherlands were of great assistance in showing us their weed problems and the techniques they are using to overcome them. Dr Hugh Dawson of the Institute of Freshwater Ecology contributed valuable information from his research on the effects of weed cutting and on the use of trees to create shade.

The Steering Group, consisting of David Woodcock (Project Leader, Midlands Region), Gary Lane (Topic Leader, Southern Region), John Fitzsimons (Midlands Region, previous Topic Leader), Ian Hart and Geoff Beel (Anglian Region) and Bill Grigg (South Western Region), all gave excellent advice and guidance and were of enormous help in arranging trials and demonstrations of various weed control operations.

Thanks are also due to the staff of the Centre for Aquatic Plant Management who helped with this project. In particular, Gina Snowden worked tirelessly typing the manuscript and all the amendments and additions.

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P R F Barrett
1998

EXECUTIVE SUMMARY

In many river and drainage channels, aquatic weed control is an essential part of the management regime. If well planned and executed, it can be cost effective and environmentally beneficial; if poorly executed, it can be expensive, environmentally damaging and of limited benefit.

These Guidelines provide a source of information on the range of weed control techniques available, with guidance on the selection of best practice options.

It must be borne in mind that weed problems and the techniques to combat them are constantly evolving. Similarly, the legislative frame applicable to management of water also changes. These factors may have a significant impact on selection of best practice.

The biology and ecology of aquatic weeds and the environmental implications of weed control operations are outlined, to ensure that optimum techniques can be selected, and adverse impacts minimised.

The performance of different mechanical, chemical, biological and environmental control techniques are described, with flow charts to aid selection. Integrated management, aimed at reducing costs and enhancing performance, is also described.

All the common aquatic weed species are described individually, together with the control options appropriate to those weeds. Control recommendations include those which can be applied selectively to control only the target weed species, or applied locally to limit the area of control where such techniques exist.

The selection of the "best practice" for weed control in any water body must combine cost-effectiveness with environmental acceptability. In order to achieve this, clear, long-term, management objectives on the level of service must be flexible and capable of dealing with changing weed problems.

Addresses of machinery and herbicide manufacturers, a list of approved herbicide products and advice on the management of SSSIs and other sensitive areas, is provided. A bibliography is included.

KEYWORDS

Aquatic weeds, weed control, mechanical control, chemical control, biological control, environmental control, integrated management, herbicides, ecology, environmental impact, channel management.

1 INTRODUCTION

One of the more difficult aspects of river management is to reconcile the wide range of responsibilities and interests, including flood defence, water quality, fisheries, recreation and conservation, which can be affected by maintenance operations. The control of aquatic weeds is one area where these interests have to be balanced. Flood defence for both agricultural and urban requirements relies on effective drainage, thus channels must be clear, open and effective weed control is essential. Most rivers are also fisheries, needing weed to be retained to provide spawning sites and cover for fish, and fish-food organisms. Conservation, generally, requires minimum ecosystem disturbance, to preserve as wide a range of habitats as possible. All these objectives are directly affected by the growth of aquatic weeds and their management. At first sight it may seem that these objectives are difficult or impossible to reconcile. The purpose of the Guidelines is to show how good management can balance these objectives and how a predetermined degree of control can be achieved in the most cost effective and environmentally sensitive way, minimising the potential conflicts between the various interests.

"Best Practice" implies that there is only one answer to a weed problem. This is clearly not true; many factors influence the selection of the most appropriate method of control. These include the type of weed, the size of the watercourse, the scale of the weed problem in it, the level of service required and any specific requirements of flood defence, recreation and conservation which are unique to that particular watercourse. These factors must be identified and given some order of priority by the local manager, in consultation with other interested parties, before deciding the "Best Practice" management for a particular situation. Once the level of service has been agreed and any other specific requirements have been identified, these Guidelines can provide information as to how that level of service can best be achieved.

All the factors mentioned above are liable to change, often in an unpredictable way. Similarly, the legislation concerned with water and its use is not static. Thus, these Guidelines must not be viewed as being definitive. They will require periodic revision to account for the evolution of aquatic ecosystems and any changes in management or legislative requirements.

1.1 Structure of the guidelines

The guidelines are a reference document on specific aspects of aquatic weed control and a source of background information and advice on good management practices. They cover both the specification and operational aspects of weed control.

- Section 2 provides general information on the biology and ecology of aquatic plants and how this affects the selection and application of weed control techniques.

- Section 3 shows how weed control, and other forms of management, can affect the aquatic environment and change the spectrum of aquatic weeds.

- Section 4 describes mechanical, chemical, biological and environmental techniques of weed control and discusses the relative advantages and disadvantages of each. It also covers the disposal of aquatic weed and describes ways of minimising associated costs and problems.

- Section 5 is a reference section in which the control of individual weed species is described in detail. Specific information on aspects of the biology and reproduction of most common aquatic weeds, which may affect control methods. The methods are discussed with recommendations for their use, timing and limitations.

- Section 6 provides information on machinery and herbicide manufacturers, management procedures where SSSIs form part of, or are adjacent to, rivers and notes on the preservation of habitats for fish, mammals and birds. There is also a reference list and recommended additional reading.

2 ECOLOGY OF AQUATIC WEED CONTROL

2.1 Introduction

Aquatic plants are a very valuable part of the aquatic ecosystem. They are a primary food source for aquatic fauna and provide habitats, egg laying sites, and shelter for a wide diversity of wildlife. They protect the banks and bed of the river from erosion and help to modify the velocity of water. They absorb or degrade pollution and improve water quality. They become nuisance weeds when their growth becomes excessive and they adversely affect the functions of the channel or the wildlife in it. At this point, some form of plant management becomes necessary. Good management should aim to encourage a diversity of plant species and prevent any one species or group to become so dominant that it harms either human or wildlife interests.

2.2 Reasons for Weed Control

Weed control in a watercourse becomes necessary, most commonly, when aquatic weeds reduce channel capacity, increasing the risk of flooding and waterlogging of adjacent land. This occurs principally in summer when the growth of most weeds is at its maximum. However, the dead stems and leaves of many emergent weeds may persist into the autumn and winter and impede winter flows. Weeds may also cause silt beds to build up, impeding flow and increasing the need for dredging.

Weeds interfere with navigation, fishing and other forms of recreation. Again, these problems tend to occur mainly in summer and autumn, when the majority of boat traffic and recreational activities take place. However, where frequent boat movements occur, weed growth is limited both by the chopping action of propellers and by increased turbidity, by increased surface water disturbance.

Detached weeds and algae drift downstream and may block pumps, sluices and filters. Weed screens help to remove larger plants but filters become blocked by small fragments of weed and by algae.

Some weeds, primarily algae, can deoxygenate water, killing fish and invertebrate animals, especially in hot, calm periods. This is caused most frequently when blooms of algae absorb large quantities of oxygen at night by respiration, producing very low oxygen levels around dawn, when, in normal conditions, the oxygen level is at its lowest. This often results in the death of fish at this time.

Floating plants, such as Duckweed (*Lemna* spp.) and the Water Fern *(Azolla filiculoides),* also cause deoxygenation by covering the water surface and preventing light from reaching submerged plants. Very occasionally, submerged weeds cause, or contribute to, deoxygenation. Usually this occurs only during extremes of weather when a sudden die-off of the plants occurs. An example occurred in the River Wye in 1976, when water temperatures became so high, and the flows were so low, that the Water Crowfoot (*Ranunculus* spp.) died, contributing to the death of many salmon.

Apart from adverse effects on wildlife, deoxygenation can result in serious odour problems and complaints from residents living close to the water. Excessive weed growth, especially of algae, can also lead to taint problems in abstracted water. This can be particularly severe if associated with deoxygenation.

Excessive weed growth can be very damaging to habitats, mainly when a single species becomes so dominant that it prevents growth of other plants. Areas of open water, which are essential for many fish and other forms of wildlife, are lost and habitats become impoverished.

Aquatic weeds can have a number of other adverse effects. They harbour pests and diseases, damage structures and cause gauging weirs to give false readings. However, weeds also have beneficial effects and total eradication of all weed would be as damaging to a river ecosystem and to the management of the river, as would the absence of any weed control.

Some understanding of the types of aquatic plants, the factors which make them potentially troublesome and their ability to survive and reproduce is necessary when trying to establish the best aquatic weed control practice. This does not require detailed knowledge of every species of aquatic plant but does involve a few simple facts and the application of common sense. This process is outlined in the following sections.

2.3 Identification of Weeds

Before considering the methods of controlling a weed problem, it is essential to identify the weed. In the first instance, weeds can be identified as being in the categories shown below.

2.3.1 Emergent Weeds

Plants which grow with the majority of their stems and leaves above water level throughout most of the summer.

This group contains the majority of problem-causing emergent weeds, including rushes, reeds, sedges and grasses. Almost all members of this group are perennial plants, overwintering as rhizomes buried in the sediment. Long, narrow leaves emerge in the spring, either growing from the base of the plant, or produced on tall erect stems. They grow in water up to about 1 m deep. Flowers are usually inconspicuous, dull yellows, browns or greens. Most species produce seeds, but the majority of spread is by rhizome growth.

These plants may be locally troublesome but seldom produce the extensive growth of the narrow-leaved species. Examples include Watercress, Water Mint, Water Dock and Water Plantain. Plants may be annuals, biennials or perennials. Leaves may emerge from the base of the plant or are carried on stems. They do not usually grow in water more than about 0.5 m deep. Flowers are usually conspicuous and viable seeds are produced in large quantities.

2.3.2 Floating-leaved plants

The upper leaf surface has a waxy cuticle which encourages water to run off the leaf and keeps it dry. Leaves normally float on the water surface but may be forced above the water surface when dense infestations occur.

These plants grow from rhizomes buried in the sediment, and produce the leaves on long stalks, which grow until the leaf blade reaches the surface. Examples include the Water-lilies, Broad-leaved Pondweed and Amphibious Bistort. They are most common in water less than 1.5 m deep. Flowers can be conspicuous (eg Water-lily), or dull yellows and pinks (eg Pondweed). Some viable seed is produced but spread is mainly from rhizome growth.

The most common free-floating plants are Duckweeds and the Water Fern (*Azolla filiculoides*). They can grow in any depth of water but are not tolerant of waves of turbulence, and are flushed away in fast flowing waters. They are annuals, which overwinter as spores (eg Water Fern), or as turions (eg Duckweeds). Growth rates are rapid and a surface cover of the water can become several centimetres thick within a few weeks, particularly when wind or currents force the floating fronds into a confined space.

2.3.3 Submerged plants

These are plants which grow mainly below the water surface but are rooted in the sediment. They may grow up to the surface and flowers may be carried at or above, water level. The leaves do not have a waxy cuticle and become desiccated if they are exposed to air.

Submerged plants can form dense beds which impede water movement. They can grow in almost any depth of water, provided sufficient light penetrates to the surface of the sediment. Examples include Water-crowfoots, Water Milfoil, Canadian Waterweed and many species of Pondweed. Flowers are usually borne at the water surface, and some seed production occurs, although almost all submerged weed species reproduce readily from fragments, which become detached by mechanical action, or by grazing animals.

A few submerged weeds do not produce roots, but drift freely in the water, or become entangled with other rooted weeds. Examples include Rigid Hornwort and Ivy-leaved Duckweed. They are found mainly in static, or slow flowing waters, and do not generally cause management problems when growing in isolation, but may contribute to an overall problem when growing in communities with other submerged weeds. Spread occurs mainly by vegetative growth.

2.3.4 Algae

Although there are several thousand species of algae with many different growth forms and habits, the two most common and easily identifiable forms are filamentous and unicellular algae. They are simple plants, which reproduce by dividing to form two new cells, or by producing spores. Spores are also produced under adverse conditions, and in autumn as a method of surviving over winter.

Filamentous algae are also called Blanket Weed or Cott. Most species die back in autumn and grow from spores or fragments in the following spring. The spores are usually attached to the sediment or to submerged plants, but when the mass of filaments becomes thick enough, it traps bubbles of oxygen, which causes it to float to the surface, where growth continues. Eventually, the floating mats of algae cover the surface, forming a blanket of green, sometimes slimy filaments. These are particularly troublesome in slow flowing waters, but are flushed away in faster flowing rivers.

It is not strictly accurate to call all other algae unicellular, because they can exist in colonies of two or more cells, or may even form fine filaments, but to the naked eye, they are too small to see individually and appear as a green turbidity, or scum, in the water. Cell division can be very rapid, and dense blooms may form within a few days, sometimes persisting for months, or disappearing rapidly, only to reappear again later. This group also includes the blue green algae, Cyanobacteria, which can produce toxins.

These categories are useful when discussing the type of problem that exists in a watercourse. However, identification down to species level is necessary, firstly to select the most appropriate method of control, secondly to apply the control at the optimum time of year and, thirdly, to prevent any adverse consequences. For example, poisonous plants, such as Dropwort or Common Ragwort, may be present, even if they are not the primary weed species. These weeds are normally avoided by livestock but become palatable after cutting or spraying and can be consumed, especially if cut material is deposited on the banks.

There are many books on aquatic plant identification. For general use, the book "Aquatic Plants: A Guide to Recognition" by Spencer-Jones and Wade is recommended. It contains colour photographs of common aquatic weeds and a brief description of their biology. It also contains a reference list of other, more detailed, books on weed identification.

2.4 Growth Habits and Life Cycles of Weeds

As well as being able to recognise nuisance aquatic plant species, a knowledge of their growth habits is essential for good river management. Some aquatic plants are able to adapt their growth form to suit local conditions while others always have the same appearance, and vary only marginally in size. An example of the latter is Common Reed (*Phragmites australis*) which always grows as an emergent plant with erect stems reaching up to 3 m high. An example of the former is Common Clubrush (*Bulboschoenus lacustris*). Although normally seen as an emergent plant growing to about 3 m, in fast flowing water it can produce submerged and floating leaves which appear similar to Unbranched Bur-reed (*Sparganium emersum*). In some situations, both leaf types occur together but in others only one is present. Another example is the Yellow Water-lily (*Nuphar lutea*). This plant produces both floating and submerged leaves but, in flowing water, the former may be absent. The submerged leaves are sometimes called "Cabbage-lily" because they appear similar to the outer crinkly leaves of a cabbage.

There are numerous examples of variations in the growth form of aquatic plants, because they are able to adapt their form to suit local conditions. Water depth and velocity are probably the two most important factors which influence growth form.

The selection of control methods must take local variations in habit into account. For example, application of a foliage applied herbicide will be inappropriate if the plant is only producing submerged leaves.

Many emergent, floating, and some submerged aquatic plants are perennial, overwintering as rhizomes (underground stems) buried in the mud and producing shoots in the spring. Cutting the shoots has little effect on the rhizomes and eradication will only be achieved by methods which remove or kill the rhizomes. Although many of these perennials also flower, only a few produce viable seeds in significant quantities, (e.g .Bulrush, *Typha latifolia*) and regrowth from seedlings is not common. However, some aquatic plants are annuals and regrowth each year is totally dependent on seeds (e.g. Starworts, *Callitriche* spp.). Other vegetative and sexual methods of reproduction employed by aquatic plants include spores, produced by algae and the Floating Fern *(Azolla filiculoides),* and tubers and turions produced by plants such as Fennel Pondweed *(Potamogeton pectinatus)* and Duckweeds *(Lemna* spp.) respectively.

All of these mechanisms not only help the plant to reproduce and to survive adverse conditions, but help to overcome attempts to control it. The efficacy of control can be significantly improved if these survival techniques are taken into account when selecting the type and timing of control methods. For example, controlling an annual weed after it has produced seed will have little or no effect on the numbers of plants regrowing in the following season.

2.5 The Cause of a Weed Problem

Aquatic plants only become a problem if their biomass becomes excessive. This occurs because the conditions are highly suitable to that particular weed or group of weeds. In general, the conditions which suit aquatic plants can be summarised as good availability of nutrients, light, carbon dioxide, an adequate depth of water with a tolerable velocity and (for most species) a suitable substrate into which they can root. However, within these general conditions, there is considerable variation between the requirements of individual species. This is why weed problems vary so much between different Regions, between individual rivers systems and even between different reaches of one river. For example, Water Crowfoots (*Ranunculus* spp.) can be a serious problem in fast flowing chalk streams but are never present in any quantity in slow flowing clay rivers.

Generally, one of the main causes of increasing weed problems is a rise in the quantity of nutrients in the water or eutrophication. Nutrients enter the water from sources such as sewage, industrial effluents, as fertilizers in run-off, and drainage from farmland and forestry. Attempts, such as limitations on the use of nitrate fertilizers in nitrate sensitive areas, are being made to reduce the quantity of agricultural fertilizer entering watercourses. Where the Environment Agency has the authority to control the discharge of sewage or industrial effluents, this should be used to limit the quantity of nutrients entering watercourses as much as possible. Although this is a long-term approach, it is one of the best ways of preventing the development of weed problems.

Conventional forms of weed control, using cutting or herbicides, will not affect water conditions sufficiently to prevent the return of the problem weed or of any other species with similar requirements. Techniques, (*e.g.* shade, channel re-sectioning) which alter conditions sufficiently to permanently prevent the return of a weed problem, are discussed later. However, these are long-term projects which cannot be applied universally. Even where they are applied, conventional control measures may still be required for a considerable period.

During weed control operations, it is often tempting to remove as much weed as possible in the interests of short term efficiency and with the intention of reducing the frequency of weed control.

However, this creates space, which may be invaded rapidly by other troublesome species. Therefore, the best practice of weed control in rivers must recognise that, no matter how effective a control measure may be initially, weeds will return and some form of regular control will be required.

The frequency of control will depend on the following factors:

- The effectiveness of controlling the existing weed
- The rate of recovery or recolonisation of the weed (or another weed)
- The size of the area controlled

2.6 Timing of Weed Control

The optimum time for a weed control operation depends on three factors.

- the species of weed determines how quickly it grows and when control is most likely to be needed
- the preferred method of control will be effective for only a limited period in the year. Unfortunately, limitations of staff and equipment sometimes make it necessary to start weed control activities before, or continue them after, the optimum time and this can reduce effectiveness.
- avoiding or minimising risk to the other components of the ecosystem, especially during nesting or spawning periods.

In order to consider timing of weed control in more detail, it is necessary to look at both the methods and weed groups. Recommendations for timing, as a general guide, are given below and details of timing of control of individual weeds are given in Section 5.

2.6.1 Timing of Weed Control Operations

The following table gives an indication of the optimum time for various weed control operations to be carried out. These timings are subject to variations caused by geographical or seasonal differences.

Table 2.1 Timing of weed control operations

TIME	TARGET WEEDS	TECHNIQUE
April - early May	Submerged weeds & algae	Dichlobenil and terbutryn
May - July	Water Crowfoot	First cut
Late May - June	Submerged Weeds	Diquat or diquat alginate
Late May - June	Common Reed	Glyphosate
Late May - July	Free-floating weeds	Diquat or glyphosate
July - August	Emergent, floating, submerged and algae	Cutting/raking
July - August	Water-lilies	Glyphosate
August - early September	Emergent weeds	Glyphosate
September - October	Water Crowfoot	Autumn cut
September - December	Emergent weeds	Channel cleaning/cutting

2.6.2 Cutting of emergent weeds

Early season cutting of most emergent weeds results in rapid regrowth, and the need for a further cut later in the season. It is also most damaging to birds and invertebrates, which use these plants during their reproductive cycle. Therefore, cutting of emergent weeds is not normally recommended until July, at the earliest. Many emergent rushes and reeds remain standing after they have died back in the Autumn, and cutting of the dead vegetation can continue through the Autumn to clear watercourses for winter flows.

2.6.3 Cutting of rooted floating and submerged weeds

Rooted floating (e.g. Water-lilies) and submerged weeds can both regrow rapidly after cutting - which should, therefore, be delayed until as late as possible. The timing of cuts will be determined by a local assessment of flood risk (or other adverse effect) produced by the weed growth. Later cuts reduce the risk that regrowth will occur, necessitating a second cut. However, when the weed is cut late, there may be significant quantities of weed requiring disposal. Recent (Waste Management Licensing Regulation, 1994) requiring the disposal of cut weed in recognised tips, has added to the costs of this type of weed control, especially when the weeds are cut and collected in large quantities. In some instances, it has been more cost-effective to cut the channel frequently, like mowing a lawn, so that the quantity of weed produced by each cut is small and removal and disposal costs are minimised.

2.6.4 Cutting of free-floating weeds and algae

Conventional cutting techniques are totally ineffective against these weeds. Raking and skimming techniques can help to control some free-floating weeds, and filamentous algae, but fragments always remain and lead to rapid regrowth. Where mechanical control is the only option available, regular operations are likely to be necessary throughout the season.

2.6.5 Herbicides on emergent weeds

Spray applications are normally most effective in mid to late Summer, although some weeds (e.g. Common Reed) can be controlled effectively by spraying as early as mid May. Spraying after mid September is not usually recommended, in case early frosts cause die-back before the herbicide has been fully absorbed and translocated to the roots and rhizomes.

2.6.6 Herbicides on floating weeds

Rooted floating weeds (e.g. Water-lilies) can be sprayed after full leaf emergence, usually in July or August. In some instances, they can also be controlled by herbicides applied to the water in the Spring, before leaf emergence takes place. Free-floating weeds (e.g. Duckweed) can be controlled by spraying at any time when the fronds are present but before the layer of floating fronds has become more than one or two layers thick. After this, the herbicide will be absorbed by the upper layers, and the lower layers will remain undamaged. Sometimes, these plants can also be controlled by a herbicide added to the water early in the Spring.

2.6.7 Herbicides on submerged weeds and algae.

These herbicides should normally be applied in the Spring or early Summer when the plants are young and growing actively. Later in the season, the plants tend to be less susceptible to the herbicide and there is an increased risk of causing deoxygenation by killing large quantities of weed when water temperatures are higher and dissolved oxygen levels low. Localised control with special herbicide formulations is sometimes possible in summer when small areas of weeds can be controlled. Deoxygenation is prevented by diffusion of oxygen from the surrounding undamaged plant community.

2.6.8 Biological and environmental control of all weeds.

These tend to be slow acting, long-term processes, and timing is generally less important than for mechanical or chemical control. Timing is generally governed by the requirements of the method, rather than those of the weed (e.g. trees to create shade are best planted in Autumn to ensure good survival of the trees).

2.7 Changes in Weed Species

Some weeds form very stable populations which continue to grow in the same location for many years. Others can suddenly appear in a river, remain for a year or longer and then disappear with equal rapidity. In general, the larger emergent and floating plants are more stable than small plants such as Duckweed and the Floating Fern (*Azolla filiculoides*). Even submerged weeds such as Canadian Waterweed *(Elodea canadensis)* and Fennel Pondweed (*Potamogeton pectinatus*) have been observed to decline suddenly, for no known reasons, from being serious problems to being present only as a few isolated individuals. These changes are unpredictable, and, while relatively infrequent, reinforce the need for some flexibility in an approach to long-term weed control planning.

2.8 Long-term Effects of Weed Control

Regular weed control will affect the range of plant species present in a river in the long term, although it may not alter the quantity of weed present each year. Plant species susceptible to a particular form of weed control will gradually be eradicated and replaced by tolerant species. This has already happened in many waters where regular annual weed cutting has taken place. In some drainage systems, repeated use of herbicides has changed communities dominated by higher plants to those dominated by algae. The value of herbicide treatment depends on wise, careful use, to suppress, rather than to eradicate, troublesome weeds within a community.

In a river regularly managed by a particular method, which is cost-effective and environmentally acceptable, it may be 'best practice' to maintain the same management. Unfortunately, several factors can affect the types of weed present in a river over a long period. Water abstraction or periods of drought can reduce flows and lower river levels, land drainage and urbanisation may alter flow patterns and nutrient levels. These effects lead to changes in the types of weed and, so, to the need to adapt weed control techniques.

An example of the changes to weed composition in recent years is the reduction in the growth of Water Crowfoot (*Ranunculus* spp.) in many chalk streams, which appeared to be associated with the drought between 1989 and 1992. Often, Water Crowfoot was replaced by extensive growths of the filamentous alga *Cladophora*, which benefited from the lower velocities and, probably, from higher concentrations of nutrients. At the same time, the lower water levels allowed emergent weeds to spread into the channels, restricting the flow to a narrower bed width. The resultant increase in velocity may have favoured the survival of the Water Crowfoot, nevertheless, control of algae and emergent weeds requires a different approach from the traditional cutting of Water Crowfoot. Subsequent increased rainfall has encouraged the return of Water Crowfoot, with a possible decline in the filamentous algae, but has had little effect on the emergent weed.

Thus, in the long term, it is unlikely that any one method of control will remain as the "best practice" option for a particular watercourse.

2.9 Conclusion

There is little likelihood that weed problems will diminish in the future. Indeed, the need for weed control may increase as a result of growing demands for abstraction, and recreational use of water. This means that less weed may be tolerated, and regular maintenance will be required. The selection of the "best practice" for weed control in any water body must combine cost-effectiveness with environmental acceptability. In order to achieve this, clear, long-term, management objectives on the level of service must be flexible and capable of dealing with changing weed problems.

3 ENVIRONMENTAL IMPLICATIONS OF AQUATIC WEED CONTROL

3.1 Introduction

The ecology and impact of weed control on river ecosystems is well covered in The New Rivers and Wildlife Handbook, published jointly by the RSPB, Environment Agency and Wildlife Trusts. It gives many examples of how good management can be used to enhance river ecosystems, to the benefit of wildlife, without adversely affecting land drainage which, especially in lowland areas, is often the primary function of the river. The management of smaller watercourses and drains is described in Nature Conservation and the Management of Drainage Channels, published by the Nature Conservancy Council and the Association of Drainage Authorities. The purpose of this section is to summarise and reinforce the main points in these two documents.

Within any ecosystem, there is both competition between species and dependency of one species on another. Over a number of years these lead to a relatively stable ecosystem in which the plants and animals co-exist in a dynamic balance. As the conditions change, so the balance changes, but, under natural conditions, the conditions generally change only slowly and the ecosystem has time to adapt. However, human influences can produce changes to the ecosystem which are too rapid and too fundamental for this balance to be maintained and often lead to violent swings in numbers of individual species.

Plants are the primary producers on which all other species depend, and sudden changes in the species, and numbers of plants in a river, influence all other components of the ecosystem. Clearly, any human activity which affects plants will affect the whole community. This applies to abstraction, water level management, nutrient inputs, land drainage and other activities, as well as weed control operations.

Many of these activities tend to encourage plant growth which, without the natural checks and balances, leads to excessive growth. The plants then cause problems and must be controlled, leading to further destabilisation of the ecosystem, and often to yet more plant growth. Once an ecosystem has been destabilised so much that a major weed problem has developed, it can seldom be left long enough to recover naturally and regular management is necessary. This applies particularly to the lowland rivers which have been dredged, impounded and restructured over many years. Although, generally regarded as natural habitats, most of these rivers are now so modified by human activities that they could not be returned to their former condition and will require periodic continued management to prevent further deterioration and loss of their value as an ecosystem. Careful and well applied weed control is an essential part of this management to improve the ecosystem.

3.2 Environmental Impacts of Weed Control

Weed control has three distinct impacts on the ecosystem. Two of these are almost invariably adverse in their effect on other components of the ecosystem, while the third may be good or bad depending on what is affected.

The first impact is a direct and immediate effect on non-target organisms. For example, weed cutting removes the weeds, and with them the eggs of invertebrates, fish and birds, and some of the adult animals hiding in the weed. Other forms of weed control do not have such a direct and immediate impact. Herbicides, for example, are tested to ensure that there is no direct toxic effect, provided that they are used correctly. Biological and environmental control techniques are usually too slow acting to produce a direct and immediate effect.

The second impact is an indirect effect resulting from the death of the weed. Inappropriate use of herbicides and weed cutting can result in large masses of weed dying and decomposing in the water. This causes deoxygenation and resulting mortality of fish and invertebrate animals. Cut weed must be removed from the water and the timing of herbicide applications carefully judged to prevent deoxygenation.

The third impact is the result of effective weed control and the consequent, unavoidable change in the habitat. Animals which depend on those weeds will be reduced in numbers, or migrate to untreated areas, while those which require open water will benefit. The longer the weed control lasts, the greater will be this effect. Neither barren water, without any plants, nor a dense monoculture of one species, are good habitats. The best habitats are, generally, those which contain a range of plant species with open areas around them. Diverse habitats, with many distinct boundaries between their components, are usually the richest in terms of the numbers of plants, invertebrates and fish which they can support.

The environmental considerations relating to good weed control practice should aim to minimise adverse environmental impact, and maintain a diverse habitat, with as many different weed species as possible, but without allowing any one of them to become so dominant that other habitats are destroyed.

3.3 Over Widening of Channels

In the past, it has been the practice in some rivers to dredge and enlarge the channel, with the mistaken impression that this would reduce future management costs. The combination of enlarged channels and reduced flows has produced wide, shallow, slow flowing channels which are ideal for weed growth. This has probably increased management costs. When the weed in these rivers are managed, it is tempting to clear the whole width of the channel. This recreates the same wide, shallow and empty channel, so that the same problem arises again. The alternative to this expensive and short-term approach is to clear only part of the channel. Most of the water flows in the cleared channel, which helps to scour the silt, and may even re-establish a gravelly bed, which grows less weed and, partly at least, restores the original habitat.

3.4 Environmentally Sensitive Management

There is no evidence that any particular method of weed control is intrinsically more or less environmentally damaging than any other. All methods can be damaging if used wrongly, or in the wrong situation. Weed control will have the greatest impact where it is applied to large areas and the entire habitat is altered. A localised and selective application, removing only some of the plants in particular sites, will minimise environmental impact without adding to costs.

Where a river is of special value, because of the presence of a rare plant or animal, or for some other reason, the first reaction is to leave it alone. Such valuable sites may, however, result from prolonged use of a particular form of management, and the best way to conserve them is to maintain the same form of management. In general, any change to the management is likely to alter the environmental impact and habitat structure, especially if it is applied on a large scale. Thus, in sites which have special environmental value, very careful thought should be given before a new form of management is introduced. Rare plants or communities require special consideration of their legal status, as many species are protected under the Wildlife and Countryside Act 1981. If there is any doubt about the environmental status of a site, or the presence of rare plants, it is advisable to contact the local office of English Nature or the Countryside Council for Wales.

The management of rivers in or close to Sites of Special Scientific Interest (SSSIs) is subject to special rules. These are outlined in Section 6.4.

3.5 Water Level Management Plans

The management of some rivers is likely to be affected by the Water Level Management Plans currently being introduced. The objectives of these plans are set out in a document "Water Level Management Plans, A Procedural Guide for Operating Authorities" published by MAFF, The Welsh Office, ADA, English Nature and the Environment Agency. These Plans will apply particularly to watercourses where the flow is controlled so that water levels can be managed. The objective is to ensure that water levels are maintained in ways which take into account the interests of agriculture, flood defence and conservation. Each plan will prescribe the timing and nature of maintenance activities, including weed control, which may affect water levels. Where the plan calls for a change in the current water level, or in the range of acceptable water level tolerance limits throughout the season, it is likely that this will affect the weed composition or density. It is difficult to predict changes in weed populations in particular situations. In general, increased water depth will discourage emergent and floating weeds but, if water depth is increased, velocity will fall (given a constant discharge) and growth of submerged weeds and algae may, then, be encouraged. River managers should anticipate, therefore, that any change in current water level management may change the weed composition and density, necessitating modified weed control regimes.

4 WEED CONTROL TECHNIQUES

4.1 Introduction

Traditionally, aquatic weeds were cut by hand using scythes or chain scythes. This was partly for control purposes but also because some aquatic plants were harvested for uses such as thatching and making baskets and mats. Hand cutting, however, is very slow and unpleasant work and has a high labour cost. It is now used only rarely where other methods are inappropriate and usually where the site is too small or inaccessible to justify transport and other costs associated with more modern techniques.

Surprisingly, biological and environmental methods of aquatic weed control have also been practised for centuries. In some of the smaller, shallower rivers, cattle were driven along the river where they grazed on the emergent weeds and trampled much of the submerged vegetation. In hot dry summers, when grazing is poor, cattle will wade into rivers and graze on the submerged weeds and can significantly affect the quantity of weed. Unfortunately, they can also cause considerable damage to the banks.

Environmental control, in the form of shading by trees, was also common. Several species of tree were planted along river banks where they shaded the water surface, reducing the amount of weed growth. The trees were regularly pollarded and the poles and branches used for fencing, hurdles and firewood. The roots of the trees also helped to stabilise the banks and reduced erosion and slippage. Many of these trees were removed when the demand for fencing and other wood products declined and when weed cutting machines were developed which required good access along the banks.

Herbicides are thought of as modern products but even they have been used for over a century. Copper sulphate was used in the nineteenth century for control of algae; other chemicals, such as sodium azide and sodium arsenate, were found to control submerged weeds. Modern organic herbicides, however, did not come into use until the 1950s and 1960s.

In general terms aquatic weeds can be controlled in four ways which can be described under the headings of mechanical, chemical, biological and environmental control. Under each of these main headings there are a number of techniques which are described in more detail in this section.

4.1.1 Mechanical control

Mechanical control covers weed cutting by hand held knives, weed cutting bucket or weed cutting boat and also includes raking and dredging. Currently, it is the most widely used method within the Environment Agency, accounting for some 80% of all weed control operations. There are two advantages to mechanical control over other methods. First, it has an immediate effect as there is no delay between the action of cutting or removing the weed and the relief of the problem. Second, there is no persistence of effect unlike the other methods, all of which remain (as herbicide residue, biological control agents or altered environment) for various lengths of time after application. Mechanical methods are effective against emergent weeds, some floating weeds and submerged weed. They tend to produce poor results when used against filamentous algae and the small free-floating weeds such as Duckweed and have no effect on unicellular algae. With the exception of the weed cutting bucket and the dredger, most forms of mechanical control cut the weed but do not remove it from the water. The most expensive and time consuming part of the operation is the removal and disposal of cut weed.

4.1.2 Herbicides

Herbicides are often perceived poorly by the general public because of much adverse and sometimes inaccurate publicity. There have been very few incidents where herbicides used for aquatic weed control have produced any adverse effect and most of these have been the result of misuse. Studies comparing the impact of herbicides and other forms of weed control (usually cutting) have shown that herbicides are no worse than the alternative and, in some cases, were less damaging. Nevertheless, because herbicides are usually more effective and produce longer-lasting control than cutting techniques they do alter the environment for a longer period. Their use must, therefore, be approached with caution to ensure that the more effective control achieved does not cause adverse effects to the river. Barley straw can also be included with the herbicides because, as it rots in water, it releases a chemical which acts as an algicide. Although the identity of this chemical has not been fully established, it appears to have no effect on higher plants, on fish or on invertebrate animals. Straw is now being used widely in both static and flowing water bodies to give effective, selective control of algae.

4.1.3 Biological control

Biological control has, at present, very limited use in river systems. There are a number of native animals which have an impact on weed populations in addition to the introduced Chinese Grass Carp. This fish eats a range of submerged and floating weed and even filamentous algae. However, its use is restricted to enclosed water bodies from which it cannot escape into the wild and so it is not used in rivers. Other biological control agents include ducks, geese and swans, all of which eat water weed but are difficult to control and tend to move away when grazing becomes poor. Large congregations of waterfowl can cause pollution problems, especially in contained waters. They may also graze on, or cause damage to adjacent crops. Some invertebrate animals, eg *Daphnia* spp., feed on unicellular algae and can be quite effective in clearing water. Unfortunately, they are eaten by many species of fish and the only way to encourage their numbers is to reduce the stock of fish. This technique has been used in selected areas in the Norfolk Broads but is not generally popular with fishermen. Some species of native fish, particularly carp and bream, also act as biological control agents. They are bottom feeders, taking mouthfuls of silt and filtering out invertebrate animals. During this process, they uproot small submerged plants and suspend silt in the water, reducing the penetration of light and so suppressing plant growth. This encourages the growth of unicellular algae. In slow flowing rivers which have soft, easily suspended sediments stocking with Carp and Bream may improve the flow by controlling submerged weeds but is not easily managed and not always desirable because it makes the water turbid.

4.1.4 Environmental control

Environmental control is achieved by altering the conditions in or above the water so that they are less suitable for plant growth. For successful growth, all plants need light, nutrients, carbon dioxide and water. Although water is always available in a river, water velocity can be very important, some species of weed only growing in static or very slow flowing water and others requiring fast flowing conditions. By altering the water velocity or by reducing the availability of one of the other growth requirements, weed growth can be reduced or the species composition altered. Light can be reduced by creating shade by, for example, planting trees along the bank, or by making the water deeper. Nutrients are difficult to remove from the water but various attempts are being made to prevent their entry. These include limitations on the use of agricultural fertiliser and improvements in sewage treatment works. There is also evidence that marginal vegetation, 'buffer strips', can help to reduce the level of nutrients and pollutants draining into a watercourse.

Channel shape can have a major impact on the amount and type of weed growth. Steep sided, deep, narrow channels tend to grow less weed than shallow, wide channels with gently sloping sides. Fast flowing rivers, especially those with gravel or rocky bottoms tend to grow less weed than slow flowing, silt bottomed rivers. The application of environmental control techniques, especially in terms of channel re-shaping, can be expensive and is, generally, a very slow process but produces long-lasting effects. It is most applicable when reconstruction work is being undertaken and consideration of the effects on weed growth can be built into the channel design.

4.2 Selection of Weed Control Options

This section outlines a step-by-step approach to the selection of weed control options.

- Any weed control operation should be carried out in accordance with an existing long term management plan. If the watercourse is part of, or close to, any type of conservation site, SSSI or ESA, the management plan should be drawn up in consultation with the Conservation Body responsible for the site. Where appropriate, Water Level Management Plans should be prepared. The presence of rare or uncommon plants should be identified so that selective and non-harmful control techniques can be chosen.

- Decide on the standard of service required for the watercourse. This will determine the timing, frequency and degree of weed control required. This can range from total annual weed control to selective or partial control in localised areas or to the periodic control of an individual species.

- Identify the target weeds to species level. Identifying weeds only as emergent, floating, etc. does not allow the selection of best practice options. Other non-target plants should also be identified as far as possible so that control techniques which minimise harm to non-target species can be selected. The presence of poisonous plants should be identified and measures taken to reduce risks to livestock.

- Assess the need for bankside management and integrate the bankside management plan with the aquatic weed management plan. Ensure that the timing and methods used in each operation will not impede or reduce the efficacy of the other.

- Check the weed control options for the target weeds listed in section 5. This lists most of the common weed species.

- If there is more than one target weed species, compare the control options listed against each weed to find if there is a single technique which is common to all target weed species.

- Check that this option is acceptable and falls within the criteria listed above. If it does, it is likely to be the most cost effective technique available as only one method of control is required.

- Check that the appropriate equipment and trained operatives are available to employ this option. If equipment or training cannot be obtained, this option becomes unacceptable.

- If there is no common option which will control all the target species or, if this option is identified as unacceptable, consider the use of the two (or more) best alternatives shown in section 5. Ensure that these options can be integrated. (see section 4).

- Compare the options identified by this process with the current method(s) of weed control (if any). If they are the same, maintain the existing management practice.

- If the options for weed control are markedly different from existing management practice or there is no weed control currently undertaken, compare the range of options listed in section 5 (and existing practice, if any) for cost effectiveness (section 4.13) and environmental impact (section 3).

- Select the options which are most cost-effective but have the minimum adverse environmental impact.

Note:

(1) The Environment Agency has a Technical Information Agreement with the Centre for Aquatic Plant Management. Technical assistance from the Centre can be obtained through the Regional Contact Officer or the Regional R&D Coordinator.

4.3 Mechanical Control

Weeds can be cut by hand, weed bucket or weed boat. There are also a number of hybrid weed cutting machines which combine the benefits of land mounted and boat mounted cutters. Most weed cutters use reciprocating knives similar to those used in traditional agricultural mowing machines. The individual knife blades are either rivetted or bolted onto the cutter bar. Some operators prefer the bolted system because individual blades can be removed more easily for sharpening or replacement. The other form of mechanical cutter is a trailing V shaped blade. These are usually operated in pairs attached by a chain to a cam on the stern of a boat so that the blades are jerked along alternately behind the boat. The length of the chain can be adjusted to ensure that the blades cut close to the bottom and may even penetrate the bottom silt to cut the plant roots.

4.3.1 Hydraulic efficiency

Generally weed cutting is most efficient when the cutters are as close to the bottom as possible. This has the greatest impact on the weeds, which take longer to recover, and reduces the need for a later second cut. Unfortunately, it also maximises the amount of weed which has to be removed for disposal. Where the cut can be delayed until late in the season, it can be shallower, provided that it still achieves the desired standard of service, as there is less time for regrowth to occur.

It may not always be necessary to cut the entire width of the channel. Estimates as to the most efficient proportion of the channel width which should be cut, range from 50 to 80%. There is a negligible difference in the hydraulic resistance of a channel when between 80 and 100% of the width is cut and the benefits decrease proportionally as the cut increases above 50%. Nevertheless, the width of the channel section which needs to be cut must be decided for individual rivers where the level of service can be determined locally.

.There are several advantages to leaving a proportion of the river uncut.

- The cutting operation is faster with less weed to remove.

- Some habitat is preserved and environmental impact is reduced.

- Provided that the uncut proportion includes the margins, the remaining weed may protect the banks from erosion.

- Some weed species die back after flowering early in the season but regrow if cut before they have flowered. Also, cutting of some weeds synchronises their regrowth so that they all reach maximum biomass at the same time. Where sections of the river are left uncut, some of the weed in the uncut sections will die back earlier than that in the cut sections and the weed growth rates in the two sections will not be synchronised. Thus, the hydraulic resistance of the weed across the whole width of the river may not be any greater throughout the season than if all the weed was cut and regrew in a synchronised way.

- Partial cutting allows for some selection of which species are cut and which are left. Floating weeds, such as Water-lily or Broad-leaved Pondweed are sometimes beneficial because they tend to suppress the growth of submerged weed but do not create as much hydraulic resistance. If these weeds are cut, light levels increase and submerged weeds can become established and increase resistance.

For these reasons, partial cutting should be practised wherever possible.

4.3.2 Timing of cuts

Although some weed species may be found at almost any time of year, cutting is generally not effective until significant quantities of weed have grown in the spring. This is also the time when most invertebrate animals, fish and birds are dependent on the weed for reproduction and survival. Furthermore, cutting weeds early in the season allows time for them to regrow, possibly synchronising regrowth, so that a second cut may be needed later in the season. For these reasons, early season cuts should be avoided if possible.

<u>CAUTION. Cutting is not normally recommended until mid or late July.</u>

Most floating and submerged weeds start to die back in September or October and are not normally troublesome throughout the remainder of the autumn and winter. Therefore, cutting of these weeds is usually limited to the period between July and September. There is evidence, however, that an autumn cut of Water Crowfoot can delay its regrowth in the following spring. Where several rivers within a Region are affected by this weed, cutting in September or October in some of the rivers will delay regrowth in the following spring for up to 8 weeks thus desynchronizing growth and allowing more time for weed cutting throughout the Region.

Many emergent weeds remain standing throughout the autumn and winter. In small, shallow watercourses, these weed residues can cause a serious flood risk by trapping detritus. They can be cut during the summer but, in some instances, clearing them in Autumn may be preferable as weed cutting equipment is then free during the summer to concentrate on the floating and submerged weeds.

4.3.3 Effectiveness of different cutting methods

The choice of the most effective method depends more on the size and conditions of the site where the weeds are growing rather than on the characteristics of the method.

Weed boats have the greater output and are the most effective method of cutting in large watercourses. They become progressively less efficient as the size and depth of the river decreases and the boat has to negotiate shallows and narrow corners. Few weed boats remove the cut weed and their benefits can be offset by the cost of collecting, removing and disposing of the weed. Few weed boats can cut below 1.5 m depth and, in the relatively rare instances where dense weed growth occurs in water deeper than this, the boat is unable to cut close to the bottom.

Weed cutting buckets are most effective in narrow channels, where they can reach across the whole width of the channel. The maximum reach of most excavators operating weed buckets is about 15 m. The depth of water makes very little difference to their performance but large quantities of weed can slow their work rate because the bucket may be filled before the whole width of the channel has been cut and it has to be emptied and a second swathe made. Weed buckets have an advantage over weed boats in that they capture the weed as it is cut so that it can be deposited on the bank. Because it is deposited longitudinally along the bank, rather than collected at one point, it may not be regarded as waste material, which must be deposited at a licensed tip. Weed buckets usually cut closer to the sediment than weed boats and so produce better, longer lasting control, although the difference may not be important where a single cut each season, by either method, is adequate. As with weed boats, weed buckets can be used to produce localised control. The main limitation on the use of weed buckets is that the excavator or tractor must have access along the bank. Trees, fences, side channels, standing crops and buildings can all slow the work rate and, in some situations, make the use of land-based machines with weed buckets uneconomic.

Amphibious weed cutters can be effective, especially where the river is too shallow to allow a conventional boat to work effectively and where access along the bank is obstructed. Amphibious machines use cutting knives but do not generally collect and remove the cut weed. Thus, the removal and disposal of the cut weed presents the same problems as are found with weed boats.

Hand cutting is limited to shallow water where the bottom is hard enough to allow a man to wade. It can be the most effective method when control is required in small, inaccessible areas, where machines cannot be used or where the cost of heavy equipment is prohibitive.

Hand cutting can be highly selective and localised so that individual weed beds can be cut or retained.

Most weeds can be easily cut by hand but hand removal of the cut weed is very laborious, often requiring two or three men to remove the weed cut by one. It may be possible to float the weed downstream to a boom where it can be removed by machine.

CAUTION. Where rare plants and animals are present, hand cutting may be the only safe option.

4.3.4 Work rates of different cutting methods

The work rate achieved by different methods of cutting is affected by local conditions. In practice, the most common factors which determine the work rate of individual techniques are:

- The physical characteristics of the watercourse including the size and shape of the channel, the water depth and velocity, and ease of access (particularly for machinery).
- The type and density of weed growth.

Because of the wide variation which these factors can cause in work rate between sites and even between cutting operations on different occasions at the same site, it would be misleading to quote specific figures for the work rate of different cutting methods.

4.3.5 Effects of cutting on conservation and fisheries

Over a period of years, cutting is less likely to alter the plant community in an established ecosystem than any other form of weed control, especially where cutting has already been used regularly as a form of management. Few plants are killed by cutting, usually regrowing either later in the season or in the following spring. However, where an invasive weed begins to dominate the river and to destroy valuable habitats, it may be preferable to find an alternative, more effective method of control which will selectively kill the target weed and leave the remaining habitat unaffected. The control of individual weed species is described in section 5.

Despite the low environmental impact of cutting, it can still damage fisheries and conservation interests unless applied carefully. The following should be borne in mind when planning and carrying out weed cutting operations.

- Avoid cutting weeds which are not causing problems, especially the less common species such as Sweet-flag and Flowering Rush. Cutting weeds which do not cause problems may allow more troublesome weeds to invade.

- Leave an uncut margin along one or both banks. To encourage nesting birds, such as Reed Warblers or Reed Buntings, a fringe at least 2 m wide is recommended.

- Leave some submerged weed, even if this means cutting parts of the fringe of emergent weed in order to gain adequate channel capacity. These areas of submerged weed are valuable habitats for fish and invertebrate animals.

- Delay cutting as late as possible in the season. Cutting weeds before mid July is damaging to nesting birds and to spawning fish.

- Some plants, such as Mare's-tail, Water Milfoil and Stoneworts, survive for much of the winter and provide valuable habitats for fish. Where the option exists to cut either these or other plants which die back in the autumn, the overwintering species should be retained.

- Weed boats usually produce a more effective cut when working in an upstream direction and this allows some invertebrate animals and fish to escape from the weed as it drifts downstream. Even then, up to 20% of the invertebrates which live amongst the weed will be removed with the weed when it is harvested. Weed buckets remove 40-60% of these invertebrates.

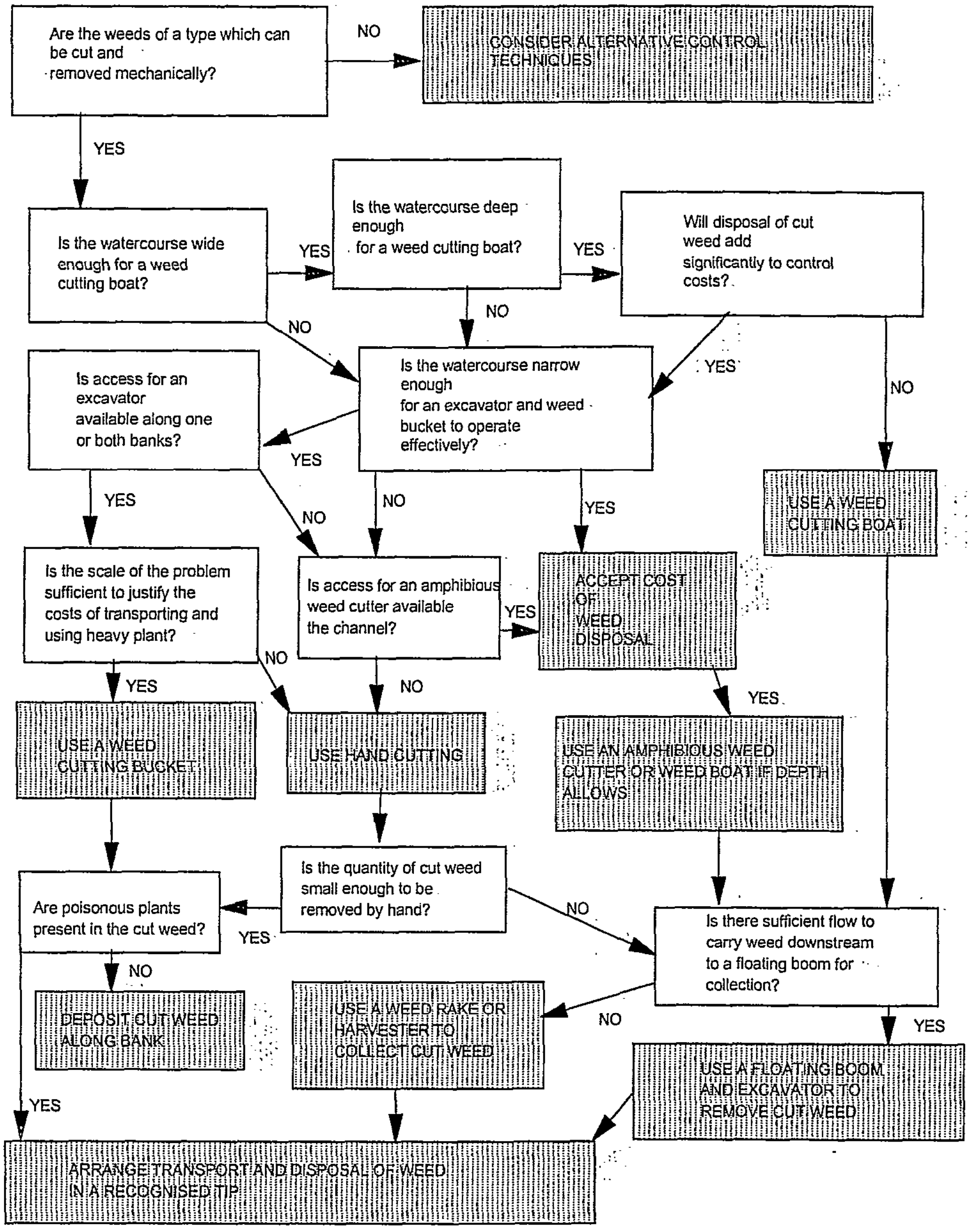
- Weed buckets should, if possible, be operated from one bank only and the plant communities on the other bank should be left uncut and allowed to develop for as long as possible.

  Shallow cutting is less likely to damage a diverse and valuable plant community than deep cutting.

- Deep cutting, especially when the cutter penetrates the sediment and damages roots and rhizomes, can help to increase species diversity where monocultures have developed by allowing other plants to colonise the cut areas. Selective or partial cutting can then be used to enlarge these areas.

For further information see the New Rivers and Wildlife Handbook. (Section 6.6).

SELECTION CHART 4.1 - MECHANICAL CONTROL OPTIONS



4.4 Weed Boats

4.4.1 Choice

Most weed boats use reciprocating cutting knives; some use stern mounted V-shaped trailing cutter blades. The reciprocating cutters are either in the shape of an inverted T (eg Conver) or an upright U (e.g. Barracuda, Simplex Bateaux Faucardeurs). A number of manufacturers have introduced weed harvesting equipment which can collect the weed as it is cut. Other weed harvesting boats are reported to be under design or construction. The majority of weed boats are propelled by Archimedes screws, which do not become entangled in the cut weed. Some Simplex boats are powered by paddles, which give greater maneouvrability and can operate in very shallow water.

Some boats have attachments for trailing knives operated by cams at either side of the stern of the boat which alternately jerk the knives forward. These knives tend to cut weeds closer to the bed than reciprocating cutters and are particularly effective against submerged weeds.

Marginal vegetation above and below water level can be cut using either side mounted cutter bars, available on some models, or by tilting the front cutter bars on other models.

On some boats, front mounted collecting baskets can be fitted, as an alternative to the cutter bars, and used to collect floating vegetation, for disposal to bankside. It is increasingly common practice, by some IDBs working in large drainage channels, to operate weed cutting and weed collecting boats in tandem so that weed is deposited in small quantities along the bank, and not left in the water to drift to a collecting point.

Most weed harvesting boats can be supplied in a range of models and accessories, and prices vary considerably. A list of manufacturers is given in section 6.1.

4.4.2 Operation: Direction of travel

In flowing water, weed boats are generally more effective travelling upstream when the flow of water holds the weed tightly against the cutter. When operating downstream, especially in fast flowing water, the weed is flattened by the flow and can be pushed further down by the knives, which may slide over the weed and produce a poorer cut. In still and slow flowing water, weed boats operate equally effectively in either direction.

In shallow water, where the depth is only sufficient for the boat to operate because water is held back by the weed, it may be preferable to cut short sections leaving bars of uncut weed at the downstream end of each section to maintain adequate depth. These are then cut at the end of the operation usually working in a downstream direction using the retained water.

Where a single pass gives an adequate cut, and the water is very shallow, it may be preferable for the boat to operate in a downstream direction to maintain sufficient depth of water in front of the boat.

4.4.3 Style of Travel

In some situations, a cut across the entire width of the river is required. This is achieved by a series of passes which can be either alternately upstream and downstream or all in an upstream direction with a return passage between each cut. The latter gives a more effective cut in fast flowing rivers but wastes time on the return runs. Often, cutting only part of the channel width will achieve the desired degree of service. Depending on the size and shape of the channel, and the degree of service required, the cut path can vary from a "straightest possible line", to a meandering line where the boat deliberately manoeuvres from bank to bank across the river. In some regions, engineers have placed marker posts at roughly 200 m intervals and the boat crosses to the other side of the channel opposite each post; opposite sides are cut in alternate years. This style of cutting is less efficient hydraulically but, by producing a variety of flow conditions within the channel, is reported to benefit fish and invertebrates.

4.4.4 Frequency of operation

If cutting is delayed until mid summer or later, one cut each season is usually adequate. However, by delaying the cut, large quantities of weed may develop and present a removal and disposal problem. Where there is prolific weed growth and where boat traffic or other activities require a constantly weed free environment, it has sometimes been found to be more efficient to maintain a frequent cutting regime. This has two advantages over one annual cut. First, cutting is faster because there is less weed to cut each time. Second, the quantity of weed released on each cut is small and may not need removal and disposal. This may offset the additional cost of more frequent cutting.

4.5 Amphibious Machines

4.5.1 Choice

Amphibious boats have advantages over other weed cutting equipment in shallow rivers with little or no access along the banks. Some amphibious boats are wheeled but may be fitted with overtracks; other makes have only tracks. The tyred wheels are probably better in rivers with stony bottoms and firm banks, tracked forms coping better with soft, silty bottoms and muddy banks. New models are being developed and potential users should consult the manufacturers. (See section 6.1).

4.5.2 Operation

The recommendations for cutting direction, style and frequency for weed boats apply equally to amphibious boats. Because of the range of water depths in which they can be used, they can have applications as alternatives to both weed boats and weed buckets. Where possible, they should not be used on gravel spawning beds during the breeding season for salmonids (October and November) or for invertebrate animals (May or June).

4.6 Weed Buckets

4.6.1 Choice

Weed buckets range in size from 1 to 4 m wide. Most are intended for use with hydraulic excavators and bucket size depends on the machine onto which it will be attached and the size of watercourses in which it will be used. Smaller sized weed buckets can be operated by tractor mounted hydraulic arm. Some weed buckets can be operated by a dragline. These can be useful in very large watercourses where the additional reach of a dragline allows the whole width of the channel to be cut. A hydraulic pump is attached to the dragline engine to power the bucket and hydraulic hoses are attached to the jib (see Engineering & Hire, section 6 para 3).

The cutter bar on the front of the bucket is powered by a hydraulic motor which may be mounted on one side of the bucket or centrally. The centrally mounted versions tend to suffer less from vibration and the hydraulic pipes are shorter. The individual knife blades may be bolted or rivetted to the cutter bar. Bolting allows individual blades to be removed for sharpening or replacing.

4.6.2 Operation

In small watercourses, weed buckets can cut from bank top to bank top across the entire width of the channel. For conservation purposes, this practice should be avoided where possible. Preferably, the machine should work from alternate banks each year leaving the far bank and a fringe of emergent weeds and some submerged vegetation uncut. Generally, the deeper the bucket cuts, the longer control will last. Buckets are sometimes operated with the cutter blades penetrating into the silt as this removes roots and rhizomes, giving longer term control and lengthening the period between operations. However, this can only be done in soft silt and will damage cutting blades if stones or hard objects are encountered.

In narrow channels, weed cutting can be speeded up by dumping the cut weed on the facing bank, avoiding the need to swivel the jib to dump weed on the nearside bank. This is not appropriate where one bank is to be left undisturbed. Weed should always be dumped above flood levels. Particular care should be taken that any poisonous plants are not dumped in reach of livestock. Some filamentous algae are very slow to rot and should not be dumped on steep or unstable banks. The mats of algae kill underlying vegetation and can cause bank slippage.

Where possible, drivers should return fish trapped in the bucket to the channel. Where large numbers of fish and invertebrates are being caught, the bucket should be kept in the water at the end of each cut long enough to allow them to escape before dumping weed on the bank.

4.6.3 Other weed cutting machines

There are a number of specialised weed cutting machines mostly designed for use in smaller watercourses. Some of these are narrow tracked or have a tricycle wheel arrangement which allows them to operate along narrow banks or with minimum damage to crops growing adjacent to the watercourse. Some use weed buckets, while others have mowing and rake equipment.

4.7 Manual Techniques

4.7.1 Choice

Weeds can be cut with scythes, long-handled sickles, chain scythes and various locally produced or modified cutting tools. The standard chain scythe consists of 9 linked blades, each 1m long, and weighing about 2.5 kg. A rope is attached to each end and the chain of blades dragged along the channel with a sawing motion. Another hand tool used from a boat (or by wading) is a V-shaped pair of scythe blades, attached to a wooden handle and operated by hand in the same jerking motion as the boat mounted trailing V blades. In soft silt, weeds can be hand pulled. This removes the rhizomes and so produces longer lasting control.

Various forms of rake are used to collect and remove the cut weed.

4.7.2 Operation

Hand cutting and pulling is generally used only in small or highly sensitive areas, where it is not efficient to transport heavy machinery to the site or where environmental damage would result from the use of large machines. Hand cutting and pulling can be highly selective in both the species and areas controlled. In fast flowing, shallow reaches, hand cutting can be rapid as the weed is washed away from the cutter. In slow flowing water, the cut weed can become entangled with uncut weed, slowing the work rate. For the same reason, hand cutting is almost always more effective in an upstream direction.

4.8 Disposal of Cut Weed

Under the and the Waste Management Regulations 1994, waste materials must be disposed of in an approved manner which usually means that they must be taken to a recognised tip. Water weeds and the spoil produced by dredging could be regarded as waste material. However, weed cutting and dredging, and the disposal of the resulting waste material, is an exempt activity provided that the quantity of material does not exceed certain limits and that the **Waste Regulation Authority is advised that such an activity is or will take place.**

The limit on the quantity of waste or plant matter under this exemption is 50 tonnes per linear metre of bank or 5,000 tonnes per hectare of land where the weed or dredgings are spread for purposes of agricultural or ecological improvement.

In the unlikely event that the quantity of material exceeds these limits, or where there is insufficient space to dispose of the weed or dredgings along the bank or on agricultural land, the waste material may have to be transported to a recognised tip. The cost of disposal of aquatic weed in this manner can be equal to, or greater than, the cost of cutting and harvesting the weed. Where possible, the techniques outlined in the following sections should be used to avoid or minimise disposal costs.

More details on disposal of cut vegetation are given in the Environment Agency R&D Technical Report W138.

4.8.1 Disposal Practice

Weed bucket/weed rake

The weed should be dumped in small volumes, longitudinally, along the bank top. Dumping near to the waterline is not recommended because the weed can be washed back into the watercourse during periods of high flow. The dumped weed also enriches the soil, encouraging nutrient loving plants such as nettles and cleavers which are undesirable bankside species. In narrower watercourses where the excavator can reach both banks, it may be slightly more efficient to dump the cut weed on the bank opposite the excavator. This avoids the need to slew the excavator after each pass.

CAUTION Ensure that no poisonous plants are left on the banks within reach of livestock.

Some filamentous algae (particularly Cott - *Vaucheria dichotoma*) do not rot quickly and can kill underlying vegetation. This can destabilise banks leading to slippage. Cott also clogs and interferes with agricultural machinery. Take particular care when dumping these algae.

Ponds, hollows and marshes adjacent to rivers are often valuable wildlife habitats. Do not use them as dumps for cut weed.

Weed boat and boom

Floating booms should be arranged at an angle so that weed floats to the side on which the excavator is located. In some Rivers, it has been found useful to attach tines or nets which hang below the boom to prevent weed escaping beneath it.

Local conditions and transport availability determine whether it is more cost effective to transfer the weed directly to a lorry or to dump it for later transfer. Storage allows some of the water to drain out of the weed and reduce volume but involves a second handling cost when the weed is transferred to the lorry. If the weed is to be stored on the bank, a channel or bank should be dug around the weed heap to contain water and liquor draining from the weed. In some instances, it has been found useful to add straw to the weed to aerate the heap and to absorb some of the liquor. However, this practice should be avoided if the weed is to be transported to a recognised tip as it adds bulk and cost. Further information on good practice for the building and maintenance of storage facilities for rotting organic waste can be found in the MAFF Code of Good Agricultural Practice for the Protection of Water. July 1991, available from MAFF Publications, London SE99 7TP.

CAUTION

- Ensure that the harvesting rate can keep up with the quantity of cut weed being washed downstream so that it does not escape under the boom or cause the boom to break under the pressure of weed.
- Ensure that the location of floating booms and the bank onto which the weed will be harvested are best placed for ease of transporting the weed to a tip.

- Do not allow liquor from rotting weed heaps to drain back into the river.

- Do not leave weed heaps to rot until they become anaerobic as this results in unpleasant odours.

4.8.2 Reducing disposal costs

The cost of transport and tipping add significantly to the overall costs of mechanical weed control. These costs can be reduced by:

- Cutting with a weed bucket and depositing the weeds along the bank.

- Cutting with a weed boat sufficiently frequently that the small amount of weed cut each time can be safely left in the river to wash away or decompose.

- Allowing harvested weed time to drain and partially dry before disposal.

- Find a use for the cut weed.

4.8.3 Uses for harvested water weed

Very little research has been done on this subject mainly because, until recently, weed could be left on the bank to decompose. The cost of transport has usually meant that the expense of using weed was disproportionally high when compared with alternative, more easily transported materials. However, since the introduction of the Disposal of Waste Regulations, the weed may have to be transported anyway and so it may be cheaper for the Environment Agency to give the weed away, if a use can be found, thus saving the cost of tipping.

The following suggestions for ways of disposing of harvested weed are put forward for consideration but may need to be investigated in detail before large scale application.

- Soil Conditioning. Water Crowfoot has been used on acid, sandy soils as a soil conditioner. The calcium in the Crowfoot helps to neutralise acidity and the organic matter helps to hold soil moisture. Other types of water weed may also be useful on soils which would benefit from the addition of organic matter. The weed can be spread onto the soil using a shredder/blower (e.g. Silachop) machine. It is likely that additional nitrogen would need to be added to soil where large quantities of weed were incorporated.

- Composting. Aquatic weeds can be composted and this is now common practice in the Netherlands. Some research on composting has been done by Regions in the Environment Agency. The compost produced may have a market but is low in nutrients, requires costly drying and chopping and large quantities of noxious liquor are produced by the process.

- Mulching. Filamentous algae, which degrade only slowly, and other weeds harvested from the river could make a useful mulch especially around young trees where the suppression of grasses and herbs aids establishment. This would be especially convenient where trees are planted along river banks. However, they should not be used for mulching on river banks where the suppression of grasses could cause destabilisation of the bank.

4.9 Chemical Control

4.9.1 Introduction

Herbicides can offer cheaper, more effective and longer lasting control than mechanical alternatives. Although there is an understandable reluctance to use herbicides in the aquatic environment, there is no evidence that they are more environmentally damaging than alternative methods when used correctly. However, if used incorrectly they can be expensive, ineffective and very damaging to the environment.

Herbicides should be used only:-

- By properly trained operators holding the appropriate NPTC Certificate of Competence. The address of the National Proficiency Test Council is shown in section 6.6.
- In accordance with the instructions printed on the product label and any accompanying literature.
- In conjunction with the MAFF "Guidelines on the use of herbicides on weeds in or near watercourses and lakes" (Available from MAFF Publications, London, SE99 7TP. Tel. 0645 556000).
- In accordance with Environment Agency Code of Practice "The use of herbicides to control weeds in or near water" and with Regional Policy on the use of herbicides.

4.9.2 Herbicide names and terminology

There is sometimes confusion about the names of herbicides and the products which contain them. When a new herbicidal molecule is discovered, it is given a full chemical name, for example *N*-(phosphonomethyl) glycine. This is usually shortened to a more user-friendly form, in this example, glyphosate. That is the name of the active molecule, which is also referred to as the active ingredient, in a product. When the chemical is sold as a herbicide, it is in a formulation, which may contain water and adjuvants to improve the performance of the chemical, and is sold under a product name. Different manufacturers may produce slightly different formulations. In the example used above, there are products containing glyphosate named Roundup, Roundup Pro Biactive, Spasor, Helosate and a number of others. All of these products are approved for use in water. However, this is not always the case and there are other herbicides sold under several product names containing the same active ingredient only some of which have approval for use in water.

Products approved for use in or near water will always carry specific recommendations for this use on the product label. These give the dose, timing, susceptible weeds and other relevant information. If that recommendation is absent from the product label, it should not be used in or near water.

There are various terms which describe how herbicides are used and how they work. These have been developed mainly to describe how herbicides perform when used in terrestrial situations and they are not as clear-cut when applied for aquatic use. However, as they may appear on product labels, an understanding of their meaning may help users.

Selective and non-selective herbicides

Selective herbicides are those which will affect only a limited range of plants. The susceptibility of a plant to a selective herbicide often depends on the shape of the leaves. For example, most broad-leaved weeds are susceptible to 2,4-D amine but grasses are not. Therefore, on a river bank, 2,4-D amine can be used to control germinating seedlings of nettles and thistles without killing the grasses which stabilise the bank. In contrast, glyphosate would kill both the grasses and the broad-leaved weeds and, so, is regarded as broad-spectrum or non-selective. However, neither of these herbicides would affect submerged weeds and algae if they were accidentally sprayed into the water, so they are both selective to some degree. In fact, there are no completely non-selective herbicides, that would kill all plants from trees to single celled algae, in common use. The description of a herbicide as selective or non-selective is best applied together with the situation in which it is being used. Thus, 2,4-D amine is a selective herbicide for the control of broad-leaved weeds in grass while glyphosate is a non-selective herbicide in the same situation, but is selective between emergent and submerged weeds.

Contact and translocated herbicides

A contact herbicide is one which kills only the part of the plant with which it comes into contact. A very simple example is sulphuric acid which was used to burn off the green haulms (stems) of potatoes to facilitate harvesting. A drop of the acid on the leaf of almost any plant would burn it but would be unlikely to kill the whole plant. Even if all the stems and leaves were burnt, the plant might still survive if it had a root or rhizome system carrying buds from which shoots could regenerate. On the other hand, translocated herbicides are absorbed by one part of the plant and move through the plant to a location where they kill the plant by affecting some vital process. As a general rule, therefore, translocated herbicides are more effective in killing plants than contact herbicides. The exception to this is when the plant has such a poorly developed root or rhizome system that it is unable to survive the loss of the leaves and aerial buds. This is why, for example, the contact herbicide diquat, will kill small plants, such as Duckweed and some of the weakly rooted submerged weeds, but causes only minor damage to well rooted plants, such as Water-lily. In contrast, dichlobenil, a translocated herbicide, kills many submerged and floating leaved species which have extensive roots and rhizomes.

Persistent and non-persistent herbicides

All herbicides persist in the soil, water or sediment for a period after they have been applied. Persistence may continue for hours, days or even months depending on the herbicide and the conditions in the soil, water or sediment. However, many herbicides are **active** only if they come directly into contact with foliage or other plant organs and have no activity in the soil, sediment or water. These herbicides are described as non-persistent. This does not mean that residues disappear immediately; it may be possible to find the chemical, sometimes chemically bound to soil particles, for perhaps weeks after application. However, they have little or no herbicidal activity in this condition and gradually decompose.

Of the herbicides approved for use in or near water, glyphosate has no persistent effect while dichlobenil and terbutryn can retain activity in water for 2-3 months. Diquat remains active for only a few hours or days and is rapidly absorbed and inactivated on contact with clay or organic material.

Foliage and water-applied herbicides

Herbicides used to control aquatic weeds may be applied in one of two ways. Some are applied as sprays onto exposed foliage to control emergent or floating leaved weeds. Others are applied into the water as granules, liquids or gels, to control submerged weeds and algae. Of the herbicides approved for aquatic use, 2,4-D amine and glyphosate are applied as sprays onto exposed foliage and dichlobenil and terbutryn as granules added to the water. Diquat has two formulations, a liquid and a gel. The gel is used only to control submerged weeds and algae but the liquid can be applied either as a spray onto some floating leaved plants or added to water, at a much higher dose, to control submerged weeds and algae.

These definitions of the types and behaviour of different herbicides only apply when the herbicide is used at the recommended dose rate. Selectivity, persistence and behaviour can change if the dose or concentration of the chemical is outside the recommended rates. For example, 2,4-D amine is a selective, foliage applied herbicide with little or no persistence when sprayed at the recommended rate of 2 to 4,5 kg/ha to control some broad-leaved emergent and floating plants. However, applied directly into water at a concentration of 1.0 mg/l (equivalent to 10 kg/ha if applied to water 1 m deep), it behaves as a relatively persistent, unselective herbicide which controls many species of submerged weed as well as some floating and emergent species.

Irrigation interval and maximum permitted concentration limit

In order to ensure that there is no risk to crops irrigated with water which has been treated with a herbicide, a time interval and/or residue concentration is specified. Treated water should not be used for irrigation until either the irrigation interval has passed or the concentration has fallen below the concentration limit. In addition, a maximum permitted concentration is specified which requires operators to ensure that, when applying a herbicide, it is evenly distributed and that locally high concentrations do not pose a risk to the environment or to irrigated crops. (See Table 4.5).

Table 4.1 Herbicide Products approved for use in water

Herbicide	Product	[a.i.] in product	Irrigation Interval / conc.	Max permit conc. in water	Behaviour and use
2,4-D amine	Atlas 2,4-D Dormone Agricorn D	470 g/l 465 g/l 500 g/l	21 days and conc. <0.05 mg/l	5 mg/l	A selective, translocated, non-persistent foliage applied herbicide used to control bankside, emergent and floating broad-leaved weeds.
dichlobenil	Casoron G. Casoron GSR.(this product is no longer manufactured)	67.5 g/kg 200 g/kg	14 days or conc. <0.3 mg/l	3 mg/l	A broad-spectrum (non-selective), translocated, persistent, water applied herbicide used to control submerged and floating weeds.
diquat	Midstream. Reglone.	100 g/l 200 g/l	10 days or conc. <0.02 mg/l	2 mg/l	A broad-spectrum, contact, short persistence, foliage or water applied herbicide used to control submerged and floating weeds and algae
glyphosate	Barclay Gallup Amenity, Buggy SG, Clayton Swath, Clinic, Danegri, Glyphosate 360, Glyfos, or Glyfos 480, Glyper, or Glyphogan, Helosate, MSS Glyfield, Roundup, Roundup A, Roundup Biactive, Roundup Biactive Dry, Roundup Pro, Roundup Pro Biactive, Spasor, Spasor Biactive, Stetson.	all 360 g/l	Nil	0.2 mg/l	A broad-spectrum, translocated, non-persistent, foliage applied herbicide used to control emergent and floating weeds.
terbutryn	Clarosan 1FG Clarosan	10 g/kg 10 g/kg	7 days 7 days	0.1 mg/l 0.1 mg/l	A broad-spectrum, translocated, persistent, water applied herbicide used to control floating and submerged weeds and algae.

4.9.3 Herbicide dose

The correct dose for every herbicide product is printed on the product label. The following information is given for guidance only and product labels should always be checked before application to ensure that the correct dose is being applied.

The quantity of any herbicide which is applied as a foliar spray is always expressed as the volume of product per unit area (usually as litres per hectare) together with equivalent weight of active ingredient (a.i.) per unit area. For example, glyphosate is applied as 5 l of product (e.g. Roundup) per hectare which is equivalent to 1.8 kg a.i. per hectare.

Herbicides applied directly to water are formulated in different ways and this affects calculation of dose. The doses of the liquid formulation of diquat (Reglone) and the granular formulation of terbutryn (Clarosan) are calculated by estimating the volume of water to be treated and adding the correct quantity of product to achieve the required concentration. This concentration is seldom achieved in practice because some of the herbicide will be absorbed and lost from the water before the treatment has been completed or the herbicide has been released from the formulation. The recommended dose of Reglone is 25-50 litres of product per 10,000 m^3 which is equivalent to 0.5 - 1.0 g a.i./m^3. The recommended dose for terbutryn (Clarosan) is 50-100 kg product per 10,000 m^3 which is equivalent to 0.05 - 0.1 g a.i./m^3.

The other herbicides recommended for direct treatment of water are diquat alginate (Midstream) and dichlobenil (Casoron). Both of these formulations are designed to sink rapidly and either stick to the submerged weeds (Midstream) or be absorbed into the hydrosoil (Casoron). Because these formulations sink rapidly, the depth of water can be disregarded and the doses of both these products are calculated on the area of water surface. For Midstream, the recommended dose is 100 litre of product per 10,000 m^2 water surface, which is equivalent to 1 g a.i./m^3 (assuming that the water is 1 m deep). For Casoron, the dose is equivalent to 1.0 g a.i./m^3 in water 1 m deep. In shallow water of less than about 0.5 m deep, the dose of Midstream is reduced to ensure that the concentration of active ingredient does not exceed the maximum permitted level.

CAUTION. The maximum recommended dose on the product label should never be exceeded. For some products, there is a range of recommended doses which vary with the susceptibility of the target weed and local conditions. If in doubt, always use the lower dose. In a few instances, doses lower than those recommended can be applied experimentally or where experience has shown them to be effective. However, such doses usually produce poor results and increase the risk of inducing resistance in plants which survive the treatment. Manufacturers will not accept liability if such treatments fail to produce satisfactory results.

Risk of deoxygenation

Control of submerged weeds and algae with a herbicide, causes large masses of weed to die rapidly and decompose. This absorbs oxygen from the water and levels can fall to the point where fish or invertebrate animals are endangered. Deoxygenation can be particularly severe when terbutryn, which blocks photosynthesis, is used. Thus, before the plants die, their respiration is added to the oxygen demand of the other aquatic fauna and microorganisms without any compensating photosynthesis to maintain oxygen levels.

To prevent deoxygenation of water, herbicides should normally be applied early in the spring when water temperatures are low and the quantity of weed is still small. Treating large areas of dense growths of submerged weed and algae in summer gives a risk of deoxygenation. In such situations, weeds should be controlled mechanically or localised treatments with a herbicide may be used, provided that only small areas are treated at any one time, allowing fish and invertebrates to move into adjacent oxygenated areas. More areas can be treated after an interval of two or three weeks.

Deoxygenation is not a problem when herbicides are used on floating or emergent weeds as the quantity of weed is usually smaller and they die and decompose slowly.

Deoxygenation can occur naturally when dense floating weed prevents light penetration and underlying submerged weeds die because they are unable to photosynthesise. Occasionally, herbicides have been used to control mats of floating weed which had already caused deoxygenation of the water below. As the weeds died and sank, dead fish were exposed and it was assumed wrongly that the herbicide was responsible for the fish mortality. Algae can also cause deoxygenation particularly when dense blooms die back suddenly.

4.9.4 Application

The appropriate equipment for applying herbicides in or near water depends on two factors. The formulation of the herbicide determines whether it is applied with spraying equipment, granule applicators or gel applicators. Access and area involved then determine the size of the equipment needed to perform the operation effectively.

Sprayers

Knapsack sprayers and Controlled Drop Applicators (CDA) are hand-held equipment suitable for one or two man operation applying glyphosate and 2,4-D amine to relatively small areas. They are most commonly used from the bank for spraying small watercourses, although they can sometimes be used from a boat. One of the difficulties of applying herbicides with hand-held sprayers is to achieve sufficient reach from the bank or from a boat to apply the herbicide accurately over the target weeds. Long lances are available from certain manufacturers (see section 6.1) which increase the reach of knapsack sprayers up to about 6.5 m from the bank and help to overcome this problem. When the area involved is too large for hand-held equipment to be used economically, spray booms on tractors or all-terrain-vehicles (ATVs) can be used provided that there is sufficient access along the bank and the boom is long enough to reach over the watercourse. The spraying equipment is often constructed from agricultural equipment using the same spray tank and pumping system powered from the Power Take Off but with the boom off-set to one side and individual or groups of nozzles equipped with taps so that sections of the spray boom can be switched on and off as required by the operator. Similar equipment is sometimes mounted in boats.

There are two problems associated with boat mounted spraying. One problem is to maintain an accurate speed over the water to ensure that the correct dose rate is applied. This is particularly difficult when the boat is moving through dense weed beds. Operator practice and experience, together with NPTC training and certification, is the best way of ensuring that accurate doses are applied. The second problem is that the boat submerges floating or emergent leaves and washes off the spray solution. Where these boat tracks cannot be left untreated, a second pass can sometimes be made about two weeks after the first treatment when the submerged leaves have refloated and can be distinguished from the treated weeds. Some emergent weeds will not recover from being broken by the boat. These can only be treated in the following season when the damaged plants have regrown.

Granule spreaders

Granular formulations can be applied by hand, spinning disc applicator or air blower. Small areas (e.g. swims for anglers) can be treated by hand, using a beaker or scoop, to throw a measured volume of granules in an arc. Spinning disc applicators consist of a rotating disc, onto which a stream of granules falls and is thrown in an arc. The disc may be operated by hand, or powered electrically. Air blowers are usually worn as a back pack, and consist of a small petrol engine which propels a jet of air down a flexible tube. Granules fall into the tube through a calibrated orifice, and are blown out as a cone, which is directed onto the target area with the flexible tube. Watercourses up to about 10 m wide can be treated, using an air blower, from one or both banks. Larger watercourses are usually treated from a boat with electrically powered spinning disc applicators mounted on a boom on the stern of the boat, and spaced so that they give a wide swathe. For safety reasons, hand held equipment is not recommended for use from a boat, unless the operator can work in a seated position.

The herbicide dichlobenil and terbutryn are formulated as granules and can be applied using any of these application systems. Performance of the herbicides can be enhanced by ensuring that the granules are distributed evenly over the water surface. This applies particularly to dichlobenil granules, which sink to the bottom, and release the herbicide close to the plant roots, so that uneven distribution leads to patchy performance. Both these herbicides are applied early in the spring, before weed growth reaches the surface, so that boat movement is not normally impeded by weed growth. Dichlobenil may produce poor results if dense weed masses have survived overwinter and remain in the water to intercept the granules as they sink, so preventing them from releasing the active ingredient close to the plant roots.

Gel Application

Diquat alginate is a viscous gel which is applied by a specially modified knapsack sprayer. The jet of diquat alginate has a range of up to 10 m but, because of its viscosity, it is difficult to pump the gel by hand and knapsack applicators are suitable for treating only relatively small areas. A motorised applicator is also available from Claxton Engineering Ltd. (section 6.3) and this can be mounted in an ATV or a boat. The motorised unit can supply diquat alginate to a boom mounted on the back of a boat for wide swathe treatments or to individual hand-held lances for localised or spot applications.

Safety and efficacy aspects

SAFETY PRECAUTIONS appropriate to the use of individual products are printed on product labels and should always be observed. NPTC certificated operators will have been trained in the safe and effective use of herbicides and should be aware of the required safety precautions. The following information is given for general guidance only.

Liquid Sprays. Herbicides applied as sprays can drift and damage non-target plants. The ideal spraying conditions are in dry weather when a gentle breeze is blowing.

- Avoid spraying under windy conditions when the wind speed exceeds 10 km/h.
- Avoid spraying in completely calm conditions when convection currents can lift spray droplets and carry them away from the target area.

- Use a coarse, low pressure nozzle which produces large spray droplets and a well defined swath.

- Do not over-wet the leaves to the point where spray droplets run off the leaves.

- Do not spray when rain is forecast.

- Do not spray when water levels are temporarily high so that emergent and floating plants are partly or totally submerged.

- Work in an upstream direction to avoid a local build-up of herbicide concentration in the water.

- Avoid trampling on, breaking or submerging leaves as this impairs translocation and efficacy. Floating leaves which are submerged by the passage of a boat will need to be retreated when they have dried off.

Granules. Herbicides applied as granules can be washed out of the target zone if water velocities are too high.

- Do not apply terbutryn (Clarosan) when water velocities exceed 20 m/h.

- Do not apply dichlobenil (Casoron) or diquat (Reglone) when velocities exceed 90 m/h.

- Work in an upstream direction to avoid a build-up of herbicide concentration.

- Where possible, stop or reduce water flow for 7 days or longer during and after application.

- Do not apply if heavy rain is forecast.which could increase water velocity.

- In early spring, do not apply if very cold weather is forecast. Falling water temperatures stop plant growth and reduce efficacy.

Gel Formulations. Diquat alginate can be used in any water velocity but is adversely affected by suspended mud or silt.

- Do not wade or stir up bottom sediment while treating.

- Work in an upstream direction to avoid build up of herbicide concentration.

- Treat plants which are young and growing actively. Older plants which are covered with sediment, epiphytes or calcium marl will be less susceptible.

- In flowing water, aim the jet of gel sufficiently far upstream of the target weeds so that the gel sinks onto the weed as it is carried downstream.

- Do not spray into clear areas where the gel will sink to the bottom and be inactivated.

4.9.5 Conservation and Ecological aspects of chemical control

The Environment Agency Code of Practice for the use of herbicides gives further guidelines for the user including storage, transportation and safe working procedures.

[Environment Agency written notifications are necessary for both Environment Agency Internal and External users].

Herbicides are more effective and, therefore, potentially more damaging than cutting. It is, therefore, important to avoid treating non-target weeds, especially rare or uncommon species. Where sensitive or valuable plant communities are present, herbicides should not be used unless the target weeds can be controlled in a highly selective and localised way.

Even where only common weeds are present, avoid treating weeds unnecessarily and retain untreated areas where possible as habitats for wildlife and for bank protection.

There is another reason why herbicides should only be used where strictly necessary. Over zealous use of herbicides can eradicate whole groups of weed. For example, it is relatively easy to spray all the emergent weeds in a channel and, at first sight, this may appear to be advantageous because it might be thought to reduce the need for further weed control. However, the effect of removing the emergent weeds is to allow more light to penetrate the water surface thus encouraging the growth of floating and submerged weeds. These weeds can impede flow more effectively than the emergent weeds and so increase the need for and cost of weed control. If they are controlled, they are often replaced by algae which are generally the most troublesome and least environmentally desirable of the groups of aquatic weed. Such, unintentionally, over-zealous management, under which total suppression of all weeds was attempted, occurred in some of the drainage ditches in East Anglia and is almost certainly the reason why many of these ditches are dominated by extensive growths of filamentous alga (Cott).

Until recently, the only effective treatment for Cott was to apply terbutryn. This herbicide controls both algae and submerged vascular plants so that repeated use prevents the establishment of vascular plants but, because of their ability to rapidly recolonise treated water, does not prevent the regrowth of algae. An additional problem arose when it was found that the Cott in some of the channels which had been treated over a number of years had developed resistance to the herbicide. Subsequently, it has been found that barley straw will control the algae selectively allowing vascular plants to recolonise the water. These are easier to control than algae and more environmentally beneficial.

If the initial control of the reeds in the channels had been limited only to maintenance of a clear channel along the ditches, it is unlikely that the present problems caused by the Cott would have arisen. It is also likely that the annual maintenance costs would have been considerably less than the costs of controlling dense growth of filamentous algae.

4.10 Herbicides Approved For Use in Water

4.10.1 2,4-D Amine

2,4-D amine is a selective herbicide used for the control of many annual broad-leaved weeds on banks and for the control of some emergent and floating leaved plants in water. It can affect submerged weeds if applied at higher dose rates than are recommended for control of emergent weeds but its use for this form of control is not recommended in the UK. Products approved for use in water are Atlas 2,4-D (Allied Colloids) and Dormone (Rhône Poulenc Agricultural Ltd.) and Agricorn D (Farmers Crop Chemicals Ltd.)

Formulation
Aqueous solutions containing 480 g/l (Atlas 2,4-D), 465 g/l (Dormone) and 500 g/l (Agricorn D) a.i.

Application
Applied as a spray direct to exposed foliage at the water surface. Do not apply direct to water.

Timing
Can be applied at any time when adequate leaf cover is present but, for the control of annual weeds, is most effective early in the season before flowering and the formation of seeds.

Dose
2.25 - 4.5 kg/ha. See individual product labels for appropriate dose of product.

Maximum permitted concentration in water under COPR
5.0 ppm.

Irrigation interval
3 weeks and until concentration falls below 0.05 ppm.

Taint and odour
Can be detected at 0.001 ppm after normal chlorination process.

Safety precautions
See Product Label.

Susceptible species
Alisma plantago-aquatica (Water Plantain)
Juncus effusus (Soft Rush)
Mentha aquatica (Water Mint)
Rorippa nasturtium-aquaticum (Water-cress)

Moderately susceptible
Nymphoides peltata (Fringed Water-lily) *
Sparganium erectum (Branched Bur-reed)

Moderately resistant
Equisetum fluviatile (Water Horsetail)
Nuphar lutea (Yellow Water-lily)
Nymphaea alba (White Water-lily) *
Polygonum amphibium (Amphibious Bistort)
Rumex hydrolapathum (Greater Water Dock)

Resistant
Most grasses, reeds and sedges
All submerged weeds and algae (unless concentration in water reaches about 1.0 ppm in which case submerged weeds except algae may be controlled).

Note Plants marked with * are scarce plants in Britain and should only be controlled if maintenance of a weed-free channel is considered essential.

Symptoms
Within 2-3 days, susceptible plants show abnormal growth with twisting of stems and leaf stalks. Plants become pale green and die after 2-3 weeks.

4.10.2 Dichlobenil

Dichlobenil is a broad-spectrum, translocated herbicide used for the control of many floating and submerged weeds. It controls a few emergent weeds and the Stonewort group of algae but has no effect on other species of algae. It is sold as a granule formulation, Casoron G,(Nomix-Chipman Ltd. and Rigby Taylor Ltd). Casoron GSR is no longer available.

Formulation
Granules containing 6.75% w/v (20% Casoron GSR - withdrawn)

Application
Direct to water. Following the withdrawal of Casoron GSR (the slow release formulation) application of Casoron G to deep or flowing water should be carried out very carefully. If possible flow should be stopped for 1 day before application and up to 4 days afterwards. It is also now very important to apply Casoron G **before** the end of April when plants are small, thus allowing granules to sink all the way to the bottom.

Dose rates for GSR are included because some stocks are still available.

Timing
Early in the season when growth is just starting and well before plants reach the water surface. Later treatments may be effective if the plants are first cut, which stimulates regrowth, and then treated. However, this technique has not been fully evaluated.

Dose

	Water depth	Dose (kg/ha)
Casoron G	300 mm	45
	600 mm	84
	900 mm	123
	>900 mm	150
Casoron GSR	300 mm	not applicable, use Casoron G
	600 mm	28
	900 mm	40
	>900 mm	50

Maximum permitted concentration in water under COPR
3 ppm.

Irrigation interval
2 weeks or until concentration falls below 0.3 ppm.

Taint and odour
Threshold odour concentration 0.02 ppm

Safety precautions
See product label

Susceptible species
Callitriche spp. (Starworts)
Chara spp. (Stoneworts)
Elodea canadensis (Canadian Waterweed)
Equisetum spp. (Water and Marsh Horsetails)
Fontinalis antipyretica (Willow Moss)
Glyceria fluitans (Floating Sweet-grass)
Hippuris vulgaris (Mare's-tail)
Hydrocharis morsus-ranae (Frog-bit) *
Hottonia palustris (Water Violet) *
Lemna trisulca (Ivy-leaved Duckweed)
Myriophyllum spp. (Water-milfoils)
Potamogeton crispus (Curled Pondweed)
Potamogeton pectinatus (Fennel Pondweed)
Ranunculus spp. (Water Crowfoots)
Rumex hydrolapathum (Great Water Dock)
Saggitaria sagittifolia (Arrow-head)
Stratiotes aloides (Water Soldier) *
Zannichellia palustris (Horned Pondweed)

Moderately susceptible
Alisma plantago-aquatica (Water Plantain)
Berula erecta (Lesser Water-parsnip)
Oenanthe spp. (Water Dropworts)
Potamogeton natans (Broad-leaved Pondweed)
Rorippa nasturtium-aquaticum (Water-cress)

Moderately resistant
Nuphar and Nymphaea spp. (Water-lilies)
Polygonum amphibium (Amphibious Bistort)
Potamogeton lucens (Shining Pondweed)
Sparganium erectum (Branched Bur-reed)

Resistant
Most emergent rushes, reeds and sedges
Lemna minor (Common Duckweed)
All algae except *Chara* spp.

Note * Plants marked with * are scarce plants in Britain and should only be controlled if maintenance of a weed-free channel is considered essential.

Symptoms
Symptoms do not usually appear for at least one week. Plants become brittle and may show some discolouration, collapsing slowly and decomposing after about 4 weeks.

4.10.3 Diquat

Diquat is a non-selective, contact herbicide. It is used as a spray for the control of free-floating weeds such as Duckweed and for the control of submerged weeds and algae by application to water either in the liquid formulation as Reglone (Zeneca) or Levi (P.S.I Phoenix Scientific Innovation UK Ltd.) or in the gel formulation as Midstream (Scotts Company (UK) Ltd. or Zeneca Professional Products).

Formulations
The liquid (Reglone or Levi contains 20% w/v active ingredient. The gel formulation (Midstream) contains 10% w/v a.i.

Application
As a contact spray, Reglone is applied using conventional spray equipment direct to exposed foliage. For use against submerged weeds and algae, Reglone is applied either diluted or undiluted from the container or through low pressure hoses to the water surface or by sub-surface injection. Midstream is applied in an undiluted form by modified knapsack or motorised applicator, producing a pencil jet of gel which is spread over the water surface so that the gel sinks onto the weeds.

Timing

As a spray, diquat can be applied at any time but is most effective when free-floating plants are no more than one layer thick, usually in late spring or early summer. For the control of submerged weeds and algae, Reglone or Midstream are usually applied in late spring when submerged plants are young and growing actively. Localised control with Midstream can be applied throughout the summer but control tends to become poorer as the plants become older and tougher and are protected by surface cover of epiphytes and silt.

Dose

As a contact spray	3 l/ha (600 g a.i.//ha)
For submerged weeds (Reglone)	25-50 l/ha/m depth (0.5-1.0 mg a.i./l)
For submerged weeds (Midstream)	1 l/100 m^2 (1 l/200 m^2 if water is less than 50 mm deep) (1.0 mg a.i./l)

Water Velocity

Midstream can be used in water flowing at any velocity. Reglone should not be applied to water flowing at more than 90 m/h.

Maximum permitted concentration in water under COPR

2.0 ppm.

Irrigation interval

10 days or until concentration falls below 0.02 ppm.

Taint and odour

Not available.

Safety Precautions

See product labels.

Susceptible species

Callitriche spp. (Starworts)
Ceratophyllum demersum (Rigid Hornwort)
Elodea canadensis (Canadian Waterweed)
Fontinalis antipyretica (Willow Moss)
Hydrocaris morsus-ranae (Frog-bit) *
Lemna spp. (Duckweeds) #
Lemna trisulca (Ivy-leaved Duckweed)
Myriophyllum spicatum(Spiked Water-milfoil)
Potamogeton crispus (Curled Pondweed)
Ranunculus spp. (Water Crowfoots)
Zannichellia palustris (Horned Pondweed)
Most species of Duckweed are susceptible to diquat as a surface spray except *Lemna miniscula* (also called *Lemna minuta*). All species of Duckweed are susceptible to subsurface treatment with diquat at 1.0 ppm.

Moderately susceptible
Cladophora (Blanket-weed)
Enteromorpha intestinalis (Gut-weed or bladder-weed)
Hottonia palustris (Water Violet)
Potamogeton lucens (Shining Pondweed)
Potamogeton natans(Broad-leaved Pondweed)
Potamogeton pectinatus (Fennel Pondweed)
Sparganium emersum (Unbranched Bur-reed)
Spyrogyra (Blanket-weed)

Resistant
Hippuris vulgaris (Mare's-tail)
Nuphar lutea (Yellow Water-lily)
Nymphaea alba (White Water-lily) *
Polygonum amphibium (Amphibious Bistort)
Vaucheria dichotoma (Cott or Blanket weed)
Most emergent weeds including rushes, reeds and sedges.

Note Plants marked with * are scarce plants in Britain and should only be controlled if maintenance of a weed-free channel is considered essential.

Symptoms
Floating or emergent plants which are sprayed with diquat will show yellowing in characteristic spots within 24 hours where the spray drops landed. If the whole plant is sprayed, it turns yellow and leaves die off within 2-3 weeks. Most emergent and rooted floating-leaved plants are resistant and produce new leaves soon afterwards.
Submerged plants start to show symptoms in about 48 hours. Leaves become a grey-green colour, eventually turning grey or white and start to rot from the leaf tips moving downwards. After about one week the plants are rotten and collapse onto the bottom and break up.
Symptoms appear more rapidly under sunny than dull conditions but the degree of control is not altered.

4.10.4 Glyphosate

Glyphosate is a powerful translocated herbicide used for the control of most emergent and floating leaved plants. It has no effect on submerged weeds or algae. There are 23 products containing glyphosate on the market for use in the agriculture, horticulture, forestry and amenity sector, which have approval for use in or near water. These are:

*Barclay Gallup Amenity (Barclay Chemicals UK Ltd.)
Buggy SG (Sipcam UK Ltd.)
Clinic (Nufarm UK Ltd.)
Danagri Glyphosate 360 (Danagri Aps)
Glyfos] (Cheminova Agro (UK) Ltd.)
Glyfos 480]
*Glyfos Proactive (Nomix Chipman Ltd.)
*Glyper (Pan Britannica Industries Ltd.)
Glyphogan (Pan Britannica Industries Ltd.)
Glyphosate 360 (Danagri Aps)
Glyphosate Biactive (Monsanto plc)
Helosate (Helm AG)

Ipiglyce 36 SL (I Pi Ci)
MSS Glyfield (Mirfield Sales Services Ltd.)
Roundup]
Roundup Amenity]
Roundup Biactive]
Roundup Biactive Dry] (Monsanto plc)
*Roundup Pro]
*Roundup Pro Biactive]
Spasor (Rhône Poulenc Amenity)
Spasor Biactive (Rhône Poulenc Environmental Products)
Stetson (Monsanto plc)

Formulation
Water soluble formulation containing around 36% w/v a.i. (360 g/l).

Application
Applied as a spray direct to foliage exposed at or above water surface. *Controlled Droplet Application: Five glyphosate formulations are approved for use in CDAs and for use in or near water. These are Barclay Gallup Amenity, Glyper, Glyfos Proactive, Roundup Pro and Roundup Pro Biactive. These formulations may be appropriate for use when extensive riparian or aquatic weed control using glyphosate is required.

Timing
Normally applied in mid to late summer when full leaf emergence has occurred. Free-floating plants should be sprayed when the surface cover is no more than one layer thick. Some emergent plants (e.g. Common Reed and Reed Sweet-grass) can be sprayed from late May or June, onwards.

Dose
Product. 5-6 l/ha (check product label)
1.8-2.2 kg a.i./ha

Maximum permitted concentration in water under COPR
0.2 ppm.

Irrigation interval
Nil.

Taint and odour
No taint detectable up to 10 ppm.

Safety precautions
See product label.

Susceptible species
All Reeds, Rushes, Sedges and emergent marginals
Agrostis stolonifera (Creeping Bent)
Carex spp. (Sedges)
Catabrosa aquatica (Water Whorl-grass) *
Glyceria maxima (Reed Sweet-grass)
Juncus effusus (Soft Rush)
Lemna minor (Common Duckweed)
Nuphar lutea (Yellow Water-lily)
Nymphaea alba (White Water-lily) *
Phalaris arundinacaea (Reed Canary-grass)
Phragmites australis (Common Reed)
Rorippa nasturtium-aquaticum (Water-cress)
Schoenoplectus lacustris (Common Club-rush)
Sparganium erectum (Branched Bur-reed)
Typha latifolia (Bulrush)

Resistant
All submerged weeds and algae
Polygonum amphibium, Nymphoides peltata and *Potamogeton natans* are unpredictable in their response to glyphosate.

Note Plants marked with * are scarce plants in Britain and should only be controlled if maintenance of a weed-free channel is considered essential.

Symptoms
Glyphosate is a slow acting herbicide and symptoms, which vary considerably between species, do not usually appear for 2-3 weeks. In many species, symptoms first appear as discolouration of the sprayed leaves, plants eventually turning brown and decomposing after 4-6 weeks. If emergent plants are sprayed when they are still growing, growth stops almost immediately and sprayed areas can be identified later in the season because they are shorter than unsprayed areas. Some plants, e.g. Common Clubrush show no symptoms after spraying and die back naturally in the autumn along with unsprayed plants but do not regrow in the following season.

4.10.5 Terbutryn

Terbutryn is a non-selective herbicide used for the control of submerged weeds and algae. It also controls free-floating weeds such as Duckweed but has little or no effect on rooted floating weeds or emergent weeds. It is sold as Clarosan 1FG and Clarosan by Novartis Crop Protection.

Formulation
A granule containing 1% w/v active ingredient.

Application
Applied by hand or granule applicator direct to water.

Timing
In early spring when plant growth is just starting. Later treatments cause deoxygenation and should be avoided.

Dose
Dose is calculated on the volume of water being treated and is between 5-10 g product per m^3 (0.05 - 0.1 ppm). The dose range depends on the target weeds and the conditions locally. Check product label for dose selection.

Water velocity
Apply to water flowing at less than 20 m/h. If possible flow should be stopped during and after treatment for 7 days.

Maximum permitted concentration in water under COPR
0.1 ppm.

Irrigation interval
One week.

Taint and odour
Threshold odour concentration around 5 mg/l depending on water hardness.

Safety precautions
See product label.

Susceptible species
Callitriche stagnalis (Common Water Starwort)
Ceratophyllum demersum (Rigid Hornwort)
Cladophora spp. (Blanket weed)
Elodea canadensis (Canadian Waterweed)
Enteromorpha intestinalis (Bladder weed)
Hottonia palustris (Water Violet) *
Lemna spp. (Duckweeds)
Myriophyllum spp. (Water-milfoils)
Potamogeton crispus (Curled Pondweed)
Potamogeton pectinatus (Fennel Pondweed)
Ranunculus spp. (Water Crowfoots)
Rhizoclonium spp. (Blanket weed)
Spirogyra spp. (Blanket weed)
Vaucheria spp. (Cott or Blanket Weed)

Moderately resistant
Hippuris vulgaris (Mare's- tail)
-(becomes resistant when growth reaches the surface)
Nuphar lutea (Yellow Water-lily)
Nymphaea alba (White Water-lily) *
Potamogeton natans (Broad-leaved Pondweed)

Resistant
Polygonum amphibium (Amphibious Bistort)
Most emergent weeds including rushes, reeds and sedges

Note * Plants marked with * are scarce plants in Britain and should only be controlled if maintenance of a weed-free channel is considered essential.

Symptoms
Terbutryn is a slow acting herbicide and does not produce many noticeable symptoms of discolouration on leaves or stems. After treatment, floating mats of algae sink, often within 72 hours, but remain green for 2-3 weeks. Higher plants also remain green but gradually sink, slowly turning black when they, and the algae, rot on the bottom.

4.10.6 Barley straw for control of algae

Although barley straw is not a herbicide, its effects are similar and so it is included in this section. Barley straw behaves as a selective algicide. It controls all species of algae including blue-green algae (Cyanobacteria) tested to date. So far, no adverse effects on higher plants, invertebrate animals, fish or wildfowl have been detected. Other straws, including wheat, maize, linseed and lavender have all been shown to be effective but barley straw probably combines the highest level of activity with the longest effective period.

Note: The terms used in the following sections were developed for herbicide use but can be applied to straw.

Formulation
Apply barley straw in a loose form retained in netting. Bales may be used if they are the small (20 kg) size but are less effective than loose straw through which water can pass easily.

Application
Nets or bales should be spaced so that there is no more than 60 m between straw masses. The straw should be suspended by floats so that it remains close to the water surface even when waterlogged and should be firmly anchored so that bales or nets cannot drift or be washed away in fast flowing conditions. Large numbers of nets containing proportionally less straw are more effective than a few very large nets of straw.

Timing
Straw can be applied at any time but is most effective if applied early in the season before algal growth starts and again in the early autumn. Treatment should be repeated each year.

Dose
The minimum effective dose is about 10 g/m^{-2} water surface. However, initial treatments should normally be in the range of 15-25 g/m^{-2} and can be as high as 50 g/m^{-2} in highly infested waters especially when suspended mud is present in large quantities. Subsequent treatments, once the algae have been controlled, can be reduced but must not be less than 10 g/m^{-2}.

Flow control
Straw can be used in static or flowing water but well oxygenated water is required for best performance.

Maximum permitted concentration in water
No limit but concentrations should not normally exceed 250 g/m^{-2} to prevent any risk of causing deoxygenation by the rotting straw.

Irrigation interval
None.

Taint and odour
Chemicals known to cause taint and odour have not been found at higher concentrations than have occurred naturally in untreated waters.

Safety Precautions
Users who are allergic to straw should use gloves, face masks and dust filters. Care should be taken when mooring and anchoring bales or nets that the ropes do not present a hazard to swimmers, boats or wildlife. Netting used for straw should be close-woven (e.g. onion sacking) to prevent fish or birds being trapped or gilled.

Highly susceptible species
Cyanobacteria (blue-green algae)
Unicellular green algae

Susceptible - normally controlled only if straw applied before alga growth
Most filamentous green algae

Moderately susceptible - may require exposure to straw for up to 1 year
Desmids
Diatoms
Vaucheria dichotoma

Probably resistant (not fully tested)
Marine algae
Charophytes

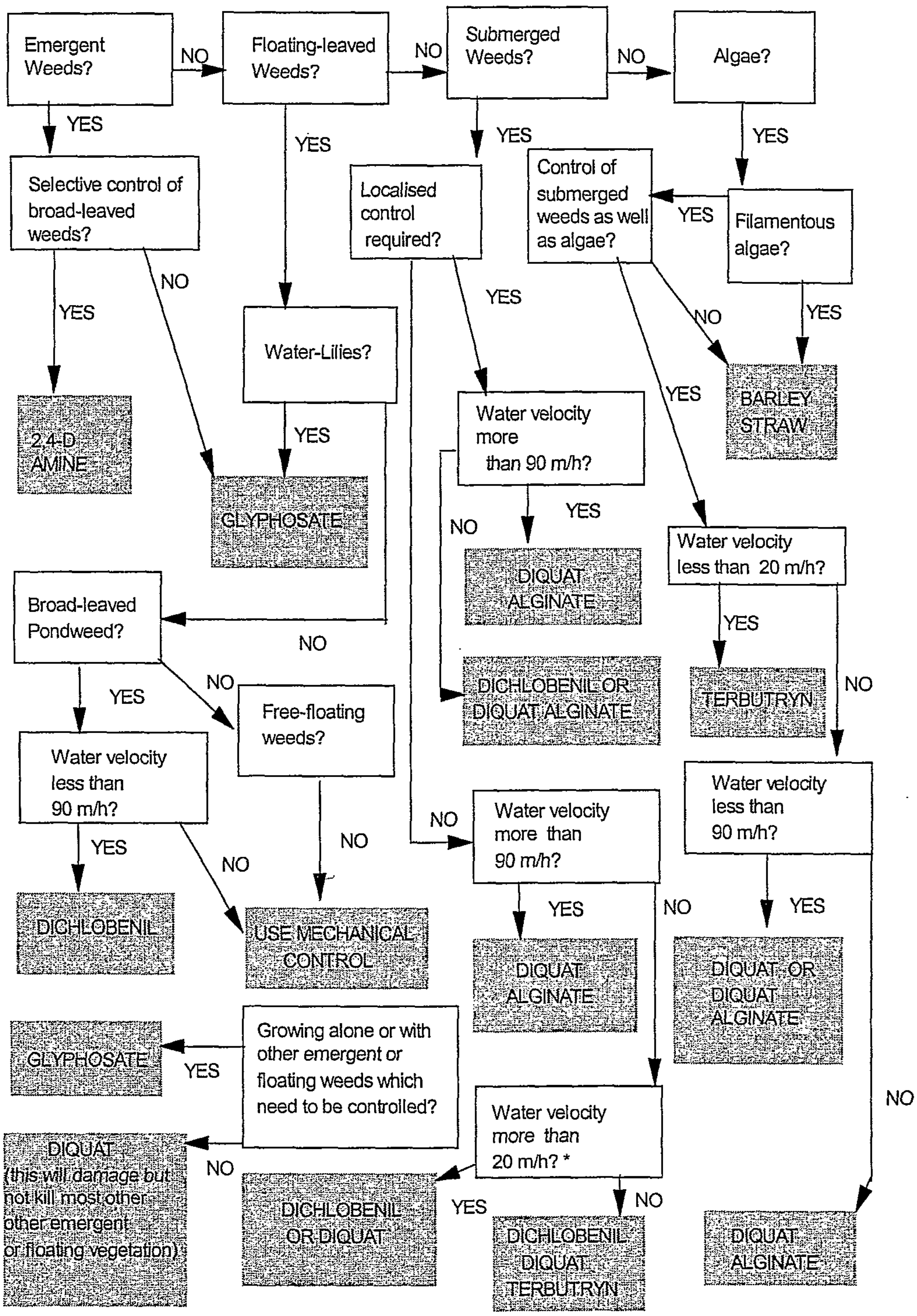
Resistant
All higher plants whether submerged, floating or emergent

Note: In laboratory experiments, the growth of *Lemna* spp. was suppressed but not controlled when high concentrations of straw were used.

Symptoms
Straw works by suppressing algal growth and cell division. Cells die off gradually as they reach the end of their natural life cycle. Short lived algae such as Cyanobacteria die within weeks but the slower-growing, longer-lived filamentous algae may survive for months before dying. There are no visible symptoms of straw treatment and algae which have been inhibited from growing by exposure to straw can recover and start to grow rapidly if the straw rots away or is removed.

Detailed information on the use of straw to control algae in different situations is available from the Centre for Aquatic Plant Management, Broadmoor Lane, Sonning-on-Thames, Reading, RG4 6TH.
Tel: 0118 969 0072 Fax: 0118 944 1730 E-mail: IACR-CAPM@compuserve.com

SELECTION CHART 4.2 - HERBICIDE OPTIONS



*Water velocities around 20 m/h are difficult to measure. In practice, terbutryn should only be used in static water bodies, or in channels where the flow can be stopped for 7 days.

4.11 Biological Control

4.11.1 Introduction

For the purposes of these guidelines, biological control is defined as the control of an aquatic plant by direct physical contact with and action of a biological agent. The agent may eat the weed or cause physical damage to it, for example, by trampling on it. Microbial agents also control weeds by inducing disease. However, the distinction between biological and environmental control is not clear-cut because biological agents can produce both direct and indirect effects in which no physical contact is made. For example, cattle can graze and trample on weeds in a shallow stream, which is a direct effect, but they may also stir up mud which increases turbidity and creates a form of shading. Where control occurs mainly as an indirect effect, it is included in the following section on environmental control.

Biological control of aquatic weeds has been the subject of less research in Britain than either mechanical or chemical control. Some forms of biological control may be exploited commercially, thus providing a return to the producer, but many are of value only to the user, who can save on the costs of weed control. Unless the potential users of biological control techniques fund research, biological control is likely to remain as only a minor part of the armoury of weed control techniques in Britain.

In other parts of the world, highly effective forms of biological control have been developed. Insects, molluscs and plant pathogens have been used to control specifically targeted weeds. Most frequently, however, the weed problem was caused by a single species of weed introduced from another country, which became so successful that it developed into a major weed problem. Water Hyacinth, Alligator Weed and *Salvinia* are examples of aquatic weeds which were exported either deliberately or accidentally, and became major problems in other countries. The biological control agent which controlled the weed was found in the country of origin and released in the new location, after careful checks to ensure that it would control only the target weed. In Britain, weed problems are caused by a wide range of species, many of which are native to this country. No single biological control agent would be likely to control all these species, so that a whole range of target specific control agents would be needed to control all the different weed species. Less specific control agents are a potential danger because, if they escape, they may cause damage to the ecosystem by eradicating desirable plant communities. This is the reason why Grass Carp are strictly controlled and can only be released into enclosed waters, where they cannot escape into the wild.

If research into biological control receives the necessary support, it is likely that the most acceptable forms will involve an approach which enhances the level of control already achieved by native control agents. This may be achieved by several means, for example, increasing the populations by breeding and stocking, culturing and applying target specific plant pathogens to enhance activity or by controlling predators on the control agents so that the numbers of the agent increase naturally. Some of these approaches are discussed in more detail in this section.

4.11.2 Cattle, sheep and horses

Cattle, sheep and horses graze river banks controlling bankside and some emergent weeds. Where control of only bankside weeds is required, sheep are preferable because they cause less damage to the banks. Cattle and horses will wade into shallow water and graze on emergent and even submerged weeds, especially in summer, when the grazing in the pastures is poor. A traditional method of weed control in some shallow watercourses was to drive cattle along the river bed, where they trampled and grazed on the vegetation, and produced some control. Common Reed has been controlled in situations where it is regularly exposed to grazing and trampling by livestock.

4.11.3 Ducks, geese and swans

Waterfowl consume significant quantities of the softer water weeds, especially submerged weeds and algae. Domestic ducks and geese can be controlled and will remain in one place where they produce useful levels of control. Wild birds tend to migrate and are difficult to manage. Juvenile swans tend to congregate in sections of rivers where there are no adults to drive them away and these have sometimes been blamed for denuding valuable stretches of trout river of all vegetation. However, a pair of adult swans will defend a territory and so keep the population too low to have much effect on weed populations.

4.11.4 Crayfish

Native crayfish and introduced signal crayfish are reported to have controlled submerged weeds and algae in small water bodies but it is unlikely that sufficient numbers could develop in river systems to have any significant effect on weed growth.

4.11.5 Other invertebrate animals

Daphnia spp. (Water fleas) feed on unicellular algae and have been used to clarify water. Experiments carried out in the Norfolk Broads to enhance the population of these invertebrates have controlled the dense algal blooms. Unfortunately, they are a preferred food of many native fish and their numbers are kept too low, especially in waters with a high fish population, to have any useful effect. In the Norfolk Broads, areas have been netted off and fish are excluded to allow *Daphnia* populations to increase. This technique is called biomanipulation.

Filter feeding invertebrates such as the Swan Mussel filter large quantities of water and remove unicellular algae and may help to clarify water. Other invertebrates such as leaf miners and borers can have an effect locally on various emergent weeds.

4.11.6 Carp and bream

These native fish are bottom feeders and take in mouthfuls of sediment, filtering out invertebrate animals and releasing the mud through their gills. During this process, they uproot small plants. They also make the water turbid which reduces light penetration and so shades the growth of submerged weeds. Ponds and lakes which have been stocked with these fish can lose their macrophyte populations within one season and the water becomes turbid and dominated by unicellular algae. It is possible that they would have the same effect in slow flowing, silty rivers.

4.11.7 Roach

Roach feed on filamentous algae although they may do this to obtain the invertebrate animals living within the algal mass. Large roach populations may help to reduce the quantity of filamentous algae in some waters.

4.11.8 Grass carp

These introduced fish are effective biological control agents of many submerged and floating weeds. They will also eat filamentous algae and even some emergent weeds when the food supply is limited. At present, their use is restricted to enclosed waters where they cannot escape into river systems. Further details of their use are available in the Environment Agency R&D Note 53, Grass Carp for Aquatic Weed Control - A Users Manual, available from the Foundation for Water Research.

4.11.9 Microorganisms

There are various pathogenic bacteria and fungi which are known to attack aquatic plants. For example, it is common to see the leaves of Reed Sweet-grass showing infections of a rust fungus in summer. Unfortunately, none of these microorganisms appears to be sufficiently virulent to produce useful levels of control. However, this is an area where research could identify target specific organisms which could be developed, perhaps in conjunction with low levels of a herbicide, to produce highly specific microbial herbicides.

4.12 Environmental Control

4.12.1 Introduction

Environmental control is based on the premise that a weed problem exists because the conditions are so suitable that excessive weed growth occurs. It aims to alter one or more of the conditions in or around the water body so that the conditions for growth are less favourable. Aquatic plants have exactly the same requirements for growth as do terrestrial species. They need light, nutrients (particularly nitrates and phosphate), water (of the right depth, quality and velocity), carbon dioxide and a suitable substrate in which to root and grow. If one or more of the requirements can be altered or reduced then the quantity of weed can be reduced or the species composition altered to a more acceptable population.

Controlling aquatic weeds by altering the environment is usually a slow process and may take a number of years to become fully effective; for example, trees are planted to create shade but may take several years to achieve full effect. Other forms of environmental control can involve a high capital cost, especially if major restructuring to control flow is required, and can seldom be justified solely for the purposes of weed control. However, they can be included during the design stage of river improvement schemes at relatively little extra cost, or when work is being undertaken for other reasons. Once in place, the benefits of lower weed control costs may last for many years. Unlike the other control techniques described in previous sections, environmental control aims to cure the cause of the weed problem rather than to treat the symptoms. The following table outlines some of the methods available and the way in which they act. These are discussed in more detail in subsequent sections.

Table 4.2 Environmental control techniques

Element of weed habitat manipulated	Manipulation method
Water	Alteration of depth - drowning and dewatering Alteration of velocity
Nutrients	Tertiary sewage treatment Bypass channels Nutrient absorption by plants
Substrate	Silt removal Prevention of silt deposition
Light	Tree shading Shade cloth or plastic Induced turbidity Floating leaved plants
Carbon dioxide	Competition from acceptable species

Environmental control is more site specific than the more commonly applied methods of mechanical or chemical control, and the choice of which method may be appropriate is highly dependent on the suitability of individual sites.

4.12.2 Water level manipulation

There are various ways in which water levels can be manipulated to control or alter aquatic weed growth. However, great care should be taken to ensure that water level manipulation is not employed where it will cause harm or is contrary to the duties of the Environment Agency to further conservation. It should also be considered in relation to any Water Level Management Plan.

Temporary manipulation. These techniques are appropriate in channels in which complete control of water levels is possible. It is most effective when extremes of temperature can be exploited, and is generally disruptive to the ecosystem, especially to fish and aquatic invertebrates.

Lakes or channels can sometimes be drained during winter (winter drawdown). This exposes the roots and rhizome systems to frost and to damage by wildlife and livestock.

Summer drawdown can be used to control aquatic plants which are very susceptible to dessication especially during the summer when leaves and stems are fully formed. Exposure to hot dry weather during the summer months tends to kill off much of the vegetative growth and can inhibit flowering and seed production. Annual and poorly rooted submerged and floating-leaved species are more susceptible than the deeply rooted emergent weeds.

Permanent manipulation. These techniques involve engineering work to alter conditions in the channel permanently. The cost is likely to be too high to be justified solely for weed control purposes but their application may be incorporated into schemes in which restructuring work is being undertaken for other purposes.

Water depth. Most emergent weeds are limited to growth in water of less than 1 m deep. Rooted floating plants and submerged plants do not usually cause serious weed problems in water more than about 2 m deep. If water depth is increased beyond these limits and the banks are steeply sloped, emergent vegetation will be restricted to a narrow marginal fringe and floating and submerged weed growth will be inhibited and restricted to the shallower margins.

Water velocity. Many aquatic plants, particularly the submerged weeds, are restricted in the range of water velocities which they can tolerate. High velocities tend to support fewer weed species and will sometimes uproot or tear off vegetative growth, thus reducing hydraulic resistance in the channel. High velocities also scour out silt beds leaving gravel or stone which support fewer weeds. In some instances, normal summer velocities can be increased by restricting the bed width of the channel by creating two stage channels. This is particularly appropriate where channels have become oversized due to excessive dredging, water abstraction and erosion of banks.

Water Level Management Plans. The implementation of Water Level Management Plans in controlled systems may have a long-term effect on the species and density of aquatic weeds. This is most likely to occur where significant changes are made to the existing water level management regime. Ensure that consideration is given to the likely impact on weed growth when plans for Water Level Management are drawn up.

4.12.3 Nutrients

High levels of nutrients in water encourage the growth of aquatic plants. The most significant of these plant nutrients are nitrogen and phosphorus. Nitrates enter water mainly from agricultural land and phosphates from point sources of release such as sewage treatment works and industrial effluents. Nitrates encourage the growth of most aquatic plants but phosphates are more important in relation to the growth of algae, particularly the blue-green algae which can fix atmospheric nitrogen and so are less dependent on this nutrient than other plants.

Point sources of release -phosphate. While it is beyond the scope of this work to deal with the requirements for water quality standards and the efforts being made to improve them, river managers should be aware that these sources of pollution are being controlled and improved. However, it is likely to take some time before the effects of lower inputs of phosphate have a significant impact on the amount of algal growth because there is already a substantial reservoir of phosphates in the sediments of many watercourses. This reservoir is recycled and is lost only slowly under natural conditions by the flushing action of rivers.

Land drainage - nitrate. In many parts of the country, areas of land have been designated as nitrogen sensitive areas. In these areas, the use of nitrogen on agricultural land is strictly controlled. However, the reservoir of nitrogen in the soil and groundwater is already high and estimates suggest that it may take as much as 30 years for all this nitrogen to be washed out.

While these control measures will take time to become fully effective, there are more immediate ways in which nutrients can be controlled.

Buffer strips - Strips of vegetation along river banks intercept nutrients, particularly nitrate, as they drain off agricultural land. Aquatic weeds such as Reed Sweet-grass and Common Reed, which will grow both in water and on adjacent land, have been shown to remove significant levels of nitrate. Trees probably have the same effect. The wider the strips are, the more effective they are in removing nutrient but strips of 10-20 m have produced useful results.

Bypass channels - Bypass channels which carry nutrients and silt around ponds and lakes reduce both silting and weed growth. Some flood alleviation schemes can also be bypassed during periods of normal flow and this reduces the level of nutrient and thus the amount of weed growth in the flood channel.

Nutrient absorption by plants - Plants growing in water can produce effects similar to those growing as buffer strips on the banks. They also help to purify water of organic contaminants by providing a support on which bacteria can grow. Reeds are particularly effective for this purpose because oxygen is transported to the roots and maintains a highly active bacterial population even in anaerobic sediments. Also the stems remain standing throughout the winter so that bacterial action can continue after the plant has died back. Sewage and industrial effluents are now being treated using Reed beds in filtration systems. In rivers, margins and localised areas of reed or other weed may help to absorb nutrients and purify water.

4.12.4 Substrates

Substrates act as a reservoir of plant nutrients. Phosphates are retained as insoluble salts which are released back into solution when the surface layers of the silt become short of oxygen in the spring and summer. Nitrates are held in organic matter and released when the silt becomes aerobic and decomposition processes are active.

Silt removal. Dredging and removal of silts reduces the reservoir of nutrients available to aquatic plants. Nutrient-rich silts should not be deposited close to the bank where nutrients can be leached back into the watercourse. Silts also provide better rooting conditions for most aquatic plants than gravel or stone. In some sections of river, gravel beds have been deliberately reintroduced to create spawning beds for salmonid fish. An additional benefit has been a reduction in the growth of some species of weed. In other situations, increased water velocities, due to restricting channel width, have washed out much of the silt leaving the gravel bed exposed and restricting weed growth.

Oxygenation of substrate surfaces. Phosphates trapped in the substrate are released back into solution when the surface of the substrate becomes anaerobic. By maintaining a flow of oxygenated water over the surface of the substrate, the phosphates remain locked in the sediment. In static waters, this is sometimes achieved by pumps and aeration systems. In rivers, it is best achieved by maintaining an adequate water velocity over the surface of the substrate.

Prevention of sediment deposition. Apart from acting as a reservoir for nutrients, sediments make the water shallower and provide a suitable rooting medium for aquatic plants. Sediment deposition can be reduced by the use of sediment traps, stabilisation of banks and maintenance of adequate flow velocities.

4.12.5 Light

All green plants require light for photosynthesis. Some species are relatively tolerant of shade while others need full sunlight. Most aquatic plants are relatively shade tolerant although there is a limit below which their growth is reduced or eliminated (< 1% full sunlight). Shade can be produced by planting trees along the banks or by retaining as much emergent or floating-leaved species as possible. Shade can also be created by various opaque floating sheets or dyes added to water.

Tree shading. The planting of trees to suppress or eliminate weed growth is a well known method of control, particularly in Germany and Denmark. Apart from the shading effect, trees provide a number of other benefits. They help to stabilise the banks, provide valuable habitats for wildlife and; absorb large amounts of nitrate. There is also evidence that the leaves from some trees which fall into the watercourse behave in a way similar to barley straw and help to control the growth of algae.

In general, the light level needs to be reduced to approximately half that found in unshaded channels for aquatic weed growth to be satisfactorily reduced. Tree species vary with the density and shading effect of the canopy and the orientation and width of the watercourse also affects performance.

Suitable channels for shading by trees

- Narrow channels are more effectively shaded than wide ones. As a general rule channels should not be more than 20-25 m wide. Even in wider channels, where the centre is too deep for weed growth, a useful benefit may be obtained by shading one or both of the shallower margins where weed growth could occur.

- Channels which do not suffer severely from sedimentation because trees are likely to interfere with dredging operations.

- Channels which are orientated in an East-West direction are more effectively shaded, especially if trees can only be planted on one (the Southern) bank.

- Channels where adjacent land is not adversely affected by the presence of trees. Ideally; a strip along the bank should be fenced during the early stages to allow the trees to establish free from grazing livestock and rabbits.

Types of tree. Deciduous, softwood, water-tolerant species are recommended. These should have rapid growth rates and the ability to withstand water inundation and flood damage. Suitable trees include Alder (*Alnus glutinosa*), Black Poplar (*Populus nigra*) and various species and clones of Willow (*Salix* spp.). Lime (*Tilia cordata*), Beech (*Fagus sylvatica*), Oak (*Quercus* spp.) and Field Maple (*Acer campestre*) may also be useful but will grow more slowly. **Coniferous species should not be used** as their needles acidify the water.

Alder is a very effective shade tree, producing a dense leaf canopy. It does not readily shed branches and is easily coppiced if required. Many varieties of Willow are also effective if managed regularly. They may be grown as large trees, which can be pollarded to reduce the chance of branches being shed in high wind, or as coppice. Willows have a particular advantage in that there is a wide range of varieties which can be used for different functions in different waterside situations. More detail on the use of willows is available in a booklet published by the Centre for Aquatic Plant Management. Both Alders and Willows have water tolerant, extensive roots that contribute significantly to bank stabilization. In contrast, the roots of trees such as Oak, Ash, Elm and Sycamore tend to grow laterally along the banks above water level. This allows the current to undercut the bank, eventually causing the trees to collapse into the channel. One advantage they offer is that the exposed buttress roots can provide suitable sites for Otter holts.

In channels less than 5 m wide, shrubs such as Elder (*Sambucus nigra*), Blackthorn (*Prunus* *spinosa*) and Hawthorn (*Crataegus monogyna*) can be effective, as can coppiced forms of Alder and some Willows. Willows with a prostrate habit should be avoided as their lower branches can partly block the channel.

In very narrow channels (1 - 2 m wide) adequate shading may be achieved simply by fencing off the bank to prevent grazing and allowing tall marginal vegetation to establish. This may cause problems in the autumn if the vegetation collapses into the channel, and some form of management may be needed in late summer or early autumn.

Planting. Unbroken, heavy shade will prevent almost all weed growth and, so, may damage the animal community. It may also produce excessive leaf fall into the channel. As a general rule, trees should be planted in intermittent stands, occupying no more than two thirds of the bank. Maximum species diversity of both aquatic plants and animals is found when the shade is broken every 40 - 50 m. A mix of trees in both species and age is preferable for both environmental and management reasons. Where banks are exposed to erosion, Alders or Willows should be planted in a row along the exposed bank. Willows can be planted conveniently and cheaply as large (0.6 - 1 m long x 5 - 7 cm diam) cuttings, whereas Alders are more usually planted as established saplings. Ideally, before planting, the bank should be graded to a slope of 1:2 or 1:3 to remove overhangs. The trees should be planted just above mean summer water level.

Where erosion risks are particularly high, Willows may be most suitable, as they produce extensive root systems rapidly, and stabilize the bank more quickly than the slower growing Alder. If Alders are preferred for any reason, it may be necessary to use stone or other artificial means of bank protection below mean summer level, to allow the Alder roots time to spread and stabilize the bank effectively.

German practice suggests that trees should be planted at 1 - 1.5 m intervals and between 20 -40 cm above water level. Where erosion is severe, US research indicates advantage from transplanting willow cuttings (at 0.5 m intervals) directly into the sediment at the toe of the bank.

Do not plant trees close to field drainage pipes.

Shading of adjacent crops can be minimised by planting trees as close to the water margin as possible.

In all cases, trees will establish only slowly, and poorly if they are subject to competition from surrounding grass and other vegetation. It is particularly important that, at least in the first year after planting, vegetation around the trees should be controlled. This can be achieved by using an approved herbicide, such as glyphosate, provided that it is applied before the saplings produce leaves, or the saplings are screened from the spray. Alternatively, mulches produce long-lasting control of grasses and smaller herbs and may be an economical alternative to glyphosate.

Newly planted Alders need to be protected from rabbits for about 4 years; Willows may not need protection. Protection against cattle is needed by both Alders and Willows for about 10 years.

Management. Alders start to produce effective shade after about 4 years (in channels less than 8 m wide). Willows are much faster, some varieties reaching heights of several metres in only two years.

The trees should be coppiced or pollarded on a regular basis with no more than one third of the trees being managed in one year. The management used may be adapted to take account of any local market, for example, for willow rods for basket or hurdle making or for willow cuttings.

New trees should be planted amongst, or close to, the existing trees before they reach maturity, to ensure a long life of the tree stand. Any planting or operations such as weed cutting or dredging should be carried out at the same time as coppicing or pollarding. Coppicing or pollarding should be carried out on Alders at 10-15 year intervals. Faster growing willows can be coppiced at 2 - 4 year intervals, or pollarded after about 10 years, and then at 5 year intervals.

Cost Some estimates put the cost of weed control by established trees at approximately 60% of the cost of conventional weed control. However, the costs of planting, and of channel maintenance until the trees become effective, will increase initial costs. Once established, some costs may be recovered by selling harvested wood. For example, cricket bat willows have a high sale value but require special management in order to produce wood of an adequate quality. Sales may be possible to basket and hurdle makers, as fuel, or, after chipping, as mulch.

Other benefits Trees provide habitats for insects, birds and animals. The insects attracted to trees, provide a valuable benefit to fisheries.

Trees stabilise banks and so steeper banks can be maintained giving increased hydraulic efficiency, requiring less land and discouraging weed growth both on banks and in the water.

Trees and other vegetation growing beneath and around the trees act as a buffer zone, reducing run-off of agricultural fertiliser and pollutants. Trees may also intercept spray drift and other airborne pollutants. They also act as wind breaks.

Shade reduces temperature fluctuations in water and this has been found to be a benefit to fisheries. There is growing evidence that branches and twigs which fall into the water provide a very valuable habitat for invertebrate animals and fish especially in channels with sandy and featureless beds.

Susceptibility to shade

Low levels of shade
Apium nodiflorum (Fools Water-cress)
Berula erecta (Water-parsnip)
Glyceria maxima (Reed Sweet-grass)
Nuphar lutea (Yellow Water-lily)
Ranunculus spp. (Water crowfoots)
Rorippa spp. (Water-cresses)
Sagittaria sagittifolia (Arrowhead)
Moderate shade
Callitriche spp. (Starworts)
Ceratophyllum demersum (Hornwort)
Elodea canadensis (Canadian Waterweed)
Phragmites communis (Common Reed)
Dense shade
Sparganium spp. (Bur-reeds)
Tolerant of prolonged shade
Crassula helmsii (Australian Swamp Stonecrop)

Shading by emergent and bankside plants. In narrow watercourses, usually less than about 4 m wide, a fringe of reed can shade the channel effectively. Tall herbaceous species on the banks have the same effect. Bankside and emergent plants help to stabilise the banks, provide nest sites for birds and reduce run-off of agricultural fertilizer. Reeds may need to be removed in autumn to maintain a clear channel and may require periodic control to prevent spread across the channel, especially in shallow water.

Shading by floating-leaved plants. Floating-leaved species, particularly Water-lily, create relatively little hydraulic resistance but produce sufficient shade to prevent the more hydraulically resistant submerged weeds from reaching nuisance levels. In a number of larger watercourses, they have been deliberately retained as fringes along both banks, where the water is sufficiently shallow to allow them to grow, to prevent submerged weed growth. Their spread into the centre of the channel is prevented either by the depth of water or, where the channel is shallow, by localised applications of glyphosate.

Artificially created shade and turbidity. Shade can be created by using various forms of plastic sheeting floating or suspended above the water surface or by adding dyes to the water. Artificially induced turbidity created, for example, by boat traffic can have similar effects although, in this instance, propeller action and turbulence caused by the wash and wake of the boat may also damage the plants.

Floating plastic sheeting
(Note: This section is included for information only. The use of plastic sheeting is not recommended in rivers or drainage channels because of the risks of adverse environmental impact or of flooding if the sheets become detached from moorings and block channels).

Black polyethylene sheeting or a compressed fibre material called Typar (manufactured by Dupont) can be floated on or suspended above the water surface to reduce light penetration into the water. The sheeting needs to remain in place for at least 3 months until the plants beneath have used up all food reserves and died. The technique has been used effectively for localised weed control mainly in static waters. Plastic sheeting can be environmentally damaging because it seals the water surface preventing gaseous exchange, the passage of invertebrate or bird life and the use of the water for fishing or boat traffic. Some of these problems can be reduced by suspending the sheeting above the water surface but the risk of sheeting being detached by high winds precludes the technique except in very small, sheltered channels.

Much of the research on this technique has been carried out by the Institute of Freshwater Ecology who found that Typar reduced light levels by 50-70% and that sheeting needed to remain in place for 2-3 months or longer to kill off root stock.

Sheeting should be positioned early in the season before significant levels of plant growth have occurred to reduce the risk of deoxygenation as the weeds die and rot.

Dyes. An American company produces a plant dye called "Aquashade" which absorbs light at the same photosynthetic wavelengths as are used by aquatic plants. It's principal application is for use in static waters where the dye will remain in situ for long enough to reduce or eliminate plant growth and it is being tested in Britain mainly for use in ornamental ponds. It is doubtful if it would have any significant use in rivers where the dye would be washed away too rapidly.

Turbidity. Research by British Waterways has shown that regular boat traffic along canals has a significant effect on weed density. As the number of boat movements increase in a canal first plant diversity increases and monocultures of weed are controlled and then, at high numbers of boat movements, both species diversity and plant density decrease. Some of this control is probably caused by mechanical damage caused by the wash and the propeller but increased turbidity may also contribute.. Boat traffic is likely to be most significant in fairly shallow channels with muddy bottoms, similar to canals. This form of mechanically induced turbidity is unlikely to have much impact in deep channels or in faster flowing rivers where silts are less easily suspended.

Turbidity is also created by various species of bottom feeding fish. In ponds and lakes, high stocking densities of Carp and Bream have almost eradicated submerged vascular plants within one year. It is likely that they would have the same effect in slow flowing channels where the silt is fine enough to be suspended by the feeding action of these fish.

4.12.6 Channel reprofiling

Many river channels have become too large for their normal summer flow which has become, shallow and slow. This creates ideal conditions for weed growth and encourages further silting to occur, making the water even shallower and providing additional rooting material for the weeds.

Narrow, steep-sided and deep channels are less suitable for weed growth and often provide a better habitat for fish and wildlife. Various trials sites have been modified by the Environment Agency and others to reduce channel width and to increase water depth and velocity. In some instances, the channels have been modified to produce two stage channels and these have a number of advantages.

In the first stage channel -

- Less weed grows because the water is deeper or the velocity higher or both
- Less submerged weed grows because the channel is more shaded by the banks and by plants growing on the second stage channel
- Less silt is deposited because of the higher velocity
- Less emergent weed spreads into the channel because of the increased velocity and depth

In the second stage channel -

- Only emergent and bankside weeds grow because it is dry for most of the year
- Weeds can be controlled by bankside mowers or by grazing livestock

Advice on channel resectioning is available in the New Rivers and Wildlife Handbook (section 6.6), and in Environment Agency R&D Note 44, Design method for straight compound channels.

4.13 Integrated Management

Introduction When the same management technique is applied repeatedly over a number of years to large areas of a water body, the more susceptible weeds are reduced or eradicated leaving those weeds which are most tolerant of that form of control. The tolerant weeds spread into the spaces left by the susceptible weeds resulting in decreased species diversity but little or no reduction in the quantity of weed. In many rivers, this has already happened and there still remains an acceptable community of plants and animals. However, there is growing evidence that weed control can be made more effective, species diversity can be increased and communities improved by combining two or more different methods of control into an integrated management approach.

Integrated weed management is the use, in conjunction, of two or more different methods of weed control with one or more of the following objectives:

- To extend the range of susceptible weeds
- To reduce the frequency of weed control operations
- To reduce costs and/or increase efficiency
- To alter or extend the period when weed control operations are carried out
- To reduce adverse environmental impact
- To increase species diversity but at an acceptable level of growth

The selection of appropriate integrated management techniques involves the same decision process as is required for the selection of individual methods but with the addition that it is necessary to ensure that the techniques do not interfere with each other. For example, if a watercourse contained a mixture of submerged and emergent weeds, there would be no point in spraying the emergent weeds with glyphosate if they were likely to be cut within a few days by a weed boat sent to control the submerged weeds. The following list shows which control techniques are compatible and where benefits can be derived from integrated management.

Barley Straw with Weed Bucket or Boat

Benefits: By controlling filamentous algae, the straw allows weed cutters to work more efficiently. Controlling the algae also reduces the drag caused by the algae entangled with the other weeds and can reduce the frequency with which weed cutting is needed.

Precautions: Ensure that the bales or nets of straw are placed so that they cause minimum interference to weed cutting operations and that the bales or nets are well anchored and will not become detached under high flow conditions.

Barley Straw with Herbicides

Benefits: In waters dominated by a mixture of algae and submerged weeds, herbicides such as diquat or terbutryn can be used to control all these weeds. Straw can be added at the same time to prevent the return of algae and so give long-lasting control and reduce the frequency of herbicide use.

Precautions: Ensure that the straw is firmly anchored.

Grass Carp (and Common Carp or Bream) with Weed Cutting

* Grass carp should be used only in enclosed waters. Common carp and bream are only likely to be effective in very slow flowing rivers with soft, silty bottoms.

Benefits: These fish will eat or otherwise control many species of submerged weeds but do not usually control some of the rooted floating weeds and emergent weeds. Their use can help to reduce the total quantity of weed and the frequency with which it is necessary to cut the remaining unpalatable weeds.

Precautions: Ensure that the fish are not removed with the cut weed.

Grass Carp (and Common Carp and Bream) with Herbicides

* Grass carp should be used only in enclosed waters. Common carp and bream are only likely to be effective in very slow flowing rivers with soft, silty bottoms.

Benefits: To achieve rapid control of submerged weeds and algae, the herbicides diquat, dichlobenil or terbutryn can be used in conjunction with a low stocking rate of Grass Carp, Common Carp or Bream. The fish will prevent or delay the return of these weeds for several years. Unpalatable emergent or floating weeds can be controlled with glyphosate while submerged weeds and algae are controlled by Grass Carp.

Precautions: Ensure that there is no risk of deoxygenating the water with a herbicide application if fish are present or about to be stocked.

Herbicides with Weed Cutting

Benefits: Any of the approved herbicides can be used in conjunction with weed cutting to reduce frequency and severity of the cutting operation and the quantity of weed which has to be removed after cutting. However, the timing of the herbicide application in relation to weed cutting has to be carefully adjusted to ensure that the results are beneficial and not antagonistic.

Emergent and floating (rooted) Weeds. If these are to be controlled by an application of glyphosate, no weed cutting operations should be carried out earlier in the season or for at least three weeks after the herbicide has been applied as damage to the foliage will reduce the effects of the herbicide. These weeds are not usually treated until mid to late summer. If cutting of submerged weeds cannot be delayed until then, it may be possible to cut only a proportion of the channel leaving as much as possible of the floating or emergent vegetation to be sprayed later. The remainder of the channel can be cut three weeks after spraying. In the following season, early cutting can be carried out in the sprayed section and any emergent or floating weeds can be sprayed in the previously untreated section.

Submerged weeds and algae. These can be controlled chemically with diquat, dichlobenil or terbutryn applied early in the spring before weed cutting would take place and it should not usually be necessary to cut weed after a successful treatment with one of these herbicides. If, however, herbicide application is delayed, the weeds can be cut and removed and any regrowth treated with a herbicide. Cutting stimulates regrowth and this can make the weeds more susceptible to the herbicide. The timing of the herbicide treatment after cutting is critical. Terbutryn and dichlobenil should be applied almost immediately after cutting and any delay is likely to increase the risk of deoxygenation of the water. Treatment with diquat should be delayed until there is adequate fresh growth of stems and leaves on which the herbicide can act, usually 2-3 weeks after cutting. These delayed treatments can be very effective in giving long-term control of some of the more difficult species such as Broad-leaved Pondweed. However, the use of herbicides later in the season than recommended on the product label should be restricted to localised control and should not be delayed beyond early summer.

Precautions: Avoid deoxygenation of the water, which might result from treating large masses of weed under warm conditions. Do not apply diquat to water where weed cutting operations are stirring up mud or silt.

Dredging with Glyphosate

Benefits: When a watercourse is due for dredging it may seem unnecessary to apply other forms of weed control. However, some emergent weeds, particularly Common Reed and Reed Sweet-grass can survive and establish on the spoil and cause problems to farmers. Where these weeds are present and the spoil will be deposited on adjacent arable land, spraying the emergent vegetation with glyphosate at least three weeks before dredging or in the previous mid-late summer will kill the rhizomes and prevent the weeds from regrowing in the spoil.

Precautions: Check that there are no poisonous plants to which livestock have access either to the sprayed foliage or to the dredged roots and rhizomes deposited on the bank.

Integrated management should be part of a long-term management plan. Local experience is invaluable in producing such a plan as the range of troublesome weeds can vary within and between individual watercourses. The following integrated management plan is given as an example of a plan suitable for a small river in a low-lying area where extensive weed growth is common.

Table 4.3 Integrated Management Plan

YEAR	MANAGEMENT
1	A. Shallow dredge. If possible, dredge only part of the channel to create a two-stage channel. B. Use barley straw if algal growth is predicted. C. Plant suitable trees to shade channel. Ensure weed growth round trees is controlled. Weed control now is more important than in subsequent years.
2	A. Spray invasive emergent weeds with glyphosate. If possible, use localised control to retain a fringe of emergent weed. B. Continue straw treatment (until submerged weeds become dominant). C. Spray or mow grasses and weeds around young trees taking care not to damage them. D. Use livestock to graze second stage channel but provide protection for trees. (Continue in subsequent years)
3	A. If necessary, treat submerged weeds in spring with Midstream or cut submerged weeds in summer. B. Spray or mow grasses and weeds around young trees.
4	A. Use Midstream or cutting on submerged weeds. B. If emergent weeds are recolonising centre of channel, control with glyphosate; submerged weeds with Midstream or cutting. Delay cutting weeds until 3 weeks after emergent weeds have been sprayed with glyphosate.
5/6	A. As year 4. By this stage weed growth may be reduced by shading effect of trees. B. Spray emergent weeds in year before dredging, if possible leaving a fringe of emergent weeds.
7/8	A. Pollard trees, if necessary to allow access for dredger. B. Shallow dredge leaving fringe of emergent weeds. Retain two stage channel.

If trees cannot be planted, then the cycle will be repeated. If shade trees can be used then the amount of weed control is likely to be reduced in the second and subsequent management cycles. In this system, weed cutting machinery is only required in about half the years of the cycle and will be further reduced if shading is present. If a number of rivers are managed on a staggered cycle, it may be possible to make savings in the number and frequency in which machines are required for this work.

5. WEED SPECIES

5.1 Introduction

Earlier sections have stressed the need to identify weeds accurately. One of the most important reasons for this is that there are many weed species which have unique reproductive or behavioural characteristics which affect how or when they can be controlled.

In this section, these growth characteristics are described and appropriate methods of control are discussed. The weeds are grouped under the headings which were shown in section 2 as emergent, floating and submerged vascular plants and algae. The more common weed species in each group are then described in more detail. When a weed problem has occurred, or seems likely to occur, and the plants which make up that problem have been identified, this section can be used as a reference to the options for weed control.

Weed problems may be caused by a single species or range of species which includes representatives of some or all of the weed groups. In the former situation, the best option for weed control will be to select the most cost-effective form of management listed under that weed. Part of the selection process should also check that the control technique will have the least possible impact on other plant species which are not regarded as weeds. When there are several weed species, perhaps from different groups, it may be preferable to find a common control option which will work adequately on all species even if this is not the most effective method of controlling individual weeds. This is not always possible, either because there is no common option or because the timing or performance of the preferred option is inappropriate for the situation. When this occurs, two or more independent control methods will be needed. These can be selected from this section but further information is also given in section 4 on integrated management techniques.

5.2 Algae

There are several thousand different species of algae which have widely differing growth forms and habits. They are found in almost all types of water body from hot springs to ice covered lakes. Algae reproduce rapidly either from spores or from fragments and, under good conditions, cell numbers can double every day giving extremely fast growth rates. They are the first plants to colonise new bodies of water or waters denuded of other vegetation by weed control or other causes. In the absence of competition from higher plants, their growth can be explosive. The problems caused by algae have increased in number and severity in recent years, mainly in slow flowing and static waters where they are not washed away by the current. This is thought to be caused largely by the increasing level of nutrients, particularly phosphate, entering the rivers. Other factors such as low flows and the loss of higher plants may also contribute to the increasing algal problems. Thus, long-term control of algal problems could best be achieved by maintaining a high population of higher plants, low nutrient levels and sufficient water velocity to continuously flush out algae. However, these objectives are not always achievable or acceptable for other reasons and are beyond the scope of normal operational practices.

Algal problems are most likely to occur, particularly in the slow flowing, nutrient rich rivers under the following conditions:

- During periods of high temperature and low flows
- Following extensive weed control operations

- After major dredging or restructuring works
- After pollution incidents, especially those in which high levels of plant nutrient are flushed into the water

Although there are many forms of algae, they can be considered in two forms for the purposes of control. Filamentous algae, also called blanket weed or cott, form masses of hair-like filaments sometimes attached to the bottom, tangled around other plants or forming free-floating blankets which cover the surface. Unicellular algae consist of single cells, or sometimes clumps of cells, usually too small to see individually with the naked eye but which collectively make the water appear as a turbid green soup.

There is also a group of organisms which is commonly called 'blue-green algae' but which are now properly called Cyanobacteria. These are included in this section under the general heading of unicellular algae, and referred to by their common name, although some of them can form fine filaments. When dense blooms of blue-green algae are present, they can form a surface scum of cells, particularly under conditions of high temperature and calm weather, which has colours ranging from green, blue-green, purple or even red. These surface scums have the consistency of paint and are often accompanied by strong unpleasant odours. Unlike other algae, they can produce toxic chemicals within the cells, some of which are extremely poisonous. These toxins are only found in roughly 50-70% of cases of blue-green algae blooms. However, it is wise to assume that all blue-green algae are toxic and to take suitable precautions when working in waters containing high concentrations of them. It may also be necessary to put up notices warning the general public of the danger and advising them to prevent their pets or livestock from ingesting the algae.

5.2.1 Filamentous algae (Cott or Blanketweed) (Common genera include: *Cladophora, Enteromorpha, Rhizoclonium, Spirogyra,* and *Vaucheria*).

Introduction

Although some species can survive over winter, it is more common for them to die back in autumn and regrow from spores early in the spring. Germinating spores are usually attached to the bottom sediment. In fast-flowing waters, the filaments form long streamers of algae which extend as the season progresses sometimes becoming detached and washed downstream. Sometimes, the whole bed of the river becomes covered with an interlocking mass of filamentous algae. When a part of this mass becomes detached, it rolls along the bottom collecting more algae, progressively increasing in size, impeding flow and eventually washing down to an obstruction, such a weir or culvert, where it causes serious problems.

In slow flowing rivers, the filaments growing from the bottom eventually become so dense that they trap bubbles of oxygen. This makes the whole mass buoyant so that it becomes detached from the bottom and floats to the surface forming a floating blanket. This can cause the water underneath to become deoxygenated, killing fish and other aquatic fauna. In severe cases, diving birds and animals can be trapped under the blankets and drown. Submerged vascular plants also die because there is insufficient light for photosynthesis. When flows increase, these blankets of algae are washed downstream and can block weirs and culverts.

Filamentous algae interfere with flood defence, fishing and other forms of recreation and reduce amenity and conservation values. They have little ecological value to other components of the aquatic ecosystem and are eaten or used as habitats by very few aquatic organisms. They are probably the most troublesome and difficult to control group of weeds.

Management

Conventional cutting equipment is almost totally ineffective against filamentous algae. Even if the filaments are cut, they continue to grow almost unchecked. Mechanical raking, using weed buckets or rakes attached to hydraulic excavators or to weed boats, removes some of the filaments but fragments always remain and regrowth is rapid. Mechanical disturbance of the floating mats dislodges the bubbles of oxygen so that the mats sink, giving the appearance that good control has been achieved, but within one or two days the mats float to the surface again as photosynthesis produces new bubbles of oxygen. Probably the most effective form of mechanical removal is with a weed harvesting boat. For example, the Miller Weed Harvester employs a conveyor belt which projects under the surface of floating and some submerged mats and lifts them out whole, drawing in algae from the sides as well as from directly over the conveyor belt.

Where filamentous algae are removed mechanically, disposal can be a problem. Some species, particularly *Vaucheria,* may persist for more than a year as a dry blanket after deposition on the river bank. These dry mats kill grasses and the consequent loss of the root structure can destabilise banks. Dry algal mats can also interfere with agricultural equipment if deposited on arable land.

In appropriate conditions, terbutryn or diquat will control filamentous algae but these herbicides also control submerged vascular plants, thus reducing competition and so encouraging the return of even more vigorous growths of algae once the herbicide has decayed.

Grass carp will eat some filamentous algae but their use in rivers is strictly limited. Also, they may prefer to feed on vascular plants if these are available so that they may control the vascular plants before the algae, thus temporarily exacerbating the problem.

Barley straw is the only management technique which effectively controls algae (both filamentous and unicellular) without any adverse effect on higher vascular plants. In some instances, effective control of algae with straw has allowed vascular plants to recolonise the water to the extent that further algal problems were reduced or eliminated.

Methods of control

Mechanical Raking

Where: Where immediate but short-term control is required.

How: By hand raking, weed bucket or cott rake attached to an excavator or weed rake attached to a boat. A weed harvesting boat may also be used.

When: At any time when significant quantities of algae are present. However, regrowth will be rapid except in late autumn and winter.

Herbicides

Terbutryn

Where: In waters flowing at less than 20 m/h and where the control of all submerged vegetation is acceptable.

How: By hand or motorised granule applicator.

When: In early spring when growth is just starting.

Diquat

Where: In waters flowing at less than 90 m/h (Reglone) or at any velocity (Midstream) and where the control of all submerged vegetation is acceptable.

How: By spraying or subsurface injection (Reglone) or by hand operated or motorised applicator (Midstream).

When: Generally in spring or early summer but localised control using Midstream can be applied at any time although the level of control is best when the filaments are young and growing actively.

Barley Straw

Where: In any water body, especially where selective control of algae is required.

How: By mooring bales or nets of straw at intervals in the channel (see section 4).

When: At any time but best effects are obtained by applying straw sequentially in autumn (to prevent algal growth in spring) and in spring to maintain control throughout the summer.

(See leaflet from Centre for Aquatic Plant Management for more details)

5.2.2 Unicellular and blue-green algae (Numerous genera)

Introduction

Unicellular algae do not impede flow and so are not of significant importance to flood defence operations. However, dense blooms can affect water quality, kill fish and fish food organisms and be harmful to recreation and conservation. In recent years, blooms of toxic blue-green algae have been particularly troublesome, giving unacceptable water taint and on occasions being responsible for the death of both pet animals and farm livestock. They can also cause severe illness and death in humans.

Unicellular algae have a very rapid growth rate with some species dividing every 12 hours. Dense blooms can suddenly appear and may persist for a few weeks or throughout the year. In faster flowing rivers they are not generally a problem because they are flushed out of the river, but in slow flowing rivers there is sufficient time for them to reach troublesome levels. In 1990 and 1991, blooms of blue-green algae occurred in over 1,200 km of the Murray River in Australia and similar blooms could occur in Britain (*e.g.* Ouse and Trent).

Blooms of unicellular algae usually occur in waters denuded of vascular plants or where nutrient levels have increased rapidly so that the ecosystem has become destabilised. In other systems, competition from higher plants and grazing by invertebrate animals helps to prevent excessive growths of these algae.

Where dense blooms of potentially toxic blue-green algae are present, Environment Agency personnel and members of the public should avoid skin contact or ingestion of water. In some instances, protective clothing should be worn if prolonged or extensive contact with contaminated water is possible. Local public health authorities may require notices warning of the presence of the problem to be prominently displayed.

Management

Unicellular algae cannot be controlled by mechanical methods. In reservoirs, a number of control techniques, including phosphate precipitation and destratification of the water, are available. None of these is applicable generally to rivers. In parts of the Norfolk Broads, control has been attempted by reducing fish numbers to allow populations of algal grazing invertebrate animals to increase. However, this approach is unlikely to be popular with anglers in many rivers.

The herbicides terbutryn and, to a lesser extent, diquat are known to control a number of unicellular algae but this method of control has not been extensively researched and the susceptibility of many algal species is unknown. Both these herbicides will control submerged vascular plants and so may, in the longer term, make the problem worse by reducing competition and by destroying the habitat for algal-grazing invertebrates. It would be unwise to use a herbicide on dense blooms of blue-green algae, partly because of the risk of deoxygenation of the water, but mainly because any toxins present in the cells would be released as the cells died, leading to temporarily high concentrations in the water. Unlike the toxins in live algal cells, these toxins would not be removed by filters.

Barley straw is the only effective method of control of these algae. Most, if not all species, appear to be susceptible and the straw can be used either as a preventative treatment or applied to an existing bloom. Unicellular algae usually die off 4-6 weeks after a straw application, although this period is probably temperature dependent. However, it is always preferable to use straw to prevent an algal bloom from developing than try to treat one that has already formed, especially if blue-green algae are present.

Methods of control.

Herbicides

Terbutryn

Where: In waters flowing at less than 20 m/h.

How: By hand or motorised granule applicator.

When: As early as possible in the season when the bloom first starts to appear.

(**Note:** Not all species may be susceptible and, if applied in summer to a dense bloom, deoxygenation is likely to occur)

Barley Straw

Where: In any water body, especially where selective control of algae is required.

How: As bales or nets of straw (see section 4.10.6).

When: At any time but preferably sequentially in autumn and spring.

5.3 Floating Leaved Weeds

For the purposes of control, floating leaved weeds can be considered in two categories. Free floating weeds, including the Duckweeds (*Lemna* spp.)and Water Fern (*Azolla filiculoides*), are not attached to the sediment but float freely on the water surface and drift about in the wind or in currents. Members of the second group are rooted in the bottom sediment and produce long leaf stalks (petioles) which grow to the surface where the leaf blade (lamina) lies flat on the water surface. When dense infestations of either group occur, some leaves may stick up above the water surface giving the appearance of emergent weeds. Free-floating weeds tend to be most troublesome in static or very slow moving water and are usually flushed out of faster flowing rivers, except where they are held back by dams or weirs, or entrained by marginal vegetation. Rooted floating weeds also grow most prolifically in slower rivers although they can grow in quite fast flowing water. It is unusual for either group to cause serious land drainage problems because they give relatively low impedance to flow and the free-floating weeds tend to be washed out in periods of high flow.

Rooted floating plants are sometimes encouraged because they compete with and suppress the more troublesome submerged weeds and algae without causing much impedance to flow. This group requires control mainly because the submerged stems and floating leaves interfere with recreation and navigation. Usually, localised control of these plants to give access for angling or a clear passage for boat traffic is sufficient and a fringe of rooted floating plants along the margins helps to suppress the growth of submerged weeds and algae. They also provide a good habitat for fish, fish-food organisms and waterfowl.

Free-floating weeds produce a number of problems. Dense infestations, which completely cover the water surface, are a danger to children, pets and livestock who may attempt to walk onto the apparently dry land without appreciating that there is deep water underneath. The dense cover of floating weeds also reduces the light level beneath the surface so that submerged weeds and algae die off. Although this may appear to be an effective form of weed control, the death of these weeds can cause the water to become deoxygenated with resulting fish kills. The dead fish are hidden until the floating weed is controlled or dies back from natural causes. At this point, the manager may be blamed for causing the fish death if he has controlled the weeds or, if he has not controlled the weeds, he may be blamed for taking no action and so causing the fish death. Fish mortalities have also occurred in fish farms when screens became blocked, preventing fresh oxygenated water from flowing into rearing ponds. Free-floating weeds can also be drawn into water intakes, blocking pumps and filters, and can mat together forming floating rafts which cause flow problems and obstructions to weirs, locks and other structures.

5.3.1 Duckweeds (*Lemna minor, L.minuta, L.gibba, L.polyrhiza)*

Introduction

These plants all produce small or very small, circular to ellipsoidal fronds which float freely on the water surface. There are usually three or four fronds joined together and, as new fronds form, they become detached to form a new plant. Growth is very rapid and the water can become completely covered within a few weeks. In the autumn, Duckweed produces disc shaped turions which look similar to the floating fronds but are a green/brown colour. These sink to the bottom and survive overwinter, refloating as new plants in the spring.

When dense infestations develop, Duckweeds can grow on top of one another so that a floating mat up to about 20 cm thick can be formed. This represents about 0.2 tonnes of plant material per square m of water surface and, as these floating mats can occur over several kilometres of river, removal and disposal problems can be enormous.

For control purposes, identification of the individual species is not necessary except when herbicides are used on *L.minuta.* This plant produces smaller fronds than any of the other species and has a very waxy cuticle on the upper surface of the fronds. This waxy cuticle prevents the entry of herbicides applied as sprays to the upper surface although the plant is still susceptible to herbicides added to the water and which are absorbed through the lower surface of the fronds.

Management

These plants are difficult to manage and timing of any control techniques is more critical than for almost any other group of plants. Conventional weed cutting buckets and boats have no useful effect because the individual fronds are too small to be cut or harvested in a bucket. Fine meshed wire or plastic netting fitted inside the weed bucket or weed rake will improve harvesting but the process is very slow because the weeds drift freely and spread back into cleared areas. Floating booms or barriers may help to hold and concentrate the weed in areas where harvesting is taking place.

In some situations, these floating weeds can be flushed out by inducing surface flows. Baffle boards can be used to raise the water level temporarily and, when removed, Duckweed is carried over the spillway with the flow. This technique is generally effective only in smaller water bodies and requires frequent operation preferably when both flow and wind have carried the weed to the downstream point.

Grass Carp will eat Duckweed but their use in rivers is very restricted. They should not be introduced when dense infestations are developing because there is a risk of the water becoming deoxygenated. They may also eat other weeds in preference to Duckweed and so the benefits are unpredictable.

Herbicides are the most effective method of control. In some instances they are applied as sprays directly onto the floating fronds. The spray must be applied before the floating layer is more than one frond thick otherwise the underlying fronds will survive and growth will continue. Even then, it is unlikely that every frond will be controlled by a single application and subsequent applications will be required to control survivors. This is best carried out when a gentle breeze has blown the remaining fronds together. Surface spraying will not control *L. minuta.*

Herbicides applied directly to the water will also control Duckweeds. Both diquat and terbutryn will be absorbed through the roots and underside of the floating fronds. These herbicides will also control other submerged weeds. Care should be taken to apply these herbicides well before the Duckweeds have formed a solid surface cover as the death of the Duckweed and any submerged weeds will contribute to the oxygen demand and increase the risk of deoxygenation.

Methods of control.

Weed Bucket or Rake (fitted with fine mesh netting) or weed harvesters

Where: Where dense infestations have already formed and where immediate control is essential.

How: By isolating and collecting the weed with floating booms and harvesting the weed.

When: At any time when the density of weed creates a danger or when a risk of deoxygenation is developing.

Booming and suction removal.

Where: Where dense growths have already formed.

How: By coralling the floating mass with a floating boom and net and removal with a sludge pump from a single collecting point.

When: At any time.

Flushing out

Where: Where a temporary barrier can be erected to raise the water level.

How: By temporarily raising the water level and allowing the weed to wash out when the barrier is removed.

When: Ongoing throughout the season when floating fronds build up against the barrier. Also when wind direction blows the fronds towards the barrier.

Herbicides

Diquat (surface spray)

Where: Where some damage to other emergent and floating weeds is acceptable (these plants will be burnt by the diquat but will recover).

How: By spraying the floating fronds with knapsack or motorised sprayers. Use low volumes and avoid over spraying as run-off reduces effect. (Not applicable for *Lemna minuta*).

When: When the layer of fronds is not more than one layer thick. Repeat treatment after two weeks to control survivors

Glyphosate

Where: Where control of other emergent or floating weeds is acceptable or desirable.

How: By spraying with knapsack or motorised sprayers. Use low volumes to avoid run-off.

When: When the layer of fronds is not more than one layer thick. Repeat treatments after three weeks to control survivors.

Terbutryn or diquat (into water)

Where: In water flowing at less than 90 m/h (diquat) or 20 m/h (terbutryn) and where control of all submerged weeds is acceptable. Also where the weed is *L. minuta* and surface sprays are ineffective.

How: By subsurface injection (diquat) or granule applicator (terbutryn).

When: Normally in spring or early summer, well before a dense surface cover has formed and there is any risk of deoxygenation.

5.3.2 Water fern (*Azolla filiculoides*)

Introduction

Azolla filiculoides is the only species of floating fern found in Britain. It reproduces both vegetatively as the fronds grow and divide and, sexually, by producing spores. Germinating spores can give rise to dense infestations of this plant within a few weeks. The plant is free-floating and drifts about on the water surface building up into thick layers where wind and currents collect it. Spore production occurs when the plants start to form dense mats. Spore production is not directly linked to the characteristic colour change from green to red. The spores are released into the water so that controlling or harvesting the floating mats after this stage will not prevent reinfestation.

Management

Conventional cutting equipment has no effect on this plant. It can be harvested with weed buckets and weed rakes, efficiency is being considerably improved by fitting fine meshed netting of wire or nylon to prevent fronds escaping through the bucket. Floating booms or barriers may help to hold and concentrate the weed in areas where harvesting is taking place.

Control can sometimes be achieved by flushing out the weed using baffle boards or barriers to raise the water level temporarily and then removing the barrier when wind and currents have collected the weed against the barrier. This technique is generally effective only in smaller water bodies and requires frequent operation.

Herbicides are the most effective form of control. The floating fronds can be sprayed with either diquat or glyphosate. The choice depends to a great extent on which other weeds are present and whether they need to be controlled or preserved. Glyphosate will kill almost all emergent and floating weeds onto which the spray is directed. Diquat will burn off emergent and other floating weeds but will not kill them (except Duckweeds). Surviving fronds may require a second or subsequent treatment if the weed is to be eliminated. This is best carried out when a gentle wind or currents have collected floating fronds together at suitable points.

This weed is also controlled by either diquat or terbutryn applied to the water. Both of these will also control submerged weeds and algae.

Methods of control

Note: If spores have already been released in the current or previous year, it may be necessary to carry out repeated control operations until all the spores have germinated.

Weed Bucket or Rake (fitted with fine mesh netting)

Where: Where dense infestations have already formed and where immediate control is essential.

How: By isolating and collecting the weed with floating booms and harvesting the weed.

When: At any time when the density of the weed creates a danger or risk of causing deoxygenation.

Flushing out

Where: Where a temporary barrier can be erected to raise water levels.

How: By temporarily raising the water level and allowing the weed to wash out when the barrier is removed.

When: Ongoing throughout the season when the weed builds up against the barrier.

Herbicides

Diquat (Surface spray)

Where: Where herbicide damage to other emergent or floating vegetation can be tolerated but control is not required.

How: By spraying the floating fronds with knapsack or motorised sprayer. Use low volumes to avoid run-off which reduces effect.

When: When the fronds are not more than one layer thick. If necessary, repeat treatment after two weeks to control survivors.

Glyphosate

Where: Where control of other emergent or floating weeds is acceptable or desirable.

How: By knapsack or motorised sprayers. Use low volume to avoid run-off.

When: When the fronds are not more than one layer thick. If necessary, repeat treatment after three weeks to control survivors.

Diquat or Terbutryn

Where: In water flowing at less than 90 m/h (diquat) or 20 m/h (terbutryn) and where control of all submerged weeds is acceptable.

How: By subsurface injection (diquat) or granule applicator (terbutryn).

When: Normally in spring or early summer, well before a dense surface cover has developed and there is any risk of deoxygenation.

5.3.3 Water-lilies, Yellow Water-lily (*Nuphar lutea*), White Water-lily (*Nymphaea alba*) and Fringed Water-lily (*Nymphoides peltata*).

Introduction

Water-lilies are characteristically found in slow flowing or static waters. Only the Yellow Water-lily is common in rivers and, unlike the other two species, produces submerged as well as floating leaves. In flowing situations, the floating leaves of Yellow Water-lily are sometimes absent and the plant has been mistakenly identified as "Cabbage-lily" because of the appearance of the submerged leaves. The White Water-lily has conservation importance and the Fringed Water-lily is a nationally scarce plant, although locally it can form dense troublesome, infestations.

All three species have extensive rhizome systems, buried in the mud, from which leaf and flower stalks emerge each year. The plants spread only slowly and are often conserved because the leaf stalks have little effect on flow but the shading effect of the floating leaves helps to suppress the growth of more troublesome submerged plants. However, all three species can produce a dense cover of the water surface and control is sometimes necessary. **Because of their scarcity, neither the White or Fringed Water-lilies should be controlled unless absolutely necessary and, where control is necessary, some plants should be left along the margins or where they are least troublesome.**

Management

Short term control, at best for one season, can be achieved by cutting, but new leaves will regrow from rhizomes later in the season or in the following year. Control for more than one season can only be achieved by killing or removing the rhizomes. These are extremely buoyant and will float if raked or dredged from the mud. However, they are very strongly held in the mud by roots and are not easily dislodged. Spraying the floating leaves of Yellow and White Water-lily with glyphosate is a very cost-effective method of control. Fringed Water-lily is sometimes controlled in the same way but results have been variable. This technique cannot be used on the Yellow Water-lily when only submerged leaves are present (usually in fast flowing situations). However, glyphosate can be applied in many situations to achieve localised control to create, for example, a clear channel down the centre of the river while retaining a fringe of lilies along the banks.

In rivers flowing at less than 90 m/h, lilies can be controlled by applying dichlobenil early in the spring when growth starts. This will also control submerged weeds but localised control in selected areas can also be achieved using dichlobenil. This technique is preferred in slow flowing situations where the lilies are growing along with submerged weeds which also require control.

Where possible, Water-lilies should be retained along the margins or in small clumps.

<u>Methods of control</u>

<u>Cutting</u>

Where: Where only short term control is required and where Lilies are growing amongst submerged weeds also requiring control. Also in fast flowing waters where Yellow Water-lily is producing only submerged leaves.

How: By weed boat or weed bucket. The cut need not be particularly close to the bottom because the defoliated stems have very little hydraulic resistance and will die off.

When: Usually as late in the season as possible to reduce the risk of regrowth.

Dragging or dredging

Where: Where dredging operations are required for other reasons and where long term control is required but herbicides are inappropriate.

How: Hydraulic excavator with dredging bucket and, sometimes, with rakes where the silt is sufficiently soft to allow the rake tynes to dislodge the rhizomes. Hand raking and pulling is very slow and only effective for small areas.

When: At any time of year but may be more effective in summer when the location of the rhizomes can be detected by the floating leaves.

Herbicides

Glyphosate

Where: Anywhere where the plants have adequate floating leaves. Other floating or emergent plants are also likely to be controlled if the spray is directed onto their leaves but there will be no effect on submerged plants.

How: Using knapsack or boat mounted sprayers. Coarse droplet sizes can be used to avoid spray drift but use low volumes to prevent run-off. The passage of a boat will submerge and wet leaves leaving an unsprayed track. Spray on one or both sides of the boat and treat the unsprayed track, if necessary, after two weeks when the track can be identified between the yellowing treated leaves.

When: In mid to late summer when the floating leaves are fully formed.

Dichlobenil

Where: In rivers flowing at less than 90 m/h and where the control of submerged weed as well as Water-lily is required.

How: By hand operated or motorised granule applicator.

When: In spring when growth is just starting.

5.3.4 Broad-leaved Pondweed (*Potamogeton natans*)

Introduction

This plant is found mainly in static or slow flowing water up to about 1.5 m deep. It has rhizomes buried in the mud from which leaf and flower stalks grow each spring. The leaf stalks produce a flat leaf blade (lamina) which floats on the surface. The veins in the leaf are more or less parallel converging at the tip, unlike Amphibious Bistort (*Polygonum amphibium*) which is very similar but has a central midrib with veins branching off each side. Flowers emerge above the water surface and are a dull yellow/green colour. Seeds are produced but spread is principally by rhizomes.

The leaves of this plant can form a dense surface cover of the water impeding fishing and other forms of recreation. It is often found in streams and drainage ditches where dense growth can impede flow and so create a land drainage problem.

Management

Short-term control, for at best one season, can be achieved by cutting but new leaves will form from rhizomes later in the season or in the following year. Longer term control can only be achieved by killing or removing the rhizomes. These are much thinner than the rhizomes of Water-lily but can be more numerous. As alternate nodes on the rhizomes carry buds, breaking or cutting the rhizomes does not control the plant and physical removal of the whole rhizome is the only effective long-term form of mechanical control.

Unlike the Water-lilies, spraying the floating leaves with glyphosate does not give satisfactory control. The treated leaves die off, giving the impression that the plant has been controlled, but new leaves emerge usually within a matter of weeks.

Broad-leaved Pondweed is controlled with dichlobenil (now only available as Casoron G) early in the spring when growth is starting. Application should be made before the floating leaves have reached the surface as dichlobenil will not work once floating leaves are visible at the surface. This is because cell division (the site of action of dichlobenil) stops and floating leaves are formed by expansion of existing cells. Thus, there is no action site for the chemical in the plant, even though it is taken up.

The plant can also be controlled by application of Casoron G later in the season (after floating leaf formation) by first cutting the plant to a depth of at least 50 cm and then applying the herbicide. Treatment is usually more effective in the Spring in most situations.

Methods of control

Cutting

Where: Where only short-term control is required or where the plant is growing amongst other submerged plants which require control.

How: By weed boat or weed bucket. Once all the leaves have emerged the cut need not be particularly close to the bottom because the cut stems produce little hydraulic resistance and will die off.

When: Usually as late in the season as possible to reduce the risk of regrowth.

Dragging or dredging

Where: Where dredging operations are required for other reasons and where long-term control is required but herbicides are inappropriate.

How: Hydraulic excavator with dredging bucket and, sometimes, with weed rakes where the silt is sufficiently soft to allow the rake tynes to pull out the rhizomes. Hand raking and pulling is generally not effective.

When: At any time of year but may be more effective in summer when the location of the rhizomes can be detected by the floating leaves.

Herbicides

Diquat alginate (Midstream)

Where: In static or flowing waters. Experience suggests that, for this species, diquat alginate should only be used where the calcium content of the water is low.

How: By hand-operated or motorised applicator.

When: Early in the season when floating leaves are starting to appear but before the surface of the leaf stalks becomes covered with epiphytes or silt.

Dichlobenil (Casoron G)

Where: In waters flowing at less than 90 m/h.

How: By hand or motorised granule applicators.

When: Early in the growing season when leaves are starting to grow from the rhizomes but before they reach the surface. Treatment can also be effective later in the season if the leaves are cut first and treatment is applied immediately afterwards.

5.3.5 Other floating-leaved plants. Species and genera include:

1. Reed Sweet-grass (*Glyceria fluitans*),
2. Unbranched Bur-reed (*Sparganium emersum*),
3. Amphibious Bistort (*Polygonum amphibium*),
4. Starwort (*Callitriche* spp.),
5. Water-crowfoot (*Ranunculus* spp.),
6. Common Clubrush (*Schoenoplectus lacustris*),
7. Arrowhead (*Sagittaria sagittifolia*)

Introduction

This group contains a wide diversity of plant species which have floating leaves during at least part of the growing season. Some of the plants listed above (Nos 1-3) produce only floating leaves although occasional leaves and flower stalks may extend above the water surface. However, for the purposes of control, these plants must be regarded as purely floating leaved species.

Others, (4-8) produce floating leaves as only part of their total leaf production. The best example of the latter is Arrowhead (*Sagittaria sagittifolia*) which produces submerged strap-shaped leaves in the spring followed by floating leaves later in the spring and finally by emergent leaves which appear in mid-summer. Some methods of control (eg cutting) can be applied to these plants during the stage when they are producing floating leaves but other methods of control may be inappropriate at this stage (eg herbicides) and are best applied at a different growth stage and more detailed control recommendations are given either in the section on submerged weeds (examples 4 & 5) or on emergent weeds (6 & 7).

Management

All of these plants can be cut by hand or using weed buckets or weed boats. Cutting will give control for a maximum of one season but, for several of these plants, the floating leaved stage occurs fairly early in the season and, if cutting is the preferred control option, it would normally be carried out later in the season when the plants are in the emergent leaf stage.

Frogbit is nationally scarce and is a free-floating plant which is easily removed by raking or capture with a weed bucket but, when this occurs accidentally during weed cutting operations, it should be returned to the water as soon as possible.

Herbicides can be used on all of these weeds but not always during the time that they produce floating leaves. Water-crowfoot and Starwort produce mainly submerged leaves and the optimum timing for treatment of these plants is before they have produced floating leaves. Arrowhead and Common Clubrush produce emergent leaves and are best controlled by spraying a herbicide directly onto the emergent foliage later in the season. Examples 1-3 can be controlled by spraying a herbicide directly onto the floating foliage, usually in mid-summer when full leaf emergence has taken place.

Methods of control

Mechanical cutting

Where: Where short term control is adequate and where herbicides are inappropriate.

How: By weed cutting boat or weed bucket. Also by hand in shallow water where small areas are involved.

When: At any time when a weed problem exists. Where possible, cutting should be delayed until mid-summer to reduce the risk of regrowth later in the season.

Herbicides

Glyphosate

Where: On species numbers 1 and 2 where adequate quantities of floating leaves are present.

How: By hand or motorised sprayer.

When: In mid to late summer when full leaf emergence has taken place.

2,4-D amine

Where: On species No. 3 where adequate quantities of floating leaves are present.

How: By hand or motorised sprayer.

When: In early to mid-summer when full leaf emergence has taken place.

Diquat alginate

Where: On species Nos. 4 and 5 in static or flowing water.

How: By hand operated or motorised applicator.

When: Early in the growing season when the plants are growing vigorously but before floating leaves have formed.

Dichlobenil

Where: On species Nos. 14,5 and 7 (possibly also on No. 2 although this has not been fully tested). In water flowing at less than 90 m/h and where control of other submerged weeds is acceptable.

How: By hand or motorised granule applicator.

When: Early spring when growth has started but before floating leaves have formed.

5.4 Submerged Weeds

Submerged weeds cause many problems in rivers. They impede flow probably more than any other group of weeds, interfere with fishing and other forms of recreation and can be very restrictive to boat traffic. On the other hand, they are important as breeding sites for many species of coarse fish and provide refugia for fish fry and habitats for fish food organisms. There is a wide range of growth forms, from simple strap-shaped leaves to more complicated stem and leaf structures. Species which produce the latter are generally considered to be more valuable as habitats to fish and invertebrate animals.

Most submerged weeds are rooted in the bottom sediment although root structures are usually weak and plants can often be uprooted by wind and wave action or during periods of high water velocity. The majority of submerged plants can re-establish themselves from fragments broken off the parent plant and, for this reason, they are easily spread by weed cutting, dredging or other forms of disturbance. A few submerged plants are free floating e.g. Hornwort (*Ceratophyllum demersum*) and do not produce roots. These plants are usually only found in static or very slow flowing water.

Many submerged plants die back in autumn and overwinter as rhizomes, seeds, turions or tubers. Others produce new shoots in the autumn which remain overwinter in a short form before rapid growth starts in the spring. These overwintering bodies are immune from most forms of control. Growth in spring is triggered either by rising water temperature or by increased day length and, once started, is very rapid for most species. In mild winters, and usually only in slow flowing rivers, some species do not die back but overwinter in a moribund condition from which growth restarts in the spring. This can be particularly troublesome because of the large biomass of vegetation already present when the season starts.

Submerged weeds (and algae) have a major impact on the dissolved oxygen content of water. They produce high levels of dissolved oxygen during the day and absorb it at night. During the spring and early summer, oxygen production exceeds uptake so that plants are nett contributors to the oxygen content of the water but, as they die back either from natural causes or because of weed control operations, they can absorb more oxygen than they produce. Under conditions of high water temperature and low flows, natural dieback has been responsible for deoxygenating water to the point where fish and invertebrate animals are killed. Mistimed herbicide applications have had similar effects as have weed cutting operations, particularly where large quantities of cut weed were left to rot in the water. However, correctly applied weed control can help to reduce the risks of deoxygenation by reducing the biomass of weed before natural deoxygenation occurs.

Submerged weeds can be controlled by cutting, herbicides, Grass Carp or by various forms of environmental control. Cutting is the most frequently used method of control, although regrowth is rapid and at least one cut each season is required. Removing the cut weed and the water entrained with it is a significant part of the operation and, under recent legislation, disposal of the cut weed can add significantly to costs. Herbicides avoid these problems but their use is not always acceptable and, particularly in large rivers, the costs can be greater than cutting. Grass Carp give long-term control of many species of submerged weed but their use is restricted and they are not generally used in river systems. Environmental control is a long-term approach which is discussed in more detail in section 4.12.

5.4.1 Water-crowfoots (*Ranunculus* spp.)

Introduction

There are many species of Water-crowfoot, some are adapted to fast flowing rivers while others grow only in static or very slow flowing water. Almost all submerged species have finely divided leaves and produce white or yellow flowers on the water surface, mainly in May and June. Generally, the more troublesome species are found in faster flowing waters, such as chalk streams, and during the drought of 1989-92 the quantity of these weeds was greatly reduced, probably because the water velocity became too slow for their growth requirements. During this period, in many chalk streams, the beds of *Ranunculus* were limited to areas where higher velocities were maintained by constrictions in the channel or where the slope of the channel was greatest. Subsequent rainfall has increased water velocities in many channels and resulted in a resurgence of many Water-crowfoots.

Most Water-crowfoots start growth early in the season, usually in early April, and grow rapidly, forming dense beds. They flower in late May or June after which most of the plant dies back leaving a very short plant which overwinters.

Dense beds of Water-crowfoot impede flow and lead to silt deposition below and downstream of the bed. Other plants can root in this silt. This is usually a temporary problem, the silt and plants, being washed out during winter spates. During the spring and early summer Water-crowfoot can seriously reduce channel capacity with adverse impacts on land drainage and increased risk of summer flooding. It also interferes with fishing and boat traffic.

Water-crowfoot is a valuable habitat for many aquatic invertebrates, some of which are responsible for the characteristic "hatches" of flies on which fish feed and for this reason, the weed is popular with trout anglers.

Management

Cutting has been a traditional form of management in many chalk streams. However, regrowth is very rapid and several cuts may be needed each season, especially in valuable trout fishing waters where open areas of water must be maintained for the anglers. One effect of cutting, especially in the spring or early summer before flowering, is to synchronise regrowth so that all the plants reach peak biomass at the same time and cause a worse problem, although for a shorter period, than would have occurred if no management had taken place. Research at the Institute of Freshwater Ecology Rivers Laboratory has shown that if the weed is not cut for four years, the quantity regrowing each year declines to the point where further control may not be necessary.

Where it is not possible to leave the weed uncut, various control strategies have been suggested. The IFE Rivers Laboratory have found that if the weeds are cut close to the bed in autumn regrowth is both reduced and delayed in the following season. If some rivers are cut in the autumn while others are left, the period in the following season during which cutting is required throughout a region is extended, and this allows more efficient use of equipment and labour. Where a spring or summer cut is essential, localised cutting of a channel, leaving the remainder of the bed uncut, will allow the uncut weeds to reach maturity and start to die back before the cut weeds recover fully. This may further suppress the uncut weeds by encouraging the majority of water flow down the cut channel and reducing the velocity around the uncut weed.

Herbicides can be used effectively on Water-crowfoots. In static or slow flowing waters, they are susceptible to any of the three approved herbicides. In rivers flowing at more than 90 m/h, diquat alginate (Midstream) has been used for both overall control and for localised control to clear channels through the weed while leaving uncleared areas along the margins.

In shallow, hard bottomed streams, cattle will graze on Water-crowfoot, especially in summer when pastures are poor. The trampling action of cattle also suppresses the weed and, in some areas, cattle are driven along the river to control the weeds.

Methods of control

Cutting

Where: Anywhere where control for not more than one season is acceptable.

How: By hand, weed boat or weed bucket. In larger rivers weed boats are preferred. Cutting in faster flowing rivers is more effective in an upstream direction. To delay regrowth, cutting should be as close to the bed as possible. Cut weed can be allowed to drift downstream and collected at floating booms. Cut weed collected in this way may have to be disposed of in a recognised tip.

When: At any time from April until autumn. If cut early in the season a second cut may be necessary. Autumn cuts delay and reduce regrowth in the following season.

Herbicides

Diquat alginate

Where: In static or flowing waters and especially where localised control to create channels is required.

How: By special knapsack applicator.

When: In spring when the weeds are growing actively but before they have reached the surface and started to flower. Later treatments for localised control are possible but the level of control tends to deteriorate as the season progresses and the plants die back naturally.

Dichlobenil or Terbutryn

Where: In water flowing at less than 90 m/h (dichlobenil) or 20 m/h (terbutryn) and where total control of submerged weeds is required. Terbutryn will also control algae. Localised control with dichlobenil is possible in static waters.

How: By hand or granule applicator.

When: In early spring when growth is just starting.

5.4.2 Unbranched Bur-reed (*Sparganium emersum*)

Introduction

This plant produces long strap-shaped leaves which grow both on and under the water surface. It can grow in static or flowing water preferring eutrophic conditions with soft silty sediments. New shoots grow from rhizomes in April or May and die back fairly early in the autumn. The flowers are characteristic green burs carried on an unbranched emergent stem. The long streamlined leaves are tolerant of spate conditions and offer relatively little resistance to flow unless present in very dense beds. It can tolerate high levels of industrial pollution and may provide valuable habitats where little else will grow. Bur-reed fruits are food for wildfowl in autumn and winter. The shading effect produced by the floating leaves may help to suppress the growth or more hydraulically-resistant submerged weeds.

Two other members of the genus, *S. angustifolium* and *S. minimum*, prefer lower nutrient conditions and are found mainly in upland Britain. **These two species are scarce plants, not normally regarded as weeds and should be conserved wherever possible.**

Management

Relatively little research has been done on the control of this weed because it does not often present a flood defence problem. It is known to recover rapidly after normal dredging operations and can re-establish stable populations within 2-3 years. It is tolerant of tree shade and is only suppressed when light levels are reduced by about 60% under a continuous canopy. If a significant proportion of the leaves are floating on the water surface, the plants may be controlled by spraying with glyphosate but, particularly in flowing situations, much of the leaf area is submerged.

Cutting produces effective control for up to one season, provided that the cut is delayed as late as possible to prevent regrowth.

Although no research has been done to confirm this, it is likely that the submerged plant is susceptible to dichlobenil in static or slow flowing waters. It is known to be moderately susceptible to diquat alginate.

Methods of control

Cutting

Where: Where control lasting for no more than one season is acceptable.

How: By hand, weed boat or weed bucket. In flowing water cutting is more effective if carried out in an upstream direction.

When: As late in the season as possible to reduce the chance of regrowth.

Herbicides

Diquat alginate

Where: In static or flowing water.

How: By hand or motorised applicator.

When: In spring or early summer when the plant is growing actively but before floating leaves are formed. Treatment will be less effective in muddy, turbid waters or where the leaves are covered with silt or epiphytes.

Dichlobenil

Where: In waters flowing at less than 90 m/h.

How: By hand or motorised granule applicator.

When: In early spring when growth from the rhizomes is just starting but well before the leaves have reached the surface.

5.4.3 Water Starwort (*Callitriche* spp.)

Introduction

There are nine species of Water Starwort, most of which are very similar in appearance and difficult to identify separately. Some are scarce but unlikely to be found in situations where weed control is necessary. They reproduce mainly from seeds which are produced in early to mid-summer and germinate in winter. They will grow in both static and flowing water where they form dense, bright green clumps beneath the water surface. In static water, growth tends to be more diffuse and the plants can grow to the surface where they produce a rosette of small floating leaves. The plant seldom grows in water more than 1.5 m deep.

Starworts are not generally troublesome and provide a habitat for many invertebrate species as well as being consumed by wildfowl. However, dense beds, usually found in shallow streams can impede flow and interfere with fishing.

Management

The plants can be cut or controlled with herbicides. Where permissible, Grass Carp can also be used. Because these plants tend to die back in mid to late summer after producing seed, control is most effective early in the season before seeds are produced, as this can help to reduce the seed bank and so reduce the problem in the following season.

Methods of control

Cutting

Where: As required. Localised control is unlikely to be beneficial in the long term because seeds produced in uncut areas will recolonise cut areas.

How: By hand, weed bucket or weed boat. Cutting should be as low as possible to discourage regrowth and seed production. In flowing situations, cutting is more effective in an upstream direction.

When: As early in the season as possible. By mid summer, cutting gives little benefit as seeds have already been produced and the plant will soon die back naturally.

Herbicides

Diquat alginate

Where: In static or flowing waters.

How: By hand or motorised applicator. In flowing waters where the plant forms dense clumps particular attention should be paid to aiming the jet of diquat alginate so that the strings of product sink into the beds. Very dense beds may require a second treatment after about 2 weeks to control surviving plants.

When: Early in the season when the plants are young and growing actively and, preferably, before the beds have become too dense to allow good penetration of the alginate formulation.

Diquat, dichlobenil or terbutryn

Where: In static or slow flowing waters (max 20 m/h terbutryn or 90 m/h diquat and dichlobenil).

How: By appropriate application technique depending on product chosen.

When: Early in the season when growth is just starting but well before the plant reaches the water surface.

5.4.4 Water Milfoil (*Myriophyllum spicatum, M. alterniflorum, M. aquaticum, M. verticillatum*)

Introduction

Water Milfoils can grow in static or flowing water sometimes up to 3 m deep. The plant is fully submerged except for the flowers which are red, yellow or greenish in colour and extend above the water surface on a spike up to 20 cm long.

Dense infestations of Water Milfoil, particularly *M. spicatum*, can occur in both static and flowing water. In these situations, it seriously impedes flow and interferes with recreation and navigation. Growth starts earlier in the season than in some other plants and continues until autumn. In mild winters, the plant may not die back so that growth continues in the following spring from already mature plants, leading to even denser infestations.

Water Milfoils form good spawning sites for coarse fish, refugia for fish fry and habitats for fish food organisms. They do not spread rapidly and conserving some of the plant where it can be tolerated is likely to be beneficial to the aquatic fauna. ***M. verticillatum* is a scarce plant in Britain and should be preserved where possible.**

M. aquaticum (Parrots Feather) is becoming a more common weed species as a result of introductions by the aquatic nursery trade. It is confined to the margins of ponds and rivers. It is easily recognised by the characteristic light green emergent, feathery growth.

Management

These plants can be controlled by cutting but effects last for one season at best. However, there is some evidence that repeated annual cutting may gradually reduce the quantity of weed. They are also susceptible to any of the herbicides approved for the control of submerged weeds; except *M. aquaticum* which is partially resistant to glyphosate treatment. Where localised control is required, and in any situation where water velocity exceeds 90 m/h, diquat alginate is the best option. In static or slow flowing waters, dichlobenil, terbutryn or the liquid formulation of diquat can be used. Dichlobenil can also produce localised control in slow flowing situations. However, when the plant has overwintered without dying back, the granules of dichlobenil tend to settle out on the leaves without sinking to the bottom and this allows the herbicide to dissolve in the water and disperse, thus reducing the localised effect of the treatment.

<u>**Methods of control**</u>

<u>Cutting</u>

Where: In any situation where control for at best one season is required.

How: By hand, weed bucket or weed boat. In flowing situations cutting is most effective in an upstream direction. Cutting should be as close to the bottom as possible to delay regrowth.

When: At any time when adequate plant material is present to make the operation worthwhile. For a single annual cut, late June, July or August is likely to be most effective.

Herbicides

Diquat alginate (Midstream)

Where: In static or flowing water, especially where localised control is required.

How: By hand or motorised applicator.

When: In spring or early summer when the plants are growing actively but before they reach the water surface and before the plants become covered with epiphytes or silt.

Diquat (Reglone)

Where: In water flowing at less than 90 m/h.

How: By hand or by motorised sprayer using sub-surface injection.

When: When plants are young and growing actively but before they reach the surface or become covered with epiphytes or silt.

Dichlobenil (Casoron G)

Where: In water flowing at less than 90 m/h and, particularly where there are other well rooted aquatic weeds which also require control (e.g. Broad-leaved Pondweed, Mare's-tail, etc.).

How: By hand or motorised granule applicator.

When: Early in the season when growth is just starting but well before plants reach the surface.

Terbutryn

Where: In water flowing at less than 20 m/h and where there are other aquatic weeds, especially algae, which require control.

How: By hand or motorised granule applicator.

When: Early in the season when growth is just starting.

5.4.5 Canadian Waterweed (*Elodea canadensis*) and Nuttalls Pondweed (*Elodea Nutallii*)

Introduction

Canadian Waterweed was introduced into this country from North America about 1760 and is now found throughout the British Isles. It is a submerged plant which can form dense stands in static and slow flowing rivers, especially in eutrophic waters. It reproduces by vegetative means and fragments become easily detached, especially during cutting operations. Detached fragments will root rapidly and establish new plants. It does not usually cause problems early in the spring but becomes increasingly troublesome throughout the summer and autumn until it dies back late in the autumn. In fast flowing rivers much of the growth is flushed out in autumn but in slow flowing waters and in mild winters, it can survive over winter with little dieback.

In small quantities the plant provides a valuable habitat for fish and fish-food organisms and may be eaten by water fowl. However, in dense stands, it can choke watercourses and destroy habitats for wildlife. Because of its ability to survive and rapidly recolonise cleared areas, it is unlikely to be eradicated even by the most severe control measures.

Elodea nuttallii grows in still or slow flowing eutrophic waters. It has replaces *E. canadensis* at many sites due to increased eutrophication. It was first found in Europe in 1939 and in Britain in 1966. It has spread to 415 sites since then. It is often found in species poor macrophyte communities subject to boat traffic, management and in eutrophic drainage ditches. It is tolerant of disturbance, oil pollution and salinity up to 14 ppt (approximately half seawater). All *Elodea* species tend to act as metal ion pumps, taking up metals from the sediment and releasing them to the water. *E. nuttallii* is very tolerant of Copper in particular.

It is most common in calcareous waters and eutrophic waters because it has a high tissue demand for both phosphorus and nitrogen. It overwinters as prostrate shoots which start to regenerate new lateral shoots as the temperature reaches 10°C. The shoots grow rapidly towards the surface without branching where they form a densely branched canopy.

Both species have whorls of three leaves around the stem. Subsequent internodes are rotated at 60° giving the appearance of being arranged in 6 rows.

E. nuttallii is distinguished from *E. canadensis* by the possession of leaves which are in most cases narrower than 1.75 mm (mean 1.4 mm, range 0.4 to 2.4 mm); usually no longer than 10 mm (mean 7.7 mm, range 4 to 15.5 mm); leaves which are folded along the midrib, somewhat recurved with undulate margins (visible with hand-lens). The leaves are pale green and flaccid and linear to lanceolate in shape (pointed tips).

E. canadensis has leaves which are usually wider than 1.75 mm (mean 2.0 mm, range 1.1 to 5 mm); mean leaf length is 8.1 mm (range 5 to 13 mm). The leaves are flat and are widely acute to obtuse or obtuse-acuminate at the tip (this means it has approximately blunt or rounded leaf tips). The leaves are dark green and crisp. *E. canadensis* also develops axillary or apical stem turions.

Management

Cutting controls the plant for no more than one season and can help to spread the plant by releasing fragments. Herbicides produce more effective control but seldom eradicate the plant and, in rivers, recolonisation from upstream can be rapid. It is readily consumed by Grass Carp but these have very limited applications in rivers. It is not particularly shade tolerant and is suppressed but not eradicated when trees, emergent vegetation or floating plants are present in sufficient quantities.

Methods of control

Cutting

Where: Where the plant is growing alone or in mixtures with other aquatic vegetation which require control and where the likelihood of spreading the plant by releasing fragments is not important.

How: By weed boat, weed bucket or by hand operated scythe or chain scythe. Cutting should be as close to the river bed as possible to reduce the rate of recovery and cut weed should be removed from the water.

When: At any time when significant quantities of plant material are present but usually as late as possible in the summer to reduce the risk of regrowth before autumn.

Herbicides

Terbutryn

Where: In waters flowing at less than 20 m/h and where the control of other submerged weeds and algae is required.

How: By hand or motorised granule applicators.

When: Early in the season when growth is starting.

Dichlobenil

Where: In waters flowing at less than 90 m/h and where the control of other submerged weeds is required.

How: By hand or motorised granule applicator.

When: Early in the season when growth is starting.

Diquat alginate

Where: In waters with any velocity and when the control of other submerged weeds is required but preferably in waters with a low level of suspended mud or clay.

How: Using specialised knapsack or motorised applicators.

When: Usually in late spring when plants are young and growing actively. Localised control in summer can also be applied to clear channels or swims but the build-up of silt on the plant surface gradually reduces effectiveness.

5.4.6 Pondweeds (*Potamogeton* spp.)

Introduction

In Britain, there are 21 species of Pondweed and 4 hybrids, some of which are rare and others very scarce. Only *P. natans, P. pectinatus, P. crispus, P. perfoliatus* and occasionally *P. berchtoldii* and *P. pusillus* should be considered as weed species. Most common British species produce submerged leaves (except Broad-leaved Pondweed, (see 5.3.4). Some produce fine grass-like leaves (e.g. Fennel Pondweed, *P. pectinatus*) while others have wider flat leaves (e.g. Perfoliate Pondweed, *P. perfoliatus*). Pondweeds grow in static and flowing water frequently up to 3 m deep and some species can grow in water up to 10 m deep. They grow annually from rhizomes buried in the bottom sediment and from tubers or turions. Pondweeds can be locally troublesome, impeding flow and interfering with recreation and navigation. Probably the most troublesome species is Fennel Pondweed (*P. pectinatus*). This plant grows in many types of water but is most prolific in eutrophic waters where it sometimes replaces Water-crowfoot as the dominant species. Fennel Pondweed produces both rhizomes and tubers which are about the size of a pea and are formed in the summer and autumn in the mud attached to the rhizomes. Even if the plant is uprooted, many of the tubers break off and germinate in the spring producing new plants. In still water Fennel Pondweed produces fine, almost hair-like stems and leaves but in faster flowing rivers, the stems and leaves are much thicker and can easily be confused as a different species.

Management

All Pondweed species can be cut but regrowth, especially early in the summer, is rapid. Where Pondweeds have been cut regularly, there is no evidence of any reduction in regrowth and the plant appears to be able to tolerate this form of management almost indefinitely.

In static waters, herbicides can give good control of most species including Fennel Pondweed, although this species is seldom eradicated, probably because the tubers are unaffected and regrow after the herbicide has degraded. In flowing waters, diquat alginate has achieved good control of many Pondweeds although Fennel Pondweed in its coarse river form is generally unaffected.

Methods of control.

Cutting

Where: Where herbicides are inappropriate and where regular annual cutting is an acceptable form of management.

How: By hand, weed bucket or weed boat. Cutting should be as deep as possible to reduce the risk of regrowth later in the season.

When: At any time when sufficient growth warrants cutting. Cutting should normally not be carried out until mid - late summer, as there is a risk of regrowth after early season cuts.

Herbicides

Diquat alginate

Where: For localised control in static water and for full or localised control in water flowing at more than 90 m/h. On Fennel Pondweed (*P. pectinatus*) in fast flowing waters, diquat alginate will produce poor control, especially in hard water, and in these conditions cutting is probably the most cost-effective form of control.

How: By hand or motorised applicator.

When: In spring or early summer when plants are young and growing actively but before they have reached the surface.

Diquat (liquid formulation)

Where: In waters flowing at less than 90 m/h and where control of algae as well as Pondweed and other submerged plants is required.

How: By spraying onto water surface or by subsurface injection.

When: In spring or early summer when plants are young and growing actively.

Dichlobenil or terbutryn

Where: In static or slow flowing rivers with a velocity of less than 90 m/h (dichlobenil) or 20 m/h (terbutryn). Where localised control is required, use the slow-release formulation Casoron G. Use terbutryn where control of algae as well as Pondweeds and other submerged weeds is required.

How: By hand or motorised granule applicator.

When: Early in the spring when growth is just starting.

5.4.7 Australian Swamp Stonecrop (*Crassula helmsii*)

Introduction

This plant was introduced into this country from Australia and has been sold in Garden Centres and aquarium shops as an "oxygenating weed", sometimes under the incorrect name *Tillaea recurva* or *Tillaea helmsii*, for use in aquaria and ponds. Attempts are now being made to stop this sale because it is a highly invasive and competitive species and, once established, it can suppress almost all other aquatic vegetation. It will grow in water at least 3 m deep and can also grow on damp ground perhaps 0.5 m above water level. It is extremely tolerant of shade and dessication. Until recently, it has only been found in isolated ponds but is now starting to appear in drains and watercourses. Once established, it will form dense stands from bottom to top of the water column and will grow up to 20 cm above the water surface. In these circumstances, it is likely to impede flow and interfere with fishing and recreation probably to a greater extent than any other species of weed.

Because of its ability to suppress most, if not all, species of native submerged and, probably, floating weed, it is likely to be extremely damaging to freshwater ecosystems. Where this plant is seen to be present, even in situations where rare or desirable plant species are also present, serious thought should be given to eradication because it will eventually suppress other species and destroy the aquatic habitat for other plants and animals.

Swamp Stonecrop is a brittle plant from which fragments are easily broken by wind, waves and wildfowl or during cutting operations. It can regenerate rapidly from very small fragments and so, once established in a watercourse, it is likely to spread rapidly downstream.

Management

Cutting, or any other form of mechanical control should be avoided because it will result in large numbers of fragments being produced which will spread the plant into new areas. Cutting produces only short-term benefits as regrowth is rapid.

The only effective forms of control so far identified are with herbicides. Where the plant is growing on banks or in shallow water with large quantities of exposed foliage above the water surface, good control has been obtained by spraying the exposed foliage with glyphosate.

In deeper water and where the plant is growing in a submerged form, diquat alginate has been found to give good control but two applications are necessary. Two applications separated by about one month are probably necessary for two reasons: first, the quantity and density of plant material present at the time of the first application may absorb much of the herbicide before it can penetrate fully through the plant canopy; secondly, the dormant buds on the plant stem appear to be highly resistant to the herbicide. Once the leaves have been killed by the herbicide, these buds germinate and produce young, tender lateral branches which are susceptible to a second treatment. The timing of this treatment is important; it is necessary to ensure that lateral buds have all germinated but treatment must not be delayed too long otherwise new resistant lateral buds will form on these branches.

In enclosed waters, Grass Carp may also help to control this plant although it is probably better to use a herbicide, especially on small localised infestations because the feeding action of the fish may release fragments and spread the plant to other unoccupied areas.

Methods of control

Herbicides

Glyphosate

Where: Where the plant is growing on banks or in shallow water where a large proportion of the stems and leaves are growing in an emergent form.

How: By hand or motorised sprayer.

When: From mid-May throughout the season. Plants die back within about one month after spraying and a second treatment on any surviving plants can then be applied.

Diquat alginate

Where: In any situation where the plants are growing in a submerged form or are only just emergent.

How: By hand or motorised Midstream applicator.

When: Usually in spring when plants are growing actively but before large quantities of emergent growth has developed. After the initial application, the plants should be left for about one month for the treated material to die off and for the undamaged lateral buds to germinate. A second treatment should then be applied. Subsequent spot treatments of any surviving material or newly identified sites should be made in order to prevent recolonisation.

5.4.8 Other submerged weeds (Including: *Ceratophyllum, Hottonia, Eleogeton, Hippuris, Juncus, Lagarosiphon, Mosses (Fontinalis)* and Charophytes (*Chara*))

Introduction

Although there are many other species of submerged weeds, such as those listed above, not covered in the preceding sections, they are found most frequently in static waters and seldom reach troublesome densities in rivers. Occasionally, almost any plant can become a problem locally and require some form of management.

Most of these species die back in autumn and overwinter as seeds, spores, turions or rhizomes. They are immune to control measures during this period and, like most other submerged weeds are most effectively controlled by herbicides in spring or early summer. The majority will regrow from fragments so that spates, cutting or other forms of mechanical damage can spread the plants.

Management

Any of the weeds listed above, as well as most other submerged weeds, can be controlled by cutting. However, this will produce results which last, at best, for one season. Cut weed must be removed and, in many situations, deposited in recognised tips. Fragments released during cutting can be carried downstream and recolonise new areas.

Many of the species listed above are known to be susceptible to one or more of the three herbicides approved for the control of submerged aquatic vegetation. In static or very slow flowing rivers (less than 20 m/h) any of these herbicides can be used and the choice may depend on what other susceptible species are present and whether they also need to be controlled. In faster flowing rivers (above 90 m/h) only diquat alginate can be used and some of these species are not well controlled by this chemical.

Where permissible, Grass Carp can be used to control some of these weeds. Details of susceptible species are given in the Environment Agency Booklet "Grass Carp for aquatic weed control: A users manual", R&D Note 53.

Methods of control

Cutting

Where: In most situations, especially where herbicides are inappropriate.

How: By hand, weed bucket or weed boat. Cutting should also be as close to bed level as possible to reduce regrowth. As much cut weed as possible should be removed to reduce the risks of deoxygenation, blockage of culverts and weirs and to prevent regrowth from viable fragments.

When: At any time when sufficient quantities of weed warrant the operation but, where possible, cutting should be delayed as long as possible to prevent regrowth later in the season.

Herbicides

Diquat Alginate

Where: In static or flowing water. Weeds known, or likely, to be susceptible include *Ceratophyllum* and *Hottonia* spp.. *Juncus bulbosus* has also been controlled in at least one flowing water situation with diquat alginate. Check product label for list of susceptible species.

How: By hand or motorised applicator.

When: When weeds are actively growing but preferably before they reach the water surface.

Dichlobenil

Where: In water flowing at less than 90 m/h. Susceptible weeds include most submerged weeds including *Ceratophyllum, Hippuris,* Mosses and *Chara* spp.. Check product label for list of susceptible species.

How: By hand or motorised granule applicator.

When: Early in the spring when growth is just starting.

Terbutryn

Where: In water flowing at less than 20 m/h. Susceptible species include most submerged weeds and algae. Check product label for susceptible species.

How: By hand or motorised granule applicator.

When: Early in spring when growth is just starting.

5.5 Emergent Weeds

Emergent weeds are rooted plants growing in shallow water usually not more than about 1.0 m deep. The majority of stems and leaves extend above the water surface some species reaching a height of 3 m (10 ft). The more troublesome weeds are the narrow-leaved species including rushes, reeds and sedges. Broad-leaved emergent weeds include Water Plantain (*Alisma plantago aquatica*), Water-cress (*Rorippa nasturtium-aquaticum*) and Water Dropwort (*Oenanthe crocata*). Emergent weeds tend to be most troublesome in shallow streams and drainage ditches where they can spread across the entire width of the channel. In larger and deeper watercourses, they are usually limited to the margins. Emergent weeds can form dense beds which impede water flow. They also interfere with access to the water and with fishing and other forms of recreation. The stems and rhizomes of these weeds trap silt and, as the rhizomes gradually spread into deeper water trapping more silt, channel capacity is reduced. Some emergent species produce stiff erect stems which remain standing when the plants die back in autumn. These dead stems trap debris and so continue to impede flow in autumn and winter so that an autumn channel clearing operation is sometimes necessary.

Emergent weeds can occur in almost any water body. They cause few problems in fast flowing, rocky bottomed rivers where the fast flow and absence of silt limits their growth to localised areas usually along the margins. In slow flowing, silty rivers they can be highly invasive. Some emergent weeds, particularly Water Dropwort (*Oenanthe crocata*), Iris (*Iris pseudacorus*) and Water Horsetail (*Equisetum fluviatile*) are poisonous to animals. Normally, these plants are avoided by grazing livestock but, after cutting or spraying, become palatable and retain the toxin within the dead plant tissue. Particular care should be taken to keep livestock away from treated river banks until the controlled plants have decomposed or been disposed of safely. Emergent water plants have a number of beneficial properties. They provide habitats, nesting sites and food for birds, mammals, invertebrates and fish. A 2 m wide stand of emergent weed, which is recommended as the minimum for colonisation by birdlife, is reported to be capable of absorbing over 60% of the erosive wave energy generated by boat traffic. One of the most beneficial emergent weeds used to protect banks is Sedge (*Carex* spp.). These plants form dense stands along the water margin but do not spread into deep water or onto the banks, thus they require little management in most situations. The presence of marginal strips of emergent and bankside vegetation may help to absorb and reduce the amount of agricultural fertiliser draining from adjacent farmland into the river.

Emergent weeds are easily cut and harvested but this gives only temporary control as the plants regrow from rhizomes and sometimes from seed. Dredging removes the rhizomes and gives long-term control especially when the water depth is increased beyond the tolerance range of emergent weeds. Grass Carp have very little use as a biological control agent for emergent weeds but cattle and sheep can sometimes be used where the plants are growing on banks or in very shallow water. Most, if not all, emergent weeds can be controlled by spraying them with glyphosate. This gives long-term control and can be applied locally to eradicate individual weed beds or to trim back invading marginal vegetation. In terms of cost-effectiveness, controlling emergent weeds with glyphosate is likely to be the best option. The use of glyphosate has the advantage that only emergent or floating weeds onto which the spray is directed are affected. Submerged weeds, even if growing within the sprayed area will not be controlled.

5.5.1 Common Reed/Norfolk Reed (*Phragmites australis*)

Introduction

Reeds can form dense stands of shoots up to 3 m high and grow on dry land and in water up to about 1 m deep. Shoots emerge in April and continue to grow until July with additional shoots emerging throughout most of the summer. The rhizomes grow as much as 1 m below soil level. The plant is a perennial and vegetative reproduction is by rhizome growth: although it flowers annually, viable seeds are hardly ever produced. Reeds colonise river margins and spread into shallow water where dense stands impede flow and cause problems to anglers and for other recreation activities. The stiff erect stems remain standing after the plant dies back in autumn and continue to cause problems throughout the winter and following spring.

Reeds provide a good habitat for birds and other wildlife and narrow fringes or clumps should be preserved where possible. Their presence along the margins of narrow watercourses produces shade which helps to suppress the growth of floating and submerged weeds. Reeds are still used for thatching although plants grown in many areas of the UK are of poor quality and rot easily. This may be caused by high nitrate levels which encourage the shoots to grow rapidly but with large, weak cell structures.

Management

Cutting will control reed for one season at best. Longer term control can be achieved by spraying the leaves with glyphosate. Dredging will only be effective if sufficiently deep to remove the buried rhizomes but there is a danger of spreading the rhizomes onto adjacent agricultural land in the spoil. Where dredging is anticipated, an application of glyphosate in the previous summer or autumn (and at least 3 weeks before dredging) will kill the rhizomes and prevent the spread of the weed with the spoil.

Regular trampling and grazing by livestock is also reported to control this plant but damage to river banks can occur and this technique is unlikely to have wide application.

<u>Methods of control</u>

Cutting

Where: Where short-term control is adequate and where regular annual cutting of other weeds is required.

How: Weed bucket or (where adequate depth exists) by weed boat. Hand cutting by scythe is also effective on small areas and where access for machinery is limited.

When: From July until Autumn. Early season cutting should be avoided because of harm to nesting birds and other wildlife and because shoot emergence continues until July or August.

Dredging

Where: Where dredging is required for other purposes.

How: Using hydraulic excavator and dredging bucket removing deep layers of silt. Note: Shallow dredging and "slopping out" is unlikely to be deep enough to remove buried rhizomes.

When: At any time of year but consider spraying the shoots in the previous summer or autumn to prevent spread onto adjacent farm land.

Herbicides

Glyphosate

Where: Where long-term control is required and where the control of other emergent or floating plants growing in or close to the Reeds is acceptable.

How: By hand operated or machine mounted sprayer. Where possible, leave unsprayed margins or clumps to conserve some Reed.

When: Usually in mid to late summer. However, spraying as early as mid-May has been effective and this reduces the risk of summer flooding and the need to clear the channel of dead vegetation before autumn. Plants which have been cut or broken prior to spraying are unlikely to be controlled.

5.5.2 Branched Bur-reed (*Sparganium erectum*)

Introduction

This widespread species forms dense beds along margins and within the channel of slow flowing silty and shallow streams where, because of its bulky and unyielding nature, it has a major impact on channel capacity. Seeds are produced on the green bur-like flower heads but spread is principally by rhizome growth. These rhizomes can spread from shallow water, where the plant is first established, into deeper water, where the dense fibrous mass of roots growing from the rhizomes traps silt and so allows the plant to spread further. It can grow in water at least 50 cm deep and reaches a height of up to 150 cms.

Bur-reed fruits are eaten by wildfowl but dense stands are detrimental to fisheries and they reduce species diversity and habitats for wildlife.

Management

The stiff, fleshy leaves of this plant are easily cut but the quantity of plant material often makes removal a difficult and expensive operation. The plant regrows after cutting so that, at best, control for only one season can be obtained. Cutting should not normally be undertaken until July to reduce environmental impact on aquatic fauna and because regrowth can occur later in the season if cuts are made too early.

This plant is susceptible to glyphosate applied in mid to late summer and control can last for several seasons, although some recolonisation may occur from germinating seeds or from rhizomes growing in from adjacent unsprayed areas. Bur-reed dies back, usually within 4-5 weeks of spraying. The leaves, which are soft and fleshy, decompose easily and do not normally require cutting or clearing after spraying.

The rhizomes of this plant are fairly shallow growing and can be removed by dredging or, in very shallow localised areas, by hand digging and pulling.

Methods of control

Cutting

Where: Where control for one season only is adequate and where herbicides are considered inappropriate.

How: By hand, weed bucket or weed boat. Choice depends on area, access and water depth.

When: Usually in late July, August or early September. In mild autumns, the plant may not die back quickly and autumn cleaning of channels may be required.

Herbicides

Glyphosate

Where: Where long-term control is required and where localised or spot treatments are preferred.

How: By knapsack or motorised sprayer.

When: In late July, August or early September. Bur-reed dies back after early frosts and so treatments should not normally be carried out after mid-September.

5.5.3 Bulrush / Reedmace (*Typha latifolia* and *T. angustifolia*)

Introduction

Bulrushes often invade freshly disturbed watercourses where dredging has taken place. They are most common in ponds and lakes and in shallow, slow-flowing channels, particularly silty lowland clay streams. Bulrushes are not normally found in faster flowing rivers. They grow from rhizomes in April and produce the characteristic, dark brown flower spike in August and September. Each spike contains over 200,000 seeds which are mainly responsible for the spread of these plants into newly dug or disturbed watercourses.

T. latifolia is more common than the thinner leaved *T. angustifolia*. Both species can grow in water up to about 50 cm deep and reach a height of around 250 cms. They provide good cover for wildfowl but dense stands impede flow and interfere with recreation. The leaves and especially the flowering stems are stiff and erect. They do not collapse easily when the plant dies in the autumn and may continue to impede flow throughout the autumn and winter.

Management

The base of the leaves and flower stalks of *T. latifolia*, where it emerges from the sediment, is thick and can jam across the front of reciprocating cutters so that it is not easily controlled by weed buckets or weed boats, although it is easily cut by hand scythe and similar large bladed cutters. *T. angustifolia* is smaller and more easily cut.

Glyphosate gives good control of these plants but early season applications (i.e. before August/September) allow seeds to germinate in the cleared areas so that long term control is not achieved. Treatments in August and September reduce the number of plants regrowing in the following season. However, the ability of this plant to grow from seeds means that repeated applications of glyphosate, perhaps on an annual or biennial basis are likely to be necessary, especially if untreated areas remain to replenish the seed bank. Applications of dichlobenil to watercourses where Bulrush seedling are germinating, appear to control the seedlings, but this has not been generally tested and any treatments should be regarded as experimental. It is very unlikely that dichlobenil will control mature established plants.

<u>Methods of control</u>

<u>Cutting</u>

Where: As required and where herbicides are considered inappropriate.

How: By hand or by weed bucket or weed boat. Note: Mature plants may be difficult to cut with reciprocating cutters, especially close to bed level where the stems are large.

When: In mid to late summer to prevent subsequent regrowth but preferably before seed heads have matured, to prevent the spread of viable seeds. In some situations, repeated cuts (2-3 per season) carried out over several seasons have been observed to reduce or eliminate the weed.

<u>Herbicides</u>

Glyphosate

Where: Where control for more than one season, or where spot or localised treatments, are required.

How: By knapsack or motorised sprayer.

When: In late August or September but before the plants start to die back. Note: Applications earlier in the season will kill the plants but seedling germination in the autumn or early in the following spring is likely to occur.

5.5.4 Clubrush (*Bulboschoenus lacustris*, syn. *Schoenoplectus lacustris*)

Introduction

Clubrush grows to a height of 3 m in a wide range of flows in water up to about 50 cm deep. In fast flowing rivers, it may form only floating leaves and can then be confused with floating leaved *Sparganium* spp.. Emergent leaves are usually present along the margins in these circumstances. These are tall cylindrical leaves with a cluster of brown flowers near the tip. Clubrush grows annually from rhizomes, reaching full height in June or July and dying back in October or November. It can form dense stands which impede flow and trap silt. In southern and eastern England particularly, it can occupy large sections of rivers, restricting flow to narrow channels and interfering with fishing and boat traffic. Although providing good cover for wildfowl, dense stands are probably harmful to the river ecosystem as a whole.

The long tubular leaves of this plant used to be dried and used for rush matting and chair or basket weaving.

Management

In common with most other emergent weeds, Clubrush is easily cut but produces a very high biomass of weed which makes harvesting and disposal an intensive and expensive operation. The plant will regrow if cutting is carried out early in the season and will regrow in the following season after later cuts. There is no evidence that repeated cutting reduces the vigour of this plant. Dense stands trap silt, which becomes bound in place by the rhizomes and roots, and so cause silt beds to increase in depth each season until dry land is formed. These shallow or dry areas may deflect the flow, causing bank erosion and so lead to more silt being deposited downstream. Cutting has little effect on this because the roots and rhizomes remain in situ and continue to bind the silt.

More frequent dredging may be necessary in rivers infested with this weed. If deep enough, dredging removes the rhizomes but recolonisation by plants from undredged areas is rapid.

Club-rush can be controlled by spraying the emergent foliage with glyphosate. Surprisingly, no symptoms appear on the leaves after spraying, which die back in the normal way in autumn. However, no regrowth appears in the following spring. The rhizomes are also killed and decompose, destabilising the silt beds and allowing them to be washed away. It may be possible, therefore, to control the location of silt beds by localised control of selected beds where open channels are required. Glyphosate will not control plants which have produced only submerged/floating leaves nor will it control plants whose leaves have been cut or severely damaged.

<u>Methods of control</u>

<u>Cutting</u>

Where: Where temporary control lasting no more than one season is acceptable.

How: By hand, weed bucket or weed boat. Cutting should be as close to bed level as possible where flow enhancement is required.

When: When sufficient weed is present to justify the operation. Preferably, cutting should be delayed until late July or later to reduce environmental impact and regrowth later in the season.

<u>Herbicides</u>

Glyphosate

Where: Where long-term control is required in localised or large areas, especially where reductions in the build-up of silt beds is required.

How: By knapsack or motorised sprayer. Because the weed often grows in very high dense beds out of reach of conventional knapsack sprayers, a long-lance sprayer may be needed.

When: Normally in mid to late summer when full leaf emergence has occurred. If leaves are likely to be bent and broken by spates or other causes, spray earlier as soon as leaves are well emerged.

5.5.5 Reed Sweet-grass and Reed Canary-grass (*Glyceria maxima* and *Phalaris arundinacea*)

Introduction

Although these two grasses are different species, they can be grouped together for purposes of control. Reed Sweet-grass can grow in water up to about 70 cm deep and reaches a height of up to 2 m. Reed Canary-grass tolerates only very shallow water and reaches 1.4 m in height. It seldom causes serious problems in rivers occurring, usually, as small clumps along the banks. Reed Sweet-grass is more invasive and sometimes spreads out into the watercourse even, on occasions, forming floating rafts.

Both species form good habitats for wildlife and food for grazing animals. As marginal vegetation, they cause few problems but may need to be controlled especially in shallow streams if growth becomes excessive.

Management

Both species can be controlled by cutting although regrowth from rhizomes tends to be rapid. They are readily grazed by cattle and sheep and, particularly in and around shallow, firm bottomed streams, grazing can be an effective form of biological control.

Both species are susceptible to glyphosate which produces a fairly rapid kill of the foliage as well as killing the rhizomes. Glyphosate has been used to trim back Reed Sweet-grass where it is spreading out from the bank into a watercourse. However, the growth rate of the rhizome is rapid and, within one year, the plant can spread back into the channel to the point where further growth is limited by increasing water depth. Therefore, localised control of this plant with glyphosate, especially along marginal strips, is unlikely to produce long-lasting control.

Methods of control

Cutting

Where: As required.

How: By hand, weed bucket or weed boat (although these plants are seldom found in water deep enough for weed boats to operate).

When: When sufficient plant material is present to justify the operation. Cutting should usually be delayed until late July to reduce environmental impact and risk of subsequent regrowth.

Grazing

Where: Along river banks, especially where shallow water allows livestock to wade and where access to dry ground is available in time of high water.

How: By fencing and use of cattle or sheep.

When: All year but mainly in summer to reduce damage to banks.

Herbicides

Glyphosate

Where: Where overall long-term control or localised short-term control is required.

How: By knapsack or motorised sprayer.

When: Usually in mid to late summer when full leaf emergence has taken place, although treatments from late May can be effective.

5.5.6 Sedges (*Carex* spp.)

Introduction

There are many species of sedge found in a wide range of habitats from moorland to river banks. Characteristic of many sedges is a serrated edge to the leaf which can be felt when rubbed with a finger. Be careful; this can cut the skin! Sedge species found in or near water grow to a height of about 1.5 m and can form very dense beds along the margins but do not usually grow in water more than about 30 cm deep. Because they do not tolerate deep water and do not grow well on dry land, they tend to form a narrow margin especially along steep sided watercourses and do not spread either up the bank or into the water. For this reason, they are valuable, stabilising the banks and protecting them from wave action without causing a serious nuisance. In a number of situations, they have been deliberately planted for this purpose. However, in shallow, slow flowing channels they can invade the watercourse and their dense growth can impede flow as well as damaging the habitat for other plants and animals.

Management

Sedges can be controlled by cutting or spraying with glyphosate. Growth and flowering occur early in the spring and cutting any time after the end of May will produce good control for most, if not all, of the remainder of the season. However, the plants will regrow in the following spring. Dredging will remove the rhizome and so produce longer-lasting control. Where reconstruction work is carried out, deepening the watercourse so that the banks slope steeply into water of 0.5 m or more will prevent the weed from spreading into the channel. It can then be retained along the banks as a habitat for wildlife and to protect the banks from erosion.

The recommended time to spray sedges with glyphosate is in mid to late summer. However, it is likely that applications in May or June might also be effective. Plants sprayed in July, August or September show only a slight yellowing of the leaf tips and die back at the same time as unsprayed plants but do not regrow in the following spring. Sedges tend to spread only slowly and thought should be given to localised control with glyphosate so that a narrow protective fringe of sedge is retained while controlling the spread into the watercourse.

Methods of control

Cutting

Where: As required.

How: By hand or weed bucket. The plant seldom grows in water deep enough for a weed boat. Care should be taken when hand cutting or handling cut material as contact with the edge of the leaves can lacerate skin.

When: At any time when sufficient plant material justifies the effort but, cutting should normally be delayed until July to protect nesting birds and invertebrates.

Dredging

Where: Where reconstruction work is taking place. Channel re-profiling to deepen water close to the margin will prevent the spread of the weed into the watercourse. Where possible, leave a narrow fringe of rhizomes along the margins.

How: By dredging bucket.

When: At any time but can be most effective when plants are visible and their position can be clearly identified.

Herbicides

Glyphosate

Where: Where long term and localised or overall control is required.

How: By knapsack or motorised sprayer.

When: Usually in mid to late summer although earlier treatments in May or June may also be effective.

5.5.7 Water-cresses and Water Parsnip (*Rorippa* spp., *Apium nodiflorum*, *Berula erecta*)

Introduction

There are several species of broad-leaved emergent aquatic plants which look and behave like Water-cress (*Rorippa nasturtium aquaticum*). These include Fools Water-cress (*Apium nodiflorum)* and Water Parsnip *(Berula erecta),* as well as two other species of Water-cress (*R. amphibia* and *R. microphylla*). They are annuals or perennials, reproducing by seed and, generally, not seriously troublesome except in very local situations. Occasionally, in shallow, fast flowing streams they can cause problems by covering the water surface and impeding flow. Plants can be easily uprooted by currents or disturbance and drift downstream where they become lodged against obstructions (often other plants) and again root. These plants produce large quantities of viable seed and cleared areas can be recolonised rapidly by seedlings.

Management

All these species can be easily cut but will usually regrow rapidly, especially if cut early in the season before flowering. If the plants are left to flower and produce seed, the seeds sink to the bottom and germinate in the autumn or in the following season. Therefore, late cutting does not reduce the seed bank and gives only very short term control.

Water-cress is controlled by several herbicides. Glyphosate and 2,4-D amine sprayed onto the emergent foliage are both effective and dichlobenil applied to the water will also control some species, especially early in the season when the seeds are germinating. However, a single application of any of these herbicides is unlikely to give long term control for three reasons. First, when a dense canopy of foliage is present, there are almost always some plants screened from a foliar spray by taller neighbours. Growth from these survivors is rapid and, unless re-treated, they can soon recolonise the area. Second, detached plants from untreated areas can be carried downstream and spread into the treated area. Third, seeds produced by earlier generations as well as those washed in from upstream germinate to produce new plants. Thus adequate control of water-cress is difficult and may require repeated operations throughout the season, until both vegetative growth and the seed bank have been exhausted.

Methods of control

Cutting

Where: Where short term control is acceptable.

How: By hand or weed bucket. The plant is seldom a problem in water deep enough for a weed boat. Cutting as close to bed level as possible will help to delay regrowth.

When: At any stage when sufficient weed growth is present to justify the operation. As regrowth is rapid, several cuts may be necessary each season. Cutting after flowering is seldom worthwhile as the plant will soon die back naturally.

Herbicides

Glyphosate or 2,4-D amine **(Note: 2,4-D amine is more selective and will leave reeds and sedges uncontrolled. Glyphosate will control all emergent vegetation).**

Where: Where long-term control is required.

How: By knapsack or motorised sprayer.

When: When full leaf emergence has occurred but before flowering. Germinating seedlings and plants drifting downstream should be re-treated before flowering and treatments should continue until the seed bank is exhausted.

Dichlobenil

Where: In water flowing at less than 90 m/h.

How: By hand or motorised granule applicator.

When: Early in the season when growth is just starting.

5.5.8 Emergent poisonous plants (Species include: Water Dropwort (*Oenanthe crocata*), Yellow Iris (*Iris pseudacorus*), Water Horsetail (*Equisetum fluviatile*), Marsh Marigold (*Caltha palustris*), Hard Rush (*Juncus inflexus*).

Introduction

Several poisonous plants which grow in water can be just as dangerous to livestock as the better known bankside weeds such as Ragwort (*Senecio jacobea*). They seldom grow in sufficient density to cause land drainage problems or to interfere with recreation or navigation. However, they can cause problems especially when surrounding weeds are controlled. Normally, these poisonous plants are avoided or ignored by grazing animals because they have an unpalatable smell or because they are beyond reach in water. However, a number of them (of which Water Dropwort is probably the best example) lose the unpalatable smell after they have been cut or sprayed, but retain their toxicity. If these plants are cut and left on the bank, or sprayed with a herbicide and left where livestock have access to them, poisoning can occur.

Management

It is relatively unusual for these plants to be present in dense infestations and they are most frequently controlled by chance when other more troublesome weeds are present. They can all be controlled temporarily by cutting but will regrow, either later in the season or in the following year. Dredging will control these species but poisoning incidents have occurred when spoil containing the roots of some of these plants has been left on the bank where livestock have access to them. Water Dropwort, for example, has large fleshy white roots similar in shape to carrots, which contain high levels of toxin.

Some of these plants are susceptible to herbicides. For example, Water Dropwort can be controlled by spraying with glyphosate and it is likely that Yellow Iris, Marsh Marigold and Hard Rush would also be controlled, although they are not listed on the product label as susceptible. Horsetail is only susceptible to dichlobenil.

In situations where these plants are present there will be a risk to animals each time weed control or dredging operations take place. In these circumstances, it may be worth using a herbicide to eradicate the poisonous weeds so as to reduce the risks for future operations. When a herbicide is used, it is important to fence the area to exclude livestock until all the weed has died back completely. If the weeds cannot be controlled by herbicide then, for each control operation, cut weed or spoil from dredging must be either transported to a safe disposal site or fenced off until all weed has decomposed.

<u>Methods of control</u>

<u>Cutting</u>

Where: Where the weeds cannot be controlled by a herbicide.

How: By hand, weed bucket or weed boat. Take particular care to ensure that cut poisonous weed is not allowed to drift downstream where it can be washed up onto banks to which livestock have access.

When: At any time when sufficient weed growth is present to justify the operation.

Herbicides

Glyphosate

Where: Where susceptible emergent weeds are present. Localised control, or spot treatments can be used where desirable emergent species are also present.

How: By knapsack or motorised sprayer.

When: Normally at full leaf emergence. Water Dropwort is known to be susceptible in June.

Dichlobenil

Where: Where Water Horsetail is present in water flowing at less than 90 m/h.

How: By hand or motorised granule applicator.

When: In early spring when growth is just starting.

5.5.9 Other emergent weeds. Including: Brooklime (*Veronica beccabunga*), Water Dock (*Rumex hydrolapathum*), Forget-me-nots (*Myosotis* spp.), Water Mint (*Mentha aquatica*), Water Plantain (*Alisma plantago-aquatica*), Spiked Rush (*Eleocharis acicularis*), Sweet Flag (*Acorus calamus*), Flowering Rush (*Butomus umbellatus*).

Introduction

In addition to those species described previously in this section, there are many other emergent weeds. It is unusual for these other species to reach nuisance levels. Locally, however, almost any species can cause a problem, although it is more likely that these less invasive weeds will be present as part of a mixed community which collectively has become too dense to be acceptable. Where possible, they should be conserved because they add to the diversity of species present in the habitat and add to the amenity value of the water. There is also a danger that, if controlled, the space will be filled by a more troublesome species requiring higher levels of control.

Management

In most instances, these plants should not be controlled. Where control of a weed population containing them is essential, localised control techniques should be used to retain as much of these less common species as possible. Cutting will not eradicate these plants as effectively as a herbicide and late cutting is preferable as it allows flowering and seed formation to occur. Most of these species are likely to be susceptible to glyphosate and this herbicide should not be used on these plants unless control is essential.

<u>Methods of control</u>

<u>Cutting</u>

Where: Only where control is essential.

How: Preferably by hand or selectively by weed bucket.

When: As late as possible in the season.

<u>Herbicides</u>

Glyphosate

Where: Where other emergent weeds require control.

How: By spot or localised spray application, preferably by knapsack sprayer, and avoiding these species as far as possible.

When: After desirable plants have seeded. In some instances, it may be possible to wait until autumn when some of these plants have died back but the target emergent weeds are still in a susceptible condition.

6. FURTHER INFORMATION

6.1 Manufacturers of Mechanical Equipment

Atlas Hydraulic Loaders Ltd. Wharfedale Road Euroway Estate BRADFORD W. Yorks, BD4 6SL	**Hydraulic Excavators (River Rig)** 01274 686827
Bomford Turner Ltd. P.O. Box 18 Salford Priors EVESHAM Worcestershire, WR11 5SW	**Tractor-mounted dyke mowers and flail mowers** 01789 773383
Engineering and Hire Co. Ltd. Marsh Lane Laughterton LINCOLN LN1 2JX	**Weedboats, weedharvesters, amphibious weedboats, weedcutting/ditching/slubbing buckets weedrakes, extension pieces, long dippers etc.** 01427 718561
JCB Sales Ltd. Rocester UTTOXETER Staffordshire, ST14 5JP	**Hydraulic excavators (River Rig)** 01889 590312
J. Mastenbroek and Co. Ltd. 83 Swineshead Road Wyberton Fen BOSTON Lincs, PE21 7JG	**Weedscreens, mowing boats, mowing, dredging, buckets, specialised equipment.** 01205 311313
Miller Water Management Ivy Cottage Rostherne KNUTSFORD Cheshire WA16 6RY	**Weed Harvester** 01565 830222
Permarine Marketing Services Pages Court St. Peters Road PETERSFIELD Hants, GU32 5HX	**Weed cutting boats (eg Wilder WaterWarrior and Aquascythe). Agents for SimplexBateaux Faucardeurs.** 01730 823667
Priestman Equipment Ltd Kingston International Park Hedon Road HULL N. Humberside, HU9 5PA	**Hydraulic Excavators** **Dragline Excavators** 01482 707070
R-B International Ltd. Beevor Street LINCOLN LN6 7DJ	**Dragline excavator, Long-reach hydraulic excavator - Variable counter weight.** 01522 525261
Rousseau Equipment Ltd. End Building Power Station Road RUGELEY Staffs WS15 2DQ	**Flail and reach mowers** 01889 500570

6.1.1 Manufacturers of Manual Equipment

Turk Scythes and Trimflex (U.K.)
18 Spiers Way
HORLEY Surrey RG7 6NY 01293 785069

6.2 Approved Products At Date of Publication for Use in Or Near Water Under the Control of Pesticides Regulations (1986).

Active Ingredient	Product Name	MAFF Number
asulam	Asulox	06124
2,4-D amine	Agricorn 2,4-D Atlas 2,4-D Dormone MSS 2,4-D Amine	07349 03052/07699 05412 01391
dalapon / dichlobenil mix	Fydulan G	00958
dichlobenil	Casoron G Casoron GSR	06854 06856
diquat	Levi Reglone	07845 06703
diquat alginate	Midstream	06824/01348
fosamine ammonium	Krenite	01165
glyphosate	Barclay Gallup Amenity Buggy SG Clayton Swath Clinic Danagri Glyphosate 60 Glyfos Glyfos 480 Glyfos Proactive Glyper Glyphogan Glyphosate 360 Glyphosate Biactive Helosate Ipiglyce 36 SL MSS Glyfield Roundup Roundup A Roundup Amenity Roundup Biactive Roundup Biactive Dry Roundup Pro Roundup Pro Biactive Spasor Spasor Biactive Stetson	06753 08573 06715 08579 06955 07109 08014 07800 07968 05784 08568 08307 06499 08327 08009 01828 08375 08721 06941 06942 04146 06954 07211 07651 06956
maleic hydrazide	Regulox K Royal MH 180	05405 07043
terbutryn	Clarosan Clarosan 1FG	08396 03859

6.3 Manufacturers of Herbicide Products and Equipment

Allied Colloids Ltd. PO Box 38 Low Moor BRADFORD, Yorks. BD12 0JZ.	**Atlas 2,4-D** 01274 417000
Barclay Plant Protection Ltd. 28 Howard Street GLOSSOP Derbyshire SK13 9DO	**Barclay Gallup Amenity (glyphosate)** 0500 360180
Cheminova Agro (UK) Limited Bishop House Bath Road Taplow MAIDENHEAD, Berks. SL6 0NX	**Glyfos, Glyfos 480 (glyphosate)** 01628 664038
Claxton Engineering Skillington GRANTHAM Lincs. NG33 5EY	**Midstream applicators** 01476 860870
Cooper Pegler (part of Hardy Group) North Seaton Industrial Estate ASHINGTON Northumberland NE63 0YB.	**Knapsack sprayers** 01670 522225
Du Pont (UK) Ltd Wedgwood Ray STEVENAGE Herts. SG1 4QN.	**Krenite (fosamine ammonium)** 01622 55471
Farmers Crop Chemicals Ltd. Thorn Farm Evesham Road INKBERROW, Worcs. WR7 4LJ.	**Agricorn (2,4-D amine)** 01386 793401
Helm Great Britain Chemicals Ltd. Wimbledon Bridge House 1 Hartfield Road LONDON SW19 3RU.	**Helosate (glyphosate)** 0181 544 9000
Mirfield Sales Services Ltd. Moorend House Moorend Lane DEWSBURY, W Yorks. WF13 4QQ.	**MSS 2,4-D amine** 01924 409782
Monsanto plc Crop Protection Business Unit P O Box 53 Lane End Road HIGH WYCOMBE, Bucks. HP12 4HL.	**Roundup, Roundup Pro, Roundup Biactive,** **Roundup Amenity, Roundup Pro Biactive,** **Roundup Biactive Dry, Stetson** 01494 474918
Nomix Chipman Ltd Portland Building Portland Street Staple Hill BRISTOL BS16 4PS	**Roundup Pro Biactive, Glyfos Proactive,** **Casoron G** 0117 957 4574
Novartis Crop Protection UK Ltd. Whittlesford CAMBRIDGE CB2 4QT	**Clarosan (terbutryn), Clarosan 1FG** 01223 833621

Nufarm UK Limited Crabtree Manorway North BELVEDERE, Kent. DA17 6BQ.	**Clinic (glyphosate)** 0808 311 7000
PBI Agrochemicals Britannica Works WALTHAM ABBEY Essex. EN9 1NP	**Glyphogan (glyphosate), Glyper** 01992 712579
Powaspray (Midlands) Ltd 7 Browntoft Lane Donington SPALDING Lincs. PE11 4TQ:	**Controlled droplet applicator sprayers** 01775 821031
Rhône Poulenc Agriculture Ltd. Fyfield Road ONGAR Essex CM5 0HW	**Regulox K, (maleic hydrazide)** **Spasor & Spasor Biactive (glyphosate)** **Dormone (2,4-D Amine), Asulox** 01277 301301
Rigby Taylor Ltd. The Riverway Estate Portsmouth Road Peasmarsh GUILDFORD, Surrey. GU3 1LZ	**Casoron G** 01483 535657
Scotts Company (UK) Ltd. Salisbury House Weyside Park Catteshall Lane GODALMING Surrey GU7 1XE.	**Casoron G, Reglone, Midstream** **(Casoron GSR)** 01483 410210
Sipcam UK Ltd. Sheraton House Castle Park CAMBRIDGE CB3 0AX	**Buggy SG** 01223 462244
Uniroyal Chemicals Ltd Kennet House 4 Langley Quay Waterside Drive SLOUGH Berks. SL3 6EH.	**Royal MH180 (maleic hydrazide)** 01753 603054
Zeneca Professional Products Fernhurst HASLEMERE Surrey. GU27 3JE.	**Casoron G for the control of rooted submerged and floating leaved weeds in water less than 1 m deep. Reglone for control of submerged or free floating plants and algae** 01428 656564

6.4 Sites of Special Scientific Interest - Consultation and Management Procedure

Notification

Under the 1981 Wildlife and Countryside act and subsequent amendments, English Nature and the Countryside Council for Wales are required to notify owners, occupiers and the Environment Agency of any SSSI's on rivers for which it has responsibility for management.

Each notification to owners and occupiers includes:

- a description of the special interest of the site.
- a list of the operations which, in the opinion of English Nature or the Countryside Council for Wales, are likely to damage the special interest of the site (these operations are termed potentially damaging operations (PDO's) and are listed below).
- a boundary map of the site.

For a new SSSI or an extension to an existing SSSI, English Nature or the Countryside Council for Wales must supply the above and specify consultation period of not less than 3 months, within which the owner or occupier may submit written objections or representations, which English Nature or the Countryside Council for Wales must consider. The consultation period provides an opportunity to discuss ways of securing the nature conservation interest of the site with the minimum of interference to the day to day activities of the owner or occupier.

Management

From the date of notification, English Nature or the Countryside Council for Wales requires the Environment Agency as owner or occupier, to give written notice of intent to carry out any potentially damaging operation (PDO) listed for the site.

The Environment Agency may still carry out work listed as a PDO if any of the following conditions are fulfilled.

- the work is carried out in accordance with a management agreement (See below).
- the Environment Agency has submitted written notice of the work and English Nature or the Countryside Council for Wales has responded with written consent.
- four months have elapsed following notification by the Environment Agency, without receiving a response from English Nature or the Countryside Council for Wales.
- an emergency arises.
- the work has planning permission under the Town and Country Planning Acts.

Management agreements

To prevent the need for repeated written consent from English Nature or the Countryside Council for Wales, routine operations - such as annual weedcutting can be covered by a management agreement. This agreement would be negotiated between English Nature or the Countryside Council for Wales's regional staff and Environment Agency conservation and operations staff. Typically the agreement specifies the timing and methods of carrying out an agreed programme of work for a series of routine operations which may extend over a period of several years.

The Environment Agency should expect to receive some financial contribution from English Nature or the Countryside Council for Wales towards any extra costs of achieving nature conservation requirements.

Written Consents

For non-routine maintenance and major engineering works a management agreement is inappropriate. After notification from the Environment Agency written consent must be obtained from English Nature or the Countryside Council for Wales. It is likely that unless work is of a very limited nature there will be extensive discussion prior to such consent being granted.

Potentially Damaging Operations which may form part of aquatic weed control operations

standard ref number	Type of Operation
2	Grazing and changes in the grazing regime.
4	Mowing or other methods of cutting vegetation. Changes in the mowing regime.
6	Application of herbicides. The use of aquatic herbicides in or near SSSI's will not normally be permitted except under exceptional circumstances. Such circumstances might include spot treatment for the elimination of invasive and/or dangerous weed species such as Giant Hogweed.
7	Dumping, spreading or discharge of any materials.
9	The release into the site of any wild, feral or domestic animal (eg grass carp), plant or seed.
10	The killing or removal of any wild animal.
11	The destruction, displacement, removal or cutting of any plant.
12	Tree/Woodland management. The introduction of tree/woodland management (includes planting).
13b	Modification of the structure of watercourses.
13c	Management of aquatic and bank vegetation for drainage purposes.
14	The changing of water levels and tables and water utilisation Severe changes in water levels (ie de-watering) should always be the subject for individual written consent. De-watering should be carried out in autumn of early winter, when plants have died back and most amphibians have left the water, but before the season of severe frosts, which may kill dormant plants and invertebrates hibernating in the mud.
15	Infilling of ditches, dykes, drains, ponds, marshes or pits.
26	Use of vehicles or craft likely to damage features of interest.

6.5 Herbicide Effects on Conservation Interests

Users of pesticides should take into account the impact of herbicides on the habitat of the following rare or protected species of flora and fauna. While these habitats most often occur in Sites of Special Scientific Interest, the distribution of these animals and plants is not restricted to these sites. Regulations exist to protect SSSIs however, extreme care should be taken not to disturb the habitat unduly if it is known that any of the following species are present in an area to be treated with herbicides. A full list of protected species is given in the Wildlife and Countryside Act 1981

Specially protected wild plants which could be affected by aquatic or bankside herbicides:

Adder's-tongue spearwort	*Ranunculus ophioglossifolius*
Brown galingale	*Cyperus fuscus*
Fen orchid	*Liparis loeselii*
Fen violet	*Viola persicifolia*
Floating Water-plantain	*Luronium natans*
Least lettuce	*Lactuca saligna*
Ribbon-leaved water-plantain	*Alisma gramineum*
Rock cinquefoil	*Potentilla rupestris*
Starfruit	*Damasonium alisma*
Teesdale sandwort	*Minuartia stricta*
Triangular club-rush	*Scirpus triquestrus*
Water germander	*Teucrium scordium*

Wild birds whose habitats are likely to be affected by aquatic or bankside herbicides

Birds specially protected at all times:

Avocet	*Recurvirostra avosetta*
Bearded tit	*Panurus biarmicus*
Bewick's swan	*Cygnus bewickii*
Bittern	*Botaurus stellaris*
Black-necked grebe	*Podiceps nigricollis*
Black tailed godwit	*Limosa limosa*
Black tern	*Chlidonias niger*
Cetti's warbler	*Cettia cetti*
Common scoter	*Melanitta nigra*
Divers (all species)	*Gavia* spp.
Garganey	*Anas querquedula*
Harriers (all species)	*Circus* spp.
Kentish plover	*Charadrius alexandrinus*
Little bittern	*Ixobrychus minutus*
Little gull	*Larus minutus*
Little ringed plover	*Charadrius dubius*
Long-tailed duck	*Clangula hyemalis*
Marsh warbler	*Acrocephalus palustris*
Purple Heron	*Ardea purpurea*
Red-necked phalarope	*Phalaropus lobatus*
Ruff	*Philomachus pugnax*
Savi's warbler	*Locustella lusciniodes*

Slavonian grebe	*Podiceps auritus*
Spoonbill	*Platalea leucorodia*
Spotted crake	*Porzana porzona*
Whooper swan	*Cygnus cygnus*

Wild birds specially protected during the close season:

Goldeneye	*Bucephala clangula*
Greylag goose	*Anser anser*
Pintail	*Anas acuta* (in Outer Hebrides, Caithness, Sutherland and Wester Ross only)

Other specially protected animals whose habitat is likely to be affected by aquatic or bankside herbicides:

Mammals	
Bats	*Rhinolophidae* and *Vespertilionidae*
Common otter	*Lutra lutra*
Amphibians	
Great crested newt	*Triturus cristatus*
Natterjack toad	*Bufo calamita*
Fish	
Turbot	*Lota lota*
Butterflies	
Swallowtail	*Papilio machaeon*
Moths	
Essex emerald	*Thetidia smaragdaria*
Other insects	
Norfolk aeshna dragonfly	*Aeshna isosceles*
Spiders	
Fen raft spider	*Dolomedes plantarius*
Snails	
Glutinous snail	*Myxas glutinosa*
Sandbowl snail	*Catinella arenaria*

Preservation of habitats for fish, mammals and birds

It is not possible to list here exact habitat requirements of every species of fish, bird or mammal likely to be found in or near water. Even if it was possible, there would be many contradictory recommendations because the preservation of a habitat for one species can often result in the destruction of the habitat of another species. Where the preservation of a particular species is important, consult conservation, fishery or biology staff. The following recommendations apply to conservation of habitats in general.

- Where a valuable community of plants and animals has been identified, maintain the same management regime, including weed control practices, as have been used in the past. If this is not possible, perhaps because a new weed is invading the watercourse, choose a control technique which is as target specific as possible and apply it selectively.

- Avoid weed control operations as far as possible during the months of May, June and early July when the majority of birds and animals are reproducing.

- Preserve as wide a range of weed habitats as possible. Patches of emergent, floating and submerged weed along with open areas of water will support a wider range of species than a channel which is either weed free or totally covered by weed.

- Where possible, stagger weed control operations leaving sections either along the watercourse or across the channel and manage these later in the season or in alternate years.
- Where a weed problem is caused by a single species or group of related species (eg algae), choose the most target specific control technique available. Retain as many of the non-target, untroublesome plants as possible.

- Do not over-dredge channels and retain gravelly bottoms where possible. Over-dredged channels with silty bottoms grow more weed, require more maintenance and provide poorer habitats than narrower, fast flowing, gravelly channels especially if these consist of pool and riffle form.

- Consult conservation officers about the particular biological value of a watercourse before carrying out weed control operations. Attempt to modify the timing or severity of operations to conserve valuable aspects and habitats.

- Do not carry out weed control or dredging operations unless strictly necessary. Removing an existing plant community can allow in a more troublesome weed which causes greater problems in the future.

- Do not remove trees unless absolutely necessary and, where possible, replant before felling old trees.

- Where possible, leave natural features such as bends and cliffs in place.

- Where restructuring work is necessary, try to use natural materials such as stone or wood in place of concrete or steel piling.

6.6 Further Reading, References and Useful Contacts

Identification of aquatic weeds

Publications dealing with aquatic weed identification include:

A *British Water Plants,* S.M. Haslam, C.A. Sinker and P.A. Wolseley. Field Studies (1975) 4: 243-351. Field Studies Council.

B *Aquatic Plants - a guide to recognition,* D.H. Spencer-Jones and P.M. Wade. ICI Professional Products, 1986.

C *A Key to Common Algae. Freshwater, Estuarine and some Coastal Species.* EG Bellinger (1992). Institute of Water and Environmental Management. ISBN 1-870752-16-3.

D *New Flora of the British Isles,* C.A. Stace, Cambridge University Press (1991). ISBN 0-521-42793-2

E *BSBI Handbooks* - *Sedges of the British Isles*
- *Charophytes of Great Britain and Ireland*
- *Pondweeds*

Books on biology and control of aquatic weeds and associated aspects of conservation

A *Aquatic Weeds - The Ecology and Management of Nuisance Aquatic Vegetation.* Peiterse & Murphy (eds). Oxford University Press. 1990. ISBN 0-19-854181-3.

B *The New Rivers and Wildlife Handbook.* RSPB/Environment Agency and RSNC, 1994. ISBN 0-903138-70-0.

C *River Vegetation. Its identification, assessment and management.* S M Haslam & P A Wolseley, 1981. ISBN 0-521-23187-6.

D *Nature Conservation and the management of drainage channels.* Nature Conservancy Council and the Association of Drainage Authorities, 1989. ISBN 0-86139-581-6.

Agency R&D Note 53. Environment Agency, Bristol. (Tel: 01454 624439. Fax : 01454 624409).

F *Water Level Management Plans.* A procedural Guide for Operating Authorities. MAFF, The Welsh Office, ADA, English Nature and the Environment Agency.

Publications relevant to the use of herbicides in or near water

A *MAFF Guidelines on the use of herbicides on weeds in or near watercourses and lakes.* 1995. Available from MAFF Publications, London SE99 7TP (Tel: 0645 556000).

B *Use of herbicides in or near water.* Environment Agency Code of Practice.

C *Code of practice for the safe use of pesticides on farms and holdings,* reprinted 1995. *(MAFF/HSE. ISBN 0-11-242892-4),* which promotes the safe use of pesticides. It covers the requirements of the COPR and the COSHH Regulations. Copies can be obtained from HMSO (Tel: 0171-873-9090). Price £5.75.

D *Code of Good Agricultural Practice for the Protection of Soil. 1993, MAFF Booklet PB 0617.* Available from MAFF Publications, London SE99 7TP (Tel: 0645 556000).

E *Code of Practice for the use of Approved Pesticides in Amenity and Industrial Areas. 1991,* National Association of Agricultural Contractors/National Turfgrass Council.

F *Approved Code of Practice for the Safe Use of Pesticides for Non-Agricultural Purposes.* (HSC, ISBN 0-71760542-6). This provides advice to those in the non-agricultural sector on compliance with the COSHH Regulations. Price £6.95.

G *COSHH in Agriculture.* AS28, 1993, HSE.

H *"The Use of Herbicides on Weeds in or near Water".* Environment Agency.

I *Code of good agricultural practice for the protection of water.* (MAFF Booklet PB0587). Available from MAFF Publications, London SE99 7TP (Tel:0645 556000).

J *HSE Guidance Note CS19 - "Storage of approved pesticides - guidance for farmers and other professional users".*

K *The Spray Operators Compendium.* Available from BCPC Publications, Bear Farm, Binfield, Bracknell, RG42 5QE. (Tel: 0118 934 2727, Fax: 0118 934 1998).

L *Guidelines for the control of weeds on non-agricultural land - your guide to herbicides in weed control.* DOE November 1992.

M *Pesticides,* MAFF/HSE Reference Book 500. ISBN 011-243-0163. £16.99. Available from HMSO (Tel: 0171-873-9090).

N *The UK Pesticide Guide.* British Crop Protection Council, 49 Downing Street, Farnham, Surrey, GU9 7PH. (Tel: 01252-733072, Publications - 0118 934 2727). Price £18.95.

O *Waste Management. The Duty of Care, A Code of Practice.* Environmental Protection Act 1990. DoE, Welsh Office. HMSO, 1991. ISBN 0-11-752557. Price £5.35.

HSC and HSE publications are now available by mail order from: HSE Books, PO Box 1999, Sudbury, Suffolk, CC10 6FS, (Tel: 01787 881165). For information about Certification of Competence in use of pesticides - contact the National Proficiency Test Council, National Agricultural Centre, Stoneleigh, Kenilworth, Warwickshire, CU8 2LG.