AQUATIC PLANTS IN BRITAIN - THEIR OCCURRENCE AND SIGNIFICANCE AS WEEDS

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Summary. In freshwater plants are considered weeds because they physically interfere with man's use of the water. However, they also form an important part of a biological system providing shelter and oxygenating the water. Many of these ecosystems have developed under annual weed cutting regimes and any change in the routine will affect the system. Results of herbicides differ dramatically from those following cutting, mainly because there is little plant regrowth. These changes must be acknowledged but need not be condemned. Whether they are acceptable will depend upon the way in which the water and water channel or lake are to be used. This must be assessed locally in each separate case and objectives and priorities stated clearly before decisions can be reached on the most suitable method of weed control to be applied. Freshwater situations and use are so diverse and complex that it is dangerous to generalise in questions of their management.

INTRODUCTION

My task in this initial paper is to set the scene by reviewing briefly the effects plants have on the management of freshwater. They can be both beneficial and a nuisance and some of the more difficult problems arise when attempting to reach an acceptable compromise between these two attributes. A very wide variety of plants grow in freshwater in Britain - ranging from minute unicellular algae to large emergent species such as Phragmites communis (common reed). However it is common practice for the term "water weeds" to be used to denote the vascular plants and sometimes the large filamentous algae. The term "weed" is often used by fishermen as an alternative for the word "plant". In this paper however I will give it its proper meaning i.e. "a plant growing where it is not wanted". In this way some of the small unicellular algae can also be called weeds and should therefore be included.

Plant species seldom occur in isolation. They usually form communities of a number of species and are closely associated with communities of animals and micro-organisms forming many and varied biological systems. They have an important role to play within these systems and any change in the composition or size of the plant communities will affect in some way or other the biological system itself. The major contributions of plants are:

(a) They are primary producers of food. However, submerged vascular plants perhaps do not have such an important input as was once thought and some workers have shown that much of the organic matter occurring within a fresh-water ecosystem has originated from outside.

(b) Submerged plants increase the levels of dissolved oxygen in the water through the evolution of oxygen during photosynthesis.

(c) Plant roots help to stabilise and hold together the substrate. By reducing the velocity of flow the deposition of silt is increased and the substrate changed.

(d) Plants form an important element of the habitat of animals and birds. They provide shelter from predators and current, and also to some extent supply food.

However plants also interfere with man's interests.

(a) They obstruct flow, thus:

i) increasing the risk of flooding

ii) reducing the effectiveness of land drainage

iii) causing the siltation and deterioration of channels

(b) They interfere with fishing, sailing, aquatic sports, and navigation.

(c) Some of the larger filamentous algae (blanket weeds) float on the surface of the water and prevent oxygenation of the water beneath them.

(d) In ornamental lakes weeds can be very unsightly when they reach the surface and in some instances can be dangerous. There have been examples when ponds covered with duckweed (Lemna minor) have been mistaken for a continuation of a lawn and children have fallen into the water.

(e) Certain phytoplankton can be poisonous. A severe bloom is also unsightly and can deoxygenate the water.

The traditional way of overcoming the disadvantages has been to remove the weeds regularly during the summer by hand and occasionally, when necessary, dredging out the bottom mud to deepen the channel or the lake. Under this management biological systems atuned to the periodic removal of the larger plants have developed and are considered by many to be the most acceptable ecosystems for our freshwater. These ecosystems are very varied in detail and not only differ from place to place but also change within themselves over a period of time. It is also widely believed that changes have been and are being induced by certain of man's activities which increase the nutrient status of freshwaters. The disposal of sewage effluent and the use of artificial fertilizers are the most common activities said to cause this enrichment.

There is of course a natural development from freshwater to dry land which is not completely arrested by cutting alone but requires occasional dredging to return the ecosystem to its original form. Those ecosystems which have developed in this way usually have a mixed population of rapidly growing macrophytes rooted in the mud and associated with them a faunal population which uses them in some way or other. Only a few of these animals attack the living plant but there are more which graze the epiphytic algae growing on the stems and leaves and many others consume detritus to which the plants contribute when they die. Plants with emergent and floating foliage also act as a bridge between the water and the air up which dragonflies and mayflies climb when they are ready to emerge. Perhaps the most important functions of the submerged weeds are the provision of shelter for fish fry and invertebrates and the maintenance of high dissolved oxygen levels in the water through photosynthesis. Although important in certain situations they are not necessarily the major source of food.

Over the last two decades it has become necessary to look for new techniques to overcome a shortage of labour willing to continue the traditional manual cutting. The first attempts have been to mechanise the cutting operations and some efficient equipment has been developed in recent years e.g. weed cutting boats. However these do not meet all the needs of those responsible for controlling water weeds and this has led to the study and development of aquatic herbicides. To date nine herbicides have been cleared under the Pesticides Safety Precautions Scheme for use in or near water and data sheets on these compounds have been distributed. When the management of traditionally maintained ecosystems is changed by the application of one or more of these new techniques it is inevitable that there will be some changes in the system itself.

WATER PLANTS

Water plants may be divided into four main groups:

i) emergent plants, i.e. those plants whose foliage emerges above the surface of the water. This group also includes plants growing at the edge of the water and on the lower parts of the banks.

ii) Floating-leaved plants, i.e. those plants with at least some of their leaves floating on the surface of the water. Most of them are rooted in the mud but some e.g. Lemna minor are free floating.

iii) Submerged vascular plants, i.e. "the true aquatics". In this group the foliage is totally submerged although in many species the inflorescence is emergent.

iv) Algae, i.e. the large filamentous forms which commonly rise to the surface as "blanket weeds". Other planktonic algae can also cause trouble and are included in this group.

Emergent plants. The best known of the emergent plants is the common or Norfolk reed (Phragmites communis). It is found over most of Britain and is an important weed in the shallow drainage ditches of the Fens and elsewhere. At one time it was valued for thatching and careful handcutting brought in an income from this source. However it seriously obstructs water flow in drainage ditches and having a robust rhizome system, was difficult to eradicate until dalapon treatments were introduced. Bulrushes (Typha spp.), burr reed (Sparganium erectum) and sweet reed grass (Glyceria maxima) frequently occur in drainage ditches but may also be troublesome in rivers and lakes. Dalapon is used to control them but it is not totally effective. Locally some species of water dropwort (Oenanthe), water parsnip (Berula), marshwort (Apium) and water cress (Rorippa nasturtium-aquaticum) form obstructions in water courses.

In drainage channels it is usually considered necessary to remove excessive plant growth on the lower part of the banks. The plants involved here, apart from those already mentioned, are one or two robust, tufty grasses and tall dicotyledons such as purple loosestrife (Lythrum salicaria) and hairy willow herb (Epilobium hirsutum). 2,4-D is normally recommended for the broad-leaved weeds and the growth retardant maleic hydrazide has been used in the place of cutting to reduce the height of the grasses.

Floating-leaved plants. Of the floating-leaved plants the commonest is probably the duckweed (Lemna minor). It occurs throughout the country on ponds and drainage channels. It can block screens at out-falls but is not usually considered a serious weed from the point of view of obstructing flow. In ornamental ponds and lakes however it is considered unsightly and can in fact be a danger to children and animals. It is readily killed by a surface spray of diquat and also by some of the treatments for submerged weeds. Two floating-leaved plants which cause more trouble are the yellow water lily (Nuphar lutea) and the floating-leaved pond weed (Potamogeton natans). These plants are normally found in still or flowing water and no satisfactory way is available at the moment to control them. However work at the Weed Research Organization has shown promise in finding herbicides which are effective when sprayed on the floating leaves.

Submerged vascular plants. There is a wide variety of submerged vascular plants throughout Britain and many of them given the right conditions could become weeds. Some are more notorious than others and perhaps the best known is the Canadian pond weed (*Elodea canadensis*). This plant causes serious problems mainly in lakes; completely filling them. However other species may be equally important although they usually occur in mixed communities. Milfoil (*Myriophyllum* spp.), fennel-leaved pond weed (*Potamogeton pectinatus*), hornwort (*Ceratophyllum demersum*) and various crowfoots (*Ranunculus* spp.) obstruct flow in sluggish rivers and drainage channels and also interfere with fishing and boating. Because submerged weeds normally occur in mixed communities, chemicals which have been developed for their control have all been nonselective, general herbicides. It is thought inappropriate to consider selective herbicides when the space vacated by one plant would be rapidly filled by one of the others. Submerged plants in the faster flowing rivers also need to be removed from time to time but so far herbicides have not been used for this purpose.

Algae. There are several species of filamentous algae which cause trouble in Britain. Some of them such as *Cladophora glomerata* occur in both rivers and still-water, but only become serious pests in lakes and stagnant drainage ditches. Here they tend to grow from the bottom during the spring and eventually float to the surface covering the whole of the water with a filamentous mat. The two most troublesome species found on lakes are *Cladophora glomerata* and *Rhizoclonium hieroglyphicum*.

Other species of filamentous algae such as the net alga (*Hydrodictyon reticulatum*) and numerous species of *Spirogyra* can also be troublesome. In the smaller land drainage channels in the Fens one of the worst weeds is the alga *Vaucheria dichotoma*. This forms a floating blanket 25 centimetres thick covering the whole of the width of the ditch and stretching in a continuous mat for hundreds of metres along its length. Because light is excluded there is little or no plant growth beneath it and the dissolved oxygen levels are very low. Its removal, essential for land drainage purposes, is very difficult without heavy equipment, such as draglines, or the use of an effective algicide. Copper sulphate has been used in the past but because of its toxicity to fish and invertebrate fauna it is not recommended and the two triazine herbicides recently tested and developed in this country are preferred.

WHERE WATER PLANTS BECOME WEEDS

Whether plants should be considered as weeds not only depends upon their own individual characteristics but also upon the use that man wants to make of the water or the water-body. Other speakers will deal in detail with the problems created by weeds under the different types of land and water use but I should like to mention them very briefly here in an attempt to put the questions raised by herbicide use into perspective.

Land drainage and flood prevention. In Britain aquatic herbicides have been used mostly in land drainage channels. This is because the local authorities responsible have an obligation to the rate-payers to maintain a high standard of land drainage and to keep costs down. The gradient of these channels is so small that any impediment to flow must be removed to ensure an adequate movement of water. Judicious use of herbicides has proved to be an economic method of weed control in many of these situations.

Active steps have also to be taken to reduce plant growth in rivers to prevent them overtopping their banks and flooding the countryside and nearby towns. Herbicides have not been used very much for this purpose because of possible risks to water users down-stream. As far as I am aware only those which are sprayed onto the aerial foliage of emergent plants have been used near rivers. However, some others may enter from treated drainage ditches and lakes.

Fishing and fisheries. Plants interfere with fishing but are considered essential for fisheries. Some sort of compromise is usually sought but is difficult to achieve with herbicides. None-the-less herbicides have been used successfully in certain fishing lakes without adversely affecting the fish population and there seems a case for the re-examination of the place of macrophytes in fisheries. This is especially so when considering management systems suitable for modern fish farming enterprises and "put-and-take" fisheries.

Ornamental waters. Some plant life is usually wanted for aesthetic reasons in ornamental waters. However growth can get out of hand or unbalanced and some form of control measure is needed. The method used will depend on the plants present and also on the resources available. When the main cause of the trouble is filamentous algae little can be done except by herbicides.

Sailing, boating and water sports. Plants interfere with all these activities none of which has a direct interest in the biology of the water and excessive plant growth can endanger human life. In these situations herbicides are an invaluable tool.

Water supply reservoirs. Vascular plants do occasionally cause trouble in water supply reservoirs but this is usually when they are also used for sailing and fishing. Planktonic algae are frequently more of a nuisance and have to be removed in some way or other. The introduction of herbicides into domestic supplies for this purpose will be one of the major topics for discussion at this meeting.

Nature conservation and nature reserves. Although I mention this at the end of the list, I in no way wish to imply that it is the least important. The conservation of rare plants and rapidly vanishing ecosystems is of urgent importance and is of growing concern as new methods of weed control are adopted.

It is now generally agreed throughout Britain and most other countries that there is a need to protect and conserve examples of rare and interesting plants, animals and biological communities. However, although this need is generally accepted, its implications are not always fully appreciated. Firstly there is the question of possible conflict between the conservation interests and the demand for other things such as higher food production for the human population. Secondly there is the practical side of the selection and establishment of nature reserves and sites of special scientific interest and the subsequent administration and management of these areas. The uninformed sometimes think that all that is necessary to conserve natural communities and plants is to create reserves and then to forget about them. It is of course essential not only to remember them, but to manage them if they are to remain in the form we wish to preserve. The relevant freshwater ecosystems are usually those which have been developed and maintained by the old-fashioned and traditional methods of management which tend to be the most expensive. If they are to be preserved the community must accept and meet this heavy commitment.

SOME IMPORTANT EFFECTS OF HERBICIDE USE

I hope that what I have said so far stresses adequately the wide range of plants and freshwater situations that exist and the fact that the problems are as varied as those encountered in the management of natural and semi-natural dry land ecosystems. The common practice of lumping them all together as "aquatic weed problems" and considering the use of "aquatic herbicides" tends to over-simplify the problems and not to recognise their complexity. I have tried to show briefly the need to consider at least each group of plants separately and the same must be done for the herbicides and water conditions too. This is the first major point I wish to make - each problem is different and requires separate detailed consideration in order to reach a satisfactory solution.

However, having said this, there are a number of general points which must be remembered when discussing herbicide use in water. These are concerned with the indirect effects the chemicals have on the plant and animal communities through changing their habitat. The possible direct effects such as toxicity to plants and animals, taint, discolouration and corrosion are determined largely by the properties of the products and are specific to any particular herbicide. Almost by definition, herbicides will bring about fundamental changes in biological systems which have developed under a management involving cutting followed by rapid regrowth, but not the death of the plants. The aim of most herbicide treatments is to kill the plants and prevent regrowth. If regrowth does occur it is usually delayed and the gap between the removal of the plants and their re-establishment is much greater than under the traditional cutting regime.

Abiotic effects.

(a) Light. Light penetration is increased especially when the taller emergent plants e.g. the common reed, are removed and may promote more rapid growth of those plants not affected by the treatment. This frequently happens when reeds have been successfully killed by dalapon. The subsequent years see an increase in the growth of submerged plants and algae in the water.

(b) Dissolved oxygen. Because when submerged plants are killed they decompose *in situ*, the biological oxygen demand is increased following herbicide treatment and oxygen levels usually drop. In certain cases however where phyto-plankton are resistant, this drop in oxygen level is much reduced. The degree of deoxygenation also depends on other factors such as weed biomass and water temperature.

(c) Plant nutrients. As the plants decompose plant nutrients are released into the water. Much more information from field studies is required to quantify the amounts involved and their availability to algae. Some recent work indicates that certain nutrients, notably phosphates, are held in an unavailable form in the mud.

Biotic effects. The major biotic effect is the change brought about in the plant and animal communities as a result of the disruption of the habitat. With none of the herbicides available at present is it possible to simulate the traditional cutting techniques. It must therefore be accepted that the ecosystems will be radically changed. The degree of change will be determined primarily by what plants were there originally and what herbicide treatment was used. Whether such a change is acceptable or not will depend on what use is to be made of the water- body and the water. Before condemning these changes on the grounds that they are different we should examine them critically in the light of our objectives and, in doing so, look closely at some of the long-held views on the role and function of macrophytes in fresh water.

This leads me to my second major point - the need to have a clearly defined objective before selecting the most appropriate weed control measures. Frequently no compromise can be found to meet the needs of all the divergent interests when the original systems of management can no longer be continued. It is then essential for priorities to be decided and decisions reached locally on the aims of management.

It is the purpose of this symposium to consider the properties and functions of a comparatively new set of tools - the aquatic herbicides - and to discuss in depth their use for the control of weeds in or near freshwater and the extent to which they meet the needs of those concerned with the maintenance and management of the various aquatic situations.

LAND DRAINAGE AND WEED CONTROL

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Summary The importance of aquatic weed control in land drainage. Water level control for best possible soil environment for plant growth, considered to be 4 feet below the lowest land level in the fens. The value of crops lost as a result of a summer flood in 1968 which would amount to £2,115,342 today over an area of 58,200 acres. Flow retardance by channel weeds, which can raise the coefficient of roughness, n, to as much as ten times the clean-channel value. Present day methods of weed control which cost approx. £1 per acre of land drained for the watercourses maintained by an Internal Drainage Board in the fens. The advantages of chemical control of submerged weeds particularly during the summer months when access for mechanical plant is not possible without damage to crops. Examples of the cost of chemical control. The need for an efficient system of controlling weedgrowth in the smaller watercourses.

LAND DRAINAGE (WATER LEVEL CONTROL)

The responsibility for the maintenance of the watercourses in this country is shared broadly speaking between the Regional Water Authorities, the Internal Drainage Boards and the farmers. The Water Authorities are responsible for the main rivers, the Internal Drainage Boards for the arterial watercourses within their districts and the farmers for their field ditches.

The control of aquatic weeds is of vital importance in land drainage and is the largest item of annual maintenance expenditure for Internal Drainage Boards, particularly in the fens.

To provide the best possible soil environment for plant growth, it is essential that the water level in the arterial watercourses is maintained at the most beneficial level. In the fens it is considered to be about 4 feet below the lowest land level. There are two water levels to be considered, the designed maximum flood level and the normal retained summer water level. It is not always practicable to maintain the desired 4 feet freeboard during maximum flood conditions and for design purposes a 3 feet freeboard is often adopted.

In a normal summer in the fens there is little if any run-off of surplus water, the majority of the summer rainfall being dispersed by evaporation and evapo-transpiration of the crops and vegetation. Indeed, by September there is usually a soil moisture deficit of approximately 5 inches. By October the majority of the crops in the fens have been harvested, evaporation is considerably less and each rainfall gradually increases the water table until eventually all rainfall has to be evacuated by pumping or other means.

The aim of the land drainage engineer is therefore to ensure that by October in each year the arterial watercourses are in first class order to cope with the winter run-off. But there is always the possibility of a summer flood when the crops are at their greatest value. Such a flood occurred in the Welland and Nene area in 1968 when considerable damage to crops resulted. The rainfall varied between 4½ inches and 5¼ inches over a period of approximately 8 hours.

A District Agricultural Advisor of the Ministry of Agriculture, Fisheries and Food estimated the value of crops lost over an area of 58,200 acres as follows. The total area effected by the rainfall was of course considerably greater than 58,200 acres.

Estimate of Loss

Commodity	Loss of crop	Value 1968	Value 1975
Potatoes	35,838 tons	£ 358,380	£ 1,075,140*
Sugar Beet	15,295 tons	£ 91,770	£ 244,720
Wheat	128,990 cwts	£ 128,990	£ 386,970
Barley	57,188 cwts	£ 57,188	£ 157,267
Vining Peas	1,176 cwts	£ 47,060	£ 94,120
Dry Peas	2,095 cwts	£ 104,750	£ 157,125
Total Loss		£ 788,138	£ 2,115,342

* At guaranteed price proposed (£30). Actual value Sept. '75 £75

Much of the above loss was attributed to weedgrowth in the drainage watercourses impeding the flow and the evacuation of the flood water.

For design purposes, the maximum run-off of surplus water from fen land is usually taken as ½ inch of rainfall in 24 hours. (20 cubic feet per second from 1,000 acres). For the design of drainage channels, Manning's formula

$$V = \frac{1.4858}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

is commonly used. n is the coefficient of roughness, representing the condition of the channel, and is taken as 0.025 for channels in good condition. However, with very weedy conditions it can be as much as 0.20 (Stephens 1963 and Miers 1974). The author has seen flowing water held-up by heavy weedgrowth as much as 4 feet in depth over a distance of 100 yards for days on end.

Example

Watercourse : 3 feet bed width, 3 feet depth of water

1 : 1 side slopes

$$R = \frac{\text{area of cross-section (sq.ft.)}}{\text{wetted perimeter (ft.)}} = \frac{18}{11.50} = 1.565$$

$$R^{\frac{2}{3}} = 1.565^{\frac{2}{3}} = 1.35$$

S = the fall of the water surface divided by the horizontal distance (for practical purposes)

V = mean velocity of flow = say 1 foot per second

Case I Clear of weedgrowth

$$n = 0.025 \quad \therefore \quad \frac{1.4858}{n} = 59.43$$

$$\frac{1}{S} = \left(\frac{59.43 \times R^{\frac{2}{3}}}{v}\right)^2$$

$$= \left(\frac{59.43 \times 1.35}{1}\right)^2$$

$$= 6{,}400$$

i.e. a fall of 1 in 6,400

Case II Heavy weedgrowth

$$n = 0.20 \quad \therefore \quad \frac{1.4858}{n} = 7.429$$

$$\frac{1}{S} = \left(\frac{7.429 \times 1.35}{1}\right)^2$$

$$= 100$$

i.e. a fall of 1 in 100

Very little "fall" is available in the fens. The water surface gradient can be as small as 3 inches per mile in the larger main drains and 6 inches per mile in the normal fenland dykes. Water velocity rarely exceeds 1 foot per second. To achieve these gradients, the channels require to be virtually free of weedgrowth.

WEED CONTROL (WELLAND & DEEPINGS AREA)

In the area of the Welland and Deepings Internal Drainage Board, comprising approximately 80,000 acres, the drainage channels maintained by the Board can be summarised as follows :-

	Miles		Estimated Expenditure 1975 £
(i) **Main Drains**			
Over 20 feet wide waterway and 3 feet minimum depth of water, where floating weed cutting boats are used	39.10	Banks (Mech.)	5,744
		Waterway: Mechanical	6,896
		Chemical	1,551
			£ 14,191
(ii) **Main Tributary Drains**			
Over 8 feet in depth, exceeding 25 feet top width and 2 feet depth of water, where hydraulic excavators with weed cutting buckets are used	113.45	Mechanical	19,024
		Chemical	105
			£ 19,129
(iii) **Drains**			
4 feet to 5 feet in depth, and normally dry in summer, where weed cutting is undertaken by handlabour methods	253.14	Handlabour	41,781
		Chemical	250
			£ 42,031

Main Drains (Fishing let to local Fishing Club)

Floating weedcutting boats operate continuously in the main drains from May to October. A minimum of three cuts are undertaken each year. The cut weeds require to be removed immediately or clogging of the weed-screens at the pumping stations would occur. The method of removal is to place a boom across the watercourse at approximately 2 mile intervals and allow the weeds to float down with the current or wind and then remove them by means of a mobile truck-mounted crane with weed rake attachment.

A most troublesome weed encountered is filamentous-algae, known as "blanket weed" or "cott". This requires to be removed mechanically each year or controlled chemically. For many years copper sulphate has been successfully used to control this weed in the main drains. It has been found necessary to maintain a concentration of 1 p.p.m. for seven days by periodic supplementary doses. The first application is in the spring, when the first signs of algae growth are seen. This is followed by a second treatment in the late summer.

Its effectiveness varies with the type of water and other environmental conditions. In the very hard water of the fen drains it precipitates quickly and there is still no apparent effect on fish population after many years use. It is not so effective in the saline water of the marshland watercourses near the sea.

Here, terbutryne is successfully used to control algae and the majority of the other submerged weeds. In these waters there are no fishing interests and the water is not used for spray irrigation or other farming activities.

Dalapon is used on a small scale to control Reed (Phragmites communis) when and where necessary. A flat bottom boat is used, propelled by an outboard motor, on which is mounted a spraying unit with a 12 feet spray boom.

The vegetation on the "batters" or bank slopes of the main drains is controlled by tractor mounted flail mowers. Where banks are large enough to be fenced sheep are used. In neighbouring districts, maleic hydrazide with 2, 4-D is used on a fairly large scale.

Main Tributary Drains

For centuries, weed cutting in the fens was undertaken by handlabour methods, the scythe being the main implement used and supplemented with chain scythes for submerged weeds in the larger watercourses. In recent years, with the arrival of the hydraulic excavator, a weed cutting bucket attachment with a reciprocating knife on its leading edge, is being used extensively. Being hydraulically driven the bucket can follow precisely the side slopes and bottom of the watercourse and removes all weeds in one operation. It operates from one side of the watercourse and access is therefore essential.

In the Welland and Deepings area, four tracked hydraulic excavators, with an outreach of 39'-3" from the centre of the machine, and fitted with 12 feet wide weedcutting buckets are being used. Each machine is capable of 100 metres of work per hour at a cost of £1.12 per 20 metres. A fifth wheeled machine will be introduced next year.

The weeds are cut and removed from all the watercourses twice each year. The programme is continuous from May to October.

To ensure full utilisation of plant these machines, with reduced reach, carry out the excavation work on the Board's improvement schemes during the winter months.

Drains

The large majority of weedcutting in the smaller watercourses is still undertaken by handlabour methods, (scythes). Access is the problem as far as mechanical methods are concerned. The fen farmers cultivate every square inch of land and grow crops to the very brink of all the watercourses.

It is sometimes possible to use tractor-mounted flail mowers after harvest. This is not really satisfactory as the cut vegetation falls into the bottom of the watercourses and needs to be removed.

The control of weedgrowth in the smaller watercourses is one of the big problems of Internal Drainage Boards and also of the farmers.

Farm Ditches

Many farm ditches are quite large watercourses and the farmer is faced with the same problem of weed control as the drainage authorities. In the past, he has normally carried out the weed cutting once per year after harvest when the necessary handlabour was available. Today, with considerably less labour, many are using flail mowers attached to their own tractors. I'm afraid few remove the cut vegetation that falls into the bottom of the watercourse, which impedes the flow of water and results in the necessity for more frequent mudding-out operations. The cost of handlabour weedcutting is approximately £1 per 20 metres and flail mowing approximately 30p. per 20 metres. The total mileage of farm ditches must be considerable.

CONCLUSION

The control of weedgrowth during the summer months is of great importance in the event of a summer flood. The rapid regrowth that occurs after each cut, by mechanical or handlabour methods, soon obstructs the flow again and, in many cases, watercourses remain blocked for most of the summer.

The use of chemicals to control submerged weeds in the main arterial watercourses can greatly reduce the damaging effect of a summer flood.

Big advances have been made in recent years with herbicides and many Internal Drainage Boards are now using these new chemicals. It is now practicable to control chemically virtually all submerged weedgrowth during the summer months, when access for mechanical plant is not possible without damage to crops. This is a big step forward in land drainage.

However, there is the question of economics

Example: Vernatts Drain (Main outfall drain of the Deeping Fen system with an algae problem)

Length	6.65 miles
Depth	6 feet
Water width	69 feet
Weight of water	677,000,000 lbs

(i) Terbutryne (Clarosan 1% a.i.) @ 0.1 p.p.m.w.

needs 6,770 lbs @ £0.682 = £ 4,620

(ii) Cyanatryn (Aqualin 10% a.i.) @ 0.1 p.p.m.w.

needs 677 lbs @ £11.35 = £ 7,700

(iii) Present practice (Estimated cost 1975)

Weedcutting	Labour including 50% on costs	500
	Weedcutting boat @ £3.00 per hour	1,000
Weed Removal	Labour including 50% on costs	220
	Mobile crane @ £1.75 per hour	300
Algae Control	Labour including 50% on costs	110
	Copper sulphate @ 11.5p per lb.	446
		£ 2,576

= £ 46.3 per acre of water surface

In the main tributary drains (5 feet wide waterway and 18" depth of water) chemical control of submerged weeds compares favourably in cost with handlabour or mechanical methods. Chemical control would cost approximately £30.00 per mile and keep the channel clear during the summer months. It would still be necessary to cut and remove the side vegetation after harvest.

There is still a need for an efficient system of controlling weedgrowth in the smaller watercourses, which are usually dry, particularly during the cropping season. This also applies to the farmers ditches.

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ASPECTS OF WEED CONTROL IN A WATER SUPPLY RESERVOIR WITH AMENITY USES

by

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Summary DRAYCOTE WATER is a supply reservoir covering an area of 290 ha (700 ac). When full it contains 23 x 10 L (5 x 10 gall) water. Of secondary but still of major importance are the recreational facilities available to the public. These include angling, sailing, canoeing, sub aqua diving and bird watching. In such a diverse system some weed growth is essential for the maintenance of fish food chains and as a habit for the resident wild life. There is also the aesthetic need. Excessive weed growth however conflicts with the interests of the sportsmen, whose financial contributions provide the revenue essential for the provision of first class facilities. A balance is therefore needed. Manual, mechanical and chemical methods of weed control which have been used at Draycote are described.

INTRODUCTION

Draycote Water is a pumped storage reservoir designed to provide a reliable yield of 45.5×10^6 1/day (10×10^6 gal/day). It covers an area of 290 ha (700 ac) - 250 ha (600 ac) of water at top water level and 41.6 ha (100 ac) of surrounding land. When full it contains 23×10^9 litres (5×10^9 gall) water. Planning commenced in 1963, construction was started in April 1967 and completed in July 1968. It is claimed to be one of the cheapest reservoirs for its size, and one of the quickest built - observing that the planning stages, a final appeal against its construction to the House of Lords took only 5 years. The cheapness of construction was made possible because much of the materials were obtained from within the construction area.

It was decided as a matter of policy that access to the reservoir by the general public needed to be restricted, particularly in relation to pollution, cleanliness and safety and also on account of financial considerations. Despite these decisions, a number of important recreational facilities have been made available. These include trout fishing, sailing, canoeing, sub aqua diving, bird watching, sponsored walks, cycle races and other organised visits. A 9.6 ha park (23 ac.) has been provided by the Warwickshire County Council adjacent to Draycote Water from which the public can view the water.

The trout fishing is let on a day ticket basis, at £2/day (£1.50 after 1500 hours). In addition a total of 24 boats are available to anglers at an additional cost of £2/day (£1 after 1500 hours if available). The bag limit is 8 fish with a minimum size limit of 30.5 cms (12").

The Draycote Water Sailing Club operates as a limited company with a membership of 2,000 and a maximum of 700 boats. All other recreational facilities are at present free but are strictly controlled. About 40 organised events take place annually.

Recreational waters must be financially viable and, since the greater part of the recreational income comes from the trout fishing, it is necessary to provide the ideal conditions for good trout fishing, and to do this two main factors have to be met:

1 To ensure that the stocking policy is correct for the fishery concerned.

2 To ensure that the water is fishable.

It is not intended to discuss stocking policy in this paper, since this depends on a large number of factors which could be the subject of a separate paper.

Excellent fish of a high quality and a good growth rate are produced at Draycote, but to ensure good trout fishing the water must be 'fishable', both from the bank or from a boat. A pre-requisite for bank angling is the ability of fishermen to wade in safety and for them to be able to cast and retrieve their flies with reasonable ease. A dense growth of aquatic weed can make bank fishing virtually impossible and boat fishing extremely difficult resulting in a considerable loss in fishing revenues. Suitable remedial measures must be taken.

At this stage however, it is necessary to stress the importance of some degree of weed growth as an essential adjunct to trout fishing. Weeds, in addition to providing shelter for the fish themselves, form the natural habitat of their food and as such are vital for the well-being and sustained growth of fish stocks. It is therefore necessary to strike the correct balance between the ability of anglers to fish and the natural conditions needed by the fish themselves. The degree of weed growth must therefore be most carefully controlled.

The best method of control can only be selected if the objective is known, and, for this, one has to ask why weeds must be removed. Is it necessary to remove all of the weed, or only some of the weed from selected areas? What labour force is available? What finances are available? Only when we arrive at an objective answer to these questions, can we select the method most appropriate to our needs.

Trout anglers require in the order of 13 - 14m (15 yd) of bank each for comfortable and safe fishing. Draycote Water can cater for 300 bank anglers daily. It follows therefore that, since it cannot be forecast how many anglers will decide to fish Draycote Water on any given day, we must cater for 300 anglers. This is the factor which decides the areas in which aquatic weed must be controlled. There are two basic methods of providing fishable water:

1 Cut swims in the weed, that is, clear areas of bank weed, leaving some areas where the food chain can flourish or

2 Cut or clear an area through the whole length of the bank.

Of the two methods, the clearance along the whole length of the bank is less desirable since it also removes the natural habitat - the trout larder - but the angling pressure makes this method necessary.

It must be pointed out, that this method does not remove all aquatic weed, which will certainly grow in untreated areas and so maintain the food chain.

One of the most difficult things to forecast is where top water level will be during the most active growth period, i.e. during the summer months. This is dependent upon the amount of water extracted from the reservoir during this period. The situation could arise where all the treated area is exposed and untreated areas have to be fished. Weed growth proceeds unabated in untreated areas and the whole effort is therefore ineffective.

There are three main methods of weed control and these can be listed as manual, mechanical and chemical.

Manual There is basically only one method and this is cutting by hand, but there are variations, for example using chain drag lines, using a cutting device operated by men walking along the banks, using chain drag lines towed by Land Rovers, tractors and the like, but all of these methods are labour intensive.

Mechanical There are various mechanical methods which can be used:-

The Weed Bucket
The Drag line
The purpose-built weed cutting boat

Of these three methods, the purpose built weed cutting boat probably requires the least amount of labour since in this method the removal of the weed after cutting can sometimes be carried out by changing the cutting blade for a rake attachment, and the whole operation can be done by one man, except that he will require some assistance to change from cutting blade to rake.

Depending on circumstances however this method can be likened to cutting one's lawn, or painting the Forth Bridge - having completed one cycle, one has to start again at the beginning. This can mean one man employed on this operation for the whole of the growing season, which can last for some 3/4 months depending on weather conditions. This can be very expensive e.g. £1 x 40 h x 16 weeks say £640. This method has one additional disadvantage in that cutting can only be carried out after active growth has progressed for some time, and this in itself tends to interfere with fishing.

Chemical There are various chemicals available on the market which have receeived approval by the various ministries and appropriate authorities, and before any chemicals are used it is essential that a check is made to ensure that the necessary approval has been given for use of these chemicals in Rivers, Canals, Public supply impounding etc, with particular reference to the Pesticides Safety Precaution Scheme.

The chemical method of aquatic weed control is probably the most effective. It has in its favour, accepting that the initial cost of the chemical itself is high, the fact that it requires, or should require only one treatment during the season, and it only requires one man to treat.

It has of course several aspects which have to be considered. For example the seasonal growth pattern of aquatic weeds which follow closely their land-based counterparts, in that they maintain active growth in the summer methods, when they produce seeds, or flowers prior to seeding, then die back in the autumn and resume active growth in the following spring.

It is necessary to take advantage of the natural growth cycle in the time of application, which to get the best advantage, should be at the commencement of active growth in the spring.

This early application is important from two aspects. Firstly, control of the weed growth is obtained in the early stages before it develops into a serious problem, and secondly the weed is killed before possible de-oxygenation hazards occur due to the sudden collapse of dense weed infestation. The risk of de-oxygenation is particularly great when summer water temperatures produce low oxygen levels.

ENVIRONMENTAL EFFECTS OF HERBICIDES

Any herbicide by definition must be toxic to the weeds it is designed to control and yet must be safe. It is therefore necessary to consider the effects and influence of a herbicide used on the aquatic ecosystem.

Most herbicides approved are non-toxic to operators, to domestic animals and to wild animals. Their toxicity to fish and invertebrate fauna is also low unless a massive overdose is applied. However before considering any treatment by herbicides a thorough check should be made to ensure that no unwanted side effects are likely to occur.

Experience at Draycote A situation arose at Draycote Water in 1973 when suddenly and without warning a tremendous explosion of aquatic weed growth occurred in the middle of June, after a long dry sunny spell. In prior years virtually no weed appeared in the margins and consequently no preparations had been made to deal with this problem.

This provided the situation where bank anglers could not get their flies out beyond the blanket of weed. Even if they had been able to cast their flies out, having taken a fish it would have been impossible to retrieve it successfully. This resulted in a considerable loss of revenue from fishing, because the number of anglers coming to Draycote dropped off.

The whole of Draycote staff were mobilised (3 men), and using the only equipment immediately available, an onslaught on the weed was carried out. Using chain drag lines, a Land Rover and a tractor, in six weeks some 600 tons of weed were bodily dragged from areas along the natural bank. It is interesting to note that on occasions, both the Land Rover and tractor could not cope with the weight of weed in one single sweep. This is the sort of problem that can occur without warning. It is very expensive on labour and on fuel. In an area such as Draycote Water manual control is probably the least effective method. Subsequently a purpose-built weed cutting boat was pnrchased at a cost of nearly £5,000. This method is very effective but with all methods of manual or mechanical cutting of aquatic weed a second operation is necessary. The weed must be removed either from the water or from the verges. This operation is labour intensive except when a rake can be attached to the weed cutting boat. Then one man can carry out both operations.

Herbicide experience In 1974 an experimental area was set aside for chemical treatment of the weed. Two aquatic herbicides were used, one liquid and one granular, but neither was successful. This was due to the heavy growth in the areas treated. In the case of the granular formation it is probable that the heavy growth did not allow the particles to penetrate the mass of weed, and so attack the root growth, which is essential in this type of herbicide. However a further area was treated at a later date and this proved entirely successful.

Subsequently in 1975 it was decided to treat the whole of the margins of the natural bank with Casoron G S R dichlobenil 22.5%. The water level was expected to drop during the summer to expose a band approximately 9 metres wide. It was decided not to treat this area and the herbicide was therefore applied in a band between 9 and 27 metres from the spring top water level at the recommended dose. This proved to be entirely successful in that, for most of the season little weed appeared except in small scattered areas, which were cut by the mechanical weed cutter.

An estimate of the cost of this treatment is given below, based on 1973/74 prices:

Time to spread early April

Per ½ ha (1 acre) at 2m depth (6 ft)	£126
Say 6 ha (12 acres) at £126	£1512
Cost of spreading £10 per ½ ha	£120
Total	£1758

A mechanical or electric spreader was lent by the company supplying the herbicide and the whole operation was supervised by a member of the supplier.

EDUCATION OF THE PUBLIC

All too often the use of herbicide is, to the extremist and to the uneducated members of the public, synonymous with the destruction of all forms of life including weed, bird, fish and insects and any other living thing which has the misfortune to live within the treated area. This is of course is nonsense, if this were so no herbicide would ever obtain clearance. The more enlightened naturalist is rightly concerned that the use of herbicides disrupts the environment as little as possible and for this reason the use of all aquatic herbicides which have been cleared through the Pesticides Safety Precautions Scheme is subject to a code of practice, published by the ministry, and available free of charge from the Ministry of Agriculture, Fisheries & Food (1967) Pesticides Branch, and this should be read before chemical treatment of any water is carried out.

DISCUSSION ON SESSION 1

Dr. J.M. Hellawell asked whether some plants, e.g. Lemna species should be encouraged since, while not interfering with flow, they might reduce the growth of other plants? Mr. Robson agreed but said that Lemna is not a good example because it is easily windblown. It was also pointed out by Mr. N.F. Low that it might interfere with fishing interests.

The role of aquatic plants as a primary food source was discussed and Mr. N.O. Crossland said that most invertebrates are detritus feeders. Mr. Robson said that much of the detritus comes from outside the water. Mr. C. Newbold did not agree about the importance of detritus as opposed to living aquatic plants and Mr. D.F. Westlake was not certain that detritus from outside the water contributed much as a food source. Mr. Newbold said that macrophytes provide a habitat for many invertebrates and also help to prevent algae from becoming dominant. Mr. Robson pointed out that in his experiments the removal of plants by herbicide did not appear to have harmed the fish populations.

The chairman asked if fertilizers leaching into the water were destroying the balance previously maintained by hand cutting. It was agreed that there was no evidence on this due to lack of experimental work but Mr. T.G. Cave said that in his experience there was a considerable increase in the filamentous algae but he was not sure how much the vascular plants had increased. Mr. Newman said that I.C.I. had collected figures for levels of nutrients in rivers from water authorities in England and Wales. The use of nitrogen fertilizer had doubled in each ten years in recent years but there was no evidence of direct run-off of soluble fertilizers. Mr. J.B. Shearer described the channels in the Witham 4th IDB and explained that large water courses could be cut by boat while the smaller ones were more difficult because of the problems of access. The banks he treated with maleic hydrazide in the spring and flail mowers in the autumn. In his area of 100,000 acres he spent £50,000 on weed control of which £8,000 was on chemicals. He felt that hand roding was the cheapest method for small ditches, but he would need 25 - 30 men to maintain his area (weed control) and these men would need to be paid and employed for the whole year, which ruled out the feasibility of complete hand roding.

Mr. Riddington commented on the difficulty of obtaining labour. Mr. Miles agreed that the idea of using maleic hydrazide in the spring and mowing in the autumn was a good one.

Mr. Newbold asked Mr. Shearer for more details of his costings. Mr. Shearer said that as a general rule he considered that hand-roding of small water courses cost about £1.80 - £2.00 per 100 m. (waterway weed only) but it had to be done twice a year which gave a total of about £3.60 to £4.00 per 100 m., whereas chemicals cost about £4.90 per 100 m. (including the cost of hand trimming where this was necessary).

Mr. Cave considered that although comparisons could be misleading his costs were twice those of Mr. Shearer. Hand cutting cost about £5.00 per 100 m. whereas a single application of herbicide which lasted all season only cost about £2.00 per 100 m.

Dr. J.B. Leeming asked if the continued use of copper sulphate by Mr. Miles had caused problems where water was abstracted for irrigation and whether any long term studies had been carried out into the ecological effect of herbicides in the Fenland drains. Mr. Westlake commented that the extensive use of copper sulphate can lead to a build-up of precipitated copper on the bottom but Mr. Miles said that since most ditches were dredged about every 7 years there should be no problem.

Mr. N.O. Crossland asked if local farmers objected to providing access and to the use of herbicides in ditches but Mr. Miles said that farmers realised the need for weed control and they did not usually object.

The problem of the disposal of cut weed removed from ditches was raised by Mr. D.R.H. Price but Mr. Miles explained that it usually rots away quickly and was not therefore a serious problem after removal.

The use of weed cutting buckets was discussed by Mr. R.W. Noakes who said they were easily damaged and that sludging buckets were an alternative although they tend to increase the depth of the ditch.

Mr. A.C.R. Pratt asked Mr. Miles if he would prefer to use copper sulphate or one of the recently cleared algicides. Mr. Miles replied that $CuSO_4$ had always worked well in his experience but since the chemical was not cleared and there was a zero safety factor he was now using terbutryne.

Mr. M.J. van den Heuvel said that if problems of deoxygenation were to be avoided herbicides should be used as a prophylactic treatment. Mr. Miles agreed saying that he would not consider using a herbicide in a ditch full of weeds. The ditch should be treated just as growth starts. Mr. Robson confirmed that herbicides should be applied as early as possible in the growing season.

Mr. V.E. Tomlins described weed control in British canals which are now mainly used for angling, pleasure craft, storm drainage, industrial and irrigation use, and latterly abstraction for potable supplies.

It follows, therefore, that chemical control of aquatic growth has to be selective and closely monitored in effect irrespective of approval from the appropriate Water Authority. Any material used in British Waterways Board's waters has to be non-toxic to human, animal and fish life, and the fish food chain.

The basic requirement for all canals is that there shall be a clear navigational channel, this allows free water movement and covers the requirements of all users; fringe growth is acceptable and is encouraged to provide cover and food for fish. Apart from mechanical methods, which are not always appropriate, nor able to be used to provide such a channel, they had over the past 16 years applied various chemicals with quite reasonable success.

They started with diquat (Aquacide) and were so successful with the first treatment on the Bentley canal in the Midlands that the before and after photographs were reproduced in the manufacturer's brochure. This material is still used at the reccommended rate of 2 gal/acre/ft. as required, and quite often as a spray to control Lemna spp at 6 litres/ha.

For rooted aquatic growth however, dichlobenil (Casoron) has been preferred since the spring of 1971, and this treatment as a granule at the rate of 1 ppm has proved to be effective for such growth and has had no adverse side effects apart from the normal oxygen loss common to such treatment. For this reason, all chemical treatments for aquatic control are carried out early in the season (March/April) to avoid the later more prolific growth. Apart from one early exercise on mixed growth including a large proportion of filamentous algae, all treatments have been very satisfactory; so much so that this material is the standard recommendation for rooted growth in canals.

The greatest nuisance in canal waters is filamentous algae and no satisfactory results had been obtained in the attempts to obtain control until the spring of 1975 when several application of terbutryne (Clarosan) were made at 0.1 ppm and 0.05 ppm.

The applications at 0.1 ppm were most successful, and no adverse effects were apparent at either rate except for one occasion, at the 0.05 ppm rate when a rather disturbing oxygen loss from 85% to 28% was experienced within the first 24 hours. Recovery took 9 days but there were no cases of fish mortality in quite heavily stocked water. The slow release claims for this granular material do not appear to be fully justified, but the material does a good job.

One test application of cyanatryn (Aqualin) was made in a private (enclosed) trout water at 0.2 ppm in July 1975, which proved to be most effective and caused no distress to the fish. It is claimed that this material does not affect irrigation - which was a distinct advantage. It seems that the slow release claim here has been upheld and it is commended to the Water Authorities.

It has been very difficult to obtain approval from some Water Authorities for the use of aquatic control chemicals, particularly the more recent and successful treatments of filamentous algae; but also for some of the more well-known materials such as diquat.

Hopefully 1976 will produce more experience in the use of what are the most useful tools yet provided and perhaps a slightly less adamant attitude from the water authorities.

Mr. Guiver asked if the water from Draycote reservoir was extracted directly for public supply and whether the dichlobenil had affected the quality. Cdr. Dunn replied that the water sometimes is released into the river but can also be abstracted directly. He thought that the dilution factor was so great that the herbicide had no measurable effect. Cdr. Dunn explained that the object of using herbicides was to provide good fishing and only a small area was treated. The area treated in 1975 could well be exposed in 1976 if there was a large demand for water, in which case it would be difficult to assess if there were any long term effects of the use of herbicide.

Mr. Spencer-Jones giving data on the toxicity of dichlobenil explained that its toxicity was about the same as common salt and there should, therefore, be no danger to anyone drinking treated water.

The discussion closed with a comment from the chairman, Mr. Riddington, that there may be a need to educate the public about the benefits as well as the risks involved with the use of aquatic herbicides.