Formulating Aquatic Weed Management Programs

DAVID S. MITCHELL

Principal Research Scientist
CSIRO Division of Irrigation Research,
Griffith, NSW 2680, Australia.

ABSTRACT

The management of aquatic weed problems is becoming increasingly expensive and more complex as the multi-purpose use of water resources becomes more manifest. Consequently there is now a need for formal procedures to assist in the formulation of appropriate, flexible weed management programs and to make it possible to select logically between alternative candidate systems. The procedure for cost-effectiveness analysis, which incorporates both quantifiable and non-quantifiable factors, is described with reference to water weed problems. This analysis is well-suited to aquatic situations, although a simplified cost-benefit analysis which is also outlined could be useful.

INTRODUCTION

Aquatic weed problems typically have four stages: problem identification and assessment, control selection, control implementation, and long-term management (3, 9). A field assessment form which can be used in the first stage has been suggested (5). This paper outlines procedures that should be considered in the selection of a control program (second stage). This stage can be subdivided into two parts: the evaluation of alternative control strategies; and the formulation of an appropriate program of control, which takes account of the uses of the infested water body and which has the flexibility to adapt to changing circumstances brought about by changes in water use and the availability of new control techniques (4). As multi-purpose use of water resources becomes more widespread the number of alternative control techniques increases, control programs become more expensive, and decisions involved in formulating a management program become more complex. Systematic procedures are now required for these situations to assist in choosing between alternatives with regard to the intended use of the water resource.

COST-BENEFIT ANALYSIS

One approach is to conduct a simplified cost-benefit analysis of the presence of the weed and of the various methods of handling the problem. A list of the factors which would normally require evaluation are outlined in Table 1.

Cost-benefit analyses are often difficult to apply to large water resources such as an entire river system and yet, once a weed has infested a part of a river, it is potentially able to invade other sections of the same system. In these situations, it may be more practicable to conduct two analyses: one for the whole system; and one for a particular specified locality where the problem is currently manifested.

TABLE 1. BENEFITS AND COSTS OF WATER INFESTATIONS AND THEIR TREATMENT.

Evaluation components	Purposes of Water			Total value
	1.	2.	3.	
Annual value				
Economic loss caused by present infestation				
Potential loss if all available weed habitat occupied				
Economic benefit of weed: present infestation total possible infestation 50% present infestation				
Cost of control (Method A) Capital Annual recurrent				
Cost of control (Method B) Capital Annual recurrent				
Immediate benefit of: Complete control 50% control Other specified level of control[1].				
Potential benefit of complete control (i.e. related to potential maximum loss)				

[1] There may be another level of control which would be more appropriate for specific situations than either complete control or 50% control.

A simple cost-benefit analysis such as proposed here makes it possible to assess the economic consequences of alternative forms of treatment including that of applying no control measure and allowing the weed to spread to occupy all the available habitat. Its major disadvantage is the need to evaluate all the factors in commensurate monetry units and this is difficult for any ecological and aesthetic benefits or detriments the weed or water resource may have. It is also difficult to estimate, in financial terms, the adverse effects that may be experienced as a result of the application of control measures.

COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis is a systematic method of selecting between alternatives by rational evaluation and comparison of the costs and the effectiveness of each (1, 6). Comparisons between costs (which, in addition to financial costs, include environmental, social and other costs) and effectiveness to meet objectives in terms of specified criteria make it possible to select an optimum course of action. The

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principles underlying the technique seem to be particularly germane to situations where a choice has to be made between different management procedures which will have both financial and environmental costs.

The characteristics of cost-effectiveness analysis which would seem to be applicable to decisions involved in formulating water weed management programs are: 1. objectives are carefully formulated and unambiguously stated, 2. both non-quantifiable and quantifiable factors are taken into account, 3. judgments based on experience are employed in the analysis, 4. alternative courses of action are explicitly evaluated, 5. selection of alternatives is based on either fixed costs (the most efficient use of limited or precious resources) or fixed effectiveness (the least costly method of achieving an essential degree of effectiveness), 6. all the factors required to reach a sound decision are objectively displayed for the decision maker.

The suggested procedure outlined in the following paragraphs takes account of these principles and is based on the standardised approach suggested by Kazanowski (2).

Define Objectives of the Management Program. A clear statement of objectives in order of priority is an essential requirement for the formulation of an appropriate weed management program.

Specify Requirements to Achieve Objectives. This step in the procedure often depends on experience and, where this is absent, small-scale pilot experiments may have to be conducted. For example, to meet the objective that a certain volume of water flow along an irrigation canal, it may be necessary to eliminate plant growth to an extent which has to be determined. Furthermore, care has to be taken not to specify requirements which may eliminate the possibility of considering potentially useful alternatives. Thus, in the above example, the requirement that all plant growth be eliminated would exclude the possibility of replacing the weed with a turf of small aquatic plants which would not impede water flow to an undesirable extent and which at the same time would prevent the invasion of troublesome species and bind the bottom sediment.

Formulate Alternative Methods of Meeting Objectives. In the past, alternative methods of weed control have been seen as largely exclusive but recent experience has shown that different methods can be integrated to form very successful management programs (7). All practicable alternatives should be considered, including that of taking no action and allowing the weed growth to reach a maximum.

State Criteria for Evaluating Effectiveness of Program. Depending on the pattern of water use, criteria which could be desirable in an analysis of effectiveness against a waterweed problem are: quantity of weed removed, rate of weed removal, financial cost (both capital and recurrent), environmental effects, etc.

Decide between Fixed Cost or Fixed Effectiveness. A fixed effectiveness approach is likely to be best for most aquatic weed problems, since it is often difficult to be precise about environmental costs, whereas measures of effectiveness can usually be made specific. Also there would be no point in incurring any costs at all, if a particular degree of effectiveness cannot be achieved.

Determine and Tabulate Capabilities of each Alternative

in Terms of Evaluation Criteria. The capabilities and effects of each alternative system must be expressed in terms of the criteria. Whenever possible this should be done quantitatively.

In fixed effectiveness analysis, overall cost to financial and other resources will be the main basis for selecting between alternatives and the components by which this is made up are best displayed for the decision maker in tabular form as not all the costs will be quantifiable. Comparison of quantifiable and non-quantifiable measures of effectiveness can then be facilitated by ranking the performance of the alternative systems against each criterion independently. However certain cost criteria will be more important (more expensive) than others and it is therefore necessary to list them in order of priority.

Since the alternative systems will differ in their effectiveness as well as their cost, it is also necessary to display these differences in the table and, as before, this is facilitated by ranking the alternatives against separate criteria of effectiveness, which again should be listed in order of importance.

A hypothetical example of the type of table that is envisaged is given in Table 2 (the rankings in the table are purely speculative but are immaterial to its present purpose). In this case, a single criterion of effectiveness has been specified and listed first as it is the most important criterion overall and there are real differences between the alternative treatments in terms of their effectiveness. In other situations, where there is little difference in effectiveness of alternative systems, it would be more sensible to list cost criteria first. The alternatives have been displayed in the order in which they are able to satisfy the most important criteria. This should make it possible to eliminate some of the alternatives (in this case that of no treatment) and limit further analysis to two or three possibilities.

TABLE 2. RANKING OF ALTERNATIVES AGAINST CRITERIA IN THE COST-EFFECTIVENESS EVALUATION OF A WATER WEED PROBLEM.
Hypothetical example:
pondweed (*Potamogeton* sp.) in an irrigation canal

System criteria (in order of importance)	Herbicide application	Mechanical harvesting by dragline	Periodic canal drainage	No treatment
1. *Effectiveness*				
Elimination of weed	1	2	3	4
2. *Cost*				
Interference with use of water for:				
irrigation	2	1	3	4
domestic consumption	3	1	4	2
Capital cost	3	4	2	1
Recurrent cost	4	3	2	1
Need for treatment repetition	2	4	3	1
Environmental impact	4	3	2	1

The advantage of tabulating the data in this way is that the decision maker is able to see at one time all the relevant factors affecting his decision. However there is a strong tendency to read more into the rankings than is justified. The temptation to add the figures for each alternative and thus compute the most suitable must be resisted, as it does

not take account of the differential values between criteria. The possibility of overcoming this by weighting criteria has been discussed by Kazanowski (2) and an objective way of doing so by paired comparisons has been suggested by Drobny, Oasim & Valentine (1). The danger in this approach is that the assumptions underlying the assessments are concealed in an array of figures. A safer course of action may be to avoid the use of rankings and to specify quantitative data in the table and document non-quantifiable factors separately. However this is likely to bias the value given to the quantitative data and, in general, the approach described above would appear to be preferable, provided it is used sensibly and carefully.

Analyse Advantages and Disadvantages of each Alternative. The arrangement of alternative weed management programs in order of their capability to satisfy the most important criteria facilitates selection of the best system. The basis of selection must be explained in a written statement, accompanying the table for the benefit of the ultimate decision maker.

Carry Out Sensitivity Analysis. A cost-effectiveness analysis is often very sensitive to assumptions made in the course of the analysis. This has to be determined by modifying the initial assumptions and establishing the effect this has on the analysis. For example it may have been assumed that a weed removed by a herbicide will not be replaced by another problem plant which could be more difficult to control. If the analysis is shown to be very sensitive to such assumptions then, either sound justification for the assumption should be developed, or the sensitivity of the results to the assumption should be clearly indicated.

Documentation of Basis for Analysis. Detailed documentation of the whole process of analysis is essential for a clear understanding of the bases and limitations of the con-
clusions reached. The task of the analyst is to communicate lucidly and concisely the results of his knowledge, experience, and judgment in understanding the multidimensional interrelationships between objectives, criteria and alternative systems.

SUMMARY

Cost-effectiveness analysis provides a framework for a systematic evaluation of both quantifiable and non-quantifiable data which are relevant for the management of aquatic weed problems. The bases underlying decisions are immediately apparent, if modifications to the program are required to meet changing circumstances. For these reasons, it is suggested that this approach merits trial when expensive control measures are called for in complex situations.

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