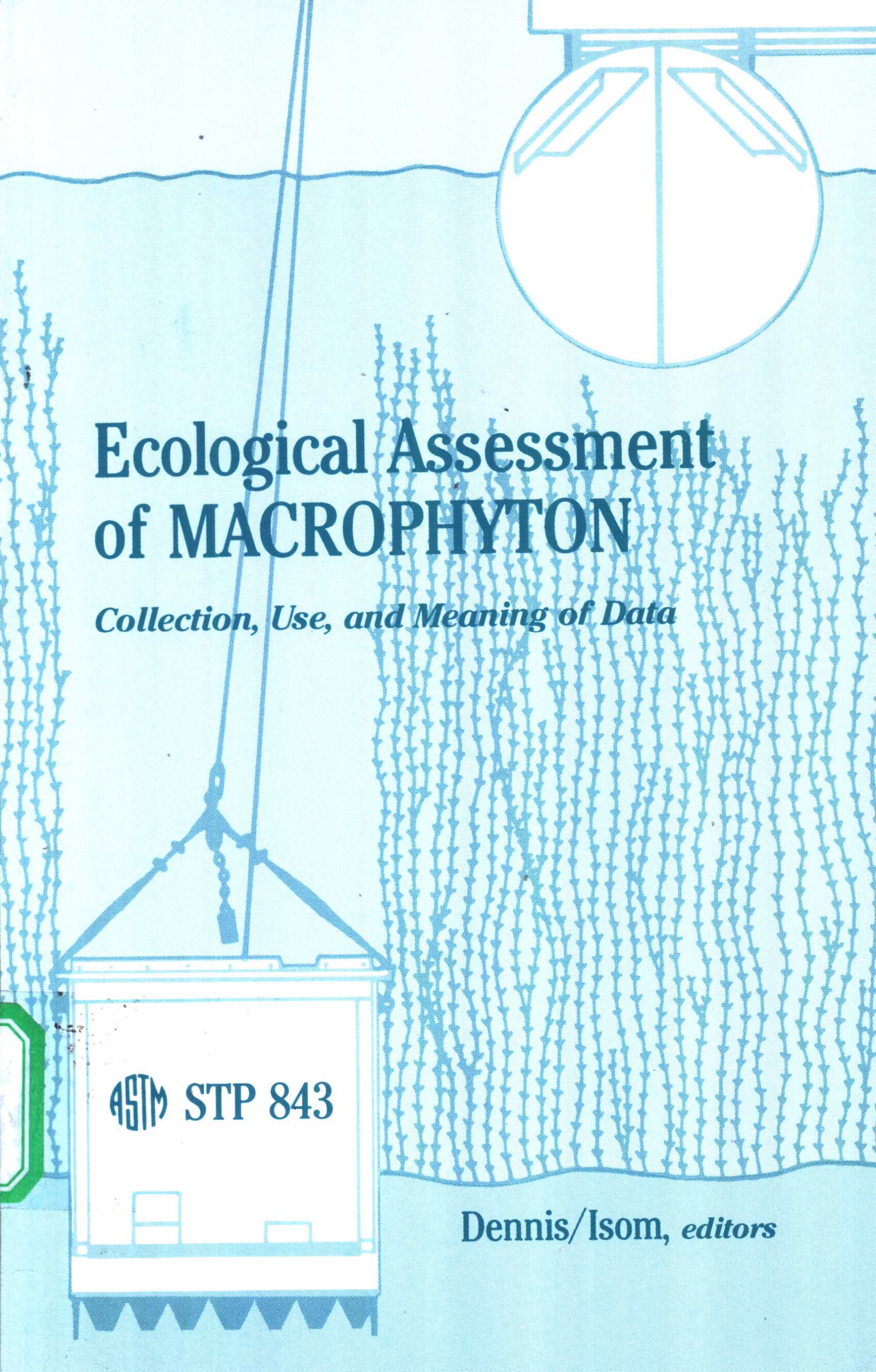

Ecological Assessment of MACROPHYTON

Collection, Use, and Meaning of Data

ASTM STP 843

Dennis/Isom, *editors*

ECOLOGICAL ASSESSMENT OF MACROPHYTON: COLLECTION, USE, AND MEANING OF DATA

A symposium sponsored by
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Fort Lauderdale, FL
15–16 Jan. 1983

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Foreword

The symposium Ecological Assessment of Macrophyton: Collection, Use, and Meaning of Data was presented at Fort Lauderdale, FL, 15–16 Jan. 1983. The symposium was sponsored by ASTM Committee D-19 on Water. W. Michael Dennis, Breedlove Associates, Inc., and Billy G. Isom, Tennessee Valley Authority, presided as chairmen of the symposium and editors of the publication.

Related ASTM Publications

Aquatic Toxicology and Hazard Assessment: Sixth Symposium, STP 802 (1983), 04-802000-16

Aquatic Toxicology and Hazard Assessment (Fifth Conference), STP 766 (1982), 04-766000-16

Ecological Assessments of Effluent Impacts on Communities of Indigenous Aquatic Organisms, STP 730 (1981), 04-730000-16

Native Aquatic Bacteria: Enumeration, Activity, and Ecology, STP 695 (1979), 04-695000-16

Methods and Measurements of Periphyton Communities: A Review, STP 690 (1978), 04-690000-16

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

ASTM Committee on Publications

Contents

Introduction

This volume deals with sampling populations of aquatic macrophytes. For those not familiar with the term, aquatic macrophytes (aquatic macrophyton) are an artificial grouping of taxonomically unrelated plants, sufficient in size to be seen with the unaided eye, which grow and reproduce primarily in aquatic habitats. It is a term of convenience and utility that includes the few aquatic lichens, macroscopic algae, bryophytes, ferns, fern allies, and angiosperms. This taxonomically diverse assemblage of plants also varies greatly in size and growth form. This diversity of size, form, and taxonomic affinity leads to problems in sampling design, accuracy, and precision. These problems are identified and explored in the following pages along with some proposed solutions.

The symposium that produced the papers presented here was an attempt to establish a baseline. In recent years much attention has been focused on aquatic macrophytes, both the beneficial functions they provide to aquatic systems and the problems they are more often causing in natural and artificial waterways. The need for methods that accurately and precisely describe and measure populations of aquatic macrophytes has become acute. Review of published literature reveals a lack of uniformity in methods. This lack of uniformity has led to results that are often not comparable, repeatable, or statistically valid. The symposium and these resulting papers was an attempt to gather workers experienced in dealing with these problems to establish a baseline or compilation of currently used methods with the hope of moving forward to modify, improve, and standardize methods for sampling aquatic macrophyte populations.

The papers presented accomplish the intended purpose of the symposium. General protocol for designing sampling programs are discussed. Traditional methods of sampling are presented. Statistical problems of adequacy of sampling are explored with special attention given to the solutions to the problem of high variance. Several mechanical sampling devices are described along with results of their efficiency. Finally, methods and utility of aerial photography in aquatic macrophyte sampling are presented. This compilation of state of the art methods and presentation of inherent problems and shortcomings will be a valuable aid to any scientists working with the description, quantification, or management of aquatic macrophytes.

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W. Michael Dennis[1]

Aquatic Macrophyton Sampling: An Overview

REFERENCE: Dennis, W. M., "**Aquatic Macrophyton Sampling: An Overview,**" *Ecological Assessment of Macrophyton: Collection, Use, and Meaning of Data, ASTM STP 843,* W. M. Dennis and B. G. Isom, Eds., American Society for Testing and Materials, 1984, pp. 2–6.

ABSTRACT: Aquatic macrophytes constitute an integral part of aquatic ecosystems, contributing to primary productivity, providing habitat for various organisms, and modulating water quality. Recent attention on the characterization and understanding of aquatic macrophyte communities within North America has primarily been the result of water-use problems caused by excessive infestations of "weedy" aquatic plant species.

Aquatic macrophyte communities have been sampled using such devices as oyster tongs and rakes, drag chains, various fixed-size quadrats, and complex hydraulically controlled pontoon-mounted mechanical biomass samplers. More recently, subsurface sampling techniques have evolved using scuba, and remote sensing techniques have been developed using various platforms from balloons to fixed-wing aircraft to satellites.

Sampling protocol for aquatic macrophyte studies should be designed to answer the specific question(s) at issue, applicable to the physical characteristics of the system, and able to provide reproducible results that allow comparison with other studies. The level of sampling detail is dictated by the complexity of the questions under consideration. Typical questions include what species are present, where, and in what amount. More complex questions may involve the functioning of aquatic macrophytes in nutrient and heavy metal uptake and turnover, their utilization as indicator organisms, and their effects on ambient water quality conditions.

KEY WORDS: aquatic plants, sampling, weeds, qualitative sampling, quantitative sampling, sampling strategies

Aquatic macrophyton (macrophyte) is a term of convenience that has gained popularity in recent years because of its utility. It has been defined variously, but in general, refers collectively to plants that customarily live and grow in aquatic habitats and are of sufficient size that their structural features can be discerned with the unaided eye. Use of the term, aquatic macrophyton, allows reference to a functionally related group of organisms that are not systematically closely related. Included as aquatic macrophyton are such diverse taxonomic entities as lichens, macroscopic algae, liverworts, mosses, and vascular plants. Macrophyton occupy various niches in many diverse habitats, for example,

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streams, ponds, lakes, rivers, canals, reservoirs, seas, and oceans and exhibit a variety of life forms that have led most investigators to classify them as floating, submersed, or emersed, based on habit. Macrophyton are significant components of aquatic ecosystems as they contribute to primary productivity, provide micro-habitat and macro-habitat for other aquatic organisms, modulate water quality through dissolved oxygen generation/depletion and nutrient uptake/cycling, and affect flow patterns and sediment deposition.

The most comprehensive works on aquatic macrophyton ecology, morphology, and function include Arbor's pioneer book *Water Plants* [*1*], Sculthorpe's extensive compilation and synthesis of the literature on *The Biology of Aquatic Vascular Plants* [2], Hutchinson's *A Treatise on Limnology, Volume III—Limnological Botany* [*3*], and Haslam's *River Plants* [*4*]. Taxonomic and floristic literature include *A Manual of Aquatic Vascular Plants of North Carolina with Habitat Data* [*5*], *Water Plants of the World* [*6*], *Aquatic and Wetland Plants of Southwestern United States* [7], *A Guide and Key to the Aquatic Plants of the Southeastern United States* [*8*], *A Manual of Aquatic Plants* [*9*], *Aquatic and Wetland Plants of Southeastern United States: Monocotyledons* [*10*], *Aquatic and Wetland Plants of Southeastern United States: Dicotyledons* [*11*], *A Flora of the Marshes of California* [*12*], and *Aquatic Plants of the United States* [*13*].

During the past 20 years, much attention has been focused on problems associated with excessive growths of aquatic macrophyton. Eurasian water milfoil (*Myriophyllum spicatum* L.), hydrilla (*Hydrilla verticillata* [L.f.] Caspary), and various species of naiad (*Najas* spp.) have joined water hyacinth (*Eichhornia crassipes* [Mart.] Solms) in being particularly noxious pest species. This increased interest in aquatic plant pests in particular and all aquatic macrophyton in general has brought about the need for more precise and accurate methods for sampling aquatic macrophyton. These efforts have been complicated and, to an extent, thwarted by the problems associated with sampling such a diverse group of organisms that vary so greatly in life form and environmental preference. For example, watermeal (*Wolffia* spp.) is approximately the size of a pinhead and grows floating on the water surface, while American lotus (*Nelumbo lutea* [Willd.] Pers.) has leaves to 60 cm wide and grows rooted in water 2 m deep. Other aquatic macrophyton, such as riverweed (*Podostemum ceratophyllum* Michx.), grow firmly attached by "hold-fasts" to rocky substrates of fast-flowing rivers; milfoils and hydrilla grow rooted and submersed in rivers, canals, lakes, and reservoirs in such quantities as to impede navigation.

The protocols that have been devised for sampling aquatic macrophyton have varied greatly in design and sophistication. Aquatic macrophyton have been sampled using such devices as oyster tongs and rakes, drag chains, various fixed-size quadrats, line intercepts, and complex hydraulically controlled pontoon-mounted mechanical biomass samplers. More recently, subsurface sampling techniques have evolved using scuba, (self-contained underwater breathing apparatus), and remote sensing techniques have been developed using various platforms from balloons to fixed-wing aircraft to satellites.

Sampling design has been as varied as the devices used in obtaining the samples. Peculiarities of the physical environment, diversity of reasons for conducting studies, and limitations of time and fiscal resources have led to extreme variation in sampling techniques and design; thus, the results produced, in many instances, cannot be appropriately treated statistically and are often not comparable with other studies.

Sampling Protocols

In developing a protocol for sampling aquatic macrophyton, the following considerations should be addressed.

1. What question(s) are being asked? That is, why is the sampling being conducted?
2. What are the environmental conditions of the area being sampled?
3. What are the life and growth form characteristics of the species being sampled?
4. How should the study be designed to allow for statistical treatment of the data and comparison to other studies?

Question One

The investigator may simply want to know what species are present in a particular water body. This is accomplished through a reconnaissance-level survey. Dominant species and their locations within the water body are noted along with general characteristics of the habitat. Reconnaissance may be conducted using aircraft, aerial photography, surface survey, or underwater survey using scuba. Intensive recurring reconnaissance surveys conducted over the entire growing season or several years should yield a complete listing of species present within a water body. This complete listing constitutes a floristic inventory for the water body under study.

A next level of inquiry would provide data on how regularly individual species occur, in what species assemblages they occur, and how these assemblages are structured. Qualitative vegetation analyses can be used to answer such questions. Plot or plotless sampling can be established to determine presence/absence for each species occurring within the water body under study. Visual estimates are also made of percent areal cover of the designated sampling unit.

A further, more detailed level of inquiry requires quantification of the amount of aquatic macrophyton present at a place and point in time. This typically requires population estimates through determination of standing crop or biomass, which can be converted into productivity estimates. Recently, more realistic estimates of productivity have been calculated using productivity models such as those developed by Fisher and Carpenter [*14*]. These models use biomass as a basis for determining productivity but also consider such factors as mortality before and after peak biomass. Other methods for determining productivity involve using oxygen generation and carbon-14 fixation.

Other more complex questions such as nutrient cycling and heavy metal uptake require utilization of a combination of these methods and other special techniques such as tissue analysis and controlled chamber studies.

Question Two

Water body type, substrate, and geographic location all affect development of a sampling protocol. Fast-flowing rivers, small streams, large reservoirs, lakes, and oceans all require special modification of sampling protocol. The mere problem of remaining stationary on the bottom of the fast-flowing river to take a bottom quadrat sample illustrates how different it can be to sample a river as opposed to a lake or reservoir. Sampling methods designed for clear lake systems that rely on unhampered visibility are useless in highly turbid rivers or reservoirs.

Substrates vary among water body types and often within the same water body. For example, substrates typically vary between pool and riffle habitats within a river; they may vary from predominantly sand, clay, rock, or cobble within a water body. This variation in substrate type often dictates either different species assemblages or different growth patterns of the same species.

Question Three

Growth habit must be considered, that is, floating, submersed, emersed. Wind can move extensive mats of duckweed or water hyacinth from one shoreline to another. A station that was completely choked one day may be completely free of macrophyton the next. Position of the plant within the water column is significant in sampling. Seldom do aquatic plants grow directly up through the water column at 90° angles. The floating leaves of a pondweed sampled from a 0.1-m^2 quadrat placed on the substrate may be 1 m removed from the quadrat.

The growth pattern of the species being sampled must also be considered, as growth patterns may vary according to geographic location, that is, latitude. Eurasian water milfoil and sago pondweed (*Potamogeton pectinatus* L.) exhibit standard single peak biomass curves in the more northern latitudes of Canada and the adjacent tier of the United States. However, in the southern United States, these same species exhibit a bimodal biomass curve with peaks in June and August [*15*].

Question Four

The fourth consideration in developing a sampling protocol is how to make the study amenable to statistical treatment and comparable to other studies. Time and money are always limited in any study. The single method most utilized to reduce the number of samples required to meet acceptable variance limits is the stratified random design. This increases the homogeneity of the sample, which reduces the variance. The investigator should be cautioned, however, that populations of aquatic macrophyton are by nature highly variable, and, whereas variance in sampling should be reduced where possible, the variance may be an accurate reflection of the natural system. Utilization of accepted methods, such as line, belt, and quadrat sampling, along with detailed documentation of the methods used and the environmental conditions under which the sampling was performed, will provide a basis for comparison of data from different studies.

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Stanley A. Nichols[1]

Quantitative Methods for Assessing Macrophyte Vegetation

REFERENCE: Nichols, S. A., "**Quantitative Methods for Assessing Macrophyte Vegetation,**" *Ecological Assessment of Macrophyton: Collection, Use, and Meaning of Data, ASTM STP 843*, W. M. Dennis and B. G. Isom, Eds., American Society for Testing and Materials, 1984, pp. 7–15.

ABSTRACT: Terms commonly used by terrestrial plant ecologists and applicable to the aquatic situation are defined in this paper. These terms include: quantitative and vegetation; the vegetation descriptors—frequency, density, and dominance; regular and random sampling patterns; and areal and arealess survey methods. Sampling strategies for planning an efficient sampling program are also discussed. The purpose of the sample, equipment, logistics, and costs are all important design considerations as are sample size and confidence. A strong case is made for an optimally allocated, stratified random sampling system, and practical sampling considerations are included.

KEY WORDS: aquatic plants, terminology, sampling and stratification, quantitative vegetation description, sampling strategies, stratified random sample

Any sampling effort should collect the best data, for the needed purpose, most efficiently. To date, the tools for sampling and describing macrophyton have not been standardized and are not readily available in the methods manuals commonly used by aquatic scientists. There are at least three reasons for this void:

1. The techniques involved in conducting aquatic plant surveys are techniques used by terrestrial plant ecologists, a subject with which aquatic biologists may not be familiar.
2. Most recent research has been directed at measuring the productivity or other ecophysiologic parameters of aquatic plants, not at describing aquatic vegetation.
3. Often the only interest in aquatic plants is to extirpate them.

However, the standardization of techniques and terminology becomes more important as more persons become involved in aquatic resource management.

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Federal agencies (such as the U.S. Environmental Protection Agency, U.S. Forest Service, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Bureau of Reclamation, and Tennessee Valley Authority), state agencies (such as departments of natural resources or natural history surveys), university scientists, and private consultants all do aquatic plant surveys. The uses of the information provided by a good plant survey for management purposes, for scientific purposes, and for educational purposes are too important to be rendered useless by shoddy or nonstandardized techniques. Cost, alone, is an important argument for collecting data of lasting value.

This paper defines a variety of terms applicable to the aquatic situation that are commonly used by terrestrial plant ecologists. It also discusses sampling strategies, based on statistics and experience, which will increase sampling efficiency.

Definition of Terms

The first two terms that should be defined are quantitative and vegetation. A quantitative survey is one that gathers numerical data in such a standardized and unbiased manner that it is repeatable by different observers. The value of such a survey is that it forms a standard base of reference. A vegetation study implies that not only are the kinds of plants identified (that is, flora) but also that there is an indication of their individual importance or influence in the plant community.

The common practice used in many aquatic plant surveys of assigning an abundance value to a plant species based on a visual estimate is considered a qualitative survey. Even though a numerical value is assigned that may accurately reflect the abundance of the species, the technique is not repeatable by different observers, and the bias in the system is not known. If the observer is experienced, the technique can provide a good floral description of the water body, but as a means of quantitatively describing vegetation, the technique is not adequate.

There are a number of terms that are used to quantitatively describe vegetation. Frequency is the probability of finding a plant at a given location. Density is the number of plants per unit area. Dominance describes the influence of the plant on the community. It is usually reported as biomass (weight per unit area), cover (either as an absolute area or percentage of the area studied), or productivity (change in biomass over time). Often the data are relativized so that one species can be more directly compared to another.

Ecologists have not decided which indicators are the best representation of the importance of a plant in a community. For instance, a plant like *Najas flexilis* may be frequent and dense, but it is small of stature so its biomass is not great. To surmount this problem, ecologists have developed synthetic indices, sometimes called importance values, which average, for instance, relative frequency and relative biomass.

Regular and random are the two sampling patterns commonly used in vegetation surveys. The sampling units of a regular sample are distributed evenly throughout the population so there is thorough coverage of the area. A grid would be an example of a regular sampling pattern. The regular pattern may have great utility for mapping vegetation, but for most cases a random sample, where each sampling unit has an equal and independent chance of being selected, is better because statistical analyses can be applied to the results.

A third pattern, haphazard, is all too common. Throwing a hoop over the left shoulder to determine sample location is an example of haphazard sample selection. There may be no conscious bias in selecting a sample in this manner, but the random selection where there is consciously no bias applied to sample choice is a much better alternative.

Quantitative surveys fall into two general types—arealess and areal. An arealess sample is nondimensional or unidimensional. In other words, arealess sampling units are located at a point or along a line. Line intercepts are the most common arealess method used for macrophyte surveys. The presence or absence of a species is a type of data that can be gathered by arealess techniques.

Using areal methods, a sample is gathered from a two-dimensional location. The sampling unit is termed a quadrat. Quadrats have traditionally been square, rectangular, or circular in shape. Presence-absence, density, and biomass data can be gathered using quadrats.

For those readers unfamiliar with the terminology, Refs *1* and *2* review sampling techniques and vegetation attributes including their mathematical descriptions. Other studies provide examples of plant surveys using line intercept methods [*3–5*] and quadrat sampling techniques [*6*].

Sampling Strategies

Planning for an efficient sampling program may be the most important, but often the most overlooked, step in the sampling process. A system based on statistics and good sense should prevail.

Purpose of Sample

A primary consideration is the purpose of the sample. Is it to describe the aquatic vegetation of a state or region? Is it to determine habitat factors that control the distribution of a single species in a single water body? Is it to determine the productivity of a common plant species? The information needed to answer each question is different as are the cost, logistics, and time involved in collecting the data.

Let us assume in the first case that a description of the aquatic vegetation of a state is needed. Some considerations for selecting a technique would be: one that is rapid so that little time need be spent on any one water body; one that is not greatly influenced by the growth pattern of the plants so that a longer sampling season can be used; one where the equipment is mobile, rugged, and easily repaired so that a sampling crew is not stranded with unworkable equipment;