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Proceedings: Third Wetlands Conference

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PROCEEDINGS: THIRD WETLANDS CONFERENCE

Held on June 14, 1975 at Storrs, Connecticut

Report No. 26

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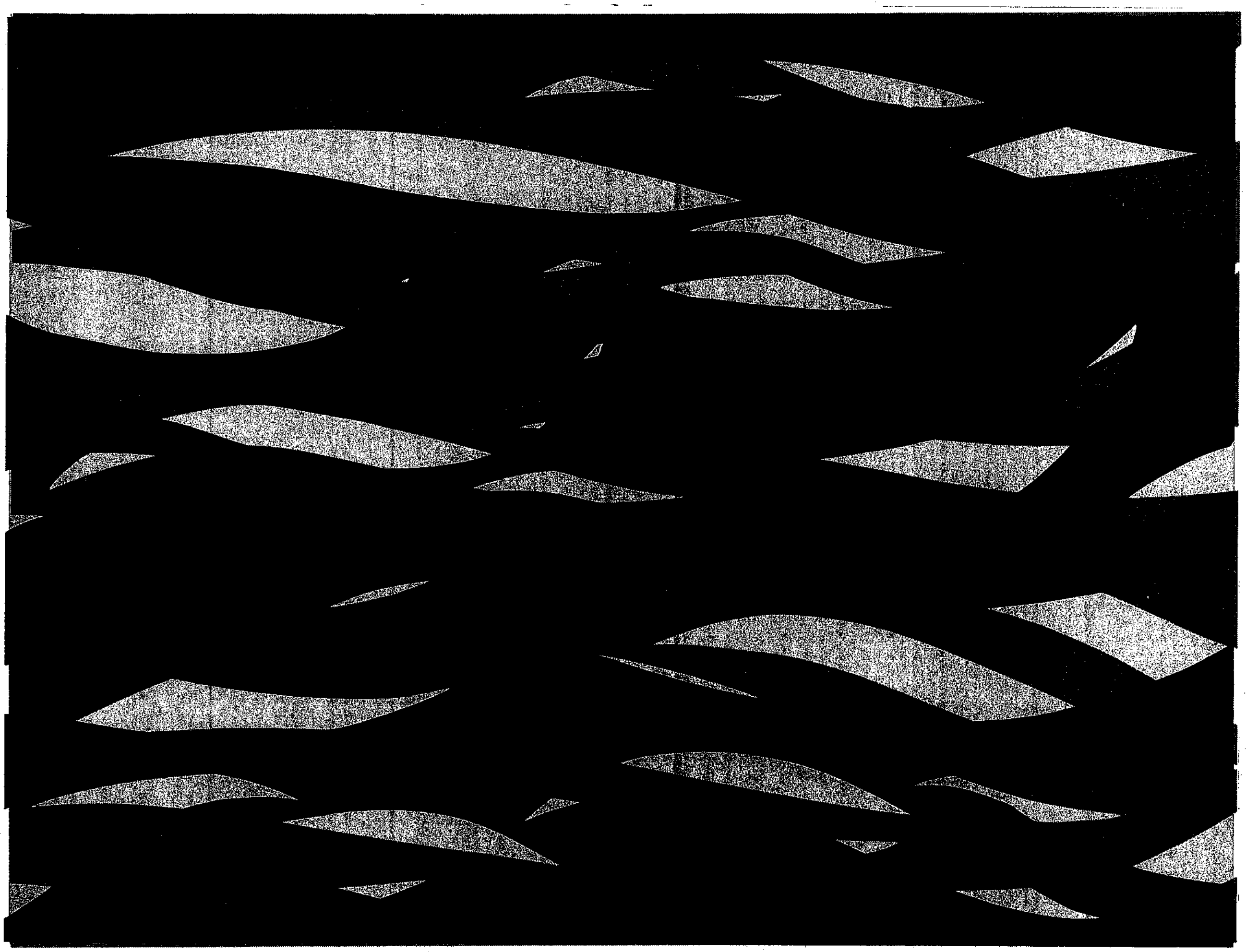

INSTITUTE OF WATER RESOURCES
The University of Connecticut

The University of Connecticut Institute of Water Resources
Report No. 26

PROCEEDINGS:

THIRD WETLANDS CONFERENCE

Held June 14, 1975
at the University of Connecticut,
Storrs.

M. W. Lefor, W. C. Kennard, & T. B. Helfgott,

Editors

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August, 1976

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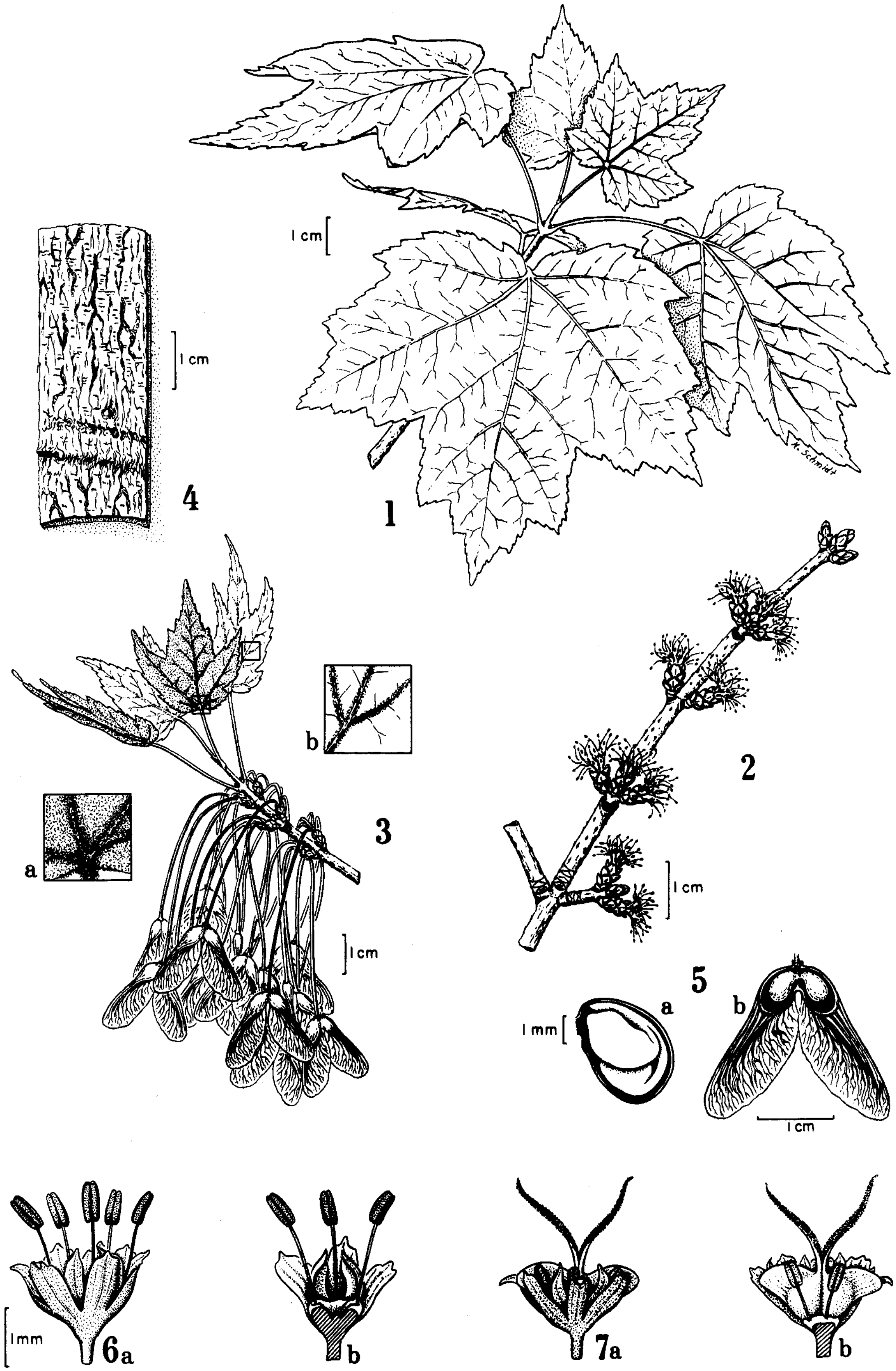
FRONTISPIECE

Acer rubrum L. (Red Maple), perhaps the most common wetland plant in Connecticut. 1. Mature leaves, and 4, bark, from *J. F. Collins s.n., May 27, 1908,* CONN; 2. flowering branch with male flowers, and 6a., b., male flowers from *G. S. Torrey s.n., Apr 6, 1911,* CONN; 3. fruiting branch; 3a. leaf lower surface; 3b. leaf upper surface, from life; 5a.,b. fruits from *G. S. Torry s.n., May 20, 1911,* CONN; 7a.,b. bisexual flowers from *Bazzolo 4A,* CONN. (Artist: K. Schmidt).



Acer rubrum L.

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DIRECTOR'S STATEMENT

This volume constitutes the third report of an unusual research effort which involved the ultimate user and decision-maker in the actual study. Unlike the usual approach to research where the scientist works in the laboratory or field and deals only with his colleagues, then later, often much later, attempts to reconstruct his findings into popular language, the investigations into the utility and delineation of inland wetlands in Connecticut have involved town officials and other non-scientists from the very start. As the Editors have noted in their introduction, a great deal of information was lacking on the structure and function of inland wetlands at the time the protective legislation was made into law. There was thus a great deal of catching-up to be done before the towns could make effective use of this legislation.

Because of this research and conference effort, everyone concerned with wetlands has gained greatly in a relatively short period of time. Those who have been the beneficiaries of the wide variety of seminars and workshops have come to appreciate these three volumes which constitute the record of this effort.

The Institute of Water Resources is pleased and very proud to be able to publish this third volume. It wishes to extend its most sincere thanks and congratulations to Drs. M. W. Lefor, W. C. Kennard and T. B. Helfgott for their outstanding contributions to this research work.

- Victor E. Scottron*

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INTRODUCTION

The papers presented in this volume are those presented at the Third Wetlands Conference sponsored by the University of Connecticut Institute of Water Resources, Dr. Victor E. Scottron, Director. The papers of the June 14, 1975 conference were assembled to complete a package of basic information on the wetlands of Connecticut and related systems of the northeastern United States. The editors feel that the three wetland conference volumes, those from June 1973 and January 1974, along with this one give substantial technical backing to the intents of the Connecticut Inland Wetlands and Watercourses Act. While the Tidal Wetlands Act of 1969 was written from an exhaustive background of scientific research on those important areas, a great deal of information was lacking on the structure and function of inland freshwater wetlands prior to the passage of the Inland Wetlands Act of 1971. Further research on both ecosystem types in needed, of course; but especially in the inland wetlands, where science has yet to know where to ask questions. One first question is that of definition: What *is* an inland wetland? The paper by Helfgott, Lefor, and Kennard examines this question. The contribution by Welsh *et al.* examines the system function of a wetland and points the way to the proper management of wetlands in community planning. The manipulation of wetland ecosystems for societal purposes such as waste treatment, a subject of great current interest in the ecological community, is examined in a lengthy paper by Richardson and others; unique characteristics of wetland metabolism and energy flow are outlined by Rich and Kowalczewski. Wildlife values of wetlands, such as those enumerated by Golet, can be ascribed to wetlands of various cover types, helping the ecosystem manager make better decisions; and Connecticut's most common type of wetland, the Red Maple swamp, reveals new potentials for forest management. The interactions of wetlands and man are discussed by E. W. Mood in his paper on wetland epidemiology, and Zwerling and Grupp in their comprehensive study. To provide for uniformity, a list of the equivalents of common and scientific names appears as an appendix.

The editors are grateful for the excellent aid and sponsorship provided by the Institute of Water Resources, Director Dr. V. E. Scottron and its Assistant Director, Ms. Frances de Lara; to the Department of Environmental Protection and its Commissioner, the Hon. Joseph N. Gill; and to the Water Resources Unit of the U.S. Geological Survey and the U.S.D.A. Soil Conservation Service. Special thanks are due S. Tunick, L. Kile, and T. Lopez for typing this manuscript, and to the Biological Sciences Group Illustration Staff for certain of the figures.

- M. W. Lefor, W. C. Kennard, & T. B. Helfgott,

Editors

INLAND WETLANDS DEFINITIONS

by

T. B. Helfgott*, M. W. Lefor**, and W. C. Kennard+

Introduction. This paper is a condensation of the results of an independent, yearlong investigation into the definitions of inland wetlands. The authors assembled a team of over 15 contributors, who along with a team of 30 students, prepared definitions of inland wetlands from the viewpoints of their specialized fields in individual research projects, in seminar, or in consultation. Areas of Botany, Zoology, Geology, Hydrology, Water Chemistry, Sociology, Political Science, Engineering, Law, Public Health, and Economics were represented. The authors undertook this exercise in intercommunication because of their concern over the ways in which natural systems often are defined by law. Inland wetlands in particular are a fundamental ecosystem, the importance and attributes of which are only lately being recognized; thus they are attractive for study.

The three steps in the administration and preservation of any natural ecosystem are *define*, *delineate*, and *regulate*. In order for a governmental unit to regulate an area, its location must be known; some sort of map must be prepared. In order to draw a map, it is necessary first to know what one is drawing a map *of*: one must have a *definition*.

The authors feel that any truly effective definition of a natural system must apply not only to the principal area, but also to as many adjoining natural systems as possible. We realize, however, that to accomplish this is impossible; but we felt that assembling a comprehensive definition of a natural system which included all viewpoints might come closest to that goal.

In meeting with researchers and students to discuss aspects of the definition problem, our first difficulty was one of communication; learning the specialized vocabularies of persons from many different fields in order to communicate effectively. To be sure, at least a part of our current environmental problems has been created by a lack of understanding among scientists, engineers, legislators, and administrators. This lack of understanding has generated many problems, *e.g.* why do engineers sometimes design

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and build roads through the centers of wetlands? Why do legislators write laws that administrators and political scientists find either unworkable or unacceptable to society? We found that what might be legal might not always be environmentally moral. Moreover, if technical jargon is simplified and honest questions are asked and honestly answered, then understanding follows.

This paper is organized according to the logic we followed in formulating its endpoint: an *idealized* comprehensive definitional statement for freshwater wetlands. The definitions of wetlands taken from individual fields (in italics and designated by Roman numerals) are considered one by one, and then the final definition is assembled. The final definition is called "idealized" because we know that to take it to practicality will require changes of detail to make it fit different regions as well as the requirements of the law. A definition in legal form for Connecticut follows as well; it does contain, however, scientific information and a realistic administrative approach so as to encompass all basic parameters of the wetland condition. The last definition presented is a proposal amendment to the Connecticut Inland Wetlands Act.

Definitions from Single Fields. It is a matter of public knowledge that inland wetlands have been abused. These ecological niches need preservation and protection, or at least, carefully regulated use. With recent popular recognition of the ecological values of these land and water resources, legislation has been enacted in many states throughout the country to protect these valuable areas. Yet technically weak definitions have appeared in the Law, thereby placing wetlands in further jeopardy. In Connecticut inland wetlands have been defined by statute* expediently to violate accepted dictionary definitions and theoretical understandings to some degree. The Law preceded Technology in this case, in contrast to legislation protecting tidal wetlands, founded on sound technical criteria. Nevertheless, as a stopgap measure the Connecticut Inland Wetlands Act has focused attention on the ongoing rapid destruction of wetlands by articulating the intent to preserve these segments of the environment. The present law has thereby provided the time necessary for comprehensive studies so that further definitions and preservation techniques can be developed.

In this paper we would like to suggest definitions of inland wetlands that draw upon as many scientific areas as possible so as to bring Law and Science closer together for the purpose of preserving wetlands and water resources. A theoretical definition was distilled from the several definitions collected here, one which suggests practical alternatives to present methods of wetland preservation; one that is clear, fair and leads to accurate wetland delineation. This definition is offered as a way to preserve, when justified, those inland wetlands of clear value for their long-term beneficial contributions to the Earth's environment.

The Legal Definition in Connecticut. The definition of inland wetlands and watercourses in Connecticut is paraphrased in Definition I. On a first

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* Sects. 22a-37 through 22a-45, inclusive, of the 1975 Revision to the General Statutes of the State of Connecticut.

reading of this one might think that *poorly drained* and *very poorly drained* are just the common-language use of these phrases, but they are not; these phrases are part of a highly technical vocabulary based on empirical observations and data of the U. S. Soil Conservation Service, used to classify soils after field investigations.

> I. *"Wetlands" means land, including submerged land, ...* [*otherwise not regulated*]*... *Which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial and flood plain by the National Cooperative Soil Survey of the U.S. Department of Agriculture.*
>
> *"Water Courses" means rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs and all other bodies of water, natural or artificial, within the state or any portion thereof ...* [*not otherwise regulated*] ...

Apparently, wetlands have therefore been distinguished from water courses by separate and mutually exclusive legal definitions. Legally, "water courses" includes some things we all think of as water courses -- rivers, streams, brooks, waterways, lakes, ponds, -- but also some of the things we usually consider wetlands -- marshes, swamps and bogs! Because of this confusion between common usage and the legal definition many readers of this law are uncertain of exact meanings. Wetlands and watercourses need not be defined in mutually exclusive terms since one often has great difficulty in distinguishing wetlands from water courses under natural conditions. Only in extreme cases is the difference absolutely clear. Inside the definitional framework of a wetland where a boundary line can be drawn relatively easily, we might subcategorize the concept into swamp, marsh, mudflats and alluvium; but one has a greater difficulty in drawing the boundary lines around these sub-groups. There are of course, broad areas of overlap between areas with different soil and water properties. Why force a distinction that is neither natural nor functional? It would be more useful to use terminology that encompasses all those areas we are trying to protect before we subcategorize and draw lines. Another source of confusion in the existing law is that of the technical terms *alluvial* and *flood plain*. These are partially redundant because the soils of a flood plain are normally alluvial, although not all alluvial soils are flood plain. In addition there exists a separate law designed to protect flood plains in Connecticut.

Definition of a Definition. Before we go further we should define "definition". Definition II is an extract from a dictionary statement. Essentially a definition is the answer to the question: What is an X? What is a thing? For wetlands, a definition is not a delineation technique, nor a description or a statement of functional role. A definition is a response to the inquiry, "What is it?".

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*[ ] = authors' inserts.

II. *A* Definition *is a phrase expressing the essential nature of a thing or class of things. It is an answer to the question: "What is an X?"*

The term "wetland" is not listed in the 1968 edition of Webster's New International Dictionary. Three years later, though, as interest in wetlands and the environment developed, the term "wetland" came into that and other dictionaries, as shown in Definition III. The present Connecticut law, as noted before, seems to be in conflict with this common usage. Note that in courts of law, the 'Webster's Unabridged' is the final authority in matters of definition of terms.

III. [Wetlands are] ... *land containing much soil moisture (as swamps or bogs)* ...

The component parts that should go into any effective definition are listed in Table I. Individual contributors of these parts were asked to be "narrow-guage"; that is, to supply a definition within their special fields of expertise and to avoid stepping out of the bounds of those areas.

A Layman's Definition of Wetlands. Before considering the scientific and legal definitions which follow let us present a lay conceptual definition of wetlands, (IV), to bring in an intuitive expression of understanding. Many contributors pointed out that unless our trial definition is understood by the educated layman (the ultimate audience to whom this presentation,, and indeed the Law, is directed), then that definition would not be useful in legislation nor practical for conserving wetlands. One intuitive definition, a bit tongue-in-cheek, is: 'if you stick your boot into an area and it goes "squish", that's a wetland'. If there is obviously water on the ground or if the water is more than a millimeter deep that's obviously the wetland (or water course) to be dealt with. What about an area where the water is only *near* (not *at*) the surface and then only for part of the year? This is the wetland which is more difficult to locate, delineate, and assess.

Laymen have additional concepts of wetlands, which although not precise are rich in connotation. Inland wetlands are places which are wet; with muddy soils and/or standing water; they seem malodorous to some. They are considered mysterious places with animals and plants different from those normally found in drier lands such as forests and fields. Although these intuitive descriptions do not satisfy scientists, they convey the spirit of what people feel about wetlands.

Table 1. Basic Inputs to an Inland Wetlands Definition

Layman's Concepts	Water Chemistry
Soil Technology	Public Health
Biology	Economics
Botany	Political Science
Zoology	Legal Acceptability
Ecology	Compatability with Delineation Technique
Geology	Sociology/Anthropology
Hydrogeology and Hydrology	

IV. *Layman's Conceptual Definition:*
An inland wetland is a damp, insect-ridden, often foul smelling and mysterious area of muddy soils and relatively still surface water where strange and different animals and plants reside.

Water in the Definition of Wetlands. In our study, almost all the scientific contributors felt strongly that any definition of wetlands should be based primarily on water, and specifically on the position of the water table relative to the ground surface. If water is at or above the land surface there is no question the land is wet. If water is below but near the surface, some difficulties arise, such as how near to the surface the water is, how long during the year it is at that level, and what influences it has on plant growth.

The position of the water table is primarily important because it determines all of the other factors of concern. The occurrence of water determines the engineering of structures such as septic tanks, leaching fields and other activities in wetlands. The presence and extent of water controls the flora and fauna and it influences soil type and the chemical activity that takes place in the soil. The water table position determines whether the soil environment there is aerobic or anaerobic. If the soil environment becomes anaerobic, the soil's physical and chemical properties change -- there is a darkening (e.g. organically bound iron), odors (sulfides, amines, mercaptans, etc.) are evident and there are changes in rate of the decomposition of organic compounds and their end products. Soils scientists classify the soil as *poorly drained* or *very poorly drained* not only by signs of recent water table positions but by texture, color, the appearance of soil mottling, and content of organic compounds.

The flora and fauna that survive in this environment are different from those of uplands. An organismal biologist can look at the life forms of an area and determine if a true wetland condition exists there.

Statement V recognizes the first principle involved: a definition of inland wetlands should be based primarily on the position of the water table; all else follows from this fact.

> V. *Inland wetlands should be defined primarily on the position of the water table relative to the ground surface. The flora, fauna, soil type and chemical activities that can be used to delineate wetlands are uniquely related to the position of the water table.*

Biological Factors in a Definition of Wetlands. Definition VI represents in concise language a biological definition of wetlands which uses an ecosystem function aspect. Life forms in wetlands are different in number and kind from those in the uplands. The uniqueness of these plants and animals is a result of special adaptations to the varying free oxygen content of the wetland soils, which may approach zero. Since plants, the most obvious and constant feature of wetlands, need free oxygen for a complete metabolism, the roots of these plants are shallow -- near the air.

> VI. *Inland Wetlands are those wet areas which, during a significant portion of the year, provide a unique habitat for certain species of higher plants specifically adapted to environments with low and varying available oxygen and with acidic conditions; shallow-rooted and/or aquatic plant species capable of aerobic and anaerobic metabolism are favored. Animals native to these areas are those which are dependent on the above types of plants for food and shelter or upon other animals which frequent these areas. In general, wetlands are distinguished from uplands by the type and diversity of the flora and fauna.*

Diversity. A diversity index (D.I.) could be useful in quantifying the value of wetlands, since not all wetlands are of equal worth. In general, those wetlands with a greater number of species, without the dominance by only a few plants or animals, are more valuable from an ecological point of view. Such diverse wetlands are generally more stable, less polluted and harbor the mixture of life forms we want to protect.

There are many forms of D.I. One simple D.I. is the ratio of the number, sum, Σ, of individuals of species present, S_i, to the total number of species present, S_T, in that specific locale:

$$D.I. = \Sigma \frac{S_i}{S_T}$$

The D.I. criterion, however, should be coupled with other mathematical parameters that lead to the value of a wetland: *e.g.* its hydraulic recharge/discharge potential and economic value.

Animals. The animals found in and around wetlands in a greater frequency than in the uplands are there because they need these special environments for food and shelter. Animals cannot be omitted from the final theoretical definition of wetlands because animals (such as waterfowl) are one of the major factors for which wetlands are being defended. It is difficult to delineate a wetland via animals because of their mobility; but it would be neglectful to omit them as part of the definition.

Plants. Typical plant life forms of wetlands include the many species of aquatic algae, species of ferns, many sedges, grasses, orchids, water lilies, skunk cabbage, dogwoods, red maple, buttonbush, and many others all adapted to the physiological rigors of the aerobic-anaerobic environment. Last but not least of the biota are those *people* who visit and use the wetlands for their aesthetic and economic worth. People should be considered a part of the biota.

Ecological Definitions of Wetlands. An ecosystem statement appears in Definition VII as well as V and contains a viewpoint different from the definitions presented previously. Definition VII emphasizes the point that wetland plants have their uppermost portions in a zone of free oxygen and their roots in an anaerobic (free oxygen absent) zone; therefore most wetland plants are shallow-rooted.

> VII. *A wetland is an ecosystem that is compressed vertically, as compared to a true watercourse for instance, so that the photosynthetic zone and the zone of anaerobic decomposition are interconnected by plants. While the shoots of the plants exist in an environment of light and free oxygen, the roots are in a reducing zone-- the anoxic sediments and water-saturated soils.*

A Soils Definition. Definition VIII is an attempt at a definition from the viewpoint of a soils hydrologist. The contributor felt strongly that a soil definition must contain factors other than those of the single view with which he was charged. Wetlands might be delineated by soils but can not be defined by soils criteria alone, except as they relate to water. A wetland definition, it again is insisted, should be based on the position of the water table. As previously stated, the flora, fauna, soil types and chemical activity associated with wetlands are uniquely related to the water level in the wetland. This is an easy criterion for verification either directly or by remote sensing techniques.

VIII. *The characterization of an area as a wetland or a non-wetland is based entirely on the position of the water table relative to ground surface. The flora, fauna, soil type and chemical activity commonly used to define wetlands are uniquely related to the position of the water table.*

The position of the water table relative to ground surface is a function of the topography, hydrology and subsurface properties of the area in question.

It must be noted that both upland and wetland soils originated from the same geological materials before they were modified over long periods of time by the position of the water table, the addition of organic materials, and weathering. The soil type might change with time, again due to relocation of the water table (either man or nature induced) because that influences the free oxygen tension from which other phenomena follow. Soils are good long-time indicators but plants and animals as well as man's functional role must be added to any comprehensive definition. Finally, the motivation for wetlands preservation is not the soil itself, but rather the indigenous plants and animals.

Hydrological Definition of Wetlands. Hydrological definitions of wetlands were contributed to the overall formulation: one restricted to Southern New England and another more general in scope suitable as well for other areas of this Nation. Definition IX is regional in scope and fits with some thoughts expressed here previously, specifically the importance of the inclusion of the water table. It is emphasized here that not only may wetland water be connected to an aquifer or surface water system, but that most wetlands are part of a continuum of surface and subsurface water movement.

This points out the problem in protecting wetlands without considering other related water systems. If waste water were to be discharged on a hill near a wetland, one should not be surprised if some pollutants show up in the wetland. If a large area near a wetland is paved, the increased water runoff rate influences the hydrological condition of that wetland.

While Definition IX represents the usual hydrological condition for the Southern New England area it cannot be applied across the nation due to many exceptions-- raised bogs, peat plateaus and other upland surfaces that hold water and ice. The accuracy, clarity and technical acceptability of this general definition is striking:

IX. *Wetlands are areas where the water table is at or above the ground surface during the growing season, and under conditions of specific antecedent precipitation. Balances between precipitation, percolation, evapotranspiration and runoff govern water accumulations in wetlands.*

Another hydrologic definition offered by its contributors is in the form of a simplified version of a highly mathematical statement presented in seminar. Applicable to the Nation, this mathematical definition of wetlands (to be reported elsewhere) uses a hydrologic model based on a water budget. Through dimensional and regression analyses an elegant definition can be formulated by sub-categorizing the class "wetland" into the following, all functions of the location of the water table:

1. Ponded wetlands;

2. Water-at-surface wetlands; and

3. Sub-surface-water wetlands

Factors are added for precipitation, evapotranspiration (in the season of maximum plant growth), surface runoff, groundwater flow, flow in the zone of aerating infiltration, storage changes, soil moisture content and change, level of surface water and aeration zone, surface areas exposed and many other physical-chemical parameters. These factors can be grouped to arrive at a composite term, W, that expresses quantitatively the degree of certainty of wetland designation; *i.e.*, a probability number. To this factor W could be added diversity index, the economic value and a weighted value for aesthetic worth to arrive at a numerical scale which expresses comprehensively the full range of wetland possibilities.

While such a composite numerical index would be of invaluable assistance in arriving at decisions, unfortunately the data base needed for such a numerical evaluation is neither presently available nor anticipated in the near future without a massive research effort. An additional problem is that the user public would find such an approach more academic than practicable.

The hydrologic approach offers some key points that should not be neglected in any comprehensive definition: specifically the inclusion of a statement on the growing season as a time to observe the level of the water table and the prerequisite of specific antecedent precipitation. It is axiomatic that the time to look for wetlands is after a reasonable amount of rainfall. The hydrologic approach essentially states that to arrive at the wetland condition, balances between water inputs and water outputs need to be known since these govern the net seasonal accumulation of water in any wetland.

Economic Definition of Wetlands. A very concise economic definition of wetlands, Definition X brings out some very crucial points and serves as a crux to turn from the contribution of the natural sciences to those of the political and social science contributions to the definition of wetlands. To an environmentalist, the definition sounds cold and devoid of any considerations for environmental values, but it is a basic fact of economics and much of society. Almost everyone believes, however, that the true value of wetlands includes intangible and long-term benefits to man and the environment for which dollar values are difficult, if not impossible to compute; hence the development of protective legislation.

X. *An area can be considered a wetland when its value to society as a wetland is higher than when it is used for any other purpose.*

If wetlands are appreciated only for their dollar value then most of these areas might rapidly disappear to take the form of housing developments, dumping grounds for pollutants, filled land, etc. This definition points out sharply that no one factor, neither dollar value nor soils characteristics nor biology, should be used to define wetlands.

A Definition Leading to Delineation. It would be equally unwise to arrive at a definition that does not permit effective delineation. Definition XI offers a statement that could lead to delineation and permits the use of remote sensing as well as field characteristics. One workable manner of delineation is to fly over an area at low altitute (6000') or at some appropriate level suitable for the necessary accuracy in the proper season--early spring in Southern New England -- and obtain photographs of the ground, prepare maps, and then on site in areas of dispute get expert "wetlanders" together to make the exact delineations. Such a group could constitute a committee whose collective judgement would pass on wetland designation and regulation. Next, bring in U.S. Soil Conservation Service staff members to characterize the soils and locate the water table, have biologists trace the lines between spaced test holes and have a qualified surveyor place the lines on high quality maps. All this information is necessary to arrive at an optimal delineation. Public health officers and public representatives should have review authority over wetland maps created in such an endeavor.

XI. *For a definition that leads to delineation, surface characterization of vegetation, water level and soil type are features that may be detected with aerial photographic techniques and then refined on the ground as necessary through field observation.*

Water Use Strategy in Land Use Planning - The Watershed Region. A multidisciplinary committee of wetlanders that could serve as wetland designators and delineators cannot be independent of overall considerations of land use since the entire environment is an interactive unit. Yet some specification of territory is necessary to set responsibilities. A natural and meaningful area is a watershed region. A water management policy which is part of a land use planning strategy should be based on areas which are natural watershed regions. This will have to be modified by political boundaries as a matter of practicality.

Political and Social Science Definition of Wetlands. All the previous technical definitions will be meaningless unless the political and social factors that govern legislation are included. Definition XII is a composite of the key point made by our sociopolitical and legal contributors, namely, A WETLAND IS WHAT THE LAW SAYS IT IS. The Law is the Law and science can only suggest factors that may help in the definition.

XII. *Legally, wetlands have been defined as public goods. In practice, however, wetlands are those land areas which duly appointed or elected public officials choose (or are required) to regulate under the appropriate statutes. This decision, which may or may not involve the use of scientific knowledge, is subject to appeal.* A Wetland is Whatever the Law Says it is.

As a matter of practical consideration that will make legal definitions more useful, any environmental law should be scientifically sound. Therefore such a law should include, in addition to a soils statement, factors for vegetation, water budget and water table location. Any effective definition will also include economics as well as social realities, point to means of delineation, and ways of reasonable and fair regulation and enforcement.

The social science contributors taught us that there must be supporters of wetland conservation if the law is to work. That is, it must serve individual and group interests so that people will be concerned with making the law work. Most of the vested interests concerned with wetlands are held by persons who want to develop them into areas of immediate exchangeable dollar value. In a less organized way, the common interest may want to preserve wetlands for aesthetic and ecological values for the distant future.

Conclusion. The conclusion of this paper is summarized in Definition XIII. It is offered as more than a compilation of contributor inputs; it is a constructive synthesis of many factors. In review:

1. Why Inland Wetlands? Because wetlands cover 25% of the states land area and are vital for their ecological values.

2. The water table location is the prime factor in any inland wetland definition and delineation.

3. Wetlands are detected most readily in wet seasons.

4. Wetlands are an integral part of the entire aquatic environment, interacting with streams, rivers, lakes, estuaries, and reservoirs and they must be considered part of this system.

5. The flora and fauna of wetlands are a response to this special environment: water table at or near the surface, varyingly low dissolved oxygen tensions that make the soils chemically and physically different from upland soils, and which support, for example, shallow-rooted plants able to function in aerobic and anaerobic, mildly acidic environments. The wetland animals which live in or pass through these zones need this special environment for food and shelter. A wetland is often diverse and the plant and animal composition is different from that of uplands and water-bodies.

6. To determine wetland boundaries, surface water, water table position, and location of wetland aerial vegetation,photographs or ground studies can be used. No one criterion is sufficient for accurately locating this complex environment, and indeed these few characteristics are the minimal inputs for passing judgement on wetland boundaries. Field testing of soil types and identification of vegetation assisted by aerial photography are the tools of wetland surveyors which can lead to the fairest and least expensive mapping of wetlands.

7. While laws can decree what and where wetlands are, nevertheless wetlands are best designable and regulated by groups of people that represent legal, social and administrative viewpoints and the many areas of biology, soil science, hydrogeology, engineering and public health. These provide significant information for wetland use or preservation.

8. In order to gain a constituency of support for wetland conservation, public benefits must be shown. (A campaign of public education may be necessary.)

Any practical definition must include at least soil, vegetation and water balance statements for technical correctness. A truly idealized definition, if it includes salient scientific factors with realistic administrative applications built into it, would in fact be practical. If the multi-faceted inputs are technically correct and politically and socially sound then the practical definition will correspond to the ideal definition.

While not in the form necessary for a legal definition, XIII is a statement encompassing all of the inputs to our study. It is followed by legal form (XIV), and a proposed practical definition for Connecticut (XV), in which the principal results of our study are embodied:

XIII. *"Freshwater inland wetlands" means areas where, because of topographic, hydrologic and subsurface properties, the water table is at or near the ground surface for those parts of the year with the highest rainfall. Wetlands are not completely separable by definition or functional role from water courses and aquifers. The unique wetland flora, fauna, soil types and chemical activities are functions of the wetland water chemistry and depth of the water table. Because the soil substrates are not well drained, the free oxygen level in the soil-borne water is low and varying; therefore, anoxic and mildly acidic conditions characterize wetland soils. These characteristics provide a special habitat for shallow-rooted aquatic plants, capable of both aerobic and anaerobic metabolism. The photosynthetic zone and the zone of anaerobic decomposition are interconnected by certain aquatic higher plants. Fauna native to wetlands is dependent on wetland plants for food and shelter or upon other animals which frequent wetlands. Thus, the diversity and composition of wetlands flora and fauna are different from those of drylands. Wet soil conditions can be determined by test holes,*

surface water, and unique wetland vegetation. Wetland surface characteristics, such as vegetation, standing water and soils are visual features that can be discerned at ground level or by aerial photography. Subsurface characteristics can be discerned by field testing of the soils and by observation of geological conditions.

Economically, certain wetlands have value to socity as common public assets in which their exchangeable and intangible benefits are greater than for any other use or altered functional role.

In law, however, wetlands are whatever the law says; thus, wetlands can be whatever a duly constituted watershed region committee (or other governing body), deems them to be. To be politically and scientifically sound a wetland commission should be composed of at least a public representative, persons knowledgeable in hydrogeology and biology, a public health officer, an engineer and a surveyor so that wetland boundaries can be established as part of an overall land-use strategy based on concern for public health, safety and the long-term preservation of the environment. Wetland preservation should be part of overall land use planning based in part on watershed regions as natural encompassing areas for water management. Land use maps showing wetlands, watercourses and other important boundaries should be published for public and private use to gain a constituency of support for such service. Wetlands are a part of a continuous environmental system and should not be segmented artificially from surrounding areas; overall land use planning would protect wetlands as part of the ecosystem that benefits the common good of all the people.

XIV. *"Inland wetlands" means those areas not regulated where the water table is at, above, or below but near the ground surface for those parts of the year with the highest rainfall, and includes but is not limited to water courses and aquifers. Indicators of wetlands in addition to ground water table include but are are not limited to unique wetland flora, fauna, soil types, chemical activity, low and varying free oxygen levels in soil-borne water and anoxic and mildly acidic conditions. In order to regulate hereunder an agency must promulgate a map of inland wetlands in accordance with the requirements for the promulgation of regulation provided hereunder. Only areas approved on a properly promulgated map may be mapped for the purpose of regulation. Wetlands soil conditions may be assessed by U.S. Soil Conservation District maps, test holes, surface water, and the unique characteristics, such as vegetation, standing water and wet soils, which are visual features that may be discerned by direct observation at ground level or by aerial photography, as may certain animals discerned by field testing of the soils and by the observation of geological conditions.*

XV. PROPOSED AMENDMENT TO THE INLAND WETLANDS AND WATERCOURSES ACT,

General Statutes, Section 22a-38, paragraphs 15, 16.

(Items in brackets are to be deleted; items in upper case letters are to be added.)

(15) "Wetlands" means land, including submerged land, not regulated pursuant to sections 22a-28 to 22a-35, inclusive, which consist[s] of any of the soil types designated as poorly drained, very poorly drained, alluvial, or flood plain by the National Cooperative Soils Survey, as may be amended from time to time, of the Soil Conservation Service of the United States Department of Agriculture; AND SHALL INCLUDE, BUT NOT BE LIMITED TO, MARSHES, SWAMPS, BOGS, RIVERS, STREAMS, RIVER AND STREAM BANKS, AREAS SUBJECT TO FLOODING OR STORM FLOWAGE, AREAS WHERE GROUND WATER, FLOWING OR STANDING, SURFACE WATER, OR ICE PROVIDE A SIGNIFICANT PORTION OF THE SUPPORTING SUBSTRATE FOR A PLANT COMMUNITY; EMERGENT AND SUBMERGENT PLANT COMMUNITIES IN WATER BODIES; AND THAT PORTION OF ANY BANK WHICH TOUCHES ANY INLAND WATERS.

"MARSH" MEANS THOSE AREAS WHERE A VEGETATIONAL COMMUNITY SHALL EXIST IN STANDING OR RUNNING WATER, AND WHERE THAT COMMUNITY SHALL INCLUDE, BUT NOT BE LIMITED TO, SOME, BUT NOT NECESSARILY ALL, OF THE FOLLOWING: HORSETAILS (Equisetaceae); BUR-REEDS (Sparganiaceae); CATTAILS (Typhaceae); PONDWEEDS (Zosteraceae); WATER-PLANTAINS (Alismaceae); HYDROPHYTIC GRASSES (Gramineae); SEDGES (Cyperaceae); ARUMS (Araceae); DUCKWEEDS (Lemnaceae); RUSHES (Juncaceae); PICKERELWEED (Pontederiaceae); PIPEWORTS (Eriocalonaceae); SWEET GALE (*Myrica gale*); TEAR-THUMBS (Polygonaceae); WATER LILLIES (Nymphaeaceae); FROG'S-BITS (Hydrocharitaceae); WATER-MILFOILS (Halorrhagidaceae); DOGWOODS (*Cornus* spp.); ARROWWOOD (*Viburnum* spp.); BLADDERWORTS (Lentibulariaceae); AND BUTTONRUSH (*Cephalanthus occidentalis*).

"SWAMP" MEANS THOSE AREAS WHERE GROUND WATER SHALL BE AT OR NEAR THE SURFACE FOR A SIGNIFICANT PORTION OF THE GROWING SEASON, OR WHERE RUNOFF WATER FROM SURFACE DRAINAGE SHALL COLLECT FREQUENTLY, AND WHERE THE VEGETATIONAL COMMUNITY SHALL INCLUDE, BUT NOT BE LIMITED TO, SOME BUT NOT NECESSARILY ALL, OF THE FOLLOWING: EASTERN WHITE CEDAR (*Chamaecyparis thyoides*); HEMLOCK (*Tsuga canadensis*); SKUNK CABBAGE (*Symplocarpus foetidus*); WILD FALSE HELLEBORE (*Veratrum viride*); WILLOWS (Salicaceae); BIRCH (Betula alleghaniensis); ALDERS (*Alnus* spp.); MARSH MARIGOLDS (*Caltha palustris*); SPICE BUSH (*Lindera benzoin*); BLACK ALDER (*Ilex verticillata*); POISON SUMACH (*Rhus vernix*); RED MAPLE (*Acer rubrum*); SWEET PEPPER BUSH (*Clethra alnifolia*); BLUEBERRIES (*Vaccinium corymbosum* group); ASH (*Fraxinus nigra*); SWAMP AZALEAS (*Rhododendron* spp.).

"BOG" MEANS THOSE AREAS WHERE STANDING OR SLOWLY RUNNING WATER SHALL BE AT OR NEAR THE SURFACE DURING A NORMAL GROWING SEASON, AND WHERE THE VEGETATIONAL COMMUNITY SHALL HAVE A SIGNIFICANT PORTION OF THE GROUND OR WATER SURFACE COVERED WITH SPHAGUM MOSS (*Sphagnum sp.*), AND WHERE THE VEGETATIONAL COMMUNITY SHALL INCLUDE, BUT NOT BE LIMITED TO, SOME BUT NOT NECESSARILY ALL, OF THE FOLLOWING: EASTERN WHITE CEDAR (*Chamaecyparis thyoides*); BLACK SPRUCE (*Picea mariana*); SEDGES (*Cyperaceae*); BOG-COTTON (*Eriophorum* spp.); ORCHIDS (*Orchidaceae*); PITCHER PLANT (*Saraaceniaceae*); SUNDEWS (*Droseraceae*); BLUEBERRIES (*Vaccinium corymbosum* group); CRANBERRIES (*Vaccinium oxycoccos, V. macrocarpon*); LEATHERLEAF (*Chamaedaphne calyculata*); BOG ROSEMARY (*Andromeda glaucophylla*); SWAMP AZALEAS (*Rhodedendron* spp.); LAURELS (*Kalmia* spp.); AND BOG ASTER (*Aster nemoralis*).

"GROWING SEASON", FOR PURPOSES OF THIS ACT, SHALL MEAN THE PERIOD FROM APRIL 1 TO OCTOBER 1, INCLUSIVE, OF ANY CALENDAR YEAR.

THE IMPORTANCE OF AN HOLISTIC APPROACH TO ECOSYSTEM MANAGEMENT AND COMMUNITY PLANNING

by

Barbara L. Welsh, Janet P. Herring, Diane Bessette, and Luana Read*

Introduction. In the present upsurge of environmental awareness, a primary focus has been placed on inland wetlands, resulting in a host of programs to define, describe, identify, survey and legislate every patch of this soggy heritage. Although wetlands are usually relatively stationary entities, they are but one functional component of a highly dynamic hydrologic unit, the watershed. Their viability must lie not only in their own exclusive protection, but also in the preservation of their vital links with the hydrologic system and the maintenance of the life-blood of this system, the flow of water. In turn, the functioning (or dysfunctioning) wetland contributes to the parent system, often affecting its character and stability far beyond the boundaries of the wetland itself. Unfortunately, the practical aspects of ecosystem theory have not kept pace with the need for a reasonably limited number of measurement parameters, obtainable within realistic economic and time constraints. By means of these parameters we can "take the pulse" of a hydrologic system as a whole and provide some guidelines and limitations for management in the face of increasing development pressures.

The new wetlands measurements must be quantitative, functional, and integrated indicators of hydrologic importance. A hierarchy of these integrated parameters has already been established in biology (Table 1). On considering individual organisms, one might measure respiration or growth, and therefore determine its energy flows regardless of the responses of individual cells or tissues. Measurement of aspects of the individual give way to parameters such as birth rates, death rates and age distributions of populations, and these may be integrated to describe population density and population diversity in communities or discrete habitats. At present, population density and diversity are heavily extended to indicate the characteristics of whole ecosystems, where we still use a "shot-gun" approach -- measuring everything in sight. Biology has not yet developed a series of measurements which will transcend the diversity within ecosystems in describing the basic functional attributes necessary for the maintenance of stability of dynamic balances.

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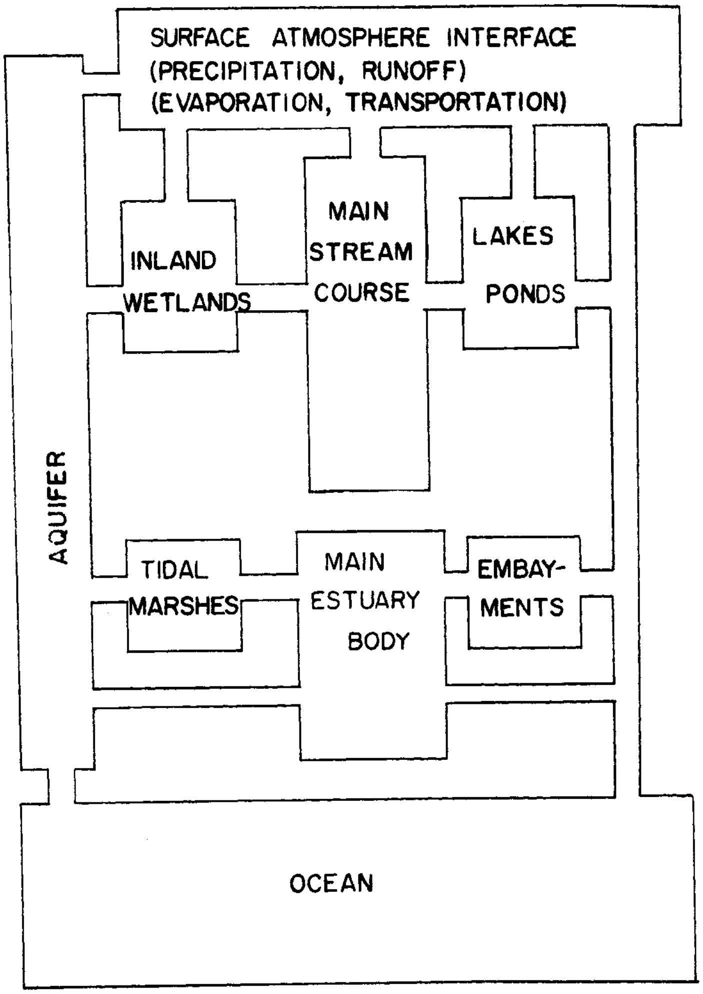
Table 1. Some Examples of the Hierarchy of Integration in Ecological Measurements

LEVEL	MEASUREMENT	INDICATOR PARAMETER FOR STABILITY
Organism	Respiration, Growth, etc.	Metabolism, Energy flow
Population	Birth Rates, Death Rates, Age Distr.	Population Structure
Community or Habitat	Numbers of Organisms, Numbers of Species	Density, Diversity
Ecosystem	?	?

COMPONENT	FUNCTION
Inland Wetlands	Storage, Recharge, Discharge Linkage with Aquifer Climatic Stabilization Oxygenation of Water Primary Production (solar energy trap)
Lakes and Ponds	Water Storage and Discharge Primary and Secondary Production Sediment Trap
Streambelt	Corridors of Transport and Communication between Components, including Aquifer Oxygenation of Water Nutrient Transport Releases of Surpluses
Estuaries	Mixing of Fresh and Salt Waters Buffer Zone between Fresh and Salt Areas Nutrient Regeneration Zone High Productivity Zone Sediment Trap
Tidal Marshes and Embayments	Buffer Zone against Salt Intrusion Energy Absorber and Dissipator Nutrient Regeneration Zone Filter, Sediment Trap

Table 2. Major Functional Components in the Watershed System

WATERSHED SYSTEM



POTENTIAL MEASUREMENTS

AREA OF WATERSHED, VOLUME OF PRECIPITATION

MILES, AREA, VOLUME OF STREAMBELT

AREA OR VOLUME OF LAKES, PONDS

AREA OR VOLUME OF WETLANDS

STREAMFLOW
- VOLUME
- AMPLITUDE
- PROGRAMMING

AREA OF ESTUARY

AREA OF TIDAL MARSHES

AREA OF TIDAL EMBAYMENTS

TIDAL FLOW
- VOLUME
- AMPLITUDE
- PROGRAMMING

Fig. 1. A diagrammatic representation of linkages within the watershed and between the watershed and its three adjacent systems; the atmosphere, the aquifer, and the ocean. The list at right provides some potential elements for a whole-system parameter.

One of the greatest obstacles to extending the hierarchy of ecosystem descriptors lies in defining an appropriate Unit Ecosystem. For the purpose of this study, we have chosen the watershed as one such unit. Its functional components include both inland and estuarine areas joined to three adjacent systems: the atmosphere, the aquifer and the ocean (Table 2). We have focused on water flow in particular because the water provides the communication between the other components of the study ecosystem. We have concentrated especially on conditions which would affect the linkage between the freshwater portion of a system and its estuary.

Our study area was the Fenger Brook watershed, located in Waterford, Connecticut. This system empties into eastern Long Island Sound. Its estuary, Alewife Cove, has a highly fluctuating salinity. Since freshwater inflow and tidal flow are the prime dynamic determinants of estuarine circulation patterns (*1*), it appears that salinity fluctuations might be a prime indicator of the state of flow balance within the system as a whole. The amount of water available would depend to a large extent upon interactions between the watershed and its adjacent systems (atmosphere, aquifer and ocean), but the programming of the flow balance should be a function of the wetlands and impoundments within the watershed. These could serve to store and release water; marshes and embayments within the estuary could damp the intrusion and removal of salt water on every tidal cycle. They have been shown to do so during heavy storms, but on a much less dramatic scale.

If stability within our unit ecosystem could be shown to depend upon the damping function of these storage and release facilities in both the freshwater and saltwater areas, then the relative proportions of such subunits within the mosaic of hydrologic factors might provide basic elements for a whole-system measurement (Fig 1.). If such a parameter could predict the effects of losses of wetlands and marshes on a system as a whole, it could provide a valuable management tool for deciding how much development would be allowed in that system.

From an ecological standpoint, salinity fluctuations are a major stress factor which determines the distribution of plants and animals within the estuary. In particular, Conover (*2*) has linked low productivity of benthic communities to the fresher portions of estuarine mixing zones. The interaction of fresh and salt water in that area causes flocculation of dissolved or suspended materials which are too soft to support the more productive types of organisms. If this is true, then an unstable salinity regime, expected to spread the fresh/salt water interface over a wide zone as it oscillates from one extreme to the other, might well be expected to result in a net loss of productivity to the system.

Field Observations. Over a period of one year the salinity patterns in Alewife Cove fluctuated from the classic salt wedge estuary or fjord type (dominated by freshwater inflow), to a salt-pond type with virtually no horizontal or vertical salinity gradient from head to mouth (Figs. 2,4). While such shifts of salinity distribution do occur in some temperate estuaries on a regular seasonal basis, such changes are usually not only predictable but they occur relatively slowly. As a result the native

organisms are able to adjust to the new condition. This cove, however, shifted violently from one extreme of salinity to the other over short periods of time (2 weeks), even after a single rainfall (Figs. 4-7).

These large shifts in salinity were consistent with the Prichard models for estuarine circulation types (Table 3). The tidal volume during spring tides was only about 1/7 larger than that of the neap tides, but the freshwater inflow varied by a factor of 11. Thus the flow ratios would place the Cove on the highly stratified end of Prichard's moderately stratified estuary when high freshwater input coincided with neap tides, but would shift it toward the vertically homogeneous structure when low deliveries from the watershed occurred during spring tides.

As a result of such shifts, salinity fluctuated most at the upper stations (Fig. 8). If 0-7 ppt. represents the critical salinity range for flocculation (*3*), then such a phenomenon may be taking place at one time or another over nearly one-half of the estuary. If the critical zone of deposition for the flocculated material is at the upper end of saltwater intrusion (*4*), then such deposition may be spread over the upper one-third of the estuary.

Samples of the Benthic (bottom) zone indicated that the stations farther up the system might be indeed highly stressed and not very productive. The organisms there were mostly small polychaetes. Bivalves and gastropods were absent. The substrate was a fine silt of a high organic content, and sediment temperatures were higher than could be accounted for by the overlying water. This suggested high bacterial activity in the sediment. These observations were consistent with those of Conover (*2*) for mixing zones in Charlestown Pond, and with his hypothesis that the size of the organisms decreases with increasingly stressful conditions. Although the bacterial productivity might be quite high, the "useful" productivity of the area in terms of food for higher organisms such as fish may be low.

Historical Aspects. A survey of the Fenger Brook portion of the watershed revealed why the delivery of new water to Alewife Cove might be so variable: urban development has heavily impacted the watershed. Full 50% of the watercourses and 55% of the inland wetlands of the upper portion of the watershed had been lost or separated from the lower portion of the system (Fig. 9). The major barrier was a raised railroad right-of-way lacking a culvert for the main stream channel. South of the railroad embankment, apartment complexes with their attendant parking lots and access roads overlie former wetland areas on the east, altering drainage patterns and increasing surface runoff. A large marshy pond at the head of Alewife Cove has been replaced by an apartment complex and an impoundment of perhaps 10% of its former area. These apartments use city water, but some still discharge into septic tanks. This increases the local water load on the residual system. As a result approximately 20-30 acres of wetlands and woodlands in this section have become impounded, containing a depth of 6-18

PRICHARD RATIOS

CIRCULATION TYPE	RATIO (Tidal Volume: River Flow)
Highly stratified (salt wedge or fjord type)	1:1
Moderately stratified	10:1-100:1
Vertically homogeneous or salt pond type	1000:1

ALEWIFE COVE RATIOS

Highest Brook Flow: Neap tides	10:1
Lowest Brook Flow: Spring tides	114:1

Table 3. A comparison of the Prichard (1) ratios with the fresh water flows and tidal volumes in Alewife Cove. Flow units are in cubic meters per tidal cycle (12 hr.).

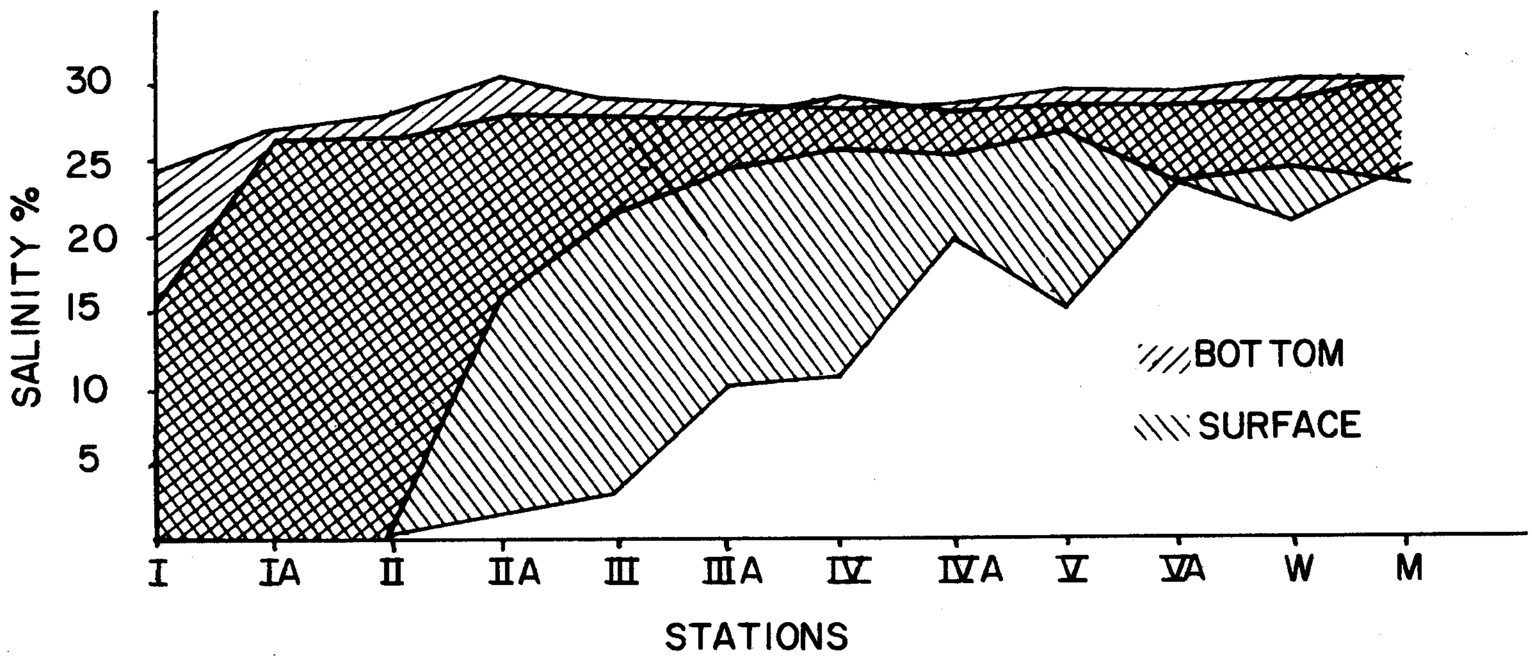


Fig. 2. Extremes of salinity observed along the axis of Alewife Cove over an annual cycle. Stations correspond to those in Fig. 3., with "A" at the source and "M" at the mouth.

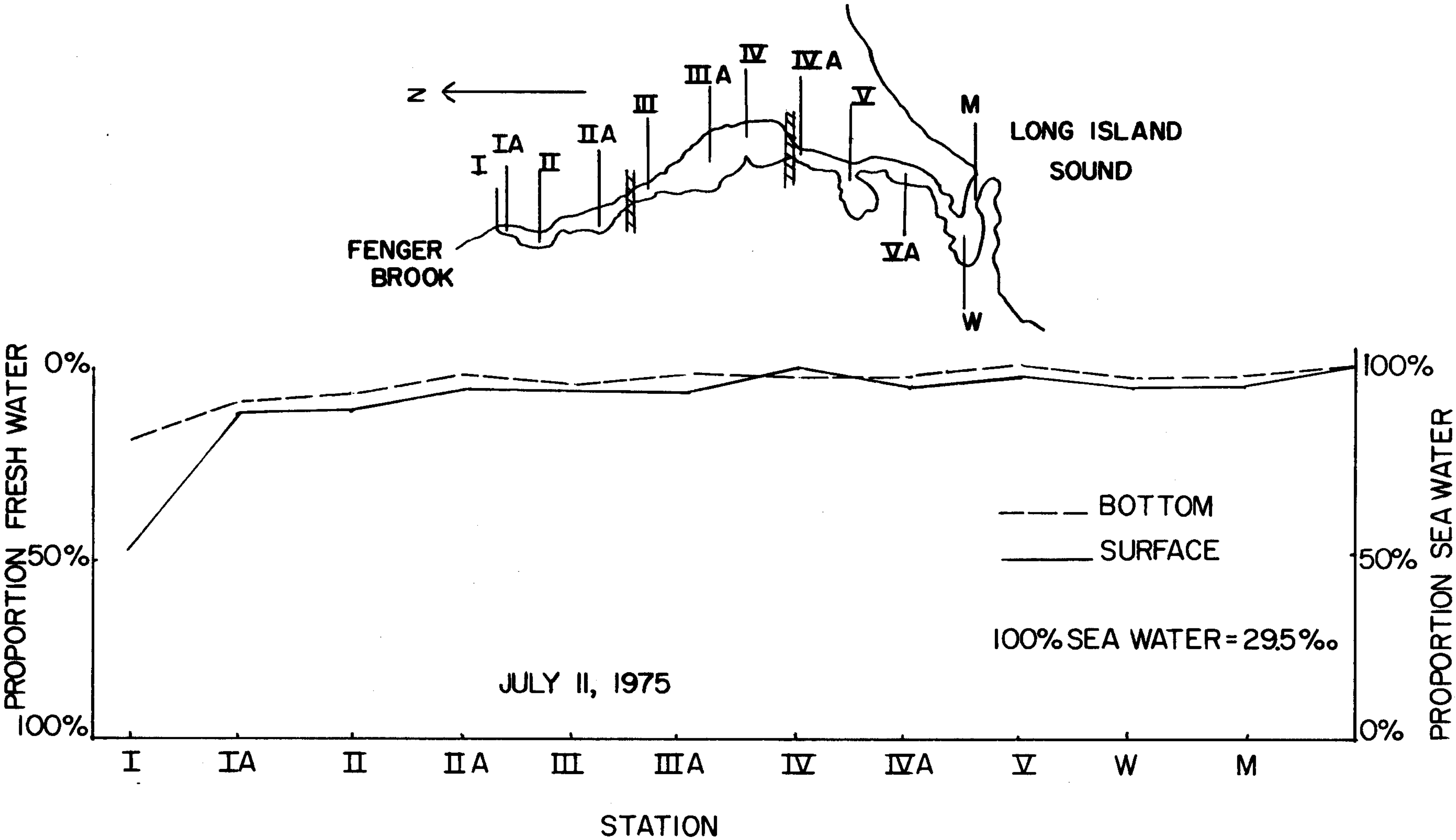


Fig. 3. Salinity regime in Alewife Cove on July 11, 1975 during a dry spell.

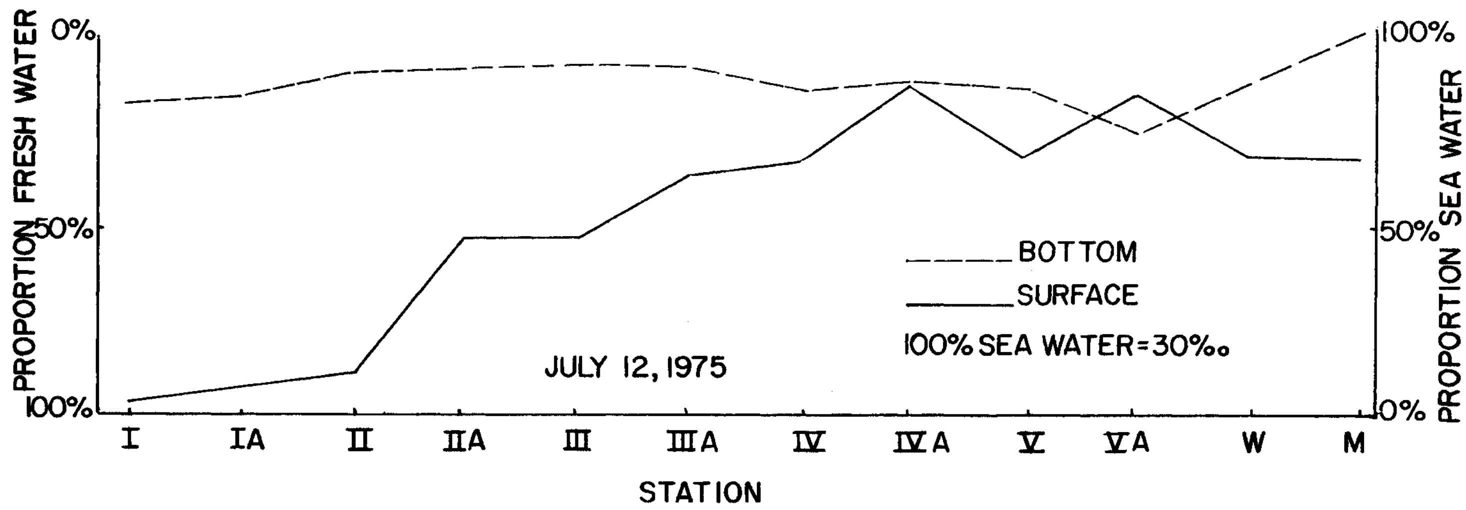


Fig. 4. Salinity regime in Alewife Cove on July 12, 1975, during a rainstorm.

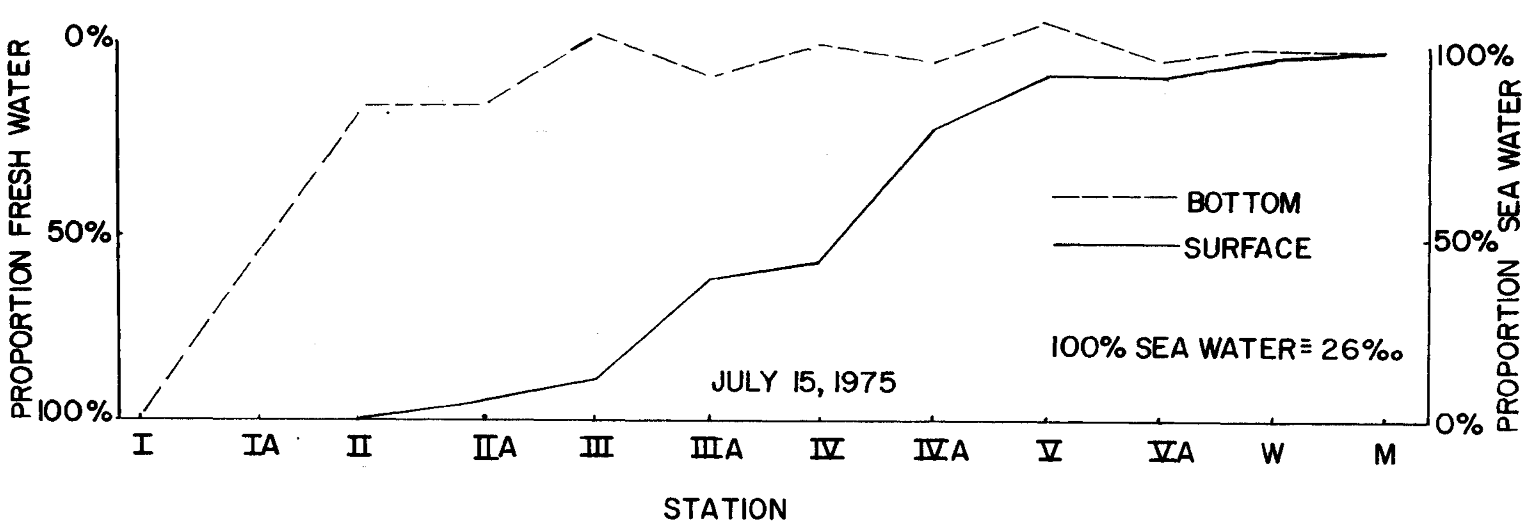


Fig. 5. Salinity regime in Alewife Cove on July 15, 1975, three days after rain had stopped, showing the fullest development of stratification for that particular rainstorm.

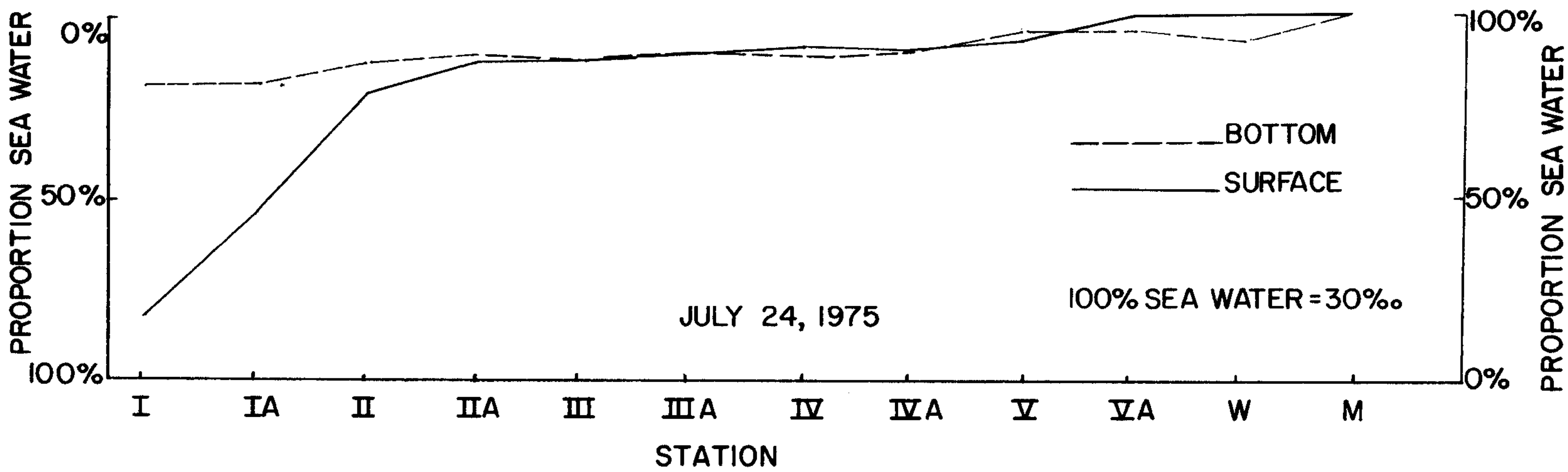


Fig. 6. Salinity regime in Alewife Cove on July 24, 1975, showing a return to near homogeneous conditions within two weeks of a rainstorm.

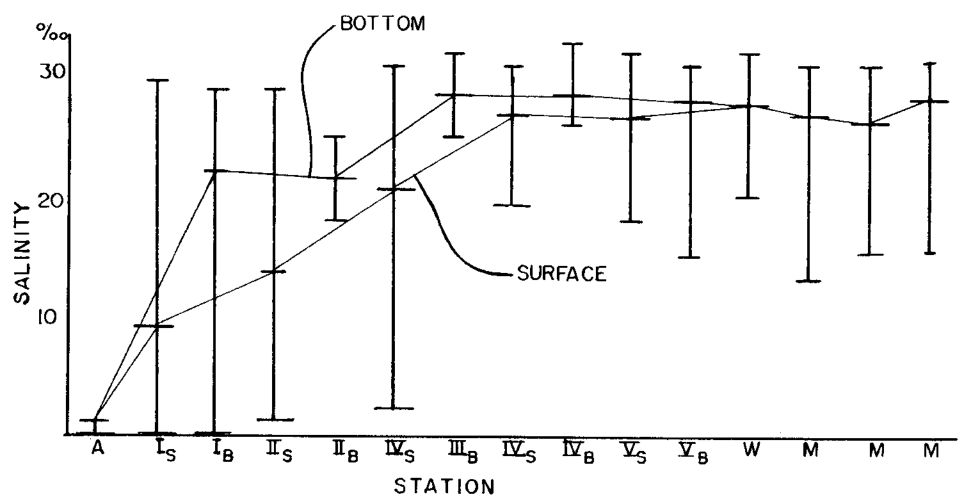


Fig. 7. Salinity ranges of surface water and bottom water along the axis of Alewife Cove during the fortnight following the July 12 rainstorm.

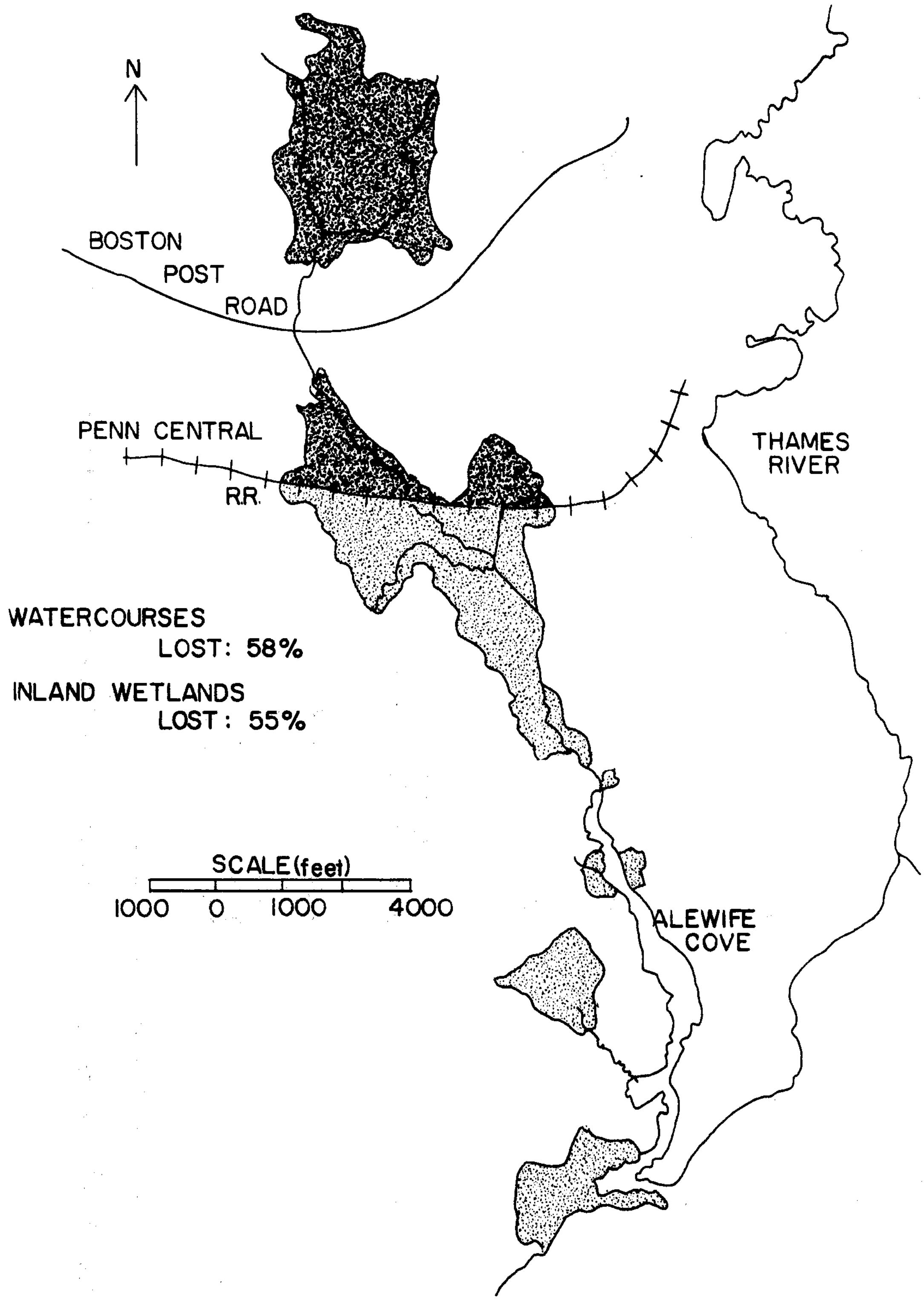


Fig. 8. The Fenger Brook watershed system. Stippled areas represent wetlands. Darker areas represent wetlands which have been functionally severed from the system by Man.

Date	Cove	West Marsh	East Marsh	Upper Marsh
1884	17	20	11	6
1906	13	13	8	2
1915	11	9	1	1.5
1935	11	9	0.9	0.9
1962	10	8	0	0.9

RATIOS
(Marsh Area:Cove Area)

1884	2.2
1906	1.8
1915	1.0
1935	1.0
1962	0.9

Table 4. Historical changes in tidal marsh and cove areas in relative units (see Fig. 10).

inches of water (more during heavy rains). Hardwoods and shrubs have died and been replaced by a heavy growth of duckweed.

It appears that the newly impounded area may be the only alternative available in the system for replacing the water storage capacity of the lost wetlands. Wetlands function to accumulate excess water during periods of heavy precipitation, preventing excessive discharge and erosion and providing a continued water flow during later dry periods. With their loss, an increase in the amplitude of variation in freshwater discharge is expected. High flows and resultant erosion would then increase the load of alluvial material washing into the estuary after brief rains. During drier periods the freshwater inflow may be insufficient to keep the estuaries flushed, thus their shoaling and filling rates are increased.

Downstream, the estuarine areas have also undergone change (Fig. 10). The 1884 U.S. Coast Guard Coast and Geodetic Survey maps show extensive tidal marshes covering over twice as much area as the Cove itself (Table 4). By 1935 the marshes had been reduced by 70%, and the Cove had lost about one-third of its former area; the marsh and cove areas were then about equal. Following the hurricane that year, a public beach was built on the east bank of the Cove, eliminating not only the marshes, but a substantial embayment was filled for a parking lot. The resultant ratio of marshlands to watercourse is now less than 1:1. Minor illegal filling continues, and although a 95-acre park protects the only remaining tidal marsh of any size, public use is wearing it away along its banks.

As in the case with the freshwater areas, tidal basins and marshes in the estuary (downstream from the mixing zone) would be expected to absorb tidal energy, damping its oscillations. Hence, loss of these areas would be expected to widen the mixing zone during the tidal cycle. In addition, marshes remove suspended particles from the water column. Without such a filter, more sediment would be available for deposit in channel areas, especially during periods of poor flushing (low freshwater flow).

Therefore, losses of wetlands in both the upstream (freshwater) and the downstream (saltwater) portion of the system would be expected to contribute to reduced productivity in the estuary, first by increasing the amount of material available for sedimentation and then by expanding the area over which it is deposited. Aerial photographs indicate the shoal area of marine sediments in Alewife Cove has been slowly migrating upstream toward the lower bridge (Fig. 11) and that there is increased shoaling of sediments above that bridge. A proposal has been initiated in the Connecticut State Legislature to dredge the cove (Proposed Bill No. 5963, Hendel and Tanger, 1975). Unfortunately, such action might merely increase tidal flow and accelerate the filling process unless the freshwater flow is also restored to the point where it will maintain its flushing function between rainstorms.

HISTORICAL COAST AND GEODETIC SURVEY MAPS OF ALEWIFE COVE AREA

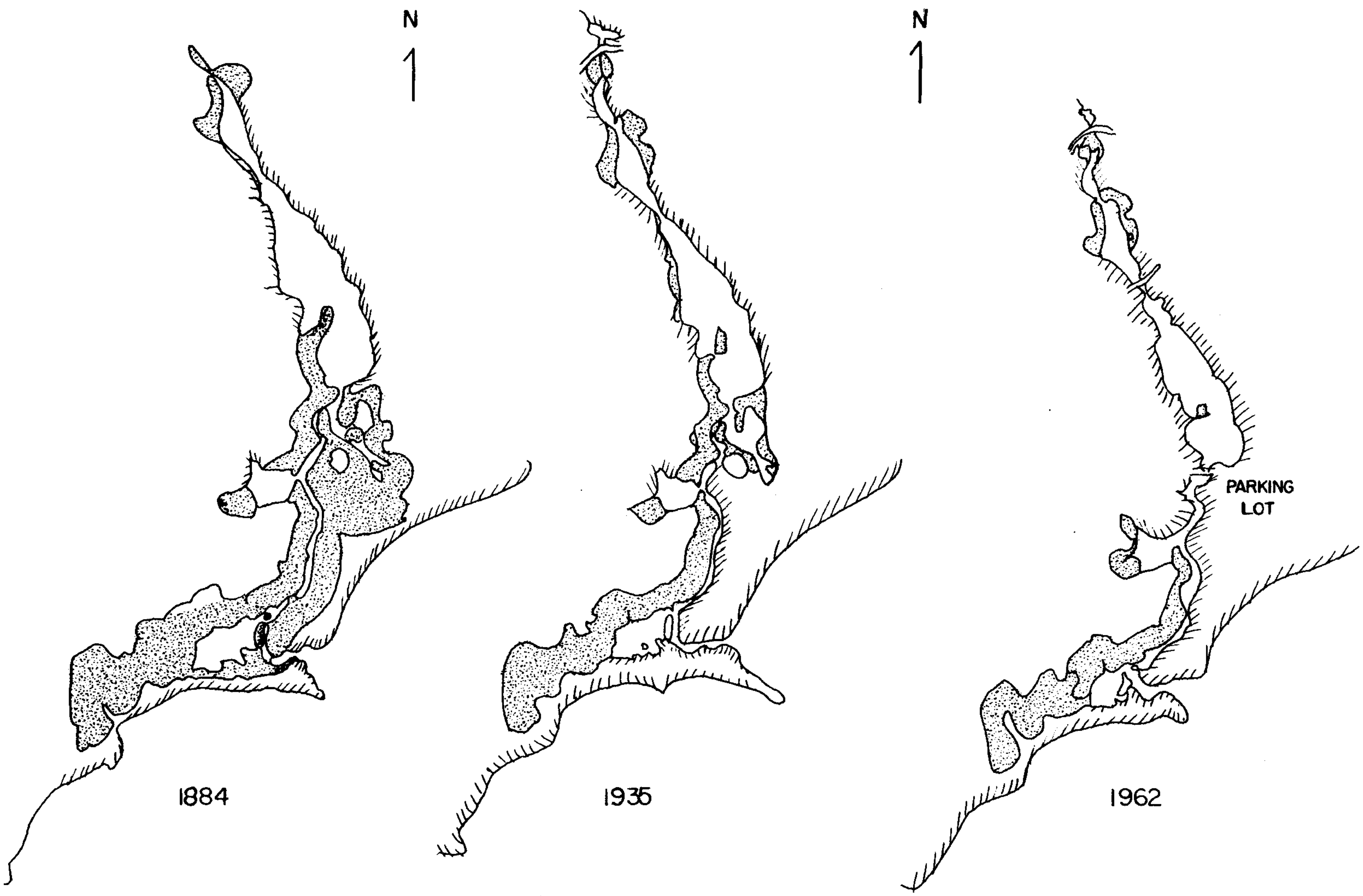


Fig. 9. U.S. Coast and Geodetic Survey maps, showing changes in the estuary since 1884.

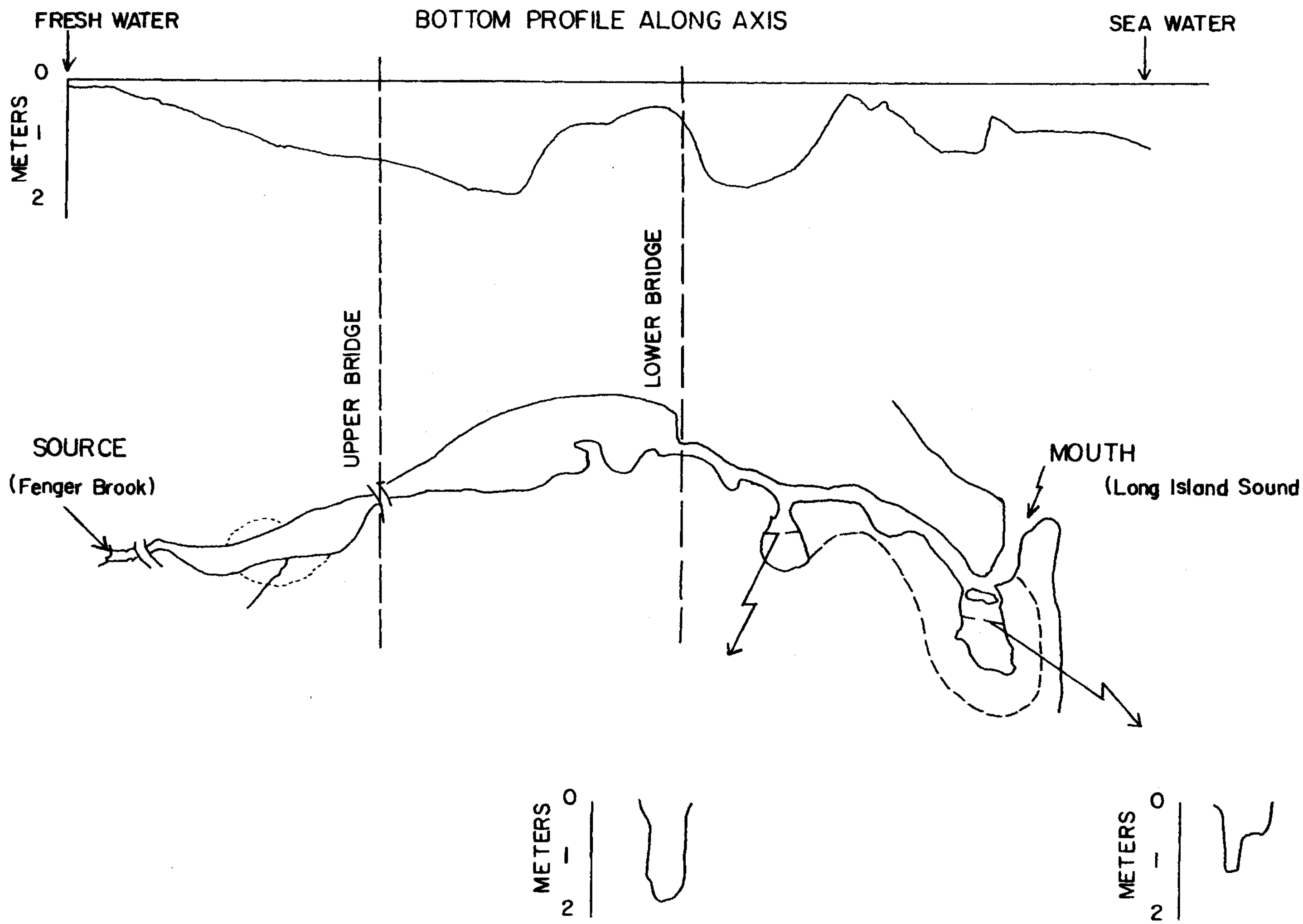


Fig. 10. Bottom profile along the axis of Alewife Cove, showing shoaling above and below the lower bridge.

Relevance to Coastal Planning. To a large extent Man has been most active on the banks of streambelts, generally oriented perpendicular to the adjacent coastline (*5*). Overland communication and service routes from center to center have then developed across these streambelt watersheds. Quite logically, industrial and commercial zones are developed as broad, continuous bands along these transportation routes. Unless buffer zones are maintained where they intersect the watersheds, whole portions of a functionally integrated system may be cut off. In addition, wetlands are often the first to be sacrificed to urban development, just when a resultant increase in surface runoff (which comes with paving over the landscape) actually increases the need for Man to program the increased flow of water.

We are exploring the development of ratios between these wetlands as storage and release areas and the tidal freshwater volume serviced (as well as tidal volumes). This ratio will express the critical limits beyond which hydrologic stability may be lost (such as in an estuary), or when a system may undergo spontaneous and radical redesign (such as in a flooded hardwood area). These effects may occur some distance from the lost wetland. Such a ratio should provide the type of system criterion needed as a guideline for successful planning and management of the whole watershed.

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The authors wish to thank P. Clem for her contribution to the watershed survey, portions of which were used in this paper; to R. Tudor and T. Fogg for their information on sediment size distributions and temperature data; and to Dr. H.T. Odum for his constructive comments on self-design in disturbed ecosystems.

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BACKGROUND ECOLOGY AND THE EFFECTS OF NUTRIENT ADDITIONS ON A CENTRAL MICHIGAN WETLAND

by

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Introduction. In central Michigan, studies are currently underway to determine the effects of nutrient additions on the structure and function of a wetland°° (peatland) ecosystem. A series of field experiments and a simulation model are being used to determine the feasibility of using a wetland as a means of tertiary treatment of secondary municipal waste treatment effluent (*1,2,3*).

Secondary treatment of domestic sewage reduces many organic wastes to inorganic compounds, thus creating nutrient-rich water. This effluent is generally slightly alkaline (pH 6.8-7.2) (*4,5*). Nitrogen (N) is present in secondary effluent mainly as ammonium compounds and organic nitrogen, and phosphorus (P) can be present as up to 85% orthophospate (*6*). The ranges of concentration of major plant nutrients and the characteristics of secondary treated

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°°Wetlands are areas with substrates periodically or permanently inundated or saturated and which have characteristic vegetation and/or animal life and ecosystem structure and function. (Definition adopted by Michigan Wetlands Group, June 1975.).

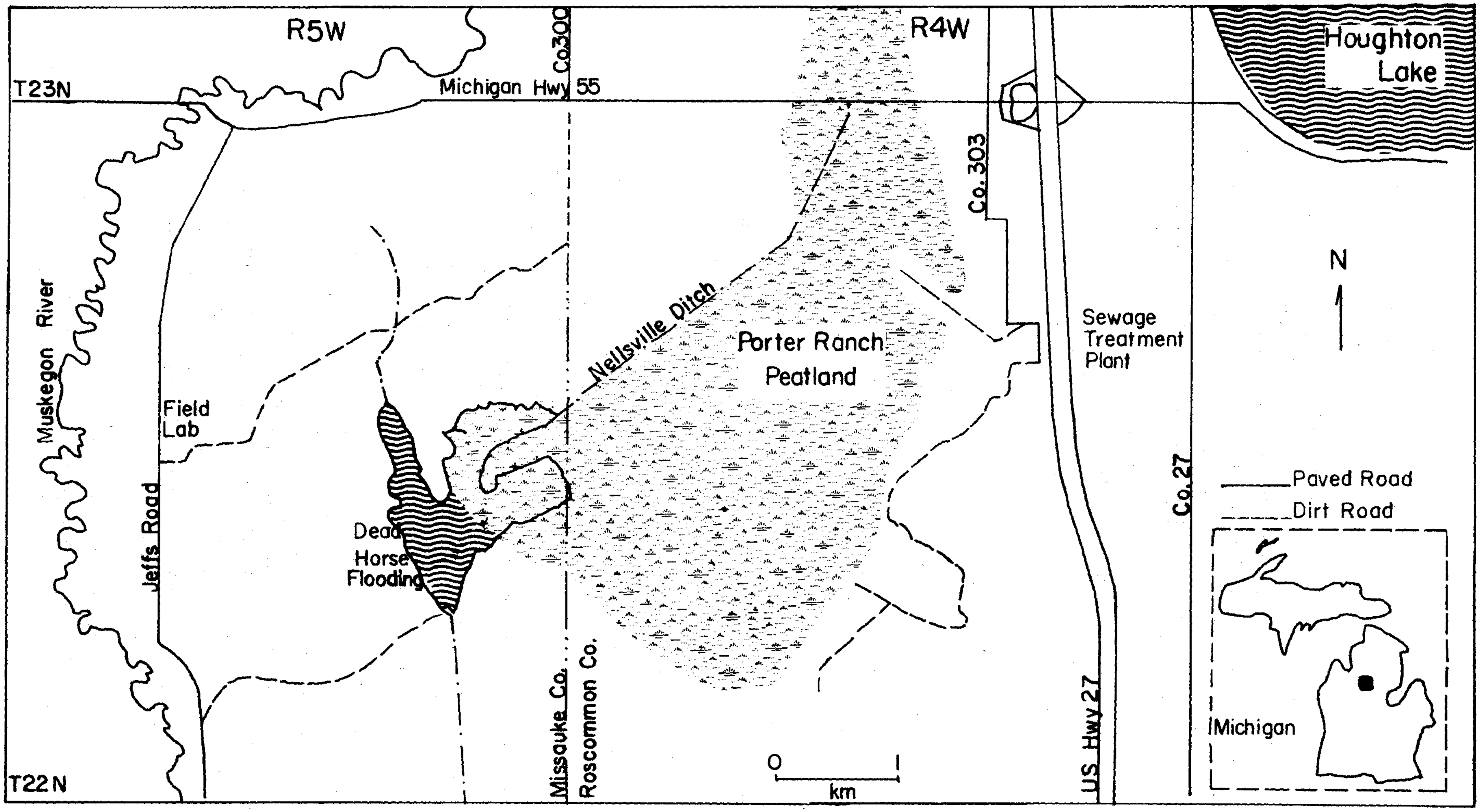

Fig. 1. Location map of the Houghton Lake wetland (Porter Ranch peatland), Roscommon and Missaukee Counties, Michigan.

sewage effluent are given by Bouwer and Lance (*7*), Hunter and Kotalik (*5*), Shindala (*6*), and Sopper and Kardos (*4*).

A wetland is a complex hydrologic and biogeochemical ecosystem which can transform various chemical additions into compounds that may or may not improve water quality. Peatlands are generally characterized as areas (a) which have periodic or permanently waterlogged soils with significant denitrification potential (*8,9*); (b) where characteristic organic soils have high cation exchange and sorption capacity (*10*); (c) which support nutrient-deficient or low nutrient-tolerant plants (*11*); (d) which have slow decomposition rates (*12*); (e) whose evolution is random chance and is influenced by local events (*13,14*) and (f) which function as biotic nutrient filters, sediment traps and which control water fluctuations from watershed runoff (*15*).

Many of the above characteristics seem to render peatlands capable of acting as biological filters for the disposal of treated effluents. This paper will attempt to document some of the changes that took place in a central Michigan wetland after nutrient addition. Factors to be discussed in this paper are net primary production, nutrient uptake and transfers, water quality, and decomposition rates.

Study Area. Porter Ranch Peatland, the study site, is a 716 ha. (1768 a.) wetland located 2.3 km. southwest of Houghton Lake in Roscommon and Missaukee Counties in central Michigan (Fig. 1). The area is one of low relief at an elevation of 346 meters above sea level. It is located in the Houghton Lake Wildlife Research Area and is part of the Houghton Lake State Forest.

The vegetation of the study site is typical of northern peatlands and is composed of two main cover types -- Leatherleaf-Bog Birch (*Chamaedaphne calyculata* (L.) Moench, and *Betula pumila* L.) and Sedge-Willow (*Carex* spp. and *Salix* spp.). The sedge and the willow (sedge + willow + sedge-willow) and the leatherleaf-bog birch cover types account for 68.3% and 19.1% of the cover area respectively (Table 1). The twenty-five most common species or species groups are given in Table 2. A complete description of species composition and abundance of vascular plants is given as by Wentz (*16*).

Organic soils in the peatland are categorized as Rifle peat and Houghton muck with underlying Newton loamy sand (*17*). Peat depth ranges from 0.5 to 3+ m A typical profile is as follows (Fig. 2): peat and muck (0-3.0 m, sand (3.0-3.5 m), clay (3.5-9.0 m). An example of a soil profile from the center of the wetland is given in Figure 2. Analyses of soil cores taken throughout the wetland indicate that an apparently continuous clay layer separates surface water and groundwater. The pH of surface and ground water (below 10 meters) ranges from 5.9 to 6.3 and 7.1 to 7.6 respectively.

A comparison of 1973-74 precipitation and temperature data with a 29-year average is given in Table 3. The amount of rainfall in 1973 and 1974 was 4.85 cm below and 5.81 cm above the 29-year average

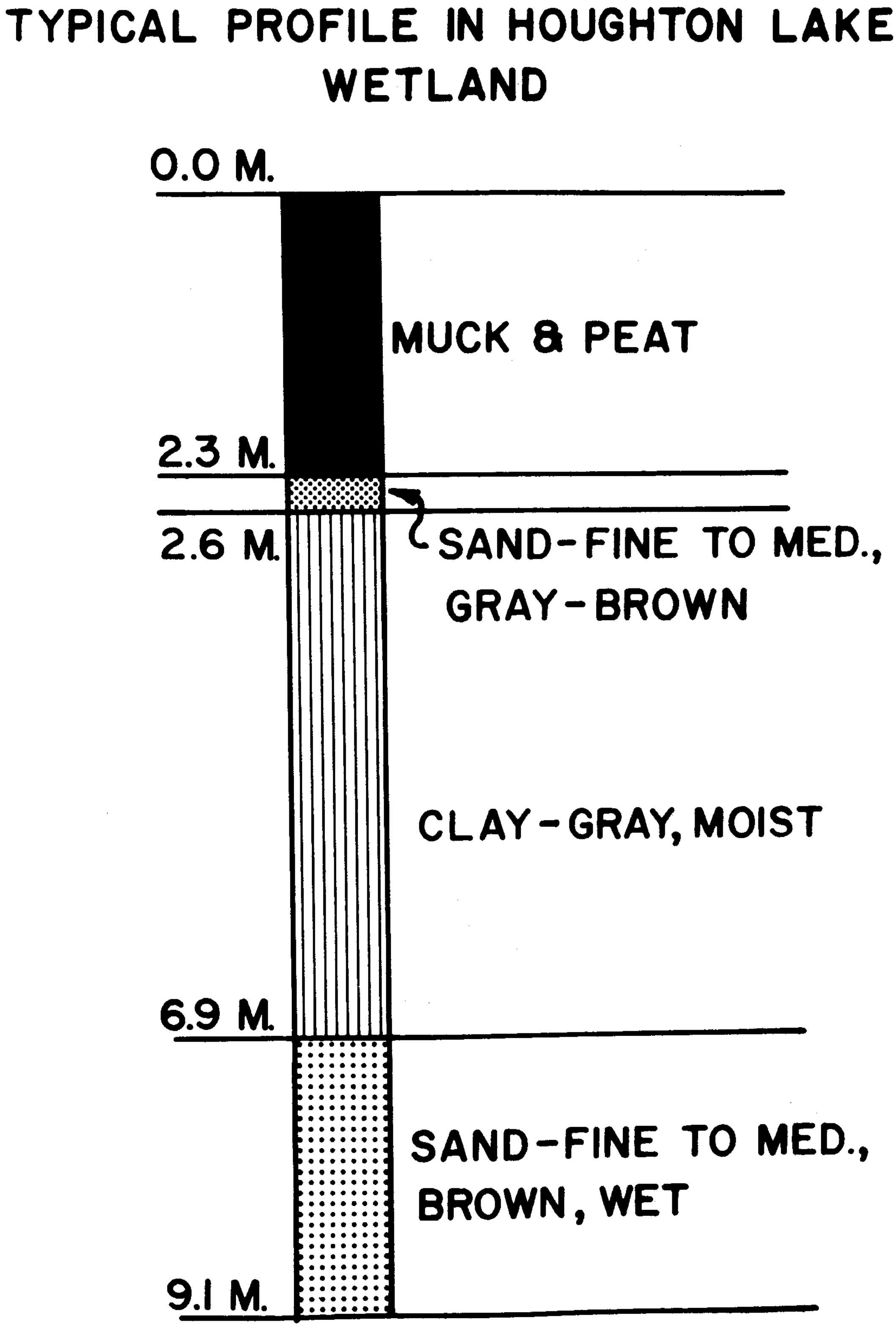

Fig. 2. Soil profile in Houghton Lake wetland.

Table 4. Simulated sewage effluent treatments 1973-1974.

Chemical	1x(Kg/ha/year)[2]	TREATMENT LEVEL[1] 2x(Kg/ha/year)
$Na_2H_2Po_4, 7H_2o$	51.3	100.7
$NaHco_3$	167.2	332.5
NH_4No_3	19.0	36.1
NH_4cl	43.7	87.4
Nacl	214.7	431.3
Fe(10%)[3]	58.9	119.7
Totals[1]	554.8	1107.8

[1]Other elements added (Mg/L) through use of groundwater Ca-35, Mg-12, Na-2, K, Cl, No_3, Po_4 and Fe = 1. For 4X and 10X treatment multiply 1X by 4 and 1X by 10.

[2]Nineteen weekly applications during each year (April-September).

[3]Technical sodium ferric diethylenetriamine pentaacetate equivalent to 14.2% Fe_2O_3..

respectively.

Methods

Nutrient Addition Experiments. In April 1973, sixteen 6 x 6 m plots were laid out randomly in the Bog Birch, Leatherleaf and Sedge-Willow cover types and randomly assigned experimental treatments. Twenty subplots 1 m x 1 m inside each plot were established, numbered and randomly given harvest dates. A factorial arrangement of treatments with simulated effluent (4 treatments x 5 collection periods x 4 replications x 2 cover types) consisted of four control plots (no treatment), four plots receiving water only (12.6 liter/m^2/week), four low water (6.3 liters/m^2/week) and low nutrients (1x), and four water (12.6 liters/m^2/week) and high nutrients (2x) (Table 4). Nutrient concentrations were PO_4 (phosphate) 15mg/l, NH_4 (ammonium) 16 mg/l, NO_3 (nitrate) 12 mg/l, Fe (iron) 5mg/l, Na (sodium) 120mg/l, Cl (chlorine) 135 mg/l, HCO_3 (bicarbonate) 102 mg/l. Ground water was used in these applications from late April through early September in 1973 and 1974. Groundwater nutrient concentrations averaged: Ca, 35 mg/l; Mg, 12 mg/l; Na, 2 mg/l; and less than 1 mg/l for K, Cl, NO_3, NH_4, PO_4 and Fe.

During May 1974, three additional treatment plots of 3 x 6 m were established in an area dominated by sedges (*Carex aquatilis* Wahlenb., *C. lasiocarpa* Ehrh. and *C. oligosperma* Schkuhr). The treatments here were: control (no application); 4x (four times the 1x level applied) (Table 4) and 10x. The simulated effluent was added biweekly from late May to late September in just enough water to dissolve the chemicals and allow even dispersal (about 7 liters).

Plant Biomass Harvesting and Growth Analyses. During the 1973-74 low fertilization experiment (1x, 2x) a random subplot (1 m^2) from each of the 6 x 6 m plots was harvested monthly from May through September 1974 in the high fertilization experiments (4x, 10x). New growth and old growth , stems, leaves, flowers, standing dead matter and litter were sampled. Mean standing crop per unit time was used to calculate relative growth rates (RGR) and net assimilation rates (NAR) according to the methods of Sestak *et al.* (*18*).

Soil cores were taken at three depths during May and July 1973 and chemical analyses were performed at the Michigan State University Soil Testing Lab (*19*). Hydraulic conductivity on intact soil cores was completed in our laboratory (*20*).

Litter Sampling and Decomposition Studies. Following removal of aboveground vegetation, four random 1m^2 subplots per treatment were sampled for litter down to the peat surface in each cover type during five sampling periods in May-September 1973 and twice in May and August 1974. All samples were oven dried to a constant weight at 85°C.

In September 1973 a total of 1300 litter bags (20cm x 20cm in size) with a 1mm opening were divided equally between the two cover types. Half of the bags were positioned at the surface, and half with their remaining portions placed 20 cm below ground level. Sixteen litter

PLANT TYPE	PERCENT OF AREA	AREA (HECTARES)	AREA (ACRES)
CATTAIL	1.8	12.6	31.2
ASPEN	2.5	17.9	44.2
ALDER	3.4	24.3	59.9
WILLOW	3.9	28.2	69.6
OPEN WATER	5.0	35.8	88.4
LEATHERLEAF-BOG BIRCH	19.1	136.6	338.0
SEDGE	21.8	155.8	384.7
SEDGE-WILLOW	42.6	304.4	751.9
TOTALS	100.0	715.6	1767.9

Table 1. Vegetation cover types on the Houghton Lake wetland, Michigan, 1973.

Table 2. Frequency of occurrence ($1M^2$ plots) of vascular plants in the Houghton Lake wetland, Michigan, 1973.

	SPECIES	FREQUENCY (%)
1.	*Carex* spp. (narrow leaved)	82
2.	*Aster junciformis* Rydb.	82
3.	*Salix* spp.	72
4.	*Betula pumila* L.	70
6.	*Spirea alba* Duroi.	66
6.	*Calamagrostis canadensis* (Michx.) Beauv.	64
7.	*Chamaedaphne calyculata* (L.) Moench	60
8.	*Solidago* spp.	55
9.	*Muhlenbergia glomerata* (Willd.) Trin.	49
10.	*Carex* spp. (wide leaved)	32
11.	FERNS	25
12.	*Lycopus* spp.	19
13.	*Iris virginica* L.	19
14.	*Typha latifolia* L.	17
15.	*Lysimachia* spp.	16
16.	*Cicuta bulbifera* L.	16
17.	*Scirpus cyperinus* (L.) Kunth	15
18.	*Populus tremuloides* Michx.	14
19.	*Andromeda glaucophylla* Link.	13
20.	*Alnus rugosa* (Duroi) Spreng.	13
21.	*Campanula aparinoides* Pursh.	12
22.	*Vaccinium macrocarpon* Ait.	10
23.	*Utricularia* spp.	10
24.	*Bidens tripartita* L.	9
25.	*Hypericum virginicum* L.	9

Table 3. Monthly climatological summary for Houghton Lake, Michigan (1940-1969, 1973, 1974)[1]

	Temperatures (Celsius)					Precipitation (cm)		
Month	Mean	1940-1969 Maximum	Minimum	1973 Mean	1974 Mean	1940-1969 Mean	1973 Mean	1974 Mean
Jan.	-6.94	-2.50	-11.44	-5.50	-6.70	3.71	3.10	7.95
Feb.	-6.44	-1.22	-11.72	-7.72	-10.89	3.02	3.38	2.90
March	-1.83	4.06	-7.72	3.39	-2.61	4.14	4.95	3.66
April	6.28	12.78	-0.28	6.17	5.77	6.12	4.22	8.81
May	12.44	19.67	5.17	10.33	9.72	7.19	12.40	7.42
June	17.94	25.11	10.83	18.28	15.72	8.53	7.21	11.68
July	19.78	27.17	12.44	19.83	19.19	7.92	5.94	11.94
Aug.	19.11	26.17	12.00	20.50	17.67	6.50	5.82	7.16
Sept.	14.83	21.28	8.39	14.11	11.22	7.90	4.95	6.43
Oct.	9.61	15.67	3.50	10.72	5.78	6.91	7.99	3.56
Nov.	2.17	6.22	-1.94	2.11	2.50	6.30	3.40	3.58
Dec.	-4.33	-0.56	-8.17	-5.06	-	4.57	4.60	3.63
				Average Annual Total		72.81	67.96	78.62

[1]Data summaries from Michigan Department of Agriculture (1975)

[2]Average annual snowfall was 151.38 cm for years 1940-1969.

bags from each group were collected at 215, 265, 320 and 370 days and 8 bags were sampled at 590 days. For further detail on methods and experimental design see Chamie (*21*).

Water Sampling Procedures. Surface water samples were collected from 45 locations following standard limnological techniques (*22*). Half of each sample was filtered at 0.45 micron and frozen along with the unfiltered half for chemical analyses. These were completed within the two months following. Peat interstitial water was collected from screened wells placed at 15 cm and 45 cm in 29 locations on a .4 km grid through the wetland.

At the 6 x 6 m test plots water was collected from screened wells located in the center of each plot, and at 1.0 m and 2.5 m outside of each test plot. Due to low hydraulic conductivity and surface contamination, collections were taken from sample wells 24 hours after being pumped dry to insure collection of soil water only. All subsurface samples were filtered at 0.45 micron because finely divided detritus introduces variability in nutrient analyses. Acidity and conductivity were measured on unfiltered aliquots within two hours of their collection.

Precipitation samples were collected in acid-washed plastic rain collecters. Samples were collected immediately following rains and frozen within two hours for nutrient analysis.

Hydrology and Climatology. A series of marked staffs were used in a bimonthly sampling of surface water levels within the wetland. Each collection station was equipped with a local bench mark. Outflows from the wetland were measured at six outflow channels. Estimates of water velocity, channel depth and width were used for calculating volumetric flows. Rainfall was collected in a standard rain gauge at each end of the wetland. Evapotranspiration was measured with a class A weather pan (U.S. Weather Bureau) and a Piche evaporimeter. Daily temperature data was collected at several locations within the wetland. Stream inflows are ephemeral and were measured as above. Total inflow by percolation was determined by difference.

Laboratory Plant Analyses. All plant material was oven-dried to a constant weight at 85°C, weighed and then ground to pass a 20 mesh Wiley Mill screen All plant weights (standing crop, biomass, etc.) are reported here on a dry weight-basis. Materials were stored in plastic vials up to six months prior to wet washing (*23*). Total nitrogen was determined using semi-micro Kjeldahl digestion (*19*). Phosphorus was determined colorimetrically by the molybdate vanadate technique after acid digestion (*24*). Total carbon was determined by dry combustion at 550° for 12 hours (*19*). Cations were determined by atomic absorption spectrophotometry after wet ashing (*24*). For more complete descriptions of the techniques used see Chamie (*21*), Wentz (*16*) and Richardson, *et al.* (*26*).

Laboratory Water Analyses. All water samples were frozen within two hours after collection. Cation analyses (Ca^{++}, Mg^{++}, K^+ and Na^+) were completed following standard procedures of atomic absorption spectrophotometry (*25*). An auto-analyzer (*27*) was used to analyze for NO_3, NH_4, PO_4, Fe and Cl.

Nitrate was measured by the Greis-Ilsovay reaction and is reported as NO_3-N (*22*). The Berphelot reaction was used to analyze for NH_4-N (*22*). After manual digestion total phosphorus was analyzed using the molybdate reaction (*22*). Chloride analyses followed standard auto-analyzer techniques (*27*).

Statistical Analyses. Data analyses were conducted using MIDAS statistical computer programs from the University of Michigan Statistical Research Laboratory (*28*). All two-way and three-way variance analyses were run using the BMDX64 factorial program. Simple and complex contrasts were determined using the *a posteriori* test developed by Tukey (*29*) and Scheffe (*30*) respectively.

A critical level $\alpha = 0.10$ was initially set for all ANOVA's in the field experiments. This level was chosen based on the inherent variability in population sampling and problems in field procedures. Representative sets of results from each type of analysis were tested and appeared to meet the assumptions of the model. Summary statistical analyses followed Sokal and Rohlf (*31*).

Background Ecology. This section gives baseline levels for vegetation productivity, soil and water chemistry and hydrology. An understanding of the functioning of the Porter Ranch Peatland ecosystem is a first principle in decision-making on the effects of nutrient perturbations.

Vegetation Productivity. Seasonal changes in net primary production for the Bog Birch-Leatherleaf cover type for 1973 are given in Figure 3. The total above-ground live weight (dry weight in g/m^2) of Leatherleaf increased from a low of 448.7 g/m^2 in early May to over 635.2 g/m^2 by September. The average net productivity for leatherleaf on this site was 186.5 $g/m^2/yr$ with relative growth rates (RGR) and net assimilation rates (NAR) of 3 mg/g/day and 1.42 $g/m^2/day$, respectively. Net production of Leatherleaf at our site is considerably higher than the 106.1 $g/m^2/yr$ reported for Leatherleaf by Reader and Stewart in Southern Manitoba (*32*). The total above-ground dry weight of live Bog Birch increased from 302.2 g/m^2 in May to a high of 453.1 g/m^2 in July (Fig. 3). Average net production was 150.9 g/m^2 with RGR and NAR equalling 7 mg/g/day and 2.47 $g/m^2/day$ respectively. Bog Birch maintained a higher net productivity from May through July than Leatherleaf but its overall standing crop is less due to its higher leaf litter fall (*21*) and shorter growing period. Leatherleaf is an evergreen species which retains its leaves until the next season's foliage has matured (*33*). Total live standing biomass (Leatherleaf + Bog Birch + herbs, in g/m^2) for the Leatherleaf-Bog birch plots in May, June, July, August and September of 1973 was 765.65 ± 72.75, 705.89 ± 96.10, 936.26 ± 138.39, 799.43 ± 83.85, 948.00 ± 180.74, respectively.

During 1973 the total above ground live biomass of all vascular plants for Sedge-Willow plots (SW) increased from 132.50 ± 45.25 g/m^2 in May to a high of 411.18 ± 48.46 g/m^2 in August. This change in standing crop of some of the individual components is given in Figure 4. Sedge increased from 47.8 g/m^2 im May to 240.16 g/m^2 in September. The standing crops of Sedge reported here are outside the range of

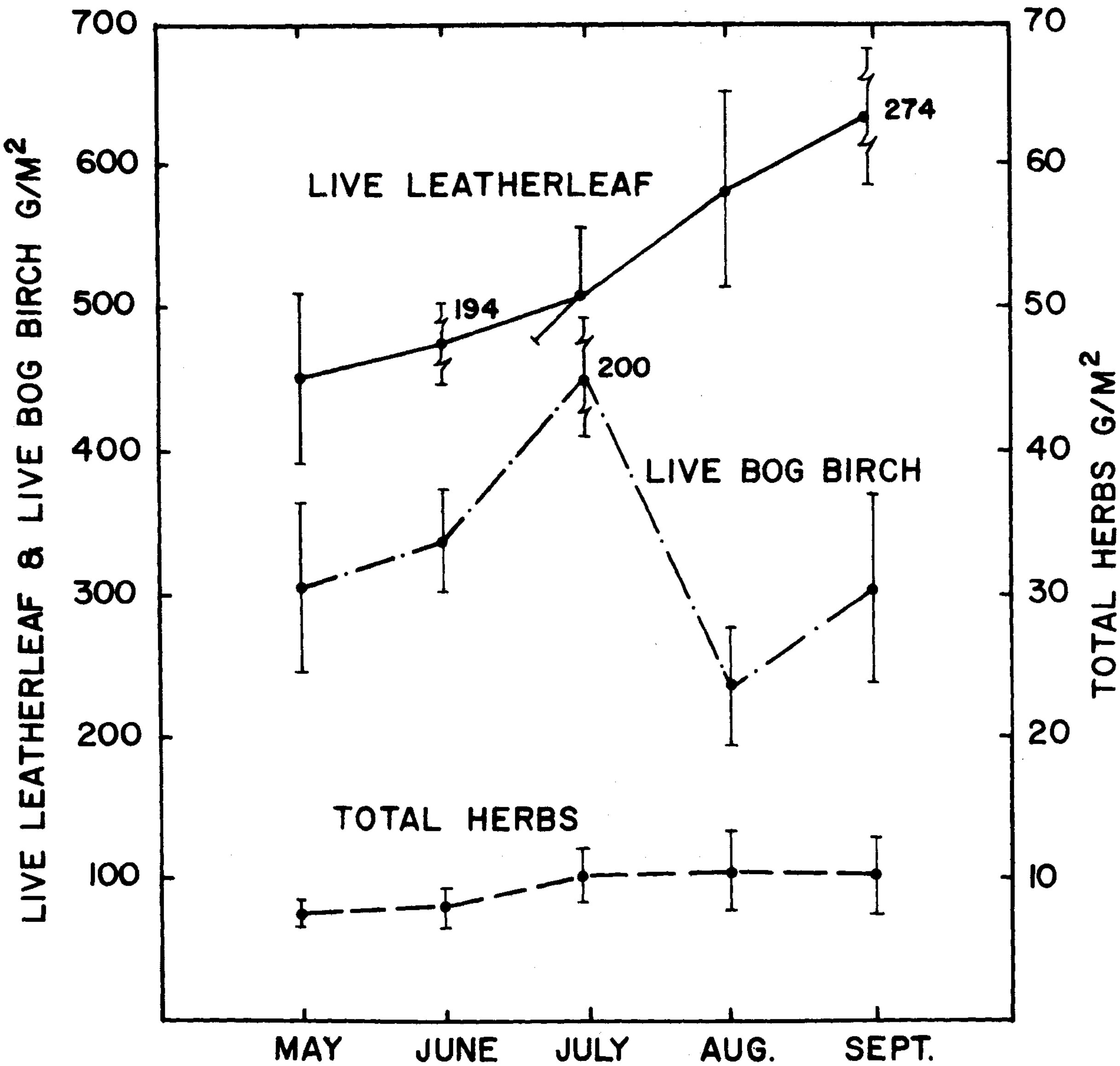

Fig. 3. Seasonal changes in dry weight of standing crop of the principal plant components in Leatherleaf - Bog birch cover type in the Houghton Lake wetland, 1973. Error bars denote one standard error of the mean. Numbers on the error bars indicate actual ± values.

Table 5. Summary of Chemical[1] Characteristics of Peat soils, Houghton, Michigan, 1973.

	Depth and Date Samples Were Taken				
	15 cm		30 cm		105 cm
	May	July	May	July	May
S-W Cover Type					
pH Range	5.5-5.7	5.9-61	5.2-5.7	6.0-6.3	6.5
Carbon (Percent)	32.2	38.7	35.8	29.5	1.9
Phosphorus (PPM)	1.9	6.9	1.0	3.0	0.8
Nitrates (PPM)	-	18.3	-	19.2	-
Calcium (PPM)	1588.0	1693.0	1906.0	2473.0	1137.0
Magnesium (PPM)	149.-	193.0	174.0	223.0	103.0
Potassium (PPM)	56.0	89.0	34.0	29.0	14.0
LL-BB Cover Type					
pH Range	5.1-5.4	5.3-5.9	5.1-5.5	5.1-5.8	6.0
Carbon (Percent)	40.8	45.3	47.0	41.7	24.3
Phosphorus (PPM)	1.8	2.3	1.6	1.0	1.8
Nitrates (PPM)	-	18.8	-	38.1	-
Calcium (PPM)	1358.0	1363.0	1842.0	1451.0	1684.0
Magnesium (PPM)	149.0	162.0	190.0	176.0	203.0
Potassium (PPM)	29.0	30.0	23.0	29.0	17.0

[1]Tests were performed by the Michigan State University Soil Testing Laboratory. Phosphorus was determined using the Bray P1 procedure. Total exchangeable K, Ca and Mg were extracted with neutral normal ammonium acetate in a 1 soil: 8 extractant ratio shaken for one minute. Carbon was determined by dry combustion.

values (283-1071 g/M2) reported for a wide variety of Sedges and are below the average of 545 g/m^2 given by Bernard (*34*). Our lower Sedge values are due in part to the high frequency and abundance of Willow, grass and herb species in some of the plots.

Herbivory by insects and highly clumped distribution of Willow made seasonal growth patterns difficult to interpret. Live Willow biomass values ranged from 98.77 ± 123.62 g/m^2 in September to a seasonal high of 264.38 ± 652.41 g/m^2 in June and averaged 166.6 ± 28.3 g/m^2 during the season. Grasses and herbs made up less than 15% of the total standing live biomass throughout the season (Fig. 4). The total standing dead portions decreased through the growing seasons until August. Late summer dieback began in mid-August and was noted in the September harvest.

Soil Chemistry. Chemical analyses of Houghton peat (a histosol) reveal that the highest levels of carbon and soluble phosphorus are found in the upper layers of the soil profile (Table 5). Acidity and potassium content decrease with depth in both cover types. Higher carbon but lower phosphorus and potassium levels are found in the Leatherleaf-Bog Birch cover types. The status of calcium and magnesium was relatively uniform throughout the profile in both cover types. The chemical composition of the Houghton peat closely follows the characteristics of peat soils as reported by Buckman and Brady (*10*) and Walsh and Barry (*35*).

Soil Physics and Hydrology. Surface water from the west side of Houghton Lake drains into the peatland from the northeast. It exists to the south and southwest toward the Muskegon River, primarily over the Dead Horse Dam (Fig. 1). Most of the water that passes through the wetland is surface flow, with the largest amount leaving during the spring overflow. Values for hydraulic conductivity of Sedge-Willow peat soils ($35.1 \pm 8.5 \times 10^{-5}$ cm/sec) measured in the laboratory indicate that it will take approximately nine years for a unit of water to flow one kilometer through subsurface peat (15-30 cm deep). This flow rate of about 30 cm/day is close to values reported by Boelter (*20*) for herbaceous and partially decomposed peat, and indicates the importance of surface flow vs. subsurface flow in peat soils.

Standing water is present through most of the growing season. Lower water levels are found during late summer and early fall (Fig. 5). During 1973 evapotranspiration increased during May and June, and then declined during the balance of the summer (Fig. 5). Outflow levels were directly proportional to major rains and were highest during late May to early June, and then declined during the balance of the summer. Inflow also paralleled the rainfall curve.

Water Chemistry. A comparison of the normal geographic and temporal nutrient levels for the nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N) and total dissolved phosphorus (PO_4) for stream inputs, outputs-the Muskegon River above and below Porter Ranch Peatland and the wetland surface water itself is given in Figure 6.

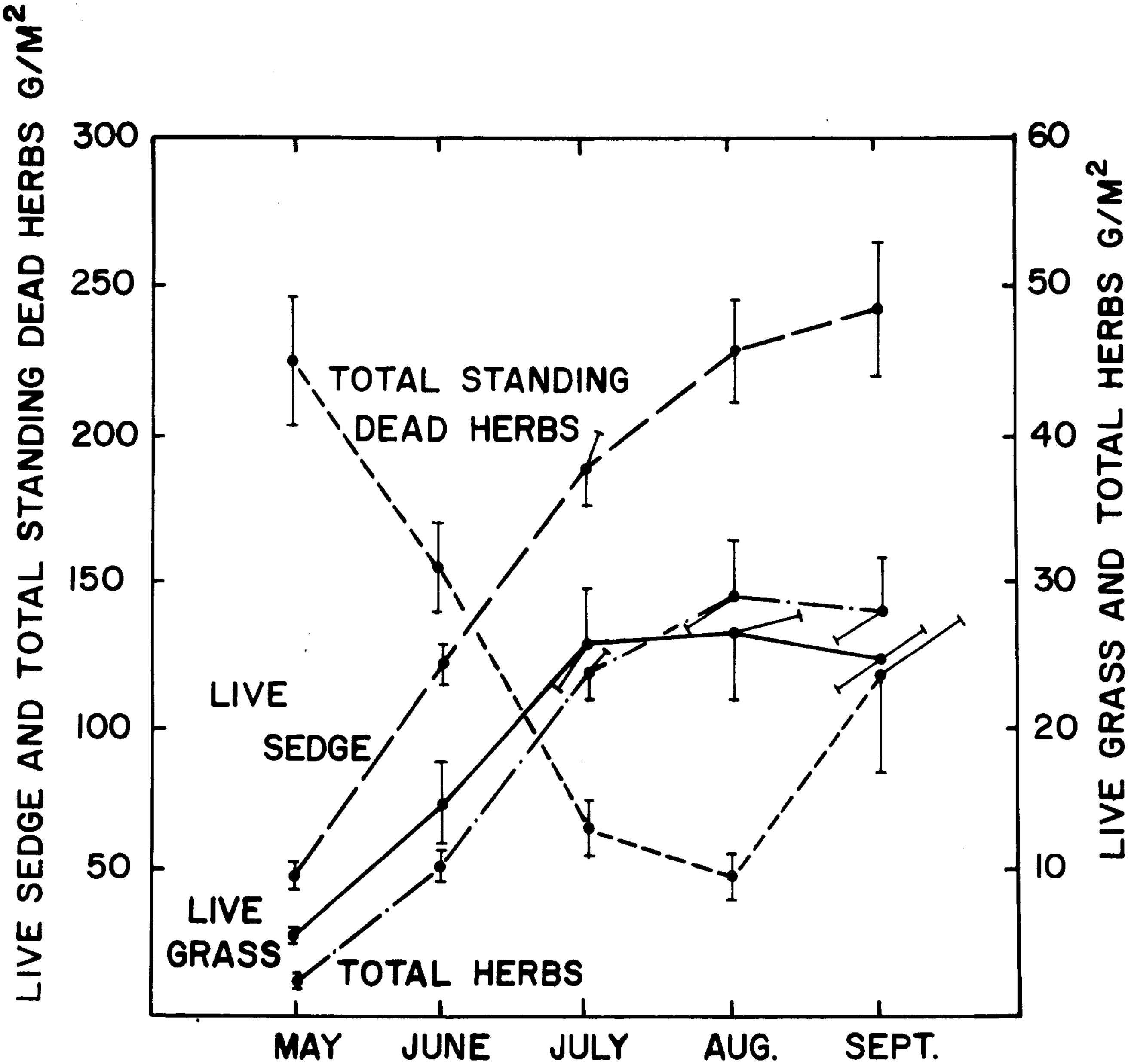

Fig. 4. Seasonal changes in standing crop of the principal plant components in Sedge - Willow cover type in the Houghton Lake wetland, 1973. Error bars denote one standard error of the mean.

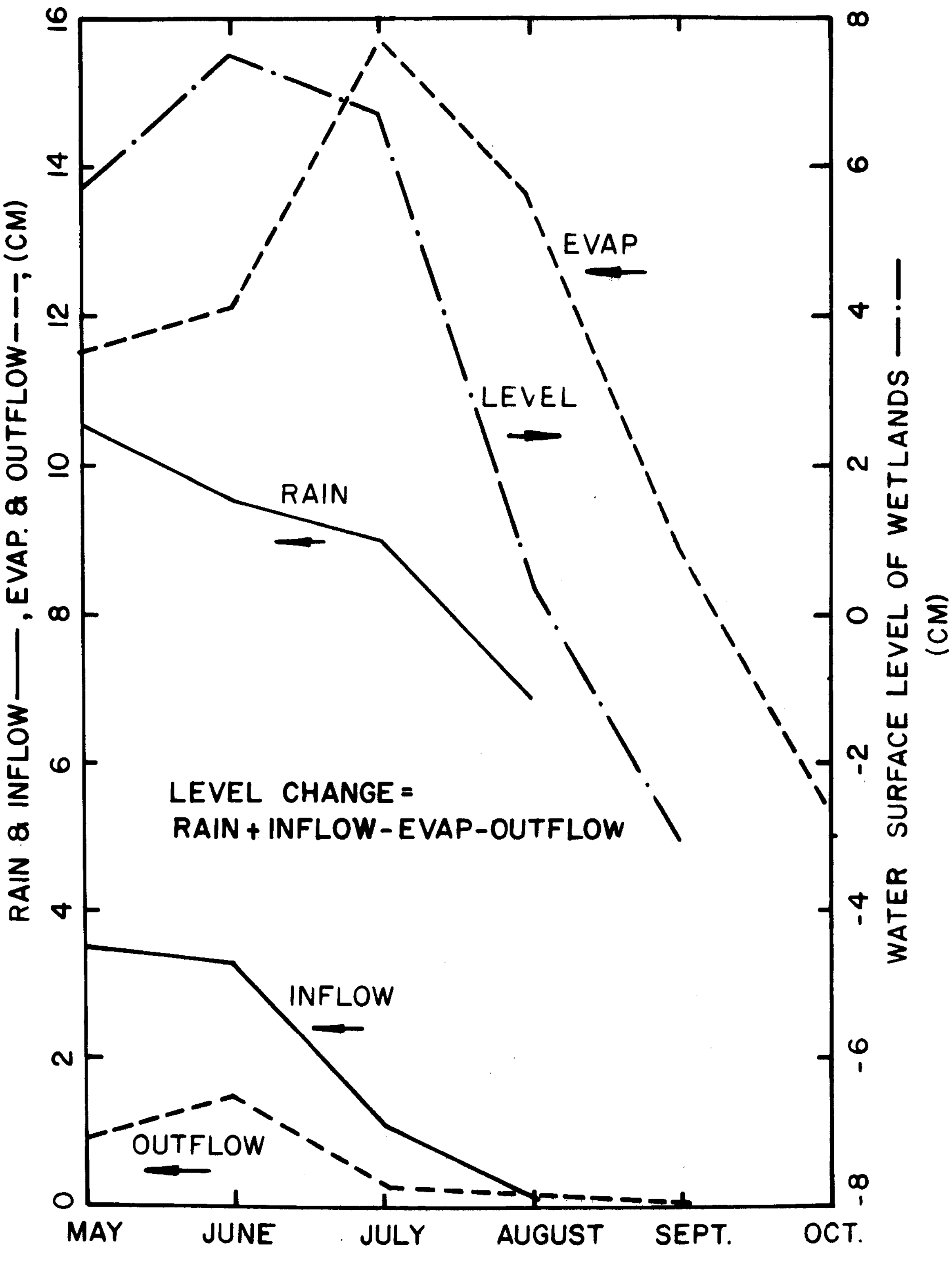

Fig. 5. Monthly totals for the Houghton Lake wetland water budget. Field data are represented except for inflow, which is determined by difference.

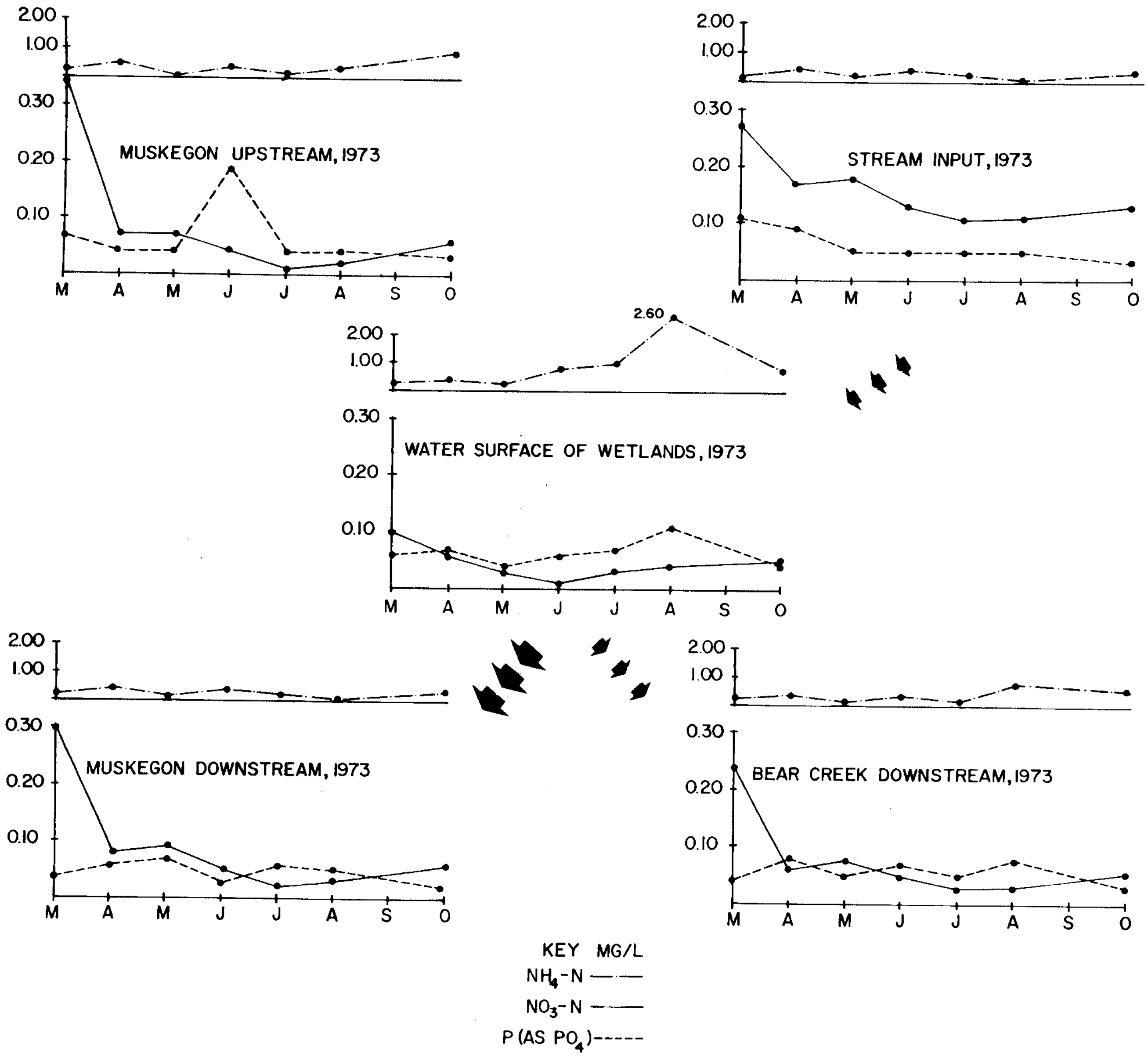

Fig. 6. Seasonal background nitrate-nitrogen, total dissolved phosphorus (as PO_4), ammonium-nitrogen concentrations in water for the peatland surface, stream inputs and outputs, and for the Muskegon River above and below the wetland.

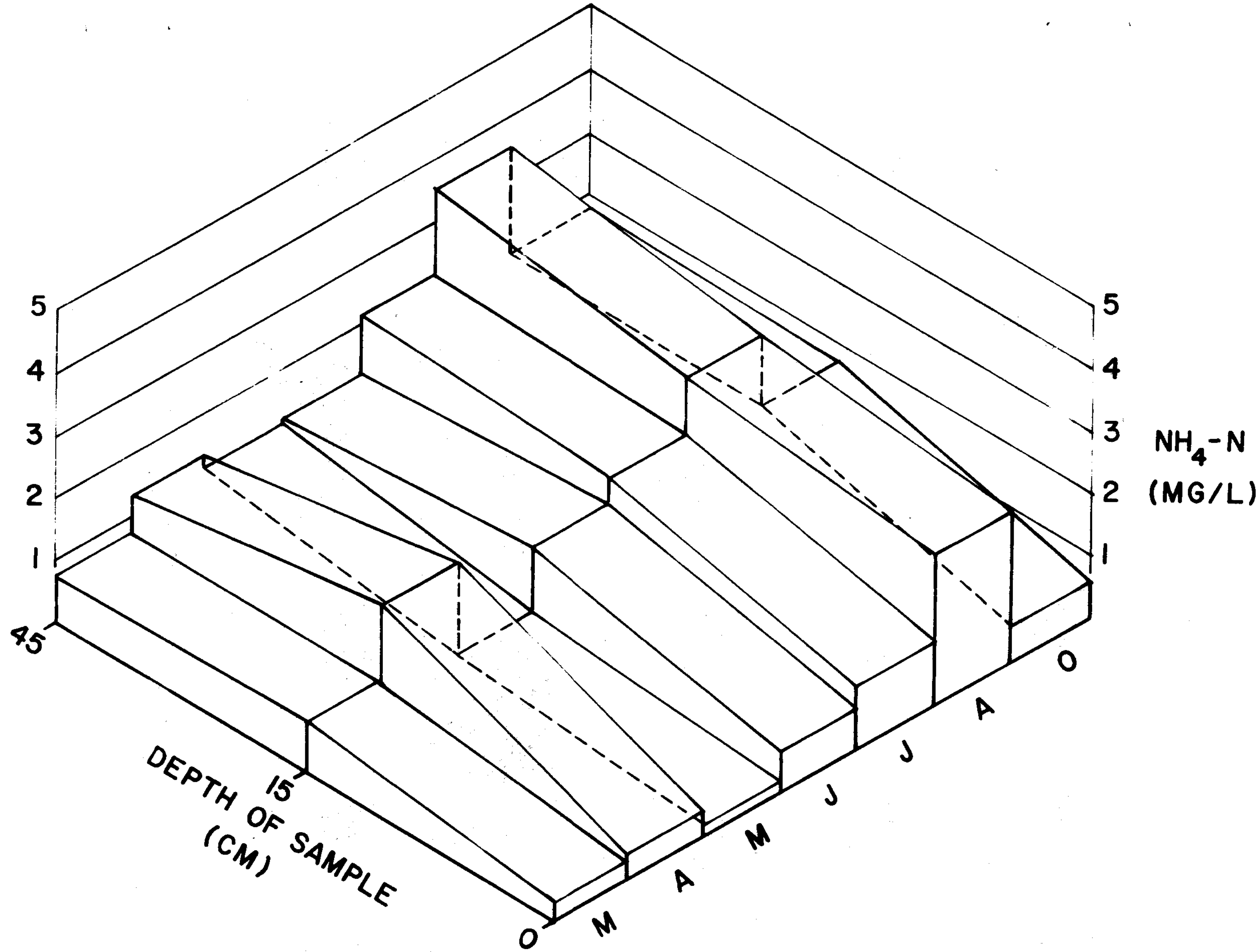

Fig. 7. Ammonium-nitrogen concentrations in interstitial and surface water during the 1973 growing season.

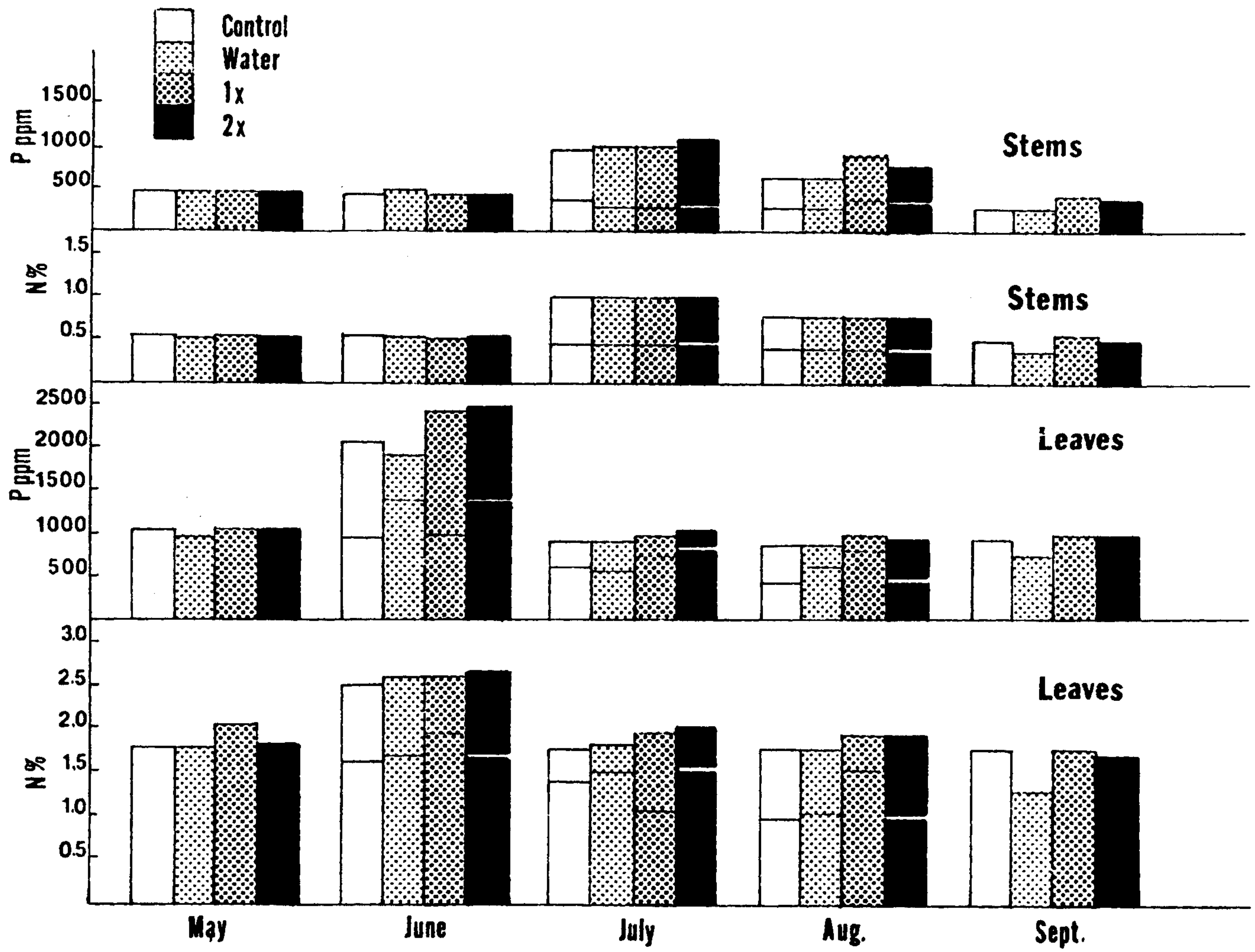

Fig. 8. Effects of simulated sewage effluents on nitrogen and phosphorus concentrations in Leatherleaf leaves and stems; broken columns indicate new tissue above and old tissue below (refer to Table 4 for treatment levels.

Table 6. A Comparison of Average Yearly Water Chemistry Concentrations for Houghton Lake Wetland

	Ion (mg/L)					
	NO_3-N	NH_4-N	PO_4-P	Ca	Mg	Na
	$\bar{x}$ S.E.	$\bar{x}$ S.E.	$\bar{x}$ S.E.	$\bar{x}$ S.E.	$\bar{x}$ S.E.	$\bar{x}$ S.E.
Muskegon River Downstream	0.09±0.04	0.24±0.05	0.05±0.01	33.70±2.30	9.00±0.82	6.17±0.82
Dead Horsedam Overflow	0.07±0.03	0.91±0.34	0.08±0.02	18.17±2.71	4.29±0.76	2.11±0.34
Wetland Surface	0.05±0.01	0.83±0.31	0.06±0.01	18.37±1.26	3.79±0.24	7.01±0.77
Wetland 45 cm	0.07±0.01	1.71±0.41	0.09±0101	32.94±3.31	6.36±0.49	4.57±0.41
Wetland Deep Well (10 meters)	0.11±0.01	0.26±0.14	0.04±0.01	35.50±4.39	11.50±1.40	2.17±0.22
Precipitation	0.33±0.06	0.42±0.07	0.08±0.02	1.30±0.25	0.20[2]±0.05	0.40[2]±0.06
Simulated Sewage Effluent	12.00±0.00	16.00±0.00	15.00±0.00	35.00±0.00	12.00±0.00	120.00±0.00

1. S.E. = one standard error of the mean (n for Muskegon = 7, overflow = 34, surface 146, 45 cm, 162, Deep well 3 and precipitation 10). Simulated sewage effluent was prepared to uniform concentrations for each treatment.

2. Data from Pellston, Michigan (1973), a rural collection station 70 miles from Houghton Lake, Michigan.

The highest NO_3-N levels were found in early spring and slowly decreased until late summer (Fig. 6). The wetland surface water generally had lower levels of NO_3-N than all inputs or outputs. Ammonium-nitrogen values remained below 1 mg/L (ppm) throughout the season in input and output surface waters (Fig. 6). The levels of NH_4-N were greater than 2 mg/L in the wetland surface by late summer. This may have been due to increased ammonification of dead plant tissue during higher summer temperatures. The geographic and seasonal fluctuations in dissolved phosphorus (Fig. 6) are variable and difficult to interpret. In most cases PO_4 declined over the period of study, but in the peatland itself there was an increase which peaked at the end of August. The increased PO_4 may be due to the increased aerobic decomposition of organics caused by a drop in the level of water in this wetland (Fig. 5). Radio-isotope experiments (*32P*) are currently underway to help determine P transfers between the biotic and abiotic components of this ecosystem.

The discharge concentrations of the NO_3-N, NH_4-N and PO_4 are in the range of values previously reported for marsh discharge in Wisconsin (*15*). It should be stressed that marked seasonal variations of concentrations of these nutrients *do* occur in wetland ecosystems, and that they are important in calculating total input-output budgets.

We found variations in interstitial water nutrient concentrations varying with depth in the soil profile. For example, the highest concentrations of NH_4-N were found at the 45 cm depth (Fig. 7). This is due to increased nitrate reduction and ammonification found under anaerobic (waterlogged) soils (*8*). Increases in late summer NH_4-N concentrations at all levels parallel the increases in plant decomposition (*20*).

Results and Discussion

1973-4 Low Level Nutrient Experiment (1x, 2x). These results must be considered preliminary for two reasons. First, according to ecological theory and practice, short-term data from small test plots can be suggestive but not conclusive. Second, a complete analysis of long-term total ecosystem effects must await the completion of total hydrologic and input-output nutrient budgets over several seasons after our present larger-scale study of 151,000 l/day on a 4 ha plot (*36*). However, the background ecology of the Porter Ranch Peatland when coupled with our findings from research on the 1x, 2x, 4x and 10x treatments (see Table 4) gives us an indication of the effects sewage effluent nutrients have on various ecological components of this wetland.

A general comparison of dissolved nutrient levels for the various divisions of this wetland ecosystem is given in Table 6. While yearly averages of nutrient levels may be deceptive, the relative magnitudes of nutrient types in various components of the system give us some basis for comparing the effects of the nutrient loadings on the ecosystem. For example, the sewage effluent introduced will be an order of magnitude higher in concentration than nutrient loading via precipitation (Table 6). However, precipitation inputs of N-NO_3 are much higher than background levels in most compartments. As noted before, the highest N-NH_4 concentrations are found beneath the surface of the wetland.

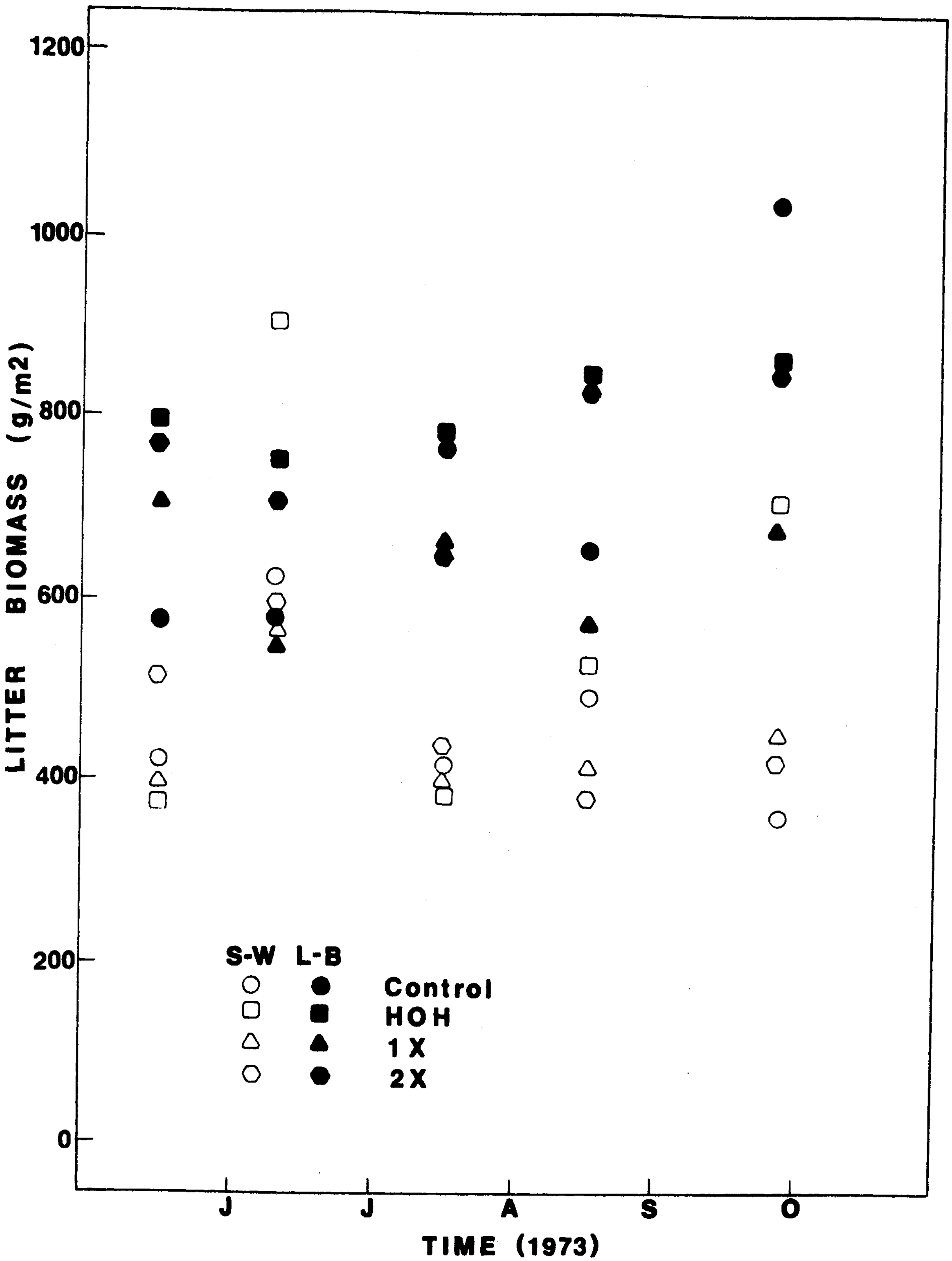

Fig. 9. Oven-dried litter biomass collected from the four groups of treatment plots (Control, HOH, 1X, and 2X) in the L-B and S-W cover types during 1974.

Table 7. Summary of Statistical Analyses for Two-way ANOVA
1973 Litter Biomass

Variable[1]	Source of Variation[3]	df[4]	F Ratio	Variable[2]	Source of Variation[3]	df[4]	F Ratio
Nitrogen	D	4	NS	Nitrogen	D	4	NS
	T	3	11.94*		T	3	2.88*****
	DxT	12	NS		DxT	12	NS
Phosphorus	D	4	3.72***	Phosphorus	D	4	3.49****
	T	3	13.93*		T	3	8.06*
	DxT	12	2.55****		DxT	12	NS
Potassium	D	4	4.18***	Potassium	D	4	NS
	T	3	NS		T	3	NS
	DxT	12	NS		DxT	12	NS
Sodium	D	4	5.93*	Sodium	D	4	6.61*
	T	3	13.68*		T	3	18.96*
	DxT	12	2.57****		DxT	12	2.13*****
Calcium	D	4	NS	Calcium	D	4	NS
	T	3	6.33**		T	3	5.05**
	DxT	12	1.80******		DxT	12	NS
Magnesium	D	4	NS	Magnesium	D	4	2.30******
	T	3	NS		T	3	8.45*
	DxT	12	NS		DxT	12	NS

[1]Samples from Sedge-Willow cover type

[2]Samples from Leatherleaf-Bog Birch cover type

[3]D = Date, T = Treatment

[4]Error term contains 52 degrees of freedom

*	P < .001
**	P < .005
***	P < .01
****	P < .025
*****	P < .05
******	P < .10

The major compartments of the treatment plots discussed here with respect to nutrient loading effects are leaves, stems, roots of key species, litter, recent litterfall, soil and water. The effects of low level nutrient additions on the net seasonal production, growth rates (RGR, NAR) and standing crops of Leather-leaf, Bog Birch, Sedges, Willow and Grasses were not significant at an α level of 0.10 during 1973 and 1974. There were also no significant statistical differences ($p < 0.10$) in N or P concentrations in leaves or stems of the same communities due to the different treatments. However, levels of N and P generally decreased in stems and leaves through the 1973 growing season. Nutrient analysis on 1974 plots for uptake is now being completed. An example of seasonal trends for vegetation components of Leatherleaf is given in Figure 8.

Due to a lack in growth response, there were no significant statistical differences due to treatment in litter biomass in the 1973 collections (Fig. 9). There were significant differences ($p = 0.001$) between the litter biomass collected from the Sedge-Willow cover type ($n = 72$, $\bar{x} = 486.0 \pm 29.6$ $gm.m^2$) compared with the Leatherleaf-Bog Birch cover type ($n = 72$, $\bar{x} = 737.0 \pm 29.5$ gm/m^2). The Leatherleaf-Bog Birch litter biomass of our study agrees with the total Muskeg litter biomass value of 840 g/m^2 reported for a Manitoba peatland by Reader and Stewart (*37*).

The lack of growth and nutrient uptake by plants in response to 1973 treatment suggested that the nutrients were either (a) lost from the system by leaching, volatization or runoff etc.; (b) absorbed or adsorbed by litter or soil; (c) taken up in the roots and stored; or (d) diluted extensively by surrounding water and rainfall.

A water analysis 4-7 days after treatment additions revealed that there were no consistent gradients from the centers of the plots to 2.5 m outside them. Kadlec *et al.* (*2*) also noted unchanged nutrient levels in interstitial water taken from the center of all treatment plots. Surface flow or diffusion outward from the plots could account for this. However, low water levels in the Leatherleaf-Bog Birch plots and low water levels during the latter part of the summer in the Sedge-Willow plots plus the low hydraulic conductivity of the peat soils ($35.1 \pm 8.5 \times 10^{-5}$ cm/sec) suggests minimal flow or leaching from the test plots. Work by Tusneen and Patrick (*8*) supports the loss of nitrogen in waterlogged soils by denitrification.

An analysis of soil nutrient status at three depths (15, 30, 105 cm) over several months indicated no difference in nutrient concentrations between control, 1x and 2x treatment plots.

A comparison of nutrient concentrations (N, P, K, Na, Ca, and Mg) in the litter component of this ecosystem revealed significant differences between test plots and control areas for every element in both cover types except for K and Mg in the Sedge-Willow type and for K in the Leatherleaf-Bog Birch cover type (Table 7).

An *a posteriori* test for complex contrasts combining the 1x with 2x plots and the water-only plots with control plots showed that fertilized plots were always significantly higher in nutrient concentration of litter than the unfertilized plots. Seasonal trends (1973-4) and treatment effects

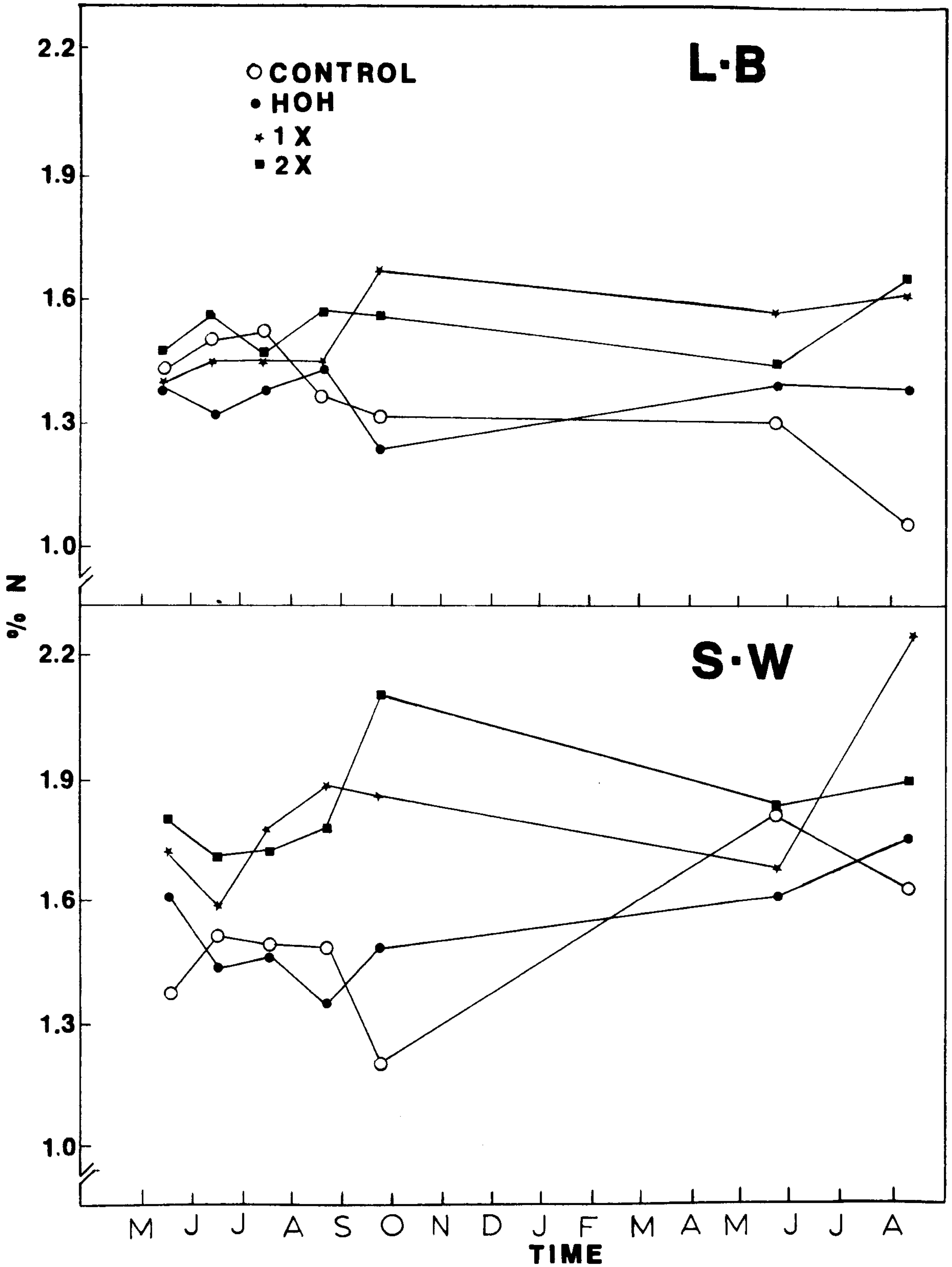

Fig. 10. Nitrogen concentrations in litter biomass collected from the L-B and S-W cover types, by treatment (Control, HOH, 1X, and 2X) during 1973 - 1974. All points represent a mean of four samples, except that for September, for which there were only two samples. Standard errors about the means never varies more than 15%.

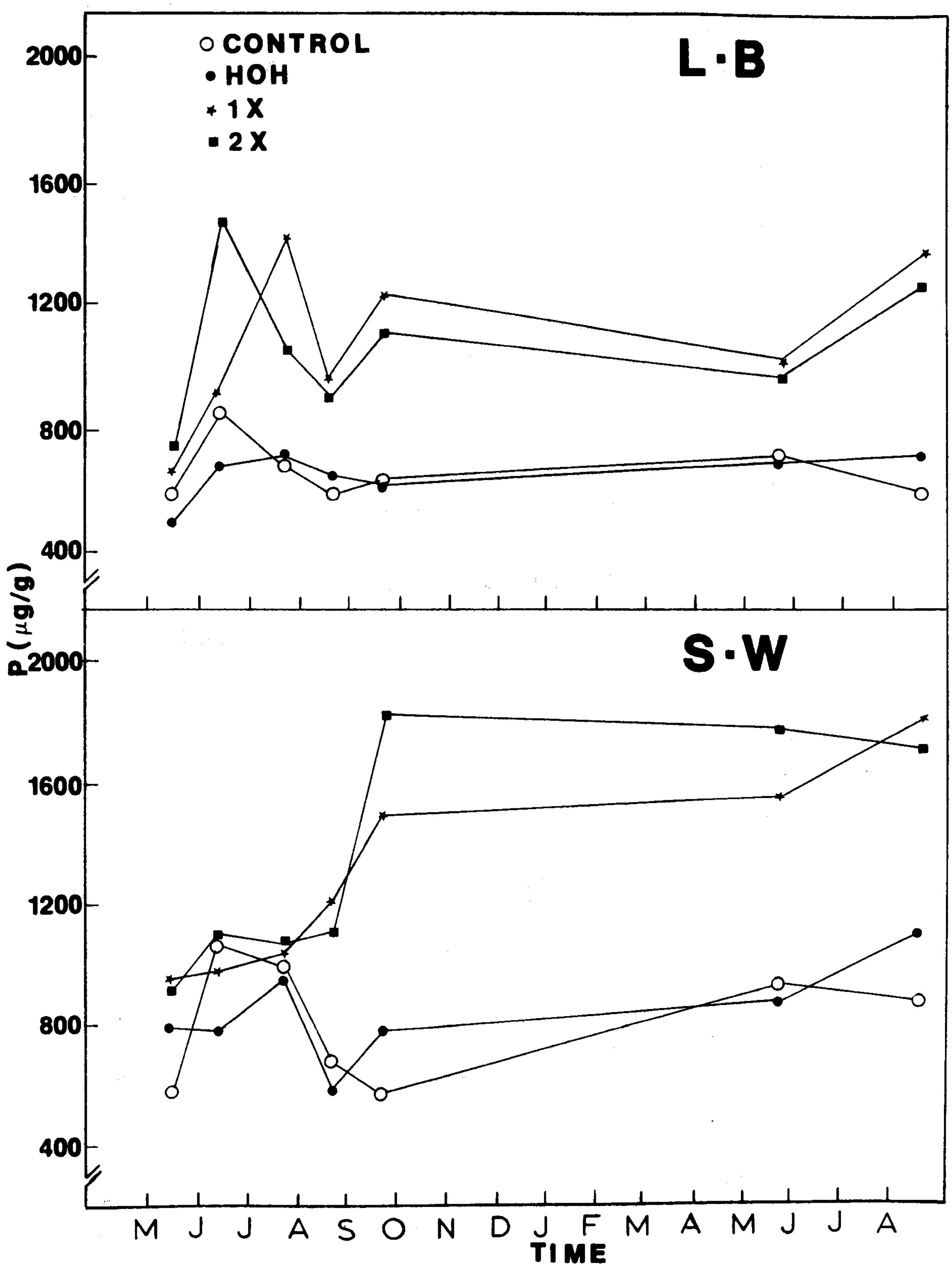

Fig. 11. Phosphorus concentrations in litter biomass collected from the L-B and S-W cover types, by treatment (Control, HOH, 1X, and 2X) during 1973 - 1974. All points represent a mean of four samples, except that for September, for which there were only two samples. Standard errors about the means never varied more than 20%.

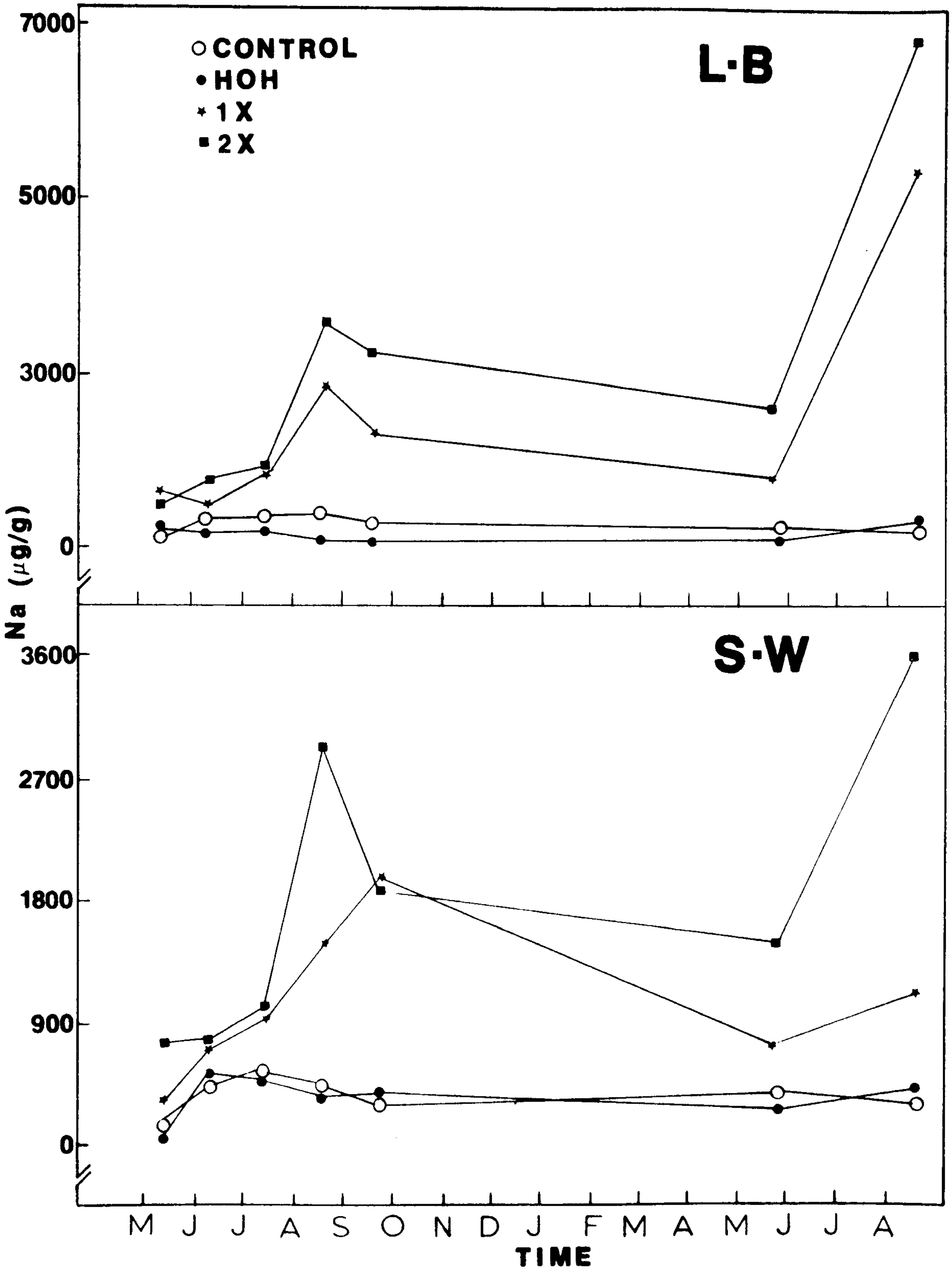

Fig. 12. Sodium concentrations in the litter biomass collected from the L-B and S-W cover types, by treatment (Control, HOH, 1X, 2X) during 1973-1974. All points represent a mean of four samples, except that for September, for which there were only two samples. Standard errors about the means never varies more than 32%.

on N, P and Na are shown in Figs. 10-12.

N, P, and Na in litter show a drop in concentration during the latter part of summer and early fall in the control plots (Figs. 10-12). The levels of N, P and Na in the treatment plots (1x, 2x) generally increase through the growing season. The Sedge-Willow/Leatherleaf-Bog Birch treatment plots, and control and water plots show a slight decrease and increase, respectively, in N concentration over the winter (Fig. 10) (*21*). The May 1974 concentrations for P and Na are the only elements that did not decrease to May 1973 levels in both cover types. This implies that Na and P are either tightly bound chemically or in insoluble forms less susceptible to leaching or uptake. The resistance to loss of P and Na is in part supported by Rodin and Bazilevich's (*38*) rate of loss sequence for bog-forests (N>Ca>K>MG = P>Na). Potassium, the most readily leached cation in wetland ecosystems (*39*) did not show significant treatment effects. This was expected because of the low level added in the simulated effluent and its high leaching rate.

The above data indicate that the litter layer is very important in the retention of added nutrients in our wetland ecosystem. Further analyses on its total sorption and exchange capcity are currently underway to test long-term capabilities. Peat soils also possess high cation exchange and sorption capacities (*10,21,40*). Thus, organic soils and litter may be acting as a major sink for a large portion of our nutrient additions. The effects of nutrient additions on peat buildup and decomposition rates are important in long-term ecosystem function and community stability.

The effects of nutrient additions on decomposition rates can be summarized as follows: (a) no significant differences ($p < .10$) by treatment were noted for weight or elemental losses -- (significant differences were detected through time (*21*); (b) weight losses never exceed 42% during the first year, with barely detectable losses occurring thereafter; (c) concentrations of elements decreased rapidly during the first seven months and the rate of loss for each element=K > Mg > P > N > Ca > Na. This closely followed the rate of loss reported for *Juncus* leaves by Latter and Cragg (*39*).

Laboratory experiments indicated that significant effects on growth and nutrient concentrations of N and P occurred from 1x and 2x nutrient loadings on sand grown Willow and Sedge (*16*). This suggests that if nutrients become available for uptake (not tied up in litter and soil) key wetland species could increase growth and nutrient concentrations.

High Nutrient Experiments. An analysis of 1974 higher nutrient loadings (4x, 10x treatment plots) on narrow leaf Sedge (*Carex lasiocarpa, C. oligosperma, C. aquatilis*) plots showed that after mid-summer the 4x and 10x treatment plots had significantly higher above aground standing crop than did controls (Fig. 13) (*16*). The maximum average standing crop on 10x treatment and control plots during early September was 506 g/m^2 and 49 and 385 g/m^2 reported from Alberta, Canada for *C. aquatilis* (*41*) and were in the range of 300-700 g/m^2 for *C. lasiocarpa* from Sweden (*42*).

The greatest biomass among the plots was that of the below ground samples (Fig. 13) (*16*). Peak below ground weight was found in early fall and reached 4289 g/m^2 on the 10x treatment plot in September. Below ground

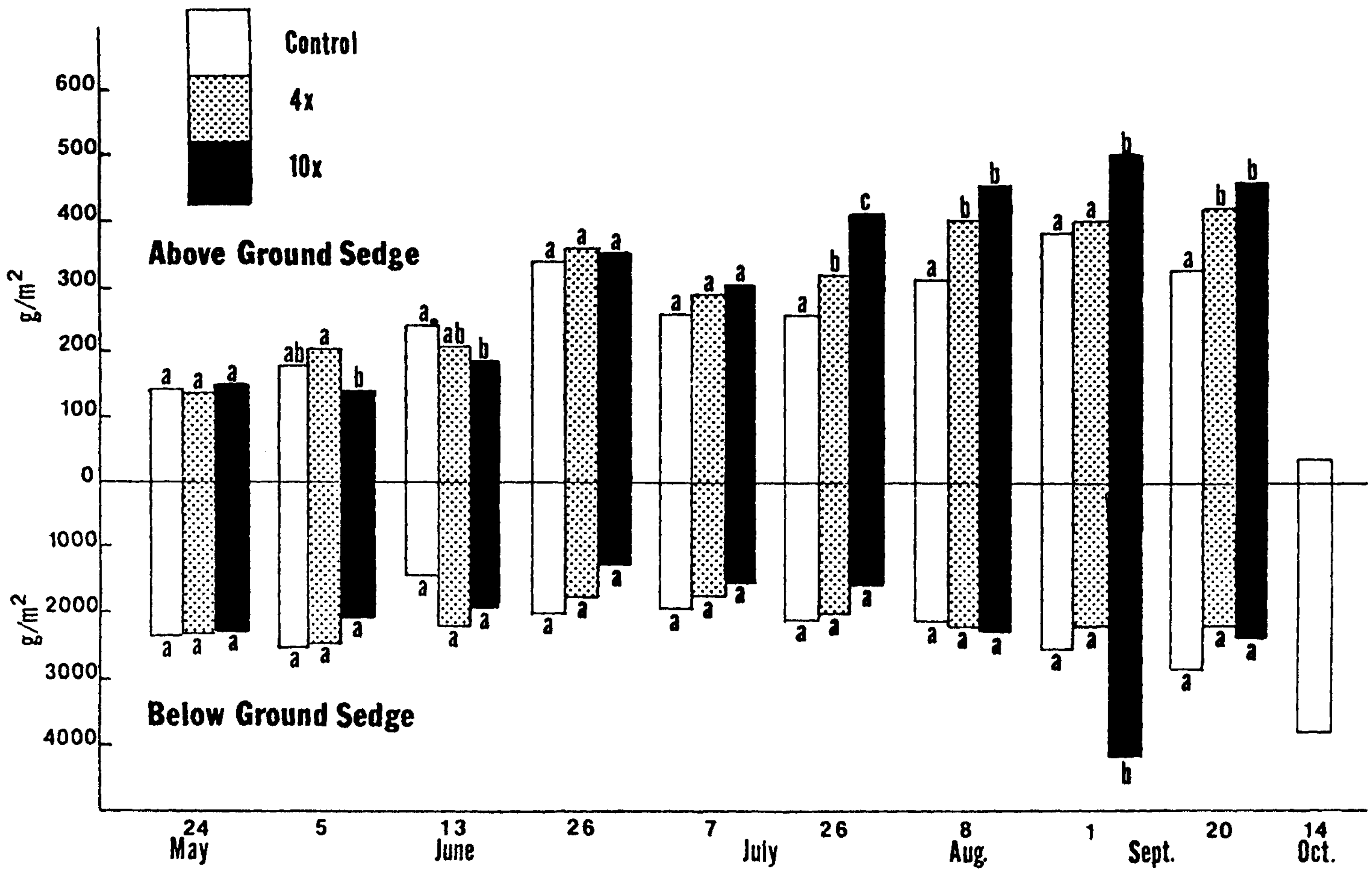

Fig. 13. Effects of simulated sewage effluents on standing crops of narrow-leaved Sedges. Unlike letters on the columns indicate significant differences at = .10 (refer to Table 4 for treatment levels).

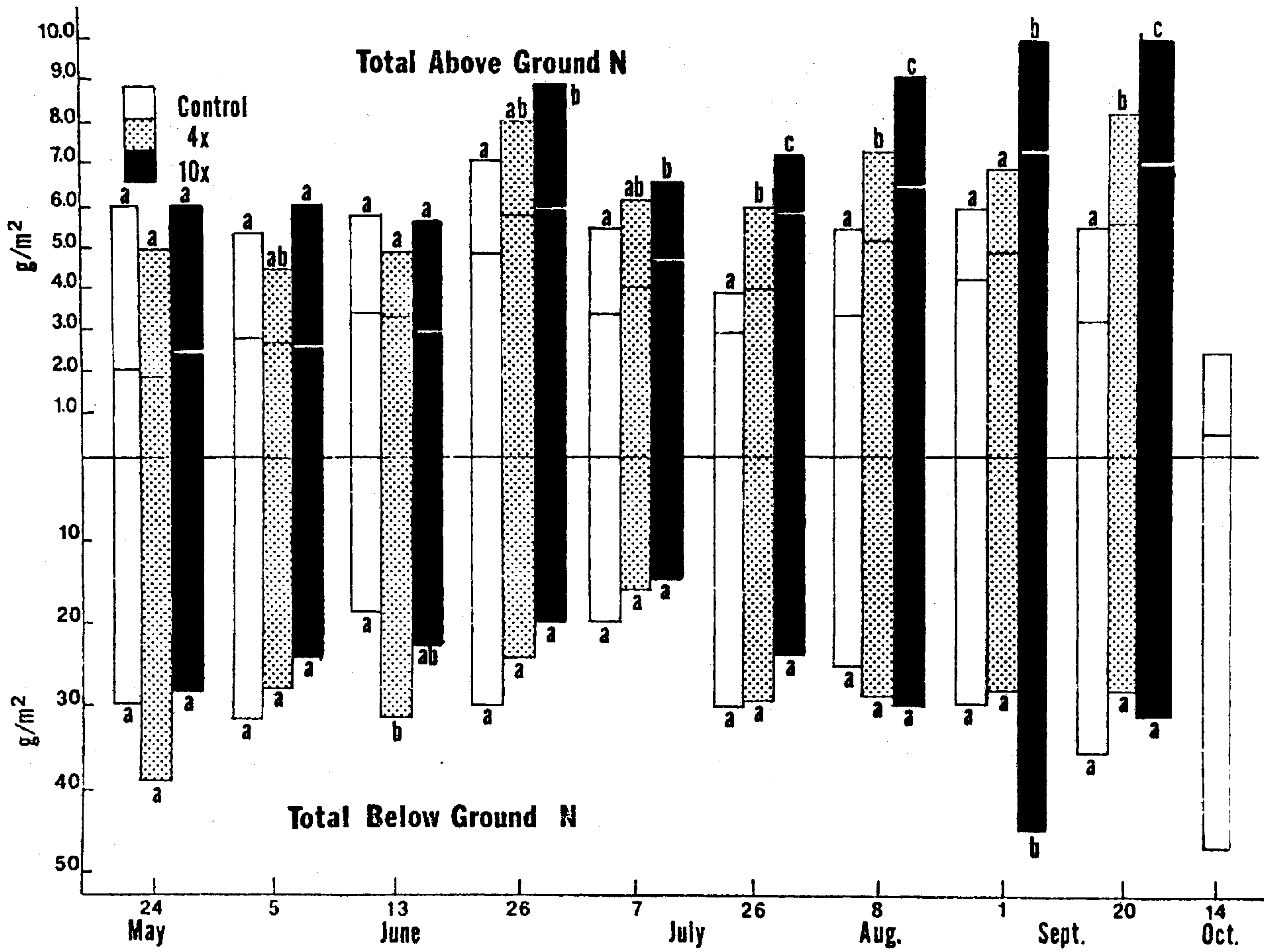

Fig. 14. Effects of simulated sewage effluents on the weight of nitrogen in narrow-leaved Sedges. Unlike letters on the columns indicate significant differences at = .10, and broken columns indicate the weight of nitrogen in live (below) and dead (above) tissue (refer to Table 4 for treatment levels).

net production averaged 1617.5 $g/m^2/y$ for all treatments combined. Thus, below-ground productivity is nearly 4 to 6 times as great as above-ground productivity.

The actual weight of nitrogen in above and below ground Sedges is shown in Figure 14 (*16*). Although the total weight of nitrogen in above-ground tissues on the control plots showed very little change during the growing season, the 4x and 10x treatment plots showed significant increases in total nitrogen weight through the season. A high correlaton ($r = 0.89$) exists between the increased nitrogen weight in above-ground Sedge on the treated plots and the total amount of nitrogen applied after mid-June (Fig 15).

Above-ground live sedge on treated plots (4x, 10x) showed significantly higher concentrations of phosphorus than did the control plots (Fig. 16) (*16*). Phosphorus concentrations decreased during the season on the control plots but increased in the treatment plots during the same period, reaching a maximum of 2030 ppm by mid-September (per g dry weight). The increase of phosphorus was also positively correlated to the amounts of P applied. Below-ground phosphorus concentrations were approximately the same for all treatment plots until late September (Fig. 16). Significant differences in sedge root P concentrations for September are difficult to explain since high levels in above ground parts seem to negate translocation to the roots. Increased availability and uptake by roots of P may result from increased decomposition of organics due to decreasing water levels in early fall. The current series of ^{32}P studies should help clarify the transfer rates between various components of the wetland ecosystem.

A great increase in P during early fall was also noted in the litter (Fig. 17) (*21*). This rapid increase in September was also found in the 1973 Sedge-Willow litter P concentration (Fig. 11) and closely followed the high P noted in August surface water (Fig. 6). This suggests some chemical change in the solubility of P and an uptake by sedge and litter.

There were no significant differences for N litter concentrations among treatments over time in the 1974 high treatment study (4x, 10x). Nitrogen, despite its high concentrations, was not chemically bound in the litter biomass but became incorporated into living plant tissue (Fig. 14).

The response of *Muhlenbergia glomerata* and *Aster junciformis* to the higher nutrient treatments was quite different from the sedge response. The highest standing crop (34.0 g/m^2) for *M. glomerata* was in September on the 4x treatment plots. In general, the 10x treatment resulted in decreased growth (*16*). This may be due to toxic effects of high nutrients or simply may be the results of being competed out by greater sedge growth.

Aster growth was reduced significantly by increased nutrient and salt applications. The highest levels (10x) resulted in almost complete disappearance of Aster by late summer (*16*). The decrease in Aster biomass on these plots corresponds to the loss of this genus reported from old field plots in Pennsylvania treated with sewage effluents for a 10 year period (*42*). A more complete summary of the responses of plants to high nutrient treatments is given by Wentz (*16*).

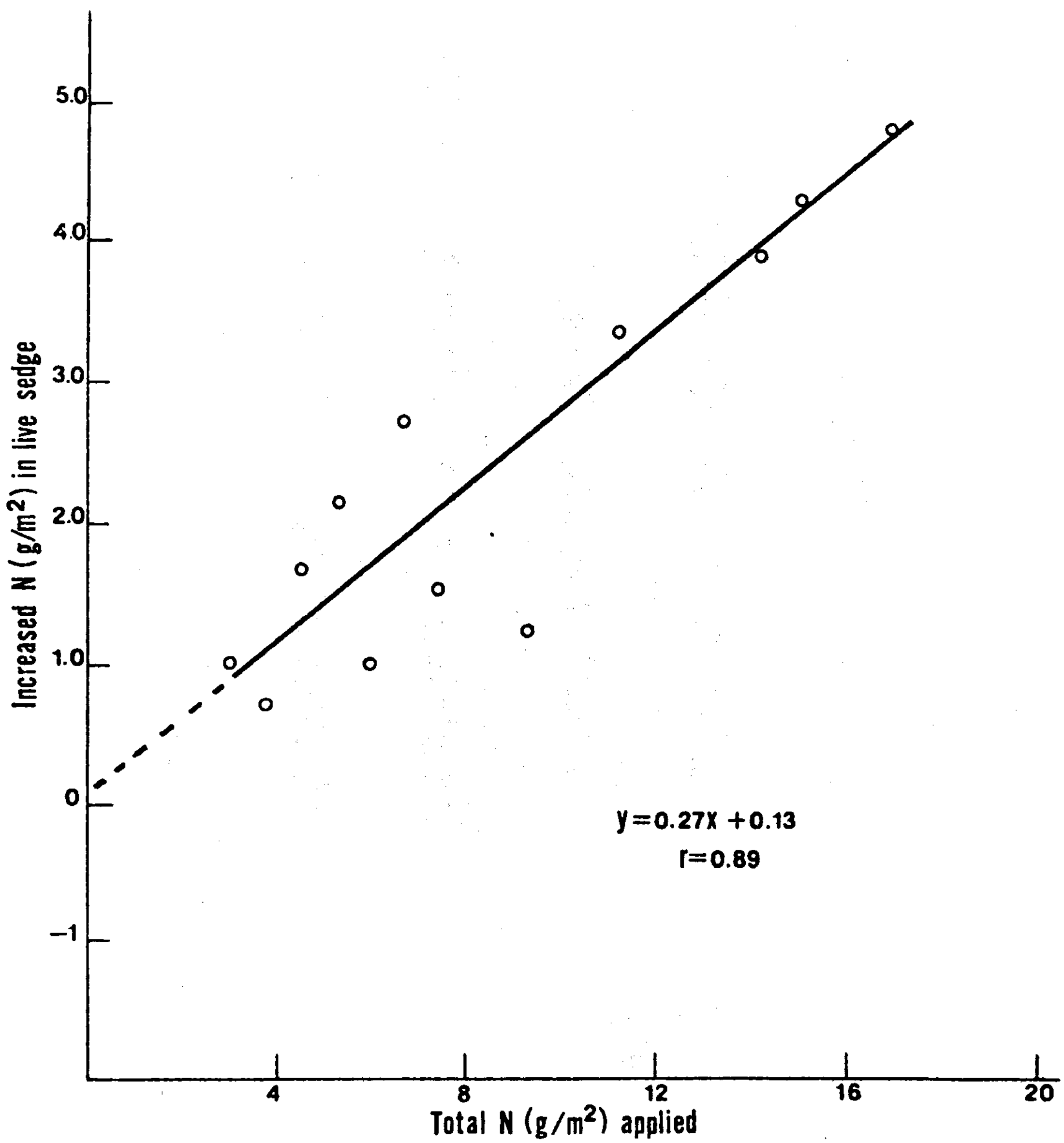

Fig. 15. The relationship of total nitrogen applied as simulated sewage effluent and the increased weight of nitrogen (average nitrogen quantity in treated plot minus average nitrogen quantity in control plot) in live Sedge tissues.

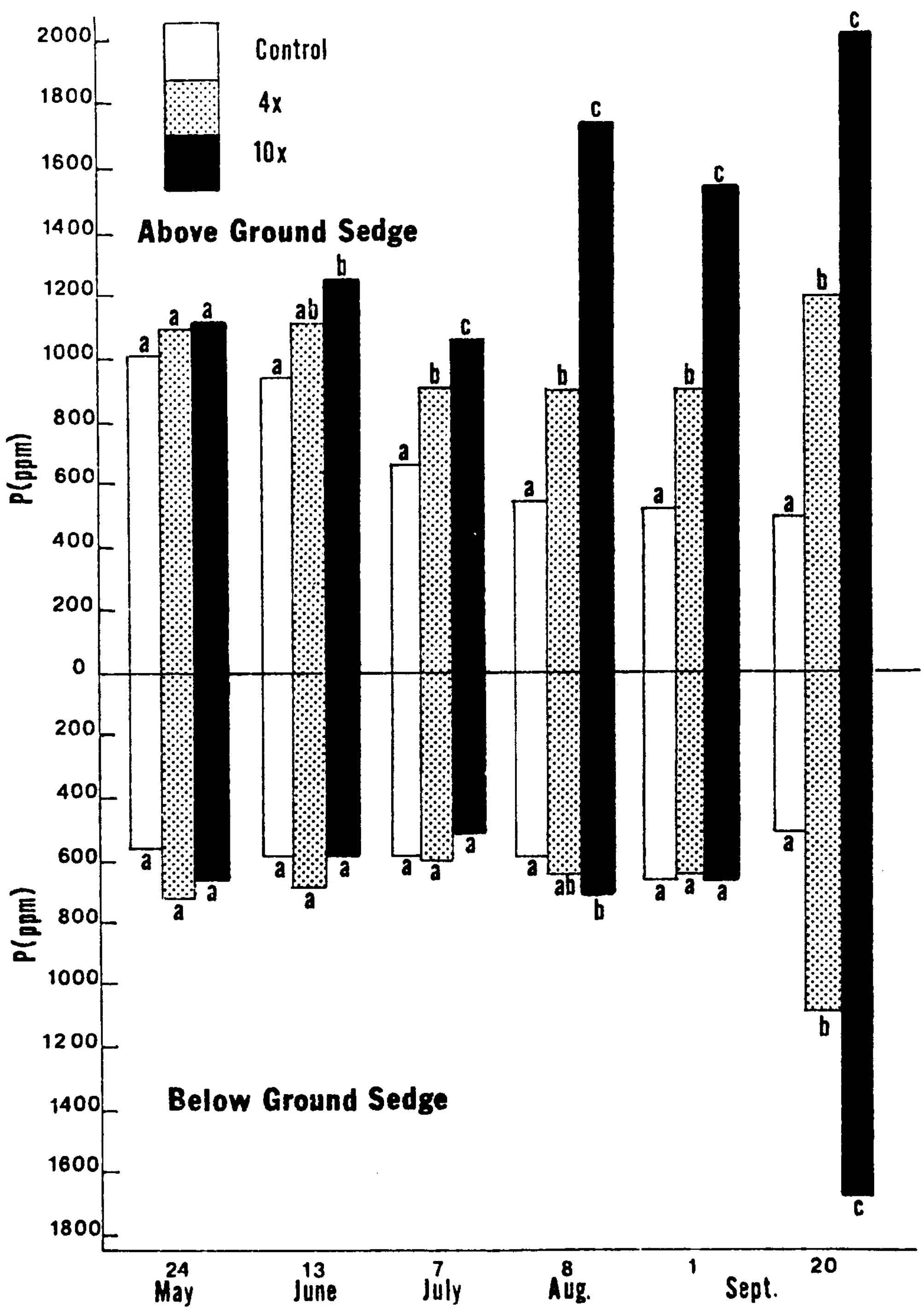

Fig. 16. Effects of simulated sewage effluents on phosphorus concentrations in live narrow-leaved Sedges. Unlike letters indicate significant differences at = .10 (refer to Table 4 for treatment levels).

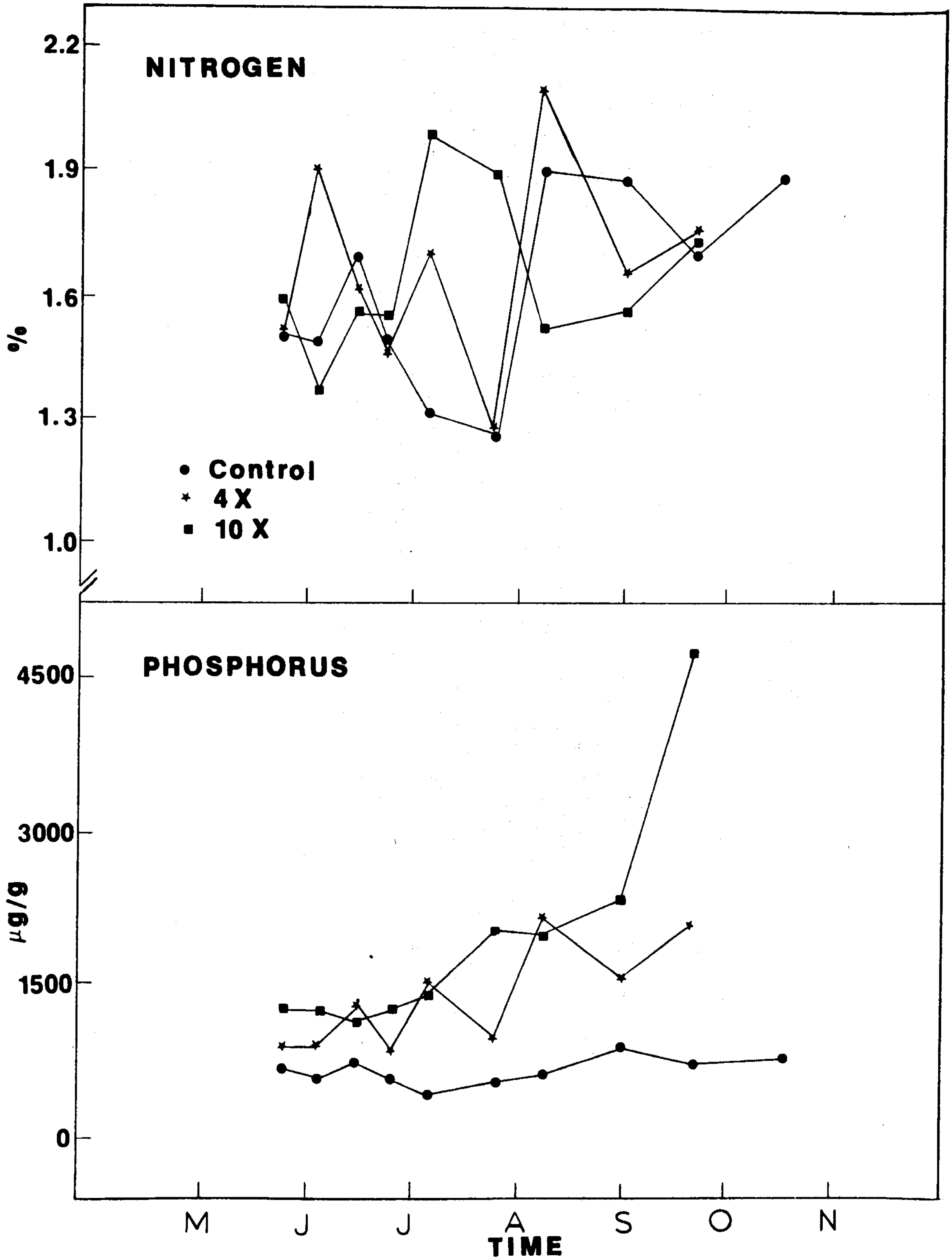

Fig. 17. Concentrations of nitrogen and phosphorus in the litter biomass collected from high fertilizations plots by treatment (Control, 4X, and 10X) during 1974.

Summary and Conclusions. In the porter Ranch Peatland, there were no significant differences in the N and P of the vegetation analyzed due to 1x and 2x treatments. This was probably due to the unavailability of these nutrients to the plants. However, laboratory studies indicated that increased growth and N and P concentrations occurred on Willow and Sedge when nutrients were available. Sedges in the 4x and 10x treatment plots showed higher above-ground biomass along with higher N and P concentrations than the control plots. Less abundant species, grass and aster, showed decreased growth.

The nutrient status of the litter biomass in the 1x and 2x study indicated that the fertilized plots were significantly higher than the unfertilized plots. Due to treatment effects, no significant differences were detected in the litter biomass. Only phosphorous concentrations showed increases in the 4x and 10x litter biomass. Nitrogen was apparently more available as reflected by increased concentrations and productivity in the above-ground Sedge biomass in 4x and 10x plots.

Per treatment, no significant differences were detected in the decomposition rates of the plant species tested. Measurements of water flow and leaching rates from the test plots also suggested that nutrient losses were minimal.

The slow rate of subsurface water movement (about 30 cm/day), the high denitrification rates for waterlogged soils, the high nutrient sorption capacity of organic litter and peat soils and nutrient uptake by some plant species all indicate that a peatland ecosystem has potential as a biological filter for plant nutrients. Definite long-term results of nutrient additions to the wetland ecosystem are yet unknown. The exact nature and extent of these changes are being tested in a large scale use of the peatland as an effluent disposal site. However, much of the evidence from our fertilization studies indicates that growth of some species will be enhanced, tissue nutrient concentrations will be increased, a few species (Asters and some Grasses) may be adversely affected, and the litter and organic soil will function as a nutrient sink.

However, all wetlands do not function the same ecologically; they undergo change in response to perturbations according to their individual structural and fundtional latitudes. Thus the conclusion that these natural filtering systems offer at least a short-term solution for removing a limited amount of nutrient input may only be applicable to peatland systems.

ACKNOWLEDGEMENTS

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WETLAND METABOLISM

by

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Introduction. All lakes are bordered by wetlands, and this area, the littoral zone, has received growing attention recently as the most metabolically active zone of lakes (*1,2*). The high level of biological activity in the littoral zone is sustained by nutrients and organic matter entering from watershed, by water from the lake, and by the solar radiation which supplies the energy of photosynthesis. The products and effects of the intense metabolism at the lake edge, in turn, are important factors influencing benthic and pelagic metabolism in the lake itself (*3*). Thus lake characteristics, including rate of eutrophication, depend upon the outcome of watershed/littoral zone/lake interactions.

Lakes may fill up with mineral and organic matter from their watersheds, or they may fill up with organic matter of their own making if their watersheds provide sufficient nutrients. Most of the post-glacial lakes formerly in our area are now extinct, having disappeared shortly after their creation during the retreat of the last glacier. Those lakes which remain, and which are the only ones available for direct study, represent a very select group of survivors, which, in their lifetimes, may have received from their watersheds many times the amount of organic matter needed to fill them up and many times the anount of dissolved nutrients needed to cause them to be obliterated by eutrophication. Thus we may hypothesize that the natural lakes of Connecticut experience forces counter to those influences which would fill them up. Further, wetlands occuring in the lake watershed, representing an extended littoral zone of intense ecological metabolism, are the most likely sites in which to find such homostatic mechanisms.

In this report we describe our speculations upon what makes wetlands unique in terms of ecological function and why they are so productive. Further, we will describe a field of study of the effect of a wetland upon the quality of surface runoff and upon its associated lake.

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AREA (A)	4.74 HA
VOLUME (V)	114,140 M^3
MAX DEPTH (Z_M)	4.6 M
MEAN DEPTH ($\bar{Z}$)	2.4 M
SHORE LINE (L)	853 M
MEAN RADIUS	123 M
SHORE LINE DEV (D_L)	1.11
VOLUME DEV (D_V)	1.6
RELATIVE DEPTH (Z_R)	3.7%

DUNHAM POND

Table 1. Morphometric data for Dunham Pond.

The Oxidized Rhizosphere. In our view, the best definition of a wetland is "a wetland is a place where aquatic plants are found". In turn, the best definition of an aquatic plant is "a plant which can aerate its roots in an anaerobic soil". Because of the relatively low solubility of oxygen in water (about 9-10 mg/l) water-saturated soils are usually anaerobic and distinctly different from unsaturated soils. In particular, saturated soils are frequently highly organic due to the absence of rapid aerobic decomposition. Toxic by-products of anaerobic processes, such as H_2S (hydrogen sulfide), can further reduce decomposition.

In the process of aerating their roots, wetland plants oxidize their rhizospheres and create a source of oxygen in an otherwise highly reduced situation. Anaerobic and microaerophilic microbes can colonize their particular optimal zone in the oxidation-reduction gradient between the oxygen-rich roots and the strongly reduced soil in a way analogous to the cytochrome system in cells. As a consequence, a flow of energy and materials can occur in the wetland ecosystem in which organic constituents are oxidized, reduced, made soluble, and/or volatilized. For instance, wetlands are important sources of atmospheric carbon (as methane), sulfur (as hydrogen sulfide), and nitrogen (as ammonia) which enter into important biogeochemical cycles. Further, through their roles in mediating the respiration of organic matter, wetland plants behave as important secondary producers (consumers) in the ecosystem.

Wetlands are also among the most productive places in the temperate zone, and one may hypothesize that this results from advantages that accrue to plants able to live in anaerobic substrates. For instance, the current level of carbon dioxide in the atmosphere is well below that in which green plants evolved. Thus, aquatic plants which have an abundance of carbon dioxide forming in their roots can realize enhanced photosynthesis. Similarly, oxygen was at much lower levels when higher plants evolved, and has risen to inhibitory levels since. An aquatic plant is literally rooted in an *oxygen sink*, and, as a result, may experience relief from the potentially poisonous effects of otherwise high oxygen levels in its tissues. We have found the intense metabolic activity of wetland plants (specifically those of the littoral zone of lakes and rivers) to be of critical importance to the ecological functioning of the system (*1*, *2*, *4*), and we suspect it is the cause of the effects we find at our experimental area.

Water, the Universal Solvent. Unlike fully terrestial plants, wetland plants are more or less frequently inundated in a very efficient solvent: water. Water is a very good polar solvent and a moderately good nonpolar solvent. Consequently, significant amounts of the carbohydrates formed by photosynthesis in wetland plants are lost from the plant and appear as dissolved organic carbon (DOC) in wetland surface water. For the same reasons, soluble and colloidal organic compounds are leached from leaves falling into wetlands from terrestrial vegetation as well as from decomposing soil organic matter. Bacteria process DOC very rapidly so that the actual concentration of DOC in wetland water is a poor indication of what has a actually become available there. In fact, the DOC found in wetland water

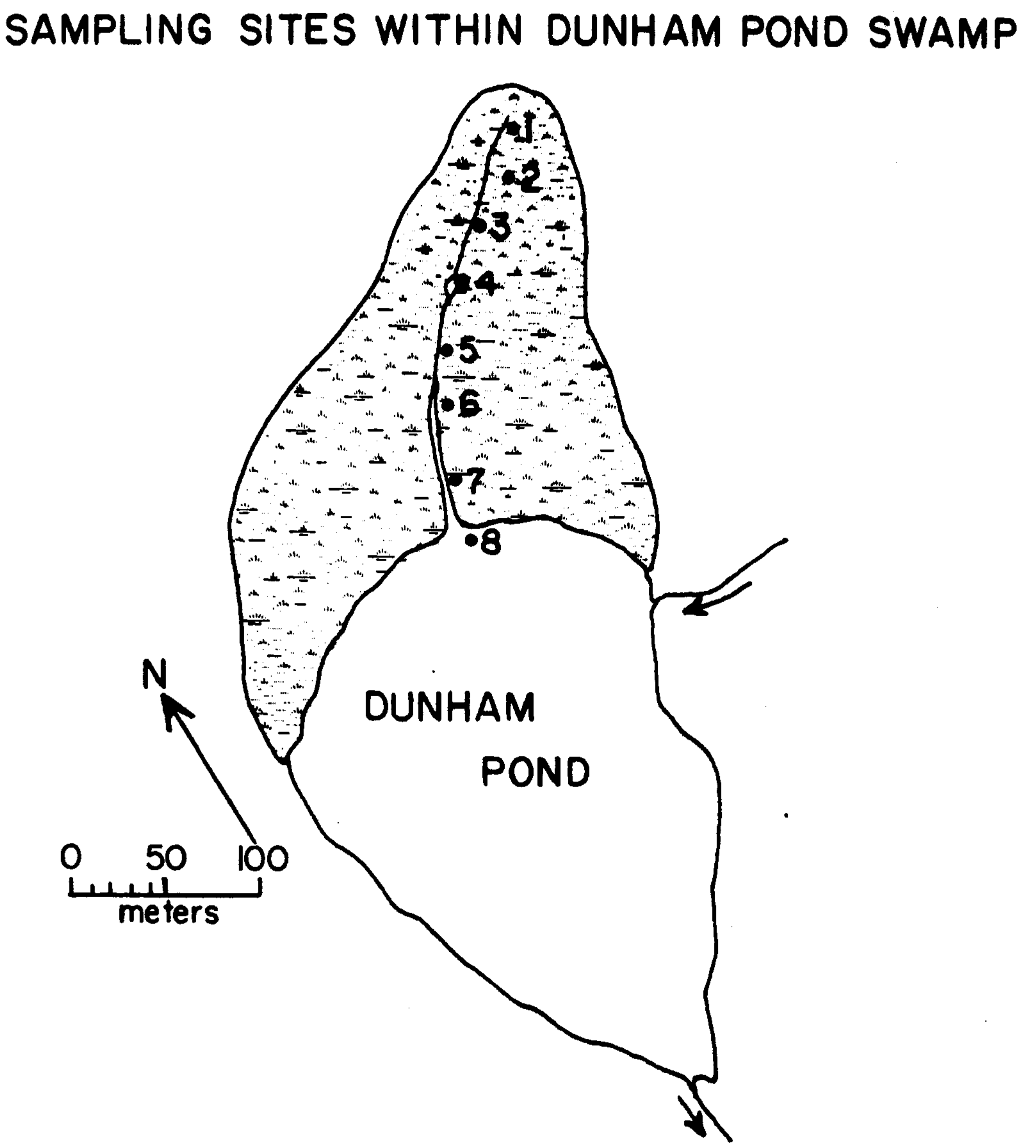
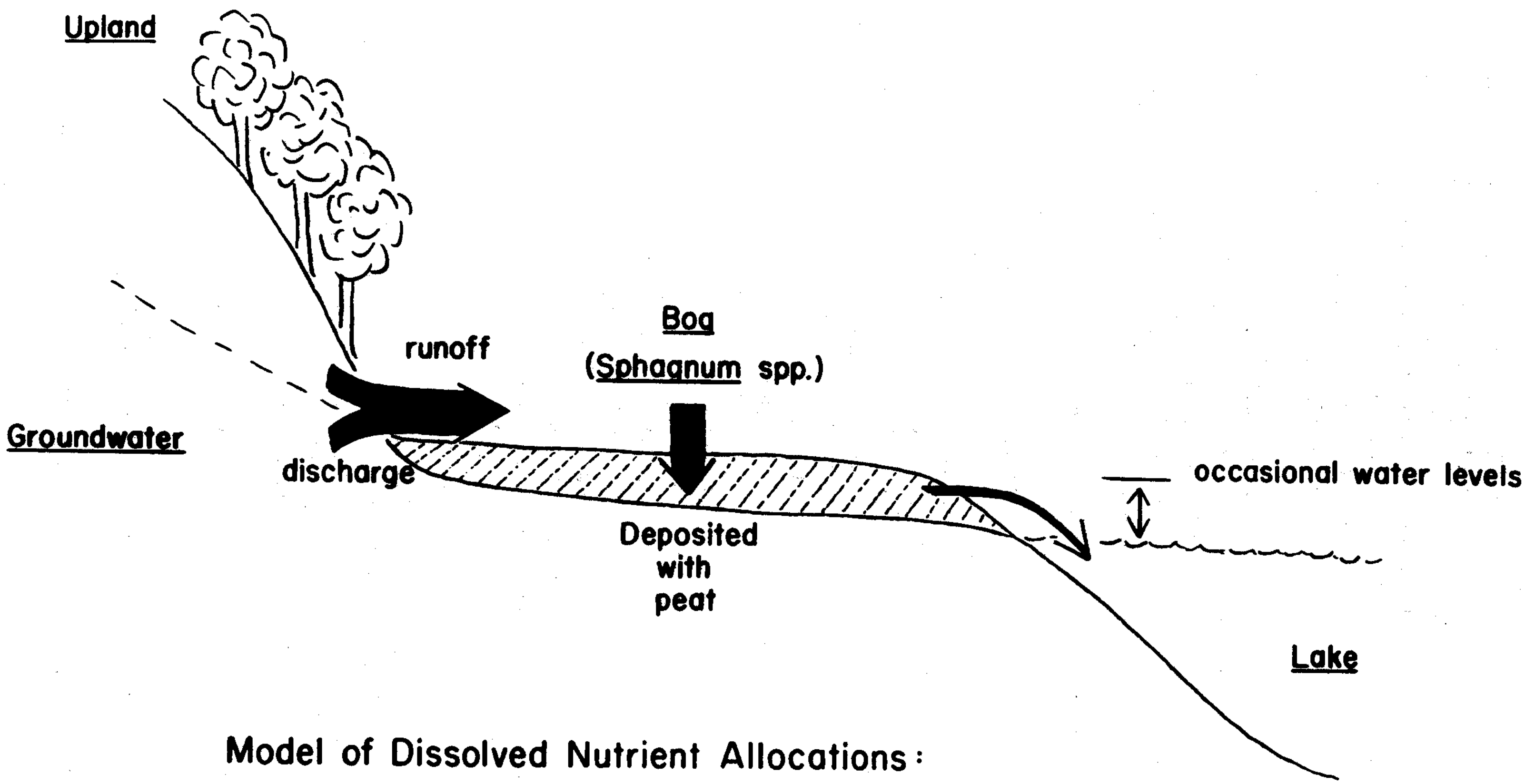


Fig. 1. Dunham Pond and associated *Acer rubrum* - *Sphagnum* swamp, showing locations of sampling sites along the stream draining the swamp.

Fig. 2. Preliminary model of a wetland ecosystem indicating dissolved nutrient allocations during early successional stages.



Model of Dissolved Nutrient Allocations:

"Early" Succession

[Dissolved organic carbon from *Sphagnum* spp.]

is that relatively minor fraction which is resistant to bacterial decomposition, not the more important fraction of labile DOC which has long gone to microbial respiration. The amount of refractory DOC in wetland water can be signigicant, however. More importantly, the effects of refractory DOC (humic substances) in "brown swamp water" remain very poorly understood despite widespread recognition of their importance.

Dunham Pond. Dunham Pond (Fig. 1; Table 1) is a small, shallow lake near the campus of the University of Connecticut in Storrs, Connecticut. It receives water from two incoming streams: a woodland stream entering from the east over mineral soil and a wetland stream entering from the north through an *Acer rubrum - Spagnum* swamp. Water leaves the lake through an outlet to the Willimantic River. The lake lies in young till ground moraine except for its northern end, consisting of 0.5-1.0 m of peat and muck overlying stratified sand and gravel (*5*).

A preliminary examination of the water in the two incoming streams and in the lake revealed that the water in the wetland was deficient in dissolved salts and was more highly colored compared to the water in both the woodland stream and the lake. Further study revealed that water entering the wetland was emerging groundwater, and not very different from the water in the woodland stream. Based upon these observations we proposed a model of the wetland system (Fig. 2) in which nutrients are removed from surface discharge by plant uptake or absorption and buried by organic accretion. We also hypothesized that humic DOC would accumulate in the wetland discharge.

Materials and Methods. With the above model in mind, we initiated a 14-month field investigation of the water chemistry in the wetland stream. Eight sampling stations were located along the stream (Fig. 1) with the first at the origin of the stream and the eighth at the mouth of the stream on the lake. Station 2 was located aside from the main stream. Water retention time there was longer than at other stations. Water samples were taken weekly at each site and analyzed for dissolved CO_2, pH, conductivity, color (OD_{350nm}), DOC, and four cations: sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg).

Results and Discussion. All water chemistry factors studied showed significant changes over the length of the wetland stream; distinct seasonal trends were also noticable. The changes in water chemistry indicate a metabolism in the wetland ecosystem which results in the accumulation of metabolic products in the stream. Annual mean changes in water flowing through the wetland, expressed as percentages relative to the water at the origin of the stream (site #1), are shown in Figure 3.

Conductivity and concentration of cations (Na, K, Ca, and Mg) decreased from the origin of the stream to the center of the wetland, then increased to the mouth of the stream of the lake shore. Among these cations, sodium and calcium showed the most regular changes. The greatest differences were observed for potassium. The concentration of dissolved CO_2 in the stream had a similar pattern. At the peak of the growing season, however, CO_2 was produced in the central part of the swamp. The pH dropped as the water

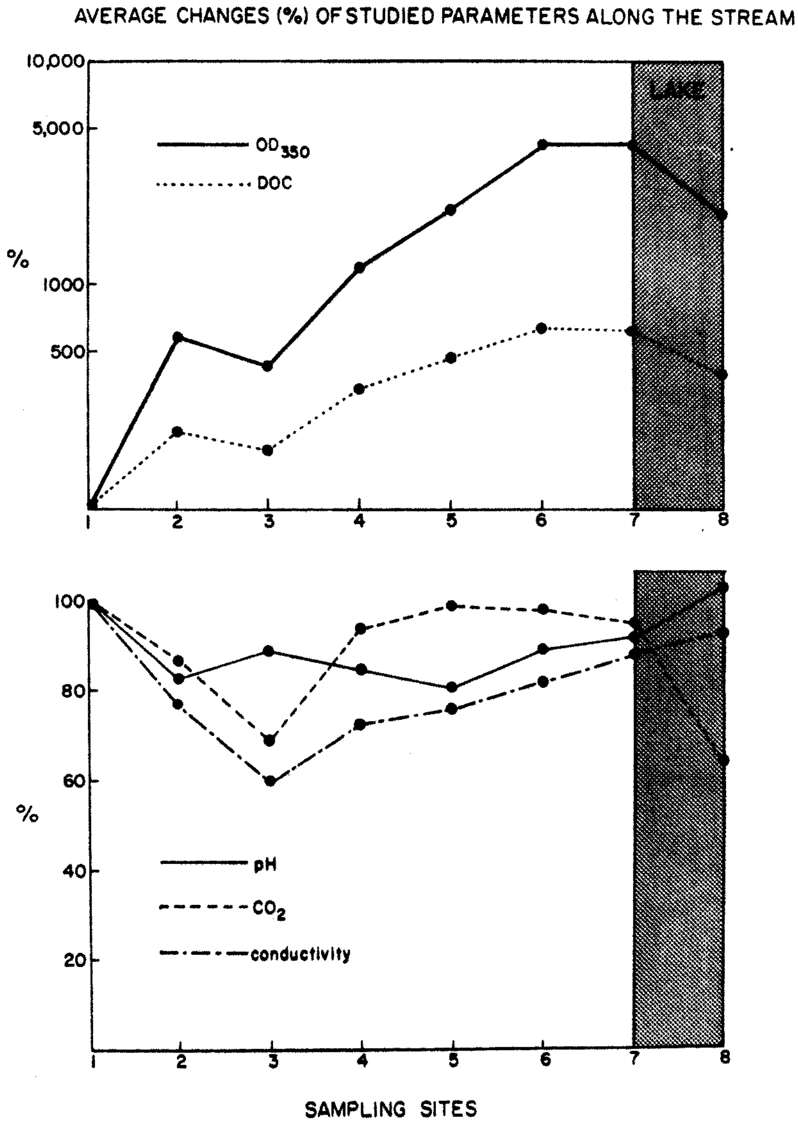


Fig. 3. Annual mean percentage changes in water chemistry over the length of the wetland stream. Data for emerging groundwater at the origin of the stream (sampling site no. 1) is assumed to be 100%.

moved through the wetland, then rose under the influence of the lake surface water. Greatest changes for all factors occurred in the summer, and fluctuations were much less in the winter under snow and ice cover. However, observable effects were present throughout the year.

Unlike the above variables, optical density (at 350nm) and dissolved organic carbon (DOC) increased throughout the year, but during the winter accumulations were slower than in the summer. The accumulation of dissolved organics indicates active decomposition and leaching processes within the swamp. The consistently elevated values of both DOC and color at site #2 suggests that water retention time is an important factor in the accumulation of colored organics. Thus, larger wetlands with slower flows of water should have greater accumulations of colored dissolved organics. This was checked at two other larger wetlands in the area and was confirmed to be true.

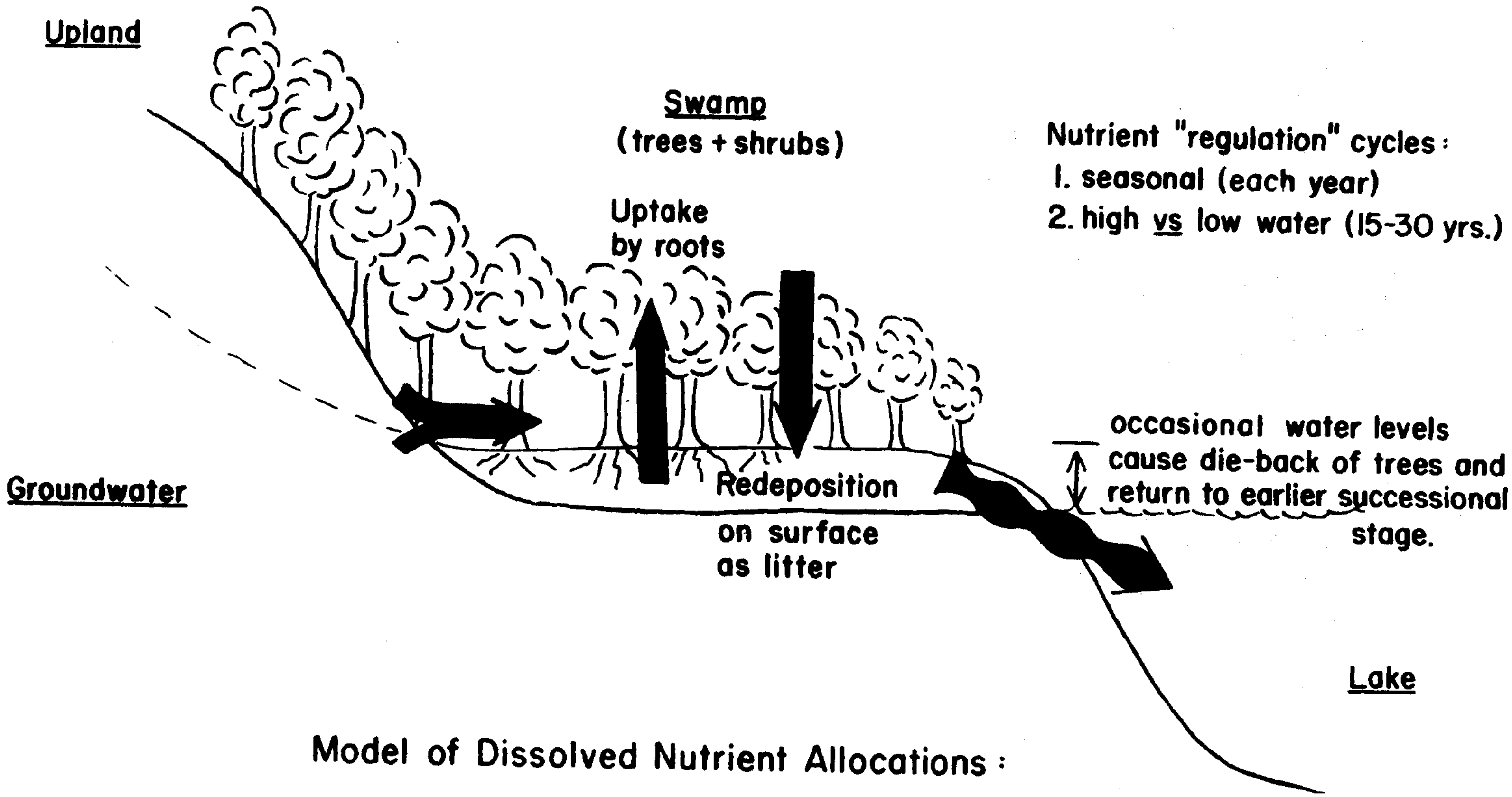
Given the above effects observed through time and space, we can distinguish two basic zones in the Dunham Pond swamp and two basic periods in the metabolic year of activity in the wetland. The first zone, from the area of emerging groundwater representing the origin of the stream to the center of the wetland, is where production processes dominate over decomposition processes. In the second zone, from the middle of the wetland to the lake sphere, decomposition is more important than production. Thus for the Dunham Pond swamp the lakeward edge of the wetland appears to be growing (if at all) as a heterotrophic community in which net production would be negative unless subsidized by inputs from the landward edge of the wetland. It is also possible that we observed the wetland during a period of stronger metabolic activity, both productive and destructive, and the winter period of lessened but consistent activity.

The presence of a wetland in a lake watershed has distinct effects upon water flowing into the lake. The size and hydrology of the wetland will determine the extent to which the final status of water leaving the wetland is different from that entering the wetland with respect to dissolved nutrients and pH. Part of those nutrients in incoming water will be taken up to produce organic matter, but some part of those nutrients incorporated in organic matter previously will be released to the water leaving the wetland. CO_2 and pH equilibrate relatively easily with the buffered and well aerated lake surface water. On the other hand, accumulation of dissolved organic matter (colored and otherwise) in water leaving the swamp represents a constant and very important influx to the lake. This input is perhaps decisive in determining the typical dystrophic character of the lake.

Conclusions:

1. Wetlands are sites of intense metabolism. This conclusion is supported by the strong trends in all variables and the seasonable responses in CO_2 in particular.

Fig. 4. Modified model of a wetland ecosystem indicating dissolved nutrient allocations during later and more stable successional stages.



Model of Dissolved Nutrient Allocations:

"Late" Succession

[Dissolved organic carbon from leaf leachate]

2. Humic DOC accumulates steadily, indicating a reasonably constant production rate throughout the wetland.

3. Nutrient uptake is not consistent throughout the wetland, and our model must be modified (Fig. 4). The accumulation of nutrients in the lakeward end of the wetland stream may represent the removal of buried nutrients by tree and shrub roots and their return to the wetland surface as litter, or it may represent a temporary "die-back" associated with higher water levels since the drought years of about a decade ago.

4. Finally, what is kept out of a lake by a wetland may be less important than what goes into a lake from a wetland. The effect of water color alone may be preserving Dunham Pond from an overgrowth of macrophytes simply by reducing light penetration into the lake. The maximum depth of Dunham Pond is only 15 feet. If it were not a "bog lake" it would be available for macrophyte colonization throughout.

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FRESHWATER WETLANDS AS WILDLIFE HABITATS*

by

Francis C. Golet**

Introduction. Freshwater wetlands provide habitat for a great variety of wildlife. For the sake of illustration, wildlife species can be divided into two groups, according to their degree of dependence upon wetlands. Wildlife in Group 1 require wetlands for survival. Some taxa, such as waterfowl, herons, muskrats, fish and certain turtles, depend almost entirely upon wetlands. Other types live primarily outside of wetlands but use them on a seasonal or periodic basis. Many toads and salamanders, for example, live in upland areas throughout the year, but must lay their eggs in shallow water; thus, wetlands may play a vital role in assuring the perpetuation of their species.

For many other kinds of wildlife, the wetness of the wetland environment is neither a limiting factor nor a requirement. Species in Group 2 often occur in as great abundance in upland areas as in wetlands and may live virtually their entire lives in either habitat. They are not directly dependent upon wetlands in any way, however. Nevertheless, some species in this group seem to prefer the wetland habitat during certain seasons. Cottontail rabbits and Ring-necked pheasants spend relatively little time in wetlands during the summer, but in the winter they seek out the dense, persistent cover that shallow marshes, shrub swamps and wooded swamps provide. Similarly, although many forest songbirds reside in both uplands and wetlands during the breeding season, bottomland forests seem to be utilized more intensively during early spring migrations. Group 2 includes such diverse birds as Crows, Grouse, Thrushes, Owls, Warblers and Vireos; and mammals such as Foxes, Snowshoe hares, Cottontails, White-tailed deer and Raccoons.

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In assessing the values of wetlands to wildlife, our primary concern should be with the species in group 1. However, the importance of wetlands to wildlife in group 2 can hardly be ignored. The sheer biomass of group 2 species using wetlands probably far exceeds that of group 1 species, excluding fish. This is because the dominant wetland types in the northeast are the wooded swamp and the shrub swamp. These are the types most attractive to wildlife in group 2.

Habitat Requirements of Wildlife. The basic requirements of all wildlife are food, water and cover. Cover is any material that furnishes concealment and protection from predators or adverse weather conditions. In natural situations, cover is provided chiefly by vegetation. A fourth requirement, adequate space, is sometimes listed as well. This is characteristic of territorial species, especially birds, which select and defend areas of land for mating, breeding, feeding or a combination of these.

In addition to these basic needs, many species have special requirements. Most songbirds, for example, need elevated song-posts usually trees or shrubs, within their nesting territory. From these perches the males proclaim their "ownership" of the delimited area by singing and displaying. Wood ducks, Tree swallows and many other birds need natural tree cavities or nesting boxes in which to nest; these species cannot create their own cavities as do Woodpeckers. In order to build adequate lodges, Muskrats need stands of robust emergent vegetation such as Cattails or Bulrushes. All of these are examples of special habitat requirements.

In northeastern wetlands, and probably in most habitat types throughout the world, vegetation is the most important component of wildlife habitat. It provides food in itself and in the invertebrate life it harbors; it is the sole source of cover for most wildlife species; and it provides many of their special requirements. In short, wildlife habitat for most species can be reduced to two major elements: Vegetation and a substrate, either soil or water.

Many studies have shown that wildlife are adapted primarily to the <u>life form</u> of vegetation rather than to particular plant species (*1,2,3*). Life form is the physical structure or growth habit of a plant, including height, branching pattern, robustness and leaf shape. There are five major life forms of wetland plants important in describing wildlife habitat: trees, shrubs, emergents, surface plants and submergents. Differences in wildlife value exist even between plants which belong to the same life form. For example, Cattails and Pickerelweed offer very different types of cover although both are emergents. To recognize such differences, I have divided each life form into subforms (*4*). Figures 1 and 2 illustrate the principal life forms and subforms of plants found in northeastern freshwater wetlands. Excluded are life forms such as ferns and vines which occur in wetlands, but which are never the dominant plant type.

Each wildlife species uses one or more habitat types during the year. Each habitat type in turn consists of one or more life forms of vegetation, represented in certain quantities and arranged in a

particular spatial pattern. Some species such as the Muskrat have relatively simple requirements; this animal needs only shallow water and emergent vegetation that is suitable for food and lodge construction. In this case, only one life form is required.

Most species of waterfowl have a considerably more complex set of needs. Wood ducks, for instance, require a natural nesting cavity or an artificial nesting box during breeding season. This may be located over water or up to one-half mile away in an upland or wetland forest. Dense, abundant cover is an essential requirement once the ducklings have hatched and left the nest; prior to this time, abundant cover is less important. While the young are growing, the most critical needs besides adequate cover are shallow water and plentiful food, particularly invertebrates which are the main source of protein for young birds. Once the duckling can fly, the need for concentrated supplies of food and cover decreases. Later in the summer, adult waterfowl molt their wing feathers so that even they are flightless for a short period of time. This time must be spent where food, water and cover are again concentrated. During spring and fall migrations, the major prerequisites are shallow water for resting and feeding and a minimum of cover. Wood ducks then require at least three life forms at different times during the year: trees for nesting, aquatic shrubs or emergents for cover and submergents for food. It is sometimes necessary for waterfowl to move from one wetland to another to satisfy these varied requirements.

Wetland Types and Wildlife Communities. Between 1969 and 1972 I took part in an interdisciplinary research project at the University of Massachusetts, designed to provide criteria for the evaluation of freshwater wetlands for water supply, wildlife habitat and visual-cultural benefits (*5*). I was responsible for devising criteria to evaluate wetlands as wildlife habitat (*6*). Early in my study, it became apparent that a detailed classification system for wetlands was needed before criteria could be devised. The U.S. Fish and Wildlife Service classified the wetlands of the United States into 20 types (*7*), but these types are too broad for use in intensive research or management at the regional or local level. My first step, then, was to redefine the eight northeastern freshwater wetland classes recognized in the federal system and to subdivide them into 24 subclasses (*8*).

Wetland classes are differentiated on the basis of the dominant life form of vegetation and the depth and fluctuation in level of surface water. A wooded swamp, for example, is a wetland that is dominated by woody vegetation greater than 20 feet tall and which is seasonally flooded with up to 12 inches of water. Subclasses, which differ in dominant subforms of vegetation (Figs. 1,2), are recognized within the classes. Wooded swamps can be divided into deciduous wooded swamps, which lose their leaves in the fall, and evergreen wooded swamps which do not. Table 1 lists the principal wetland classes and subclasses found in the northeast.

Most wildlife species tend to occur in certain wetland types more than others. It is therefore possible and quite appropriate to describe wetland wildlife species by wetland class and subclass. One must realize,

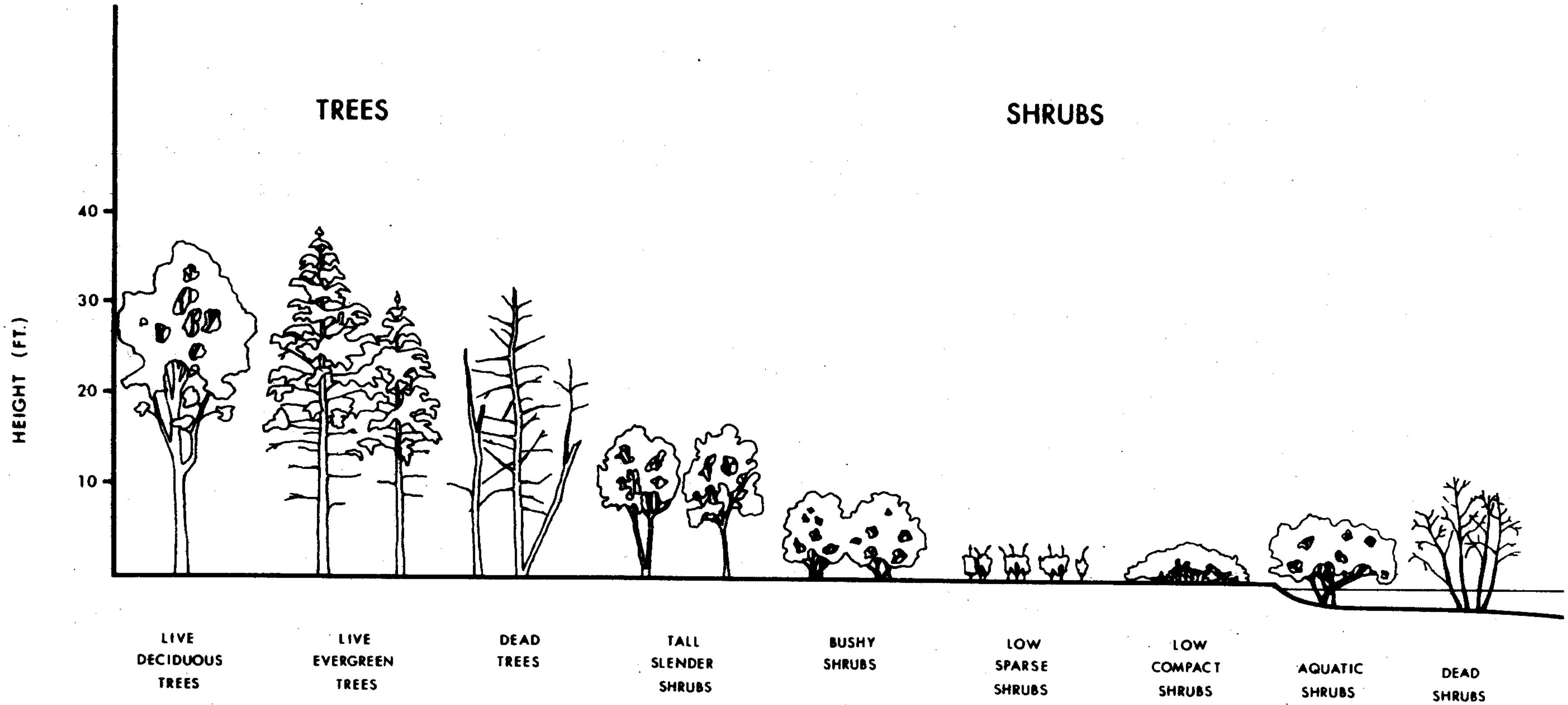


Fig. 1. Subforms of wetland trees and shrubs.

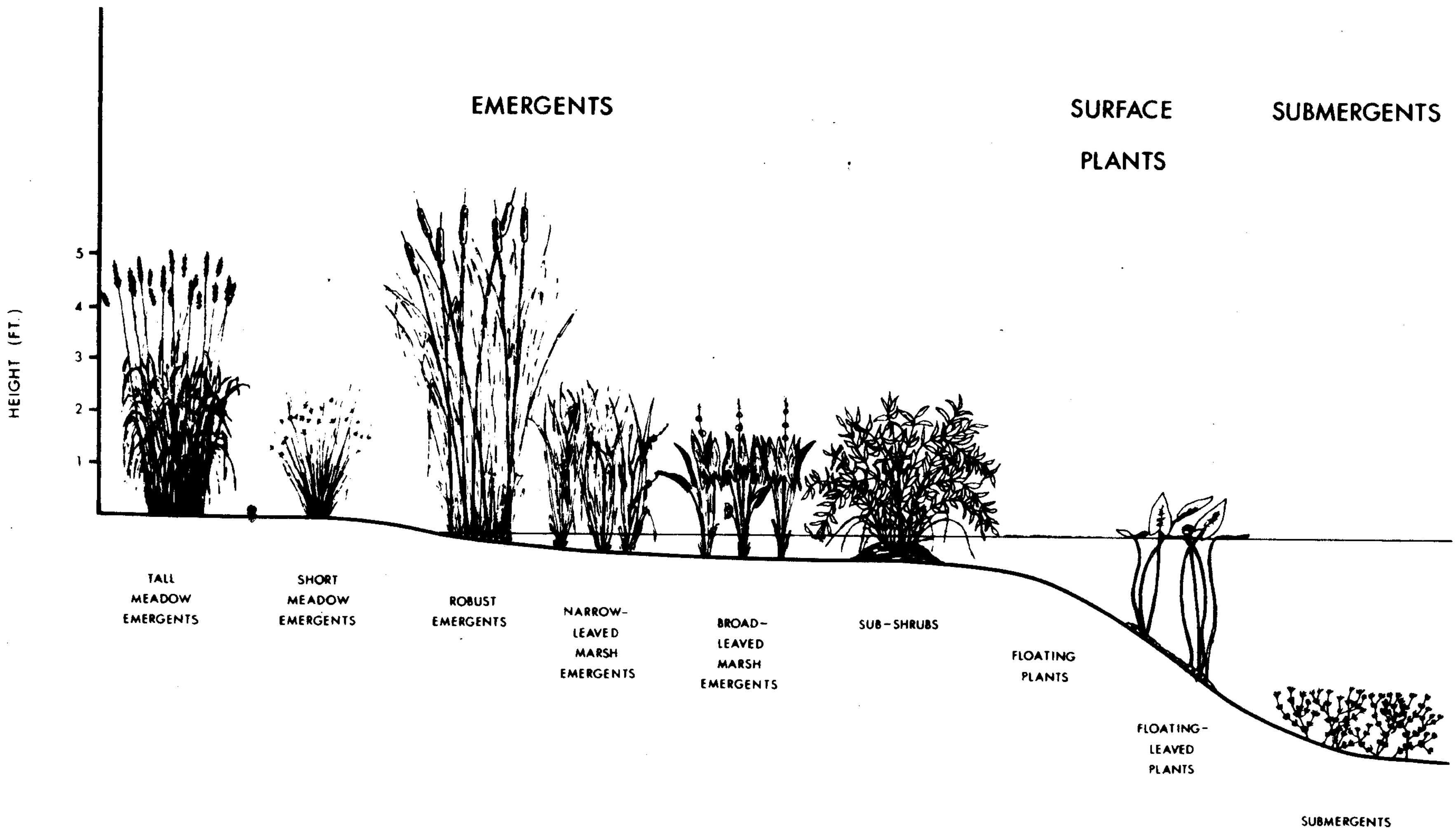


Fig. 2. Subforms of wetland emergents, surface plants, and submergents.

however, that some such associations are only seasonal or casual, and that some species may be associated with several wetland types while others are quite specialized.

Appendix A lists some of the most common species of birds and mammals found in southern New England wetlands and the principal wetland classes in which they occur. Some of these species are permanent residents (e.g., Yellowthroat), and still others are present only for brief periods during migration (e.g. Goldeneye). This is not meant to be a complete list of all wildlife using freshwater wetlands. Species which utilize wetlands, but do not occur there in abundance have been excluded.

The following is a general summary of the wildlife value of the eight wetland classes and some of the subclasses. A more detailed treatment of this topic appears in Golet and Larson (*8*).

Open Water (OW). This class applies to water 3 to 10 feet deep; deeper bodies are considered ponds or lakes. Vegetation, if present, consists of submergent and surface water plants such as Water lilies. Open water provides resting and feeding habitat for waterfowl during migration, and is used most extensively by diving ducks which can reach deep-water plants. Vegetated open water (OW-1) is generally more valuable than the nonvegetated subclass (OW-2).

Deep Marsh (DM). This class includes wetlands with an average water depth between 6 inches and 3 feet during the growing season, and with primarily emergent vegetation or aquatic shrubs. Surface plants and submergents are present in open areas. Deep marshes are the most valuable all-purpose waterfowl habitat for all kinds of waterfowl. In addition, they are one of the primary habitat types for Herons, Muskrats and several songbird species, including Red-winged blackbirds and Long-billed marsh wrens. The value of an individual deep marsh for particular species depends upon its subclass or dominant vegetation type. For example, deep marshes dominated by dead trees and shrubs (DM-1) or live aquatic shrubs (DM-2) are especially valuable for Wood ducks, while Cattail marshes (DM-4) are preferred habitat for Grebes and Coots.

Shallow Marsh (SM). This class applies to wetlands dominated by robust or marsh emergents with an average water depth of less than 6 inches during the growing season. Throughout the year, shallow marshes provide excellent Muskrat habitat. During the breeding season they are used for nesting by Bitterns, Red-winged blackbirds, Long-billed marsh wrens, Coots and several species of dabbling ducks. During the winter they provide cover and food for Cottontail rabbits and Ring-necked pheasants. The dense vegetation of most shallow marshes serves as ideal cover for young waterfowl and other types of marsh wildlife.

Seasonally Flooded Flats (SF). These are extensive river floodplains where flooding to a depth of 12 inches or more occurs annually during the late fall, winter and early spring. Vegetation may either be predominantly emergents (SF-1) or predominantly shrubs with interspersed emergents (SF-2). In either case, seasonally flooded flats are of outstanding value to

Table 1. Wetland Classes and Subclasses

WETLAND CLASS	WETLAND SUBCLASS
Open Water	(OW-1) Vegetated (OW-2) Non-vegetated
Deep Marsh	(DM-1) Dead Woody (DM-2) Shrub (DM-3) Sub-shrub (DM-4) Robust (DM-5) Narrow-leaved (DM-6) Broad-leaved
Shallow Marsh	(SM-1) Robust (SM-2) Narrow-leaved (SM-3) Broad-leaved (SM-4) Floating-leaved
Seasonally Flooded Flats	(SF-1) Emergent (SF-2) Shrub
Meadow	(M-1) Ungrazed (M-2) Grazed
Shrub Swamp	(SS-1) Sapling (SS-2) Bushy (SS-3) Compact (SS-4) Aquatic (SS-5) Evergreen
Wooded Swamp	(WS-1) Deciduous (WS-2) Evergreen
Bog	(BG-1) Emergent (BG-2) Compact Shrub (BG-3) Bushy Shrub (BG-4) Evergreen Shrub (BG-5) Wooded

waterfowl, Rails, Herons and shorebirds during migration. When water levels subside during the summer, excellent habitat remains for Muskrats, breeding ducks such as Mallards and Teal, and a wide variety of wetland songbirds (See Appendix A).

Meadow (M). This class applies to wetlands dominated by meadow emergents, with up to 12 inches of surface water in the late fall, winter and early spring. During the summer the soil is saturated, but the surface is exposed. Meadows occur chiefly on agricultural land where grazing or mowing keeps shrubs from becoming dominant. They provide resting and feeding places for migrating Mallards, Black ducks, Teal, Herons and shorebirds, and ungrazed meadows (M-1) accomodate generally low to moderate populations of nesting ducks. Muskrats, Redwings and Song sparrows breed here during the winter. Grazed meadows (M-2) are of relatively low wildlife value because of the scarcity of cover.

Shrub Swamp (SS). Shrub swamps are wetlands dominated by shrubs or young trees less than 20 feet tall and seasonally flooded with as much as 1 foot of water. Meadow emergents and ferns usually provide cover beneath the shrubs and in the openings. Shrub swamps offer habitat for a wide variety of wetland and upland wildlife. Some of the most common species found here include Woodcock, Ruffed grouse, Cottontail rabbits, Catbirds, Yellow warblers, Goldfinches, Swamp sparrows and Song sparrows.

Wooded Swamp (WS). This class applies to wetlands dominated by trees greater than 20 feet tall and flooded seasonally with up to 1 foot of water. Because wooded swamps contain several different life forms of vegetation, including trees, shrubs and emergents, as well as ferns and vines, they probably support a greater diversity of songbirds than any other wetland types (See Appendix A). In addition, they provide seasonal or permanent habitat for many other species of wetland and upland wildlife including Mallards, Black ducks, Wood ducks, Deer, Raccoons, Opossums, Rabbits, Ruffed grouse, Red-shouldered hawks and Barred owls.

Bog (BG). This is a wetland class where the accumulation of *Sphagnum* moss and other plant remains forms peat and thus creates a nutrient-poor environment where most wetland plants typical of other classes either cannot survive or grow very poorly. As a result, bog vegetation includes a number of highly specialized and often relatively uncommon plants such as Pitcher plants, Sundews, Buckbean and certain orchids. Low compact shrubs including Sweet gale and Leatherleaf are commonly abundant in non-wooded sections. In central and northern New England, Black spruce, Tamarack and sometimes Balsam fir are the most common tree species. In coastal areas, especially from Massachusetts to New Jersey, Atlantic white cedar is the dominant tree.

Traditionally, the wildlife value of bogs has been described as low, mainly because of the scarcity of food and cover plants preferred by muskrats and most species of waterfowl. However, bogs are used to a considerable extent by breeding and migrating Black ducks, Ring-necked ducks and Wood ducks. The overall value of a particular bog to wildlife depends upon the diversity of subclasses and the amount of open water present. Emergent bogs (BG-1) (sometimes called "fens") which are

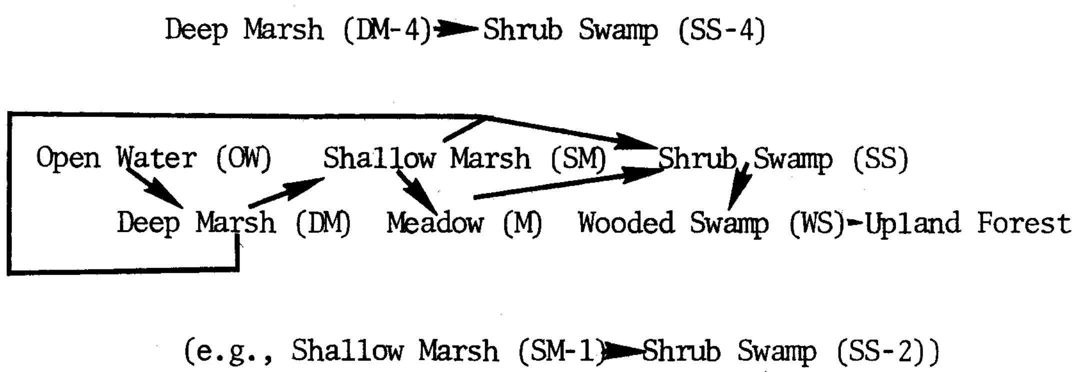
similar in appearance to meadows, are relatively low in value except for Voles, Shrews and a small number of songbirds including Swamp sparrows and Red-winged blackbirds. Compact shrub bogs (BG-2) have limited value as well because of the density and low stature of the dominant vegetation. Bushy shrub bogs (BG-3), evergreen shrub bogs (BG-4) and wooded bogs (BG-5) provide habitat for the same species that inhabit shrub swamps and evergreen wooded swamps (WS-2). My own studies have shown that cedar bogs with several subclasses provide breeding habitat for Kingbirds, Yellow warblers, Red-winged blackbirds, Song sparrow, Swamp sparrows, Yellow-throats, Catbirds, Black and White warblers, Veeries, Wood ducks and Black Ducks. These same bogs support Otter, Deer, Masked shrews and Red-backed voles. Northern New England bogs are of great importance as moose habitat.

Wetland Dynamics and Wildlife Values. Most of our present-day wetlands in the northeast originated as ponds and lakes after glaciers last retreated some 18,000 to 12,000 years ago. Gradually these water bodies collected sediment that washed in from the surrounding land as well as the remains of dead plants and animals that lived in the water or on the edges. As the water depth decreased, first submergent plants and Water lilies could colonize the pond, and later, emergents, shrubs and finally, trees. In shallow ponds it took only hundreds of years for the ponds to change to wetland forest; in deep ponds, this process usually takes thousands of years. Eventually, if soils build up sufficiently above the water table in wooded swamps, upland trees will become established and the transition from open water to upland trees will be complete. The entire process is called hydrarch succession.

Succession may travel along one of two routes depending upon the environmental conditions in the wetland basin when the process begins and as it continues (Fig. 3). If surface water drainage and pond water circulation are unrestricted, and particularly if mineral-rich waters feed the basin, succession will follow the path shown in Figure 3A. It will pass through open water, marsh, meadow and swamp stages. If, on the other hand, drainage is restricted, circulation is poor, and if ground water is not rich in minerals, succession will probably follow the route shown in Figure 3B. In this case, the wetland passes from open water through several bog subclasses and finally to wooded swamp. The process of succession is considerably more complicated than the diagrams indicate, however, and land use practices may have a great impact on the speed and direction of successional events.

It should be evident that as a wetland changes from one class to another, its wildlife populations will change as well. Today the majority of our northeastern wetlands are wooded swamps and shrub swamps. We can assume that during the period since glacial retreat there has been a gradual change from a regional wetland fauna dominated by such open water, and marsh wildlife such as waterfowl and Muskrats, to a fauna comprised predominantly of swamp wildlife such as Raccoons, Opossums, Deer and forest songbirds. A diversity of wildlife species can only be maintained through periodic reversals of the successional process or creation of new wetland basins, either by natural agents such as beavers or by Man.

(A) Unrestricted Drainage; good water circulation; mineral-rich ground water:



(B) Restricted drainage; poor water circulation; mineral-poor ground water:

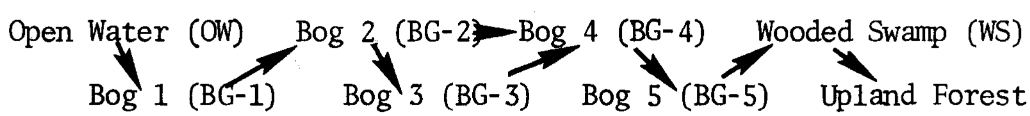


Fig. 3. Proposed pathways of hydrarch succession in northeastern freshwater wetlands under natural conditions.

Evaluation of Freshwater Wetlands as Wildlife Habitats. An acquaintance with the most common types of wildlife inhabiting various wetland classes and subclasses is just the first step toward understanding the problem of wetland wildlife habitat evaluation. Laws have been passed in several northeastern states to protect freshwater wetlands, but since the passage of the first act, decision-makers have been faced with two questions: 1) how to evaluate individual wetlands for their natural values, and 2) how to compare the natural values of wetlands with their values in an altered state.

Our recently completed research project at the University of Massachusetts has provided some answers to both questions (*5*). We recommend that wetlands be evaluated in a 3-step process. The first step involves the application of 10 criteria to identify outstanding wetlands, ones which should not be altered because of one or more clearly outstanding values. From the wildlife standpoint, a wetland would be recommended

for preservation if it satisfies any of the following:

1. supports rare, restricted, endemic or relict species;

2. supports species at, or very near, the limits of their geographic range;

3. is of statewide significance in the production of native waterfowl; or

4. is heavily used by large numbers of migrating waterfowl, shorebirds, marsh birds or wading birds.

If the wetland meets none of the outstanding criteria, it is then rated for each value (e.g., wildlife, water supply), using seperate sets of criteria and a standardized scoring system. There are 10 criteria for the evaluation of wetlands as wildlife habitat. Through an appraisal of the wetland's physical, biological and chemical features, it is rated against a standard of maximum wildlife diversity and production (5,9). Very briefly, the wildlife criteria are:

1. Wetland class richness - the number of wetland classes present

2. Dominant wetland class - the class with the largest area

3. Size category - the wetland's size in acres

4. Subclass richness - the number of wetland subclasses present

5. Site type - the wetland's topographic and hydrologic location

6. Surrounding habitat types - the nature and diversity of land-cover types bordering the wetland

7. Cover type - the ratio of cover area to water area and their degree of interspersion

8. Vegetative interspersion - the degree of interspersion of different life forms and subforms

9. Wetland juxtaposition - the proximity of the wetland to other wetlands and the nature of their hydrologic connection

10. Water chemistry - chemical composition pH of wetland waters

Each of these criteria is assigned a fixed value (significance coefficient) which represents its relative importance. For each criterion there are a number of categories into which a given wetland might fit, and each of these categories has a rank associated with it, ranging in value from 3 to 1. To score a wetland, the significance coefficient for each criterion is multiplied by the category rank achieved and these products are summed for all criteria. For example, if a wetland contains three different wetland classes, it receives a rank of 2 for the first criterion, wetland class richness. This value is multiplied by 5, the significance coefficient for that criterion, and a subscore of 10 results. If the subscores of the other nine criteria totalled 76, the total wetland score for wildlife would be 86. Table 2 gives an illustration of scoring for an imaginary wetland.

Criterion	Significance Coefficient	Rank	Subscore
1. Class Richness	5	2.0	10.0
2. Dominant Class	5	3.0	15.0
3. Size Category	5	3.0	15.0
4. Subclass Richness	4	2.5	10.0
5. Site Type	4	2.0	8.0
6. Surrounding Habitat	4	3.0	12.0
7. Cover Type	3	2.0	6.0
8. Veg. Interspersion	3	1.0	3.0
9. Juxtaposition	2	2.0	4.0
10. Water Chemistry	1	3.0	3.0
	Total Wetland Score		86.0

Table 2. Scoring for hypothetical wetland.

The result of this second step in evaluation is a score for each major value. The absolute value of a score is meaningless; the score only takes on meaning when compared with the score of other wetlands. These scores can be combined, giving all values equal weight of giving certain values (e.g., water supply) more weight than others (e.g., wildlife). Thus, wetlands which are not considered outstanding in some way can be arrayed on a point scale according to their combined natural values. The first step in evaluation is the economic ananysis of natural values versus altered values (*5*,*10*).

We feel that our approach is an appropriate one because it bases evaluation primarily on the physical and biological features of wetlands, and because it permits ranking of wetlands through objective, standardized criteria. The wildlife criteria and scoring system have been formally adopted by the Rhode Island Department of Natural Resources for evaluating wetlands where applications to alter have been submitted (*11*).

Clearly, the value of wetlands to wildlife is immense. Without certain types of wetlands, many species would quickly disappear and many more would become far less abundant. We now have a reasonably good knowledge of the kinds of wildlife that live in freshwater wetlands, and our understanding of their specific habitat requirements is improving, though far from complete. We have become so bold as to devise systems to score wetlands as wildlife habitat and to place faith in our results!

The key question that remains is: How important a place does wildlife hold in man's present and future needs? Wetland values such as water supply and flood control will undoubtedly continue to assume prime importance because they directly affect man's health and safety. Wildlife values have traditionally been placed low on the list of priorities, especially in highly urbanized areas, but this may change as people seek more diverse forms of recreation and become more concerned about the quality of their lives.

How important is wildlife to man? Wildlife biologists can suggest an answer to this question, but the only meaningful answer will emerge as the net result of the actions of concerned citizens at public hearings and court proceedings and the inaction of apathetic ones dealing (or not) with such issues as wetland alteration.

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APPENDIX

Wildlife Species	Wetland Classes							
	OW	DM	SM	SF	M	SS	WS	BG
BIRDS								
Pied-billed Grebe	X	X						
Great Blue Heron		X	X	X				
Green Heron		X	X	X		X		
Black-crowned Night Heron		X	X	X				
American Bittern		X	X	X				
Mute Swan	X	X	X					
Canada Goose	X	X	X	X				
Mallard		X	X	X	X	X	X	
Black Duck		X	X	X	X	X	X	X
Green-winged Teal		X	X	X	X			
Blue-winged Teal		X	X	X	X			
American Widgeon		X	X	X				
Wood Duck		X	X	X		X	X	X
Ring-necked Duck	X	X		X				
Common Goldeneye	X							

APPENDIX (continued)

Wildlife Species	Wetland Classes OW	DM	SM	SF	M	SS	WS	BG
Bufflehead	X							
Hooded Merganser	X							
American Merganser	X							
Red-tailed Hawk							X	X
Red-shouldered Hawk							X	X
Marsh Hawk			X	X	X			
Osprey	X	X		X			X	
Ruffed Grouse						X	X	X
Bobwhite				X	X	X	X	
Ring-necked Pheasant			X	X	X	X		
Sora		X	X	X				
American Coot		X	X					
Killdeer			X	X	X			
American Woodcock				X	X	X	X	
Common Snipe		X	X	X	X			
Spotted Sandpiper		X	X	X	X			
Great Horned Owl							X	X
Barred Owl							X	X
Belted Kingfisher	X	X						
Common Flicker							X	X
Hairy Woodpecker							X	X
Downy Woodpecker							X	X
Eastern Kingbird		X		X		X	X	X

APPENDIX (continued)

Wildlife Species	Wetland Classes							
	OW	DM	SM	SF	M	SS	WS	BG
Great Crested Flycatcher							X	X
Eastern Phoebe						X	X	X
Tree Swallow	X	X	X	X	X	X	X	X
Barn Swallow	X	X	X	X	X	X	X	X
Blue Jay							X	X
Common Crow							X	X
Black-capped Chickadee				X			X	X
Tufted Titmouse							X	X
White-breasted Nuthatch							X	X
Red-breasted Nuthatch							X	X
Brown Creeper							X	X
House Wren						X	X	
Long-billed Marsh Wren		X	X	X				
Gray Catbird				X		X	X	X
American Robin				X	X	X	X	
Wood Thrush							X	
Veery							X	X
Eastern Bluebird					X	X	X	
Cedar Waxwing		X					X	X
Starling				X	X	X	X	
White-eyed Vireo				X		X	X	
Red-eyed Vireo				X		X	X	
Black-and-white Warbler							X	X

APPENDIX (continued)

Wildlife Species	Wetland Classes							
	OW	DM	SM	SF	M	SS	WS	BG
Yellow Warbler				X		X	X	X
Yellow-rumped (Myrtle) Warbler			X	X		X	X	X
Ovenbird							X	X
Northern Waterthrush				X		X	X	X
Common Yellowthroat		X	X	X	X	X	X	X
Canada Warbler							X	
American Redstart							X	
Red-winged Blackbird		X	X	X	X	X		X
Northern (Baltimore) Oriole						X	X	
Common Grackle		X	X	X	X	X	X	X
Brown-headed Cowbird							X	
Rose-breasted Grosbeak							X	
American Goldfinch						X	X	X
Dark-eyed (Slate-colored) Junco						X	X	
Tree Sparrow				X	X	X	X	
White-throated Sparrow						X	X	X
Swamp Sparrow		X	X	X		X	X	X
Song Sparrow		X	X	X	X	X	X	X
MAMMALS								
Opossum				X	X	X	X	X
Masked Shrew				X	X	X	X	X

APPENDIX (continued)

Wildlife Species	Wetland Classes							
	OW	DM	SM	SF	M	SS	WS	BG
Short-tailed Shrew		X	X	X	X	X	X	
Star-nosed Mole		X	X	X	X	X		
Little Brown Myotis (Bat)	X	X	X	X	X	X	X	X
Eastern Pipistrel (Bat)	X	X	X	X	X	X	X	X
Big Brown Bat	X	X	X	X	X	X	X	X
Eastern Cottontail			X	X	X	X	X	
New England Cottontail				X		X	X	
Snowshoe Hare							X	X
Gray Squirrel							X	
Red Squirrel							X	X
Southern Flying Squirrel							X	X
Beaver	X	X	X			X	X	X
White-footed Mouse						X	X	
Boreal Red-back Vole						X	X	X
Muskrat		X	X	X	X	X		
Meadow Jumping Mouse				X	X			X
Woodland Jumping Mouse				X		X	X	X
Red Fox			X	X	X	X	X	X
Gray Fox						X	X	X
Raccoon		X	X	X	X	X	X	X
Short-tailed Weasel			X	X		X	X	
Long-tailed Weasel			X	X	X	X		

APPENDIX (continued)

Wildlife Species	Wetland Classes							
	OW	DM	SM	SF	M	SS	WS	BG
Mink		X	X	X	X	X	X	X
Striped Skunk			X	X	X	X	X	
River Otter	X	X	X	X		X	X	X
White-tailed Deer			X	X	X	X	X	X

THE MANAGEMENT OF WETLAND FORESTS

by

James R. Grace*

Introduction. In the past, forest researchers and practitioners alike have chosen to keep their feet dry and have customarily neglected the forest vegetation occupying the substantial acreage** of inland wetlands located throughout Connecticut and much of the northeast. Therefore, very little has been known about the types of forest vegetation inhabiting these wet sites and even less is known about how to manage them.

With the advent of legislation such as the Inland Wetland and Watercourses Act passed by the Connecticut General Assembly in 1972, building and construction may be very limited or forbidden on these poorly drained areas. There has thus been a newfound interest in managing the vegetation on these sites for various forest benefits such as timber, wildlife, water and recreation.

The development of management schemes for these wet areas requires a basic understanding of the types of vegetation which occur on them and their vegetation dynamics. In order to gain such information a study was begun in the summer of 1972 by the Connecticut State Department of Environmental Protection via the Connecticut Forest and Park Association (*3*). The main objective of this study was to determine what kinds of successional development there might be in the wetland forest vegetation and to determine the extent to which any such patterns of change might be influenced by soil differences. Using Connecticut's soil-based definition of wetlands, the major effort of this study was aimed at making field observations of as wide a diversity of wetland vegetation and soils as could be found. Much of the information derived from this study was qualitative, and its interpretations were based largely on the writer's efforts in constructing patterns of change and space from ground observations.

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**Over 58% (190,000 acres) of Massachusetts' (326,000 acres) interior wetlands are forested (*1*). In all probability an equal percentage of Connecticut's 700,000 acres of interior wetlands are also forested.

The main emphasis of this study was placed on the wetland forest as a producer of wood (timber). Management for other uses will in any case depend on the potentialities of the vegatation.

Even though the observations from the above study were limited to northeastern Connecticut, much of the results are probably applicable to other portions of Connecticut as well as much of Massachusetts and Rhode Island.

The Connecticut definition of wetlands, based on soil types, is the basis for the following discussion. The soils containing wetland forest vegetation fall into three basic catagories: 1) wet mineral or gley soils, 2) organic soils and 3) flood plain soils.

Vegetation and Management: Forested Upland Wetlands. With the exception of fresh water marshes there appears to be very little variation between species composition or successional trends on wet mineral soils and wet organic soils. The following discussion will thus be applicable to both types of sites and is placed under the more general heading of Forested Upland Wetlands.

Most of these wet sites have large amounts of water above ground level for a major portion of the year. A series of hummocks, scattered evenly throughout the area, usually rise out of the water. The various tree species there generally become established on these hummocks or on fallen dead logs or any other available dry spot.

The tree species present on these poorly drained sites tend to vary somewhat from site to site, but they also seem to follow a consistent successional pattern. In going from field to forest, the first stage in the successional development is, in most cases, dominated by Red maple (*Acer rubrum*). Red maple seems to be a species that is very tolerant of high moisture levels, and there is a good seed source near most all areas in northeastern Connecticut. On these wet sites Red maple, in its early stages, seems to possess the ability to compete out all other species, often completely occupying the entire site. Red maple also possesses the ability to reproduce itself prolifically by stump sprouting; thus, in the case of any heavy cutting it is generally the first species to reoccupy the site. These stump sprouts can form very dense stands and generally establish themselves in groups of four to six per stump. Early growth is rapid.

In some cases where wetlands have been cultivated, pastured, and abandoned, White pine (*Pinus strobus*) is capable of becoming established where there is an ample seed source. If the pine has come to compete with the Red maple, however, it is usually eliminated. If the pine is established in a nearly pure stand, it will most likely go through one rotation and then be replaced by Red maples, which then start the normal successional development.

In most cases the dominant seed source around abandoned wetland pastures are those maples which were left growing along the small streams which frequently run adjacent to the fields where the Red maple swamp type soon becomes established. Other tree species also found in small numbers scattered through these Red maple wetlands are Black ash (*Fraxinus nigra*), Black gum (*Nyssa sylvatica*), Yellow and Black birch (*Betula allegheniensis, B. lenta*), Hemlock (*Tsuga canadensis*), and White pine. Various shrub species seem to become established when Red maple and associated species have grown to "pole" size. The most abundant of these shrubs is Sweet pepper bush (*Clethra alnifolia*), Witch hazel (*Hamamelis virginiana*), Alder (*Alnus spp.*), Hobble bush (*Virburnum alnifolium*), Spice bush, (*Lindera benzoin*) and Mountain laurel (*Kalmia latifolia*) frequently are also present, however.

In summary, young Red maple swamps (i.e., those less than 40 years old) are characterized by an abundance of Red maples of 3-7 inches D.B.H. of either seedling or stump-sprout origin. The trees grow mostly on the hummocks and are often surrounded by small pools of water. A large proportion of the wetland vegetation in Connecticut, Massachusetts and Rhode Island is presently in this stage of development.

The subsequent stages of development of these wetland sites depend greatly on the surrounding seed sources. Most of the species referred to so far are capable of becoming established if there is a sufficient seed source nearby. If enough Hemlock seed is available, that species often becomes established one or two at a time, scattered through the stand while the Red maples grow larger or disappear because of rot or windthrow.

White pine does not seem able to establish itself until the Red maple trees are 25-40 years old. The fact that they are established at this time may be due to a slight lowering of the water table from increased transpiration of the overstory Red maple. It may also be due to the reduction in the amount of competition at ground level. By age 30 or 40 the Red maple trees are usually 30-40 feet high and the White pines in the understory have more room in which to grow.

It is very significant that Red maple stands do not seem to be able to perpetuate themselves through the continued growth of new individuals. Once these stands have become established (15-20 years) it is rare that any Red maple seedlings are found in the understory. Unless there is a major disturbance the Red maple begins to lose its hold on the site and other species begin to take over their growth in the understory. Thus it is preordained that these sites support Red maple forever.

When seed sources are available most other indigenous species are present in the stand to some degree by the time the Red maple is 30-40 years old. At this time the Hemlock or White pine are generally established in the site, but in most cases it is probably at age 70-90, depending on the vigor of the maple trees. In the various sample plots studies, Red maple appeared to lose dominance at 75-90 years of age; however, it was often difficult to determine exact age because most of the older maples

appeared to be gaining dominance at 70-85 years of age while the White pine (1-30 years old) were generally in the lower stories.

Hemlock seems to be much more aggressive in these wet situations than does White pine. Once established, Hemlock seems to be able to succeed in these sites, while pine seems to stagnate unless a neighboring tree dies or is windthrown. However once the pine are enable to grow on these sites they seem to grow quite well. The problem is that pine does not often find itself in this condition; many die or stagnate in the understory before they have a chance to grow properly.

When Red maple stands begin to decline and there are no actively growing new individuals of tree species to fill in the gaps in the systems, the various shrub species (especially Sweet pepper bush) seem to dominate such areas. These understory shrubs often become so dense that they form an extremely thick, jungle-like vegetation which totally succeeds on the site and restricts any future tree growth. Usually this thick vegetation only occupies small patches in wet areas, but in certain situations where there is no seed source of tree species (other than Red maple) shrubby vegetation may occupy fairly large areas. The presence of Hemlock or White pine in the understory seems to aid considerably in preventing the establishment of shrubby vegetation. It is important, however, that these coniferous species become established *before* the Red maple begins to die. If the conifers species are not established by that time, then chances are that the shrub species will occupy the space vacated by maples.

The species composition of the vegetation sites depends somewhat on the surrounding vegetation during the later stages of development. If a large Hemlock source is nearby, the later stages will most likely be dominated by that species. Because windthrow is quite common in Red maple swamps small components of the various hardwood species and White pine on wet sites will undoubtedly be present in older stands also. The presence of Hemlock in these stands seems to make them very stable, and any stage in which it is prominent can probably be considered climax.

In the absence of a plentiful Hemlock seed source, the later successional stages on these wetland sites might very well resemble the stand in one of the sample plots of Compartment 45 of the Yale Forest in Union, Connecticut. The stand occupying this wet organic site contained a great number of fairly large (up to 23" D.B.H.; 3+ logs high) the growth of which probably had probably been favored during an earlier period in the stand's life. There was also a component of various hardwood species present in this stand, the most numerous being Ash and Black and Yellow birch. The latter were of very poor quality. These other hardwoods generally seemed to be younger than the Red maple (30-50 years old) and may have been released when a light cordwood cutting was carried out on this area about 25 years ago. A very thick understory of shrubs (especially Sweet pepper bush) was also present. I suspect that as more of the Red maple drop out of stands such as these, and unless there is a major disturbance of the site these shrubs will gain a stronger foothold and might eventually dominate the area.

One of the few references found on such wet site vegetation is that by Bromley (3). In his paper, Bromley describes the Lawson Lot, located on the Woodstock-Union town line. In 1917 the Lawson Lot supposedly contained a virgin stand of timber which covered a swamp and the side of a ridge. The forest vegetation occupying the swamp consisted of White pine, Hemlock, Yellow birch, Red maple and Elm. The crests of the White pine overtopped the other species by 10-40 feet. After World War I Bromley returned to the stand, now cut and noticed (by observing the stumps) that the pine had been considerably younger (150 years) than most of the hardwood species (200+ years). This would appear to strengthen the conclusion that White pine does indeed become established under the hardwoods and that once "released", it has the potential to grow to a good size.

Management. In managing wet timbered areas, efforts should center around three basic objectives:

1) The growth of good quality Red maple
2) Encouragement of the establishment and succession of White pine and Hemlock
3) Prevention of the dominance of shrub species

When deciding on the silvicultural methods resulting in these objectives one must first consider the composition and successional stage of the stand being dealt with. For the purposes of this disuccsion it will probably be easiest to start at the earlier stages of the life of the stand.

As pointed out in the preceding section of this paper most wet abandoned fields will turn to Red maple stands without any help from the forester. This is also true of the cut-over areas which return to vigorous stands of Red maple stump sprouts. In fact, most wet areas in northeastern Connecticut are now composed of such young Red maple trees. The first of our objectives can probably be best accomplished at this stage in the life of the stand.

The wood quality of Red maple trees growing on wet sites seems to be quite variable. In somes cases the trees are very sound and produce valuable, high-quality wood. In other cases however, the Red maples are of very poor quality and have a large percentage of heart rot.

While more experimentation is needed on this subject to find the reasons for the differences in the wood quality of the plants, I suspect that poor quality trees are a result of overcrowding in dense stands of seedlings or of congestion within sprout clumps.

To promote the growth of good quality trees it would be advantageous to go through these young maple stands (20-30 years old) and release the more promising trees by either removing or killing (herbicides) some of their competitors. This practice is especially helpful in dealing with competing trees in a sprout clump. At the same time other valuable tree species which might be present in the stand, such as White pine, Hemlock, or some of the better hardwoods, would also be favored. The trees to favor in this process are those that are straight and free of rot. It is also well to favor those trees growing on hummocks or other dry areas.

There is generally a sufficient number of good trees scattered throughout these stands so that this weeding process can greatly improve the quality of the stand in its later years.

In past years many have thought that the best way to manage Red maple stands was to clear-cut them and to be content with new sprout stands of the same species. Were there a good market for Red maple cordwood, this might be a useful procedure, but in the absence of such a market, it is probably the worst way to handle these areas. A perfect example of this exists on the Natchaug State Forest. There about thirty years ago, a Red maple stand of about 30 years was clear-cut and the area planted with White pine. There is a nondescript dense stand of Red maple stump sprouts with just a few scattered pines remaining from the many that were initially planted. At an early age, the Red maple stump sprouts are so vigorous on these wet areas that no other species can compete with them. It is even possible that such heavy cutting in these maple stands will result in a perpetuation of Red maple. If one wishes to go to the expense of killing all the sprout clumps with some form of herbicide, clear-cutting and planting pine might be successful. However, it is difficult to believe that the results would come close to justifying such heavy expense.

As noted earlier, one of the characteristics of Red maple stands is that they are not able to perpetuate themselves by establishment of advanced growth; they are replaced by a variety of other species. From a management standpoint it would be most beneficial to advance the succession to a vegetation containing Hemlock and/or pine if at all possible. By the time a Red maple stand is 30-40 years old there should be scattered White pine or Hemlock growing in the understory if a local seed source for these species is present. If they are not present, it may be worth the expense to underplant either these or other tolerant conifers such as Larch or Spruce. When underplanting, one needs only about one hundred trees per acre; the trees should be planted on the best sites available -- preferably on the drier hummocks.

Neither pine nor Hemlock seem to be vigorous enough to succeed these wet sites at first, but both species seem capable of growing in the understory once the maple has become of pole size. As stated previously, Hemlock seems to be more aggressive than the pine on these sites under natural conditions; however, the pine may have greater potential in a managed stand. Hemlock in these areas seem to grow slowly and it is very susceptible to windthrow. On the other hand, it does an excellent job of competing out the shrubs and its wood seems to be of fair quality.

White pine, if released, will grow quite rapidly and with very good form. I suspect that it will be relatively productive in wet areas. More often than not pine is not released in the unmanaged natural stands. However, it has been noticed that on some of the sites observed where pine has been released because of windthrow or some other natural cause they have grown to a very good size and with excellent form. Because pine grows well in the understory during its younger years, much of it appears to be free of the menace of White pine Weevil. This contributes to its good form

when released. It may also be that wet sites are inhospitable to the Weevil. Since the adult Weevil overwinters in the litter, it is not impossible that they might drown on these sites. Further experimentation however is needed to test this speculation.

Upon establishment of these evergreens in the understory there is usually not too much trouble with vigorous growth of the shrub zone.

Once a Red maple overstory is 60-70 years old, it is time to carry out the next cutting. What happens at this stage depends considerably on the quality of the trees themselves. If the stand has been successfully managed to this point, and there is a large component of fair-to-good quality maple trees putting on good growth, it would probably be most beneficial to carry out a light to moderate thinning of the stand for its own benefit. This curring would remove the poorer trees, slowing down in growth, but would still leave the most productive trees for a later harvest. At the same time it would be wise to release as many of the pine and Hemlock as possible. Regardless of the quality of the overstory maple, cutting should be heavy enough so as to provide enough light for the understory conifers to survive.

If the Red maples are primarily of poor quality, it may be best to carry out a heavier cutting which would remove most of the maple overstory and release as much of the evergreen understory as possible. Care should be taken, however, not to remove the overstory trees where there are no understory trees to replace them. If this care is not taken, maple may merely be replaced by shrubs.

There may also be other species of hardwoods scattered throughout a stand and the more valuable species should also be favored in selective cuttings. Ash seems to occur frequently on these sites and, in localized areas, several species of Oak may also be present. In many poorly drained areas there are often slight rises in topography which tend to lower the water table to some degree, thereby providing sites on which some of the Oaks and other dry-site species grow. When localized sites such as these are found, these other hardwood species should be favored.

It is difficult to say at what age all Red maple or overstory hardwoods should be harvested. So few of the wet areas have been managed in the past that there is no way of predicting the performance of these trees on managed sites. The managing forester will have to observe these trees occasionally and begin removing them when their growth rate begins to slow down and rot appears to develop.

Hopefully once a Red maple overstory is totally removed, a new stand composed primarily of Hemlock or White pine will be left to replace it. In the case of White pine a new stand should be dealt with as any other stand of White pine. Before the pine has matured and is removed, the stand will probably be invaded by Red maple once again and the cycle might repeat itself. In the case of Hemlock succeeding the Red maple, this writer is not quite sure of the outcome. Hemlock may perpetuate itself for more than one generation or it may be possible to keep a stand com-

posed of a combination of the Hemlock, Red maple and other wet site hardwoods.

Since most of the wetlands in northeastern Connecticut are in the yound Red maple stage, the preceding discussion may help in giving the forester some idea of how he can attempt to manage these areas.

Where it is desired to grow trees on abandoned old wetland fields, it may be beneficial to try planting White pine. This seems to be one of the only situations where pine can succeed maple.

The secret to managing poorly drained areas successfully lies undoubtedly in the ability to establish conifers in the succession with Red maple. Conifers are not only relatively productive on wet sites, but they also aid greatly in subduing shrub species which present the greatest management problems on these sites.

The most difficult forest stands to deal with in wet areas are those where Red maple has matured and there are no other species to replace it once it is removed save for the shrub species. If there are not enough hardwood species to continue growing once maple succumbs, there is a real risk that these sites will be dominated by less useful species. This situation may be one of a few which lends itself to productive clear-cutting with the hope of having the maple return. It may, however simply give the shrubs more room to grow. Experimentation with herbicides may also give some answers on how to curb this difficulty. More study of some of the wetland shrub species, especially Sweet pepper bush, will greatly aid management of these wetlands.

One species not mentioned in this report, but very appropriate to a discussion of wetland vegetation, is Atlantic white cedar (*Chamaecyparis thyoides* BSP.). At one time this species was present on many of the swamp areas in northeastern Connecticut (Nichols, *4*) but at present its occurrence is very infrequent there. While this writer found very few examples of this species in his survey, it may be possible to reestablish this valuable tree on some wetlands. Little (*5*) has covered the ecology and management of this species and Noyes (*6*) has covered the topic with specific reference to eastern Connecticut. *Chamaecyparis* would probably best occupy areas of organic soils but it is up to the results of future experiments to indicate the more exact site requirements of White cedar in northeastern Connecticut.

Some mention should also be made as to the logging problems on these wet sites. Logging activity for the most part should be limited to the winter months when the swamp surface is frozen. An exception might be some of the less poorly drained areas which tend to dry up during the later summer months. Because of time limitations, it will generally be fruitless to deal with wet areas simultaneously with the adjacent drier areas. For persons or organizations with large land holdings it may be most expedient to wait for markets for these wet site products to become favorable and then deal with many of the sites simultaneously.

Flood Plain Forests. It is very difficult to generalize about the types of forest vegetation which appear in flood plains. The forest vegetation of alluvial plains is quite variable; almost all of our native tree species can be found if a seed source is available. Since portions of flood plains are often relatively dry, one often finds a mixture of wet and dry species growing near one another. The following species all appear quite regularly on the flood plains studied:

White pine
Eastern hemlock
Sugar maple (*Acer saccharum*)
Ash
Birch; yellow, grey, black (*Betula alleghaniensis, B. populifolia, B. lenta*)
Black cherry (*Prunus serotina*)
Oak; red, black, white (*Quercus rubra, Q. velutina, Q. alba*)
Tulip poplar (*Liriodendron tulipfera*)

The heavy shrub understory often found on other wet sites is nonexistent on flood plain areas except for a few small scattered patches of Mountain laurel or Sweet pepper bush. Understory vegetation on these sites is generally dominated by various grasses and sedges; thus these flood plains almost appear parklike. This is especially true on sandier soils. The lack of understory shrubs may also have something to to with the cyclical nature of water flow on these areas.

Tree species which do appear on the flood plains seem to have a fairly good growth rate. This is especially true in the flood plains of larger streams which possess very fertile bottomland soils. One plot was established in a planted White pine stand, growing on one of these bottomland areas (almost a Saco soil but with more organic matter) on State Forest land along the Natchaug River; the growth rates of these trees was exceptional, the trees averaging about 14.5 inches D.B.H. at 34 years of age. The White pine growing on a plot in a sandier Rumney soil on the flood plain of Bushmeadow Brook in Yale Forest, Compartment 13, were also growing well with an average diameter of about 13 inches at 40 years of age.

Management. The best advice that can be given pertaining to the management of alluvial sites is that each site must be dealt with separately. There is such a variety of situations that no generalized set of rules would apply to all situations. For the most part, however, very few problems should be incurred when managing this type of area unless one wished to maintain pure White pine stands of simple vegatative composition.

Since the alluvial plains often form relatively narrow strips through larger forest tracts, their management scheme will depend greatly on the surrounding vegetation. In general, if their seed sources are available most valuable tree species will grow there.

The two plots previously mentioned illustrate that White pine can grow quite well there. On the more sandy flood plains, White pine will

probably grow as well or better than any other tree species; however, on the more silty an effort should be made to favor the more valuable hardwoods. These bottomland types are probably the most productive tree growing sites found among wetland areas, or perhaps anywhere in northeastern Connecticut; they will likely produce excellent hadrwood growth. There should not be much difficulty incurred in getting hardwoods to regenerate in bottomlands. The most productive silvicultural effort would most likely be directed to an early weeding favoring the most valuable trees. On the Natchaug River plot, for example, there is a farily thick understory of Red maple seedlings 5-6 feet tall coming in under the pine. Once the pine overstory is removed these seedlings will undoubtedly grow quite vigorously; in order to avoid stagnation however, it may be worth the effort to make an early weeding or thinning favoring the best Red maples as well as any other valuable hardwoods such as Sugar maple, Tulip poplar, the several Oaks, or possibly even Silver maple. Once established, most of these tree species should develop into fine timber trees on this soil. The White pine plantation occupying the Natchaug site at the present time is an excellent one but it would take a great deal of effort and expense to regenerate this species once the overstory is removed; in the long run the hardwoods would probably be as valuable and easier to manage.

On sandier flood plain areas an effort should be made to favor White pine whenever possible. This species seems to grow much better on the coarser textured soils than do the various hardwood species. The lack of a dense shrub layer in these areas may also make the planting of pine a feasible consideration. This can be done either after the overstory has been removed or by underplanting 4-5 years before the harvest. When the expense of planting is not desirable it is best to work with available species. If pine is present, it should be favored and released when possible. In many cases, however, a pine source is not available, and Hemlock or some of the various hardwoods may be the dominant species occupying the site. In these situations the best trees (regardless of species) should be favored at the discretion of the forester. The management plan for the surrounding vegetation will undoubtedly also play a controlling factor.

Most areas studied did not seem to present many problems that a forester could not handle readily. For the most part management of these areas is not a great deal different from that of the drier areas surrounding them. One additional consideration which ought to be mentioned is the need for protection of the stream, although this is nothing new to the alert forester.

One last thing that might be said about flood-plains forests is that some have the potential of being very productive sites for timber. With the passage of the Inland Wetlands and Watercourses Act the use of these flood plains, whether well or poorly drained, would likely be restricted to some form of agricultural or forest use.

As far as future study of these areas, it would be well for someone to look into the growth variation of the various tree species on various alluvial soils so that one could arrive at a good indication as to which of the species grows best on the different soil types.

Freshwater Marsh. Freshwater marshes are too wet to support timber production. For the most part these areas have a foot or more of standing surface water. The vegetation they support consists of thickets of woody shrubs, sedges, reeds, and a few scattered dwarfed Red maple trees. Draining such marshes for silviculture would be expensive and probably not result in good tree growth; damage to other interests could be severe. The best use of this type of wetland definitely lies in the hands of the wildlife manager.

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EPIDEMIOLOGIC AND PUBLIC HEALTH IMPLICATIONS OF WETLANDS

by

Eric W. Mood*

Introduction. In any collection of writings dealing with an environmental issue the epidemiologic and public health aspects should be considered critically and carefully before any comprehensive discussion of the issue takes place or before any conclusion is reached. Historically, agencies and people who deal with public health have played major roles in alerting the public of the need to abate and prevent pollution and of the desirability to preserve "the amenities" -- particularly natural amenities.

In part, the present-day environmental movement was generated by a public health education program initiated by the U.S. Public Health Service and others to obtain Congressional support for the Water Pollution Control Act later passed by Congress in 1948. This Act was considered to be temporary water pollution control legislation as Congress and the public were not ready to concede that environmental pollution was a problem of sufficient magnitude to merit federal legislation, or moreover that there was a need to preserve and conserve the environment through federal legislation.

Problems related to water resources, water supply, wastewater treatment, wastewater disposal and the land-to-water interface have been of concern to medical and public authorities for thousands of years. Hippocrates, the great Greek scholar, once wrote:

> "Whoever wishes to investigate medicine properly should consider the seasons of the year, the winds and the waters in relation to health and disease".

I shall examine briefly some of the epidemiologic and public health aspects of water and land as embraced in the frame of reference we now identify as wetlands.

Wetlands; Wastewater Treatment; Wastewater Disposal. One of the principal public health concerns involving wetlands is the use of sub-surface absorption systems in or immediately adjacent to wetlands as means of wastewater disposal. In those portions of communities which lack community sewers and community wastewater treatment processes, it is necessary to dispose of

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wastewater by subsurface absorption. It is conceded generally by sanitary engineers, soil scientists and others that subsurface systems cannot function in an acceptable manner unless there is at least one and one-half feet of permeable soil between the bottom of any subsurface leaching system and the maximum groundwater level. By definition, wetlands include those lands in which the groundwater level is near, at, or slightly above the soil surface.

Failure to provide at least one and one-half feet of permeable soil between the bottom of any subsurface wastewater leaching system and the maximum groundwater table usually results in the creation of unsanitary conditions and hazards to the public health. A high groundwater table may force the wastewater in a subsurface leaching system upward toward the surface. Or, the wastewater may flow into a groundwater aquifer without sufficient filtration through the permeable soil. This eliminates a major portion of the contaminants and thereby contaminates and pollutes the groundwater.

Frequently, engineers, when designing subsurface wastewater leaching systems for installation in land with a high groundwater table -- and therefore often in the proximity of a wetland -- include a groundwater drain to lower the groundwater table such that at least one and one-half feet of clearance is maintained between the bottom of the leaching area and the maximum groundwater table. These groundwater drains, often called blind drains, curtain drains, or French drains, may and usually do affect any wetland which may be in the immediate vicinity. The effect may be the ultimate destruction of the wetland.

In cases of existing structures which have been built in the immediate vicinity of wetlands, public health considerations may require the lowering of the groundwater table to eliminate a health hazard with a concomitant effect of wetland destruction. This may be unfortunate but necessary. Human health must be protected! The Public Health Service through a series of epidemiologic studies has demonstrated conclusively that there is a higher incidence of enteric disease among children if and when there is any untreated (or inadequately treated) wastewater with human input on the ground surface within a radius of one-half mile of their residence.

In those cases where structures have not been built or where sub-division development is proposed, and where there is a high groundwater table supporting a wetland in the immediate vicinity, prohibiting of the construction of groundwater drains may be in the agreement with public health goals.

Recently, there have been some data presented (and proposals promulgated) to utilize wetlands as biological filters of wastewater. For public health reasons, such proposals involving raw sewage or effluents of primary wastewater treatment are probably impracticable and uneconomical if the wetland is located within one mile of human habitation. One of the fundamental reasons is that the wastewater must be completely and throughly disinfected so that no viable pathogenic organisms are present in the wastewater before discharge into the wetland for biologic filtration. Such disinfection may have an undesirable effect on the ecology of the wetland.

Wetlands and the Ecology of Mosquitoes. While many forms of life are dependent upon wetlands, public health officials are particularly concerned with the role of wetlands in the ecology of mosquitoes. Some of the mosquitoes which breed in wetlands are of public health importance and may be direct or indirect vectors of human disease. Of classic importance is the role of wetlands in the life cycle of anopheline mosquitoes, the vectors of malaria. In fact, it was the wetlands in the vicinity of Rome -- the Pontine Marshes -- that gave this disease its name. The ancient Romans believed that malaria was caused by the "vapors" - the *mala aria* (bad air) which came from the marsh lands. Hence, *mala aria* = malaria.

The more successful programs of malaria control in almost all areas of the world have included as a basic element the destruction of wetlands which were located within zero to two miles of human habitation. Such controls are generally deemed to be permanent and are often the only effective methods available.

The use of chemical sprays, either of the non-persistent, non-residual types or of the persistent, residual types, are but temporary measures and should be used primarily to quickly reduce large populations of mosquitoes to a lesser level.

If the public health is to be protected in areas where mosquitoes are important vectors of human disease, wetlands in or near areas of human habitation must either be destroyed or subjected to intensive insecticidal control and treatments which usually involve the use of chemicals. There are no alternatives to these measures at the present time. If non public health-oriented preservationists insist on a "hands-off" policy for wetlands located in or immediately adjacent to areas of human habitation, they themselves must be held responsible for any cases of human disease that is caused either directly or indirectly by mosquitoes which live and/or breed in wetlands.

Connecticut Wetlands and Human Disease. While in Connecticut mosquitoes appear not now involved in the biologic transmission to humans of malaria and yellow fever (as once was the case) there is a mosquito-borne disease which involves wetlands, and which poses a serious threat to human health. The sword of Damocles hangs ominously over our heads. I am referring to the disease eastern equine encephalitis (EEE). Very fortunately, there has never been a human case of EEE contracted within Connecticut, to the best knowledge of health officials. But the disease is in the state and every year pheasants and other birds are infected with this disease and sometimes die! Occasionally, horses become infected and die.

The primary enzootic vector of eastern equine encephalitis is the mosquito *Culiseta melanura,* a predominantly swamp-inhabiting insect which feeds on birds. The summer reservoir of this disease is maintained in wild birds by the transmission of the virus from bird to bird by *Cs. melanura.* While this insect vector is primarily a bird-feeder, it does bite humans.

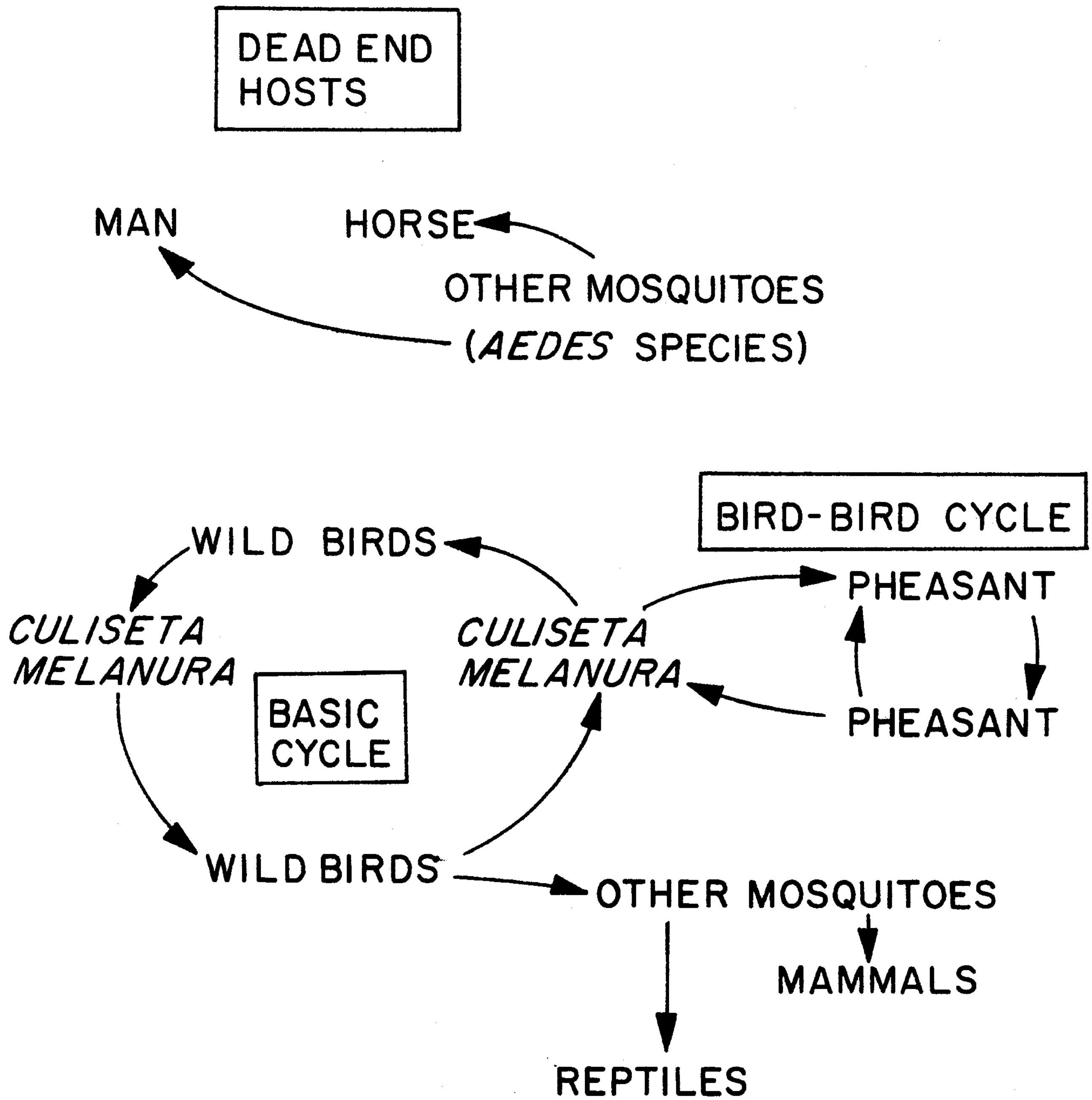

Fig. 1. Infection cycle of Eastern Equine Encephalitis.

There are several basic cycles in the chain of infection of eastern equine encephalitis (Fig. 1). There is the basic cycle of transmission of the virus between wild birds with *Cs. melanura* being the primary vector. There is a bird-to-bird cycle which has been identified among pheasants. This cycle appears to be initiated by infected *Cs. melanura* mosquitoes feeding on pheasants. And then there are the dead-end hosts: horses, other mammals, reptiles, and man. Infections in these dead-end hosts may be caused by *Cs. melanura*, but there is some evidence to suggest that these deaths are caused by other mosquitoes, probably of the genus *Aedes*, which feed alternately on infected wild birds and upon the dead-end hosts.

In 1959, there was a major outbreak of eastern equine encephalitis in New Jersey with a considerable number of fatal cases in humans. Two different species of mosquitoes, both of which breed in wetland waters, were implicated in this epidemic. Epidemic studies implicated *Cs. melanura* as the primary sylvan vector bringing the virus to the epidemic centers, and *Aedes sollicitans* (the pestiferous salt-marsh mosquito) as the primary vector infecting humans.

Eastern equine encephalitis is a dreaded disease which is characterized by a high fatality rate and serious sequelae, largely mental retardation, among a high proportion of survivors. Steps must be taken to prevent an epidemic of this disease among humans in Connecticut. In and near densely populated areas, wetlands must be controlled to minimize breeding of the important vectors of this disease.

In Connecticut *Culiseta melanura* is found primarily in *Sphagnum* bogs and cedar swamps. It appears to be exceedingly selective in its breeding places and tends to choose secluded shady sites with cool acid water in permanent fresh-water swamps. *Aedes vexans*, which has been implicated also in transmission of EEE from wild bird to man, is a flood-water mosquito. It breeds along the flood plains of rivers and lays its eggs along the muddy edges of receding pools, where they may hatch the same season when water due to intermittent flooding or freshets reaches them, or they may carry over to the next season.

Conclusion. While from the public health point of view, it is desirable to preserve (and conserve) as much of our wetlands as practicable, there is a basic health need to exert a degree of control over those wetlands which are either in the midst of human settlements or adjacent to residential areas. In exercising this control, some wetlands will be destroyed and others may have to be treated periodically and intensively with insecticides to control mosquitoes.

It is important that wetlands which are remote from human habitation be protected from encroachment by developers. It is highly desirable that a protective buffer zone be provided for wetlands which are to be preserved. Failure to provide this protective fringe may require that intensive environmental control measures be exercised in these wetlands in the interest of protecting the health of the public. But for the public health, many wetlands may be destroyed or their ecology changed extensively.

INLAND WETLAND REGULATION IN CONNECTICUT

(Babes in the Bogs)

by

Stephen Zwerling* and Fred W. Grupp, Jr.**

Introduction. Despite the fact that Garrett Hardin's allegory about "the tragedy of the commons" has not yet fully captured the public imagination, considerable progress has been recorded on a number of environmental fronts (*1*). Not only have we been able to enact legislation for the protection of public natural resources but today we are on the verge of claiming, or in some instances reclaiming, private natural resources in the name of the public interest.

We have reluctantly come to the conclusion that in a finite world there are in fact some limits to growth. It is not yet clear exactly where those are or what might be done to avoid them but it does seem clear that human activity must somehow be regulated. The precise form of controlling human activity remains to be determined but if recent trends are any indication, the preferred solution strategies are administrative rather than political, and macroscopic rather than microscopic (*2*).

To approach the future with any degree of confidence, we are in need of a rational, centralized authority capable of developing and implementing a coherent set of values to guide us. Not only is such a solution strategy inconsistent with American political history--and, hence unlikely to be heeded--but the cure may be worse than the disease. In this paper we argue in favor of political rather than administrative solutions and at local levels rather than state or federal levels, using, as a case in point, a recent piece of environmental legislation in Connecticut.

In 1972 Connecticut became the first state in the nation to enact legislation intended to provide for the preservation, protection, maintenance, and use of inland wetlands and watercourses (*3*). Inland wetlands represent a complex interface of biological, soil and water resources; from a functional and ecological perspective wetlands are considered to be essential to the health, welfare and safety of the state's citizens. It has been

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estimated that between 20-25% (approximately 800,000 acres) of Connecticut's land area can be legally classified as wetlands.

The legislation is significant in several respects, not the least of which is the intended purpose of public regulation over what is essentially private property. The issue of public rights versus private rights is always sensitive, particularly where property is concerned; in this instance, the property subjected to regulation amounts to approximately one-quarter of the total land area in the state. Although the legislation will affect individuals, inland wetlands are not a high-visibility issue in the public eye (*4*). Moreover, the legislation is somewhat ambiguous; the power and authority of enforcement agencies is unclear; and various constitutional issues remain to be decided. These considerations notwithstanding, the law *requires*, rather than authorizes, action either by local or state agencies.

There is a difference between approving legislation and enforcing it, and the effectiveness with which the regulations are implemented remains to be seen. Connecticut's politics being characterized by a strong emphasis on local control, the state's 169 towns were given the option of regulating wetlands themselves. Approximately 80%, 136 towns, of the communities favored local control; the remaining 20%, 33* towns, opting to have the State's Department of Environmental Protection (DEP) regulate town wetlands. The issue, then, is under what conditions inland wetlands are likely to be protected: local or state regulation (*5*).

Theoretical Concerns. Insofar as the Connecticut legislature has determined that wetland conservation is a public interest, wetlands must be understood as a common, collective or public good. Loosely defined, a public good is such that if any person in a group "consumes" it, it cannot feasibly be withheld from others in that group (*6*). In other works, a public good is available to everyone if it is available to anyone; those who do not participate in helping to secure a public good cannot be excluded from sharing in the consumption of it (*7*). The good in this instance is the protection of wetlands in the present and for the future; the group is the people in the town or the state, depending upon the level at which regulation is to occur.

While it may be reasonable to suppose that individuals act rationally and self-interestedly, Olson argues that the behavior of groups is not necessarily similar. Indeed he asserts that

> . . . unless the number of individuals in a group is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, *rational, self-interested individuals will not act to achieve their common or group interests* (*8*).

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*now approximately 25 (March 1976). - Eds.

The benefits derived from acting to protect wetlands, considered here as a public good, are inclusive and general rather than exclusive and specific. Unless the benefits are noncollective -- e.g., distributed according to the degree of effort invested to secure them -- Olson would think it unlikely that rational, self-interested individuals will act to further their general interests.

Similarly, Anthony Downs has reasoned that citizen apathy is rational in many instances (*9*). Since the cost of acquiring information is relatively high in terms of effectively influencing political decision-making, only those who stand to benefit specifically (i.e., unequally) are willing to bear the costs associated with active participation. Downs contends that this explains why democratic governments often seem to be biased in favor of "producer" interests and against "consumer" interests. Producers organize to act on their interests because the benefits and costs to them are particular and make participation worthwhile. Consumers on the other hand, have more diffuse interests, and the collective nature of the costs and benefits associated with pursuing such interests makes it difficult -- if not irrational -- for them to organize and/or act on them.

Both Olson and Downs consider the nature of the goal to be paramount. In a somewhat different approach, McConnell and Schattschneider regard the structure of political conflict (of the size of the decision-making constituency) as the critical variable (*10*). The notion of the small constituency has a hollowed position in America's political mythology, emphasizing such values as autonomy, freedom, individualism and privacy. Both writers contend that private interests prevail in small political constituencies because they are over-represented vis-a-vis public interests. Their prescription is to enlarge the size of the constituency. The wider the scope of conflict, the greater the likelihood that the public intersts can prevail.

To recapitulate the theoretical argument, those seeking the attainment of public goods (effective regulation of wetlands) in a decision-making context characterized by relatively small units (towns) have little reason to be confident about policy outcomes. If the theory is sound, wetlands are apt to be more effectively regulated by the State; yet approximately 80% of Connecticut towns have decided to regulate wetlands themselves. Insofar as the points raised by Downs, Olson, McConnell and Schattschneider seem reasonable, we must conclude that the future of wetlands regulation is not hopeful.

It is possible however, to imagine an alternative construction (*11*). A political system characterized by decentralized decision-making with multiple points of access to the decision process is one which inhibits rather than facilitates action. It is biased in favor of incremental change and against fundamental change. While one might be tempted to conclude that minorities (or private interests) rule in such a political system, it is also possible to conclude that numerous points of access which inhibit action is a situation quite favorable to the protection of public interests. That is, the greater the likelihood that wetlands will remain undeveloped.

The existence of a local regulatory authority does not mean *ipso facto* that wetlands will be protected. What is required for effective regulation is the creation of an active, pro-wetland constituency. Since local level wetland commissions play a pivotal role in the decision-making process, it is important to learn how they understand their mission. Toward this end, we surveyed local level wetlands commissioners in Connecticut with two purposes in mind: first, what are they like in terms of biographic data and what their attitudes and perceptions are regarding wetlands regulation, and second, what if any are the differences between town wetland commissions in terms of understanding the political dimensions of wetland regulation.

Research Methods and Results. The universe of towns opting for local control of wetlands was requested from the State Department of Environmental Protection (DEP). This generated a list of towns that included the name and home address of the chairperson of each town's wetland regulatory agency. Letters were mailed to each of the 133 chairpersons requesting the names and home addresses of the other members of the wetland agency in their town. Usable lists were received from 111 of the 133 town chairpersons (83%).

Each of the 716 wetland commissioners identified by this process was mailed a four-page questionnaire with a cover letter from the director of the University of Connecticut's Institute of Water Resources and a postage-paid, self-addressed envelope in which to return the completed questionnaire. A second mailing was sent to those commissioners who did not respond within a three-week period.

A total of 474 (66%) usable questionnaires was returned. A response rate of this magnitude indicates that the data base is representative of wetlands commissioners throughout the state. In addition, it is noteworthy that one or more of the completed questionnaires was received from 103 of the 111 towns. This response constitutes 93% of the towns surveyed and 77% of all towns retaining local regulatory control. Thus there is ample reason to believe that the responses are representative of town commissions as well. This is an important point since our analysis takes two forms: 1. a profile of attitudes, perceptions, and biographical data of individual commissioners; and 2. an analysis in which commissioner responses are aggregated by town -- i.e., where the composite profile of the town commission, rather than the individual commissioner, is the unit of analysis.

Biographic Data. Based on the sample, the "typical" local level wetlands commissioner in Connecticut is a 47-year old male who has lived in the town he represents for about 19 years. He is a college graduate, most likely with post-graduate education, and his major field of study was probably natural science or engineering. In terms of employment, he is a "professional", as is his spouse if she is employed. He has not had prior governmental experience, and he does not hold any local governmental position concurrently with his position on a wetlands commission. In sum, the commissioners tend to be very well educated, long-term residents in their towns, and they rank quite low on an index of political experience. Given the inherently political element in the regulation of wetlands, the less skilled are the commissioners in terms of bargaining, compromise and negotiation, the more susceptible they may be to the claims made by private interests.

Perceptions of Wetlands Commissioners. It was noted earlier that there is considerable ambiguity surrounding the technical definition of the term "wetland". Nevertheless, most commissioners are confident of their ability to recognize a wetland when they see one; moreover, approximately half of the respondents were able to list two of the three most sophisticated criteria for on-site determination of what is and is not a wetland.

But the regulatory process is demand-activated rather than initiated by the commissioners. Hence, it is important that townspeople be aware of wetland regulations. The commissioners believe that the extent of citizen awareness is fairly well divided between "moderate" and "low". They estimate that between 10-20% of their townspeople feel strongly about wetlands; however, those who do feel strongly are believed to be favorable to regulation.

In terms of budget, 75% of the respondents reported that town funds had been appropriated for wetland regulation, the mean budget being approximately $3,000. Since the implementation process is just beginning, it is difficult to assess the adequacy of town wetland budgets. According to the commissioners, however, the major types of expenses expected in wetland regulation will be administrative (i.e., for technical assistance and enforcement personnel) rather than adversarial (i.e., litigation costs).

The commissioners are able to identify specific groups and interests concerned with wetlands regulation. Approximately half of the respondents were able to name two or three proponents and/or opponents, which suggests that they are not aware of constituencies. In terms of potential commissioner bias regarding regulation, 33% of the respondents cited only those groups favorable to regulation, while 9% cited groups opposed to regulation.

What are the contending interests? According to the decision-makers, citizen conservationists, miscellaneous citizen groups and state administrative officials are perceived to be supporters of regulation. With these perceptions in mind, it is of interest to note that those groups most likely to be affected by regulatory activity (e.g., business, developers and agriculture) are not heavily represented on local wetlands commissions.

Earlier in this paper it was noted that while the function of a wetland commission is regulatory, the public is not well acquainted with wetland regulation. Adding to this the fact that the principal opponents of regulation are perceived to be private and organized interests, it seems reasonable to suppose that education of the public is an important component of the mission of a local wetland commission. Educational activities serve two purposes: 1. increasing public consciousness about the issues (e.g., what wetlands are, why they are important, and the rules and procedures governing their use); and 2. building a political constituency.

Yet the survey results indicate the opposite. The respondents indicated that their town commissions had sponsored few activities to acquaint people with wetlands. More significantly, when queried about the types of

commission-sponsored activities, more than half of those who had responded in the affirmative replied that the impetus originated with the citizens rather than from the commission!

It is not surprising that 88% of the respondents believe that local level enforcement is preferable to state enforcement. What is surprising is that the local level commissioners have not been actively engaged in educating their constituents. More importantly, in reply to an open ended invitation to share with us their concerns, the respondents imagine themselves to be illsuited to implement the laws, inadequately informed, and lacking the support of state government. They perceive a need for more specific working in the legislation, and they seek State assistance in the form of education for themselves and the general public. If they are to perform well in their roles as regulators, commissioners feel that the State must provide them with technical assistance and greater enforcement powers.

The general results of the survey of Connecticut's local level wetlands commissioners suggest that this is a situation in which a rather significant piece of legislation, in terms of its potential impact, has managed to get onto the decision agenda despite little evidence of public concern (*12*). In the absence of strong public demand for such legislation, policy has been promulgated by state legislators. Those charged with carrying out this policy, however, view themselves as inadequate to the task, with obvious consequence that they are not encouraged by their mission. Whether this state of affairs can be turned around is an open question. State level policy makers, who should know better by virtue of their experience, must attend to issues of implementation more seriously than they have to date (*13*). Wetland commissioners, on the other hand, must counterbalance their political inexperience with active efforts to develop public awareness of wetlands as a prelude to building a supportive constituency. Otherwise, the concern for protecting wetlands is likely to abate, policy being viewed more as symbolic than as substantive (*14*).

Town Wetlands Commissions. Our interest is in substantive policy outcomes, and because decision-making is a collective activity, we rearranged the data on individual commissioners so that it would reflect town commissions. By taking the mean scores of individual commissioner responses in each town as a composite profile of the town's wetland commission, we have attempted to predict the future of wetland regulation in Connecticut. It should be emphasized that data on the effectiveness with which the regulations are enforced is meager because the implementation process is just now beginning. Hence we are trying to predict outcomes rather than explain them.

The logic of our argument is as follows. Private interests are more apt to be served where the size of the constituency is small and where, by definition, the scope of conflict is limited. Since control of wetland regulation is likely to remain predominantly at the town level, the protection of wetlands depends upon the creation of a supportive, pro-regulation constituency within the town. In the absence of such a constituency, town wetland commissions are apt to accede to private interests at the expense of protecting wetlands. In brief, a "public interest" constituency

contributes to political conflict which, in turn, serves to promote wetland conservation.

Three variables have been selected for analysis in terms of producing organized town support for effective regulation of wetlands: 1. the existence of a specific, single-purpose unit for wetland regulation; 2. the amount budgeted for wetland regulation; and 3. the number of educational activities sponsored by the town's wetland agency. We believe that each of these three variables is positively related to constituency-building, political conflict, and wetland protection.

Single-purpose regulatory agencies. The decision regarding the proper unit to regulate wetlands was made by town elected officials prior to our survey. Having opted for local control, towns could either create a new agency or add the function to an already existing unit of town government, e.g., conservation commission or planning and/or zoning boards. The fact that almost two-thirds (64%) of the towns established single-purpose wetland agencies is an important finding insofar as it suggests that regulation is a serious matter in the minds of the town's elected officials, who appointed wetland commissioners.

Equally important is the fact that a single-purpose unit is more visible to the public and provides an additional point of access to decision-making about local land-use. The greater the number of points at which decisions can be affected the easier it is to stop action. Hence, if the right to alter existing arrangements must be secured from an additional agency, then wetlands are more likely to be protected because their use can be more carefully scrutinized.

Town wetland budgets. The size of the town's budget for wetland regulation is important not only for the technical aspects of regulation but for the political aspects (e.g., building a supportive constituency) as well. Ranging from $50 to more than $20,000, the average town budget for wetlands is approximately $3,000; two-thirds of the towns have budgeted $6,000 or less for wetland regulation. The adequacy of wetland budgets depends upon the workload of the agency and the types of expenses incurred in regulatory activity. Earlier we reported that the commissioners anticipated expenses in the following rank order: Administrative (47% of all responses), adversarial (29%) and consulting expertise (24%). It is significant that the commissioners did not consider educational programs to be a major expense. Thus, the size of the budget may be off-set by commission activities.

Commission-sponsored activities. Unlike the decisions about the proper regulatory authority and the size of the budget, educational activities are controlled solely by the commissioners. The extent of informational activity is a measure of the efforts of wetland commissions to increase the salience of, and create a supportive climate for, regulation in the towns. We noted earlier that only half of the towns had sponsored any educational activities and that those activities which were sponsored had been initiated by citizen requests rather than by the commissioners. Overall, town wetland commissions have not attempted to create a suppor-

tive constituency within their towns, and this must be corrected (in our view) if wetlands are to be effectively regulated.

What factors, then, are associated with, or predict, the three analytic variables? The survey data was analyzed using a stepwise multiple regression technique and one that deserves more precisely measured data than are available to us; however, our interest is less in explaining variance than in learning which types of variables (i.e., political, technical or environmental) are the best predictors.

Findings. Table 1 displays the results of the analysis concerning the establishment of a single-purpose town wetland agency. Together, the four variables explain 13% of the variance; the bulk of the variance remains unexplained, but this is to be expected given our reliance on data from a mail questionnaire. The ordering of the variables is extremely interesting, however. The more important factors are the attitudes of the townspeople toward wetlands and the support of conservation groups.

The single best predictor is the heterogeneity of public opinion. If the town is perceived as containing both strong supporters and strong opponents of wetland regulation, the town response was to establish a single-purpose agency. In other words, the greater the potential for political conflict, the greater the tendency of town officials to provide a forum in which the conflict can be resolved.

The support of groups is also important in the decision to establish a single-purpose agency. The greater the percentage of the total number of interested and supportive groups in a town, the more likely it is that a single-purpose regulatory unit has been established.

The extent of wetland area in a town, which is a measure of the potential workload of a regulatory agency, is a far less important predictor. The density of a town's population explains only 1% of the variance. Note too, that town wealth might have expected a single-purpose agency to be perceived as more expensive.

Table 2 displays the results of the analysis of the size of the wetland budget. The two best predictors of the budget size are the number of commission hearings and the town's wealth. These findings seem reasonable; the number of hearings reflects the number of applications for land deregulation, while town wealth constrains all aspects of a town's budget.

The third best predictor is the average level of natural science training. It should be noted that the average level of political experience is much less important. When this fact is combined with the relative unimportance of public awareness of wetland regulation in the regression analysis, it suggests to us that the size of the town's wetland budget is unrelated to the awareness of potential political conflict. Instead, wetland regulation appears to be perceived as a technical issue, much like public works, in which funds are allocated on the basis of the number of claimants on agency time and overall availability of tax dollars. This

Table 1. Factors Associated With the Establishment Of a Single-Purpose Wetland Agency

Factors	β	R^2
Homogeneity of opinion	-.223	.06
Percentage of town's groups favoring wetlands regulation	.189	.10
Percentage of the town which is wetland	.137	.12
Population density	-.098	.13
Per capita income	-.060	.13

Note: In this and the following tables, Beta is the standardized coefficient in the multiple regression analysis with the effects of the other variables accounted for. R^2 indicates the cumulative percentage of variance explained by the set of predictors.

Table 2. Size of Wetland Regulation Budget

	β	R^2
Number of Public Hearings	.285	.09
Per Capita Income	.208	.16
Level of Natural Science Training	.228	.20
Population Density	.202	.23
The Townspeople are very aware of Wetland Regulation	.213	.26
Percentage of Town Perceived to be Wetland	-.228	.29
Level of Political Experience	.171	.32
Establishment of a Single-Purpose Wetland Agency	.132	.33

finding is in sharp contrast to the decision to create a single-purpose agency since public opinion and conservation group activity were the important factors.

Table 3 displays the results of the analysis on the numbers of informational activities sponsored by the wetland commission. This is, by far, the best predictor we have of the extent to which a wetlands agency perceives the need to establish a supportive constituency in the town.

The most important factor associated with educational activities is the average number of years that the wetlands commissioners have lived in their town; commissions populated by longterm residents are less likely to engage in educational activities. We interpret this finding as a measure of a town's political "style" because sponsored activities are not related to the average age of the commissioners.

The levels of sophistication in on-site determination of wetlands and natural science training are both positively related to educational activities. Of the six predictors, four are measures of the commissioners' personal characteristics. This is to be expected insofar as the commissioners have considerable control of their agency's activities. Significantly neither prior political experience nor attitude of the townspeople appear in the list of strong predictors; the same is true for town characteristics such as the percentage of wetland area in a town, per capita income and population density.

The findings suggest that the motivation for sponsoring educational activities may stem from a well developed awareness of the technical complexity of wetlands rather than from any "feel" for the political aspects of regulation. To the extent that this is true, commissions characterized by political naivete but high levels of technical expertise may promote educational activities leading to the development of a supportive constituency without intending to do so. In other words, the "scientific commissioners" may be performing a vital political function unwittingly.

Conclusions. Although it is too early to test the three analytic variables in terms of policy outcomes, we have identified three variables which we believe are related to the effective protection of wetlands. With respect to the factors associated with each of the analytic variables, the surprising result is that political conflict, and hence the desirability of prior political experience of wetlands commissioner--does not seem to count for very much. On the other hand, perhaps to be attributed to serendipity, the commissions appear to be doing the "right" things, albeit for the "wrong" reasons. Whether the town wetland regulators will be able to develop an active constituency remains to be seen as the implementation process unfolds.

At least one town in Connecticut is preparing to return wetlands regulation to the State DEP evidently due to the unwillingness of the townspeople to commit funds for local regulation. Should this develop into a trend among Connecticut towns, we would predict a weakening in regulatory activ-

ity. At the present time* the DEP's wetlands unit is staffed by only three individuals; thus, charged with administering wetlands regulation on a widespread basis, the DEP would be stretched beyond its capabilities. A related concern is that the towns with the greatest percentage of wetland area are the towns with the least amount of taxable wealth. It is the towns with the greatest potential ability for regulatory activity that may be most likely to give up local control of wetlands to the State in the interests of the economy. This could exacerbate the management problems for the DEP.

The question arises as to whether it would have been, or would be preferable for the State to regulate wetlands. State government, because it has a more encompassing responsibility, is often thought to be the proper repository for management activities rationally understood and to be sure, there appears to be emerging trend away from local control and toward regional, state or federal control. Presumably, this stems from the increasing complexity and interdependence of contemporary society. It is thought that more encompassing authorities are more rational, systematic, efficient, coordinated and consistent (*15*).

We view this trend with dismay for it has the consequence of casting politics, the expression of social preferences, in administrative clothing. Politics does not, however, disappear in the process of administrative decision-making; it simply alters the form of politics in a way that we think is undesirable for wetlands regulation both specifically and in general (*16*). To argue in favor of state control requires the assumption that civil servants are somehow different than ordinary citizens; there is no evidence that this is true. Moreover, reliance on one unit at a state wide level seems risky insofar as there is no guarantee that policy outcomes will be "good". Regulation on a local level may be uneven from town to town but the element of risk is considerably reduced.

It is our feeling that political decisions are most appropriately (*14*) made at the smallest possible level, problem boundaries being determined by the people most directly affected by a possible decision. The support for this position is both theoretical and empirical (*17*). California's Local Government Reform Task Force concluded, much to the surprise of Governor Reagan, that not only were local governments in most cases more responsive to their constituents but that they were more efficient and effective as well (*18*). In addition, a study of the differences in policy outcomes between unregulated and regulated land-use in the Lake Tahoe, California area concluded that there were none (*19*).

In essence, then, we believe that the proper level at which to regulate wetlands is town government. But effective regulation can only occur in a context of competition and conflict; this in turn, depends upon the pro-wetlands constituency. Connecticut's local-level wetlands commissioners seem in fact to be "Babes in the Bogs". Whether they will sink or swim depends upon their ability to cope with the political aspects of wetlands regulation.

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*Early summer 1975 - Eds.

Table 3. Number of Informational Activities Sponsored by the Agency

	β	R^2
Average Number of Years the Wetlands Commissioners have Lived in Their Town	-.231	.09
On-site Sophistication Level	.194	.14
Number of Public Hearings	.181	.18
Level of Natural Science Training	.133	.20
Percentage of Townspeople Perceived as Feeling Strongly About Regulation	.110	.22
Level of Political Experience	.109	.23

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3. *General Statutes of the State of Connecticut,* Ch. 22a, Sect. 36. (Public Act No. 155: An Act Concerning Inland Wetlands and Watercourses).

4. Wetlands regulation, surprisingly, was not a particularly salient public issue at the time of the bill's passage. Although a variety of environmental groups participated actively in providing support for the legislation, the political navigator was a freshman State Representative who is neither a lawyer nor a known conservationist.

5. Earlier versions of this paper attracted some criticism regarding the usage of works such as "conservation" and "preservation" as applied to wetland legislation. Insofar as the legislation includes the "use" of wetlands in its wording, such criticism may be justified. It is our feeling, however, that there should have been no need for wetland legislation had publics and officials been comfortable with the ways in which wetlands had been and were being used. Hence, while the legislation does not prohibit use, its intent is clearly in the directions of conservation, preservation, and protection.

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APPENDIX I. SELECTED EQUIVALENTS OF COMMON AND SCIENTIFIC NAMES

Alder = *Alnus rugosa* (DuRoi) Spreng. [Betulaceae] and others.

Andromeda glaucophylla Link [Ericaceae]. = Bog rosemary.

Aster junciformis Rydb. [Compositae]. = Aster. This species common to wet places. See paper by Richardson *et al.*

Balsam fir = *Abies balsamea* (L.) Mill. [Pinaceae].

Bidens tripartita L. [Compositae]. = Beggar's tick. This species introduced and naturalized from Europe.

Black spruce = *Picea mariana* (Mill.) BSP. [Pinaceae].

Bog Birch = *Betula pumila* L. [Betulaceae].

Buckbean = *Menyanthes trifoliata* L. [Menyanthaceae; Gentianaceae-Menyanthoideae].

Buttonbush = *Cephalanthus occidentalis* L. [Rubiaceae].

Calamagrostis canadensis (L.) Beauv. [Gramineae]. = Blue joint. A tussock-forming grass of wet places.

Campanula aparinoides Pursh [Campanulaceae]. = Marsh bluebell.

Cattail = *Typha latifolia, T. angustifolia* L. [Typhaceae].

Cicuta bulbifera L. [Umbelliferae]. = Water hemlock.

Dogwoods = *Cornus* spp. [Cornaceae]. Those common to wet areas are *C. stolonifera* Michx., *C. amomum* Mill., and *C. obliqua* Raf.

Grasses = Gramineae. The term "grass", in lay usage generally means any plant with narrow, linear leaves; in fact, "grass" refers specifically to the Grass family, Gramineae. These plants are characterized in part by their highly modified laterally compressed flowers with bilateral symmetry. See also *Juncus*; Sedge.

Hypericum virginicum L. (= *Triadenum virginicum* (L.) Raf.) [Guttiferae]. = Marsh St. John's-Wort.

Iris virginica L. [Iridaceae]. = Southern Blue flag. Richardson's is more likely *I. versicolor* L.

Juncus = Rush. Often termed a "grass" in lay parlance, the Rushes are members of the Juncaceae. These linear-leaved plants are characterized by trimerous radially symmetical flowers with 3 sepals and 3 sepals surrounding 3 or 6 stamens and a 3-parted ovary. See Grasses; Sedge.

Leatherleaf = *Cham daphne calyculata* (L.) Moench [Ericaceae].

Lycopus spp. [Labiatae]. = Water-horehound. Common wetland species are *L. uniflorus* Michx. and *L. virginicus* L., and others.

Lysimachia spp. [Primulaceae]. = Loosestrife. The yellow-flowered plants carrying this common name, such as *L. ciliata L.* and *L. terrestris* (L.) BSP. are members of the Primulaceae, or Primula Family; the taller, purple-flowered swamp "Loosestrifes" are *Lythrum alatum* Pursh and *L. salicaria* L. of the Lythraceae, or Loosestrife family. This example points out the occasional difficulty of common names.

Muhlenbergia glomerata (Willd.) Trin. [Gramineae]. = Muhly.

Orchids = Orchidaceae.

Pitcher plants = *Sarracenia purpurea* L. [Sarraceniaceae].

Populus tremuloides Michx. [Betulaceae]. = Quaking aspen.

Red maple = *Acer rubrum* L. [Aceraceae]. See frontispiece.

Scirpus cyperinus (L.) Kunth [Cyperaceae]. = Bullrush. See *Sedge*.

Sedge = Cyperaceae. The term "sedge", in practice usually refers to members of the genus *Carex*. The cyperaceae, another linear-leaved group of plants, have the radially symmetrical 3-parted flowers without sepals and petals. The flowers are often also unisexual (in *Carex*); the ovary is simple (of one unit). See *grasses; Juncus*.

Skunk cabbage = *Sumplocarpua foetidus* (L.) Nutt. [Araceae].

Sphagnum = Sphagnum moss [Sphagnaceae]. A large and complex moss genus; its members are found in wet, acid areas such as bogs, often forming an extensive spongy mat on the ground surface. Compresses and partially decomposed *Sphagnum* is the essential substance of peat and peat moss.

Sweet gale = *Myrica gale* L. [Myricaceae].

spp. [Compositae]. = Goldenrod.

Sundew = *Drosera* spp. [Droseraceae].

Tamarack = *Larix laricina* (DuRoi) K. Koch [Pinaceae]. also "Larch".

Typha latifolia L. = Cattail, q.v.

Utricularia spp. [Lentibulariaceae]. = Bladderwort.

Vaccinium macrocarpon Ait. [Ericaceae]. = Cranberry.

Water lillies = *Nymphaea* spp. [Nymphaeaceae].

Willow = *Salix* spp. [Salicaceae].

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