September 1978

Transition Zones of Forested Inland Wetlands in Northeastern Connecticut

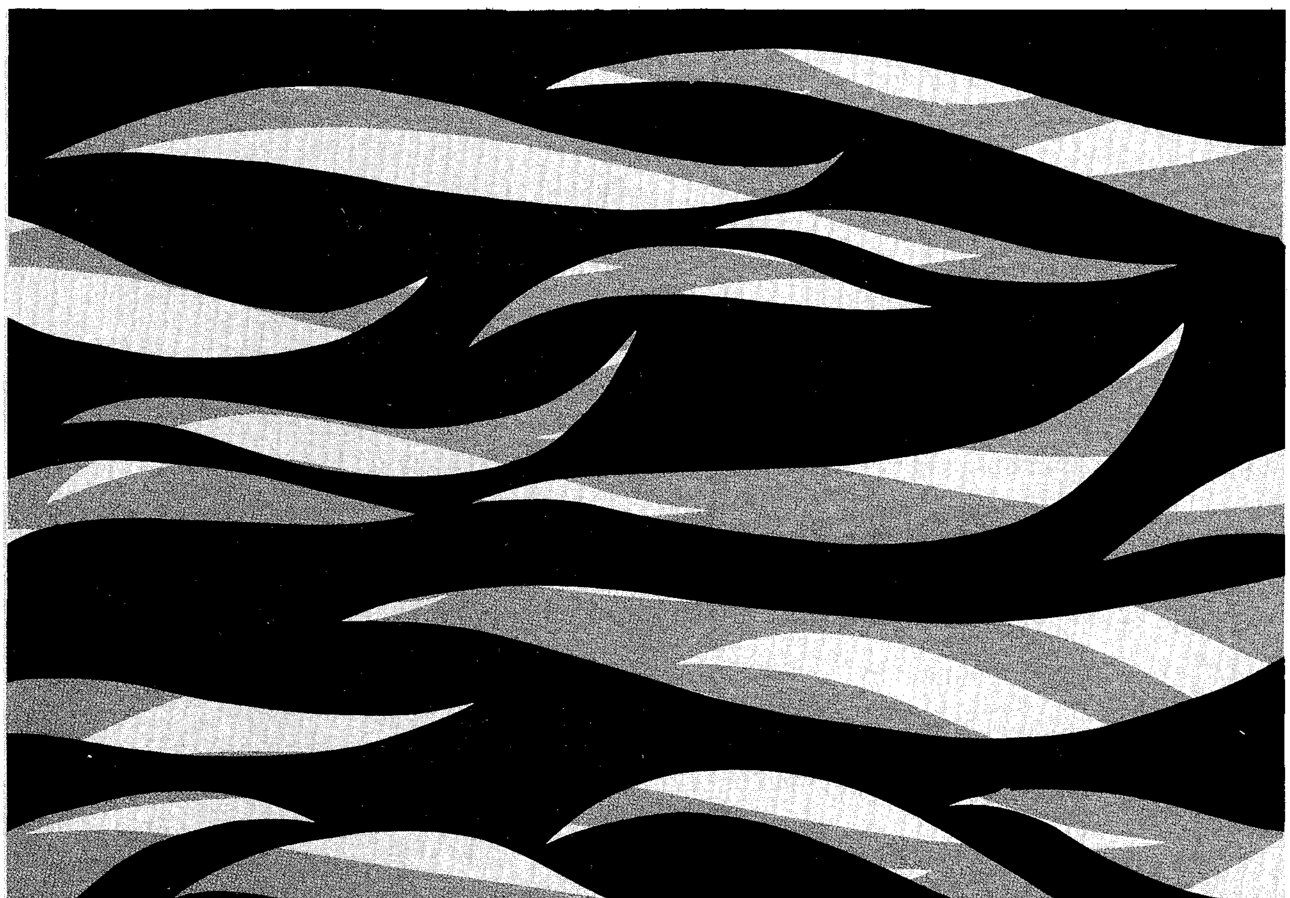
P. H. Anderson

Michael W. Lefor
University of Connecticut

William C. Kennard
University of Connecticut

Transition Zones of Forested Inland Wetlands in Northeastern Connecticut

Report No. 29 September 1978



INSTITUTE OF WATER RESOURCES
The University of Connecticut

Report No. 29 September 1978

TRANSITION ZONES OF FORESTED INLAND WETLANDS IN NORTHEASTERN CONNECTICUT

P. H. Anderson, M. W. Lefor, and W. C. Kennard

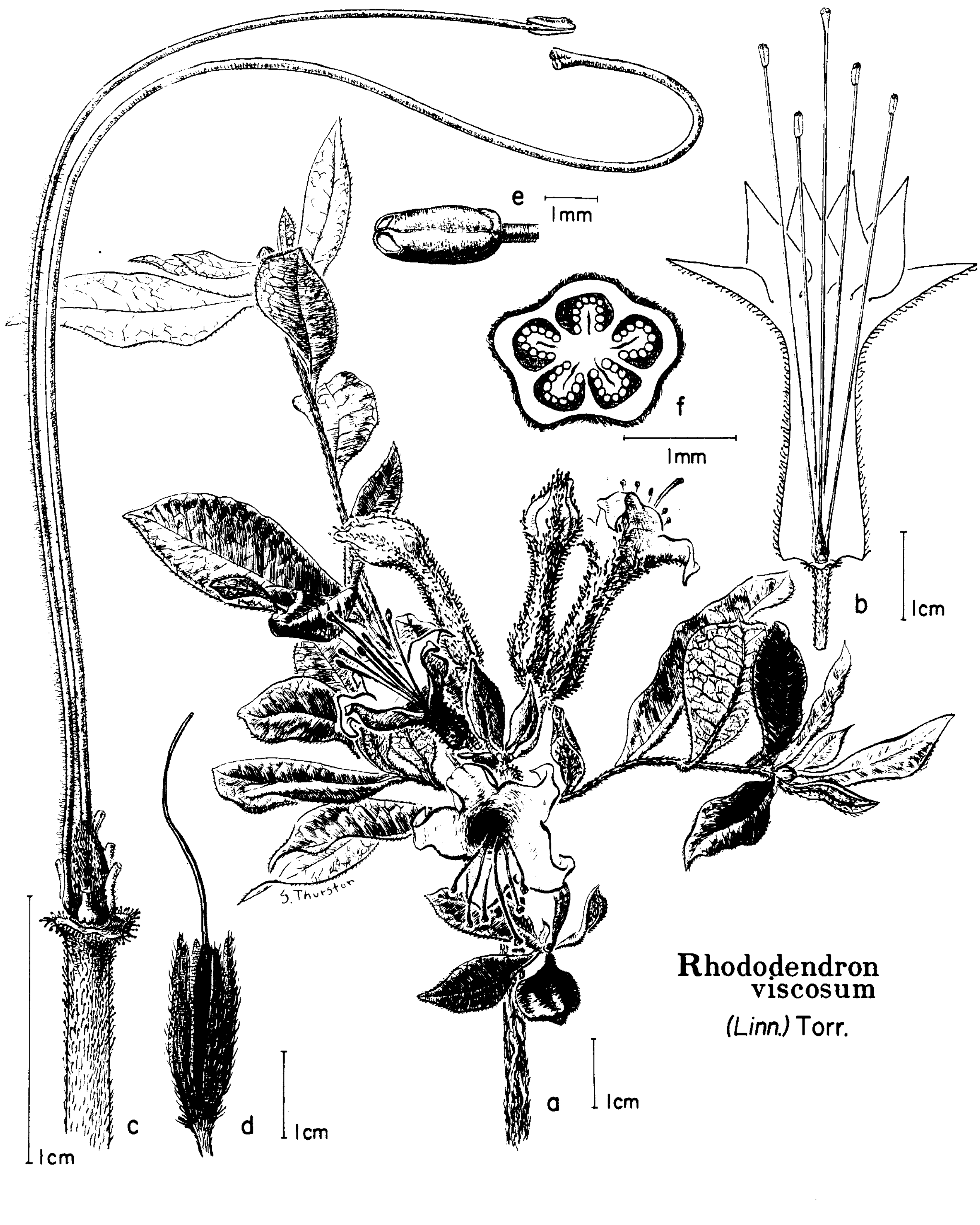
Institute of Water Resources

The University of Connecticut

The research upon which this publication is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Research Act of 1964, Public Law 88-379, as amended.

FRONTISPIECE

Rhododendron viscosum (L.) Torr., a common understory shrub of forested inland wetlands in northeastern Connecticut. a. Flowering branch; b. flower, opened along the corolla; c. gynoecium and androecium (four stamens removed); d. fruit; e. anther; f. ovary, x. s. From living material. (Artist: S. Thurston)


e
1mm
f
1mm
b
1cm
S. Thurston
Rhododendron
viscosum
(Linn.) Torr.
c
1cm
d
1cm
a
1cm

FOREWORD

In recent times, the Institutes of Water Resources have been charged with increased responsibility by the Congress of the United States to make the results of academic research available to the public and to a wide variety of individuals who must make decisions. As a matter of policy, every attempt is made to present these results in a useful form. The report which is presented here is the fifth in a series on inland wetlands* resulting from a carefully planned mixture of research, conferences, and seminars which have taken place over the past five years. In all of these efforts, the objective has been to bring to the public a more effective means to implement Connecticut's Inland Wetlands and Water Courses Act (P.A. 155) of 1972.

The objectives of this research were to: (1) investigate vegetation distribution and selected physical and chemical properties of wetland and upland soils and the interface between the two; and (2) provide the ground truth necessary for the identification and delineation of deciduous wetland forests using false-color infrared imagery. We believe that this report demonstrates the successful accomplishment of these objectives. Furthermore, the results are presented in such a form that those persons concerned with the identification of wetlands will be greatly assisted by means of the listings of plant species which show preferences for wetland or upland sites.

The Institute of Water Resources is most pleased to be able to publish this report as a continuation of its studies on inland wetlands. The authors are to be complimented for this fine presentation.

Victor E. Scottron**

---

*1. Proceedings: Wetlands Conference (June 20, 1973), Report No. 21, December 1973.
2. Proceedings: Second Wetlands Conference (January 9, 1974), Report No. 24, October 1975.
3. Proceedings: Third Wetlands Conference (June 14, 1975), Report No. 26, January 1976.
4. Inland Wetlands Definitions, Report No. 28, November 1977.
5. Transition Zones of Forested Inland Wetlands in Northeastern Connecticut, Report No. 29, 1978.

**Director, Institute of Water Resources, The University of Connecticut, Storrs, Connecticut 06268.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The authors wish to thank Messrs. Dominic J. Morales, Arthur Lilquist, Mallory N. Gilbert and Philip E. Toussaint for their aid in the field data collection, Mr. Steven Thurston for the frontispiece and other graphics, and Ms. Wendy Fall for typing the manuscript.

We extend thanks also to Dr. V. E. Scottron, Director, and Ms. F. S. de Lara, Research Assistant III, both in the Institute of Water Resources, for reviewing the manuscript and for their constructive comments. Mr. Daniel L. Civco's critical review of the manuscript and his continuing assistance in preparing it for publication are gratefully acknowledged.

ABSTRACT

Inland wetlands are valuable natural resources intimately associated with the hydrologic cycle. This study was designed to (1) investigate vegetation distribution and selected physical and chemical properties of wetland and bordering upland soils and the interface between the two, and (2) provide the ground truth necessary for the identification and delineation of deciduous wetland forests using false-color infrared (FCIR) imagery.

All study sites were within the 45 $mi.^2$ Town of Mansfield in northeastern Connecticut. Field research was conducted during the growing season of 1975. Line transects were laid out across wetland to upland transition zones. Plant species were identified and their positions on line transects were recorded. Crown cover was determined for herb layers, shrub layers, and the tree canopy. Changes in soil water content, soil pH, depth to water table, and elevations were determined along the transects.

In order to describe the distribution of plant species among the various zones (wetland, transition, upland), a statistical "index of abundance" was developed. Discriminant analysis applied to the abundance data showed which plant species best separate wetlands from uplands and which are representative of natural plant associations.

Differences in soil pH occurred along the transects, but were of such magnitude that they probably have little impact on plant distribution. There was a significant change in soil water content along the wetland to upland gradient. Soil water and topographic position were found to govern plant distribution and were the principal factors accounting for the distinct separation between wetland and upland plant associations.

Of the criteria studied, vegetation distribution, soil water content, and relief are the most useful for delineating deciduous wetland forests. These results are valuable for identifying and delineating inland wetlands using remote sensing imagery.

TRANSITION ZONES OF FORESTED INLAND WETLANDS IN NORTHEASTERN CONNECTICUT

by

P. H. Anderson[1], M. W. Lefor[2], and W. C. Kennard[3]

INTRODUCTION AND LITERATURE REVIEW

This study was undertaken to investigate vegetation distribution and composition and selected physical and chemical properties of the soils of wetland to upland transition zones. The results provide the bases for the on site verification necessary for the identification and delineation of deciduous wetland forests and to correlate ground features with false color infrared (FCIR) aerial photographs.

Inland wetlands are valuable natural resources intimately associated with the hydrologic cycle. They are also productive, floristically rich, and provide significant wildlife habitats. Therefore, they are beneficial to man in their natural state. In recognition of this the State of Connecticut General Assembly passed the Inland Wetlands and Water Courses Act in 1972 (70), which regulates the use of those areas. This act has since been amended three times (71).

Presently, Connecticut inland wetlands and water courses are defined in Section 22a-38, paragraphs 15 and 16, of the State

---

1. Environmental Scientist, GCA - Technology Division, Bedford, MA 01730.
2. Research Associate in Biology, Botany Section, Biological Sciences Group, The University of Connecticut, Storrs, CT 06268.
3. Professor, Natural Resources Conservation Department, The University of Connecticut, Storrs, CT 06268.

Statute as follows:

> (15) "Wetlands" means land, including submerged land, not regulated pursuant to sections 22a-28 to 22a-35, inclusive [tidal wetlands regulations]*, which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial, and 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;
>
> (16) "Water courses" means rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs and all other bodies of water, natural or artificial, public or private, which are contained within, flow through or border upon this state or any portion thereof, not regulated pursuant to sections 22a-28 to 22a-35, inclusive.

The soils method of delineation produces many discrepancies, as described by Hill (36). He states that "the use of the Soil Survey as a regulatory tool to define wetland boundaries may be limited if high degrees of accuracy are required in the location of the boundaries on a map." Bartelli (7) suggests that remote sensing techniques correlated with intensive field studies would provide a rational approach to the delineation of inland wetlands.

In 1953 Martin *et al.* (48) published a nationwide classification of wetlands. Their classification system is based on the depth of water during the growing season, salinity, tidal influence, degree of water table fluctuation, and the presence of characteristic vegetation. Of the twenty wetland types recognized by Martin *et al.*, eight freshwater types are represented in Connecticut. These are the seasonally flooded basins and flats, fresh meadows, shallow fresh marshes, deep fresh marshes, open water, shrub swamps, wooded swamps, and bogs. Other investigators

---

* [ ] = Authors' inserts.

have developed more comprehensive national wetland classification systems in the United States (23, 64, 67) and in Canada (86). Inland wetlands have also been defined and classified on state and regional levels (1, 21, 33, 70, 72, 73, 74, 75). The problem in delineating these unique ecosystems has been approached (7, 8, 36, 42), but has yet to be solved.

Inland wetlands are low-lying tracts of land which have a high soil water content throughout a major portion of the year and support characteristic plant species. In this work, we recognize five types of inland wetlands in our region: seasonally wet meadows, marshes, shrub swamps, wooded swamps, and open water. These five types are differentiated on the basis of the degree of fluctuation of the water table during the growing season and on the presence of members of certain plant species.

The first two, the seasonally wet meadows and marshes, are dominated by herbs. The soils associated with these wetland types may dry out during the later stages of the growing season (seasonally wet meadows) or they may remain submerged throughout the year (marshes).

Shrub swamps are dominated by woody plants which seldom grow more than six meters (20 ft.) tall. While there may be standing water at times, in general the water table is at or near the ground surface throughout the year.

Wooded swamps are dominated by trees which commonly grow to a height of more than six meters (20 ft.). The water table associated with this type of inland wetland also is at or just below the surface throughout the year. Also included in this type are streambelts and bogs; floodplains are also included due to their predominantly woody vegetation.

Open water includes permanent or seasonal water courses (rivers, streams, and drainage areas) and water bodies such as lakes and ponds.

The delineation of forested inland wetlands requires the close field examination of the biological and physical gradients between wetlands and their bordering uplands (8). The vegetation component of the gradients can be used alone to delineate forested wetlands (8, 33, 80). Delineation, however, should not be based only on vegetation, but should be used along with the physical components of the environmental gradient. Topographic relief and soil water content of that gradient markedly influence the distribution of plant species. Contrasts in soil water content characterize the extremes of the gradients, and separateness of these extremes varies with slope (80).

Beschel and Webber (8) showed that along topographic gradients standardized sampling techniques can be used to correlate changes in environmental factors with overall changes of vegetation. In the study presented here, changes in vegetation, important soil properties, and topographic relief were recorded along line transects laid out across wetland to upland transition zones. Plant species composition varies continuously along the wetland to upland gradient, and the transect data can be used to relate those plant associations to the environmental conditions of the gradient.

The variability of vegetation along any given wetland to upland transect is the result of the variation in the environmental factors governing plant growth: light, water, temperature, and nutrients. The interaction of some or all of these factors, any one of which at some time may become a limiting factor, results in an environment supporting a specific plant association (39). Billings (9) states that a limiting environmental factor for members of a plant species is one which falls below the minimum required or which extends beyond the maximum tolerated by that particular species. In nature, habitats where one of the life-supporting factors is limiting usually become highly distinctive. Deserts are examples of a condition where lack of water is the limiting environmental factor. Conversely, an inland wetland represents a condition where the excess of soil water, while beneficial to some species, often limits the growth of others.

Hosner and Boyce (38) state that "Forest compositional changes along drainage gradients into wetlands reflect the relative tolerance of species to excessive soil water conditions." The time of the year in which flooding occurs and duration of that flooding will have a marked effect on species composition (50).

The saturated soil condition of most inland wetlands affects the growth of plants in several ways, many of them unfavorable (41). The aboveground water table level associated with forested inland wetlands during the early spring months adversely affects root development and consequently impedes plant growth. During the later stages of the growing season, the water content of the soil itself and its aeration status above the water table are considered the principal factors affecting plant growth in wetlands (85).

The anaerobic condition associated with wetland soils restricts root respiration. As a result upland plants growing under these conditions may wilt and die due to desiccation. Hosner and Boyce (38) have suggested that plant species capable of tolerating excessive soil moisture have anatomical and physiological characteristics that make them resistant to desiccation.

The rate of decomposition of organic matter is substantially reduced under anaerobic conditions. The accumulation of organic matter creates a soft substrate unfavorable for mechanical support, and increases the water-holding capacity of the soil (10, 60). Only those plant species which are adapted to this wetland soil condition or at least can tolerate it will become established. As a result, plant species found growing on wetland soils are generally other than those found growing on upland soils.

In the spring the temperature of wet soils is considerably lower than that of dry soils. The lower temperatures are due partially to evaporation and partially to the higher specific heat of a wet soil (10). Cool temperatures in the spring create a condition unfavorable for seed germination in most species. This wetland condition favors first growth of seeds of those species which are adapted to germinate under cooler soil temperatures.

Information from quantitative ground sampling or surveys is accurate but costly and time-consuming to obtain. On the other hand qualitative observations often provide inadequate or misleading information. Aerial photography has been used successfully to obtain qualitative and quantitative information about various natural resources (2, 19, 20, 40, 43, 46, 65, 84). Because of their relative inaccessibility, dense vegetation, soft substrate, and numerous small areas of open water, wetlands are more readily identified and inventoried using aerial photographs than they are by field surveys. Sampling sites, field collection areas, survey points, and construction routes are all more easily located using aerial photographic coverage (61).

The results of the analysis and interpretation of aerial photographs have been used to inventory, classify, and map broadly defined zones in various types of wetlands (44, 47, 55, 61). Detailed studies have shown the utility of color and false-color infrared imagery (FCIR) in recognizing plant associations and even members of plant species (3, 4, 5, 16, 17, 18, 22, 49, 66).

False-color infrared photography has been found to be superior to conventional color photography in delineating wetland vegetation (4). Recorded spectral reflectance patterns of wetland plants indicate that members of plant species are difficult to differentiate on conventional color aerial photography (4). Reflectance patterns in the near infrared, however, show rather significant differences between plant species. The reflectance characteristics of vegetation makes FCIR imagery a superior means of discriminating vegetation types (6). Tone and color differences in FCIR film are excellent and provide a good means of identifying spatial distributions of important wetland plant communities. Differences in the spectral reflectances in wetlands on FCIR imagery can be used to delineate members of plant species, small bodies of water, moist soils, and drainage patterns (16). The colors of leafy vegetation on FCIR prints are various shades of red. Bodies of water, drainage areas, and moist soils appear dark blue to black on infrared films because of the almost complete absorption of near infrared radiation by water. This makes wetlands, bodies of water, and water courses appear very dark and distinctive (49).

The following physiological and morphological properties of leaves are responsible for variations in spectral reflectance patterns: differences in pigmentation, differences in mesophyll cell structure, differences in water content, and differences in the leaf surface (pubescence, glaucescence, etc.) (31). Pigmentation and surface characteristics are the two most significant features affecting spectral reflectance (31).

Other factors influencing the spectral reflectance characteristics of plants as recorded on remote sensing imagery are: seasonal changes in the reflectance of members of plant species and their distribution, a shift in leaf orientation, and certain environmental conditions such as disease and insect infestation, drought, flooding, and pollution (16).

Seasonal changes and physiological stress can cause changes in spectral reflectance patterns of plants, which contribute to color and tonal differences in the plant images on FCIR film. "There is considerable tonal change in wetland vegetation during the growing season, reflecting a decline of some species and a succession of others." (4) Healthy green vegetation usually appears red on FCIR photographs, whereas dying, stressed, or aging vegetation appears pink. These color differences are not caused by the change in near-infrared reflectance, but by the increase in visible (red) light reflectance. As leaves age, their chlorophyll begins to break down and less visible red light is absorbed; therefore more red light is reflected and more of the magenta dye on FCIR film exposed. This results in a pink image on the photograph (37).

Individuals of plant species have their own combinations of morphological and physiological characteristics. That is, in the aggregate no two species of plants have identical pigmentation, anatomy, shape, size, and orientation throughout; therefore, members of plant species exhibit different reflectance properties. Because of those differences, a unique spectral signature can be assigned to each plant species, and these signatures can be discriminated using FCIR imagery (35). When attempting to assign spectral reflectance signatures to plants, it is necessary to differentiate between the reflectance of the plant and the reflectance of the soil (16). Therefore, field observations are necessary for the correct assignment of spectral reflectances.

Delineation of inland wetlands on any photograph must be based on experience and information obtained from ground studies. Before any photographic interpretation and subsequent delineation of landforms or surface features can be undertaken, the criteria on which delineation will be based must be established by those studies (7, 8, 42).

MATERIALS AND METHODS

Description of the study areas. All wetlands examined in this study are within the Town of Mansfield, Connecticut, located in the northeastern hills physiographic region of the State (Fig. 1). Mansfield, approximately 11,655 hectares (28,000 a.), represents roughly 1% of the land area of the State. This town was chosen as the test site because (1) its inland wetlands are representative of those found within the State, (2) it is of a manageable size for field work and for low-altitude aerial photographic coverage, and (3) it has within its boundaries the University of Connecticut with its available laboratories and computers.

As with the rest of Connecticut's land area, inland wetlands cover approximately 20 percent of Mansfield. Similarly, 60 percent of these inland wetlands are forested (34). For this reason and the fact that forested inland wetlands are the most difficult to delineate both in the field and on aerial photographs, this type of inland wetland was selected for intensive study.

The climate of the northeastern hills is typical of humid temperate regions. The annual mean temperature is 8.9°C (48°F) with an average annual precipitation of 117 cm (46 in.) (13). The normal length of the growing season is 156 days (13). Soil conditions, exposure, and topography influence the microclimates of a region. One therefore expects deviations from the climatic norm to occur in different areas of the region, and such is the case. In undisturbed habitats, these climatic differences are

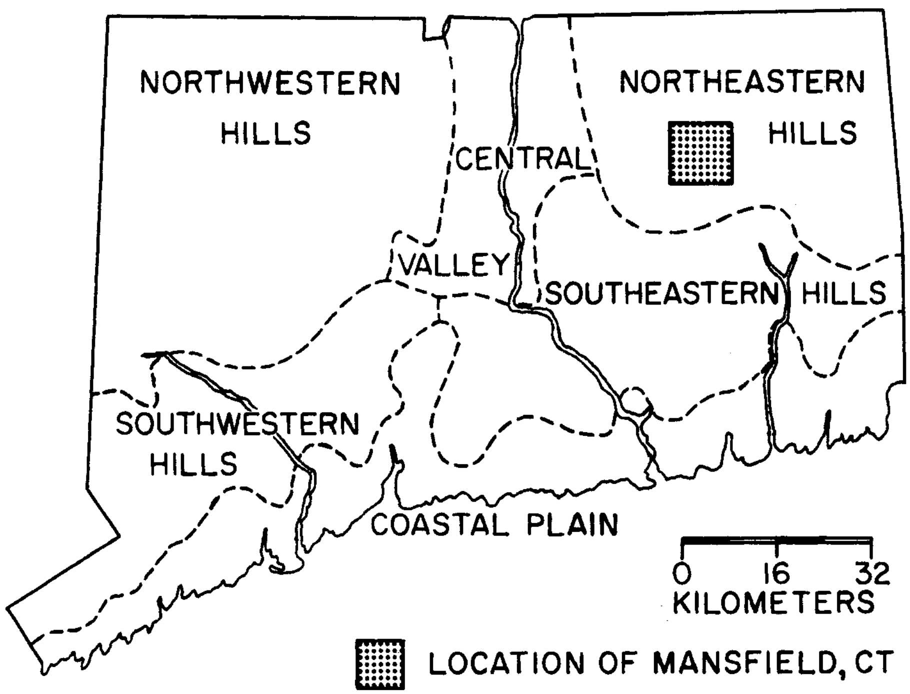


Figure 1. Physiographic Regions of Connecticut.

one of the major influences in the distribution of plant species and associations.

Glaciers, which covered Connecticut approximately 15,000 years ago, markedly influenced the landscape of the northeastern hills region. The area is characterized by gently sloping hills, drumlins, eskers, and narrow valleys. The bedrock of the area is blanketed by a layer of glacial till or stratified drift of variable thickness. This glacial till is commonly associated with the hills, slopes and drumlins, and the stratified drift deposited mostly in the river valleys. The parent materials are derived from bedrock, predominately granite, schist, and gneiss (77).

The soils of the Town of Mansfield are predominantly sandy loams and stony sandy loams. They are strongly acid, mostly well drained and deep, but with some areas shallow to bedrock. The soils of the town fall into the following three associations: (1) Hinckley-Merrimac-Podunk, (2) Charlton-Gloucester-Hollis, and (3) Paxton-Charlton (77). The nonuniform distribution of these soils (the result of glacial action, type of parent material, and hydrology) accounts for radical differences in soil type over relatively short distances. These differences often are correlated with differences in the vegetation present.

The major forest type of this region is Central Hardwood-Hemlock-White Pine. This forest type is characterized by a dominance of Oak, Maple, Birch, Ash, Hickory, Hemlock, and White Pine. Differences in species composition can be attributed to local climate, soil properties, relief, altitude, and history of land use (24, 77).

Presently the forested inland wetlands of the northeastern hills are in the physiographic climax stage of succession. This stage represents an earlier level of vegetation development than the climatic climax (45). Inland wetlands represent areas unfavorable for climatic climax development because of saturated soils and low soil pH.

The common deciduous tree species found in Connecticut's inland wetlands are *Acer rubrum* L., *Ulmus americana* L. *Fraxinus americana* L., *F. nigra* L., *Quercus bicolor* Willd., *Betula alleghaniensis* Britt., and *Nyssa sylvatica* Marsh. (12, 28, 53). The upland vegetation is dominated by *Quercus velutina* Lam., *Q. borealis* (Michx. f.) Farw., *Quercus alba* L., *Carya ovata* (Mill.) K. Koch, and *Carya cordiformis* (Wang.) K. Koch (28, 79). The following species are also present: *Acer rubrum* L., *A. saccharum* Marsh., *Quercus prinus* L., *Q. coccinea* Muench., and *Betula lenta* L. (28, 79).

Coniferous wetland forests represent only a small percentage of the forested wetlands in the northeastern hills region, and are easily identified in the field and on aerial photographs. The Hemlocks and White Pines of this region are largely found growing on upland soils. Occasionally one finds a forested wetland dominated by *Tsuga canadensis* L. or *Chamaecyparis thyoides* L. In Connecticut, those few wetlands dominated by these two species represent a relatively stable stage of vegetation development (12, 45).

Two forested wetlands in each of the following four natural soil groups were studied: terrace soils (over sands and gravels), upland soils (over friable to firm glacial till), upland soils (over compact glacial till), and upland soils (rocky and shallow to bedrock) (78).

A preliminary field survey was conducted during the late winter and early spring of 1975 to determine the general physical and biological characteristics of the wetland study areas and their surrounding uplands. This survey was followed by detailed field studies of eight selected wetlands during the late spring, summer, and early fall months of 1975. The eight wetland study sites were chosen according to the following four criteria: (1) well established wetland forest vegetation, (2) soil type, (3) undisturbed vegetative and edaphic conditions, and (4) surrounded by typical upland forest vegetation. The average size of each study site is three hectares (7.4 a.).

Meteorological data. Temperature and precipitation data were obtained from the National Weather Service station located at the University of Connecticut Agronomy Farm in Mansfield. These data were used in correlating fluctuations in soil water content, soil pH, and depth to water table with changes in climatic conditions during the study period.

Comparison of the meteorological data of 1975 to a thirty-year average (1931-1960) (13) shows that during the study period the temperature was near normal with only a 0.4°C departure from the annual norm (Table 1). There was more precipitation than normal as demonstrated in a 25 cm. departure from the annual norm. The greatest precipitation increases occurred in September and October 1975 (Table 2). This increase, however, had little if any effect on the distribution of plant species because it occurred so late in the growing season.

Transects. Line transects were used in examining the distribution of the vegetation and the soil properties in the wetland to upland zone. Line transects are commonly used to analyze biological and physical gradients of ecotones (25) and are useful

TABLE 1: Temperature Data for Mansfield, Connecticut, 1975.

Month	Thirty Year Average 1931-1960 (13)	1975	Departure from the Norm
January	-3.3°C	-1.1°C	2.2°C
February	-2.9	-2.4	0.5
March	1.2	0.8	-0.4
April	7.5	5.5	-2.0
May	13.6	15.5	1.9
June	18.5	18.1	-0.4
July	21.3	21.5	0.2
August	20.3	20.4	0.1
September	16.3	14.3	-2.0
October	11.0	12.0	1.0
November	5.0	8.0	3.0
December	-1.6	-1.1	0.5
Annual	8.9°C	9.3°C	0.4°C

TABLE 2: Precipitation Data For Mansfield, Connecticut, 1975.

Month	Thirty Year Average 1931-1960 (13)	1975	Departure from the Norm
January	9.2 cm.	12.7 cm.	3.5 cm.
February	7.2	8.4	1.2
March	10.7	10.7	0.0
April	9.9	8.3	-1.6
May	9.8	8.9	-0.9
June	8.8	10.7	1.9
July	9.9	10.5	0.6
August	12.6	8.1	-4.5
September	10.4	25.3	14.9
October	8.8	13.7	4.9
November	10.8	13.8	3.0
December	9.3	11.4	2.1
Annual	117.4	142.3	24.9

for constructing vegetation profiles (57). Cain and Castro (15) define the ecotone as the zone between two plant communities containing characteristic species of each, and possessing environmental conditions intermediate between the two.

The advantages of the line transect for this type of study are: (1) it can be used to identify vegetation boundaries, (2) its use assures a high percentage of recording all plant species in the transition zone, and (3) sampling methods are rapid (82).

After preliminary field checking and soil studies, eight meters was determined to be a length adequate to assure representative sampling of wetland, transition, and upland soils. Two eight-meter transects were laid out in each of the eight wetlands in order to examine the uniformity in soil properties of each site. The orientation of each transect was at a right angle to contours.

The number of vegetation transects needed to assure an adequate sampling size was determined by a species area curve (68). This method was somewhat modified to predict the number of transects needed for a representative sample and not the size of the sample area. The number of species encountered in the sampling is plotted against the number of transects sampled. The curve produced first rises abruptly because many new species occur in the first samples, and then tends to level off as fewer species are added with increased sampling (56). Braun-Blanquet considered sampling to be adequate when the curve becomes horizontal; therefore, the minimum number of transects is established when there is no substantial increase in the number of new species for each additional transect (11) (Appendix A). Cain (14), however, suggested that sampling will be sufficient when a ten percent increase in sample area (number of transects in this case) results in an increase of species equaling ten percent of the total present. According to Cain's method, twelve transects were adequate to sample the vegetation of the interface between wetlands and uplands. Complete vegetation analyses were conducted along a total of 31 transects. The length of the vegetation transects varied depending on the slope associated with each sampling gradient. The steeper the slope, the more compressed the vegetation zones, thus the shorter the transects needed for sampling those zones (15). Nineteen additional transects were sampled in order to compare variations in species composition within and between the eight forested wetlands, and to assure the examination of at least two vegetation transects for each site.

All sampling sites were established by driving wooden stakes into the ground at the endpoints of each transect.

Relief. A tripod-mounted Dumpy level was used to measure slope changes along all transects. Elevation changes were determined along the ground surface at one meter intervals proceeding from the wetland towards the upland topography and were plotted for each line transect.

Soils. The following soil properties of the wetland to upland gradient were investigated: (1) water content, (2) pH,

(3) moisture-tension characteristics, (4) organic matter content, (5) particle size, and (6) depth to water table.

Soil water content. Soil water content was determined by the gravimetric method (30). Samples of moist soil were weighed, placed in an oven at 100°C - 110°C for 36 hours and then reweighed. Water content is expressed as a percentage of the oven dry weight.

The coefficient of variation was used to describe the relative deviation associated with the gravimetric method and to determine the minimum distance between soil sampling points. The sample estimate is:

$$CV = \frac{s}{\overline{X}}$$

where the standard deviation (s) is expressed as a percentage of the mean ($\overline{X}$). A coefficient of variation between five and fifteen percent signifies a homogeneous sample with no significant variation; a value greater than fifteen percent signifies either an error in calculation or a substantial variation within the sample (69).

The coefficients of variation from preliminary gravimetric tests in the laboratory revealed that there were no significant differences in soil water content between samples taken from the same soil type under identical moisture conditions. Therefore, only one sample was taken at each sampling point along the soil transects.

Soil samples were taken along the transects at one meter intervals. Preliminary studies were conducted in order to establish the minimum distance between sampling points. The coefficients of variation calculated for these studies indicated that one meter sampling intervals would show meaningful differences in soil water content along the transects.

Samples taken for soil water content determinations were removed at a depth of 25 cm (10 in.) from the ground surface with a corkscrew auger and placed in tared aluminum cans. The 25 cm depth is coincident with the root zone of many woodland plants (39). The samples were then oven dried as above. Sampling was designed to examine soils in equilibrium with environmental conditions. Soil water content was determined weekly, except when there was a period of heavy rain three days or less prior to sampling.

Since samples were taken weekly, a grid system was developed so as to disturb the soil as little as possible. This simulated grid, seven meters long and 60 centimeters wide (having 28 units one meter by 15 centimeters) was superimposed over the established soil transects. Weekly sampling was done in rotation, starting on the center line of the grid, then moving 15 centimeters (6 ± in.) left and right, then 30 centimeters (12 ± in.) left and right at each sampling point along the transects. This procedure was repeated three times during the course of the study period.

Soil pH. Determinations of soil pH in biweekly samples were made using Peech's method (59). Each soil sample was readied in duplicate pH determination by preparing a slurry consisting of 10 gm. of soil and 20 ml. of 0.01M $CaCl_2$. A solution of 0.01M $CaCl_2$ is approximately equivalent to the electrolyte concentration of the soil solution under natural soil conditions at optimum field water contents (59).

Moisture-tension characteristics. Moisture-tension characteristics, organic matter content, and particle size were determined on bulk soil samples (taken from a depth of 25 cm) representing wetland, transition, and upland soils for each of the eight test areas. The results of these analyses yield information about important soil properties and are necessary for the interpretation of the soil water content and soil pH data.

In this study, soil water content was determined on soil samples held at one-third, one, two, and five atmospheres according to Richards' method (62). The soil samples tested were portions of those described above under *Soil pH.* A pressure membrane apparatus was used to measure the water content-matric tension relation in the bulk samples (eight wetland, eight transition, eight upland). Samples were run in five replications at one-third, one, and two atmospheres, and in three replications at five atmospheres. Graphs of these results should reveal the differences in the water-holding capacity between wetland, transition, and upland soils.

Organic matter content. Organic matter content determinations were made according to Mitchell's method (51). The organic matter content of a soil is determined by its weight loss on ignition and is expressed as a percentage of the oven-dry weight of that soil. A soil is considered to be "organic" if it contains more than 20% organic matter when the clay content is low or more than 30% organic matter when the clay content is as high as 50% (10).

Particle size analysis. Particle size analysis is the determination of the various amounts of the different soil particles (clay, silt, and sand) in a given sample. This analysis is important for the determination of soil texture. The hydrometer method of particle size analysis was employed in this study (26).

Depth to water table. Depth to the water table was recorded at each sampling point for which soil water content and soil pH had been determined. A corkscrew auger was used to dig a hole to the water table a depth of one meter. At several sampling points either very stony soil, a hardpan, or a soil shallow to bedrock prevented attaining the one meter depth. A 2.5 cm. inside diameter plastic tube was inserted into each hole. All 128 tubes were capped to prevent rainwater from entering. Depth to water table measurements were made weekly at the same time samples were collected for soil water content determinations. A hollow lead weight tied to the end of a nylon line was used to locate the water table surface. The length of the line and weight was measured to give depth to water table. When the water table level was below the tube bottom, it was so noted and the length of the tube recorded as the depth.

Vegetation. Any detailed vegetation study is based on the description of plant communities or of community subunits recognized in the field (52). Sampling procedures are then designed or selected to reveal the structure and composition of the vegetation.

Preliminary surveys resulted in the recognition of the vegetation units and strata of the study areas. The wetland to upland vegetation gradient is formed of more or less regular, successive plant associations. This arrangement of vegetation units is related to changes in the physical components of the environmental gradient, *i.e.*, soil water content, soil type, and relief (76). Sharp vegetation boundaries are often directly related to abrupt changes in topography, soil conditions, and geology (82). Gradual transitions between plant associations, however, are the usual case (80).

Each plant association has its own characteristic composition and structure. "Composition" refers to the plant species in the association; "structure" refers to the habit of those species, *i.e.*, herbs, shrubs, or trees. When characterizing a plant association, one records all of the species of that association, because a definite association of species, rather than a single species, serves as a more reliable indicator of environmental conditions (82).

Analytical methods were selected to develop an index to that floristic composition of the vegetation gradient which differentiates wetlands from uplands. Therefore, sampling was conducted in areas which appeared to represent the totality of the interface between wetlands and uplands. Methods followed were those of Gates (32), Cain & Castro (15), and Mueller-Dombois and Ellenberg (52).

Plant species of the ground cover, shrub, and tree strata of the wetland to upland gradient were identified and their positions recorded along transects. Because this research was designed to investigate the plant species composition of the wetland-upland ecotone, presence or absence of species was considered more important than minor variations in number of individuals. All plants which touched a steel tape corresponding to the line transect, or the imaginary vertical plane associated with it, were recorded in the order in which they appeared along the transects. This method is primarily qualitative.

Heights and crown cover were determined for all plants which intercepted the vegetation transects. Cover measurements were made by estimating the length of transect line covered by plant crowns. Heights (in meters) were determined by direct measurement or with a clinometer and estimation. A clinometer was used first to verify tree height estimates; later, heights were estimated to save sampling time. Data were gathered from wetland to upland. The strata were analyzed in ascending order of height.

RESULTS AND DISCUSSION

Analysis of the data revealed that there are distinct changes in the biological and physical components of the environmental gradient as one proceeds from wetland to upland.

Of the sixteen soil transects surveyed, data collected from eight were analyzed. The following gradients, each beginning with wetland soils and proceeding to upland soils, were examined:

Transects 1 and 2	- Leicester, Ridgebury, Whitman Complex - Sutton
Transects 3 and 4	- Peat and Muck - Sutton - (Hollis)
Transect 5	- Leicester, Ridgebury, Whitman Complex - Woodbridge
Transect 6	- Peat and Muck (shallow)* - Charlton
Transect 7	- Alluvial Land - Tisbury - Merrimac
Transect 8	- Peat and Muck - Raynham - Sudbury

A preliminary survey of U.S. Department of Agriculture Soil Conservation Service published soil surveys revealed that of the forested inland wetlands of Mansfield, Connecticut, 55% occur on upland wet mineral soils, 19% occur on organic soils, 14% occur on floodplain soils, and 12% occur on terrace soils. Of the upland wet mineral soils, 92% are of the Leicester, Ridgebury, Whitman Complex; of the organic soils 77% are of the deep Peat and Muck type; and of the floodplain (streambelt) soils, Alluvial Land represents 27%.

---

* Peat and Muck (Shallow) underlain by Leicester, Ridgebury, Whitman Complex.

Soil water content. The soil water content along each transect varied significantly from wetland to upland (Table 3). The data show that not all wetlands are necessarily wetter than the surrounding uplands during all parts of the growing season. Data from two transects (5 and 8) showed the upland soils had a higher average water content than the wetland soils. These latter results are explained by one or more of the following: (1) the upland soils associated with each of these gradients contain at least the same amount of organic matter as the wetland soils (Table 4); (2) the upland soils have a lesser amount of sand than the wetland soils (Table 5); (3) the upland soils have at least the same water-holding capacity as the wetland soils (Figs. 2, 3, and 4, grouped according to soil gradients); or (4) the wetland soil characteristics are principally developed during the wet season when the groundwater is discharging to the wetland area (sampling was not conducted during this period).

Analysis of soil water content data showed that the greatest fluctuation in water content occurred in the organic soils (Table 6). This can be attributed to (1) the absorptive characteristics of organic matter, and (2) upon removal from the ground, water dripped off the sample as it was placed in the sampling can. Even though wide fluctuations occurred, it was noted that in all cases the soil was saturated.

The results of the moisture-tension characteristics of the bulk soil samples show that as the tension on a soil increases

TABLE 3: Statistical Results - Soil Water Content Correlated with Topographic Gradient and Soil pH Correlated with Topographic Gradient+.

Transect Number and Soil Gradient	Soil Water Content	Soil pH
1 Leicester, Ridgebury, Whitman (Peat and Muck Shallow)# - Sutton	-.6708**	.7677**
2 Leicester, Ridgebury, Whitman (Peat and Muck Shallow)# - Sutton	-.7977**	.7592**
3 Peat and Muck - Sutton	-.8780**	.8319**
4 Peat and Muck - Sutton	-.2730**	.4537**
5 Leicester, Ridgebury, Whitman - Woodbridge	.3371**	.8586**
6 Peat and Muck (Shallow)# - Charlton	-.2506**	.1904 n.s.
7 Alluvial Land - Tisbury - Merrimac	-.2074*	-.7517**
8 Peat and Muck - Raynham - Sudbury	.1773*	-.0099 n.s.

\+ Statistical analyses were made using Pearson Correlations (8).
\# Shallow peat and muck underlain by Leicester, Ridgebury, Whitman Complex.
* 5% alpha level.
** 1% alpha level.
Numbers = correlation coefficients.
n.s. = not significant.
\- = inverse relationship.

TABLE 4: Organic Matter Content of Bulk Soil Samples Taken from the Wetland, Transition, and Upland Zones of the Eight Study Sites.

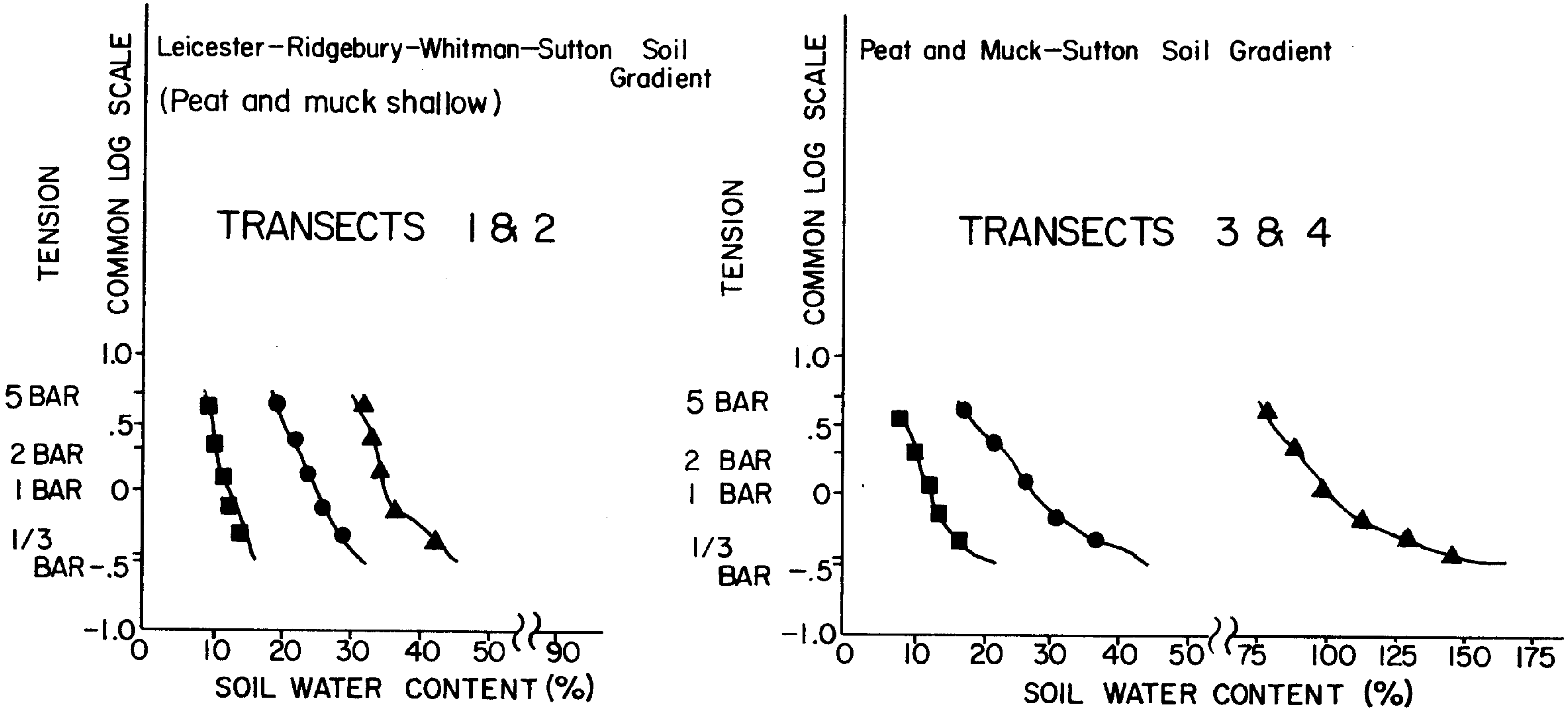
Transect Number(s) and Soil Gradient	Zone	Organic Matter Content of Soil (%)
1 and 2 Leicester, Ridgebury, Whitman (Peat and Muck Shallow)[1] - Sutton	Wetland	30.3
	Transition	9.8
	Upland	4.3
3 and 4 Peat and Muck - Sutton	Wetland	70.4
	Transition	12.0
	Upland	3.7
5 Leicester, Ridgebury, Whitman - Woodbridge	Wetland	5.3
	Transition	10.9
	Upland	11.3
6 Peat and Muck (Shallow)[1] - Charlton	Wetland	30.1
	Transition	11.7
	Upland	7.0
7 Alluvial Land - Tisbury - Merrimac	Wetland	6.7
	Transition	6.3
	Upland	4.1
8 Peat and Muck (Shallow) - Raynham - Sudbury	Wetland	9.4
	Transition	7.2
	Upland	7.7

[1] Peat and Muck (shallow) underlain by Leicester, Ridgebury, Whitman Complex.

TABLE 5: Results of Particle Size Analysis of Bulk Soil Samples Taken from the Wetland, Transition, and Upland Zones of the Eight Study Sites.

Transect Number(s) and Soil Gradient	Zone	Sand (%)	Silt (%)	Clay (%)	Textural Class[2]
1, 2	Wetland	- - -	organic	- - -	
Leicester, Ridgebury, Whitman (Peat and Muck Shallow)[1] - Sutton	Transition	74.4	19.0	6.0	sl
	Upland	63.4	22.0	14.6	sl
3, 4	Wetland	- - -	organic	- - -	
Peat and Muck - Sutton	Transition	48.0	42.8	9.2	l
	Upland	68.8	26.0	5.2	sl
5	Wetland	70.8	22.0	7.2	sl
Leicester, Ridgebury,	Transition	63.0	31.4	5.6	sl
Whitman - Woodbridge	Upland	64.8	25.0	10.2	sl
6	Wetland	- - -	organic	- - -	
Peat and Muck (Shallow)[1]	Transition	51.4	36.0	12.6	l
- Charlton	Upland	50.0	40.4	9.6	l
7	Wetland	52.8	40.0	7.2	sl
Alluvial Land - Tisbury	Transition	56.8	33.0	10.2	sl
- Merrimac	Upland	62.8	30.0	7.2	sl
8	Wetland	46.0	42.8	11.2	l
Peat and Muck (Shallow)	Transition	57.0	33.4	9.6	sl
- Raynham - Sudbury	Upland	61.4	28.0	10.6	sl

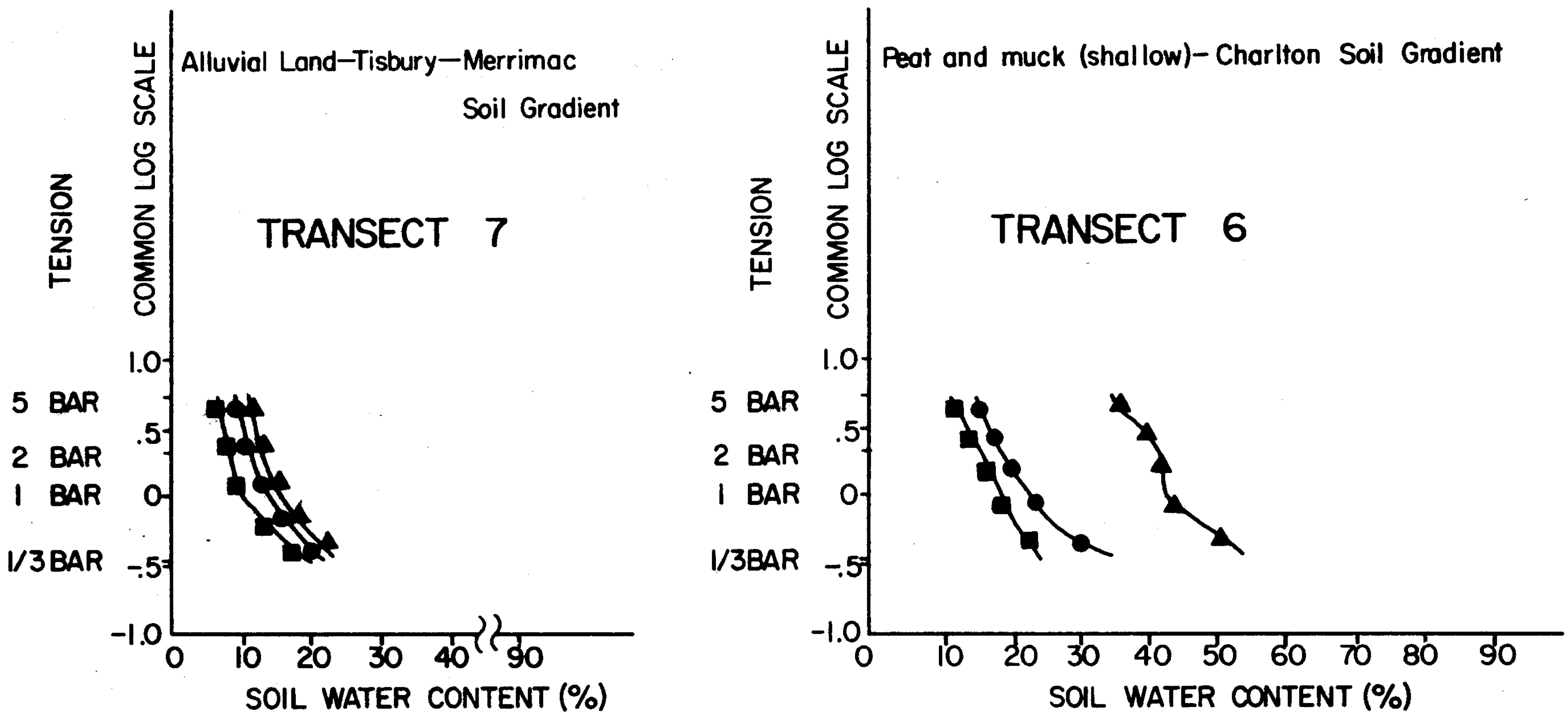
1 Peat and Muck (Shallow) underlain by Leicester, Ridgebury, Whitman Complex.
2 sl = sandy loam; l = loam.



	SOIL TEXTURE	ORGANIC MATTER CONTENT
▲ WETLAND	ORGANIC	30.3%
● TRANSITION	SANDY LOAM	9.8%
■ UPLAND	SANDY LOAM	4.3%

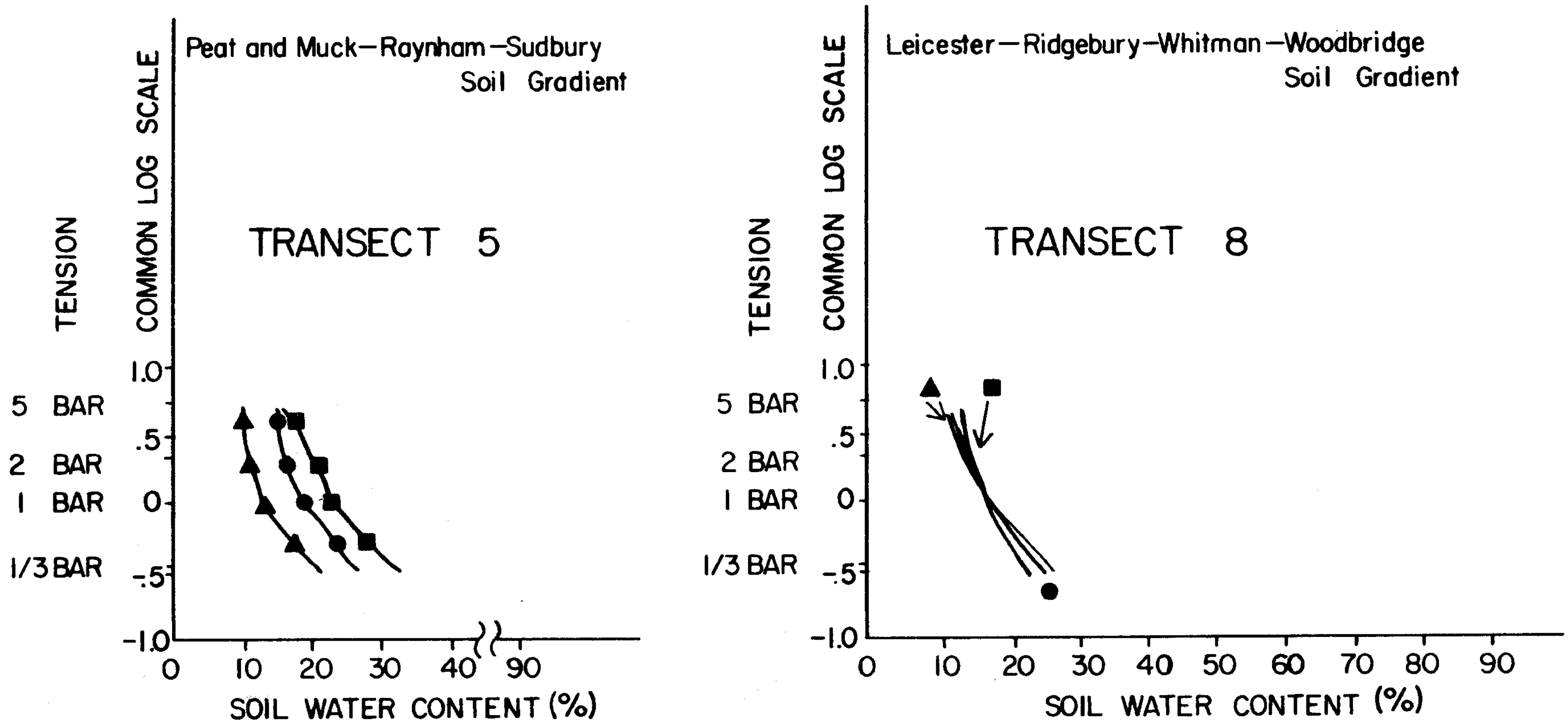
	SOIL TEXTURE	ORGANIC MATTER CONTENT
▲ WETLAND	ORGANIC	70.4%
● TRANSITION	LOAM	12.0%
■ UPLAND	SANDY LOAM	3.7%

Figure 2. Moisture-Tension Curves for Transects 1, 2, 3, and 4.



Transect 7	SOIL TEXTURE	ORGANIC MATTER CONTENT	Transect 6	SOIL TEXTURE	ORGANIC MATTER CONTENT
▲ WETLAND	SANDY LOAM	6.7%	▲ WETLAND	ORGANIC	30.5%
● TRANSITION	SANDY LOAM	6.3%	● TRANSITION	LOAM	11.7%
■ UPLAND	SANDY LOAM	4.1%	■ UPLAND	LOAM	7.0%

Figure 3. Moisture-Tension Curves for Transects 6 and 7.



	SOIL TEXTURE	ORGANIC MATTER CONTENT		SOIL TEXTURE	ORGANIC MATTER CONTENT
▲ WETLAND	SANDY LOAM	5.3%	▲ WETLAND	LOAM	9.4%
● TRANSITION	SANDY LOAM	10.9%	● TRANSITION	SANDY LOAM	7.2%
■ UPLAND	SANDY LOAM	11.3%	■ UPLAND	SANDY LOAM	7.7%

Figure 4. Moisture-Tension Curves for Transects 5 and 8.

TABLE 6: Soil Water Data for the Eight Soil Transects.

Sampling Location Within Transects	Mean Soil Water Content (%)							
	Transect No.							
	1	2	3	4	5	6	7	8
Wetland 0	69.3	145.0	126.0	106.0	40.9	30.0	32.2	136.5
1	93.8	52.2	111.0	131.0	32.2	40.9	33.8	87.4
2	78.7	59.5	104.7	66.8	39.3	68.2	35.3	85.8
3	57.7	53.1	73.3	82.1	29.2	65.2	38.6	59.0
4	57.5	48.4	74.5	60.7	43.5	55.6	38.1	48.8
5	50.5	37.0	61.0	63.6	48.9	49.0	39.7	57.2
6	45.5	39.9	46.1	65.7	46.4	38.8	38.6	72.4
7	44.8	38.0	43.7	49.5	39.8	36.0	36.6	83.2
Upland 8	37.3	32.0	36.4	37.3	48.4	30.8	35.4	105.3

the water content decreases (Table 7). This procedure simulates water absorption by plant roots. The results also revealed that throughout the course of the study period, the water content of the soils examined never fell below field capacity. A soil is considered to be at field capacity when the rapid downward movement of water becomes negligible. Under these conditions the tension with which the water is held is approximately one-third atmosphere (10). The data in Table 7 illustrate the differences between the water-holding capacity of the wetland, transition, and upland zone soils. The similarities in organic matter content and textural class of the soils along Transect 8 explain the closeness of their water-holding capacities. Fig. 4 also shows that the upland soil had a higher water-holding capacity than the wetland soil. This can be explained by the greater amount of organic matter in the upland soil than the wetland soil.

TABLE 7: Water Content of Bulk Soil Samples at Various Atmospheres of Tension[1].

Transect Number(s) and Soil Gradient	Zone	Atmospheres of Tension 1/3	1	2	5
1, 2	Wetland	44.6	34.6	34.0	30.5
Leicester, Ridgebury,	Transition	31.4	24.5	22.5	18.5
Whitman (Peat and Muck	Upland	15.0	11.2	10.6	8.5
Shallow)[2] - Sutton					
3, 4	Wetland	163.0	101.0	91.3	75.3
Peat and Much - Sutton	Transition	43.1	27.6	23.8	16.6
	Upland	20.9	12.7	10.8	7.8
5	Wetland	20.3	12.9	11.4	9.8
Leicester, Ridgebury,	Transition	27.1	19.6	16.3	14.9
Whitman - Woodbridge	Upland	32.9	22.6	21.0	15.8
6	Wetland	54.4	42.4	42.2	35.1
Peat and Muck	Transition	35.2	22.9	19.8	15.0
(Shallow)[2] - Charlton	Upland	24.9	18.2	15.9	11.7
7	Wetland	23.7	15.5	13.1	11.1
Alluvial Land -	Transition	22.3	14.0	11.8	9.9
Tisbury - Merrimac	Upland	15.6	10.4	8.8	7.0
8	Wetland	26.1	18.7	15.7	13.9
Peat and Muck (Shallow)	Transition	24.3	17.4	16.2	13.3
- Raynham - Sudbury	Upland	24.5	17.7	15.6	13.3

1 Soil water content determined by the gravimetric method. Values listed are expressed as a percentage of water (gm.) to oven-dry weight of soil (gm.).

2 Peat and Muck (shallow) underlain by Leicester, Ridgebury, Whitman Complex.

TABLE 8: Soil pH Data for the Eight Soil Transects.

Sampling Location Within Transects	Mean pH[1]							
	Transect No.							
	1	2	3	4	5	6	7	8
Wetland 0	3.8	3.5	3.6	4.2	3.9	4.5	4.9	3.7
1	4.1	4.2	3.6	3.7	4.0	4.1	4.7	3.9
2	4.3	4.4	3.0	3.6	3.7	4.0	4.4	3.6
3	4.5	4.6	3.6	4.0	3.8	4.0	4.2	3.7
4	4.5	4.6	4.0	4.4	4.1	4.3	4.2	4.1
5	4.5	4.3	4.2	4.3	4.1	4.3	4.1	4.2
6	4.6	4.6	4.3	4.0	4.3	4.4	4.2	4.0
7	4.6	4.5	4.2	4.3	4.2	4.4	4.2	3.8
Upland 8	4.7	4.5	4.5	4.3	4.3	4.2	4.2	3.7

[1] Soil pH determined with 0.01M $CaCl_2$.

Soil pH. Significant differences in soil pH along the wetland to upland gradient occurred on six of the eight transects (Table 3). Of these, five showed an increase in pH along the soil gradient, while one showed a decrease. The results also show that there was no significant fluctuation in pH during the study period (Table 8). Soil acidity is one of those ecological factors which influence the growth and distribution of plant species. Individual plant species appear to exhibit preferences for a particular pH range (10), although it has been suggested that soil pH is never an independent factor controlling plant growth (39).

Because members of plant species often exhibit a wide tolerance to soil pH,the presence or absence of a single species may be irrelevant to the evaluations of site conditions (58). Wilde (81) states that "the occurrence of different species within certain ranges of soil reaction can be caused by numerous conditions other than the soil pH values, such as physical make-up of the soil, soil water content, available nutrients, presence of toxic substances, and competition with other species." Therefore it is often difficult to correlate plant distribution with soil pH values because of the diversity of physiological responses of individual species to a particular habitat (10).

It is likely that the relative differences in soil pH along the transects in this study has no major effect on the distribution of the vegetation.

Only in one case (Transect 7) was the pH of the wetland soil noticeably higher than that of the upland soil (and also of other wetland soils). Found growing on this site were *Ribes triste* Pall. and *Monotropa uniflora* L. These two species were not found on any other wetland site. It is noted that this wetland was within a streambelt and had a sandy loam soil low in organic matter which dried out in late spring and remained relatively dry through September. The higher soil pH found on this site may be attributed to a fairly sandy soil low in organic matter. Pearsall (58) has shown that soil acidity may be directly related to organic matter content. In his work, soils with higher organic matter had a lower pH than similar soils with less organic matter. Examination of Tables 4 and 9 show that those soils high in organic matter tended to have a lower soil pH.

TABLE 9: Mean Values of Soil Water Content, Soil pH, and Relief Data for the Eight Soil Transects.

Sampling Point	Soil Water Content (%)	Soil pH[1]	Relief (cm)
Wetland 0	85.7	4.0	0.0
1	72.8	4.0	10.7
2	67.3	3.9	17.8
3	57.3	4.1	29.0
4	53.4	4.3	38.6
5	50.7	4.3	49.8
6	49.1	4.3	61.0
7	41.7	4.3	70.1
Upland 8	45.7	4.3	73.2

[1] Soil pH determined with 0.01M $CaCl_2$.

There is a substantial difference between a soil with a pH of 5.0 and one with a pH of 3.5-4.0 regarding its effect on plant growth (10). Wetland soils with extremely low pH values can create conditions where the levels of micronutrients and of Al^{+3} and H^+ may become so high as to be toxic to plant roots (10). The soil pH of the streambelt wetland was approximately 5.0 -- high when compared to the 3.5-4.0 pH range of most of the other wetland soils. This pH difference was reflected in a difference in species composition. Acidophilic plants such as *Vaccinium corymbosum* L. and *Rhododendron viscosum* L. were not observed on the streambelt site but were commonly found on the remaining wetland sites. This suggests that on this particular site, soil pH as well as a seasonally high soil water content are the two principal factors influencing plant species composition.

The mean data for soil water content and soil pH listed in Table 9 show that on the average wetlands are wetter than the bordering uplands and are slightly more acidic. The drop in soil pH at the two-meter sampling point is coincidental and should not be interpreted as a unique point of change along the wetland to upland gradient. The data also suggest that there might be some inverse relationship between soil moisture and soil pH. The existence of such a relationship, however, is difficult to prove because of the diverse chemical and physical factors involved.

The data in Table 9 have been plotted against the mean topographies of the eight soil transects so as to show the relationship among these three components of the environmental gradient (Fig. 5).

Depth to water table. As previously stated, the depths of many of the piezometers were not adequate to locate the water table during part of the study period. In all but eight cases out of 64 the water table fell below the bottom of the piezometer. The data recorded from June through October therefore show where the water table was *not*. Transect profiles and the location and depth of piezometers installed in Transects 2 and 8 are shown in Figure 6. The high water level found in the study period is shown in those graphs with corresponding dates. The lower line indicates the lowest water level recorded; the line is dashed when the water level fell below the piezometer.

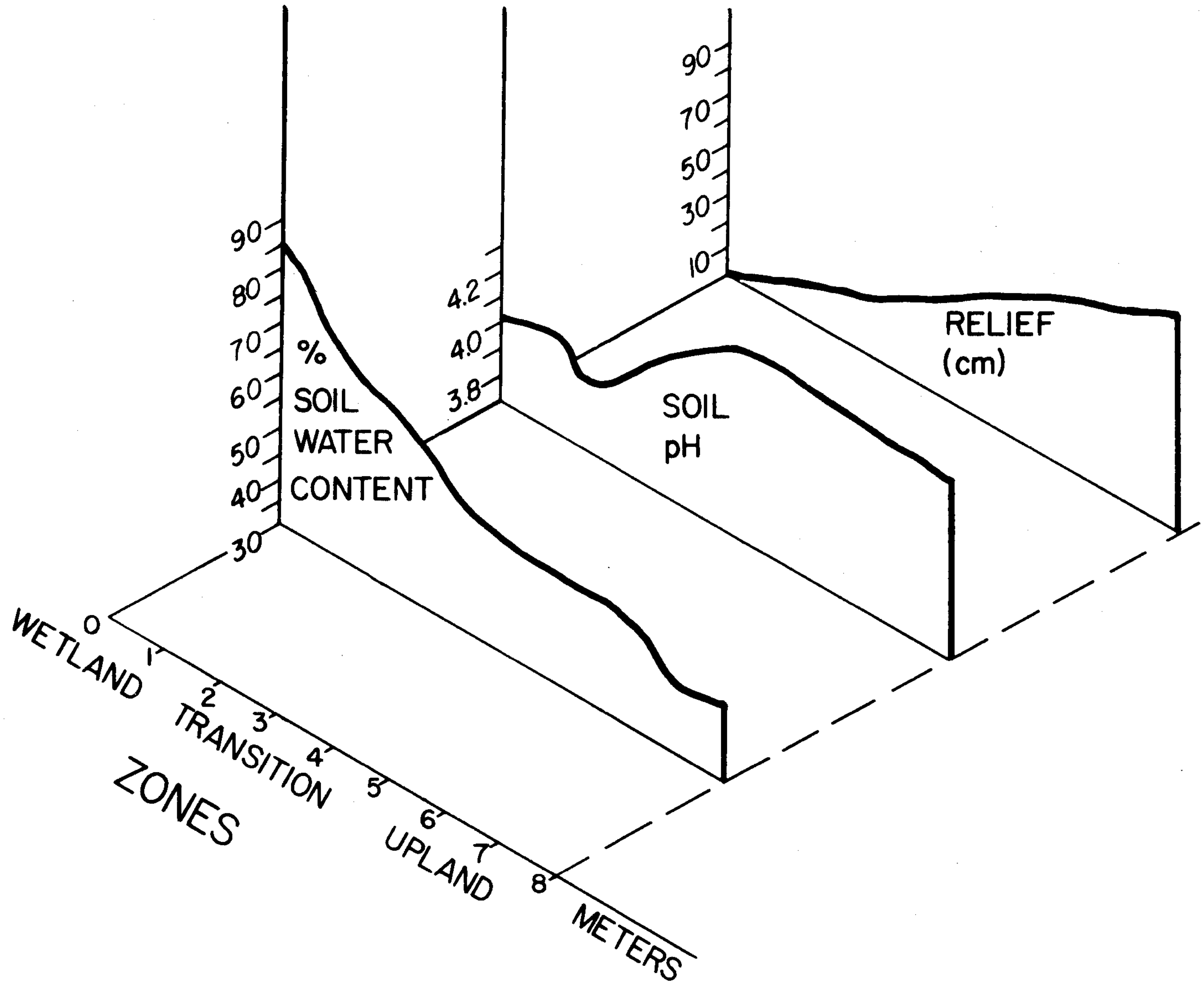


Figure 5. Mean Soil Water Content, Soil pH, and Relief Data for Eight Soil Transects.

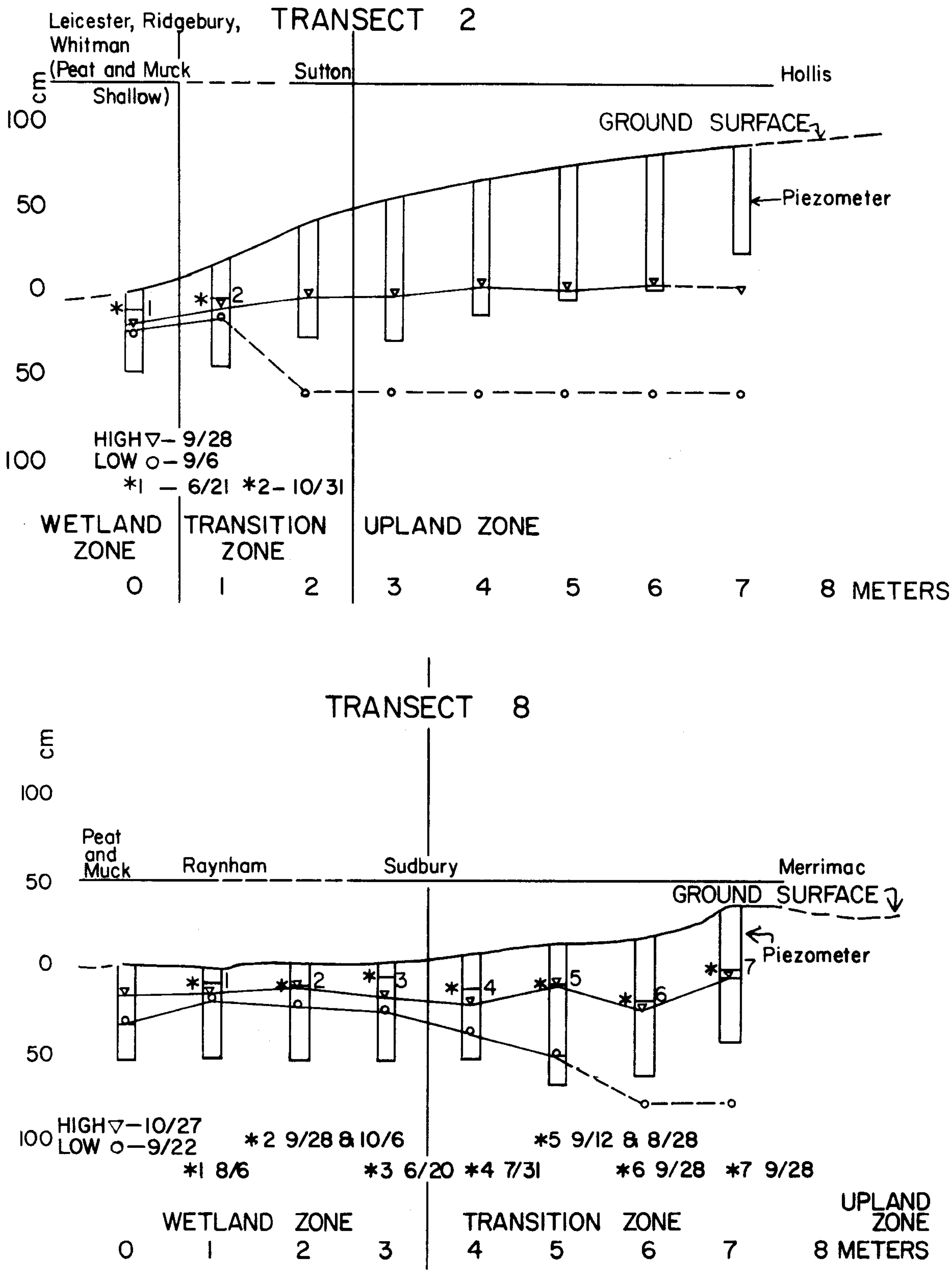


Figure 6. Depth to Water Table along Transects 2 and 8.

Young (85) states that of all the factors affecting soil water content, the water table is the most influential. His study shows that a direct relationship exists between soil water content and depth to the groundwater table. Applying his findings to the results of these studies, a wetland soil should have a higher water content than an upland soil because of its intimate association with the water table; such is the case.

Data on depth to seasonal high water table for each of the soil series studied here have been published by the Soil Conservation Service. "Seasonal high water table" refers to the mean depth to the water table from November to May. Those findings and the data collected during this study (June through October) provide valuable information for the evaluation of environmental conditions influencing the growth and distribution of wetland plants.

Vegetation analyses. Vegetation analyses were made on data collected from 31 vegetation transects. Tabular classification of the vegetation followed the method of Mueller-Dombois and Ellenberg (See details in Anderson, M.S. Thesis 1977). This method of vegetation analysis attempts to relate the spatial distribution of plant associations to environmental conditions. Each transect was divided into segments based on similar environmental conditions, primarily soil water content and topography. These results were used to formulate a field key to the vegetation (Fig. 7), and to calculate relative density, frequency of occurrence, and an index of abundance for each plant species.

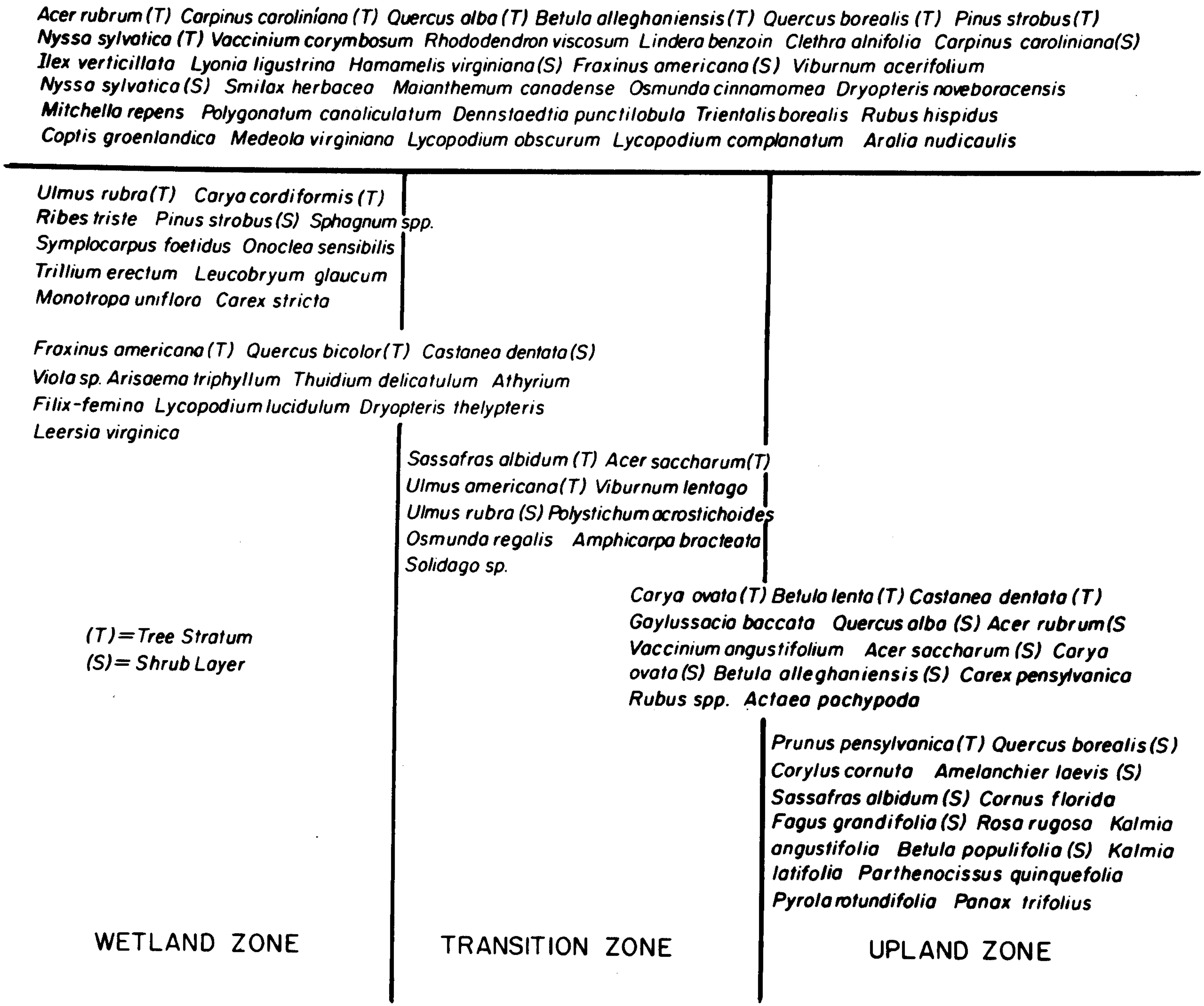


Figure 7. Field Key to Vegetation.

The results of the classification show the distribution of the plant species and their association with wetland, transition, and upland zones. The key is designed to be used in the field to assist in the identification of forested inland wetlands and the location of their boundaries.

Data on relative density, frequency of occurrence, and index of abundance were calculated to show the distribution of each plant species recorded (Tables 10, 11, and 12). Relative density (RD) is a measurement which compares the concentration of individual plant species in each of the three zones (wetland, transition, upland). The density for each zone is calculated by the following formula:

$$RD = \frac{S_z}{S_T \times 100}$$

where S_z = number of individuals of plant species recorded in a zone

S_T = total number of individuals of plant species recorded in all three zones

Frequency of occurrence (FO) is an expression of the presence or absence of a number of plant species in a given zone. Per zone, this is calculated by the following equation:

$$FO = \frac{T_s}{T_T \times 100}$$

where T_s = number of transects sampled which possess the plant species

T_T = total number of transects sampled

TABLE 10: Plant Species Distribution: Frequency of Occurrence and Index of Abundance. Tree Stratum.[1]

		Frequency of Occurrence (%)			Index of Abundance (%)		
		W[2]	T	U	W	T	U
1.	*Acer rubrum*	74.2	38.7	38.7	48.9	25.5	25.5
2.	*Carpinus caroliniana*	3.2	6.5	12.9	14.2	28.8	57.1
3.	*Quercus alba*	12.9	6.5	41.9	21.0	10.6	68.4
4.	*Betula alleghaniensis*	6.5	3.2	9.7	33.5	16.5	50.0
5.	*Quercus borealis*	3.2	3.2	9.7	19.9	19.9	60.2
6.	*Pinus strobus*	3.2	3.2	6.5	24.8	24.8	50.4
7.	*Ulmus rubra*	6.5			100.0		
8.	*Carya cordiformis*	3.2			100.0		
9.	*Nyssa sylvatica*	6.5	3.2		67.0	33.0	
10.	*Fraxinus americana*	6.5	3.2		67.0	33.0	
11.	*Quercus bicolor*	3.2	9.7		24.8	75.2	
12.	*Sassafras albidum*		3.2			100.0	
13.	*Acer saccharum*		3.2			100.0	
14.	*Ulmus americana*		3.2			100.0	
15.	*Carya ovata*		3.2	12.9		19.9	80.1
16.	*Betula lenta*		6.5	3.2		67.0	33.0
17.	*Castanea dentata*		3.2	6.5		33.0	67.0
18.	*Prunus pensylvanica*		3.2				100.0

1 Based on vegetation data from 31 transects.
2 W = Wetland Zone
T = Transition Zone
U = Upland Zone

Calculation of an index of abundance (IA) for a plant species is based on the frequency of occurrence for that species. The index for each zone is derived by the following equation:

$$IA = \frac{FO}{\Sigma FO \times 100}$$

where FO = frequency of occurrence of a plant species for a zone
ΣFO = summation of frequency of occurrences for the plant species in all three zones.

Table 11: Plant Species Distribution: Frequency of Occurrence and Index of Abundance. Shrub Stratum.[1]

		Frequency of Occurrence (%)			Index of Abundance (%)		
		W[2]	T	U	W	T	U
1.	*Vaccinium corymbosum*	45.2	58.1	51.6	29.2	37.5	33.3
2.	*Rhododendron viscosum*	32.3	41.9	41.9	27.8	36.1	36.1
3.	*Lindera benzoin*	38.7	22.6	16.1	50.0	29.2	21.0
4.	*Clethra alnifolia*	19.4	22.6	16.1	33.4	38.9	27.7
5.	*Carpinus caroliniana*	6.5	19.4	12.9	16.8	50.0	33.2
6.	*Ilex verticillata*	16.1	19.4	9.7	35.6	42.9	21.5
7.	*Lyonia ligustrina*	3.2	9.7	12.9	12.4	37.6	50.0
8.	*Hamamelis virginiana*	6.5	3.2	3.2	50.4	24.8	24.8
9.	*Smilax herbacea*	3.2	3.2	3.2	33.3	33.3	33.3
10.	*Fraxinus americana*	3.2	6.5	9.7	16.5	33.5	50.0
11.	*Viburnum acerifolium*	3.2	16.1	16.1	9.0	45.5	45.5
12.	*Nyssa **sylvatica***	3.2	6.5	3.2	24.8	50.4	24.8
13.	*Ribes triste*	3.2			100.0		
14.	*Carya cordiformis*	3.2			100.0		
15.	*Pinus strobus*	3.2			100.0		
16.	*Castanea dentata*	3.2	6.5		33.0	67.0	
17.	*Viburnum lentago*		3.2			100.0	
18.	*Ulmus rubra*		3.2			100.0	
19.	*Gaylussacia baccata*		3.2	32.3		9.0	91.0
20.	*Quercus alba*		12.9	35.5		26.7	73.3
21.	*Acer rubrum*		12.9	22.6		36.3	63.7
22.	*Vaccinium angustifolium*		3.2	19.4		14.2	85.8
23.	*Acer saccharum*		3.2	9.7		24.8	75.2
24.	*Carya ovata*		3.2	3.2		50.0	50.0
25.	*Betula alleghaniensis*		3.2	3.2		50.0	50.0
26.	*Quercus borealis*			16.1			100.0
27.	*Prunus serotina*			16.1			100.0
28.	*Corylus cornuta*			9.7			100.0
29.	*Amelanchier laevis*			6.5			100.0
30.	*Sassafras albidum*			6.5			100.0
31.	*Cornus florida*			6.5			100.0
32.	*Fagus grandifolia*			3.2			100.0
33.	*Kalmia angustifolia*			3.2			100.0
34.	*Betula populifolia*			3.2			100.0
35.	*Kalmia latifolia*			3.2			100.0
36.	*Parthenocissus quinequefolia*			3.2			100.0
37.	*Rosa rugosa*			3.2			100.0

[1] Based on vegetation from 31 transects.
[2] W = Wetland Zone
T = Transition Zone
U = Upland Zone

Table 12: Plant Species Distribution: Frequency of Occurrence and Index of Abundance. Herb Stratum.[1]

		Frequency of Occurrence (%)			Index of Abundance (%)		
		W[2]	T	U	W	T	U
1.	*Maianthemum canadense*	48.4	71.0	41.9	30.0	44.0	26.0
2.	*Osmunda cinnamomea*	51.6	83.9	48.4	28.1	45.6	26.3
3.	*Dryopteris noveboracensis*	12.9	38.7	41.9	13.8	41.4	44.8
4.	*Mitchella repens*	12.9	29.0	35.5	16.7	37.5	45.9
5.	*Polygonatum canaliculatum*	16.1	35.5	32.3	19.2	42.3	38.5
6.	*Dennstaedtia punctilobula*	6.5	12.9	32.3	12.9	25.0	62.5
7.	*Trientalis borealis*	6.5	9.7	32.3	13.4	20.0	66.6
8.	*Rubus hispidus*	9.7	6.5	6.5	42.7	28.6	28.6
9.	*Coptis groenlandica*	19.4	22.6	9.7	37.5	43.7	18.8
10.	*Medeola virginiana*	6.5	6.5	19.4	20.1	20.1	59.9
11.	*Lycopodium obscurum*	25.8	48.4	74.2	17.4	32.6	50.0
12.	*Lycopodium complanatum*	9.7	16.1	22.6	20.0	33.3	46.7
13.	*Aralia nudicaulis*	3.2	22.6	29.0	5.8	41.2	52.9
14.	*Sphagnum* spp.	32.3			100.0		
15.	*Symplocarpus foetidus*	19.4			100.0		
16.	*Onoclea sensibilis*	6.5			100.0		
17.	*Trillium erectum*	3.2			100.0		
18.	*Leucobryum glaucum*	3.2			100.0		
19.	*Monotropa uniflora*	3.2			100.0		
20.	*Carex stricta*	3.2			100.0		
21.	*Viola* sp.	12.9	3.2		80.1	19.9	
22.	*Arisaema triphyllum*	9.7	3.2		75.2	24.8	
23.	*Thuidium delicatulum*	9.7	6.5		59.9	40.1	
24.	*Athyrium Filix-femina*	12.9	6.5		66.5	33.5	
25.	*Lycopodium lucidulum*	6.5	3.2		67.0	33.0	
26.	*Dryopteris thelypteris*	6.5	3.2		67.0	33.0	
27.	*Leersia virginica*	3.2	3.2		50.0	50.0	
28.	*Polystichum acrostichoides*		9.7			100.0	
29.	*Osmunda regalis*		3.2			100.0	
30.	*Amphicarpa bracteata*		3.2			100.0	
31.	*Solidago* sp.		3.2			100.0	
32.	*Carex pensylvanica*		16.1	41.9		27.8	72.2
33.	*Rubus* spp.		6.5	9.7		40.1	59.9
34.	*Actaea pachypoda*		3.2	3.2		50.0	50.0
35.	*Pyrola rotundifolia*			3.2			100.0
36.	*Panax trifolius*			3.2			100.0

1 Based on vegetation data from 31 transects.
2 W = Wetland Zone
T = Transition Zone
U = Upland Zone

TABLE 13: Zonal Classification of Plant Species Based on Frequency of Occurrence Data.

W	T	U	Tree Strata	W	T	U	Shrub Layer	W	T	U	Ground Cover
VA	A	A	*Acer rubrum*	A	VA	A	*Vaccinium corymbosum*	A	VA	A	*Maianthemum canadense*
R	O	F	*Carpinus caroliniana*	A	A	A	*Rhododendron viscosum*	A	VA	A	*Osmunda cinnamomea*
F	O	A	*Quercus alba*	A	F	F	*Lindera bezoin*	F	A	A	*Dryopteris noveboracensis*
O	R	F	*Betula alleghaniensis*	F	F	F	*Clethra alnifolia*	F	A	A	*Mitchella repens*
R	R	F	*Quercus borealis*	O	F	F	*Carpinus caroliniana*	F	A	A	*Polygonatum canaliculatum*
R	R	O	*Pinus strobus*	F	F	F	*Ilex verticillata*	O	F	A	*Dennstaedtia punctilobula*
O			*Ulmus rubra*	R	F	F	*Lyonia ligustrina*	O	F	A	*Trientalis borealis*
R			*Carya cordiformis*	O	R	R	*Hamamelis virginiana*	F	O	O	*Rubus hispidus*
O	R		*Nyssa sylvatica*	R	R	R	*Smilax herbacea*	F	F	F	*Coptis groenlandica*
O	R		*Fraxinus americana*	R	O	F	*Fraxinus americana*	O	O	F	*Medeola virginiana*
R	F		*Quercus bicolor*	R	F	F	*Viburnum acerifolium*	F	A	VA	*Lycopodium obscurum*
	R		*Sassafras albidum*	R	O	R	*Nyssa sylvatica*	F	F	F	*Lycopodium complanatum*
	R		*Acer saccharum*	R			*Ribes triste*	R	F	A	*Aralia nudicaulis*
	R		*Ulmus americana*	R			*Carya cordiformis*	A			*Sphagnum* spp.
	R	F	*Carya ovata*	R			*Pinus strobus*	F			*Symplocarpus foetidus*
	O	R	*Betula lenta*	R	O		*Castanea dentata*	O			*Onoclea sensibilis*
	R	O	*Castanea dentata*		R		*Viburnum lentago*	R			*Trillium erectum*
		R	*Prunus pensylvanica*		R		*Ulmus rubra*	O			*Leucobryum glaucum*
					R	A	*Gaylussacia baccata*	R			*Monotropa uniflora*
					F	A	*Quercus alba*	R			*Carex stricta*
					F	F	*Acer rubrum*	F	R		*Viola* spp.
					R	F	*Vaccinium angustifolium*	F	R		*Arisaema triphyllum*
					R	F	*Acer saccharum*	F	O		*Thuidium delicatulum*
					R	R	*Carya ovata*	F	O		*Athyrium Filix-femina*
					R	R	*Betula alleghaniensis*	O	R		*Lycopodium lucidulum*
						F	*Quercus borealis*	O	R		*Dryopteris thelypteris*
						F	*Prunus serotina*	R	R		*Leersia virginica*
						F	*Corylus cornuta*		F		*Polystichum acrostichoides*
						O	*Amelanchier laevis*		R		*Osmunda regalis*
						O	*Sassafras albidum*		R		*Amphicarpa bracteata*
						O	*Cornus florida*		R		*Solidago* sp.
						R	*Fagus grandifolia*		F	A	*Carex pensylvanica*
						R	*Kalmia angustifolia*		O	F	*Rubus* spp.
						R	*Betula populifolia*		R	R	*Actaea pachypoda*
						R	*Kalmia latifolia*			R	*Pyrola rotundifolia*
						R	*Parthenocissus quinquefolia*			R	*Panax trifolius*
						R	*Rosa rugosa*				

	No. of Transects Plant Found On	Frequency of Occurrence (%)
R = Rare	1	3.2
O = Occasional	2	6.5
F = Frequent	3-8	9.6 - 25.8
A = Abundant	9-16	29.0 - 51.6
VA = Very Abundant	17-	54.8-

The purpose of this measurement is to establish a relative index to the distribution of a plant species in each of the three zones. The above three measurements of plant distribution show which species are best used as indicators of zone conditions.

A procedure for evaluating quantitative vegetation data for taxonomic purposes is the discriminant analysis developed by Fisher (29). It is a multivariate statistical procedure that presupposes a correct assignment of individuals to groups, and determines how the groups can best be distinguished on the basis of a set of discriminating variables. It is most useful in situations where distinctions between groups are not clear-cut and where gradations between groups may occur. The mathematical objective of discriminant analysis is to weight and combine linearly the discriminating variables in some fashion so that the groups are forced to be as statistically distinct as possible (54).

Discriminant analysis was applied to the abundance data in a computer to determine (1) which plant species best distinguish wetlands from uplands and (2) to define natural associations of plant species.

The initial assignment of plant species to one of the three zones (wetland, transition, upland) was based on index of abundance values (discriminating variables). In running the discriminant analysis computer program, a decision had to be made as to the cutoff percentage of the discriminating variables for each zone. Individuals of plant species were assigned to the zone in which they had an abundance value of 65% or greater.

Selection of this cutoff percentage was augmented by: (1) a careful analysis of the raw data (Tables 10, 11, 12) and a familiarity with the plant species in the three zones, and (2) knowledge that 65% represents a statistical majority of abundance for a given zone. Because the classification matrix indicates that there is a high correlation between predicted zone membership and assigned zone membership, a change in the cutoff percentage did not appear justified (Table 13). If this high correlation had not occurred, a different cutoff percentage would have been selected and the plant species abundance data reprocessed.

Results of this analytical procedure are presented in Tables 14 and 15. Note that there are distinct groups of plant species associated with each of the three zones. The discriminant analysis computer program used permits calculation of classification equations for each zone based on the index of abundance values (27). Each classification equation yields a probability of zone membership (54); a plant species is classified into the zone for which it has the highest probability of being a member (Table 14). As a result, plant species are assigned to one and only one zone. But this method of classification is too restrictive to be applied to field conditions: most plant species, as shown in Table 15, overlap one or more zones. The high percentage (94.5%) of correct classification of plant species, however, indicates that the variables selected (abundance values for each zone) were very good discriminators. Tabular classification of the vegetation (Table 16 - In pocket of back

TABLE 14: Results of Discriminant Analysis Based on Index of Abundance Data $\geq$ 65%: Classification Matrix -- Assigned Zone Membership vs. Predicted Zone Membership.[1]

Classification Matrix

Assigned Zone	No. of Plant Species	Predicted Zone Membership		
		Upland	Transition	Wetland
Upland	15	15 100.0%	0 0.0%	0 0.0%
Transition	57	3 5.3%	52 91.2%	2 3.5%
Wetland	19	0 0.0%	0 0.0%	19 100.0%

Percent of assigned species correctly classified: 94.5%

[1] Results were obtained using the Discriminant Analysis Method of the Biomedical Computer Programs developed by Dixon (27).

cover) is more useful for illustrating species distribution, whereas discriminant analysis appears to be more useful in defining plant associations.

Vegetation profiles were constructed in order to show the distinct changes which occur in plant species composition and structure along the environmental gradient from wetland to upland. Mean data of the position, height, and crown cover of each species and the mean relief of the 31 vegetation transects are plotted (Figs. 8, 9, and 10) indicating vegetative physiognomy.

The above analyses showed that slight variations in species composition can be expected from one wetland to the next, but that on the whole, all well-established forested wetlands tested in

TABLE 15: Classification of Plant Species by Discriminant Analysis: Predicted Zone Membership.

Wetland Zone		Upland Zone	
1.	*Sphagnum* spp.	1.	*Quercus borealis* (S)
2.	*Symplocarpus foetidus*	2.	*Prunus serotina* (S)
3.	*Onoclea sensibilis*	3.	*Corylus cornuta*
4.	*Ulmus rubra* (T)	4.	*Amelanchier laevis* (S)
5.	*Ribes triste*	5.	*Sassafras albidum* (S)
6.	*Carya cordiformis* (S)	6.	*Cornus florida* (S)
7.	*Trillium erectum*	7.	*Pyrola rotundifolia*
8.	*Leucobryum glaucum*	8.	*Fagus grandifolia* (S)
9.	*Carya cordiformis* (T)	9.	*Parthenocissus quinquefolia*
10.	*Pinus strobus* (S)	10.	*Panax trifolius*
11.	*Monotropa uniflora*	11.	*Rosa rugosa*
12.	*Carex stricta*	12.	*Kalmia angustifolia*
13.	*Nyssa sylvatica* (T)	13.	*Betula populifolia* (S)
14.	*Viola* sp.	14.	*Kalmia latifolia*
15.	*Arisaema triphyllum*	15.	*Prunus pensylvanica*
16.	*Athyrium filix-femina*	16.	*Gaylussacia baccata*
17.	*Lycopodium lucidulum*	17.	*Carya ovata*
18.	*Fraxinus americana*	18.	*Vaccinium angustifolium*
19.	*Dryopteris thelypteris*		
20.	*Thuidium delicatulum*		
21.	*Leersia virginica*		

Transition Zone

1.	*Acer rubrum* (T)	27.	*Viburnum acerifolium*
2.	*Vaccinium corymbosum*	28.	*Aralia nudicaulis*
3.	*Rhododendron viscosum*	29.	*Quercus borealis* (T)
4.	*Lindera benzoin*	30.	*Pinus strobus* (T)
5.	*Clethra alnifolia*	31.	*Nyssa sylvatica* (S)
6.	*Maianthemum canadense*	32.	*Castanea dentata* (S)
7.	*Osmunda cinnamomea*	33.	*Quercus bicolor* (T)
8.	*Dryopteris noveboracensis*	34.	*Polystichum acrostichoides*
9.	*Mitchella repens*	35.	*Sassafras albidum* (T)
10.	*Polygonatum canaliculatum*	36.	*Acer saccharum* (T)
11.	*Carpinus caroliniana* (S)	37.	*Ulmus americana* (T)
12.	*Dennstaedtia punctilobula*	38.	*Viburnum lentago*
13.	*Trientalis borealis*	39.	*Ulmus rubra* (S)
14.	*Carpinus caroliniana* (T)	40.	*Osmunda regalis*
15.	*Ilex verticillata*	41.	*Amphicarpa bracteata*
16.	*Rubus hispidus*	42.	*Solidago* sp.
17.	*Coptis groenlandica*	43.	*Quercus alba* (S)
18.	*Medeola virginiana*	44.	*Acer rubrum* (S)
19.	*Lyonia ligustrina*	45.	*Carex pensylvanica*
20.	*Hamamelis virginiana*	46.	*Rubus* spp.
21.	*Smilax herbacea*	47.	*Acer saccharum* (S)
22.	*Lycopodium obscurum*	48.	*Actaea pachypoda*
23.	*Lycopodium complanatum*	49.	*Betula lenta* (T)
24.	*Quercus alba* (T)	50.	*Carya ovata* (S)
25.	*Fraxinus americana* (S)	51.	*Castanea dentata* (T)
26.	*Betula alleghaniensis* (T)	52.	*Betula alleghaniensis* (S)

(T) = Tree Stratum (S) = Shrub Stratum

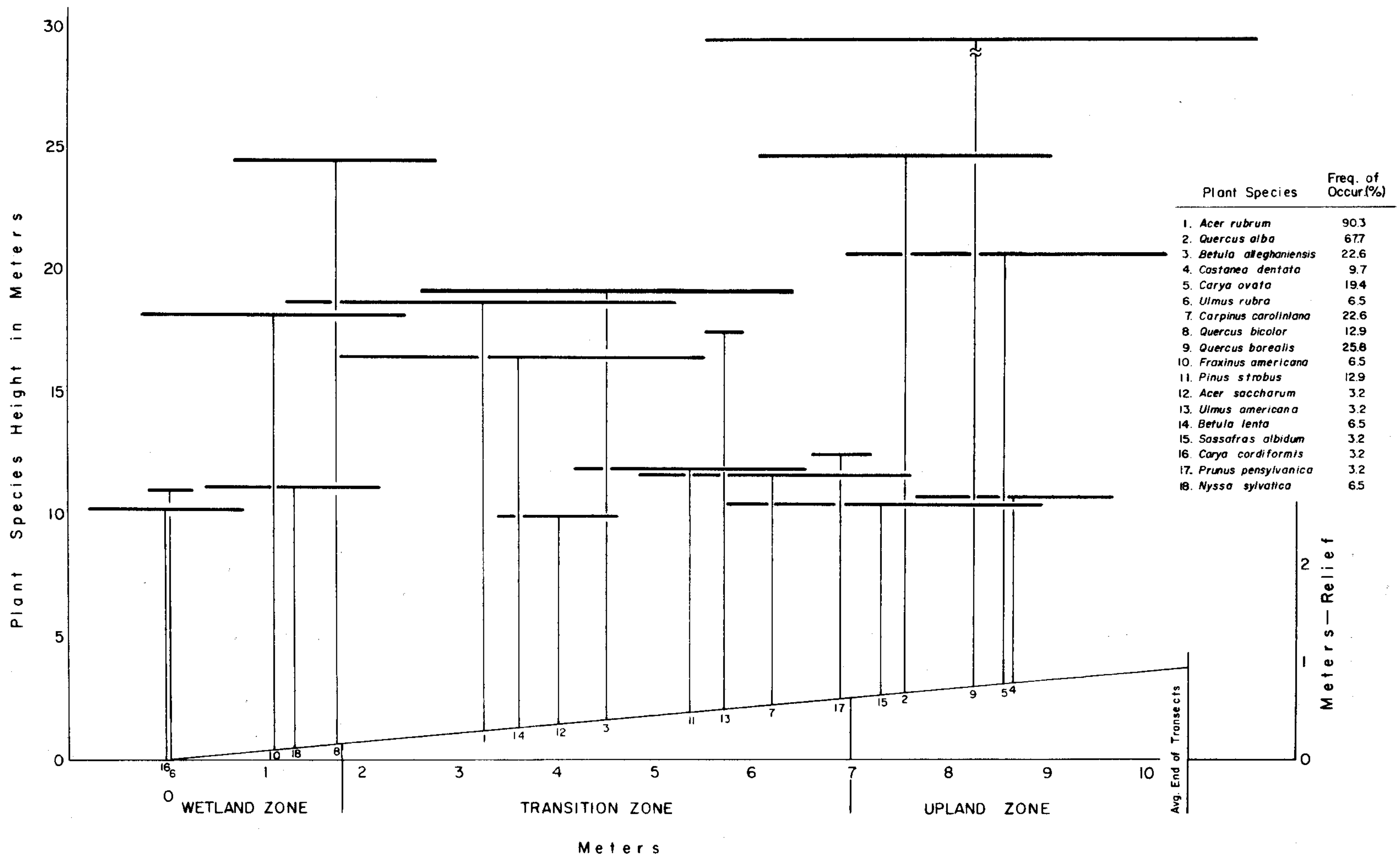


Figure 8. Vegetation Profile - Tree Stratum.

Plant Species	Freq. of Occur.(%)	Plant Species	Freq. of Occur.(%)	Plant Species	Freq. of Occur.(%)
1. *Lindera benzoin*	45.2	14. *Quercus borealis*	16.1	27. *Viburnum lentago*	3.2
2. *Carya cordiformis*	3.2	15. *Prunus serotina*	25.8	28. *Kalmia angustifolia*	3.2
3. *Quercus alba*	45.2	16. *Nyssa sylvatica*	9.7	29. *Hamamelis virginiana*	3.2
4. *Fraxinus americana*	16.1	17. *Acer saccharum*	9.7	30. *Cornus florida*	3.2
5. *Carpinus caroliniana*	29.0	18. *Carya ovata*	6.5	31. *Kalmia latifolia*	3.2
6. *Rhododendron viscosum*	54.8	19. *Corylus cornuta*	9.7	32. *Betula populifolis*	3.2
7. *Lyonia ligustrina*	29.0	20. *Ribes triste*	3.2	33. *Pinus strobus*	3.2
8. *Vaccinium corymbosum*	80.6	21. *Acer rubrum*	29.0	34. *Amelanchier laevis*	6.5
9. *Betula alleghaniensis*	6.5	22. *Gaylussacia baccata*	35.5	35. *Smilax herbacea*	6.5
10. *Castanea dentata*	6.5	23. *Ilex verticillata*	42.0	36. *Parthenocissus quinquefolia*	9.7
11. *Clethra alnifolia*	25.8	24. *Sassafras albidum*	6.5	37. *Rosa rugosa*	3.2
12. *Ulmus rubra*	3.2	25. *Fagus grandifolia*	3.2		
13. *Viburnum acerifolium*	25.8	26. *Vaccinium angustifolium*	22.6		

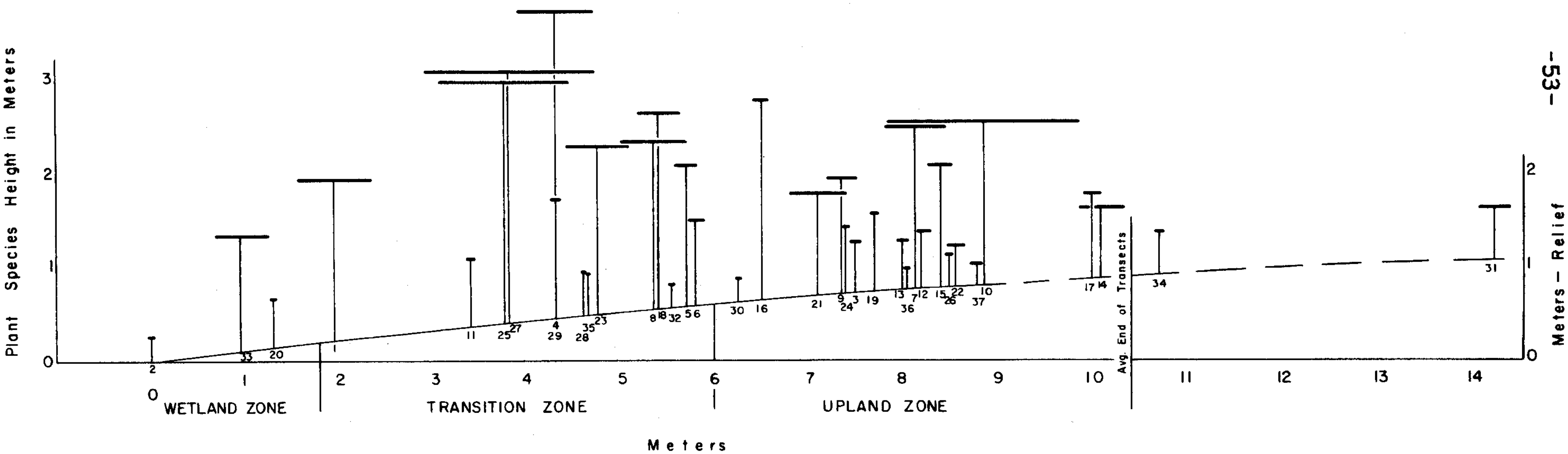
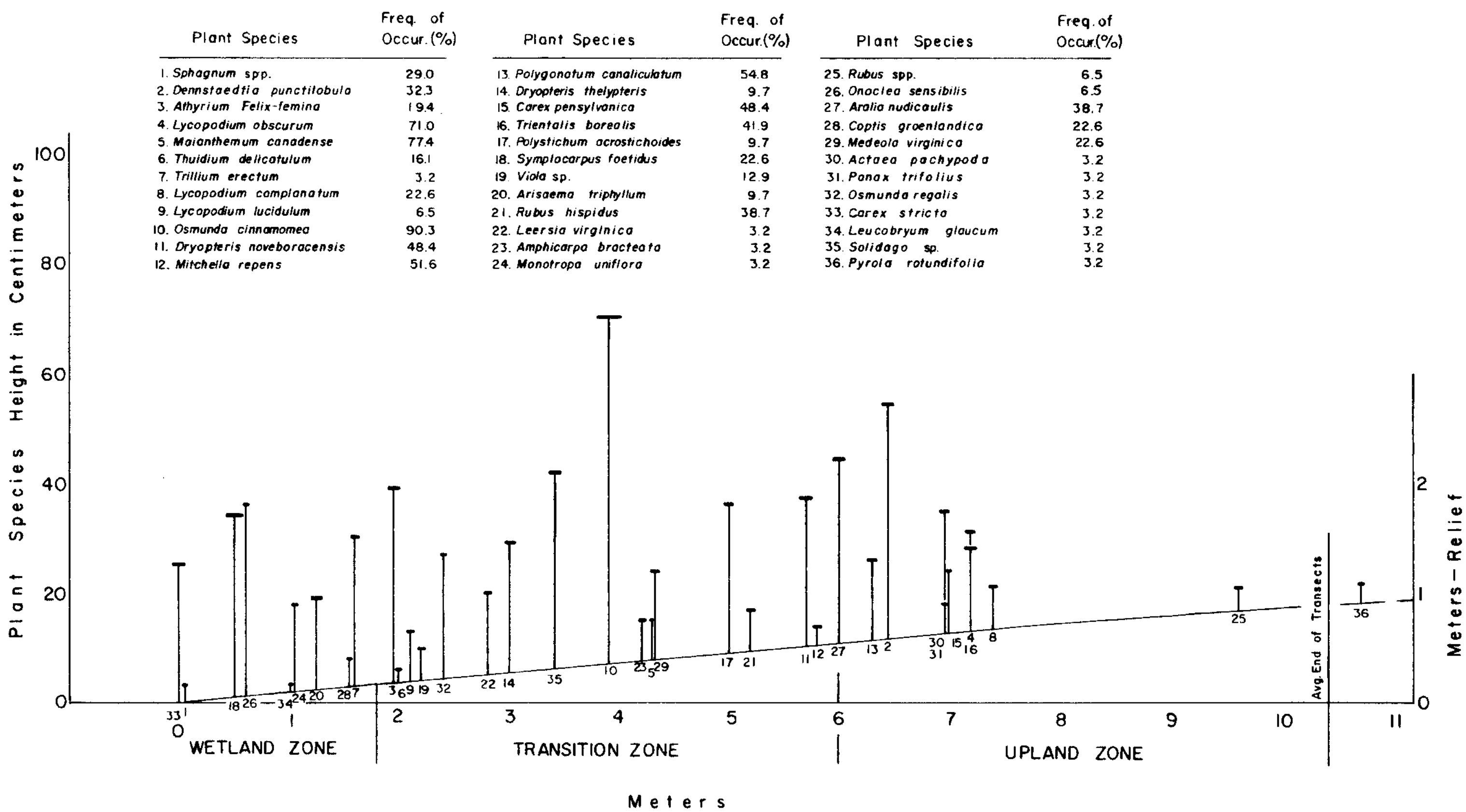


Figure 9. Vegetation Profile - Shrub Stratum.



Plant Species	Freq. of Occur. (%)
1. *Sphagnum* spp.	29.0
2. *Dennstaedtia punctilobula*	32.3
3. *Athyrium Felix-femina*	19.4
4. *Lycopodium obscurum*	71.0
5. *Maianthemum canadense*	77.4
6. *Thuidium delicatulum*	16.1
7. *Trillium erectum*	3.2
8. *Lycopodium complanatum*	22.6
9. *Lycopodium lucidulum*	6.5
10. *Osmunda cinnamomea*	90.3
11. *Dryopteris noveboracensis*	48.4
12. *Mitchella repens*	51.6
13. *Polygonatum canaliculatum*	54.8
14. *Dryopteris thelypteris*	9.7
15. *Carex pensylvanica*	48.4
16. *Trientalis borealis*	41.9
17. *Polystichum acrostichoides*	9.7
18. *Symplocarpus foetidus*	22.6
19. *Viola* sp.	12.9
20. *Arisaema triphyllum*	9.7
21. *Rubus hispidus*	38.7
22. *Leersia virginica*	3.2
23. *Amphicarpa bracteata*	3.2
24. *Monotropa uniflora*	3.2
25. *Rubus* spp.	6.5
26. *Onoclea sensibilis*	6.5
27. *Aralia nudicaulis*	38.7
28. *Coptis groenlandica*	22.6
29. *Medeola virginica*	22.6
30. *Actaea pachypoda*	3.2
31. *Panax trifolius*	3.2
32. *Osmunda regalis*	3.2
33. *Carex stricta*	3.2
34. *Leucobryum glaucum*	3.2
35. *Solidago* sp.	3.2
36. *Pyrola rotundifolia*	3.2

Figure 10. Vegetation Profile - Herb Stratum.

northeastern Connecticut support a common plant association. The individual species of an association exhibit an adaptation or tolerance to similar environmental conditions and to a degree may be considered ecological equivalents. Other factors being equal, members of plant species belonging to the same vegetative stratum (tree, shrub, herb) may replace each other in any given site. An example is where *Lindera benzoin* (L.) Blume (Spicebush) dominates the shrub stratum of one forested wetland and in another similar site *Clethra alnifolia* L. (Sweet Pepperbush) is the dominant shrub. In both cases, each plant belongs to the same stratum and is an indicator of similar environmental conditions.

Plant species identified in the study are listed by scientific names in Appendix B and by common names in Appendix C.

DELINEATION OF DECIDUOUS WETLAND FORESTS

Delineation in the field. A definitive plant association may be regarded as a manifestation of soil conditions. If, however, either the soil or plant association is in a state of active transition, such a correlation might not exist (61). The areas studied in this project were selected because they were considered to represent mature and undisturbed deciduous wetland forests. When such is the case, vegetation can be used as one of the principal criteria for identifying and delineating inland wetlands. Vegetation lends itself more readily to examination than any other wetland component both in the field and on low-altitude FCIR aerial photography.

Frequency of Occurrence, Index of Abundance, and Relative Density values provide the data necessary to assign plant species to a particular zone. The wide range of tolerance and adaptability of some plant species is shown by the occurrence of some species in each of the three zones studied, *e.g.*, *Vaccinium corymbosum* and *Clethra alnifolia* (Table 11). Species which botanists commonly consider as members of wetland associations have been observed growing in upland zones in this study. These upland zones do not represent dry site conditions *per se*, but mesic ones. There is an adequate supply of soil water available to plants growing in these zones throughout the growing season. Competition, not lack of water, is the factor governing species composition in upland zones.

The study reveals that *Vaccinium corymbosum*, *Rhododendron* *viscosum, Clethra alnifolia,* and other species commonly considered native to wet sites were found occurring in relatively high numbers and frequency in upland zones. This pattern may be accounted for by the following: (1) the upland zones in this research have sufficient amounts of soil water to support wet site species, (2) the adaptability and wide tolerance of some species allows them to grow in zones other than those possessing optimum conditions, and (3) the close proximity of seed sources. During spring flooding, the upland edge of a transition zone becomes saturated, creating a soil condition which closely approaches that of a wetland. This condition encourages the growth of wet site species. Once established, some of these species can effectively compete against upland species and tolerate the drier soil conditions which occur late in the growing season.

Conversely, some dry site species, *Pinus strobus* (White Pine) and *Quercus* spp. (Oaks) were observed growing in wetland zones (Table 11). This is not an unusual condition. The following can explain those findings: (1) during long periods of drought a drop in the water table results in a drying of the wetland soil, thus encouraging the establishment of some upland species, and (2) minor variations in topography create hummocks which are higher above the water table (thus drier) which can support dry site species; (3) evapotranspiration during the growing season may lower the water content of the wetland soil enough to create a condition which becomes favorable for the establishment of dry site species. The second case is quite common in forested inland wetlands and can create problems in identification of these areas.

Two of the conditions mentioned above pose problems when a single plant species is used as the criterion for delineating wetlands: upland species found in the wetland zone, and wetland species found in the upland zone. A plant association should be considered the determining factor when evaluating the effects of environmental conditions. It should be recognized, however, that the presence of members of a plant association is more important than their absence.

It should be noted that only some, and not necessarily all of the plant species listed here as members of wetland associations may be used to locate and delineate inland wetlands. The higher the frequency of occurrence of a plant species for any given zone, the more useful it is in defining and delineating that zone.

The results of the vegetation analyses reveal that there is very little variation in species composition among the eight areas studied. This finding agrees with that of Grace (34), who states that "...there appears to be very little variation between species composition or successional trends on wet mineral soils and wet organic soils." Individuals of a single species, however, may be restricted to sites which have specific edaphic properties. The presence or absence of such uncommon species should not be weighed heavily when evaluating vegetation and general edaphic conditions.

The predominant tree species of forested inland wetlands in southern New England is *Acer rubrum* L. (Red Maple) (34). The dominance of Red Maple in wetland zones is shown in Table 10. Examination of the vegetation analyses (Tables 11 and 15) shows, however, that Red Maple seedlings and young trees did not occur in the wetland zones studied. These results are comparable to those of Grace (34), who states that Red Maples are not able to regenerate successfully under their own canopy.

The composition and distribution of a plant association in undisturbed conditions is principally influenced by climate, edaphic conditions, and competition between species, whereas a principal factor controlling the structure of the individuals is light (63). The relative heights of the forest undergrowth can generally be considered inversely related to their tolerance to shade; that is, low-lying plants are more tolerant to shade than their taller counterparts (63). This generalization is illustrated in Figs. 8 and 9. Places where there are breaks in the canopy are filled by taller shrubs, with successively lower layers of vegetation filling in underneath.

There is relatively little herbaceous undergrowth in forested inland wetlands. The dense shrub cover in these zones intercepts almost all of the light which passes through the tree canopy. Along the transects, locations devoid of shrubs are occupied by the large *Osmunda cinnamomea* L. and other tall herbs (Fig. 10). On most all of the transects surveyed, *O. cinnamomea* became abundant at the wetland edge where the shrub canopy had thinned out but where the soil was still relatively wet.

Trees growing in upland zones were taller than those growing in wetland zones (Fig. 8). This relative difference in size accentuates the topographic gradient, and these two factors make forested inland wetlands appear topographically low relative to the bordering uplands when viewed on aerial photographs. This feature greatly assists in locating and delineating inland wetlands on remote sensing imagery (when viewed stereoscopically).

Problems may occur, however, if vegetation is the only criterion used for wetland delineation on aerial photographs taken during the growing season. The vegetation profile of the tree stratum (Fig. 8) shows an overlapping of the canopy within all three zones (wetland, transition, upland). This overlap not only obscures the edge of the wetland when viewed from above, but also prevents viewing the ground surface. Forested inland wetlands are best delineated (1) in the field, or (2) on remote sensing imagery which has been taken when the trees are leafless and the ground is exposed. Using the latter method, delineation of forested inland wetlands is based on their hydrologic features (shown best on FCIR film) and topographic position.

The type of landform bordering forested inland wetlands determines the degree of difficulty one has in identifying and delineating them. A diverse landform interface, *e.g.*, forested wetland--open field, would greatly reduce the problems of identification and delineation. Conversely, a low landform diversity at the interface between wetlands and uplands would create severe problems in identification and delineation. The areas studied represent sites of low wetland/upland interface diversity; situations where a wetland exists in a forested area. Inland wetlands of this type are common in Connecticut (34).

Delineation using remote sensing imagery. The delineation and classification of wetlands and water courses is possible from the interpretation of low and high-altitude aerial photographs. Moreover, the use of aerial photography, when combined with a moderate amount of ground verification, is a potentially comprehensive and inexpensive method of classifying and delineating plant species and associations. To accomplish this successfully, identification and classification must be based on those properties of inland wetlands which are readily recognizable on the imagery, such as vegetation, presence of standing water, high soil water content, and topography. Stewart and Kantrud (75) have shown that vegetation is one of the best indicators of water quality and permanence and that vegetation is one of the principal factors causing variations in spectral reflectance from wetland areas. The intimate relationship of certain combinations of plant species with their environment allows one to use vegetation as an indicator of soil type, fertility, and drainage conditions. Noticeable differences in vegetation on aerial photographs can be related directly to soil water content (83). Consequently, differences in spectral reflectance occur at the boundary between wetlands and uplands (5).

Wetlands occurring under the canopy of hardwood forests are difficult to delineate. The time of the year best suited to delineate this type of inland wetland is during the early spring using false-color infrared (FCIR) aerial photography, as described above.

Identification and delineation of wetland plant species is most accurate using large-scale aerial photography. As the scale of the photograph increases, the amount of detail in the image increases. The accuracy of interpretation of objects on aerial photographs depends largely on the interpreters' experience and knowledge of ground features.

Olson (55) states that "Before interpretation of aerial photographs can be made, the images on the photographs and their counterparts on the ground must be defined into recognizable groups." Aerial photographs cannot be used in defining inland wetlands, but can be used in delineating them. Inland wetlands should be defined in such a way as to make them easier to delineate on aerial photographs, using criteria that can be readily and accurately identified. Obvious wetland features would be vegetation, water, and topography.

Inland wetland delineations will vary depending on the criteria used for determining their boundaries. Natural gradations occur in the biologic, hydrologic, and edaphic components of the interface between wetlands and uplands. The extent of the gradations vary with slope. The steeper the slope, the more well-defined the differences in environmental conditions at the interface between wetlands and uplands. Problems arise, however, because a sharp boundary line is required for inland wetlands and water course regulations. The gradation of natural conditions at the wetland-upland interface makes it difficult to identify and locate precise boundary lines.

Presently, inland wetland maps provide resource managers with the general location of boundary lines. On site inspection is often required to make a final decision on the exact location of any inland wetland and its boundaries. Therefore, inland wetland maps must be often generated by the least expensive and time-consuming method, and by one that is comprehensive and as accurate as possible. One such technique to use is intermediate scale (*e.g.*, 1:12,000 to 1:20,000) aerial photographs taken in the spring with interpretive wetland delineations based on hydrologic and vegetative criteria.

The accuracy of inland wetland maps depends on (1) the method of delineation, *i.e.*, field survey and/or photographic interpretation, (2) the process of data transfer to base maps and rectification, and (3) the adjustments necessary to attain the desired final scale. The completeness of the wetlands survey depends on (1) the method of delineation, *i.e.*, field survey or photographic interpretation, (2) the criteria selected for delineation, and (3) the size of the minimum mapping unit.

The ground accuracy of inland wetland delineations on aerial photographs varies with the scale of the imagery. The width of the boundary line becomes narrower as the scale of the imagery increases. Ground features appear in greater detail on large scale (greater than 1:12,000) aerial photographs, thus enabling sharper boundary lines to be drawn. Large scale coverage, however, can reach the point of diminishing returns. Information extracted from such coverage may better be acquired from field surveys. The larger the scale of the aerial photography, the greater the number of photographs to be interpreted and thus the more time needed to complete an inland wetlands survey.

EVALUATION OF CRITERIA USED TO DELINEATE DECIDUOUS WETLAND FORESTS

Deciduous wetland forests can be detected using vegetative, hydrologic, and soil criteria. The boundaries of such wetlands can be identified by field and remote sensing surveys. The criteria are evaluated on the basis of their usefulness in delineation both in the field and on aerial photographs. The remote sensing aspects are described in terms of the appearance of ground features on low-altitude FCIR aerial photographs.

Soil type. Because Soil Surveys had been completed for 70 percent of the State of Connecticut (at the time of legislation), soil type was established as the principal criterion for defining and delineating inland wetlands. The availability of the soil data supported the use of soil types as the logical criterion for wetland delineation. The relatively slow rate of change in soil properties from one year to the next further supports the use of soil type for delineation purposes.

The delineation of inland wetlands by a soil survey is fairly comprehensive. The width of the soil type boundary line, however, may range from three to five meters along sharp breaks in the topography, to 21 to 79 meters where more gradual slopes occur (36). These variations in line width detract from the usefulness of soil surveys in delineating inland wetlands. Resource managers will find it difficult to implement and enforce Connecticut's inland wetlands and water courses regulations with boundary lines as wide as those published in the Soil Surveys.

Another factor limiting the use of the Soil Survey is the two acre (0.8 ha.) minimum mapping unit. Many inland wetland forests in Connecticut are less than two acres in size. As a result, these smaller wetlands will not be delineated by the Soil Survey. When based on hydrologic features, inland wetlands as small as 0.1 hectare (0.25 a) or less can be identified using low-altitude (6,000') FCIR aerial photographs taken in the spring. This latter method provides a more comprehensive means of delineating inland wetlands.

The major disadvantage of using soil type as the principal criterion for delineating wetland forests is that most soil types cannot be discerned directly on conventional aerial photographs and that a substantial amount of advanced study and field experience is required to identify and map soils correctly. Because of the many years of training required to attain the expertise, there are relatively few people qualified to conduct soil surveys. As a result, it is expensive and time-consuming to produce and update wetland maps based on soil types. Many man-hours are required to collect the field data needed to generate a detailed and accurate map.

Large scale maps provide detailed and comprehensive information to resource managers. Such maps, however, when based on field surveys or large scale aerial photographic coverage can be cost-prohibitive. Similarly, large scale wetland maps based on soil type delineations would be more time-consuming and expensive to generate than maps based on vegetative criteria. Large scale soil surveys require time-consuming core samples and pits to be dug for the determination of soil types. The rapid reconnaissance of vegetation types reduces the time in producing inland wetland maps; although soil scientists do use vegetation directly and indirectly to assist in delineating soil types. Inland wetland maps based on vegetative criteria eliminate timely field determination of soil types, thereby providing a more cost-effective method of delineation.

While the Soil Survey was not intended to be used for wetlands regulation, it has been very beneficial in implementing Connecticut's inland wetlands program. The fact remains, though, that it is an incomplete method of defining and delineating inland wetlands. An alternative system should be developed to handle effectively the problems which arise when carrying out the public policy of Public Act 155 (1972) and its amendments.

Vegetation. The major advantage of using vegetation as the principal criterion for delineating deciduous wetland forests is that differences in species composition can be recognized by field surveys and remote sensing techniques. The species composition of a deciduous wetland forest changes very little from one year to the next, and since they are dominated by woody plants, forested wetlands can be delineated throughout the entire year.

Another advantage vegetation surveys have is that only a moderate amount of training and field experience is required to delineate forested wetlands based on vegetative criteria. Except for standing water, vegetation is the most conspicuous feature of an inland wetland. Differences in species composition and vegetative physiognomy are the principal factors distinguishing deciduous wetland forests from bordering uplands. Vegetative field delineations and those using remote sensing techniques are as accurate (± 5', depending on scale) as those based on soil type.

The argument for using vegetation as the principal criterion for delineating deciduous wetland forests is made stronger when remote sensing imagery is used as a mapping base. Because major differences in species composition exist between wetlands and uplands, these two zones can be distinguished on FCIR aerial photographs. Changes in species composition can be detected by texture, tone, color, and relative size differences which appear on the photographic images. As has been previously discussed, FCIR film increases the accuracy of such delineations because of its ability to provide an image which shows distinct differences between plant species, and because it can detect surface water.

Presently, detailed vegetation maps do not exist for the State of Connecticut. Using remote sensing techniques and a moderate amount of detailed field verification, maps delineating inland wetlands and other unique landforms based on vegetative features can be generated in a short time span. Similarly, the update of such maps using newly acquired aerial photographs will provide current data to resource managers.

Soil water content. As shown in the present study, field techniques can be employed to quantify soil water content along the wetland to upland gradient. However, the collection of such data is time-consuming and requires special equipment. These two factors make this method of delineation impractical.

Although quantitative field determination of soil water content is not recommended as a criterion to be used to delineate deciduous wetland forests, qualitative studies of soil water content can be very useful when attempting to gain a general understanding of plant species distribution. But qualitative field analysis of soil water content should be used with discretion, as illustrated by Transect 7. During the later stages of the growing season of this study on Transect 7, the wetland soil was as dry as the upland soil. Under these conditions, the presence of characteristic plant species should be the criterion used to delineate inland wetlands.

The delineation of wetlands on FCIR imagery taken in the spring is based almost entirely on the presence of standing water and soil water content. During the early spring months, the water table is at its highest and soils their wettest. Surface features that appear dark blue to black on the spring imagery represent standing water or soils with very high water content. Soils which have a high water content for a major portion of the growing season support wetland plant associations. Deciduous wetland forests are those areas on the spring FCIR aerial photographs which appear dark blue to black and have trees growing in them. Places on the spring imagery which show dramatic differences in soil water content represent the interface between wetlands and uplands. On FCIR images, relative differences in soil water content are so distinct that wetland delineations can be carried out solely on the basis of the tonal contrasts and color renditions. Wetland maps generated on that basis provide a means of delineation which is both accurate and comprehensive.

One of the disadvantages in using soil water content as a criterion for delineation is that it continuously fluctuates. Not only does it vary from week to week for any given soil but it also differs from one wetland to the next, depending on the location of the water table and soil differences.

Soil pH. A knowledge of soil pH assists in understanding the distribution of plant species. However, differences in soil pH cannot be observed directly in the field or on aerial photographs. Therefore, it is impracticable to use soil pH in delineating deciduous wetland forests. The variations in soil pH along the wetland to upland gradient may, however, be viewed indirectly by observing changes in species composition. The results of this study suggest that soil pH influences the distribution of some plant species more than others, but in general it does not appear to be a major factor governing species composition along the wetland to upland gradient.

Standing water. Standing water is the most obvious feature of an inland wetland. However, not all forested wetlands have standing water throughout the entire year. Fluctuations in the water table, precipitation, and evapotranspiration will govern the duration of surface water in any wetland.

During the early spring months when the trees are leafless and the water table is at its highest, most wetland forests can be readily delineated in the field or on aerial photographs by the surface water perimeter. Under these conditions delineation is based on the hydrologic features of a wetland. As with the case of soil water content, it is difficult to quantify the presence of standing water on aerial photographs. When using FCIR imagery, however, the qualitative differences between wetlands and uplands are so striking that quantitative measurements are unnecessary.

During the summer months when the water table drops and the rate of evapotranspiration is high, the soil of a deciduous wetland forest begins to dry out. Surface water is no longer present except on those sites where drainage is impeded. Wetland delineations at this time of the year should be based on differences in plant species composition, soil water content, and soil type. When viewing these areas on aerial photographs, the ground surface is obscured due to the dense vegetation canopy. Wetland delineations are thus based on apparent differences in species composition and topography.

Depth to water table. As has been stated above, there exists a direct relation between depth to water table and soil water content. Soil water content is the principal environmental factor governing plant species distribution along the wetland-upland gradient (38, 63). Consequently, an area where the water table is at or near the ground surface during a major portion of the year will be classified as a wetland and will support a characteristic plant association.

Wetlands can be delineated in the field on the basis of depth to the water table. However, clear-cut guidelines would have to be established as to what depth and duration constitutes a wetland. Since water tables fluctuate continuously throughout the year and differ from one wetland to the next, it is impractical to use depth to water table as a reliable criterion for wetland delineation. Similarly, the amount of time and equipment needed to obtain such data does not justify its use.

Because of its direct association with surface water and soil water content, depth to water table is indirectly represented in the field and on aerial photographs. It is an important environmental factor which has a tremendous influence on surface conditions. Data collected on depth to water table, as with the data on soil water content and soil pH, provide information necessary to interpret the changes in species composition along the wetland to upland gradient.

Review of delineation criteria. The criteria selected to delineate deciduous wetland forests (Table 17) vary according to the time of the year and the method used, *i.e.*, field or remote sensing surveys. Of the criteria studied, vegetation is the most useful in delineating deciduous wetland forests. It is the only wetland feature which can be applied throughout the year for delineation either by field or remote sensing techniques. Soil type can be applied throughout the year, but typically only for field surveys.

The soil type of a forested wetland may differ from one site to the next, as was the case with the eight wetlands studied. However, plant species composition does not change appreciably from one wetland forest to the next. Adoption of vegetation as the principal criterion will provide a uniform system of delineating deciduous wetland forests in northeastern Connecticut. Vegetation has long been used by soil scientists to assist in mapping the extent of a soil type. It serves as a reliable indicator of environmental conditions and provides an accurate means of delineating landforms.

TABLE 17: Evaluation of the Criteria Used to Delineate Deciduous Wetland Forests.

Criterion	Advantages	Disadvantages
Soil Type	1. Permanence throughout the year. 2. Data available for the State (CT) - 95% of the State surveyed.	1. Few soil types are represented on aerial photographs. 2. Special training required. 3. Time consuming to obtain data. 4. Width of boundary lines and minimum size of mapping unit (approx. 2 acres) pose limitations on its use.
Vegetation	1. Permanence throughout the year. 2. Represented on aerial photographs. 3. Rapid reconnaissance. 4. Moderate amount of training required.	1. Width of boundary lines. 2. No data available on State wide level.
Soil Water Content	1. Represented on aerial photographs when trees are leafless. 2. Dramatic differences occur between wetlands and uplands. 3. Tool to explain and interpret plant species distribution.	1. Difficult to quantify for delineation purposes. 2. Fluctuates throughout the year. 3. Wetlands not necessarily wetter than uplands during portions of the growing season.
Soil pH	Not applicable for delineation purposes. Sometimes useful in explaining and interpreting plant species distribution.	
Standing Water	1. Represented on aerial photographs. 2. Permanence (lakes, ponds, rivers)	1. Difficult to quantify for delineation purposes. 2. Fluctuates throughout the year (ephemeral ponds and streams).
Depth to Water Table	1. Directly related to soil water content. 2. Directly related to the distribution of plant species.	1. Fluctuates throughout the year. 2. Difficult to quantify for delineation purposes. 3. Data difficult and time-consuming to obtain. 4. Not directly represented on aerial photographs.

SUMMARY

The aim of this study was to examine the nature of the transition zone between uplands and deciduous wooded wetlands in a portion of northeastern Connecticut. Aspects of this study of *Acer rubrum* (red maple) wetlands, the most common in Connecticut, included the vegetation gradient, soil types, soil moisture gradient, and soil pH. Because delineation of wetlands is a necessary practice in Connecticut, this study also considered the practicality of using vegetation *vs.* soils as a principal criterion for delineation, both in the field and on aerial photographs.

Inland wetlands are unique habitats where an abundance of water is the major environmental factor governing composition of the vegetation. Although qualitative and quantitative differences in soil water content between wetlands and uplands can be used to delineate deciduous wetland forests, it is the wetland vegetation which is often used by resource managers in delineating them. Therefore the major plant associations along the wetland to upland gradients in our study areas were identified (see Fig. 7). The utility of these associations for wetlands delineation both on the field and in false-color infrared photographs is also discussed.

The "soils only" definition of wetlands in Connecticut law is useful and acceptable for its stated purpose. However, to more effectively delineate wetlands on a case-by-case basis, the definition should be more comprehensive. Vegetation and

hydrological criteria should also be included. Used together, these aspects of wetlands can greatly ease the detection and delineation of inland wetlands as well as point the way for intelligent (and legally recognized) assessment of environmental impact.

CONCLUSIONS

1. Vegetation can be used as the principal criterion in delineating deciduous wetland forests in northeastern Connecticut, both by field surveys and low-altitude, false-color infrared, aerial photographs. Distinct plant associations have been identified along the wetland to upland gradients.

2. The wetland transition zones examined in this study possess a characteristic vegetation dominated by *Sassafras albidum*, *Acer saccharum*, *Ulmus americana*, *Viburnum lentago*, *Ulmus rubra*, *Polystichum acrostichoides*, *Osmunda regalis*, *Amphicarpa bracteata*, and *Solidago* sp.

3. Discriminant analysis provides a useful method of classifying plant associations. Index of abundance values for each of the three zones (wetland, transition, upland) proved to be very good discriminators (94.5% correct classification) of vegetation types. Because separate classification equations were developed for each of the three zones, newly encountered species can be assigned correctly to a plant association based on abundance data. The discriminant analysis process of assigning a plant species to the zone for which it has the highest probability of membership will assist in the identification and classification of plant associations in all inland wetland types.

4. The advantages of using vegetation as the principal criterion in delineating deciduous wetland forests far outweigh the advantages of using any of the other criteria studied. The most important advantages are: (1) presence throughout the

year, (2) rapid reconnaissance, (3) represented on aerial photographs, and (4) very little variation in species composition from one deciduous wetland forest to the next.

5. The selection of the criteria used to locate the boundaries of deciduous wetland forests depends on the time of the year and the method of delineation, *i.e.*, field or remote sensing surveys.

6. Statistically significant differences in soil water content exist along the wetland to upland gradients. These differences are reflected by changes in plant species composition along the gradients.

7. Statistically significant differences in soil pH exist along wetland to upland gradients. The relative absolute differences, however, are so small that it is unlikely that soil pH has any major effect on plant species distribution along these gradients.

8. Results of the soil studies show that edaphic properties vary from one deciduous wetland forest to the next. These differences suggest that delineation, when based on soil conditions, be carried out on a case-by-case basis with on site inspections.

9. Low-altitude, false-color infrared, aerial photographs provide an excellent medium for delineating deciduous wetland forests. The use of this film type in differentiating vegetation types and in depicting hydrologic features makes it a very valuable tool for mapping inland wetlands.

10. Vegetative, hydrologic, and edaphic criteria should be incorporated to provide a comprehensive definition of inland wetlands, with combinations of these criteria used for delineation.

LITERATURE CITED

1. Adams, G. D. and S. C. Zoltai. 1969. Proposed open water and wetland classification. *In* D. S. Lacate, ed., Guidelines for Biophysical Land Classification for Classification of Forest Lands and Associated Wildlands, Canadian Forest Service Publ. No. 1264, pp. 23-41. Dept. Fish. Forest., Ottawa.

2. Aldrich, R. C. 1968. Remote sensing and the Forest Survey. ...present applications, research, and a look at the future. *In* Proc. of the Fifth Symp. on Remote Sensing of Environment. pp. 357-367. Univ. Michigan, Ann Arbor, Michigan.

3. Anderson, R. R. 1968. Remote sensing of marshlands and estuaries using color infrared photography. *In* Earth Resources Aircraft Status Review. 3:(26)1-23. NASA Manned Spacecr. Ctr. Houston, Texas.

4. Anderson, R. R. 1969. The use of color infrared photography and thermal imagery in marshland and estuary studies. *In* 2nd Ann. Earth Resources Aircraft Program Status Review. 2:(40)3-29. NASA Manned Spacecr. Ctr. Houston, Texas.

5. Anderson, R. R. and V. Carter. 1972. Wetlands delineation by spectral signature analysis and legal implications. *In* 4th Ann. Earth Resources Program Review. U.S. Geol. Surv. Program. 3:(78)1-8. NASA Manned Spacecr. Ctr. Houston, Texas.

6. Avery, T. E. 1968. Interpretation of Aerial Photographs. 2nd ed., Burgess Publ. Co., Minneapolis, Minn. 324 pp.

7. Bartelli, L. J. 1975. Using soil surveys for delineating wetlands. *In* M. W. Lefor, H. H. Ridgeway, and T. B. Helfgott, eds., Proc. 2nd Wetlands Conference. Univ. Connecticut, Inst. Water Resources. Rept. No. 24, pp. 14-20, Univ. Connecticut, Storrs.

8. Beschel, R. E. and P. J. Webber. 1962. Gradient analysis in swamp forests. Nature 194:207-209.

9. Billings, W. D. 1952. The environmental complex in relation to plant growth and distribution. Quart. Review Biol. 27(3):251-264.

10. Brady, N. C. 1974. The Nature and Properties of Soils. 8th ed. MacMillan, New York. 639 pp.

11. Braun-Blanquet, J. 1932. Plant Sociology. McGraw-Hill, New York. 439 pp.

12. Bromley, S. W. 1935. The original forest types of southern New England. Ecol. Monogr. 5:61-89.

13. Brumbach, J. J. 1965. The Climate of Connecticut. State Geol. Nat. Hist. Surv. Connecticut. Bull. 99. 215 pp.

14. Cain, S. A. 1938. The species-area curve. Amer. Midl. Nat. 19:573-581.

15. Cain, S. A. and G. M. de Oliviera Castro. 1959. Manual of Vegetation Analysis. Harper and Brothers, New York. 319 pp.

16. Carter, V. and R. R. Anderson. 1972. Interpretation of wetland imagery based on spectral reflectance characteristics of selected plant species. *In* Proc. Amer. Soc. Photogram., 38th Ann. Meeting, Washington, D.C.

17. Carter, V. 1975. The use of remote sensing data in the management of inland wetlands. *In* M. W. Lefor, H. H. Ridgeway, and T. B. Helfgott, eds., Proc. 2nd Wetlands Conference. Univ. Connecticut, Inst. Water Resources, Rept. No. 24, pp. 31-50. Univ. Connecticut, Storrs.

18. Cartmill, R. H. 1973. Evaluation of remote sensing and automatic data techniques for characterization of wetlands. *In* 3rd Earth Resources Tech. Satellite-1 Symp., Goddard Space Flight Ctr., Washington, D.C.

19. Colwell, R. N. 1964. Aerial photography--a valuable sensor for the scientist. Amer. Scient. 52(1):17-49.

20. Colwell, R. N. 1967. Remote sensing as a means of determining ecological conditions. Bioscience 17(7):444-449.

21. Cowardin, L. M. and D. H. Johnson. 1973. A preliminary classification of wetland plant communities in north-central Minnesota. U.S.D.I., Fish Wildl. Serv., Specl. Scient. Rept. - Wildl. No. 168.

22. Cowardin, L. M. and V. T. Myers. 1974. Remote sensing for identification and classification of wetland vegetation. Journ. Wildl. Mgmnt. 38(2):308-314.

23. Cowardin, L. M. *et al.* 1976. Interim classification of wetlands and aquatic habitats of the U.S. *In* Proc. National Wetland Classification and Inventory Workshop. U.S.D.I., Fish Wildl. Serv., Pub. No. FWS/OBS-76/09. Addendum of 110 pp.

24. Dansereau, P. 1957. Biogeography: An Ecological Perspective. Ronald Press, New York. 394 pp.

25. Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper & Row, New York. 300 pp.

26. Day, P. R. 1965. Particle fractionation and particle-size analysis. Methods of Soil Analysis. C. A. Black, Ed., Part 1 - Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. pp. 545-567. Amer. Soc. Agron., Madison, Wisconsin.

27. Dixon, W. J. (ed.). 1975. Biomedical Computer Programs. Univ. California Press. Berkeley, California. 789 pp.

28. Fernald, M. L. 1950. Gray's Manual of Botany. 8th ed. Amer. Book Co., New York. 1632 pp.

29. Fisher, R. A. 1936. The use of multiple measurements in taxonomic problems. Anns. Eugenics 7:179-188.

30. Gardner, W. H. 1965. Water content. Methods of Soil Analysis. C. A. Black, ed., Part 1 - Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. p. 92. Amer. Soc. Agron., Madison, Wisconsin.

31. Gates, D. M. 1970. Physical and physiological properties of plants. *In* Remote Sensing: with Special Reference to Agr. and Forest. pp. 224-252. National Academy of Sciences, Washington, D.C.

32. Gates, F. C. 1949. Field Manual of Plant Ecology. McGraw-Hill Book Co., New York. 133 pp.

33. Golet, F. C. and J. S. Larson. 1974. Classification of freshwater wetlands in the glaciated northeast. U.S.D.I., Fish Wildl. Serv., Resource Publ. No. 116. 56 pp.

34. Grace, J. R. 1972. Vegetation--management of wetland forests of northeast Connecticut. Connecticut Dept. Envtl. Prot., Hartford, Connecticut. 42 pp.

35. Hefner, J. W., W. Brown, and F. J. Wobber. 1974. Aerial photography for coastal wetlands management. Photographic Applications 9(6):24, 25, 29-40.

36. Hill, D. E. 1973. Inland wetland soils. *In* T. B. Helfgott, M. W. Lefor, and W. C. Kennard, eds., Proc. 1st Wetlands Conference, Univ. Connecticut, Inst. Water Resources. Rept. No. 21, pp. 30-39. Univ. Connecticut, Storrs.

37. Hoffer, R. M. and C. J. Johnson. 1969. Ecological potentials in spectral signature analysis. *In* P. L. Johnson, ed., Remote Sensing in Ecology. pp. 1-16. Univ. Georgia, Athens, Georgia.

38. Hosner, J. F. and S. G. Boyce. 1962. Tolerance to water saturated soils of various bottomland hardwoods. Forest Sci. 8(2):180-186.

39. Kelley, A. P. 1923. Soil acidity, an ecological factor. Soil Sci. 16:41-54.

40. Kiefer, R. W. and J. P. Scherz. 1971. Aerial photography for water resources studies. Journ. Surv. Map. Div., ASCE, Vol. 97, NO. SU2, Paper 8545. pp. 321-333.

41. Kramer, P. J. 1951. Causes of injury to plants resulting from flooding of the soil. Pl. Physiol. 26:722-736.

42. Larson, J. S. 1975. Identification and delineation of freshwater wetland values. *In* M. W. Lefor, H. H. Ridgeway, and T. B. Helfgott, eds., Proc. 2nd Wetlands Conference. Univ. Connecticut, Inst. Water Resources. Rept. No. 24, pp. 1-10. Univ. Connecticut, Storrs.

43. Lindgren, D. T. 1971. Color infrared: a tool for environmental analysis. Project in Remote Sensing. Dept. Geogr. Dartmouth Coll., Hanover, New Hampshire.

44. Lukens, J. E. 1968. Color aerial photography for aquatic vegetation surveys. Remote Sensing Envt. 5:441-446.

45. Lutz, H. J. 1928. Trends and silvicultural significance of upland succession in southern New England. Yale Univ. Sch. Forest. Bull. 22. 68 pp.

46. MacConnell, W. P. and A. Mueller. 1973. Remote sensing: 20 years of change in Bristol County 1951-1971. Plann. Resource Devel. Ser. No. 24, Coll. Food Nat. Resources, Univ. Massachusetts, Amherst. 98 pp.

47. Mann, G. E. 1964. Improved techniques for aerial wetland surveys. Journ. Wildl. Mgmnt. 28(3):575-580.

48. Martin, A. C. *et al.* 1953. Classification of wetlands of the United States. Specl. Scient. Rept., Wildl. No. 20, U.S.D.I., Fish Wildl. Serv. 14 pp.

49. Mason, C. C. 1970. Color infrared photography from 60,000 feet altitude as a tool for delineating aquatic vegetation. *In* Proc. of the Symp. on Hydrobiology. Miami Beach, Florida. pp. 317-328.

50. McDermott, R. F. 1954. Effects of saturated soil on seedling growth of some bottomland hardwood species. Ecology 35:35-41.

51. Mitchell, J. 1932. The origin, nature, and importance of soil organic constituents having base exchange properties. Journ. Amer. Soc. Agron. 24:256-275.

52. Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, Toronto. 547 pp.

53. Nichols, G. E. 1915. The vegetation of Connecticut: IV - plant societies in lowlands, Bull. Torrey Bot. Cl. 42:169-217.

54. Nie, N. H. *et al* (eds.). 1975. SPSS: Statistical Package for the Social Sciences. McGraw-Hill, New York. 675 pp.

55. Olson, D. P. 1964. The use of aerial photographs in studies of marsh vegetation. Maine Agr. Exp. Sta., Ser. Bull. 13. 62 pp.

56. Oosting, H. J. 1956. The Study of Plant Communities. W. H. Freeman and Co., San Francisco. 440 pp.

57. Pandeya, S. C., G. S. Puri, and J. S. Singh. 1968. Research Methods in Plant Ecology. Asia Publ. House, New York. 272 pp.

58. Pearsall, W. H. 1952. The pH of natural soils and its ecological significance. Journ. Soil Sci. 3(1):41-51.

59. Peech, M. 1965. Hydrogen-ion activity. Methods of Soil Analysis. C. A. Black, ed., Part 2 - Chemical and Microbiological Properties. pp. 917-926. Amer. Soc. Agron., Madison, Wisconsin.

60. Phillips, J. 1970. Wisconsin's wetland soils: a review. Dept. Nat. Resources, Res. Rept. 57. Madison, Wisconsin. 22 pp.

61. Reimold, R. J. and R. A. Linthurst. 1974. Remote sensing - wetlands. Amer. Soc. Civil Engrg. Nat. Meet. Water Resources Engrg. 19 pp.

62. Richards, L. A. 1965. Physical condition of water in soil. Methods of Soil Analysis. C. A. Black, ed., Part 1 - Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. pp. 128-151. Amer. Soc. Agron., Madison, Wisconsin.

63. Rowe, J. S. 1956. Uses of undergrowth plant species in forestry. Ecology 37(3):461-473.

64. Sather, J. H. (ed.). 1976. Proc. National Wetland Classification and Inventory Workshop. U.S.D.I., Fish Wildl. Serv., Publ. No. FWS/OBS-76/09. 248 pp.

65. Schneider, W. J. 1968. Color photographs for water resources. Photogramm. Engin. 34(3):357-362.

66. Seher, J. S. and P. C. Tueller. 1973. Color aerial photos for marshland. Photogramm. Engin. 29(5):489-499.

67. Shaw, S. P. and G. C. Fredine. 1956. Wetlands of the United States. Circ. No. 39. U.S.D.I., Fish Wildl. Serv. 67 pp.

68. Shimwell, D. W. 1971. The Description and Classification of Vegetation. Univ. Washington Press, Seattle. 322 pp.

69. Snedecor, G. W. and W. G. Cochran. 1974. Statistical Methods. 6th ed., The Iowa State Univ. Press, Ames, Iowa. 593 pp.

70. State of Connecticut. Public Act No. 155. 1972. Chapter 440, Sec. 22a-36 to 22a-45. An Act Concerning Inland Wetlands and Water Courses.

71. State of Connecticut. Public Acts Nos. 571 (1973), 133 (1974), 387 (1975). (Amendments to Public Act No. 155).

72. State of Massachusetts. Chapter 131, General Laws 1974, Sec. 40. An Act Further Regulating the Protection of Wetlands.

73. State of New York. Article 24, Environmental Conservation Law 1975, Sec. 1-0101, Sec. 3-0301, Sec. 24-1301. Freshwater Wetlands Act.

74. State of Rhode Island. Chapter 213, Public Laws 1971. An Act Relating to Freshwater Wetlands.

75. Stewart, R. E. and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated Prairie Region. U.S.D.I., Fish Wildl. Serv., Res. Publc. No. 92.

76. Tansley, A. G. and T. F. Chipp. 1926. Aims and Methods in the Study of Vegetation. Brit. Empire Veg. Comm., Whitefriars Press, London. 383 pp.

77. United States Department of Agriculture, Soil Conservation Service, 1966. Soil Survey, Tolland County, Connecticut.

78. United States Department of Agriculture, Soil Conservation Service, 1970. Natural Soil Groups Map, Town of Mansfield, Tolland County, Connecticut.

79. Westveld, M. and Committee on Silviculture, New England Sec., Soc. Amer. Forest. 1956. Natural Forest Vegetation Zones of New England. Journ. Forest. 54:332-339.

80. Whittaker, R. H. 1967. Gradient analysis of vegetation. Biol. Review. 42:207-264.

81. Wilde, S. A. 1954. Reaction of soils: facts and fallacies. Ecology 35(1):89-92.

82. Wilde, S. A. 1954. Floristic analysis of ground cover vegetation by a rapid chain method. Journ. Forest. 52: 499-502.

83. Wilson, H. L. and E. V. Berard. 1952. The use of aerial photographs and ecological principles in cover type mapping. Journ. Wildl. Mgmnt. 16:320-326.

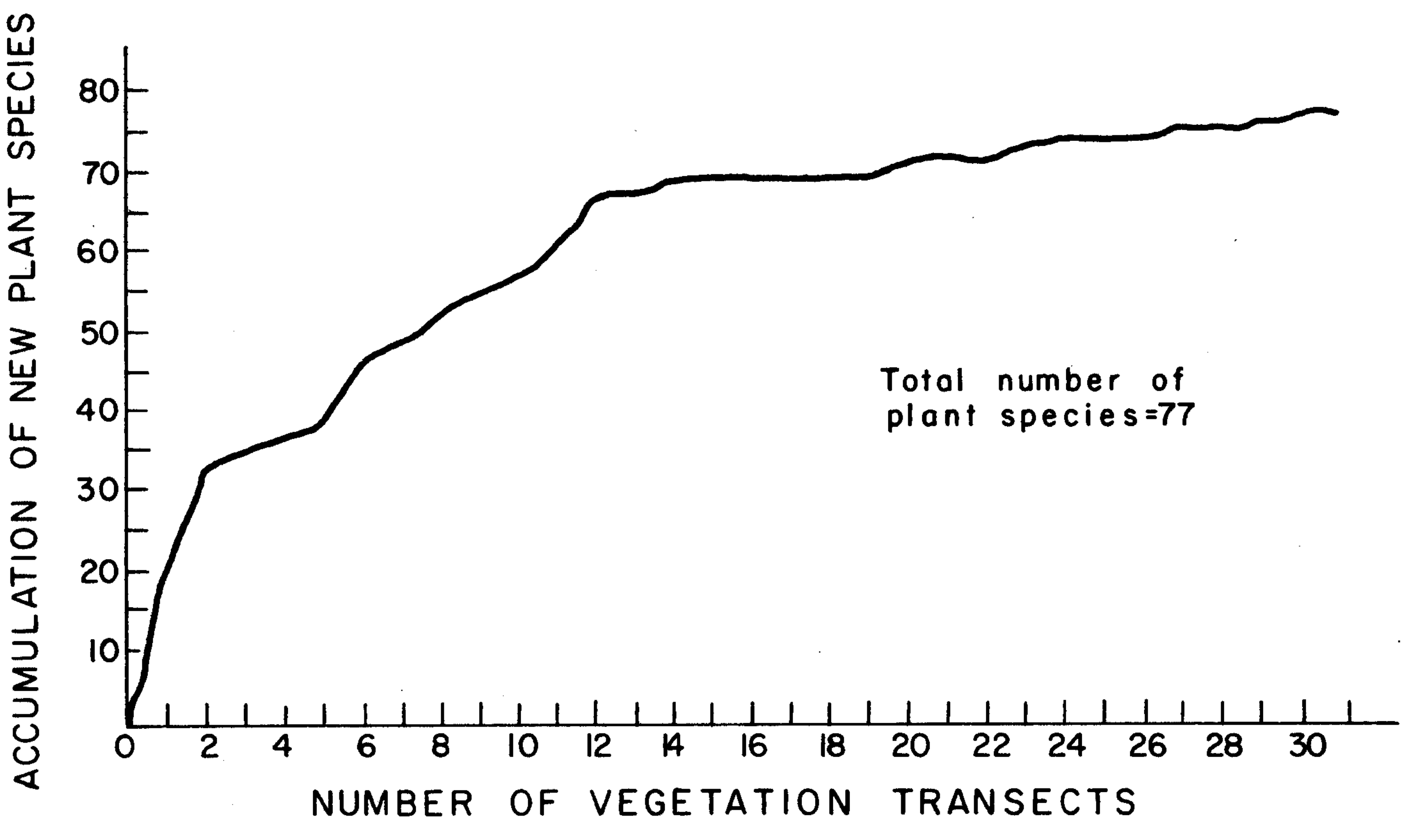
84. Yost, E. and S. Wenderoth. 1969. Ecological applications of multi-spectral color aerial photography. *In* P. L. Johnson, ed., Remote Sensing in Ecology. pp. 46-62. Univ. Georgia, Athens, Georgia.

85. Young, C. E., Jr. 1969. Water table, soil moisture, and oxygen diffusion relationships on two drained wetland forest sites. Soil Sci. 107(1):220-222.

86. Zoltai, S. C. *et al.* 1975. Developing a wetland classification for Canada. Proc. North Amer. Forest Soils Conf. 4:497-511.

APPENDIX A

Plant Species - Transect Curve



APPENDIX B

Plant Species Encountered
Listed Alphabetically by Scientific Name

	Scientific Name	Common Name
1.	*Acer rubrum* L.	Red Maple
2.	*Acer saccharum* Marsh.	Sugar Maple
3.	*Actaea pachypoda* Ell.	White Baneberry
4.	*Amelanchier laevis* Wieg.	Shadbush
5.	*Amphicarpa bracteata* (L.) Fern.	Hog-Peanut
6.	*Aralia nudicaulis* L.	Wild Sarsaparilla
7.	*Arisaema triphyllum* (L.) Schott	Small Jack-In-The-Pulpit
8.	*Athyrium Filix-femina* (L.) Roth	Lady Fern
9.	*Betula alleghaniensis* Britt.	Yellow Birch
10.	*Betula lenta* L.	Black Birch
11.	*Betula populifolia* Marsh.	Gray Birch
12.	*Carex pensylvanica* Lam.	Sedge
13.	*Carex stricta* Lam.	Tussock Sedge
14.	*Carpinus caroliniana* Walt.	American Hornbeam
15.	*Carya cordiformis* K. Koch	Bitternut Hickory
16.	*Carya ovata* K. Koch	Shagbark Hickory
17.	*Castanea dentata* (Marsh.) Borkh.	American Chestnut
18.	*Clethra alnifolia* L.	Sweet Pepperbush
19.	*Coptis groenlandica* (Oeder) Fern.	Goldthread
20.	*Cornus florida* L.	Flowering Dogwood
21.	*Corylus cornuta* Marsh.	Beaked Hazelnut
22.	*Dennstaedtia punctilobula* (Michx.) Moore	Hay-Scented Fern
23.	*Dryopteris noveboracensis* (L.) Gray	New York Fern
24.	*Dryopteris thelypteris* (L.) Gray	Marsh Fern
25.	*Fagus grandifolia* Ehrh.	American Beech
26.	*Fraxinus americana* L.	White Ash
27.	*Gaylussacia baccata* (Wang.) K. Koch	Black Huckleberry
28.	*Hamamelis virginiana* L.	Witch-Hazel
29.	*Ilex verticillata* (L.) Gray	Black Alder
30.	*Kalmia angustifolia* L.	Sheep-Laurel
31.	*Kalmia latifolia* L.	Mountain Laurel
32.	*Leersia virginica* Willd.	Cutgrass
33.	*Leucobryum glaucum* Schimp.	Moss
34.	*Lindera benzoin* (L.) Blume	Spicebush
35.	*Lycopodium complanatum* L.	Ground-Cedar
36.	*Lycopodium lucidulum* Michx.	Shining Club Moss
37.	*Lycopodium obscurum* L.	Ground-Pine
38.	*Lyonia ligustrina* (L.) DC.	Maleberry
39.	*Maianthemum canadense* Desf.	Canada May Flower
40.	*Medeola virginiana* L.	Indian Cucumber-Root
41.	*Mitchella repens* L.	Partridge-Berry
42.	*Monotropa uniflora* L.	Indian Pipes
43.	*Nyssa sylvatica* Marsh.	Sour Gum
44.	*Onoclea sensibilis* L.	Sensitive Fern
45.	*Osmunda cinnamomea* L.	Cinnamon Fern

APPENDIX B (cont.)

	Scientific Name	Common Name
46.	*Osmunda regalis* L.	Royal Fern
47.	*Panax trifolius* L.	Ginseng
48.	*Parthenocissus quinquefolia* (L.) Planch.	Virginia Creeper
49.	*Pinus strobus* L.	White Pine
50.	*Polygonatum canaliculatum* (Muhl.) Pursh	Solomon's-Seal
51.	*Polystichum acrostichoides* (Michx.) Schott	Christmas Fern
52.	*Prunus pensylvanica* L.*f.*	Pin Cherry
53.	*Prunus serotina* Ehrh.	Black Cherry
54.	*Pyrola rotundifolia* L.	Wild Lily-Of-The-Valley
55.	*Quercus alba* L.	White Oak
56.	*Quercus bicolor* Willd.	Swamp White Oak
57.	*Quercus borealis* Ashe	Red Oak
58.	*Rhododendron viscosum* (L.) Torr.	Clammy Azalea
59.	*Ribes triste* Pall.	Red Currant
60.	*Rosa rugosa* Thunb.	Rose
61.	*Rubus hispidus* L.	Trailing Swamp Blackberry
62.	*Rubus* spp.	Bramble
63.	*Sassafras albidum* (Nutt.) Nees	White Sassafras
64.	*Smilax herbacea* L.	Carrion-Flower
65.	*Solidago* sp.	Goldenrod
66.	*Sphagnum* spp.	Peat Moss
67.	*Symplocarpus foetidus* (L.) Nutt.	Skunk Cabbage
68.	*Thuidium delicatulum* Mitt.	Moss
69.	*Trientalis borealis* Raf.	Star-Flower
70.	*Trillium erectum* L.	Purple Trillium
71.	*Ulmus americana* L.	American Elm
72.	*Ulmus rubra* Muhl.	Slippery Elm
73.	*Vaccinium angustifolium* Ait.	Low Sweet Blueberry
74.	*Vaccinium corymbosum* L.	Highbush Blueberry
75.	*Viburnum acerifolium* L.	Maple-Leaved Viburnum
76.	*Viburnum lentago* L.	Sweet Viburnum
77.	*Viola* sp.	Violet

APPENDIX C

Plant Species Encountered
Listed Alphabetically by Common Name

	Common Name	Scientific Name
1.	Alder, Black	*Ilex verticillata* (L.) Gray
2.	American Beech	*Fagus grandifolia* Ehrh.
3.	American Chestnut	*Castanea dentata* (Marsh.) Borkh.
4.	American Elm	*Ulmus americana* L.
5.	American Hornbeam	*Carpinus caroliniana* Walt.
6.	Ash, White	*Fraxinus americana* L.
7.	Azalea, Clammy	*Rhododendron viscosum* (L.) Torr.
8.	Baneberry, White	*Actaea pachypoda* Ell.
9.	Beaked Hazelnut	*Corylus cornuta* Marsh.
10.	Beech, American	*Fagus grandifolia* Ehrh.
11.	Birch, Black	*Betula lenta* L.
12.	Birch, Gray	*Betula populifolia* Marsh.
13.	Birch, Yellow	*Betula alleghaniensis* Britt.
14.	Bitternut Hickory	*Carya cordiformis* K. Koch
15.	Blackberry, Trailing Swamp	*Rubus hispidus* L.
16.	Black Alder	*Ilex verticillata* (L.) Gray
17.	Black Birch	*Betula lenta* L.
18.	Black Cherry	*Prunus serotina* Ehrh.
19.	Black Huckleberry	*Gaylussacia baccata* (Wang.) K. Koch
20.	Blueberry, Highbush	*Vaccinium corymbosum* L.
21.	Blueberry, Lowbush	*Vaccinium angustifolium* Ait.
22.	Bramble	*Rubus* spp.
23.	Canada May Flower	*Maianthemum canadense* Desf.
24.	Carrion Flower	*Smilax herbacea* L.
25.	Cherry, Black	*Prunus serotina* Ehrh.
26.	Cherry, Pin	*Prunus pensylvanica* L.*f*.
27.	Chestnut, American	*Castanea dentata* (Marsh.) Borkh.
28.	Christmas Fern	*Polystichum acrostichoides* (Michx.) Schott
29.	Cinnamon Fern	*Osmunda cinnamomea* L.
30.	Clammy Azalea	*Rhododendron viscosum* (L.) Torr.
31.	Cutgrass	*Leersia virginica* Willd.
32.	Dogwood, Flowering	*Cornus florida* L.
33.	Elm, American	*Ulmus americana* L.
34.	Elm, Slippery	*Ulmus rubra* Muhl.
35.	Fern, Christmas	*Polystichum acrostichoides* (Michx.) Schott
36.	Fern, Cinnamon	*Osmunda cinnamomea* L.
37.	Fern, Hay-Scented	*Dennstaedtia punctilobula* (Michx.) Moore
38.	Fern, Lady	*Athyrium Filix-femina* (L.) Roth
39.	Fern, Marsh	*Dryopteris thelypteris* (L.) Gray
40.	Fern, New York	*Dryopteris noveboracensis* (L.) Gray
41.	Fern, Royal	*Osmunda regalis* L.
42.	Fern, Sensitive	*Onoclea sensibilis* L.
43.	Flowering Dogwood	*Cornus florida* L.
44.	Ginseng	*Panax trifolius* L.
45.	Goldenrod	*Solidago* sp.
46.	Goldthread	*Coptis groenlandica* (Oeder) Fern.

APPENDIX C (cont.)

	Common Name	Scientific Name
47.	Gray Birch	*Betula populifolia* Marsh.
48.	Ground-Cedar	*Lycopodium complanatum* L.
49.	Ground-Pine	*Lycopodium obscurum* L.
50.	Hay-Scented Fern	*Dennstaedtia punctilobula* (Michx.) Moore
51.	Hazelnut, Beaked	*Corylus cornuta* Marsh.
52.	Hickory, Bitternut	*Carya cordiformis* K. Koch
53.	Hickory, Shagbark	*Carya ovata* K. Koch
54.	Highbush Blueberry	*Vaccinium corymbosum* L.
55.	Hog-Peanut	*Amphicarpa bracteata* (L.) Fern.
56.	Hornbeam, American	*Carpinus caroliniana* Walt.
57.	Huckleberry, Black	*Gaylussacia baccata* (Wang.) K. Koch
58.	Indian Cucumber-Root	*Medeola virginiana* L.
59.	Indian Pipes	*Monotropa uniflora* L.
60.	Lady Fern	*Athyrium Filix-femina* (L.) Roth
61.	Laurel, Mountain	*Kalmia latifolia* L.
62.	Laurel, Sheep	*Kalmia angustifolia* L.
63.	Low Sweet Blueberry	*Vaccinium angustifolium* Ait.
64.	Maleberry	*Lyonia ligustrina* (L.) DC
65.	Maple-Leaved Viburnum	*Viburnum acerfolium* L.
66.	Maple, Red	*Acer rubrum* L.
67.	Maple, Sugar	*Acer saccharum* Marsh.
68.	Marsh Fern	*Dryopteris thelypteris* (L.) Gray
69.	Moss	*Leucobryum glaucum* Schimp.
70.	Moss	*Thuidium delicatulum* Mitt.
71.	Mountain Laurel	*Kalmia latifolia* L.
72.	New York Fern	*Dryopteris noveboracensis* (L.) Gray
73.	Oak, Red	*Quercus borealis* Ashe
74.	Oak, Swamp White	*Quercus bicolor* Willd.
75.	Oak, White	*Quercus alba* L.
76.	Partridge-Berry	*Mitchella repens* L.
77.	Peat Moss	*Sphagnum* spp.
78.	Pin Cherry	*Prunus pensylvanica* L.*f.*
79.	Pine, White	*Pinus strobus* L.
80.	Purple Trillium	*Trillium erectum* L.
81.	Red Maple	*Acer rubrum* L.
82.	Red Oak	*Quercus borealis* Ashe
83.	Rose, Beach	*Rosa rugosa* Thunb.
84.	Royal Fern	*Osmunda regalis* L.
85.	Sassafras, White	*Sassafras albidum* (Nutt.) Nees
86.	Sedge	*Carex pensylvanica* Lam.
87.	Sedge, Tussock	*Carex stricta* Lam.
88.	Sensitive Fern	*Onoclea sensibilis* L.
89.	Shadbush	*Amelanchier laevis* Wieg.
90.	Shagbark Hickory	*Carya ovata* K. Koch
91.	Sheep-Laurel	*Kalmia angustifolia* L.

APPENDIX C (cont.)

	Common Name	Scientific Name
92.	Shining Club Moss	*Lycopodium lucidulum* Michx.
93.	Skunk Cabbage	*Symplocarpus foetidus* (L.) Nutt.
94.	Slippery Elm	*Ulmus rubra* Muhl.
95.	Small Jack-in-the-Pulpit	*Arisaema triphyllum* (L.) Schott
96.	Solomon's-Seal	*Polygonatum canaliculatum* (Muhl.) Pursh
97.	Sour Gum	*Nyssa sylvatica* Marsh
98.	Spicebush	*Lindera benzoin* (L.) Blume
99.	Star-Flower	*Trientalis borealis* Raf.
100.	Sugar Maple	*Acer saccharum* Marsh.
101.	Swamp White Oak	*Quercus bicolor* Willd.
102.	Sweet Pepperbush	*Clethra alnifolia* L.
103.	Sweet Viburnum	*Viburnum lentago* L.
104.	Trailing Swamp Blackberry	*Rubus hispidus* L.
105.	Trillium, Purple	*Trillium erectum* L.
106.	Tussock, Sedge	*Carex stricta* Lam.
107.	White Ash	*Fraxinus americana* L.
108.	White Baneberry	*Actaea pachypoda* Ell.
109.	White Oak	*Quercus alba* L.
110.	White Pine	*Pinus strobus* L.
111.	White Sassafras	*Sassafras albidum* (Nutt.) Nees
112.	Wild Lily-of-the-Valley	*Pyrola rotundifolia* L.
113.	Wild Sarsaparilla	*Aralia nudicaulis* L.
114.	Winterberry	*Ilex verticillata* (L.) Gray
115.	Witch-Hazel	*Hamamelis virginiana* L.
116.	Viburnum, Maple-Leaved	*Viburnum acerfolium* L.
117.	Viburnum, Sweet	*Viburnum lentago* L.
118.	Violet	*Viola* sp.
119.	Virginia Creeper	*Parthenocissus quinquefolia* (L.) Planch.
120.	Yellow Birch	*Betula alleghaniensis* Britt.

TABLE 16: Tabular Classification of Vegetation.

TABLE 16: Tabular Classification of Vegetation.