FINAL REPORT

Use of Vegetation in the Designation of Wetlands

by

Thomas R. Wentworth and George P. Johnson
Department of Botany, Box 7612
North Carolina State University
Raleigh, NC 27695-7612

FINAL REPORT

Use of Vegetation in the Designation of Wetlands

by

Thomas R. Wentworth and George P. Johnson
Department of Botany, Box 7612
North Carolina State University
Raleigh, NC 27695-7612

Administrator: Department of the Interior
U.S. Fish and Wildlife Service
Division of Contracting and General Services
18th and C Streets, NW
Washington, DC

Cooperator: N.C. Agricultural Research Service
N.C. State University
School of Agriculture and Life Sciences
Box 7601
Raleigh, NC 27695-7601

Revised Draft

September 15, 1986

TABLE OF CONTENTS

ABSTRACT

Biological indicators have proven effective in environmental assessment; an example is the use of invertebrates in the determination of water quality. Vegetation is widely recognized as one of three key site characteristics (including soils and hydrology) that may be used in the designation of wetlands. Since vegetation is often the most accessible of these characteristics, its use in wetland designation should be encouraged in appropriate situations. There is, however, no consensus regarding methods which will yield the most efficient, objective and consistent wetland designations from vegetation data.

Our research has focused on information regarding the wetland indicator status of plants provided in the National Wetland Plant Species List (NWPSL), which classifies all vascular plants of the United States according to their natural frequency of occurrence in wetlands. Ecological groups recognized in the NWPSL are: obligate wetland, facultative wetland, facultative, facultative upland and (by exclusion from the list) obligate upland. Ecological indices were assigned to these groups and used to compute weighted averages (WA) for quantitative data (such as plant cover) obtained from four studies of wetland vegetation conducted in various regions of the United States. These included Currier's (1981) study of floodplain vegetation of the Platte and North Platte Rivers, Nebraska; Kologiski's (1977) study of the Green Swamp in southeastern North Carolina; Lee's (1983) study of floodplain vegetation of the Flathead River, Montana, and the Suiattle River, Washington; and Mohler's (1979)

study of floodplain vegetation of the lower Neches River (Big Thicket), southeast Texas.

Weighted averages of vegetation data proved to be an effective tool for assessing wetland status of the vegetation types included in our study. We base this conclusion on two findings: (1) WA effectively ranked vegetation types or stands in a way that was well correlated with independently-derived rankings for the same types or stands relative to environmental moisture gradients (based on personal experience, multivariate analysis of vegetation data and environmental parameters); and (2) the results of WA could be used, together with a provisional "breakpoint," to designate vegetation types as wetlands or uplands in a way that agreed well with designations based on other criteria.

Variation of weighted averages among the sample units representing a vegetation type was generally small relative to the range of ecological indices assigned. Our studies of within-type variation led to guidelines regarding the reliability of wetland designations. We also explored various ways of transforming the vegetation data (such as increasing the weighting of obligate wetland and obligate upland species), but found that these had little beneficial effect on the quality of wetland designations. Another approach, in which unweighted averages of ecological indices (INAV) were calculated for all vegetation data, provided wetland designations that were in close agreement with those of WA. Unweighted averages may be preferable to WA for routine wetland designations, because they perform well and eliminate the need to collect quantitative data.

PREFACE

In August, 1985, Dr. Russell Kologiski came to North Carolina State University to work on a methodology for the designation of wetlands using vegetation data. His experience with the National Wetlands Inventory and his work in compiling the National Wetland Plant Species List (NWPSL) had convinced him that the development of such a methodology was both timely and feasible. His committment to this project was based on two premises: 1) there was a growing need in the United States for an efficient, objective and consistent means of designating wetlands based on vegetation data; and 2) the NWPSL, then nearing completion, provided the necessary information about wetland plants for development of a methodology.

The work started at NCSU by Dr. Kologiski was funded by a work order from the U.S. Fish and Wildlife Service to Drs. Seneca and Wentworth, both of the Department of Botany, who agreed to act as consultants. When Dr. Kologiski withdrew from the project, work was continued primarily by Dr. Wentworth and the project's technical assistant, Dr. George Johnson. The present report is a summary of the research conducted by Drs. Wentworth and Johnson through June, 1986. They take credit for the accomplishments of the project and responsibility for any errors or inaccuracies that may exist.

The work presented in this report could not have been accomplished without the assistance of many individuals. We are particularly indebted to R.L. Kologiski, J.H. Montanari, E.D. Seneca and W. Wilen for their frequent contributions. Four

individuals, J.P. Currier, R.L. Kologiski, L.C. Lee and C.L. Mohler, graciously provided original data and guidance. The success of the project was dependent on the contributions of these individuals. At various times we benefited from consultation with or assistance from many other individuals. We thank the following for their contributions: G. Auble, F. Booker, S.W. Broome, J. Bruton, K.P. Burnham, L.M. Cowardin, T. Dahl, J. Hefner, M.T. Huish, L.S. Ischinger, L. Jernigan, J.B. Kimberly, J.H.H. Looney, R. Nyc, D.L. Oakley, B. Parker, R.K. Peet, R. Pywell, A.E. Radford, P.B. Reed, D. Sanders, W.S. Sipple, B.M. Teels and C. Thomas.

INTRODUCTION

Statement of Problem

Vegetation is widely recognized as one of three key site characteristics (including soils and hydrology) that can be used in the designation of wetlands. Since vegetation is often the most accessible of these characteristics, its use in wetland designation should be encouraged in appropriate situations. However, there is presently no consensus regarding methods which will yield the most efficient, objective and consistent wetland designations from vegetation data.

A recent development that may enhance the usefulness of vegetation data in wetland designation is the National Wetland Plant Species List (NWPSL), prepared by the Fish and Wildlife Service (Reed, 1986). The NWPSL classifies all vascular plant species found in the United States and Puerto Rico according to frequency of occurrence in wetlands, thus providing a tool for defining wetlands based on floristic or vegetation data. The problem addressed by our research was how to integrate such data with the NWPSL in such a way that a determination of wetland status might be obtained. We also addressed the equally important problem of how to recognize when the wetland designation of a site by means of vegetation data might be considered unreliable, to the extent that further data (regarding soils and hydrology) would be necessary for a reliable designation.

This report summarizes work completed in the investigation of the problems presented above. We outline the rationale for

selection of methods, discuss the methods selected for study, describe our approach and methods, present results and discuss our findings. We conclude with a consideration of future directions for our research.

Justification

Designation or recognition of areas characterized as "wetlands" is an important activity that has received increasing attention from the various Federal agencies responsible for regulation and management of such areas. These agencies include the Army Corps of Engineers, the Environmental Protection Agency, the Soil Conservation Service, and the Fish and Wildlife Service. Each of these agencies has made progress toward the development of objective criteria that can be consistently applied to the problem of designation of North American wetlands. At the present time, however, there is no single methodology used for designating wetlands throughout the United States. Although such a methodology may be impossible to achieve in practice, any progress toward this end will help to alleviate confusion and disagreements (often resulting in lengthy and expensive litigation), when wetland designation is mandated by Federal regulations.

Any means of determining whether or not a particular site is a wetland should combine both simplicity and accuracy. Although the Federal regulatory definition of wetlands recognizes three parameters (vegetation, soils, and hydrology), it may be possible in some cases to designate wetlands using vegetation alone (Sipple, 1985). We emphasized vegetation in our research because

it is likely to be the most accessible of these features to the field worker. We perceive a clear need for a means of wetland designation that: 1) relies first on vegetation criteria; 2) has graduated requirements for increasingly quantitative (and consequently more costly) data and methods as the problems in a particular area become increasingly demanding and complex; and 3) provides for recognition of situations where use of vegetation for wetland designation is impossible or inappropriate and where other data (i.e., soils and/or hydrology) will be needed.

Current Status of Wetland Designation by U.S. Federal Agencies

The research presented in this report complements work conducted by, or on behalf of, four federal agencies; each of these has developed a methodology for classification of wetlands or has contributed information essential to that task.

U.S. Army Corps of Engineers (CE). The most detailed approach to delineation of wetlands is that taken by the U.S. Army Corps of Engineers. In the Clean Water Act of 1977, the U.S. Congress authorized the Secretary of the Army, acting through the Chief of Engineers, to regulate the discharge of dredged or fill material into the waters of the United States (Sanders *et al.*, 1985). Because "waters of the United States" is a broad term including wetlands, regulatory personnel of CE have needed guidelines for recognizing whether a particular site is or is not a wetland. These guidelines are embodied in the "Wetlands Delineation Manual" (Sanders *et al.*, 1985), which takes a multiparameter approach to the designation of wetlands. This approach requires that positive wetland indicators for hydrology,

soil and vegetation be present for designation of a particular site as a wetland, and provides detailed instructions for determining these. Positive indicators of wetland vegetation include: (1) dominant species included on wetland plant species lists; (2) morphological adaptations such as buttressed tree trunks, pneumataphores, adventitious roots, shallow root systems, inflated stems, leaves or roots, polymorphic leaves, floating leaves and floating stems; (3) species with physiological adaptations for occurrence in anaerobic soil conditions; (4) visual observation of plant species growing in areas of prolonged inundation and/or soil saturation; (5) reproductive adaptations, such as prolonged seed viability, seed germination under low oxygen conditions, and flood-tolerant seedlings; and (6) technical literature, such as taxonomic references, botanical journals, technical reports, workshops, conferences, and symposia, and wetland plant data bases.

U.S. Environmental Protection Agency (EPA). EPA is also charged with regulating activities which affect wetlands, and has provided its field personnel with guidelines for wetland identification and delineation (Sipple, 1985). The EPA guidelines recognize the importance of hydrology, soil and vegetation in the designation of wetlands. However, EPA departs from CE procedures in using vegetation as the primary criterion, and in recognizing two situations in which wetland designation can be based upon vegetation only: (1) one or more obligate wetland species occur as community dominants (i.e., having $\geq$10% areal cover, or $\geq$10% basal area) in the absence of dominants that are obligate upland species; or (2) one or more obligate wetland

species occur as community dominants with other dominants that are obligate upland species, but either (a) the obligate upland species are restricted to areas having higher microrelief or (b) the obligate upland species are mixed with the obligate wetland species but have less than 50% of the total cover contributed by dominant obligate species (both wetland and upland). The EPA guidelines also recognize situations in which additional data on soils and hydrology will be required for designation (Sipple, 1985).

U.S. Soil Conservation Service (SCS) Many problems in wetland designation ultimately require consideration of soil characteristics for their resolution. The Soil Conservation Service has recently published a list of hydric soils of the United States (SCS, 1985) to be used as an aid in such situations. According to SCS (1985), "A hydric soil is a soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation." By identifying the soil(s) on a site to series, an investigator can determine whether or not the soil(s) is(are) hydric in nature. In the CE delineation method (Sanders et al., 1985) determination of a hydric soil condition is always a prerequisite for designating a site as a wetland. The EPA guidelines for wetland identification and delineation (Sipple, 1985) also require that information on soils be used as a supplement to vegetation data in certain situations.

U.S. Fish and Wildlife Service (**FWS**). FWS has had a long-

standing interest in wetland classification and delineation. An early classification was published as U.S. Fish and Wildlife Circular 39 (Shaw and Fredine, 1956), and this was recently superceded by Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al., 1979). The ongoing National Wetlands Inventory, conducted by FWS, (Montanari and Townsend, 1977) "will provide basic data on the characteristics and extent of the Nation's wetlands and deepwater habitats and should facilitate the management of these areas on a sound, multiple-use basis" (Cowardin et al., 1979). FWS has also been responsible for preparing the National Wetland Plant Species List, presently available in a separate listing for each of the 50 states (Reed, 1986).

In conjunction with its compilation of the NWPSL, FWS has supported research on the use of vegetation data in the designation of wetlands. Michener (1983) developed a wetland site index to be used with vegetation data, selecting an average of wetland category values (obligate wetland species = 1.00, facultative wetland species = 0.82, etc.) weighted by species abundance.

Recent legislative developments have placed additional emphasis on FWS efforts to develop methods for recognizing wetlands based on vegetation data. In particular, the 1985 Farm Bill contained a provision, referred to as "swampbuster", which denies the benefits of Federal Farm programs (price supports, loans, etc.) to "any person who in any crop year produces an agricultural commodity on converted wetland" (H.R. 2100-154, 1985). The definition of wetland used in this legislation is as

follows (H.R. 2100-152, 1985):

> **The term "wetland", except when such term is part of the term "converted wetland", means land that has a predominance of hydric soils and that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions.**

Our research has been supported by FWS to help that agency in its efforts to address the problem of identifying hydrophytic vegetation, as required for implementation of the "swampbuster" provision and for other FWS activities.

Objectives

The research described herein was designed to explore the potential for using vegetation in wetland designation, with emphasis on information available in the NWPSL. Specific objectives were:

(1) to examine existing methods which offer some potential for using vegetation in the designation of wetlands; these included:

  (a) determining the presence of wetland indicators in species lists for sites to be designated; and

  (b) averaging of quantitative data for species present, weighted by wetland indicator values of those species.

(2) to test the suitability of the above-mentioned methods, using vegetation data from studies in which relationships of vegetation to environmental moisture gradients were known and in which wetland designations existed;

(3) to determine the likelihood of correct or incorrect designation of wetland status by the above-mentioned methods; and

(4) to consider the effects of disturbance and heterogeneous environments on the performance of the above-mentioned methods.

Rationale for Selection and Evaluation of Methods

Effective wetland designation procedures must employ methods which are efficient, objective and consistent. In selecting methods for preliminary tests, we looked for the following attributes:

(1) method(s) should use the information contained in the NWPSL;

(2) method(s) should be reasonably simple and straightforward, both to make them comprehensible to users and to minimize reliance on sophisticated software or hardware for computation;

(3) method(s) should be quantitative, providing a numerical index which can be referred to established criteria for determination of wetland status;

(4) method(s) should be flexible enough to accommodate various types of data and to permit changes necessitated by modification of the NWPSL or other wetland designation criteria;

(5) method(s) should perform well throughout the geographic range of their application;

(6) method(s) should be as objective and consistent as possible, providing the same results regardless of user experience or bias; and

(7) method(s) should provide a means of evaluating the reliability of any wetland designation, preferably as a statement regarding probability of error.

These criteria appear best met by methods referred to in this report as "index averages" and "weighted averages", discussed in the following section. We were aware of considerable work using these methods in ecological studies as well as preliminary tests of weighted averages by Michener (1983) for wetland designation.

Weighted Averages and Index Averages

Whittaker (1978) summarized the development and use of weighted averages as a method in plant ecology. The method is used to generate a direct gradient analysis, which is essentially an ordering of community sample-units (stands, plots, etc.) "in terms of one or more environmental gradients accepted as given" (Whittaker, 1978). Application of the method in plant ecology dates back to work of Ellenberg (1948), Whittaker (1951), Curtis and McIntosh (1951), and others (e.g., Dyksterhuis, 1948) who independently began using the method in the late 1940's and early 1950's.

Calculation of weighted averages begins with the classification of all species encountered in a given study into "ecological groups" (Whittaker, 1978). These ecological groups combine species that have similar responses to the particular environmental gradient chosen for study. The basis for classification of the species may be extensive field observations or ecological sampling along transects representing the environmental gradient. Each species in a given ecological group is then assigned the same value of an "ecological index", with the ecological indices chosen so that they rank or order the ecological groups according to their relative positions on the environmental gradient. In the case of the NWPSL, the various categories (obligate, facultative wetland, etc.) define ecological groups which have an obvious ranking on an environmental gradient from wetlands to uplands.

Actual calculation of weighted averages involves taking the sum of products of ecological indices and importance values for

all species in a given stand or plot, and dividing this by the sum of all importance values. The algorithm is presented below:

$$w_j = \frac{\sum_{i=1}^{p} I_{ij}E_i}{\sum_{i=1}^{p} I_{ij}}$$

NB: "S" refers to summation from i=1 to p.

where: w_j = weighted average for stand j
I_{ij} = importance value for species i in stand j
E_i = ecological index for species i
p = the number of species occurring in the stand

The "importance values" used in the calculation of a weighted average may represent any quantitative measure of abundance, such as cover, frequency, density, basal area, etc. In the limiting case where only presence-absence data are available, weighting by importance values is no longer possible, and unweighted averages of the ecological indices of all species present in a stand may be used. We have used the term "index averages" in this report to refer to the unweighted averages of ecological indices. In any case, the range of possible weighted or unweighted averages that may be obtained is the same as the range of values used in the assignment of ecological indices to the respective categories.

Use of Weighted or Index Averages in Other Applied Contexts

Weighted averages have proven to be a useful tool in direct gradient analysis of vegetation data for basic research. Their utility in applied situations is also evident. As an example, we

consider the need for biotic indices of aquatic pollution. One parameter of water quality is the biological oxygen demand, or BOD. BOD can be determined by laboratory incubation, but such determination requires appropriate facilities and lengthy incubation of samples. As discussed below, biological assessment of BOD provides an attractive alternative to chemical analysis.

It has long been recognized that aquatic organisms differ in their environmental requirements relative to BOD, and that the presence and abundance of various organisms can provide an indication of the BOD in a particular body of water. Sladecek (1979) has reviewed continental systems for biological assessment of water quality. Of particular interest is his discussion of the saprobic index, developed initially by Pantle and Buck in 1955. This index is simply a weighted average of ecological indices (called saprobic indices in this application) which range from 0 (xenosaprobity) to 8 (ultrasaprobity) on a 9-point scale. In calculating the saprobic index, a sample of water or sediment is collected and the organisms present are identified to species and assigned an abundance rating according to a scale of estimation. Consultation of available lists (e.g., Sladecek, 1973, 1976) allows for determination of the saprobic indices of the species. Several studies (e.g., Sladecek and Tucek, 1975) have validated the relationship between the saprobic index and laboratory values for BOD. The utility of the method has resulted in its adoption as the most commonly used procedure for biological indication of BOD in Central and Eastern Europe (Sladecek, 1979). A related approach, which uses unweighted averages of saprobic indices, is discussed by Dresscher and van

der Mark (1976). We anticipate that biological indicators of wetland status will find equal utility and acceptance in the United States.

METHODS

Selection of Data Sets

We determined that preliminary evaluation of potential methodologies for designating wetlands would require 4 data sets, available either as published reports or dissertations. Criteria for selection of these data sets were developed and included:

(1) representation of a variety of geographic regions within the United States;

(2) availability of quantitative measures of vegetation and characterization of the environments studied;

(3) classification of vegetation into types or other units;

(4) multiple sample units representing each vegetation type;

(5) sampling of vegetation from a wide range of environmental moisture conditions, preferably on a gradient spanning sites clearly supporting wetland vegetation to sites clearly supporting upland vegetation; and

(6) some indication of the relationship of each vegetation type to the prevailing environmental moisture gradient, either through wetland designation for each type or a ranking of types relative to the moisture gradient.

Data sets satisfying the above criteria were located. These were all Ph.D. dissertations, and included Currier's (1981) study of floodplain vegetation of the Platte and North Platte Rivers, Nebraska, Kologiski's (1977) study of the Green Swamp in southeastern North Carolina, Mohler's (1979) study of floodplain vegetation of the lower Neches River (Big Thicket), southeast Texas, and Lee's (1983) study of floodplain vegetation of the Flathead River, Montana, and the Suiattle River, Washington.

Capsule Descriptions of the Data Sets

Platte and North Platte Rivers. In a study of the floodplain vegetation of the Platte and North Platte Rivers, Nebraska, Currier (1981) recognized 4 broad vegetation classes (mudflat, meadow, shrub, forest) based on canopy height. Within these classes, he designated 22 plant community (vegetation) types using two-way indicator species analysis (Hill *et al.*, 1975). Original data consist of percentage cover (in 7 cover classes) for all vascular plant species within 571 5-m x 20-m plots. These plots were located on transects placed along 200 miles (combined distance) of the rivers.

Green Swamp. The Green Swamp is a large "pocosin" area located in the southeastern coastal plain of North Carolina. The area is characterized by organic soils, long hydroperiods, frequent fires, and a dense, semi-evergreen, shrubby vegetation. In his study of a 12,000 ha tract in Brunswick County, Kologiski (1977) recognized 9 plant community (vegetation) types. Original data consist of percentage cover (in 6 cover classes) for all vascular plant species, stratified by height, within 221 stands. Cover data in these stands were recorded for all plants along either transect releves or within 3x3, 5x5, or 10x10-m plots. Use of either the transect or plot methods depended on the ease of working in the vegetation, and plot sizes were selected based on vegetation stature.

Big Thicket. In his study of the effects of environmental factors on the floodplain vegetation of the lower Neches River, southeast Texas, Mohler (1979) recognized 5 major plant community (vegetation) types. We selected a portion of the original

database. For each stand these data consist of a synthetic importance value (the mean of relative density and relative basal area) for each tree and vine species. Data were gathered within circular 10-m radius plots, and there was one plot representing each of the 132 stands.

Flathead and Suiattle Rivers. Lee (1983) studied the effects of environment on plant community distributions in the floodplains of the North Fork of the Flathead River in Flathead County, Montana, and the Suiattle River in Skagit and Snohomish Counties, Washington. Transects were placed along 48 km of the Flathead, and 35 km of the Suiattle, within areas that are currently subjected to or have been subjected to flooding within post Pleistocene times. The vegetation at several locations along each transect was sampled within stands (each consisting of a 375 m^2 circular plot subsampled with a variable number of 20 x 50-cm microplots). Vegetation was stratified into 5 growth-form classes for each stand (trees, saplings, shrubs and subshrubs, perennial graminoids, forbs-ferns-fern allies). We selected the mean species importance values across all stands representing a given vegetation type for our analyses. The data collected varied according to growth-form: frequency, density and dominance (basal area) for trees and saplings, based on point-quarter samples; constancy and dominance (canopy coverage) for shrubs and subshrubs, based on microplots; and constancy, density and dominance (canopy coverage) for perennial graminoids and forbs-ferns-fern allies, based on microplots. Relative importance values were calculated for species within each growth-

form in a stand. Lee recognized 17 community types (209 stands) in the Flathead area and 13 community types (131 stands) in the Suiattle area.

Calculation of Weighted Averages and Index Averages

Although the principal focus of our tests was on weighted averaging and index averaging (see **INTRODUCTION** and Tables 1 and 2), we also investigated several variants of these two basic methods. Each of the methods used is described below, with a brief explanation of the logic used in the selection of variant methods:

(1) weighted averaging (**WA**) - this is the basic weighted averaging algorithm as illustrated in Table 1. No transformation of the original data was employed.

(2) weighted averaging (**2X**) - this is the basic weighted averaging algorithm, but applied to transformed data. The transformation involved doubling the quantitative values for those species classified as either obligate wetland species or obligate upland species. Data for facultative wetland, facultative and facultative upland species were left untransformed. The purpose of this transformation was to slightly increase the weight given to obligate species in the determination of weighted averages. Such a transformation might be desirable if the obligates were believed to be somewhat better indicators of environmental conditions than facultatives.

(3) weighted averaging (**10X**) - this is the basic weighted averaging algorithm, but applied to transformed data. The transformation involved multiplying by 10 the quantitative values for those species classified as either obligate wetland species or obligate upland species. Data for facultative wetland, facultative and facultative upland species were left untransformed. The purpose of this transformation was to greatly increase the weight given to obligate species in the determination of weighted averages. Such a transformation might be desirable if the obligates were believed to be much better indicators of environmental conditions than the facultatives.

(4) index averaging (**INAV**) - this is the basic index averaging algorithm as illustrated in Table 2.

(5) weighted averaging (**WVMW**) - this is the basic weighted averaging algorithm, but used with a set of ecological index values that reflect the midpoints of the percentage frequency classes used in assigning species to categories in the National Wetland Plant Species List. Table 3 compares the simple 1-5 ecological index scale used in methods (1) through (4) above with the midpoint values used in this approach. The approach of using midpoints of frequency ranges for species categories was investigated because ecological indices based on such midpoints would presumably be more indicative of the ecological behavior of species than would the simpler 1-5 scale used in the other methods.

(6) index averaging (**WVMX**) - this is the basic index averaging algorithm, but used with the frequency midpoint ecological indices described for method (5) above.

All computations of weighted and index averages were performed using FORTRAN programs written by Thomas R. Wentworth for these purposes.

Statistical Analyses

In three of the four studies used in our tests, we had access to data from multiple sample units representing each vegetation type. It was thus possible to calculate weighted or index averages for each sample unit of a given type and to estimate within-type variation. Since a mean weighted or index average could be calculated for each vegetation type, we could ask the following questions with respect to within- and between type variation:

(1) How much variation is encountered among weighted or index averages calculated for multiple sample units representing a given vegetation type? We answered this question by calculating a variety of descriptive statistics for each type, including the mean, standard deviation, range, and 95% confidence interval.

(2) Do the vegetation types recognized in a particular study differ significantly from one another in their weighted or index average scores? We answered this

question in a broad sense by performing a one-way analysis of variance (ANOVA) on the scores.

(3) Do any two vegetation types recognized in a particular study differ significantly from one another in their weighted or index average scores? We answered this question by performing a Duncan's Multiple Range Test on the scores.

(4) On average, what is the minimum separation required, in terms of distance between mean weighted or index average scores, for two vegetation types to be recognized as significantly different? We answered this question by determining distances between each vegetation type and its nearest significantly different neighbor(s), when types were arranged according to decreasing mean weighted average scores. The distances for all unique nearest-neighbor pairs were then averaged to arrive at an index of minimum separation.

(5) How does the ranking of vegetation types by their weighted or index average scores compare with their ranking relative to an environmental moisture gradient or other relevant environmental parameter? We answered this question by calculating a Spearman's rank correlation coefficient between the weighted or index average scores and the relevant environmental parameter or ranking.

(6) Given that a weighted or index average score of 3.0 (or 50.0 for the frequency midpoint index, Table 3) serves as a logical "cutoff point" between wetlands (lower scores) and uplands (higher scores), does wetland/upland designation using this criterion agree well with a designation based upon other criteria? We answered this question by searching for independent designations of wetland/upland status for the vegetation types studied. In the case of the Lee (1983) studies, this process was facilitated by his designation of the Cowardin et al. (1979) wetland types. For two of the other studies (those of Currier (1981) and Kologiski (1977)) we used the "prevalence of hydrophytic vegetation" definition of wetlands (H.R. 2100-152, 1985) as a guide, computing the percentage of either total species or total cover contributed by hydrophytes. Hydrophytes were defined in two ways. The first, a broad definition, recognized as hydrophytes all species belonging to the obligate wetland, facultative wetland, facultative and facultative upland groupings. The second, a narrower definition, recognized as hydrophytes only those species belonging to the obligate wetland and facultative wetland categories. In both cases, a wetland was defined as a vegetation type with either >50% of total species or >50% of total cover

contributed by hydrophytes. We also found useful a wetland indicator (WI) percentage calculated by averaging the percentage of total species and the percentage of total cover contributed by hydrophytes.

(7) How does the ranking of vegetation types by their weighted or index average scores compare with their ranking relative to (a) percentage of total species contributed by hydrophytes, (b) percentage of total cover contributed by hydrophytes, and (c) wetland indicator score (see item (6) above). As in item (5) above, we answered this question by calculating a Spearman's rank correlation coefficient between the weighted or index average scores and the relevant parameter.

(8) What effect, if any, does elimination of drawdown species (designated in the NWPSL) have upon the weighted average means for the annual and perennial mudflat vegetation types of the Platte and North Platte Rivers (Currier, 1981)? This question was raised because of concern that the abundance of drawdown species in certain environments (e.g., mudflats) might result in weighted or index averages biased toward the facultative nature of drawdown species. We answered this question by recalculating the means for these types after elimination of all drawdown species from the data set.

All statistical analyses were performed using procedures of the Statistical Analysis System (SAS Institute, 1982). Computations of percentage species or percentage cover contributed by hydrophytes and of the wetland indicator score were performed using FORTRAN programs written by Thomas R. Wentworth for this purpose.

RESULTS

Platte and North Platte Rivers

Results of analyses on Currier's (1981) data for floodplain vegetation on the Platte and North Platte Rivers are presented in Tables 4-14 and Figs. 1-6. Table 4 provides means and descriptive statistics of weighted averages (**WA**, or basic algorithm) for each of the 22 vegetation types, ranked in order of descending mean weighted averages. ANOVA indicated that there were significant differences among these means at the $p<.0001$ level. A clearer picture of differences among weighted average means of the vegetation types may be seen in results of the Duncan's Multiple Range Test (Table 4). This test indicated that although weighted average means for vegetation types were generally not significantly different from those of types ranked adjacent to them, types separated by at least 0.46 weighted average units (on the scale of 1-5) were, on average, significantly different from one another (Table 14).

The degree of variation within different types is illustrated in Fig. 1, which shows 95% confidence intervals for the weighted average means. If lack of overlap of the 95% confidence intervals of two vegetation types is taken as a rough criterion of a statistically significant difference, then it can be seen from this figure that a difference on the order of 0.4-0.5 units is generally required for significance. This agrees well with the value of 0.46 determined from analysis of the Duncan's Multiple Range Test results (Table 14). If 3.0 (on the scale of 1-5) is taken as the provisional "break-point" between

wetlands and uplands, 5 vegetation types had weighted average means with confidence intervals which crossed this boundary (Tables 4, 14, Fig. 1).

An independent ranking of the Platte River vegetation types from extreme upland to extreme wetland was developed by R.L. Kologiski (personal communication), based on his familiarity with the study area and wetland designations used in common practice. This ranking, also shown in Table 4, was compared to the ranking based on weighted average means with a Spearman rank correlation coefficient, yielding an $r_s=.92$ ($p<.0001$) (Table 14).

Weighted averages were recalculated for the Platte River data, with all cover scores for obligate wetland and obligate upland species doubled prior to calculation (2X variation of weighted averaging). Results of this analysis are presented in Table 5 and Fig. 2. ANOVA for the 2X analysis indicated significant differences among means at $p<.0001$, and the Spearman Coefficient comparing rankings from this analysis with those provided by Kologiski was also high and statistically significant ($r_s=.93$, $p<.0001$) (Table 14). Analysis of the results of Duncan's Test (Table 5) indicated that a difference of 0.47 units was required, on average, for significant differences of means between adjacent vegetation types (Table 14). Use of the 2X variation resulted in 3 vegetation types with 95% confidence intervals overlapping the provisional 3.0 wetland/upland "break-point" (Tables 5, 14, Fig. 2).

Weighted averages were also computed for the Platte River data with cover scores for obligate and upland species increased ten times prior to calculation (10X variation). Results for this

procedure are presented in Table 6 and Fig. 3. ANOVA for the **10X** variation indicated significant differences among means at $p<.0001$, and the Spearman Coefficient for the Kologiski ranking versus the numerical ranking was $r_s=.95$ ($p<.0001$) (Table 14). Analysis of the results of Duncan's Multiple Range Test indicated that weighted average means for adjacent vegetation types had to be more than 0.58 units apart, on average, before the means were recognized as significantly different. Fig. 3 provides a visual representation of 95% confidence intervals for this analysis, and illustrates 7 overlaps of confidence intervals with the provisional wetland/upland "break-point" of 3.0 (Tables 6, 14).

Results of index average calculations (**INAV**) for the Platte River data are presented in Table 7 and Fig. 4. As with the preceding methods, ANOVA indicated significant differences among means at $p<.0001$. The Spearman coefficient comparing rankings from this method against those provided by Kologiski was $r_s=.96$ ($p<.0001$) (Table 14). Analysis of results of Duncan's Multiple Range Test indicated that a difference of at least 0.34 units, on average, was needed for significant differences between means of adjacently ranked vegetation types. As with the **10X** analysis, there were 7 overlaps of 95% confidence intervals with the provisional wetland/upland "break-point" of 3.0 (Tables 7, 14, Fig. 4).

Weighted averages for the Platte River data were also computed utilizing the basic algorithm and an alternative set of index values based on frequency midpoints (Table 3). The results of this analysis (abbreviated **WVMW**) are presented in Table 8 and

Fig. 5. Because of the different scale used for the ecological indices, the results differ from those of the preceding methods in that the scale of possible scores has a range of 0.5 to 99.5. However, results presented in Fig. 5 have been rescaled to the 1-5 range for easier comparison with those of other methods. ANOVA indicated significant differences between means at $p<.0001$, and the Spearman's coefficient comparing the results of this analysis with the ranking provided by Kologiski was $r_s=.91$ ($p<.0001$) (Table 14). Analysis of the results of Duncan's Test indicated that adjacent means of vegetation types had to differ by at least 0.46 units (adjusted to the 1-5 scale), on average, for significant difference. Five vegetation types had 95% confidence intervals overlapping the provisional wetland/upland "break-point" of 3.0 (Tables 8, 14, Fig. 5).

The last method of analysis (abbreviated **WVMX**) employed with the Platte River data combined index averaging with the alternative set of index values based on frequency midpoints (Table 3). The results of this method are presented in Table 9 and Fig. 6. As in the **WVMW** analysis, weighted average scores had a possible range from 0.5 to 99.5, but results presented in Fig. 6 have been rescaled to the 1-5 scale for ready comparison with results of other methods. ANOVA indicated significant differences between vegetation type means at $p<.0001$, and the Spearman's coefficent between the **WVMX** ranking and that provided by Kologiski was $r_s=.95$ ($p<.0001$) (Table 14). Analysis of the results of Duncan's Test indicated that adjacent means had to differ by at least 0.36 units (adjusted to the 1-5 scale), on average, to be significantly different. Five vegetation types

overlapped the provisional wetland/upland "break-point" of 3.0 (Tables 9, 14, Fig. 6).

In a final analysis of the Platte River study, data for drawdown species were deleted from the annual and perennial mudflat stands and new weighted averages (**WA**, basic algorithm only) were calculated. One annual mudflat stand was eliminated from these calculations because it contained only drawdown species. The results of drawdown removal are presented in Table 10. Elimination of the drawdown species had only a slight effect on weighted average means for the two mudflat types: the mean for the annual mudflat increased (i.e., suggesting drier conditions) relative to the original score, while the mean for the perennial mudflat decreased (i.e., suggesting wetter conditions). Means of the two types remained significantly different from one another.

The categorization of the species in the NWPSL (obligate upland, facultative upland, etc.) enabled us to determine the percentage of total species and total cover for each category in a given stand or vegetation type. These results are presented for each of the 22 Platte River vegetation types in Table 11. A broad definition of "hydrophytes" which included all except the obligate upland species (i.e., obl. + fac. wet. + fac. + fac. upl.) led to high percentages of "hydrophytes" (generally greater than 80% of both total species and cover) for all vegetation types, regardless of site moisture relationships. For this reason, obligate wetland and facultative wetland species only were combined into what we believed was a more reasonable

grouping of "hydrophytes" (Table 12). A "wetland indicator" percentage (**WI**) was also generated by averaging the percentages of total species and total cover contributed by "hydrophytes". Spearman rank correlation cofficients were calculated for all pairwise comparisons of the parameters listed in Table 12 (except the wetland indicator score), and these are presented in Table 13.

Green Swamp

Table 15 provides means and descriptive statistics of weighted averages (**WA**, basic algorithm) for each of the 9 vegetation types recognized by Kologiski (1977), ranked in order of descending mean weighted averages. ANOVA indicated that there were significant differences among these means at the $p<.0001$ level. Analysis of the results of Duncan's Test (Table 15) indicated that a difference of 0.43 units was required, on average, for significant differences of means between adjacent vegetation types (Table 21). The comparison of the weighted average means with an independent ranking developed by R.L. Kologiski (personal communication) yielded a highly significant Spearman's coefficient, with $r_s=.97$ ($p<.0001$). Two of the 9 green Swamp vegetation types had weighted average means with 95% confidence intervals which overlapped the provisional 3.0 wetland/upland "break-point" (Tables 15, 21, Fig. 7).

Weighted averages for the 9 vegetation types were recalculated for the Green Swamp data, with cover scores for obligate wetland and obligate upland species doubled prior to calculation (**2X** variation of weighted averaging). The results of

this analysis are presented in Table 16 and Fig. 8. ANOVA for this procedure indicated highly significant differences between means ($p<.0001$), and the Spearman coefficient comparing the **2X** scores with the independent Kologiski ranking of types was also highly significant ($r_s=.96$, $p<.0001$) (Table 21). Analysis of results of Duncan's Test indicated that a difference of 0.47 units was required, on average, for significant differences of means between adjacent vegetation types (Table 21). As with the untransformed data, two means had ranges which overlapped the provisional wetland/upland "break-point" of 3.0 (Tables 16, 21, Fig. 8).

The index averaging (**INAV**) method was also applied to the Green Swamp data (Table 17 and Fig. 9). ANOVA for the **INAV** method indicated significant differences among means at $p<.0001$, and the Spearman coeficient between the **INAV** scores and the ranking provided by Kologiski was highly significant ($r_s=.86$, $p<.0001$) (Table 21). Analysis of the results of Duncan's Test (Table 17) indicated that a difference between mean **INAV** scores of 0.24 units was needed, on average, for statistical significance. There were no overlaps of 95% confidence intervals with the provisional wetland/upland "break-point"of 3.0 (Tables 17, 21, Fig. 9).

The percentage of total species and total cover in each of the categories of the NWPSL were calculated for the 9 vegetation types represented in the Green Swamp data set (Table 18). A "hydrophyte" category calculated as the sum of all categories except obligate upland generally had percentages above 95% for both species and cover. A more conservative "hydrophyte"

category calculated as the sum of percentage total species or total cover for the obligate and facultative wetland categories was also calculated (Table 19). A wetland indicator (**WI**) was calculated as the mean of percentage total species and percentage total cover of "hydrophytes" as defined in Table 19. Spearman correlation coefficients were calculated for all combinations of parameters listed in Table 19 (except the wetland indicator score) and are listed in Table 20.

Big Thicket

Table 22 provides means and other descriptive statistics for weighted averages (**WA**) for each of the 5 major vegetation types recognized by Mohler (1979), ranked in order of descending mean weighted average. ANOVA indicated highly significant differences among weighted average means ($p<.0001$). Analysis of results of Duncan's Multiple Range Test (Table 22) indicated that a difference of .65 units, on average, was needed for significant differences between means of adjacent vegetation types (Table 24). Figure 10 depicts the distribution of 95% conficence intervals for vegetation type means. Only one type had a weighted average mean with a 95% confidence interval that overlapped the provisional 3.0 wetland/upland "break-point" (Tables 22, 24, Fig. 10).

A direct ranking of the Big Thicket vegetation types relative to an environmental moisture gradient was unavailable, so our weighted average scores for all 132 stands were compared to 3 different ordination scores and one environmental parameter (percent sand) available for each stand (Mohler, 1979). Mohler

independently generated weighted averages (abbreviated WAO), utilizing a set of index values, in which each species was assigned a value of 1-5 (1=wet, 5=dry). Thus his WAO index values were comparable to those developed from the NWPSL. In a second weighted average (abbreviated WAPS), Mohler assigned ecological indicies to species based upon their typical distribution (pseudoelevation) above water level with respect to a local microelevation gradient. The third ordination provided by Mohler was based on reciprocal averaging (abbreviated RAO), a multivariate method which ranks stands on an arbitrary scale based upon their relative compositional similarities (Hill, 1973). The Spearman coefficients for the comparison of our ranking with Mohler's ordination and percentage sand rankings are presented in Table 24. All correlations were highly significant.

The Big Thicket data were also analysed using the index averaging method (**INAV**, Table 23, Fig. 11). ANOVA indicated highly significant differences among index average scores ($p<.0001$). Analysis of the results of Duncan's Test (Table 23), indicated that a difference of at least .62 units, on average, was needed for significant differences between means of adjacently ranked vegetation types. The 4 independently derived stand rankings provided by Mohler had highly significant Spearman rank correlations with the **INAV** scores. There was one overlap of a 95% confidence interval with the provisional wetland/upland "break-point" (Tables 23, 24, Fig. 11).

<u>North Fork, Flathead River</u>

Table 25 provides weighted averages (**WA**) and descriptive

data for each of the 17 vegetation types recognized by Lee (1983) in his study of wetland and floodplain vegetation in the drainage of the North Fork, Flathead River. Because we used Lee's average data for each vegetation type, our work with these data did not address within-type variation, nor could we generate desciptive statistics as provided for the preceding studies. Correlations were determined, however, between the weighted averages and various parameters provided by Lee. These included leaf area estimates, site water balances, and scores from a DECORANA ordination (Hill, 1979, 1980), which is based on a method similar to the reciprocal averaging ordination used by Mohler (1979). The correlation of our weighted average scores with Lee's DECORANA scores was high (r_s=-.85, p<.0001). Correlation with the site water balance was weaker, but significant (r_s=.52, p<.0001), while the correlation with leaf area index was non-significant (r_s=.19). Wetland determinations (based on Cowardin et al., 1979) for all types and soils data for some types are also provided in Table 25.

Scores were calculated for the Flathead River data using the index averaging procedure (**INAV**). Results of **INAV** are presented in Table 26. Correlations were also determined between the index averages and the DECORANA (r_s=-.83, p<.0001), site water balance (r_s=.52, p<.0001), and leaf area index (r_s=.37, NS) scores.

Suiattle River

Table 27 provides weighted averages (**WA**) and descriptive data for each of the 13 vegetation types recognized by Lee (1983) in his study of wetland and floodplain vegetation in the drainage

of the Suiattle River. As was the case with the Flathead river data, our work did not address within-type variation, nor could we generate desciptive statistics as provided for the preceding studies. Correlations were determined, however, between the weighted averages and various parameters provided by Lee. These included leaf area estimates, site water balances, and scores from a DECORANA ordination (Hill, 1979, 1980). The correlation of our weighted average scores with Lee's DECORANA scores was high (r_s=-.66, p<.0001). Correlation with the site water balance was similar (r_s=.66, p<.0001), while the correlation with leaf area index was non-significant (r_s=.21). Wetland determinations (based on Cowardin et al., 1977) for all types and soils data for some types are also provided in Table 27.

Scores were calculated for the Suiattle River data using the index averaging procedure (**INAV**). Results of the **INAV** procedure are presented in Table 28. Correlations were also determined between the index averages and the DECORANA (r_s=-.89, p<.0001), site water balance (r_s=.83, p<.0001), and leaf area index (r_s=.00, NS) scores.

DISCUSSION

In our evaluation of the results of many variations of weighted and index averaging, we found it most useful initially to compare results within each of the 4 data sets independently. From these comparisons there emerged general patterns regarding the behavior of individual methodologies. Thus we have organized our Discussion first around the 4 data sets, with Conclusions and Recommendations presented later.

Platte and North Platte Rivers

Weighted Averaging (**WA**). Analysis by weighted averaging (basic algorithm) of Currier's (1981) data for 22 floodplain communities yielded mean scores ranging from 1.08 to 4.14 (Tables 4, 14, Fig. 1). The "average" vegetation type in this study had a mean score of 2.83 (Table 14). In evaluating this result, we selected 3.0 as a logical and reasonable "break-point" for wetland vs. upland sites, since this score represents the weighted average score that would be assigned to a stand composed solely of facultatives. Using this criterion, 11 types had weighted average means less than 3.0; these types would thus tentatively be recognized as wetlands.

The within-type variation in weighted average scores, as expressed by the standard deviation, ranged from 0.09 for the marsh type to 0.67 for the annual mudflat type (Table 4). The "average" type had a standard deviation of 0.40 (Table 14). Variation of weighted average scores among the stands representing a particular vegetation type had two implications for interpretation of results:

(1) although ANOVA indicated overall significant differences among weighted average scores, the Duncan's Multiple Range Test (Table 4) and our index of minimum separation (Table 14) indicated that types had to be separated by approximately 0.46 units, on average, before they would in fact be significantly different. A qualitative picture of this result is evident in Fig. 1, where a distance of about 0.5 units between means is required to eliminate all overlaps of 95% confidence intervals; and

(2) although the mean weighted average score for a particular vegetation type might be above or below 3.0, the range of variation within the type could overlap the "break point", raising some doubt regarding the reliability of a wetland/upland designation for that type. We felt that the 95% confidence interval was an appropriate statistic for evaluating overlap of variation with the "break point".

Of Currier's 22 vegetation types, 5 had 95% confidence intervals overlapping the 3.0 wetland/upland "break point". If we were to designate as wetlands **only** those types with means <3.0 and with 95% confidence intervals **not** overlapping the "break point", then 7 types would be so designated. The remaining 10 non-overlapping types would be designated as uplands.

An evaluation of the preceding designations can be based on the "prevalence of hydrophytic vegetation" criterion for recognizing wetlands (H.R. 2100-152, 1985). We explored two means of generating a quantitative estimate of this criterion. The first, illustrated in Table 11, combined percentage total species and percentage total cover for all categories of species except obligate upland. This statistic was apparently of little use in wetland designation, since the majority of values were well over 90% and all types (including those of drier situations like prairie/hayfield and sandy meadow blowout) qualified as having a prevalence of hydrophytic vegetation. The second

estimate of this criterion (Table 12) recognized only obligate wetland and facultative wetland species as contributing to "hydrophytic" prevalence. We chose to consider obligate and facultative wetland species because, by definition, such species are expected to occur predominantly in wetland situations; our personal field experience has confirmed this expectation.

For purposes of evaluating wetland designations, we averaged the percentages of total species and total cover contributed by hydrophytes into a "wetland indicator" (**WI**) (Table 12). The 7 vegetation types recognized as wetlands by the combined criterion of mean score below 3.0 and lack of overlap of the 95% confidence interval with 3.0 coincided exactly with the 7 types having **WI** percentages >50%. All types designated as uplands by similar criteria (mean score >3.0 and lack of overlap of the 95% confidence interval with 3.0) had **WI** percentages well below 50%.

A final criterion for evaluating the performance of weighted averaging with Currier's Platte River data was the correlation of **WA** scores with independently-derived rankings of the same stands relative to environmental moisture gradients. The only available ranking of this nature was that provided by R.L. Kologiski, based on his experience with the Platte River vegetation and prevailing criteria for wetland designation. The Spearman rank correlation coefficient of 0.92 (Table 14) provides good basis for concluding that weighted averaging does rank vegetation types in a way that is consistent with the opinion of a field worker familiar with the area. Although not independent of the **WA** score, our wetland indicator (**WI**) does provide an alternative means of ranking types relative to an environmental moisture gradient. Correlation of

the **WA** with the wetland indicator was -0.97 (Table 14), suggesting strong agreement between these two criteria.

<u>Weighted</u> <u>Averaging</u> (**2X**). Analysis of Currier's (1981) data by weighted averaging of transformed data (doubling of quantitative data for obligate wetland and obligate upland species) yielded moderate differences, when compared to results of the basic algorithm described above. Mean scores ranged from 1.04 to 4.29 (Table 14), and the "average" vegetation type had a score of 2.70, slightly lower than the average score of 2.83 for the **WA** method. There was essentially no change in the minimum separation of types required for significant difference (Table 14). Twelve types had means below 3.0, and of these types 10 had 95% confidence intervals not overlapping the "break point" of 3.0 (Table 5, Fig. 2). Both the shift of the average score to a lower value and the larger number of types that would be recognized as wetlands was a consequence of the relatively low representation of obligate upland species in Currier's data (Table 11).

Of the 10 vegetation types that might be considered wetlands as a result of the **2X** analysis, only 7 (the same types recognized by the **WA** method) had **WI** percentages above 50% (Table 12). The remaining 3 types would fail to meet the "prevalence of hydrophytic vegetation" criterion. It thus appears that the **2X** variation resulted in a more liberal inclusion of types as wetlands than did **WA**. All stands recognized as uplands by the **2X** analysis had **WI** percentages below 50%, however.

Comparison of the ranking of types by the **2X** analysis with

the ranking provided by Kologiski yielded a Spearman's coefficient of 0.93 (Table 14), indicating consistency of the two rankings.

Weighted Averaging (**10X**). Application of the **10X** transformation to the Platte River data resulted in more pronounced tendencies of the kind seen in the **2X** transformation. The range of mean scores widened to 1.00-4.58, with a lower mean for the "average" type of 2.52 (Table 14). The within-type variation increased relative to that for the preceding methods, with an average standard deviation of 0.63 for all 22 types (Table 14). The increased within-type variation is also evident in the wider 95% confidence intervals for this method (Table 6, Fig. 3).

In the **10X** analysis, 13 types had mean scores below 3.0. However, only one of these had a 95% confidence interval overlapping the 3.0 "break-point" (Tables 6, 14, Fig. 3), leaving 12 types that might be considered wetlands under our provisional criteria. This resulted in potential recognition as wetlands of 5 types failing to meet the "prevalence of hydrophytic vegetation" criterion of >50% **WI**.

Comparison of the ranking of types by the **10X** analysis with the ranking provided by Kologiski yielded a Spearman's coefficient of 0.95 (Table 14), again indicating consistency of the two rankings.

Index Averaging (**INAV**). Analysis of Currier's (1981) data by index averaging resulted in largely similar patterns to those obtained thorugh use of the basic algorithm and the two variations described above. A narrowing of the range of mean

scores to 1.31-3.91 was evident (Table 14), although the "average" vegetation type had a score of 2.87, about the same as that of 2.83 for the **WA** method. There was also a reduction in the minimum separation of types required for significant differences relative to those required for the preceding methods (Table 14). This result was a consequence of the reduced within-type variation (standard deviations averaged 0.31, Table 14) encountered with this method.

As in the **WA** analysis, the **INAV** procedure resulted in 11 types with means below 3.0, 7 of which had 95% confidence intervals not overlapping the "break-point" of 3.0 (Table 7, Fig. 4). Thus the **INAV** procedure resulted in assignment of exactly the same types to provisional wetland status as did the **WA** procedure, and all of these met the "prevalence of hydrophytic vegetation criterion", with **WI** percentages greater than 50%.

Comparison of the ranking of types by the **INAV** analysis with the ranking provided by Kologiski yielded a Spearman's coefficient of 0.96 (Table 14), indicating consistency of the two rankings. This represented the strongest correlation of any of the methods tested with the Kologiski ranking. Correlation of **INAV** with the **WI** percentage was -0.98 (Table 14).

<u>Weighted Averaging and Index Averaging</u> (**WVMW, WVMX**). These methods were identical to the **WA** and **INAV** approaches, respectively, except for substitution of an alternative set of ecological indices (Table 3). Results of **WVMW** (Table 8, Fig. 5) were quite similar to those of the corresponding **WA** approach; this can be appreciated most readily in a comparison of Figs. 1

and 5 and in the summary results of Table 14. Results of **WVMX** (Table 9, Fig. 6) were also quite similar to those of the corresponding **INAV** approach; this can be appreciated most readily in a comparison of Figs. 2 and 6 and in the summary results of Table 14.

Removal of Drawdown Species. The removal of drawdown species from Currier's data set was prompted by the observation that the annual mudflat type had a somewhat higher mean **WA** score than was anticipated, and fairly high within-type variation (Table 4, Fig. 1). However, results of this test were ambiguous. The majority of drawdown species removed belonged to the obligate wetland and facultative wetland categories (8 species of 14 total), rather than to the facultative and drier categories, as had been anticipated. Their removal resulted in an increase of the mean **WA** score for the annual mudflat type and only a slight decrease of the within-type standard deviation (Table 10). In contrast, the perennial mudflat showed a decrease of the mean **WA** score and marked increase of the within-type standard deviation, following removal of drawdowns (Table 10).

Green Swamp

Weighted Averaging (**WA**). Analysis by weighted averaging (basic algorithm) of Kologiski's (1977) data for 9 vegetation types in the Green Swamp yielded mean scores ranging from 1.33 to 3.32 (Tables 15, 21, Fig. 7). The "average" vegetation type in this study had a mean score of 2.19 (Table 21), indicating that overall the Kologiski study covered a narrower range of moisture conditions, focusing on wetland situations, than did Currier's

(1981). Using the wetland/upland "break point" criterion established earlier, we found that 8 of Kologiski's types had mean scores of less than 3.0; 7 of these also had 95% confidence intervals that did not overlap the "break point", suggesting that these were in fact wetlands (Tables 15, 21, Fig. 7).

Of the 7 vegetation types that might be considered wetlands by our provisional criteria, only one, the Pine-Ericalean Pocosin had a **WI** percentage less than 50% (48.9%, Table 19). It thus appears that designation of wetlands by these criteria would identify types that also satisfied the "prevalence of hydrophytic vegetation" criterion.

The within-type variation in **WA** scores, as expressed by the standard deviation, ranged from 0.10 for Evergreen Bay Forest to 0.37 for Pine-Mixed Shrub types (Table 15). The "average" type had a standard deviation of 0.22 (Table 21). The minimum separation required for significant difference of adjacent vegetation types for **WA** analysis of Kologiski's data was 0.43 (Table 21), quite similar to the corresponding figure of 0.46 for Currier's **WA**.

Kologiski (personal communication) provided an independent ranking of his 9 vegetation types relative to the prevailing environmental moisture gradient in the Green Swamp. Correlation of this ranking with that based on mean **WA** scores was strong (0.97, Table 21). The less independent **WI** percentage (Table 19) showed a somewhat weaker correlation in this case (-0.77, Table 21). The generally good agreement among these rankings does suggest that the **WA** procedure provided a reasonable sequencing of vegetation types relative to prevailing moisture gradients.

Weighted Averaging (**2X**). Doubling the importance of obligate wetland and obligate upland species in Kologiski's data set (Table 16) had very little effect on the results of weighted averaging, when these are compared with results of weighted averaging on untransformed data (Table 15). The **2X** variation had similar overall statistics (Table 21) and the mean scores and ranking of vegetation types were nearly identical (Tables 15, 16). Careful inspection of the results of **2X** averaging (Table 16, Fig. 8) with those of **WA** (Table 15, Fig. 7) reveals slight shifts of most types toward wetter positions; this result was expected because obligate wetland species were generally more important than obligate upland species in Kologiski's vegetation types (Table 18).

Index Averaging (**INAV**). Application of the index averaging procedure to Kologiski's data resulted in slightly greater changes than did the **2X** variation, when compared with results of the basic **WA** algorithm. The overall sequencing of types changed somewhat (Table 17, Fig. 9), as a result of shifts both upward and downward of scores for the various types. The net effect of these changes was to place means and 95% confidence intervals for all types below the provisional 3.0 "break-point". This tentative designation of all Green Swamp vegetation types as wetlands does not appear unreasonable, except in the case of the Pine-Graminoid Savanna, which had a **WI** percentage well below 50% (35.9%, Table 19). The **INAV** ranking of the Green Swamp vegetation types correlated somewhat less well with Kologiski's independent ranking (Table 21), as compared to rankings of the **WA**

and **2X** methods. Correlation of **INAV** with the **WI** percentage was -0.68 (Table 21). Other differences evident in the results of the **INAV** procedure were a slight reduction in within-type variation and a substantial reduction in the minimum distance required for significant differences between adjacent types (Table 21).

Big Thicket

Weighted Averaging (**WA**). Analysis by weighted averaging (basic algorithm) of Mohler's (1979) data for 5 vegetation types in the Big Thicket yielded mean scores ranging from 1.49 to 3.09 (Tables 22, 24, Fig. 10). The "average" vegetation type in this study had a mean score of 2.44 (Table 24). Like Kologiski's (1977) study in the Green Swamp, Mohler's work focused primarily on wetland situations. Using the wetland/upland "break-point" criterion established earlier, we found that 4 of Mohler's types had mean scores of less than 3.0; all of these also had 95% confidence intervals that did not overlap the "break-point", suggesting that these were in fact wetlands.

The within-type variation in **WA** scores, as expressed by the standard deviation, ranged from 0.19 for Floodplain Baygall Forest to 0.52 for Flatland Hardwood Forest types (Table 22). The "average" type had a standard deviation of 0.34 (Table 24). The minimum separation required for significant difference of adjacent vegetation types for **WA** was 0.65 (Table 24), higher than the corresponding figures of 0.46 and 0.43 for Currier's and Kologiski's **WA**s, respectively. We attribute these indications of greater within-type variation in Mohler's data to the fact that we selected his highest level of vegetation classification for

our analyses. If we had selected the more homogeneous types he recognized within the broader groupings used, we expect that within-type variation would have been similar to that encountered in the other studies.

Mohler's study provided several independent rankings of his stands; we selected four of these for further investigation, as discussed in the Results section. Spearman correlations of the **WA** scores with these rankings were performed at the stand level (N=132) in all cases (Table 24). As might be anticipated, the closest agreements were between our **WA** and Mohler's weighted averaging (WAO) and Reciprocal Averaging (RAO). We found a somewhat poorer agreement of our **WA** ranking with Mohler's weighted average based on species' elevational relationships (WAPS) and poor agreement with one soil parameter, percentage sand (Table 24). Mohler (1979) discussed his WAO, RAO, and WAPS rankings or ordinations in some detail, focusing on interpretations of environmental effects on vegetation and the relative advantages and disadvantages of these methods. Based on his discussion and the reasonably close agreement of our **WA** with these methods, we feel reasonably confident that **WA** adequately assessed the environmental control of vegetation pattern by local gradients of flooding effects and soil moisture. Low correlation of percentage sand with **WA** suggests that this soil parameter was not associated with prevailing environmental gradients of flooding and soil moisture.

<u>Index Averaging</u> **(INAV)**. Results of index averaging for Mohler's data were similar to those of weighted averaging. There was a slight tendency for mean scores for his types to shift

toward drier conditions (Tables 23, 24, Fig. 11). The only other evident changes were slight reductions in within-type variation and the minimum distance required for significant difference between adjacent types (Table 24).

North Fork, Flathead River

Weighted Averaging (**WA**). Because we worked with average data for vegetation types, rather than data for individual stands representing these types, our analysis of Lee's (1983) studies of floodplain and wetland vegetation did not address the issue of within-type variation. Table 25 thus presents only weighted averaging scores for 17 types recognized by Lee for the drainage of the North Fork, Flathead River. The most striking feature of these results is the relatively high scores calculated; of 17 types, only 3 had scores below the provisional wetland/upland "break point" of 3.0, suggesting that most types were probably uplands. While there was a tendency for the types with higher scores to be classified by Lee (1983) as uplands (Table 25), there were 7 types with scores above 3.0 that were classified as wetlands in the Cowardin et al. (1979) system. This apparent failure of **WA** to recognize certain wetlands as such is also indicated by the fact that 3 types with scores above 3.0 had soils classified as Fluvaquents, which are typically recognized as hydric soils (SCS, 1985).

In evaluating the problem of designating wetlands in the Pacific Northwest, it is important to recall that the success of **WA** is dependent on the ability of species to serve as indicators of environmental conditions. An inspection of Lee's species list

for the Flathead River reveals that relatively few are classified as obligate or facultative wetland species in the NWPSL, the great majority being in facultative, facultative upland or upland categories. Lee (personal communication) confirmed this finding, and indicated that many of the important species in his wetlands are broad generalists having distributions that include upland areas.

Lee (personal communication) also indicated that wetlands of the Pacific Northwest may differ from those elsewhere in the United States in several important environmental attributes that make them difficult to classify by **WA**. First, many of these areas support narrow ecotonal belts of riparian vegetation, and these may have strong influence from species of adjacent uplands. Also, the soil water in such wetlands may in fact be well-aerated because of the relatively steep gradients encountered along the major streams. Prolonged droughts are common in the region, further contributing to wetland environments that support species typically recognized as belonging to facultative or drier categories.

Of the three statistics chosen for comparison with our **WA** ranking, the DECORANA ordination had the strongest correlation (r_s=-.85). Lee (1983) concluded that this ordination reflected an environmental gradient of soil moisture or site water balance, which suggests that the **WA** ranking was also an adequate reflection of environmental control of vegetation pattern. This conclusion is also supported by the significant correlation of **WA** scores with Lee's site water balance (r_s=.53). A much weaker correlation was found in our comparison of **WA** scores with the

leaf area estimate (r_s=.19). Lee also found no relationship between his leaf area estimate and the floristic (DECORANA) ordination. It should be noted that the foregoing comments are not meant to imply that the compositional gradients found in Flathead River floodplain and wetland communities are simple reflections of environmental moisture. Lee (1983) indicated that type and frequency of inundation as well as age of existing stands are factors involved in determining floristic composition of vegetation in his study area.

Index Averaging (**INAV**). The results of index averaging on Lee's data for the North Fork, Flathead River, need little discussion. The scores for individual types and the ranking of these scores (Table 26) are quite similar to those obtained with weighted averaging of the same data (Table 25). The tendency for wetland types to have scores above 3.0 occurred in the **INAV** analysis to about the same extent as in **WA**. Correlations of the **INAV** ranking with those of DECORANA (r_s=-.83) and site water balance (r_s=.53) were similar to the respective correlations of **WA**. The correlation of **INAV** with leaf area estimate was also low (r_s=.37). These results suggest that the environmental interpretation of the **INAV** results is identical to that presented above for **WA**.

Suiattle River

Weighted Averaging (**WA**). Many of the comments made regarding **WA** analysis of Lee's Flathead River data also apply to results for the Suiattle data. Most of the scores were above the provisional "break-point" of 3.0 and several types considered

wetlands in the Cowardin et al. (1979) classification fell within this range (Table 27). Reasons for this apparent misclassification by **WA** are probably identical to those presented earlier for the Flathead River analysis.

Correlation of the **WA** ranking with the DECORANA ordination of the Suiattle data was moderate (r_s=-.65). The leaf area estimate, which was not correlated with **WA** for the Flathead River data, showed good agreement with **WA** for the Suiattle data (r_s=.66). In this respect, Lee (1983) noted that his leaf area estimate correlated well with the DECORANA ordination for the Suiattle River, but not for the Flathead. The reverse was true for the site water balance, which was not correlated with **WA** for the Suiattle data (r_s=.21). As was true for the Flathead River data, complex interrelationships among soil moisture, site water balance, frequency and type of inundation, and stand age all play important roles in determining composition of vegetation on these sites (Lee, 1983). Simple conclusions based on correlations among a few parameters are probably not realistic.

Index Averaging (**INAV**). Little discussion of the **INAV** results for the Suiattle River data is necessary. Scores and relative ranking of types by this method (Table 28) were quite similar to those determined by **WA** (Table 27). Correlation of the **INAV** ranking to Lee's DECORANA was high (r_s=-.89) as was the correlation with leaf area estimate (r_s=.83). Similarly, there was no correlation of **INAV** with site water balance (r_s=.00) for these data. These results suggest that the environmental interpretation of the **INAV** results is identical to that presented above for **WA**.

CONCLUSIONS AND RECOMMENDATIONS

Weighted Averaging (WA)

We recommend weighted averaging of vegetation data as a means of characterizing the probable environment of a site or vegetation type. When applied to the problem of designating wetlands from existing data, **WA** generally performed well in the tests we conducted. We base this conclusion on two main points: (1) **WA** effectively ranked vegetation types or stands in a way that was well correlated with independently-derived rankings for the same types or stands relative to environmental moisture gradients (based on personal experience, multivariate analysis of vegetation data, and environmental parameters); and (2) the results of **WA** could be used in a designation of sites as wetlands or uplands in a way that agreed well with designations based on other criteria. **WA** also met all the criteria established earlier in this project for selection of an efficient, objective and consistent means of wetland designation. **WA** is also well established as a methodology for analysis of biological data in environmental assessment, with many basic and applied uses.

No method for designating wetlands using vegetation data will be completely reliable. Weighted averaging is subject to inaccuracies which might result from inadequate sampling and incomplete or incorrect data regarding the behavior of plant species. We view the latter problem as particularly significant. Since results of **WA** reflect the information contained in the classification of species into indicator categories, its performance can be only as good as that classification. We

strongly urge that any use of **WA** in wetland designation be accompanied by an understanding of the kind of information conveyed by the National Wetland Plant Species List (Reed, 1986). Our experience with the data of Lee (1983) for floodplains and wetlands of the Pacific Northwest provides a possible illustration of this point. Our incorrect designation of several wetland vegetation types as uplands may have resulted from the classification of certain species found in these types in the facultative and facultative upland (or even upland) categories. When wetlands are occupied largely by facultative species, **WA** or any other analysis of vegetation data may be a poor choice for designation purposes. Further refinement of the NWPSL may also improve the performance of **WA** in certain problem areas.

Index Averaging (**INAV**)

Index averaging may be viewed as weighted averaging "without the weights". Like weighted averaging, it appears to meet the criteria established earlier in this project for selection of a reliable and efficient means of wetland designation. **INAV** has also been used in other fields for environmental assesssment based on biological data. Unlike **WA**, **INAV** does not require the collection of quantitative data, instead basing its calculations solely on a species list for the stand or type. Because each species carries equal weight in determining a designation based on **INAV**, special care must be exercised in taxonomic identification of all species. There exists a "trade-off" in the kinds of effort required for effective utilization of the **WA** and **INAV** approaches. Use of **WA** involves time and effort devoted to

quantitative sampling of vegetation, but the method is relatively insensitive to omissions of rare species (either because these are overlooked or because they cannot be identified readily). Use of **INAV** involves time and effort devoted to searching for and identification of all species present, regardless of their quantitative abundance. Careful attention must be given to the costs and benefits associated with **WA** and **INAV** when selecting one of these for a particular purpose.

In our evaluations of the **INAV** approach, we found excellent agreement with results of **WA**. The agreement was so good that we question the need for reliance on quantitative methodologies like **WA** for routine cases of wetland designation. We had some indication (based on our study of Currier's (1981) data from the Platte and North Platte Rivers) that wetland/upland designations based on **INAV** may be more conservative, i.e., scores may be less extreme than those based on **WA** of quantitative data. This would result in more designations in the "gray area", centering on facultative species, where additional data regarding soils and hydrology will be required. This is not necessarily a negative attribute of a designation method, however.

Data Transformations (**2X**, **10X**, etc.)

There are literally an infinite number of ways that variable weighting may be applied to species representing different categories (R.K. Peet, personal communication). In all cases, variable weighting reflects an implied assumption that some kinds of species are better indicators than others. We explored two applications of this form of data transformation, in which

obligate wetland and obligate upland species were given either double or tenfold weighting relative to other species. We found little advantage in these particular data transformations with **WA**; results were generally quite similar to those for untransformed data. The more extreme (**10X**) transformation resulted in an increase in within-type variation, an undesirable feature. We expect that heavy weighting of obligate species would tend to result in more liberal wetland/upland designations: i.e., vegetation types that would otherwise be in the "gray area", centering on facultative species, would be shifted away from this in the direction of the kind of obligate species (wetland or upland) that were most abundant. This might be an undesirable outcome, as it could lead to designations based on vegetation data only, when in fact inspection of other site features (soils, hydrology) might be necessary for accurate designation.

Use of Frequency Midpoints as Ecological Indices (**WVMW, WVMX**)

It is quite logical to assign as ecological indicators the frequency midpoints of the various categories (obligate wetland, facultative wetland, etc.). Evaluations of this set of ecological indices as an alternative to a simpler 1-5 scale (Table 3) were performed with both **WA** and **INAV**. The effect on results was minimal in our tests, and we concluded that either scale would be acceptable. The 1-5 scale has the advantage of being somewhat easier to remember, and the results of **WA** or **INAV** fall on a scale that is readily subdivided for interpretive purposes into several useful zones requiring different responses

from the field worker (Fig. 12).

Wetland Indicator Percentage (**WI**)

We developed the **WI** percentage in response to the legislative definiton of wetlands (H.R. 2100, Title XII). Since this definition indicates that a wetland supports "a prevalence of hydrophytic vegetation", our **WI** is simply the mean of the percentage of total species and percentage of total cover contributed by species belonging to the obligate wetland and facultative wetland categories. We then investigated the use of this percentage as a criterion for designating wetlands, working with the idea that any site or type with a **WI** percentage greater than 50 would be a wetland. Such a definition agreed well with our assessments based on **WA** and **INAV**, and we find considerable merit in using **WI** (either by itself or in conjunction with **WA** or **INAV**) as a means of designating wetlands.

We did not feel that an effective **WI** could be based on the use of obligate wetland species alone, nor did we find that a **WI** that took into account all except obligate upland species was of much value. The former approach would be likely to exclude from wetland designation certain types worthy of such designation, while the latter approach proved to be far too inclusive of drier types.

Removal of Drawdown Species

Removal of a particular category of species is a special case of data transformation in which that category is assigned a weight of zero. Our only exploration of this approach involved removal of drawdown species from data collected in mudflat

vegetation types of the Platte and North Platte Rivers. The results of this analysis were inconclusive, and we can only recommend further investigation of this and related approaches.

Within-Type Variation

Any stand or site selected to represent a particular area or vegetation type is a member of a large population of similar stands or sites. Among the members of this population there will be some variation in vegetation composition and, therefore, in measures such as **WA** or **INAV** based on this composition. It is impossible to make inferences about the characteristics of a population from a single site, regardless of how that site is selected. Only through analysis of data from a sample of sites, selected by a statistically acceptable sampling procedure, can such inferences be made.

Our analyses demonstrated that, among the stands representing any particular vegetation type, there was some degree of variation in the **WA** or **INAV** scores computed. The magnitude of this variation is undoubtedly a function of how broadly a vegetation type is defined, and may be influenced by a variety of other factors, including size and shape of sample plot, type of data collected, and environmental heterogeneity. We strongly recommend that any plan for using vegetation data in wetland designation make provision for repeated, random sampling within the vegetation type or area to be designated. Exact guidelines for the number of samples necessary cannot be specified except on a case-by-case basis, but common sense suggests that, in many cases, a sample of at least 10 sites will

be required to characterize the mean and standard deviation of a parameter like **WA** or **INAV**. From such a sample, other useful statistics, such as the 95% confidence interval, may be determined. Armed with such statistics, the researcher can then make more definitive statements regarding the designation of a particular area or vegetation type as a wetland or upland.

Sampling Procedures

As discussed in the preceding section, natural variation, always present among the members of a population of plots representing an area or vegetation type, makes some kind of sampling procedure essential. We wish to make the point that successful use of any biological indicator of environmental conditions is dependent on a solid sampling protocol; use of the methods discussed in this report represents no exception to this rule. However, there are no "special rules" associated with wetland designation by **WA, INAV** or **WI** percentage. The usual rules governing good sampling procedures for standard statistical analysis apply to these methods as well. While there may well be advantages (quality assurance/quality control) to standardizing sampling procedures at some later date, we see no reason to abandon those methods currently in use, providing that they meet standard statistical criteria.

Types of Data

Weighted averaging can be applied to any type of quantitative data; index averaging requires only species lists. As is the case with sampling considerations, there are no

"special rules" to be followed in selecting a type of data to be used with weighted averaging. If data from different strata (forbs, shrubs, trees, etc.) are to be combined for use in **WA**, obvious requirements for compatibility do exist. In general, we feel that field workers should test **WA** with the same types of quantitative data that they have been collecting for other purposes. There are many good textbooks that address the issue of appropriate sampling procedures for vegetation analysis, and these should be consulted when questions arise. At a later date, it may be useful to standardize data collection procedures for purposes of quality assurance/quality control.

<u>Break-Point for Wetland/Upland Separation</u>

We recommend provisional adoption of 3.0 as a "break-point" separating wetlands from uplands (assuming use of a 1-5 scale for ecological indices). We feel that there is a logical basis for recognition of such a "break-point" and our experiences with analysis of available data generally support the selection of 3.0. Further testing of the methodologies proposed in this report will be necessary prior to final adoption of this or any other criteria for wetland designation, however.

<u>Reliability of Wetland Designations</u>

The value of a particular wetland/upland designation will be greatly enhanced by knowledge of the reliability associated with that designation. On the basis of our work with several data sets, we offer guidelines (Figure 12) regarding the confidence with which one can designate a wetland or upland based upon **WA** or **INAV** methodologies. <u>Our guidelines are based on the</u>

assumption that one has a **WA** or **INAV** mean based upon at least ten sample units representing a reasonably homogeneous area or vegetation type. The guidelines arise from several observations:

(1) vegetation types with mean scores lying more than 0.5 units from the 3.0 "break-point" rarely had 95% confidence intervals that overlapped this point. This led us to regard the region on the 1-5 scale between 2.5 and 3.5 as a "gray zone", where designations would be unreliable.

(2) classification of vegetation types as wetlands or uplands appeared reasonable when viewed by a variety of criteria, if designations were made for only those types with mean scores lying beyond the "gray zone" of 3.0 ± 0.5.

(3) mean scores for vegetation types typically required about 0.5 units of separation before they were recognized as being significantly different.

(4) within-type standard deviations, averaged for the three studies for which such calculations could be made, were 0.35 and 0.27 for **WA** and **INAV** scores, respectively. Approximately 68% of all members of a population (in our case, a population of individual site or stand scores) lie within ± 1 standard deviation from the mean. Given a mean population score located at least 0.5 units from the 3.0 "break point", we would expect that the great majority of sites or stands belonging to the population would lie to the same side of the "break point" as the mean.

Our recommendations (Figure 12) thus have 4 basic elements:

(1) a **WA** or **INAV** score of 3.0 is selected as the "break point" separating wetlands from uplands.

(2) if a vegetation type or area to be designated has a mean score (based on adequate sampling) lying within 0.5 units of this break point, we feel that vegetation data are inadequate for making a wetland/upland designation. Additional data regarding soils and/or hydrology will be mandatory for making a designation.

(3) if a vegetation type or area has a mean score lying between 2.0 and 2.5, or between 3.5 and 4.0, we feel that there is a good probability that a vegetation-based designation of wetland or upland, respectively, will be correct. Additional data regarding soils and/or hydrology will be desirable, however, for confirming this designation.

(4) if a vegetation type or area has a mean score lying between 1.0 and 2.0, or between 4.0 and 5.0, we feel that there is a high probability that a vegetation-based designation of wetland or upland, respectively, will be correct.

Incorporating **WA** or **INAV** into a Formal Designation Procedure

Eventually we hope to see the methods of weighted and index averaging incorporated into a formal procedure for designating wetlands. Such a procedure would have specific guidelines at all levels for choices in such areas as sampling methodology, type of data to be acquired, methods of analysis, etc. Appropriate quality assurance/quality control guidelines would be incorporated. Examples of existing procedures of this nature are those used by the Corps of Engineers (Sanders et al., 1985) and the Environmental Protection Agency (Sipple, 1985). Our tentative outline for such a procedure is presented in Fig. 13.

Future Research

Our study presents a strong case for adopting weighted averaging and index averaging as methods for utilizing vegetation data in the designation of wetlands. Future research should focus on several areas. The foremost of these is field validation of the methods in a variety of "real-world" situations, involving correlation of vegetation-based designations with those based upon soils and hydrology. In particular, further clarification of the reliability of wetland/upland designations, as presented in Fig. 12, is highly desirable. Specific foci of future research could be the effects of successional and seasonal changes on wetland designations

based on vegetation. Continued work with the methods proposed in this research will no doubt result in further refinement of the National Wetland Plant Species List.

Eventually we hope to see development of a wetland designation system, utilizing microcomputer technology, that would provide for objective, consistent designations of wetlands and which would incorporate the best available data regarding vegetation, soils and hydrology. Such a system would be standardized to such an extent that any trained worker, provided with appropriate data, could arrive at a unique, defensible wetland designation.

LITERATURE CITED

Currier, J.P. 1981. The floodplain vegetation of the Platte River: Phytosociology, forest development, and seedling establishment. Ph.D. dissertation, Iowa State University, Ames, Iowa.

Curtis, J.T., and R.P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32:476-496.

Dresscher, T.G.N., and H. van der Mark. 1976. A simplified method for the biological assessment of the quality of fresh and slightly brackish water. Hydrobiologia 48:199-201.

Dyksterhuis, E.J. 1948. Condition and management of range land based on quantitative ecology. J. Range Mgmt. 2:104-115.

Ellenberg, H. 1948. Unkrautgesellschaften als Mass fur den Sauregrad, die Verdichtung und andere Eigenschaften des Ackerbodens. Ber. Landtech. 4:130-146.

Hill, M.O. 1973. Reciprocal averaging: an eigenvector method of ordination. J. Ecol. 61:237-249.

Hill, M.O. 1979. DECORANA -- a fortran program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca, NY. 52 pp.

Hill, M.O., and H.G. Gauch, Jr. 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 42:47-58.

Hill, M.O., R.G.H. Bunce, and M.W. Shaw. 1975. Indicator species analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland. J. Ecol. 63:597-613.

H.R. 2100. 1985. 1985 Farm Bill, Title XII -- Conservation. U.S. Congressional Record, December 17, 1985, No. 175, Part II.

Kologiski, R.L. 1977. The phytosociology of the Green Swamp, North Carolina. North Carolina Agricultural Experiment Station. Tech. Bull. No. 250.

Lee, L.C. 1983. The floodplain and wetland vegetation of two Pacific Northwest river ecosystems. Ph.D. Dissertation, University of Washington, Seattle, WA.

Michener, M.C. 1983. Wetland site index for summarizing botanical studies. Normandeau Associates, Inc., Bedford, NH.

Mohler, C.L. 1979. Analysis of floodplain vegetation of the lower Neches drainage, southeast Texas, with some considerations on the use of regression and correlation in plant synecology. Ph.D. Dissertation, Cornell University, Ithaca, NY.

Montanari, J.H., and J.E. Townsend. 1977. Status of the national wetlands inventory. Trans. N. Am. Wildl. Nat. Resour. Conf. 42:66-72.

Pantle, R., and H. Buck. 1955. Die biologische Uberwachung der Gewasser und die Darstellung der Ergebnisse. Gas- und Wasserfach 96:604.

Reed, P.B., Jr. 1986. Wetland plant list (50 states). National Wetlands Inventory, U.S. Fish and Wildlife Service. St. Petersburg, FL.

Sanders, D.R., Sr., W.B. Parker, S.W. Forsythe, and R.T. Huffman. 1985. Wetlands delineation manual. Wetlands Research Program, Technical Report Y-84. Environmental Laboratory, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS.

SAS Institute. 1982. SAS user's guide: statistics. Statistical Analysis System, Cary, NC.

Shaw, S.P., and C.G. Fredine. 1956. Wetlands of the United States. U.S. Fish and Wildlife Service, Circ. 39.

Sipple, W.S. 1985. Wetland identification and delineation manual. U.S. Environmental Protection Agency, Office of Federal Activities, Washington, DC.

Sladecek, V. 1973. System of water quality from biological point of view. Ergebn. Limnol. 7:1-28.

Sladecek, V. 1976. Determination of the saprobic index. Czech Ministry of Water Economy, Prague, Methodological Instructions 11:1-181.

Sladecek, V. 1979. Continental systems for the assessment of river water quality. Chapter 3 in A. James and L. Evison (eds.) Biological Indicators of Water Quality. John Wiley and Sons, New York.

Sladecek, V., and F. Tucek. 1975. Relation of the saprobic index to BOD_5. Water Res. 9:791-794.

Soil Conservation Service. 1985. Hydric soils of the United States. Soil Conservation Service, U.S. Department of Agriculture, Washington, DC.

Whittaker, R.H. 1951. A criticism of the plant association and climatic climax concepts. Northwest Science 25:17-31.

Whittaker, R.H. 1978. Direct gradient analysis. Pages 9-50 <u>in</u> R.H. Whittaker (ed.) Ordination of Plant Communities. <u>W.</u> Junk, The Hague.

TABLES

Table 1. Sample calculation of a stand weighted average. Data are from Mohler (1979), Stand 1. Index values are taken from the NWPSL.

Species in Stand	Importance Value	Index	Product (I.V. x Index)
Carpinus caroliniana	71.5	3[a]	214.5
Ilex decidua	2.3	2	4.6
Ilex opaca	8.1	4	32.4
Liquidambar styraciflua	2.1	3	6.3
Ulmus alata	9.5	4	38.0
	sum = 93.5		sum = 295.8

Weighted Average (WA) = sum of products/sum of importance values
= 295.8/93.5 = 3.16

[a] obligate = 1; fac. wetland = 2; facultative = 3; fac. upland = 4; upland (not on list) = 5

Table 2. Sample calculation of a stand index average. Data are from Mohler (1979), Stand 1. Index values are taken from NWPSL.

Species in Stand	Index Value
Carpinus caroliniana	3[a]
Ilex decidua	2
Ilex opaca	4
Liquidambar styraciflua	3
Ulmus alata	4
total species = 5	sum = 16

Index average (INAV) = sum of index values/total number of species
= 16/5 = 3.20

[a] obligate = 1; fac. wetland = 2; facultative = 3; fac. upland = 4; upland (not on list) = 5

Table 3. Ecological Indices.

Category	Range of % Frequency	Ecological Index	Freq. Midpoint Index
Obligate	0-1[a]	1	.5 (1)[b]
Fac. Wetland	1-33	2	17.2 (1.67)
Facultative	33-66	3	50.0 (3)
Fac. Upland	66-99	4	82.8 (4.33)
Upland	99-100	5	99.5 (5)

[a] We have reversed the usual definition of frequency classes; instead of representing the frequency of occurrence in wetlands, these numbers represent frequency of occurrence in uplands. This was done so the order of frequency midpoint index values would match that of the ecological index values.

[b] Values converted to the 1-5 scale.

Table 4. Means and other descriptive statistics for weighted averages (WA)[a] of 22 vegetation types on the Platte and North Platte Rivers, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation types from extreme upland (22) to extreme wetland (1) by R.L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
sandy meadow blowout	29	A	21	4.14	0.37	3.30	5.00	4.00-4.28
Juniperus/*Populus*	24	B B	18	3.59	0.23	3.18	3.98	3.49-3.69
prairie/hayfield	16	C B C B	22	3.52	0.54	2.43	4.59	3.23-3.81
shrub grassland	23	C B C B	14	3.42	0.36	2.74	4.17	3.26-3.58
Populus open meadow	20	C B D C B D	17	3.34	0.49	2.51	4.34	3.11-3.57
grazed grassland	20	C B D C D	15	3.33	0.27	2.99	3.97	3.20-3.46
Populus/*Elaeagnus*	22	C E D C E D	13	3.28	0.28	2.74	3.78	3.16-3.40
Populus/*Juniperus*	48	C E D C E D	19	3.27	0.23	2.79	3.78	3.20-3.34
mixed hardwood shrub	32	C E D E D	20	3.25	0.28	2.69	4.17	3.15-3.35
Populus shrub meadow	49	F E D F E	16	3.11	0.35	2.20	3.89	3.01-3.21
annual mudflat	16	F E F	8	3.02	0.67	1.73	4.57	2.66-3.38
Cornus/*Amorpha*	20	F G F G	10	2.95	0.40	2.26	3.71	2.76-3.14
Elaeagnus/*Populus*	18	F G F G	12	2.95	0.43	2.25	3.74	2.74-3.16
Populus shrub	27	F G G	11	2.88	0.42	1.72	3.57	2.71-3.05
Amorpha/*Cornus*	21	G	9	2.74	0.56	1.88	3.68	2.48-3.00
Amorpha/*Salix*	29	H H	5	2.32	0.49	1.44	3.26	2.13-2.51
perennial mudflat	46	I H I H	7	2.27	0.58	1.36	3.66	2.10-2.44
Populus/*Salix* wetland	34	I H I	6	2.17	0.47	1.36	2.99	2.01-2.33
Salix shrub	41	I J J	4	2.03	0.45	1.12	3.04	1.89-2.17
wetland meadow	15	K J K	2	1.87	0.48	1.20	2.63	1.60-2.14
Salix wetland	14	K	3	1.64	0.35	1.20	2.17	1.44-1.84
marsh	9	L	1	1.08	0.09	1.00	1.21	1.01-1.15

[a] WA stands for the basic weighted averaging algorithm.

Table 5. Means and other descriptive statistics for weighted averages (2X)[a] of 22 vegetation types on the Platte and North Platte Rivers, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation types from extreme upland (22) to extreme wetland (1) by R.L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
sandy meadow blowout	29	A	21	4.29	0.40	3.30	5.00	4.14-4.44
<u>Juniperus</u>/<u>Populus</u>	24	B	18	3.64	0.29	3.13	4.20	3.53-3.77
prairie/hayfield	16	C B	22	3.63	0.60	2.33	4.68	3.31-3.95
shrub grassland	23	C B D	14	3.37	0.47	2.56	4.37	3.17-3.57
<u>Populus</u> open meadow	20	C D	17	3.33	0.66	2.24	4.55	3.02-3.64
grazed grassland	20	E D	15	3.31	0.39	2.63	4.13	3.13-3.49
mixed hardwood shrub	32	F E D	20	3.26	0.35	2.65	4.44	3.13-3.39
<u>Populus</u>/<u>Elaeagnus</u>	22	F E D	13	3.25	0.36	2.44	3.93	3.09-3.41
<u>Populus</u>/<u>Juniperus</u>	48	F E D	19	3.24	0.29	2.56	3.84	3.16-3.32
<u>Populus</u> shrub meadow	49	F E G	16	3.00	0.45	1.87	4.05	2.87-3.13
annual mudflat	16	F G	8	2.97	0.77	1.50	4.76	2.56-3.38
<u>Elaeagnus</u>/<u>Populus</u>	18	G	12	2.82	0.58	1.88	3.80	2.53-3.11
<u>Cornus</u>/<u>Amorpha</u>	20	H G	10	2.75	0.52	1.95	3.80	2.51-2.99
<u>Populus</u> shrub	27	H G	11	2.69	0.53	1.47	3.55	2.40-2.90
<u>Amorpha</u>/<u>Cornus</u>	21	H	9	2.49	0.67	1.61	3.71	2.17-2.79
perennial mudflat	46	I	7	2.03	0.64	1.25	3.65	1.84-2.22
<u>Amorpha</u>/<u>Salix</u>	29	I	5	2.03	0.45	1.24	2.89	1.86-2.20
<u>Populus</u>/<u>Salix</u> wetland	34	J I	6	1.90	0.47	1.20	2.78	1.74-2.06
<u>Salix</u> shrub	41	J I	4	1.78	0.42	1.06	2.98	1.65-1.91
wetland meadow	15	J K	2	1.65	0.42	1.11	2.30	1.42-1.88
<u>Salix</u> wetland	14	K	3	1.42	0.29	1.11	2.00	1.25-1.59
marsh	9	L	1	1.04	0.05	1.00	1.11	1.00-1.08

[a] **2X** stands for a method of averaging in which the importance values of the obligate wetland and upland species were doubled for computations.

Table 6. Means and other descriptive statistics for weighted averages (10X)[a] of 22 vegetation types on the Platte and North Platte Rivers, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (22) to extreme wetland (1) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
sandy meadow blowout	29	A	21	4.58	0.46	2.81	5.00	4.41-4.75
prairie/hayfield	16	B	22	3.98	0.73	2.00	4.86	3.59-4.34
Juniperus/Populus	24	B	18	3.84	0.52	2.66	4.73	3.62-4.06
mixed hardwood shrub	32	C	20	3.28	0.61	2.00	4.85	3.06-3.50
Populus open meadow	20	C	17	3.24	1.10	1.69	4.88	2.73-3.75
shrub grassland	23	C	14	3.23	0.85	1.67	4.64	2.86-3.60
grazed grassland	20	C	15	3.23	0.89	1.62	4.43	2.81-3.65
Populus/Juniperus	48	CD	19	3.14	0.58	1.87	4.23	2.97-3.31
Populus/Elaeagnus	22	CDE	13	3.12	0.69	1.67	4.31	2.81-3.43
annual mudflat	16	DEF	8	2.74	1.03	1.14	4.95	2.19-3.29
Populus shrub meadow	49	EFG	16	2.70	0.80	1.29	4.55	2.47-2.93
Elaeagnus/Populus	18	FGH	12	2.52	0.98	1.27	4.11	2.03-3.01
Cornus/Amorpha	20	GHI	10	2.27	0.79	1.32	4.03	1.90-2.64
Populus shrub	27	HI	11	2.20	0.79	1.12	3.63	1.89-2.51
Amorpha/Cornus	21	IJ	9	1.96	0.85	1.16	3.79	1.57-2.35
perennial mudflat	46	JK	7	1.65	0.75	1.06	4.03	1.43-1.87
Amorpha/Salix	29	JKL	5	1.53	0.32	1.05	2.29	1.41-1.65
Salix shrub	41	KLM	4	1.43	0.39	1.01	3.00	1.31-1.55
Populus/Salix wetland	34	KLM	6	1.40	0.30	1.04	2.14	1.29-1.51
wetland meadow	15	KLM	2	1.31	0.26	1.02	1.86	1.17-1.45
Salix wetland	14	LM	3	1.16	0.21	1.02	1.82	1.04-1.28
marsh	9	M	1	1.00	0.01	1.00	1.03	0.99-1.01

[a] 10X stands for a method of averaging in which the importance values of the obligate wetland and upland species were increased 10 times for computations.

Table 7. Means and other descriptive statistics for index averages (INAV)[a] of 22 vegetation types on the Platte and North Platte Rivers, ordered by descending mean index average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (22) to extreme wetland (1) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
sandy meadow blowout	29	A	21	3.91	.37	3.13	5.00	3.77-4.05
Juniperus/Populus	24	B	18	3.53	.19	3.15	3.84	3.45-3.61
prairie/hayfield	16	BC	22	3.50	.27	2.83	3.85	3.36-3.64
Populus open meadow	20	BCD	17	3.35	.38	2.79	4.11	3.17-3.53
mixed hardwood shrub	32	CD	20	3.32	.22	2.94	3.83	3.24-3.40
Populus/Juniperus	48	DE	19	3.27	.21	2.90	3.73	3.21-3.33
Populus/Elaeagnus	22	DEF	13	3.18	.26	2.82	3.71	3.06-3.30
Populus shrub meadow	49	DEF	16	3.18	.26	2.56	3.74	3.10-3.26
shrub grassland	23	DEF	14	3.16	.36	2.40	3.86	3.00-3.32
grazed grassland	20	EFG	15	3.09	.21	2.76	3.44	2.99-3.19
Elaeagnus/Populus	18	FG	12	3.02	.34	2.41	3.50	2.85-3.19
Amorpha/Cornus	21	GH	9	2.91	.47	2.15	3.75	2.70-3.12
Cornus/Amorpha	20	GH	10	2.90	.38	1.83	3.47	2.72-3.08
Populus shrub	27	GH	11	2.89	.30	2.30	3.57	2.77-3.01
annual mudflat	16	HI	8	2.74	.50	1.90	4.00	2.47-3.01
Amorpha/Salix	29	I	5	2.66	.29	1.80	3.04	2.55-2.77
Populus/Salix wetland	34	J	6	2.44	.29	1.82	2.96	2.34-2.54
Salix shrub	41	JK	4	2.33	.38	1.53	3.04	2.21-2.45
wetland meadow	15	KL	2	2.16	.44	1.50	2.95	1.92-2.40
perennial mudflat	46	L	7	2.12	.40	1.56	3.00	2.00-2.24
Salix wetland	14	L	3	2.07	.23	1.70	2.58	1.94-2.20
marsh	9	M	1	1.31	.17	1.00	1.58	1.18-1.44

[a] INAV stands for index averaging, in which the index values (1-5) for each species present were added and the sum was divided by the number of species to yield the index average.

Table 8. Means and other descriptive statistics for weighted averages (WVMW)[a] of 22 vegetation types on the Platte and North Platte Rivers, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (22) to extreme wetland (1) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
sandy meadow blowout	29	A	21	81.64	9.06	59.19	99.50	78.19-85.09
Juniperus/Populus	24	B	18	68.20	6.67	56.31	89.77	65.38-71.02
prairie/hayfield	16	BC	22	64.76	15.16	33.16	89.47	56.68-72.84
shrub grassland	23	BC	14	63.52	10.42	42.09	80.75	59.01-68.03
grazed grassland	20	CD	15	60.74	7.76	47.52	77.21	57.11-64.37
Populus open meadow	20	CD	17	60.55	12.99	30.04	85.93	54.47-66.63
Populus/Elaeagnus	22	CD	13	59.35	8.33	42.96	74.85	55.66-63.04
Populus/Juniperus	48	CD	19	59.11	7.03	46.09	74.62	57.06-61.16
mixed hardwood shrub	32	CDE	20	57.78	7.91	40.65	80.54	54.92-60.64
Populus shrub meadow	49	DEF	16	54.46	10.08	30.00	76.67	51.55-57.37
Cornus/Amorpha	20	EFG	10	50.66	10.86	31.57	70.81	45.58-55.74
annual mudflat	16	EFG	8	50.51	18.60	15.56	88.74	40.60-60.42
Elaeagnus/Populus	18	FG	12	50.14	12.16	31.95	73.67	44.09-56.19
Populus shrub	27	FG	11	48.44	11.40	16.57	68.43	43.93-52.95
Amorpha/Cornus	21	G	9	45.06	15.43	18.13	73.33	38.04-52.08
Amorpha/Salix	29	H	5	34.25	13.40	11.46	61.74	29.15-39.35
perennial mudflat	46	HI	7	32.60	15.26	9.45	71.25	28.05-37.15
Populus/Salix wetland	34	HI	6	29.48	11.93	9.45	51.81	25.30-33.66
Salix shrub	41	IJ	4	26.61	11.92	3.15	54.40	22.85-30.37
wetland meadow	15	JK	2	21.49	12.51	3.87	42.11	14.56-28.42
Salix wetland	14	K	3	16.29	8.96	4.98	29.86	11.12-21.46
marsh	9	L	1	2.48	2.24	.50	6.17	.76--4.20

[a] WVMW stands for a method of averaging in which the index values are not 1-5, but are the midpoints of the frequency ranges used in the NWPSL to define the plant categories.

Table 9. Means and other descriptive statistics for index averages (WVMX)[a] of 22 vegetation types on the Platte and North Platte Rivers, ordered by descending mean index average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (22) to extreme wetland (1) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
sandy meadow blowout	29	A	21	75.78	9.78	54.38	99.50	72.06-79.50
Juniperus/Populus	24	B	18	65.91	5.19	54.50	74.19	63.72-68.10
prairie/hayfield	16	BC	22	64.24	7.74	44.99	74.05	60.12-68.36
Populus open meadow	20	BCD	17	60.73	10.52	44.11	81.09	55.81-65.65
mixed hardwood shrub	32	CD	20	60.03	6.12	49.07	74.67	57.82-62.24
Populus/Juniperus	48	CDE	19	58.64	5.90	48.33	71.92	56.92-60.36
Populus/Elaeagnus	22	DEF	13	56.30	7.34	46.11	71.14	53.05-59.55
Populus shrub meadow	49	DEF	16	56.21	7.08	36.67	71.64	54.17-58.25
shrub grassland	23	DEFG	14	55.22	9.79	35.69	74.68	50.99-59.45
grazed grassland	20	EFGH	15	53.21	5.64	44.49	62.87	50.57-55.85
Elaeagnus/Populus	18	FGH	12	51.65	9.16	35.44	64.21	47.09-56.21
Amorpha/Cornus	21	GH	9	49.55	12.71	28.44	72.60	43.76-55.34
Populus shrub	27	HI	11	48.80	8.28	31.87	66.45	45.52-52.08
Cornus/Amorpha	20	HI	10	48.47	10.32	19.78	62.60	43.64-53.30
annual mudflat	16	I	8	43.47	13.03	20.35	74.75	36.53-50.41
Amorpha/Salix	29	J	5	42.05	7.63	20.30	51.75	39.15-44.95
Populus/Salix wetland	34	K	6	36.03	7.94	19.51	51.38	33.25-38.81
Salix shrub	41	KL	4	33.33	10.06	11.54	52.72	30.15-36.51
wetland meadow	15	LM	2	28.51	12.32	8.83	49.97	21.69-35.33
perennial mudflat	46	M	7	27.66	10.55	13.24	51.01	24.52-30.80
Salix wetland	14	M	3	26.95	6.54	16.21	41.71	23.17-30.73
marsh	9	N	1	7.38	4.38	.50	15.61	4.01-10.75

[a] WVMX stands for a method of averaging in which the index values are the midpoints of the frequency ranges used in the NWPSL to define the plant categories and index averaging was used.

Table 10. Means and other descriptive statistics for weighted averages (WA)[a] of the mudflat vegetation types on the Platte and North Platte Rivers. The top lines indicate the weighted average scores of each type, and the bottom lines reflect the scores after elimination of the drawdown species. One stand (32, AM) has been eliminated because it was composed of only drawdown species. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation from extreme upland (22) to extreme wetland (1) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
		Original Scores (Drawdown Species Included)						
annual mudflat	16	A	8	3.02	0.67	1.73	4.57	2.66-3.38
perennial mudflat	46	B	7	2.27	0.58	1.36	3.66	2.10-2.44
		Revised Scores (Drawdown Species Deleted)						
annual mudflat	15	A	8	3.25	0.61	2.12	4.57	2.91-3.59
perennial mudflat	46	B	7	2.11	0.81	1.04	4.97	1.87-2.35

[a] WA stands for the basic weighted averaging algorithm.

Table 11. Percentage data for 22 vegetation types along the Platte and North Platte Rivers. Data for each type include: percentage of total species within the obligate (OBLI), facultative wet (FACW), facultative (FACU), facultative upland (FUPL), and upland (UPLA) categories; and, percentage of total cover for the species in these categories. Vegetation types ranked from extreme upland (22) to extreme wetland (1) by R. L. Kologiski (column headed RK Rank).

Vegetation Type	RK Rank	% SPECIES OBLI	FACW	FACU	FUPL	UPLA	HYDR[a]	% COVER OBLI	FACW	FACU	FUPL	UPLA	HYDR[a]
prairie/hayfield	22	2.01	11.0	37.6	33.4	16.0	84.0	1.42	11.7	36.2	34.6	16.1	83.9
sandy meadow blowout	21	2.81	5.00	18.9	44.8	28.5	71.5	1.58	3.37	12.0	45.4	37.6	62.4
mixed hardwood shrub	20	5.84	11.9	35.1	38.8	8.26	91.7	3.06	11.3	49.1	30.7	5.91	94.1
Populus/Juniperus	19	6.46	10.3	40.5	35.7	7.04	93.0	3.04	6.76	52.2	36.0	2.01	98.0
Juniperus/Populus	18	2.83	8.17	34.6	41.7	12.7	87.3	1.08	5.75	34.4	50.7	8.01	92.0
Populus open meadow	17	10.4	9.85	29.6	34.4	15.8	84.2	8.42	8.02	37.1	33.7	12.7	87.3
Populus shrub meadow	16	11.5	13.0	30.8	35.8	8.95	91.0	10.9	13.1	35.4	36.0	4.67	95.3
grazed grassland	15	11.1	18.2	30.9	30.0	9.72	90.3	7.62	15.9	21.0	46.5	9.00	91.0
shrub grassland	14	11.8	15.6	29.0	32.3	11.3	88.7	8.28	12.8	17.2	52.5	9.23	90.8
Populus/Elaeagnus	13	9.78	11.7	37.0	33.6	8.00	92.0	4.57	8.27	45.4	38.2	3.60	96.4
Elaeagnus/Populus	12	15.3	13.0	34.8	28.3	8.54	91.5	14.2	12.9	39.8	29.5	3.50	96.5
Populus shrub	11	18.5	13.9	31.7	31.5	4.44	95.6	17.8	10.2	41.3	28.0	2.75	97.2
Cornus/Amorpha	10	19.0	13.8	33.0	27.0	7.20	92.8	20.6	6.54	36.7	29.5	6.73	93.3
Amorpha/Cornus	9	20.8	11.0	30.2	32.0	5.97	94.0	28.0	7.96	31.3	28.0	4.71	95.3
annual mudflat	8	21.3	18.4	33.9	18.0	8.43	91.6	11.3	19.6	36.6	21.1	11.3	88.7
perennial mudflat	7	44.4	24.3	10.3	16.4	4.54	95.5	45.2	15.7	10.7	23.5	4.87	95.1
Populus/Salix wetland	6	30.8	18.5	29.9	18.0	2.87	97.1	42.5	11.4	33.4	11.9	0.72	99.3
Amorpha/Salix	5	26.2	18.9	23.7	25.4	5.86	94.1	44.8	13.8	9.76	28.2	3.45	96.6
Salix shrub	4	39.1	19.0	18.0	17.8	6.20	93.8	57.1	8.79	13.0	16.0	5.04	95.0
Salix wetland	3	47.4	15.6	20.7	15.3	0.97	99.0	68.3	11.1	9.66	9.94	0.99	99.0
wetland meadow	2	41.2	22.6	19.1	13.1	4.02	96.0	54.6	15.1	20.6	8.15	1.59	98.4
marsh	1	79.6	11.6	6.91	1.85	0.00	100.0	95.7	1.15	2.39	0.74	0.00	100.0

[a] Hydrophytes include OBLI, FACW, FACU, and FUPL categories.

Table 12. Percentage data for 22 vegetation types along the Platte and North Platte Rivers. Data for each type include: percentage of total species within the obligate (OBLI) and facultative wet (FACW) categories; and, percentage of total cover for the species in these categories. Vegetation types ranked from extreme upland (22) to extreme wetland (1) by R. L. Kologiski (column headed RK Rank).

Vegetation Type	N	RK Rank	% SPECIES			% COVER			
			OBLI	FACW	HYDR[a]	OBLI	FACW	HYDR[a]	WI[b]
prairie/hayfield	16	22	2.01	11.00	13.00	1.42	11.70	13.20	13.1
sandy meadow blowout	29	21	2.81	5.00	7.82	1.58	3.37	4.95	6.4
mixed hardwood shrub	32	20	5.84	11.90	17.80	3.06	11.30	14.30	16.1
Populus/Juniperus	48	19	6.46	10.30	16.80	3.04	6.76	9.80	13.3
Juniperus/Populus	24	18	2.83	8.17	11.00	1.08	5.75	6.83	8.9
Populus open meadow	20	17	10.40	9.85	20.20	8.42	8.02	16.40	18.3
Populus shrub meadow	49	16	11.50	13.00	24.50	10.90	13.10	23.90	24.2
grazed grassland	20	15	11.10	18.20	29.30	7.62	15.90	24.50	26.9
shrub grassland	23	14	11.80	15.60	27.40	8.28	12.60	21.00	24.2
Populus/Elaeagnus	22	13	9.78	11.70	21.40	4.57	8.27	12.80	17.1
Elaeagnus/Populus	18	12	15.30	13.00	28.40	14.20	12.90	27.20	27.8
Populus shrub	27	11	18.50	13.90	32.40	17.80	10.20	27.90	30.2
Cornus/Amorpha	20	10	19.00	13.80	32.80	20.60	6.54	27.10	30.0
Amorpha/Cornus	21	9	20.80	11.00	31.80	28.00	7.79	35.90	33.9
annual mudflat	16	8	21.40	18.40	39.70	11.30	19.60	30.90	35.3
perennial mudflat	46	7	44.40	24.30	68.70	45.20	15.70	60.90	64.8
Populus/Salix wetland	34	6	30.80	18.50	49.20	42.50	11.40	53.90	51.6
Amorpha/Salix	29	5	26.20	18.90	45.10	44.80	13.80	58.60	51.9
Salix shrub	41	4	39.10	19.00	58.00	57.10	8.79	65.90	62.0
Salix wetland	14	3	47.40	15.60	63.00	68.30	11.10	79.40	71.2
wetland meadow	15	2	41.20	22.60	63.70	54.60	15.10	69.70	66.7
marsh	9	1	79.60	11.60	91.20	95.70	1.15	96.90	94.1

[a] Hydrophytes include OBLI and FACW categories.
[b] Wetland Indicator = (% HYDR SP + % HYDR CV)/2.

Table 13. Spearman correlation coefficients for percentage data in Table 12. Correlations made between RK Ranking and percentage data, and all combinations of percentage data. Significant correlations ($p < .05$) are indicated by an asterisk.

	RK RANK	OBLI SP	FACW SP	HYDR SP	OBLI CV	FACW CV	HYDR CV
RK RANK	1.0000	.96951*	.68437*	.95709*	.94918*	.18351	.94466*
OBLI SP		1.0000	.70472*	.98080*	.97290*	.23207	.96951*
FACW SP			1.0000	.77084*	.64708*	.71772*	.70698*
HYDR SP				1.0000	.95144*	.30548	.96725*
OBLI CV					1.0000	.15076	.96951*
FACW CV						1.0000	.29531
HYDR CV							1.0000

Table 14. Summary data for all operations performed on Currier's (1981) Platte and North Platte Rivers data. Significant correlations ($p < .05$) are indicated by an asterisk.

Method of analysis	Range of means	Number of sig. diff. adj. means[a]	Minimum separation for diff.[a]	Number of overlaps of provisional 3.0 boundary	Spearman correlation coefficients RK Rank	WI correlation coefficients[b]
Weighted average (WA)	1.08-4.14 ($\bar{x}$=2.83, s.d.=.40)[c]	31	.46	5	.91782*	-.96784*
Weighted average (2X)	1.04-4.29 ($\bar{x}$=2.70, s.d.=.46)	31	.47	3	.92912*	NC[g]
Weighted average (10X)	1.00-4.58 ($\bar{x}$=2.52, s.d.=.63)	26	.58	7	.95001*	NC
Index average (INAV)[d]	1.31-3.91 ($\bar{x}$=2.87, s.d.=.31)	30	.34	7	.96018*	-.98157*
Weighted average (WVMW)[e]	1.08-4.28[h] ($\bar{x}$=2.89, s.d.=.44)	31	.46[h]	5[h]	.91643*	NC
Index average (WVMX)[f]	1.28-4.04[h] ($\bar{x}$=2.91, s.d.=.35)	29	.36[h]	5[h]	.95934*	NC

a Refer to methods section, Statistical Analysis item 4, for discussion of these parameters.
b Wetland Indicator for each type correlated with mean for that type.
c Overall average mean and standard deviation.
d INAV stands for index averaging method.
e WVMW stands for method in which index values are midpoints of frequency ranges used in the NWPSL to define the categories of plants.
f WVMX stands for method in which index values are midpoints of frequency ranges in NWPSL and index averaging is used.
g Not calculated.
h Values converted to 1-5 scale for comparative purposes.

Table 15. Means and other descriptive statistics for weighted averages (WA)[a] of 9 vegetation types in the Green Swamp, NC, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (1) to extreme wetland (9) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
Pine-Graminoid Savanna	12	A	1	3.32	.31	2.86	3.83	3.12-3.52
Pine-Ericalean Savanna	9	B	2	2.75	.32	2.16	3.19	2.50-3.00
Pine-mixed Shrub	10	B	3	2.68	.37	2.11	3.30	2.42-2.94
Deciduous Bay Forest	18	C	5	2.17	.17	1.75	2.53	2.09-2.25
Conifer-Hardwood Pocosin	51	CD	4	2.08	.17	1.51	2.37	2.03-2.13
Evergreen Bay Forest	45	D	6	1.98	.10	1.70	2.26	1.95-2.01
Pine-Ericalean Pocosin	54	E	8	1.73	.21	1.36	2.42	1.67-1.79
Atl. White Cedar Forest	9	E	7	1.66	.21	1.40	1.98	1.50-1.82
Sedge Bog	12	F	9	1.33	.14	1.07	1.56	1.24-1.42

[a] WA stands for the basic weighted averaging algorithm.

Table 16. Means and other descriptive statistics for weighted averages (2X)[a] of 9 vegetation types in the Green Swamp, NC, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (1) to extreme wetland (9) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
Pine-Graminoid Savanna	12	A	1	3.32	.33	2.75	3.83	3.11-3.53
Pine-Mixed Shrub	10	B	3	2.72	.39	2.11	3.36	2.44-3.00
Pine-Ericalean Savanna	9	B	2	2.72	.35	2.09	3.19	2.45-2.99
Deciduous Bay Forest	18	C	5	2.14	.21	1.55	2.49	2.04-2.24
Conifer-Hardwood Pocosin	51	CD	4	2.01	.21	1.33	2.35	1.95-2.07
Evergreen Bay Forest	45	D	6	1.94	.15	1.53	2.26	1.89-1.99
Pine-Ericalean Pocosin	54	E	8	1.60	.26	1.22	2.39	1.53-1.67
Atl. White Cedar Forest	9	E	7	1.47	.19	1.24	1.76	1.33-1.62
Sedge Bog	12	F	9	1.21	.10	1.04	1.38	1.15-1.27

[a] 2X stands for a method of averaging in which the importance values of the obligate wetland and upland species were doubled for computations.

Table 17. Means and other descriptive statistics for index averages (INAV)[a] of 9 vegetation types in the Green Swamp, NC, ordered by descending mean index average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different. The column headed "RK Rank" represents a ranking of the vegetation data from extreme upland (1) to extreme wetland (9) by R. L. Kologiski.

Vegetation Type	N	Duncan's Test	RK Rank	mean	s.d.	min.	max.	95% c.i.
Pine-Graminoid Savanna	12	A	1	2.80	.27	2.31	3.20	2.63-2.97
Pine-Mixed Shrub	10	B	3	2.65	.21	2.25	3.00	2.50-2.80
Pine-Ericalean Savanna	9	B	2	2.53	.22	2.14	2.80	2.36-2.70
Deciduous Bay Forest	18	C	5	2.12	.18	1.89	2.60	2.03-2.21
Atl. White Cedar Forest	9	D	7	1.99	.06	1.89	2.07	1.94-2.04
Evergreen Bay Forest	45	D	6	1.98	.17	1.75	2.80	1.93-2.03
Conifer-Hardwood Pocosin	51	D	4	1.94	.12	1.70	2.33	1.91-1.97
Pine-Ericalean Pocosin	54	E	8	1.66	.20	1.22	2.00	1.61-1.71
Sedge Bog	12	E	9	1.66	.16	1.38	1.91	1.56-1.76

[a] INAV stands for index averaging, in which the index values (1-5) for each species present were added and the sum was divided by the number of species to yield the index average.

Table 18. Percentage data for 9 vegetation types in the Green Swamp, NC. Data for each type include: percentage of total species within the obligate (OBLI), facultative wet (FACW), facultative (FACU), facultative upland (FUPL), and upland (UPLA) categories; and, percentage of total cover for the species in these categories. Vegetation types ranked from extreme upland (1) to extreme wetland (9) by R. L. Kologiski (column headed RK Rank).

Vegetation Type	RK Rank	% SPECIES						% COVER					
		OBLI	FACW	FACU	FUPL	UPLA	HYDR[a]	OBLI	FACW	FACU	FUPL	UPLA	HYDR[a]
Pine-Graminoid Savanna	1	2.29	37.4	42.9	13.0	4.40	95.6	1.67	30.4	40.4	24.9	2.63	97.4
Pine-Ericalean Savanna	2	6.91	45.4	36.9	9.35	1.43	98.6	5.55	39.9	44.4	9.33	0.81	99.2
Pine-mixed Shrub	3	0.80	53.3	31.6	8.81	5.58	94.4	0.63	51.2	32.0	11.6	4.54	95.5
Deciduous Bay Forest	4	12.4	65.8	19.8	1.41	0.64	99.4	8.75	69.0	21.2	0.78	0.34	99.7
Conifer-Hardwood Pocosin	5	18.5	68.9	12.4	0.22	0.00	100.0	14.2	71.7	13.9	0.28	0.00	100.0
Evergreen Bay Forest	6	13.4	75.8	10.4	0.22	0.22	99.8	10.0	81.9	7.86	0.13	0.13	99.9
Pine-Ericalean Pocosin	7	6.91	45.4	36.9	9.35	1.44	98.6	5.55	39.9	44.4	9.34	0.81	99.2
Atl. White Cedar Forest	8	14.8	71.9	13.3	0.00	0.00	100.0	22.8	64.9	12.4	0.00	0.00	100.0
Sedge Bog	9	38.1	58.2	3.72	0.00	0.00	100.0	47.8	50.0	2.19	0.00	0.00	100.0

[a] Hydrophytes include OBLI, FACW, FACU, and FUPL categories.

Table 19. Percentage data for 9 vegetation types in the Green Swamp, NC. Data for each type include: percentage of total species within the obligate (OBLI) and facultative wet (FACW) categories; and, percentage of total cover for the species in these categories. Vegetation types ranked from extreme upland (1) to extreme wetland (9) by R. L. Kologiski (column headed RK Rank).

Vegetation Type	N	RK Rank	% SPECIES OBLI	% SPECIES FACW	% SPECIES HYDR[a]	% COVER OBLI	% COVER FACW	% COVER HYDR[a]	WI[b]
Pine-Graminoid Savanna	12	1	2.29	37.4	39.7	1.67	30.4	32.1	35.9
Pine-Ericalean Savanna	9	2	6.91	45.4	52.3	5.55	39.9	45.5	48.9
Pine-mixed Shrub	10	3	.80	53.3	54.1	.63	51.2	51.8	53.0
Deciduous Bay Forest	18	4	12.4	65.8	78.2	8.75	69.0	77.8	78.0
Conifer-Hardwood Pocosin	51	5	18.5	68.9	87.4	14.2	71.7	85.9	86.7
Evergreen Bay Forest	45	6	13.4	75.8	89.2	10.0	81.9	91.9	90.6
Pine-Ericalean Pocosin	54	7	6.91	45.4	52.3	5.55	39.9	45.5	48.9
Atl. White Cedar Forest	9	8	14.8	71.9	86.7	22.8	64.9	87.7	87.2
Sedge Bog	12	9	38.1	58.2	96.3	47.8	50.0	97.8	97.1

[a] Hydrophytes include OBLI and FACW categories.
[b] Wetland Indicator = (% HYDR SP + % HYDR CV)/2.

Table 20. Spearman correlation coefficients for percentage data in Table 19. Correlations made between RK Ranking and percentage data, and all combinations of percentage data. Significant correlations ($p < .05$) are indicated by an asterisk.

	RK RANK	OBLI SP	FACW SP	HYDR SP	OBLI CV	FACW CV	HYDR CV
RK RANK	1.0000	.74478*	.54394	.71130*	.79499*	.32636	.76151*
OBLI SP		1.0000	.66387*	.84874*	.98319*	.51261	.83193*
FACW SP			1.0000	.81513*	.68067*	.93277*	.83193*
HYDR SP				1.0000	.83193*	.73109*	.98319*
OBLI CV					1.0000	.47899	.84874*
FACW CV						1.0000	.69748*
HYDR CV							1.0000

Table 21. Summary data for all operations performed on Kologoski's (1977) Green Swamp data. Significant correlations ($p < .05$) are indicated by an asterisk.

Method of analysis	Range of means	Number of sig. diff. adj. means[a]	Minimum separation for diff.[a]	Number of overlaps of provisional 3.0 boundary	Spearman correlation coefficients RK Rank	WI correlation coefficients[b]
Weighted average (WA)	1.33-3.32 ($\bar{X}$=2.19, s.d.=.22)[c]	11	.43	2	.96667*	-.77210*
Weighted average (2X)	1.21-3.32 ($\bar{X}$=2.13, s.d.=.24)	11	.47	2	.96235*	NC[e]
Index average (INAV)[d]	1.66-2.80 ($\bar{X}$=2.15, s.d.=.18)	10	.27	0	.86193*	-.67918*

a Refer to Methods section, Statistical Analysis item 4, for discussion of these paramenters.
b Wetland Indicator for each type correlated with mean for that type.
c Overall average mean and standard deviation.
d INAV stands for index averaging method.
e Not calculated.

Table 22. Means and other descriptive statistics for weighted averages (WA)[a] of 5 vegetation types in the Big Thicket, TX, ordered by descending mean weighted average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different.

Vegetation Type	N	Duncan's Test	mean	s.d.	min.	max.	95% c.i.
Floodplain Hardwood Pine Forest	15	A	3.09	.22	2.65	3.51	2.97–3.21
Floodplain Hardwood Forest	81	A	2.80	.38	1.49	3.59	2.72–2.88
Flatland Hardwood Forest	8	B	2.45	.52	1.46	2.84	2.02–2.88
Floodplain Baygall Forest	4	B	2.35	.19	2.08	2.48	2.05–2.65
Swamp Cypress-Tupelo Forest	24	C	1.49	.41	1.00	2.50	1.32–1.66

[a] WA stands for the basic weighted averaging algorithm.

Table 23. Means and other descriptive statistics for index averages (INAV)[a] of 5 vegetation types in the Big Thicket, TX, ordered by descending mean index average. Also presented are the results of Duncan's Multiple Range Test, which controlled the comparisonwise error rate at $p < .05$; means with the same letter are not significantly different.

Vegetation Type	N	Duncan's Test	mean	s.d.	min.	max.	95% c.i.
Floodplain Hardwood Pine Forest	15	A	3.05	.20	2.63	3.33	2.94-3.16
Floodplain Hardwood Forest	81	AB	2.78	.34	1.89	3.44	2.70-2.86
Flatland Hardwood Forest	8	B	2.55	.24	2.11	2.88	2.35-2.75
Floodplain Baygall Forest	4	B	2.51	.21	2.33	2.75	2.18-2.84
Swamp Cypress-Tupelo Forest	24	C	1.92	.41	1.00	2.75	1.75-2.09

[a] INAV stands for index averaging method.

Table 24. Summary data for all operations performed on Mohler's (1979) Big Thicket data. Significant correlations ($p < .05$) are indicated by an asterisk.

Method of analysis	Range of means	Number of sig. diff. adj. means[a]	Minimum separation for diff.[a]	Number of overlaps of provisional 3.0 boundary	Spearman correlation coefficients[c]
Weighted average (WA)	1.49–3.09 ($\bar{x}$=2.44, s.d.=.34)[b]	5	.65	1	WAO = .75683* WAPS = .57484* RAO = .75563* % Sand = .24689*
Index average (INAV)[d]	1.92–3.05 ($\bar{x}$=2.56, s.d.=.28)	5	.62	1	WAO = .71697* WAPS = .57629* RAO = .74616* % Sand = .23091*

a Refer to Methods section, Statistical Analysis item 4, for discussion of these parameters.
b Overall mean and standard deviation.
c Weighted averaging ordination, weighted averaging pseudoelevation, reciprocal averaging ordination, and percent sand in soil of stands.
d INAV stands for index averaging method.

Table 25. Weighted averages (WA)[a] and descriptive data for 17 vegetation types along the Flathead River, Flathead County, Montana, arranged by descending weighted average. All data from Lee (1983).

Vegetation Type	WA	DECORANA[b]	LAE[c]	Classification[d]	WB[e]	Soil Type[f]
Artemisia tridentata/Festuca scabrella	4.46	1	0.7	Upland	NA[g]	NA
Pseudotsuga menziesii/Symphoricarpos albus and Pseudotsuga menziesii/ Festuca scabrella	4.33	4	6.5	Upland	NA	NA
Abies lasiocarpa types, combined	4.29	3	15.9	Upland	-30.3	NA
Picea/Vaccinium caespitosum	4.09	2	10.4	Upland	-61.3	Andic Xerochrept
Picea/Clintonia uniflora/Clintonia uniflora	3.97	7	19.6	PFO	-43.5	Aeric Fluvaquent
Picea/Clintonia uniflora/Vaccinium caespitosum	3.94	6	19.2	Upland	-67.7	Andic Xerochrept
Picea/Smilacina stellata	3.83	8	17.5	Upland	NA	NA
Populus trichocarpa wash	3.83	11	0.3	PFO	NA	NA
Grazed Wetland	3.64	13	0.9	PEM, PSS	NA	NA
Populus trichocarpa/Salix Island	3.52	14	1.2	PFO	NA	NA
Festuca scabrella Grassland	3.40	5	0.9	Upland	-52.8	Xerollic Xerochrept
Populus trichocarpa/Hedysarum sulphrescens/ Arctostaphylos uva-ursi	3.37	9	4.1	PFO	NA	NA
Picea/Equisetum arvense	3.34	12	13.9	PFO	-50.8	Typic Fluvaquent
Picea/Galium triflorum	3.20	10	6.8	PFO	-39.1	Aeric Fluvaquent
Stream Channel	2.85	15	2.0	PFO	NA	NA
Salix/Carex Wetland	2.09	16	1.3	PFO, PSS	NA	Borofibrist Histosol
Equisetum Wetland	1.19	17	1.3	PEM	-72.9	Borofibrist Histosol

[a] WA stands for the basic weighted averaging algorithm.
[b] Rank based upon detrended correspondence analysis, from thesis.
[c] Leaf Area Estimate, from dissertation.
[d] Based on Cowardin et al. 1979.
[e] Site Water Balance, from dissertation.
[f] Soils data taken from dissertation.
[g] Not available.

Table 26. Index averages (INAV)[a] and descriptive data for 17 vegetation types along the Flathead River, Flathead County, Montana, arranged by descending index average. All data from Lee (1983).

Vegetation Type	INAV	DECORANA[b]	LAE[c]	Classification[d]	WB[e]	Soil Type[f]
Abies lasiocarpa types, combined	4.40	3	15.9	Upland	-30.3	NA[g]
Picea/Vaccinium caespitosum	4.31	2	10.4	Upland	-61.3	Andic Xerochrept
Pseudotsuga menziesii/Symphoricarpos albus and Pseudotsuga menziesii/Festuca scabrella	4.31	4	6.5	Upland	NA	NA
Artemisia tridentata/Festuca scabrella	4.16	1	0.7	Upland	NA	NA
Picea/Clintonia uniflora/Vaccinium caespitosum	4.04	6	19.2	Upland	-67.7	Andic Xerochrept
Picea/Clintonia uniflora/Clintonia uniflora	4.03	7	19.6	PFO	-43.5	Aeric Fluvaquent
Picea/Smilacina stellata	3.83	8	17.5	Upland	NA	NA
Grazed wetland	3.75	13	0.9	PEM, PSS	NA	NA
Populus trichocarpa wash	3.67	11	0.3	PFO	NA	NA
Populus trichocarpa/Hedysarum sulphrescens/Arctostaphylos uva-ursi	3.56	9	4.1	PFO	NA	NA
Stream channel	3.55	15	2.0	PFO	NA	NA
Picea/Galium triflorum	3.51	10	6.8	PFO	-39.1	Aeric Fluvaquent
Festuca scabrella grassland	3.50	5	0.9	Upland	-52.8	Xerollic Xerochrept
Picea/Equisetum arvense	3.46	12	13.9	PFO	-50.8	Typic Fluvaquent
Populus trichocarpa/Salix Island	3.44	14	1.2	PFO	NA	NA
Salix/Carex Wetland	2.67	16	1.3	PFO, PSS	NA	Borofibrist Histosol
Equisetum Wetland	1.67	17	1.3	PEM	-72.9	Borofibrist Histosol

a INAV stands for index averaging method.
b Rank based upon detrended correspondence analysis, from thesis.
c Leaf Area Estimate, from dissertation.
d Based on Cowardin et al. 1979.
e Site Water Balance, from dissertation.
f Soils data taken from dissertation.
g Not available.

Table 27. Weighted averages (WA)[a] and descriptive data for 13 vegetation types along the Suiattle River, Skagit and Snohomish Counties, Washington, arranged by descending weighted average. All data from Lee (1983).

Vegetation Type	WA	DECORANA[b]	LAE[c]	Classification[d]	WB[e]	Soil Type[f]
Populus trichocarpa-Abies grandis thicket	4.25	8	13.8	PFO	-26.2	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Cornus canadensis	4.22	1	76.9	Upland	NA[g]	NA
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Physocarpus cappitatus	4.18	7	3.5	PFO	NA	NA
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Berberis nervosa	4.17	3	45.1	Upland	-18.0	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Hylocomium splendens	4.11	2	46.5	Upland	NA	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Tiarella trifoliata-Gymnocarpium dryopteris	3.99	5	20.0	Upland	-31.0	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Acer circinatum/Polystichum munitum	3.63	4	13.9	Upland	-45.2	Typic Dystrochrept
Populus trichocarpa-Alnus rubra/Acer circinatum/Rubus spectabilis/Equisetum hyemale	3.61	9	6.3	PFO	-31.1	Typic Udipsamment or Aeric Fluvaquent
Shrub Wetland	3.37	12	0.8	PSS	NA	NA
Cobble or sand bar	3.23	11	0.1	R2UB	-58.5	Udorthent
Tsuga heterophylla-Thuja plicata/Oplopanax horridum	3.16	6	12.9	PFO	NA	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Lysichitum americanum	2.90	10	1.7	PFO	NA	Typic Dystrochrept
Typha latifolia wetland	1.82	13	0.9	PEM	-28.5	NA

a WA stands for the basic weighted averaging algorithm.
b Rank based upon detrended correspondence analysis, from thesis.
c Leaf Area Estimate, from dissertation.
d based on Cowardin et al. 1979.
e Site Water Balance, from dissertation.
f Soils data taken from dissertation.
g Not available.

Table 28. Index averages (INAV)[a] and descriptive data for 13 vegetation types along the Suiattle River, Skagit and Snohomish Counties, Washington, arranged by descending index average. All data from Lee (1983).

Vegetation Type	INAV	DECORANA[b]	LAE[c]	Classification[d]	WB[e]	Soil Type[f]
Tsuga heterophylla-Thuja plicata/Cornus canadensis	4.24	1	76.9	Upland	NA[g]	NA
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Berberis nervosa	4.23	3	45.1	Upland	-18.0	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Hylocomium splendens	4.21	2	46.5	Upland	NA	Typic Dystrochrept
Populus trichocarpa-Abies grandis thicket	4.00	8	13.8	PFO	-26.2	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Acer circinatum/Polystichum munitum	4.00	4	13.9	Upland	-45.2	Typic Dystrochrept
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Physocarpus cappitatus	3.92	7	3.5	PFO	NA	NA
Tsuga heterophylla-Thuja plicata/Polystichum munitum/Tiarella trifoliata-Gymnocarpium dryopteris	3.88	5	20.0	Upland	-31.0	Typic Dystrochrept
Cobble or sand bar	3.61	11	0.1	R2UB	-58.5	Udorthent
Tsuga heterophylla-Thuja plicata/Oplopanax horridum	3.53	6	12.9	PFO	NA	Typic Dystrochrept
Populus trichocarpa-Alnus rubra/Acer circinatum/Rubus spectabilis/Equisetum hyemale	3.51	9	6.3	PFO	-31.1	Typic Udipsamment or Aeric Fluvaquent
Tsuga heterophylla-Thuja plicata/Lysichitum americanum	3.10	10	1.7	PFO	NA	Typic Dystrochrept
Shrub wetland	2.64	12	0.8	PSS	NA	NA
Typha latifolia wetland	2.00	13	0.9	PEM	-28.5	NA

[a] INAV stands for index averaging method.
[b] Rank based upon detrended correspondence analysis, from thesis.
[c] Leaf Area Estimate, from dissertation.
[d] Based on Cowardin et al. 1979.
[e] Site Water Balance, from dissertation.
[f] Soils data taken from dissertation.
[g] Not available.

FIGURE LEGENDS

FIGS. 1 - 11

Each of the following 11 figures utilizes the same common format. The horizontal axis represents the possible range of weighted average or index average scores, from 1.0 (extreme wetland) to 5.0 (extreme upland). The score of 3.0 has been selected as a provisional "break-point" between wetlands and uplands, and is indicated by the vertical boundary, marked "^". A small vertical bar (|) locates the mean score for each of the vegetation types on the horizontal axis. The 95% confidence intervals are marked with small horizontal bars (-). Each figure displays results from an analysis of a particular data set, as follows:

Fig. 1. Weighted averages (**WA**), Platte and North Platte Rivers.

Fig. 2. Weighted averages (**2X**), Platte and North Platte Rivers.

Fig. 3. Weighted averages (**10X**), Platte and North Platte Rivers.

Fig. 4. Index averages (**INAV**), Platte and North Platte Rivers.

Fig. 5. Weighted averages (**WVMW**), Platte and North Platte Rivers.

Fig. 6. Index averages (**WVMX**), Platte and North Platte Rivers.

Fig. 7. Weighted averages (**WA**), Green Swamp.

Fig. 8. Weighted averages (**2X**), Green Swamp.

Fig. 9. Index averages (**INAV**), Green Swamp.

Fig. 10. Weighted averages (**WA**), Big Thicket.

Fig. 11. Index averages (**INAV**), Big Thicket.

FIGURE 1

95% CONFIDENCE INTERVALS FOR WEIGHTED AVERAGES

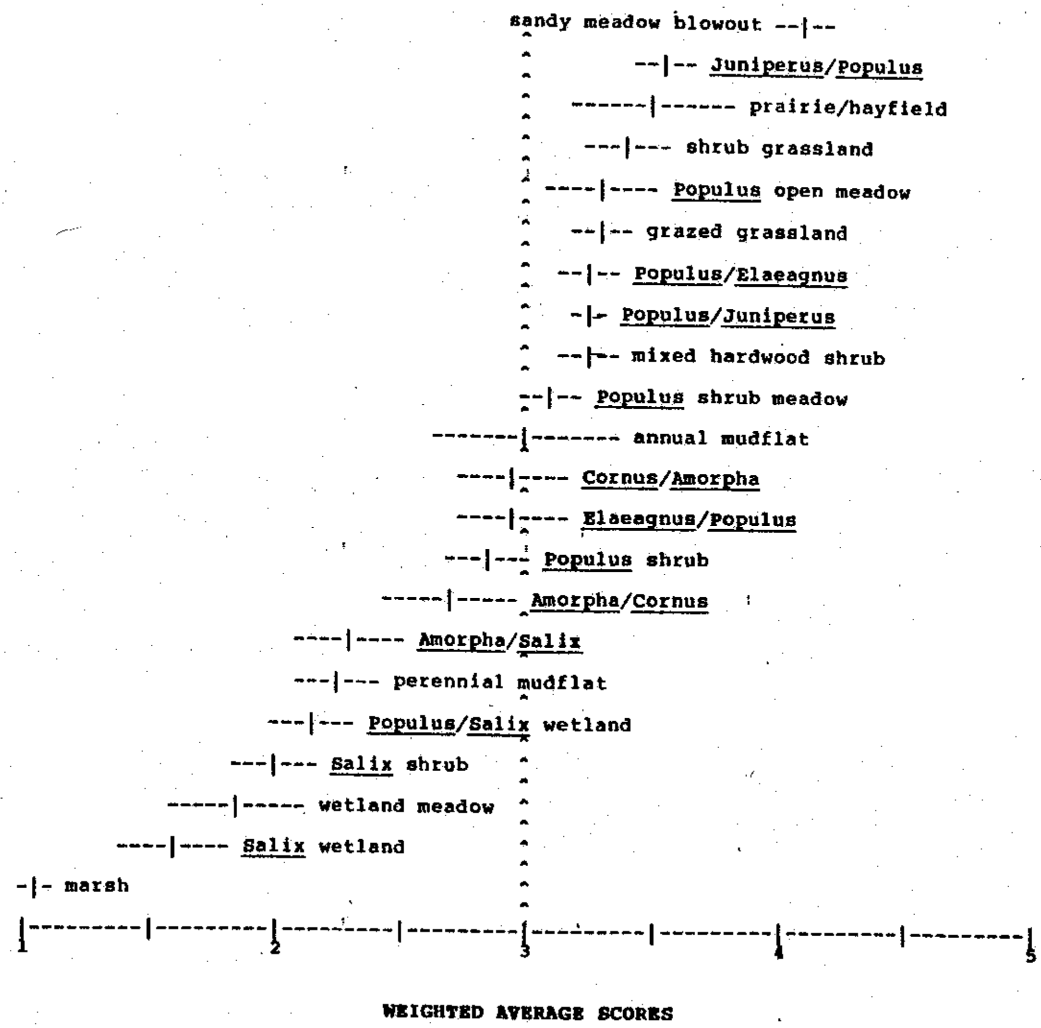
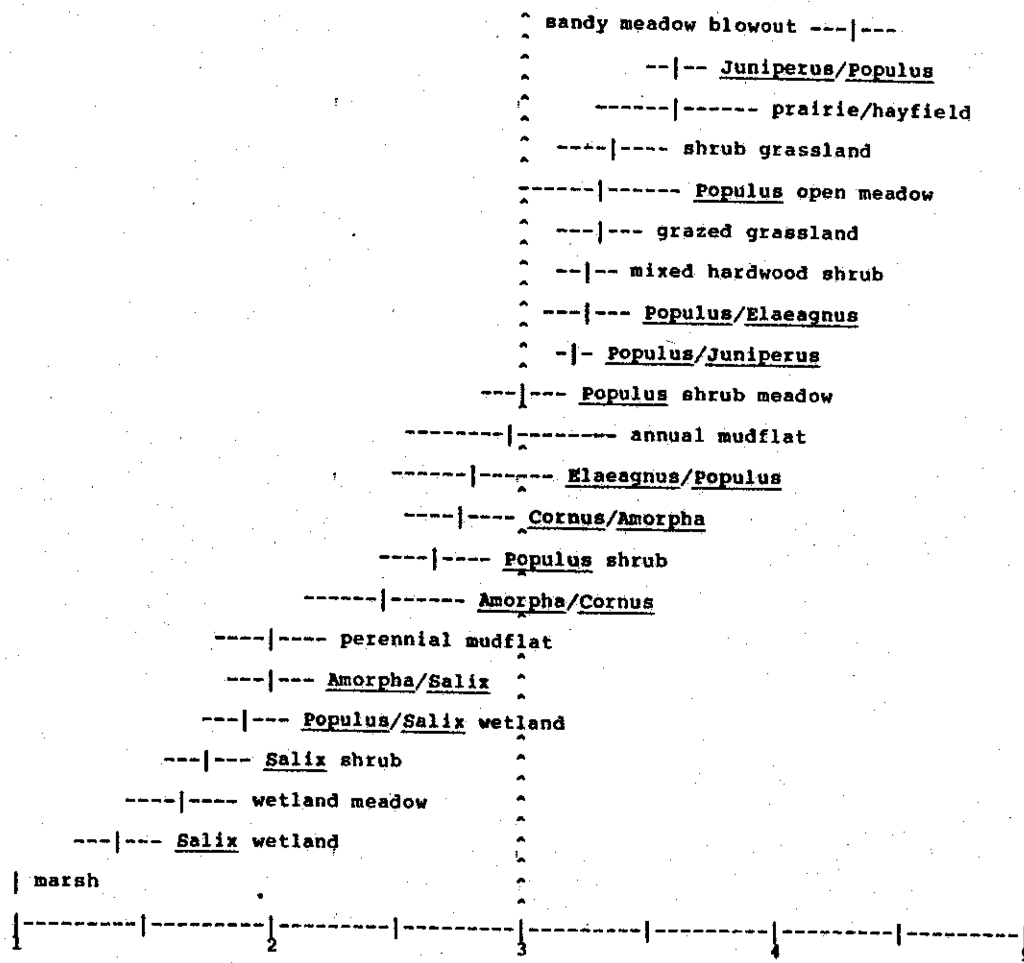


FIGURE 2

95% CONFIDENCE INTERVALS FOR WEIGHTED AVERAGES



WEIGHTED AVERAGE SCORES

FIGURE 3

95% CONFIDENCE INTERVALS FOR WEIGHTED AVERAGES

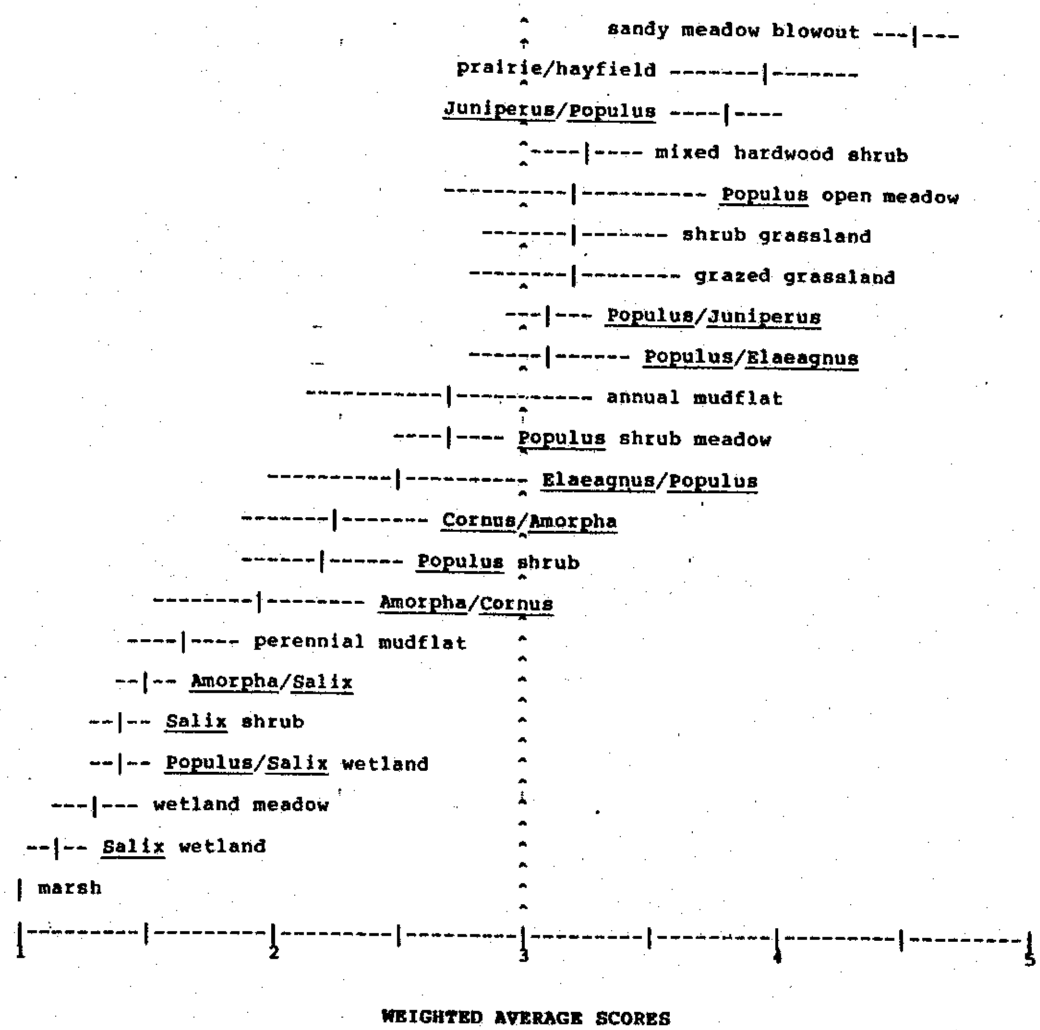


FIGURE 4

95% CONFIDENCE INTERVALS FOR INDEX AVERAGES