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WETLAND SITE INDEX FOR BOTANICAL STUDIES

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Abstract. By a series of simple arithmetic steps, a site list of plant species is reduced to a single Wetland Site Index number. The proposed method utilizes the U.S. Fish and Wildlife Service National Wetlands Inventory (FWSNWI) list of wetland indicator species as a database, and weights each species' contribution to the index by its relative abundance. A single number is produced, which represents the range of upland to wetland by values from zero to one, respectively. Preliminary results of fieldwork in the glaciated northeastern U.S. indicate that well drained soils produce communities with index values between 0.1 and 0.5; poorly drained soils between 0.5 and 0.7; and very poorly drained soils between 0.7 and 0.9. Permanently inundated soils (deeper swamps and marshes) produce values above 0.9. These values seem to concur well with wetland botanists' professional judgments of each community, and it is hoped that they will be useful as the basis for land-use planning decisions, particularly where plant communities show upland and wetland species and decisions have been previously in dispute.

INTRODUCTION

Scientists who routinely map wetlands for land-use planning need a simple means of using plant species lists to delineate boundaries between wetlands and adjacent upland areas. Such wetland-upland boundary decisions are of practical importance, and often play a part in many legal proceedings involving land use conflicts. In other fields, such as those involving water quality, animal species have been employed as indicators to form an overall value score or index (e.g. Hilsenhoff, 1982.)

Most wetland botanists agree qualitatively on the plant species which are reliably found on either wetland or upland sites, and on the frequency with which other species occur in both areas. Planners and engineers, on the other hand, are accustomed to precise quantitative determinations, and frequently express impatience when botanists take refuge during hearings in species by species delineations. To standardize this process, the U.S. Fish and Wildlife Service National Wetland Inventory (FWSNWI) is compiling a master list of all wetland indicator species for the United States (Reed 1979). The U.S. Environmental Protection Agency (EPA), the Soil Conservation Service (SCS), and the U. S. Army Corps of Engineers have cooperated in this effort. Each plant species is listed, in alphabetical order by scientific name, followed by a standardized common name, and is assigned to a category related to its frequency of occurrence on upland or wetland sites.

I propose that the next step is to take the species found at a particular site, and develop a wetland site index by means of a simple weighted average. Such an index will give both planners and biologists a good measure of the probability that the area should be designated as wetland.

METHODOLOGY CRITERIA

A method for quantifying "wetland-ness" should have these qualities:

1. Generation of a single number, allowing planners to compare various areas within a project or locality.

2. Reflection of actual frequencies or best estimates of such frequencies, with which plant forms occur in wetland areas, (agreement among wetland biologists familiar with the region should be sought).

3. The procedure should be flexible enough to allow for the incorporation of new information, permitting the database to be updated with refinements in the understanding of the hydrological requirements of the various plant species, thereby providing an increase in the precision of the methodology.

4. Avoidance of excessive dependence on the seasonal timing (as with some soil or hydrologic investigations), or intensity of site investigations, so that the relative upland-wetland value is not systematically biased by these factors.

5. The use of weighting so that index values reflect the relative abundances of each plant species; sparsely occurring species should not influence the index value as much as common species.

6. A straightforward computational protocol to facilitate acceptance by the broadest spectrum of potential users.

7. Numerical representation of the degree to which botanists are certain that the plant community represents "wetlands". Exceptional or intermediate communities should yield values which alert the user to possible ambiguity.

8. Thorough testing against a wide variety of wetland cases, including comparison among communities under different hydrological, geological, and soil conditions. Sufficient experience with the index should suggest additional uses, correlations with other environmental factors, limitations, and precautions against possible misuses.

DATABASE

The FWSNWI indicator species list was taken as the basis for developing the hydrologic categories for the index. If a site investigation revealed exclusively upland species or obligate

wetland species of plants, the judgment was obvious. Most sites, however, produced a list of plants with mixed categories. Table 1 shows the categories as defined by Reed (1981).

Table 1. Plant indicator categories as defined by the National Wetland Inventory

Name	Category	Description	Wetland Frequency Range
FACU	FACultative Upland	Seldom in wetlands	LESS THAN 33%
FAC	FACultative	Sometimes in wetlands	33 to 66%
FACW	FACultative Wetland	Usually in wetlands	66 to 95%
OBL	OBLigate	Almost Always in wetlands	MORE THAN 95%

Each plant species in the listing was evaluated by the FWSNWI for wetland or upland site preference. The frequency of wetlands occurrence was defined as the fraction of all the locations where the species was found associated with wetlands. Species designated as obligate hydrophytes (OBL) were found almost exclusively in wetland sites. This category includes all the plant species with frequencies falling between 96 and 100%.

Other species found predominantly in wetlands, but with a 5 to 33% incidence of upland sites, were designated as Wetland FACultative species (FACW), preferring wetlands. The FACultative species category (FAC), refers to plants able to tolerate wet and dry conditions. It includes species casually associated with wetlands, but tending to be associated also with uplands. This category includes all the species with wetland frequencies between 33% and 66%. Species designated as Upland FACultative (FACU) have wetland frequencies less than 33%. Species found infrequently in wetlands are not listed by the FWSNWI, and outnumber those in the above four categories.

The FWSWI has compiled wetland indicator species lists for the various biotic regions of the continental United States. Botanists within each region are presently reviewing each appropriate list for completeness and accuracy. Regional compilation avoids assuming that a plant remains in one category over its entire geographic range, and allows within-region placement of each species in the appropriate category during routine field work and assignment of categorical exceptions for the region when needed. Computer-printed lists of wetland indicator species are currently available from the FWSNWI on request. Users are invited to share hard field data with the FWSNWI center in St. Petersburg, FL, so that categories can be adjusted to represent regional differences in species' hydrological preferences.

INDEX METHODOLOGY

In developing the currently-proposed site index, certain modifications were made in the FWSNWI plant hydrologic categories (Table 1). Plant species omitted from the FWSNWI wetland indicator list were assigned "Upland" status (Table 2). Field experience in wetlands in New England has shown that many of these species occur in occasional association with wetland communities with approximately the same frequency with which many OBL species are found in uplands. This allowed five symmetric categories to be defined for the purpose of site index computations (Table 2).

Table 2. Plant indicator categories developed for calculation of wetland site index values

Name	Category and Examples	Wetland Frequency Range	Median Frequency	Computational Value Assigned
UPL	UPLand, e.g. Aster laevis, Danthonia spicata, Carex pensylvanica, Chimaphila umbellata.	0 - 4%	2%	0.00
FACU	FACultative, Upland, e.g. Dryopteris marginalis, Pinus strobus, Quercus alba, Carya ovata.	5 - 33%	19%	0.18
FAC	FACultative, e.g Acer rubrum Betula populifolia, Fraxinus americana, Kalmia angustifolia.	34 - 66%	50%	0.50
FACW	FACultative, Wetland, e.g. Osmunda cinnamomea, Aster novae-angliae, Viburnum cassinoides.	67 - 95%	81%	0.82
OBL	OBLigate, e.g Carex stricta, Onoclea sensibilis, Scirpus cyperinus, Calamagrostis canadensis, Juncus effusus.	96 - 100%	98%	1.00

Assignment of frequencies of 0 to 4% for the species of the UPL category was based on independent field experience and not on definitions developed by the FWSNWI. The limits for the FACU category (Table 2) were similarly based, and provide a 28% range for the FACU category, similar to that of the FACW category as defined by the FWSNWI. In short, I have proposed a new category (UPL), consisting of species unlisted by FWSNWI, with wetland site frequencies lying between 0 and 4%, and have redefined the FWSNWI category FACU as being species with frequencies between 5% and 33%.

Each category of plants listed for a study site should suggest a probability of wetness within its characteristic frequency range. For example, if only FAC species were identified at a site, the probability of the site being a wetland would be somewhere between .34 and .66, with the plants providing such ambiguous evidence of the sites "wetland-ness" that the proper site index would be 0.50. On the other hand, for a site containing only OBL species, the probability would lie somewhere between 0.96 and 1.00 that the site was a wetland, and the site index should be very high. The median of each frequency range (Table 2) is probably the best measure of each categories indication of "wetness".

In computing the site index, the median frequencies were adjusted by one or two percent, in proportion to their departure from 0.50, to allow the index to range over the full scale of 0 to 1, indicating the site's position in the range of upland to wetland.

SITES WITH MIXED CATEGORIES

Sites where all the listed plants belong to the same category are quite rare; therefore, a methodology representing sites with mixed categories, on the same scale as the rare single-category sites, also had to be developed. This methodology had the requirements that:

Plant species from different hydrological groups must all contribute to the final index score; and

Each species should contribute in proportion to its abundance, as estimated by the site observer.

The level of effort applied to investigating plant communities will differ from one study to another. In rigorous investigations, abundance is typically determined by sampling along transect lines, with reasonably standard sampling procedures used for the tree layer, the shrub layer, and the herbaceous layer. For practical decisions regarding wetland or floodplain zoning for building on houselots such detail is seldom required to resolve upland-wetland boundary decisions. In such cases, the relative abundance of plants is usually estimated by the experienced observer who simply visualizes percentage cover or areal dominance, or who counts stems.

Regardless of the sampling protocol followed, observers should have available to them a standardized method of measuring abundance, capable of weighting plant species categories. To illustrate the utility of such a weighting system, an example will be given of a very simple scheme where:

Plants which are dominant are given a 3 or higher;
Plants which are common are given a 2;
Plants which are sparsely distributed over the site are given a weight of 1.

Weighting given to each plant species will depend on whether many species are fairly evenly intermixed or whether one or two greatly dominate the area. It will also depend somewhat on the abilities of the observer to visually quantify the area covered by plants. The technique does not require great precision; only rough quantification of the species in different categories is needed.

The suggested method for indicating a site's "Wetland-ness" is to calculate an arithmetically weighted average of each category's "wetland-ness" scores, as shown in the examples given (Tables 3 & 4). The procedure is as follows: lump the species abundances within each category; multiply this by the computational value for that category. Add up the products formed by this process for all the categories present. Divide this sum of products by the sum of abundances for all five categories. In the example given in Table 3, red maples (*Acer rubrum*) dominate the area, and the field observer gives this species a 3 for the tree layer and a 2 for the saplings in the shrub layer, for a FAC category total of 5. There is a sparse herbaceous layer of cinnamon ferns, tussock sedges, and sensitive ferns, with each species receiving a 1 for abundance (Table 3). Cinnamon fern is a FACW species, giving this category a total abundance of 1. Tussock sedge and sensitive fern are OBL species, giving this category a total of 2. The result is a wetland site index of 0.665.

Table 3. Simple example of wetland site index calculation

Name of Category	Plant Species in the Category	Species Abundance	Total Category Abundance		Category Value		Product
FAC	Red Maple (*Acer rubrum*)	5	5	x	0.50	=	2.50
FACW	Cinnamon fern (*Osmunda cinnamomea*)	1	1	x	0.82	=	0.82
OBL	Sensitive fern (*Onoclea sensibilis*)	1					
	Tussock sedge (*Carex stricta*)	1					
			2	x	1.00	=	2.00
		TOTAL ABUNDANCE: 8				TOTAL PRODUCT:	5.32

To calculate Wetland Site Index:

TOTAL PRODUCT/TOTAL ABUNDANCE = 5.32/8 = 0.665

The same result is obtained by 1) dividing each category abundance by the total abundance, 2) multiplying the fraction obtained by the appropriate category value, and 3) summing. Thus:

5/8 = 0.625	x 0.50 =	0.3125
1/8 = 0.125	x 0.82 =	0.1025
2/8 = 0.250	x 1.00 =	0.2500
1 1.000		0.6650

In this simplified example, the contribution of each of the three categories of plants is clear: Five eighths of the observed plant abundance was contributed by FAC species. As a category, these are found in a ratio of 0.50 wetland to 0.50 upland sites. If red maples had been the only species on site, the final index value would have been 0.50. **A** sparse species in the FACW category, cinnamon fern, contributes a one eighth of its category value of 0.82, and two sparse OBL hydrophytes, tussock sedge and sensitive fern, contribute a weight of one eighth each, for a total of one quarter, to the OBL category value of 1.00. With these species present, the index value (0.665) shows the site to be a true wetland with a modest degree of "wetland-ness".

The example may be altered by substituting upland species for the wetland understory species used in the previous example. Species chosen for this example are: poverty grass (*Danthonia spicata*), pipsissewa (*Chimaphila umbellata*), and upland sedge (*Carex pensylvanica*), each found sparsely. The recalculated index (Table 4) then becomes 0.3125. Each UPL species contributes a value of zero to the overall "wetland-ness" of the site index. Such a vegetation

community is common to many northern New England hillsides, where soil and hydrological factors preclude a wetland situation.

Table 4. A second example of wetland site index calculation

Name of Category	Plant Species in the Category	Species Abundance	Total Category Abundance		Category Value		Product
FAC	Red Maple (*Acer rubrum*)	5	5	x	0.50	=	2.50
UPL	Poverty grass (*Danthonia spicata*)	1					
	Pipsissewa (*Chimaphila umbellata*)	1					
	Upland sedge (*Carex pensylvanica*)	1					
			3	x	0.00	=	0.00
		TOTAL ABUNDANCE: 8					TOTAL PRODUCT: 2.50

To calculate Wetland Site Index:

TOTAL PRODUCT/TOTAL ABUNDANCE = 2.50/8 = 0.3125

In using this or any other wetland site investigation, correct taxonomic identification is very important. For example, the upland and the tussock sedges, *Carex pensylvanica* and *C. stricta*, are relatively easy to distinguish in the field, although many sedge species are more difficult to differentiate. If identification can not be made to the level necessary to discriminate hydrological category, the taxon is omitted altogether from the index equation. Any plant specimen not in identifiable condition is left uncategorized; only positively identified taxa should influence the index value. This omission will bias the resulting index, especially where an abundant species cannot be correctly identified.

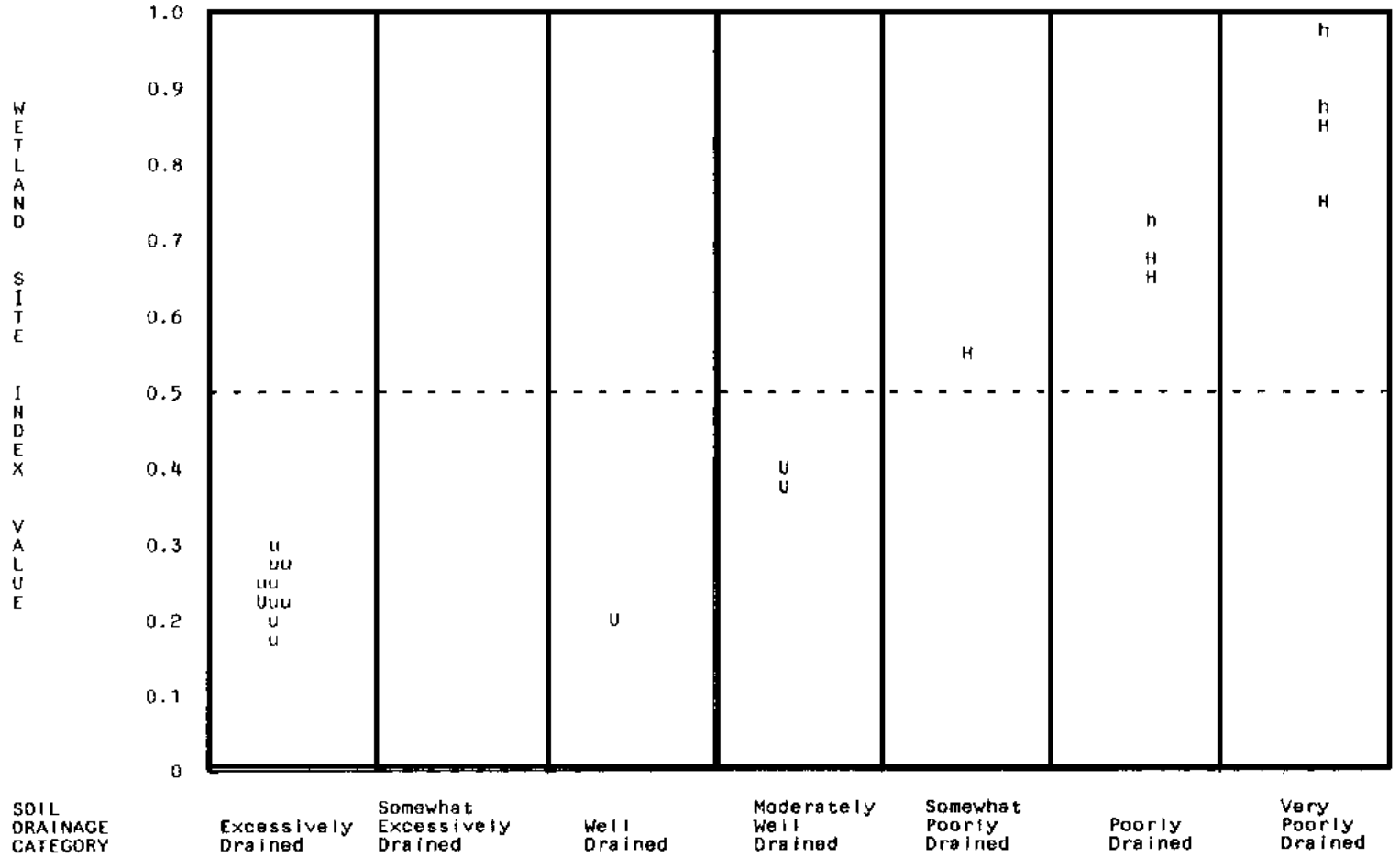
RESULTS AND USES

At Normandeau Associates, Inc. in NH, we have applied this indexing technique to more than 48 sites in New Hampshire, Massachusetts, and Connecticut. Two types of preliminary tests were made of the value of the index as an indicator: against soil drainage type and against the wetland-upland judgment of the author.

Sites in eastern Hillsborough County, NH, where recent soils information is available (Bond and Handler 1981), were censused for plant species in upland, wetland, and marginal locations. Of the 21 sites studied, nine were field checked by Mr. Russell J. Kelsea, soil scientist with the US Soil Conservation Service, whose support and help are hereby gratefully acknowledged. The results are shown in Figure 1. In every case where field work showed a soil to be hydric (a histosol, or in an aquic suborder, i.e. Poorly Drained, or Very Poorly Drained category), the wetland site index derived independently from the vegetation lists was found to lie above 0.5. Similarly, upland soils were found to support plant communities yielding wetland site index values consistently below 0.5.

In all 48 cases, independent of the availability of soils information, the judgement was made in the field as to the plant community belonging to one of four groups: clearly wetland, clearly upland, marginally wetland, or marginally upland. This was based on the author's experience with wetlands in New England. After the list of plants and abundances had been completed, the wetland site index was computed. The results are shown in Figure 2. As with the soils, in all 48 cases, the site index lay on the appropriate side of the 0.5 dividing line --above it for all wetlands, clearly or marginally so; below 0.5 for all uplands.

Since the proposed index is a rough measure of "wetland-ness" and not a precise way of comparing the desirability of sites for various purposes, it must be used with reasonable caution. To designate any site as wetland, based on a score of 0.51 or 0.52, would be an overzealous application of the method, unless the preponderance of hydrological or soils data (such evidence of deep muck or peat, or the presence of mottling near the surface) also indicated wetland properties. The index is not intended to replace investigations into the beneficial functions served by any wetland.



H = Field-checked hydric soils U = Field-checked upland soil h = Mapped hydric soil u = Mapped upland soil

Figure 1. Site index values versus soil drainage category

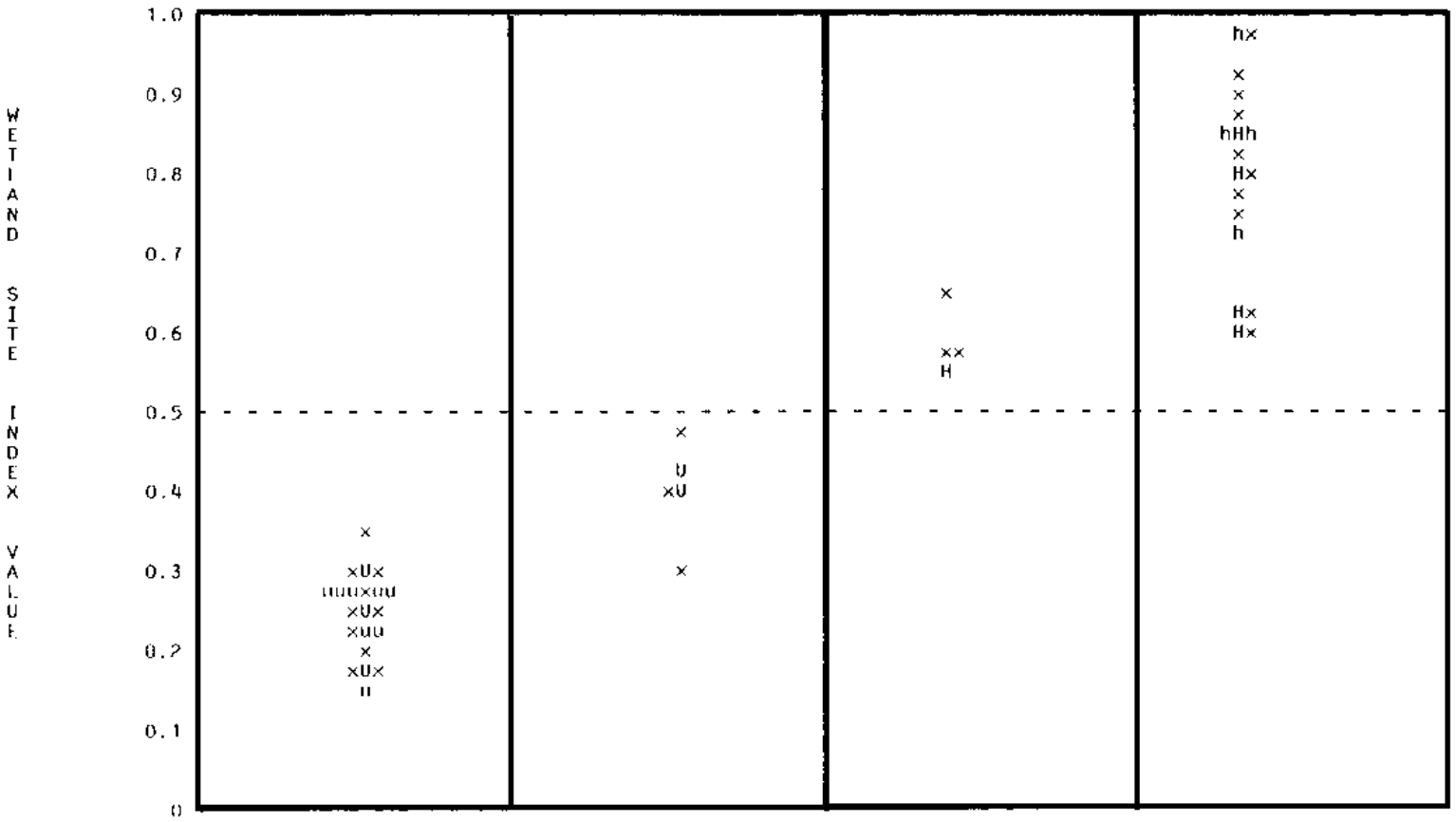


Figure 2. Site index values versus wetland judgement

For sites found to have a high "wetland-ness" index, a detailed investigation is needed to assess the potential values for pollution attenuation, wildlife habitat, flood storage or erosion protection, or whatever other benefits statutorily accrue to the public. These benefits must be weighed against the alternative uses being considered for the site, by the appropriate planning or permitting agency.

Upland-wetland boundary line mapping is presently done using "the fifty percent rule", where fifty percent of the plants are wetland and fifty percent are upland species. The four categories of "wetland-ness" are difficult to apply to this procedure unless the proposed site index is employed.

The wetland site index allows the old rule to be restated: The upland-wetland boundary line lies where the site index equals 0.50, passing into higher values on the wetland side, and lower values on the upland side. The efficient implementation of this revised procedure in the field requires familiarity with the species categories. For example, in New England recognition of the hydrologic categories of the fern species permits rapid flagging of the boundary during most seasons.

REFINEMENTS AND MODIFICATIONS

Future refinements of this index are anticipated as the database of plant categories becomes more refined, and species categories are "fine-tuned" to each geographic region. At this early stage of development, positive or negative feedback would be most welcomed by the author. Recent experience has shown the index to be very helpful to public and private clients. Among other things, the index has helped focus attention on some species identification and species category problems during the implementation of the database for site evaluation. Doubtless other users may find that it elicits discussions regarding species wetland frequencies.

Adding more plant hydrologic categories may increase the utility and precision of the index. Ultimately, each species could have its own specific wetland-upland site frequency. If such numbers were available for all the plant species in the region, these would replace the category values in the multiplication process and a much more accurate index would result. Such a compilation would require formidable research and listing effort at the present time, and must await future developments in botanical data processing. Meanwhile the efforts of the Fish and Wildlife Service in assembling wetland plant data at the National Wetlands Inventory unit are a good beginning.

Note added in proof: M. Gilbert, M. Freel, and A. Bieber (1980, unpublished) utilized a method very nearly identical to the one proposed here, to evaluate the "wetness" of sites for the purpose of ground truthing a remote sensing study in the sandhills of Nebraska. The plant species encountered were assigned to hydric categories with integers from 1 to 5 to represent upland to

wetland species preferences, then a weighted mean for each site was obtained using these hydric categories and the species' importance values. They concluded that the exact hydric-upland boundary was best delineated with this method, but that exact comparisons were impossible due to the incompatible classification schemes.

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