State of Ohio
Environmental Protection Agency

Wetland Ecology Group
Division of Surface Water

Vegetation Index of Biotic Integrity (VIBI) for Wetlands:

ecoregional, hydrogeomorphic, and plant community comparisons with preliminary wetland aquatic life use designations

Final Report to U.S. EPA Grant No. CD985875-01
Testing Biological Metrics and Development of Wetland Assessment Techniques using Reference Sites
Volume 1

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1.0 Introduction

A principal goal of the Clean Water Act is to maintain and restore the physical, chemical and *biological integrity* of the waters of the United States. 33 U.S.C. §1251(a). Biological integrity has been defined as "...the capability of supporting and maintaining a balanced integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region (Karr and Dudley 1981). "Integrity" or "Ecological integrity" has been defined as the sum of the earth's *biological diversity* and *biological processes*[1] (Table 1); the converse of ecological integrity is *biotic impoverishment*, which is defined as the systematic reduction in the capacity of the earth to support living systems (Karr 1993). Thus, "A biological system is healthy and has ecological integrity when its inherent potential is realized, its condition is "stable," its capacity for self-repair is maintained, and external support for maintenance is minimal. Integrity implies an unimpaired condition or quality or state of being complete and undivided (Karr, p. 1522, 1993)." The concept of integrity, and its measurement and description by biological surveys, underpins the development of biological criteria.

The factors in natural wetlands which can be degraded by human activity fall into several broad classes: biogeochemistry, habitat, hydrology, and biotic interactions (Table 2). The quantitative measurement (assessment) of the degree of integrity of a particular natural system, and conversely the degree of impairment, degradation or impoverishment, can be attempted in many ways. The State of Ohio has successfully developed a sophisticated system using ambient biological monitoring of fish and macroinvertebrate assemblages to assess the quality of streams in Ohio: the Invertebrate Community Index (macroinvertebrates), the Index of Biological Integrity (fish), and the Modified Index of Well Being (fish) (Ohio EPA 1988a, 1988b, 1989a, 1989b; Yoder and Rankin 1995). This type of system has been used and adopted throughout North America and Europe (Karr 1993). *See also* Karr and Kerans (1992); Barbour et al. (1992); Bode and Novak (1995); Hornig et al. (1995); Simon and Emery (1995), Hughes et al. (1998). The statistical properties of Ohio's IBI was investigated and validated by Fore, Karr, and Loveday (1993). They concluded that the IBI could distinguish between five and six nonoverlapping categories of integrity and that the IBI is "...an effective monitoring tool that can be used to communicate qualitative assessments to the public and policy makers or to provide quantitative assessments for a legal or regulatory context based on confidence intervals or hypothesis testing procedures (Fore, Karr, and Loveday, p. 1077, 1993).

Table 1. Components of ecological (biological) integrity for wetlands. Adapted from Karr and Kerans (1992) and Karr (1993).

Biological diversity	Biological Processes
Elements of biodiversity	Nutrient cycling/biogeochemistry
Genes within populations	Photosynthesis
Populations within species	Water cycling/hydrological regime
Species within communities/ecosystems	Evolution/speciation
Communities/ecosystems within landscapes	Competition/Predation/Mutualisms
Landscapes within biosphere	

[1] Karr (1993) defines biological diversity as the variety of the earth's naturally occurring *biological elements*, which extend over a broad range of organization scales from genes to populations, species, assemblages, and landscapes; the complement of biological diversity (the elements) are the *biological processes* on which those elements depend.

Table 2. Factors associated with wetlands that can be negatively impacted by human activities and which can cause wetlands to become degraded. Adapted from lists for flowing waters from Karr and Kerans (1992), Karr et al. (1986), Ohio EPA (1988a).

factor	description	examples of disturbances
biogeochemistry	natural patterns of that type of wetland for nutrient cycling, decomposition, photosynthesis, nutrient sequestration and release, aerobic/anaerobic regimes, etc.	nutrient enrichment, sedimentation, addition of organic or inorganic chemicals, heavy metals, toxic substances, etc.
habitat	natural patterns and structures of that type of wetland for floral and faunal communities.	mowing, grazing, farming, vehicle use, clearcutting, woody debris removal, shrub/sapling removal, herbaceous/aquatic bed removal, sedimentation, etc.
hydrology	natural hydrologic regime of that type of wetland: frequency, duration, amount of inundation; sources of water, etc.	ditching, tiling, dikes and weirs, additions of stormwater, point source discharges, filling and grading, construction of roads and railroad beds, dredging, etc.
biotic interactions	natural patterns of competition, predation, disease, parasitism, etc.	introduction of nuisance or nonnative species (carp, reed canary grass, purple loosestrife, European buckthorn, etc.)

Table 3. Advantages of ambient biological monitoring. Adapted from Karr and Kerans (1992).

#	description
1	Broad based ecologically
2	Provides biologically meaningful evaluation
3	Flexible for special needs
4	Sensitive to a broad range of degradation
5	Integrates *cumulative impacts* from point source, nonpoint source, hydrologic alteration, and other diverse impacts of human society
6	Integrates and evaluates the full range of *classes of impacts* (e.g. hydrologic modifications, habitat alterations, etc.) on biotic systems
7	Direct evaluation of resource condition
8	Easy to relate to general public
9	Overcomes many weaknesses of individual parameter by parameter approaches
10	Can assess incremental degrees and types of degradation, not just above or below some threshold
11	Can be used to assess resource trends in space or time

The State of Ohio's indices are codified in Ohio Administrative Code Chapter 3745-1 and constitute numeric "biological criteria" which are a part of the state's water quality standards required under the Clean Water Act. *See* 33 U.S.C. §1313. Biological criteria are numerical values or narrative expressions that describe the reference biological integrity of natural communities (U.S. EPA 1990). It is important to stress that the overall index score resulting from an IBI, as well as each individual metric represent testable hypotheses as to how a natural system responds to human disturbance (Karr 1993). Attributes of natural communities are selected and predictions are made as to how the attribute will respond, e.g. increase or decrease; not change until a particular threshold is reached and then increase quickly; increase linearly, or curvilinearly, etc. Moreover, the existing biological condition of a natural system is the integrated result of the chemical, physical, and biological processes that comprise and maintain the system, and the biological condition of the system can be conceived as the integration or result of these processes over time. The organisms, individually and as communities, are indicators of the actual conditions in that system since they inhabit the system and are subject to the variety of natural and human-caused variation (disturbance) to the system (Ohio EPA 1988a). In this regard, biological monitoring and biocriteria take advantage of this inherent integrative characteristic of the biota of a system, whereas chemical and toxicity monitoring only represents a single point in time unless costly, continuous sampling over time is performed. Table 3 lists some of the advantages inherent in biological monitoring.

"Wetlands" are a type of water of the United States and a water of the State of Ohio. *See e.g.* Ohio Revised Code (ORC) §6111.01(H), OAC Rule 3745-1-02(B)(90), 33 CFR 323.2(c). Until recently, wetlands in Ohio were only generically protected under the state's water quality standards. On May 1, 1998, the State of Ohio adopted wetland water quality standards and a wetland antidegradation rule. *See* OAC Rules 3745-1-50 through 3745-1-54. The water quality standards specify narrative criteria for wetlands and create the "wetland designated use." All wetlands are assigned to the "wetland designated use." However, numeric biological criteria were not proposed since they had not yet been developed.

An important feature of Ohio's current regulatory program for wetlands is found in the wetland antidegradation rule. *See* OAC Rule 3745-1-54. The wetland antidegradation rule categorizes wetlands based on their functions, sensitivity to disturbance, rarity and irreplaceability and scales the strictness of avoidance, minimization, and mitigation to a wetland's category. Three categories are established: Category 1 wetlands with minimal wetland function and/or integrity; Category 2 wetlands with moderate wetland function and/or integrity; and Category 3 wetlands with superior wetland function and/or integrity. The defining of these regulatory categories using actual measures of a wetland's biology and functions has been a continuing need since the adoption of the Wetland Water Quality Standards and wetland antidegradation rules.

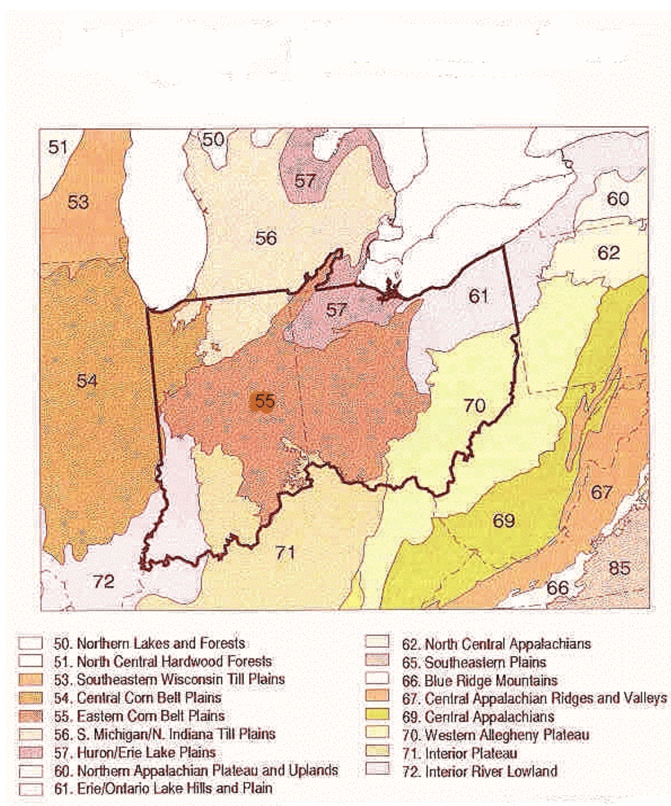

Figure 1. Ecoregions of Ohio, Indiana, and neighboring states. From Woods et al. 1998.

Ohio EPA began working on the development of biological criteria using vascular plants in 1996. To date, Ohio has sampled 121 different wetlands or separable plant communities within a wetland. These study sites have are located mostly in the Eastern Corn Belt Plains and Erie-Ontario Lake Plains Ecoregions (Figure 1) but with some sites in the Huron Erie Lake Plains, the Michigan Indiana Drift Plains, and the Western Allegheny Plateau (Table 4). These sites span the range of condition from highly degraded by human activity to relatively undisturbed, i.e. the best quality sites available or "reference conditions." This work has been funded since 1996 by several different U.S. EPA Region 5 Wetland Program Development Grants including CD995927, CD995761, CD985277, CD985276, and CD985875.

Table 4. Summary of sites sampled by year to develop Wetland IBIs based on vascular plants.

year	total	cumulative total	total minus resampled sites	resampled sites
	7	7	7	
1997	17	24	14	3
1998	3	27	3	
1999	31	58	28	3
2000	36	94	36	
2001	36	130	33	3
totals	130		121[2]	9

The objectives of the wetland biocriteria development project have been to develop Indices of Biotic Integrity (both interim and final) to evaluate ecological integrity of a wetland using vascular plants, macroinvertebrates and amphibians indicator taxa using an ecoregional approach and calibrate the ORAM using these IBIs.

Based on preliminary results (Fennessy et al.1998a, 1998b), Ohio EPA concluded that vascular plants, macroinvertebrates, and amphibians could be used as indicator organisms for the development of wetland-specific IBIs. Mack et al. (2000) proposed an initial vegetation index of biotic integrity (VIBI) based on data collected from 1996, 1997, 1998, and 1999 in the Eastern Corn Belt Plains Ecoregion. This report reevaluates the VIBI based on an additional data set from sites in the Erie-Ontario Lake Plains ecoregion.

[2] Ohio EPA has also sampled other natural and mitigation wetlands. Four mitigation wetlands were sampled in 1998 in addition to the 3 natural wetlands listed in this table. Ten mitigation wetlands were sampled in 2001 as part of a separate study of mitigation wetland performance (unpublished data). As part of an earlier study of mitigation wetlands, 17 other sites were sampled in 1995 (10 mitigation wetlands and 7 natural wetlands) (Fennessy and Roehrs 1997). Finally, as part of a separate study of the Floristic Quality Assessment Index and riparian wetlands, 10 other riparian forested wetlands were studied. Total wetlands sampled by Ohio EPA is 152 (128 natural and 24 mitigation (Fennessy et al.1998b).

2.0 Vegetation Sampling Methodology

2.1 Overview

Since the 1999 field season, Ohio EPA has used a plot-based vegetation sampling method[3] described by Peet et al. (1998). This is a flexible, multipurpose sampling method which can be used to sample such diverse communities as grass and forb dominated savannahs, dense shrub thickets, forest, and sparsely vegetated rock outcrops. Their method has been used at thousands of sites for over ten years by the North Carolina Vegetation Survey. It is appropriate for most types of vegetation, flexible in intensity and time commitment, and provides information on species composition across spatial scales. It also addresses the problem that processes affecting vegetation composition differ as spatial scales increase or decrease and that vegetation typically exhibits strong autocorrelation.

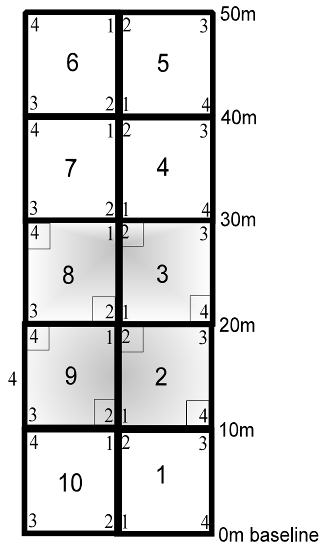

Figure 2. Standard 20x50m (2x5) plot used in vegetation sampling as recommended by Peet et al. (1998). Modules are numbered counterclockwise moving from the "front" of the plot to the "back," then from the back of the plot to the front. Module corners are numbered clockwise in the direction of movement along the centerline. Typical intensive modules are shaded and standard intensive module nested quadrats are indicated by small squares.

In addition to the advantages already mentioned, the size and square shape of the modules provide convenient building block for larger or smaller plots and the square shape is efficient to lay out and ensures the observation is typical for species interactions at that scale of observation. While this method is compatible with data from other methods, it avoids biases built into methods with distributed quadrats or high perimeter-to-area ratios (Peet et al. 1998). Finally, there is an existing body of literature using plots of this type.

The most typical application of the method employs a set of 10 modules in a 20 x 50m layout (Figure 2). Once the plot is laid out, all species within the plot are identified. For forest and shrub communities, an aggregate woody stem count is made. Four 10 x 10m modules are "intensively" sampled in a series of nested quadrats. Within these "intensive" modules, species cover class values (Table 5) are recorded for each module separately and for each nested quadrat separately. In effect then, this method incorporates the use of reléves found in the Braun-Blanquet methodology in as much as the length, width, orientation, and location of the modules are qualitatively selected by the investigator based on site characteristics; however, within the modules, standard quantitative floristic and forestry information is recorded, e.g.

[3] Refer to Mack et al. (2000) for a comparison of data from the plot-based method to data collected using transect-quadrat methods. Out of the current data set used to derive the interim VIBIs, only 20 wetlands had data collected using only the earlier transect-belt method. For these 20 sites, species observed outside of the quadrats in the "belt" area of the transect were excluded from the subsequent data analysis. In in 1999 and 2001, 6 of these 20 sites were resampled using the current method.

frequency, density, basal area, cover, etc.

2.2 Definitions

Module - A "module" is the basic unit of sampling under this method and consists of a 10m x 10m quadrat. Nested quadrats of $0.01m^2$, $0.1m^2$, $1m^2$, $10m^2$ are located in one or more corners of a module. A sampling plot is made up of one or more modules. If the size of a plot is 10m x10m, then the module is also a "plot" or a "reléve."

Plot - A "plot" is an area where vegetation is being sampled at a particular site. A plot is made up of one or more modules. Plots can also be called "reléves."

Reléve - A synonym for "plot."

Quadrat - Quadrat refers to one or more nested quadrats ($0.01m^2$, $0.1m^2$, $1m^2$, $10m^2$) that are located in one or more corners of a module. Technically, the module itself is a $100m^2$ "quadrat" but here the term quadrat is used to describe the smaller nested quadrats (or subquadrats).

Presence - "Presence" is defined as the occurrence of a species (based on the emergence of stem or stems) within a quadrat, module, or plot (Peet et al. 1998).

Cover - "Cover" is defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface. No single species may exceed 100% cover, though the sum of cover estimates across all species often exceeds 100%.

Are - An "are" is one-hundredth of a hectare (0.01ha) or $100m^2$. A single module is 1 are.

Hectare - A "hectare" is $10000m^2$ or 100 ares. A typical 2x5 plot made up of 10 modules is 0.1 hectares.

Depth (of occurrence) - "Depth" refers to the size of the subquadrat in which the presence of a species is first noted. For example, if the presence of species is first observed in the $1m^2$ subquadrat, the depth of occurrence is 2.

Level (of occurrence) - A synonym for "depth."

2.3 Procedures

Sampling procedures are summarized in the following sections. Information discussed below is taken from *Standardized Vegetation Sampling Procedures Field Manual Version 1.1, Ohio EPA Technical Report WET/2001-2* (Mack 2001b).

2.3.1 Step 1. Selecting the Plot location(s) and Configuration(s)

Plot size, shape, and location. At most sites, a "standard" plot was established consisting of a 2x5 array of 10m x10m modules, i.e. 20m wide by 50m long (equals $1000m^2$ = 1 are = 0.1 ha), within the boundary of the wetland and within each vegetation community of interest.[4] In some instances, heterogeneity of vegetation or environment, researcher time, or significance of site made a standard 0.1 ha plot inappropriate or impractical. Where the standard plot would not fit or would have been inadequate or heterogeneous, the size or shape of the plot was modified to obtain a representative sample of the community of interest.

A determination was made as to the dominant, codominant and minor vegetation communities present in the wetland and what the community of interest being sampled was. In some instances, multiple plots were needed to sample wetlands with more than one dominant vegetation community. In other instances, where the wetland was dominated by a single type of community, but had a minor presence of another, the plot was located such that at least a portion of the minor community was located within the plot (but not within any of the intensive modules). This ensured that the species present in the subcommunity were identified and enumerated. This situation occurred most frequently in scrub-shrub wetlands (e.g. buttonbush swamps) located within a forest or woodlot, where a narrow forested margin was often present, or in emergent marshes where a narrow band of shrub vegetation was present along some or all of the wetland's perimeter

Subsamples and Supersamples. At a few wetlands, subsamples of especially dense shrub vegetation were used. According to Peet et al. (1998), the standard plot can be adapted for unusually high stem densities of woody vegetation, e.g. a *Rosa palustris* thicket, or unusually low stem densities, e.g. an oak savannah, by subsampling or supersampling the “problem” vegetation. This is accomplished by adjusting the width of the module, as measured from the centerline of the plot by the appropriate percentage. Thus, after laying out a plot in or through a *Rosa palustris* thicket, the shrub stratum is measured in a 5m x10m module by reducing the width of the module by 5m or 50% (a 50% subsample).

Plot orientation (minimizing heterogeneity). Plots were placed to minimize within-plot environmental heterogeneity, which implies that the long axis of the plot encountered the least possible variation in these characteristics, unless the heterogeneity in question would not affect the goal of characterizing the vegetation. In this situation, the particular heterogeneity was ignored and the long-axis of the plot was established without regard to that gradient. The most common instance of this occurrence was in zoned emergent marshes where water depth generally decreases towards the upland boundary and the vegetation is zoned in narrow bands.

2.3.2 Step 2. Laying out the Plot(s)

Once the general location, orientation, and size of the plot was determined, the plot was delineated on the ground. The 50m baseline of plot was established using a measuring tape and the compass direction noted. Marker flags were placed every 10m along this line. Next, the 20m sides of the intensive modules are located perpendicular to the centerline. At a minimum, marker flags were placed at the corners of intensive modules and frequently at the corners of every module depending on the site. The modules in the plot were numbered *counterclockwise*, starting with the first module on the baseline to the right of the centerline and proceeding down to the end of the centerline and then back to the baseline (Figure 2). Conversely, the corners of the modules were numbered *clockwise*, starting at the centerline and moving

[4] Peet et al. (1998) recommend 1000m^2 area for forest inventory of rich mesic forests and numerous North American forest studies have employed a 1000m^2 plots. This size plot is similar to the area recommended by Mueller and Dombois (1974), i.e. 200-500m^2. According to Peet et al. (1998), numerous plot configurations are possible. Where a standard 2x5 plot of 1000m^2 will not fit, a 2x2 plot of 400m^2 can be a good substitute. Strips of two, three, four, or five modules can also be used where homogeneity considerations limit the number of modules.

up or down the centerline, depending on which side of the centerline the module is located (Figure 2) to avoid having nested quadrats being placed side by side.

2.3.3 Step 3. Selecting the Intensive Modules and Locating the Nested Quadrats

In a standard 2x5 plot, the intensive modules were generally located in the center of the plot, if possible, to ensure that the contents were as representative as possible and to reduce subjective bias associated with starting the tape in close proximity to these modules. Where a 2x2 array was used, every module was usually treated as an "intensive" module. Where narrower configurations like 1x4 or 1x5, or where a 2x3 or 2x4 plot was used, the intensive modules were usually located in the center modules and six to eight nested quadrats were measured. If other unusual conditions suggested that a specific corner would be inappropriate, alternate corners were selected.

2.3.4 Step 4. Measuring Vegetation

All vascular plant species within the modules were identified to the lowest taxonomic level possible. Immature plants or plants missing structures (e.g. fruiting bodies, etc.) that could not be identified to species were identified to genus. Otherwise, the plant was recorded as unknown and notation made as to its type (graminoid, monocot, dicot, forb, family, etc.) to the extent that could be identified. If several unknowns of the same type were present but were obviously different species, they were distinguished by assigning a number, e.g., unknown grass spp. #1, #2, etc. Nomenclature in this report generally follows Gleason and Cronquist (1990).

Presence data were recorded in the form of a couplet with the first column used for the depth at which a species was first recorded as present and the second for cover. Couplet headings were the module and corner numbers (e.g. 2-2, 2-3, etc.), except for (where applicable) an aggregate pair headed R-R (for "residual") that contained species first recorded in an aggregate of modules that supplement those sampled intensively. *See* Peet et al. (1998) for a detailed discussion of how data is recorded. All species with stems emerging anywhere within the focal module were listed and each of these species had a depth value of 4 ($0.1m^2$), 3 ($1m^2$), 2 ($10m^2$), or 1 ($100m^2$) recorded. Cover data was recorded using the cover classes in Table 5 for every species, except canopy level trees where only basal area was measured (*See* Step 5 for woody vegetation below). The midpoint of the cover class was used in all subsequent analyses.

2.3.5 Step 5. Measuring Woody Vegetation

For woody vegetation, stem counts were made and basal area was measured for all trees, shrubs and woody vines reaching 1.0 m, with the exception of multiple stemmed shrubs, e.g. buttonbush. Shrubs with multiple stems from the same root (genets) were counted once as a "shrub clump" and analyzed with the 0-1cm size class. The diameter classes and midpoints in Table 5 were used, with stems greater than 40 cm counted individually and measured to the nearest tenth centimeter. The midpoints of the class were used to calculate basal area by class.

Table 5. Cover and dbh classes recommended by Peet et al. (1998)

cover class	% cover	midpoint	dbh class	dbh (cm)	mid point (cm)	basal area (cm^2)
1	solitary or few	0.01%	1	0-1	0.50	0.063
2	0-1%	0.5%	2	1-2.5	1.75	0.766
3	1-2%	1.5%	3	2.5-5	3.75	3.52
4	2-5%	3.5%	4	5-10	7.50	14.1
5	5-10%	7.5%	5	10-15	12.5	39.1
6	10-25%	17.5%	6	15-20	17.5	76.6
7	25-50%	37.5%	7	20-25	22.5	126.6
8	50-75%	62.5%	8	25-30	27.5	189.1
9	75-95%	85%	9	30-35	32.5	264.1
10	95-99%	97%	10	35-40	37.5	351.6
---	---	---	11	>40cm	individually	individually

2.3.6 Step 6. Measuring standing biomass

Standing biomass (emergent wetlands only) was estimated by harvesting to ground level all plants rooted in $900cm^2$ quadrats located in the nest corners of the intensive modules. Samples were collected on the same day vegetation sampling of the plot was done. All plants within quadrat were cut at the soil surface and placed into paper sample bags. Plants were oven dried at 105 ^oC for at least 24 hours and samples were then weighed and the weights recorded.

2.3.7 Step 7. Measuring physical attributes of the site

In addition to the quantitative vegetation data collected, various physical attributes of the wetland being sampled was also recorded. These include depth of standing water, depth to saturated soils, litter depth, number of tussocks and hummocks, number of standing trees, number of coarse woody debris, microhabitat interspersion, physical characteristics of soils (color, texture, redox features, etc.), pH and temperature of standing water. Soil and water samples were also collected and samples were analyzed at the Ohio EPA laboratory. Grab samples for water were collected by directly filling one quart containers with water from the wetland. Soil samples were generally located within the intensive modules of the plot unless conditions at the wetland (depth of water, substrate characteristics, etc.) made this infeasible, in which case an alternative sampling location was identified. Soil samples were taken from the top 12 cm of soil. Samples were collected using a 8.25cm x 25cm stainless steel bucket auger (AMS Soil Recovery Sampler), with a butyrate plastic liner. The auger was then inserted to half its depth, filling the liner half-way. The auger was then removed and the operation repeated (filling the liner completely). Prior to 1999, a bucket auger was not used but samples were still extracted from the top 12cm of soil.

2.3.8 Step 8. Preserving Voucher Specimens and Assigning Voucher Numbers

Voucher specimens were collected at almost every site, especially the more taxonomically difficult genera and families. Although staff resources made collecting vouchers of every vascular plant infeasible, a voucher specimen of at least 10% of the vascular plant species at any given site was usually collected. In every instance in which the identity of any species could not be confirmed in the field, or where field personnel disagreed as to the identity of a species, a voucher specimen was collected for identification in the office. In particular, difficult genuses and families, e.g., Cyperaceae and Poaceae, were frequently collected. Vouchers were retained in the Ohio EPA herbarium and specimens will also be sent to regional herbariums.

2.3.9 Step 9. Assigning plants to categories

After sampling, plants found in a wetland were assigned to various categories.

1. Reproductive categories. Each plant was assigned to one of three reproductive categories: monocotyledon, dicotyledon, cryptogam (ferns and fern allies).

2. Life form categories. Each plant was assigned to various “life form” categories reflective of the plants usual height, shape, or structural characteristics including the following:

    a. forb - all non-grasslike plants including ferns and fern-allies;

    b. graminoid - all grass-like plants including species in the Poaceae, Cyperaceae, Juncaceae, Typhaceae, and Sparganiaceae;

    c. shrub - plants with woody stems that have “shrubby” growth habitat (e.g. *Cephalanthus occidentalis*, *Alnus* spp., *Salix interior*, but not *Salix nigra*);

    d. tree - woody plants which can grow into a mature forest canopy;

    e. vine - plants with a climbing, twinging, or recumbent growth habitat.

3. Wetland indicator status categories. The basic wetland indicator status of the plant (UP, FACU, FAC, FACW, OBL) for the State of Ohio as determined by appropriate U.S. Fish and Wildlife Service Publications (e.g. Reed 1988).

4. Tolerance/intolerance (to disturbance) categories. Plants with a Coefficient of Conservatism rank of 0, 1, or 2 were determined to be “tolerant;” plants with a Coefficient of Conservatism rank of 6, 7, 8, 9, or 10 were determined to be “intolerant.” *See* discussion of FQAI score and Coefficients of Conservatism in §2.5.

5. Taxa level categories. Plants were assigned to various taxa level categories including the following: *Carex, Scirpus, Juncus, Typha, Phalaris, Aster, Rosa, Cephalanthus,* Poaceae, Cyperaceae, Asteraceae, Rosaceae, Lemnaceae

6. Indigeneity categories. Plants were assigned to one of two categories, native versus nonnative species, based on whether the species was present prior to European settlement in the State of Ohio as determined by taxonomic experts and references.

2.3.10 Step 10. Calculating vegetation community attributes

The following basic vegetation community attributes were calculated:

Number (Richness). The number of plants in various categories was counted.

Relative Number (Proportion). The number of plants in the various categories listed above divided by the total number plants identified to species or genus level. Alternatively, the number of plants in a category divided by the number of plants in another category, e.g. the number of shrub species divided by the number of tree species.

Coverage (Dominance). The sum of the percent coverage values for a plant species recorded for each intensive module or at the reléve level (nonintensive modules if the plant was not observed in an intensive module). Percent cover was recorded for all species except canopy level tree species.

Relative Coverage. The sum of the percent coverage values recorded for a plant species in a plot divided by the sum of coverage values for all plant species in the plot.

Class Frequency. The number of size classes where a tree or shrub species has at least one individual of that size present in the size class.

Relative class frequency. The number of size classes that a particular woody species has individuals of that size present in divided by the total number of size classes.

Density. The number of stems per hectare of a woody plant species (tree or shrub).

Relative Density. The number of stems per hectare of a woody plant divided by the total number of stems per hectare of all woody plants in the plot.

Basal Area (Dominance). The basal area of woody plant species in m^2 per hectare

Relative basal Area. The basal area of woody plant species in m^2 per hectare divided by the sum of the basal area of all woody plant species in the plot.

Importance value. The sum of relative frequency, relative density, and relative basal area of woody plants divided by three and variants of the importance value.

FQAI Score and variants. The FQAI score and variants of the FQAI score (% cover of plants with CofCs of 0-2 (tolerant)or 6-10 (intolerant)).

2.4 IBI Development Methods

Karr et al. (1986) and Ohio EPA (1988a, 1988b) performed foundational IBI development using freshwater fish. Ohio EPA (1988a, 1988b) developed IBIs for macroinvertebrates in freshwater streams. Karr and Kerans (1992) summarized their procedure for developing a macroinvertebrate IBI for the Tennessee Valley Authority. The U.S. EPA has several guidance manuals on IBI development that recommend various procedures and methods (U.S. EPA 1990, 1998, 1999). However, there are very few published attempts to develop IBIs using vascular plants as the indicator taxa (Gernes and Helgen 1999; Carlisle et al. 1999; Adamus 1996). Some of the details of the fish and macroinvertebrate methods must be adapted to wetlands (a different type of aquatic system than flowing streams) and to vascular plants (a different taxa group). What follows in these next sections is a summary of Ohio EPA's approach to developing IBIs for vascular plants.

2.4.1 Site selection and classification

Site selection and classification for IBI development is an iterative process (U.S. EPA 1999), but generally, two methods can be employed: *a priori* classification or *a posteriori* classification. Multimetric IBI approaches to developing biocriteria generally employ what could be called an iterative-*a priori* classification approach. This has been the approach taken by Ohio EPA in developing VIBIs. A goal of a cost-effective biocriteria program is to have the fewest classes that provide the most cost-effective feedback.

Early classification schemes employed by Ohio EPA are summarized in Mack et al. (2000). Results from Mack et al. (2000) suggest that somewhat diverse wetland types may be groupable during the development of an IBI and other groups, e.g. fen and bogs, which are generally kept separate during IBI derivation can then be "regraphed" with other types of wetlands after the VIBI score is determined since the IBI scoring process has a standardizing effect on inter-class variation. The current working hypothesis is that while certain wetland types may differ in their floras at the species or community level, these species or communities of species behave in a similar manner in response to human disturbance (Premise 11 Karr and Chu 1999). Results from Mack et al. (2000) and this report suggest that 20-30 potential hydrogeomorphic or plant community classes (Table 6 and 7) may be condensable into 4-8 classes for the purposes of vegetation IBI development and application.

Ohio EPA has developed and continues to revise plant community and hydrogeomorphic classification systems (Mack et al. 2000; Mack 2000) (Table 6 and 7). The plant community classification scheme (Table 6) is based on the primary classes in the Cowardin et al. (1979) scheme (forest, scrub-shrub, emergent). Plant communities and plant community types follow, in part, the Ohio plant community classification system developed by Anderson (1982), although Ohio EPA has added several community types (forest seeps, seep fens, sedge-grass communities, tall shrub fens) not listed in Anderson (1982).

The hydrogeomorphic (HGM) classification (Table 7) can be considered an Ohio specific scheme that Brinson (1993) recommended be developed and is adapted from a system developed for Pennsylvania by Smith et al. (1995) and Cole et al. (1997).

Table 6. Interim Ohio Vegetation Community Classification (modified after Anderson 1982) and from Mack (Table 6, p. 25, 2000a). Refer to Anderson (1982) for a more detailed discussion of the community types listed below. Note: the term isolated is used in an the context of hydrogeomorphic class or landscape position and should not be construed to have any bearing on legal definitions or jurisdiction.

	class		community	type	description
I	Forest	a	Swamp forests	(1) riparian forests (2) isolated forests (3) vernal pools	Communities characterized by closed canopies of tree species. Includes swamp forests in isolated (depressional) settings, swamp forests located on floodplains and subject to regular flooding and part of a floodplain forest matrix, and vernal pools (as defined in OAC Rule 3745-1-50) which can be considered a type of isolated swamp forest that is largely unvegetated with herbaceous vegetation. Dominant canopy trees should be specified and can be one or several of the following: pin oak, swamp white oak, maple (red or silver), ash (green, black, pumpkin), white pine, elm, swamp cottonwood, black gum, hemlock, etc.
		b	Forest Seeps	(1) riparian forest seeps, (2) isolated forest seeps	Communities characterized by closed canopies of tree species with strong "break in the slope" groundwater expression, mucky soils, and often densely vegetated in the herb layer with *Carex* spp., skunk cabbage (*Symplocarpus foetidus*), and often other fen associates. Can occur in isolated positions or at bases and slopes of stream valley walls.
		c	Tamarack-Hardwood Bog Forest	(1) Tamarack-hardwood bog	Tamarack and other hardwood species (yellow birch, red maple, blackgum, quaking aspen form a closed canopy over peat or muck soils with characteristic bog understory vegetation in a "hummock and hollow" microtopography. Often grades into other swamp forest types.
II	Shrub	a	Shrub swamps	(1) riparian swamps (2) isolated swamps	Characteristic species include willows, alders, dogwoods, swamp rose, meadow sweet. Buttonbush and alder shrub swamps have over half their cover in buttonbush or alder, respectively. May occur as narrow zones around bogs, fens, or marshes. Dominant species of shrub canopy should be specified and can be one or several of the following: buttonbush, alder, dogwood, willows, blueberries, spirea, chokeberry (*Aronia melanocarpa),* winterberry (*Ilex verticillata)*.
		b	Bog or Fen Shrub Swamps	(1) tall shrub bog (2) tall shrub fen	(1) Shrub bogs have massive, continuous sphagnum carpets, in addition to bog shrubs and herbs, but may grade into "boggy" mixed shrub, alder, or buttonbush swamps, or marshes but these lack sphagnum carpets; (2) Shrub fens are similar to other fen communities in the herb layer but have continuous to partially continuous to occasionally discontinuous canopies of dense shrub vegetation. Species can include willow (*Salix* spp.), chokeberry *(Aronia melanocarpa),* winterberry (*Ilex verticillata)*, catberry (*Nempopanthus mucronatus*), blueberries (*Vaccinium* spp.), *Gaylussacia baccata*, alder (*Alnus* spp.), poison sumac (*Toxicodendron vernix*), viburnums, dogwoods (*Cornus* spp.), etc.
III	Emergent	a	Marshes	(1) submergent marsh, (2) floating-leaved marsh, (3) mixed emergent marsh, (4) cattail	Characterized by herbaceous vegetation in isolated, depressional settings, adjacent to or part of lakes, and sometimes in proximity to or in mainstem or headwater positions of streams but development and succession not influenced by perennial or nearly perennial connections to a stream. Typical species can include *Sagittaria* spp., *Typha* spp., *Sparganium* spp., *Peltandra virginica*, *Pontederia cordata, Nuphar advena, Decodon verticillatus, Carex* spp., *Juncus* spp., *Scirpus* spp., *Cyperus* spp., *Eleocharis* spp., Poaceae spp., various ferns, *Lycopus* spp., *Scutellaria* spp., *Iris* spp., and other wetland forbs and floating aquatic plants.

Table 6. Interim Ohio Vegetation Community Classification (modified after Anderson 1982) and from Mack (Table 6, p. 25, 2000a). Refer to Anderson (1982) for a more detailed discussion of the community types listed below. Note: the term isolated is used in an the context of hydrogeomorphic class or landscape position and should not be construed to have any bearing on legal definitions or jurisdiction.

	class		community	type	description
III	Emergent	b	Sedge-grass Communities	(1) Wet Prairies including slough grass-bluejoint prairies, (2) Sedge meadows, (3) Seep fens	Communities dominated by sedges and grasses with other prairie or fen-associate forbs. (1) Wet prairies are characterized by *Calamogrostis* spp, *Spartina pectinata*, and *Carex* spp. as well as other "prairie" forbs and grasses like *Lythrum alatum, Pycnanthemum virginianum, Liatris spicata, Silphium terebinthinaceum,* etc.. (2) Sedge Meadows are dominated by various *Carex* spp. including *Carex lacustris, Carex stricta, Carex trichocarpa,* and *Carex atherodes*. Wet prairies may grade into sedge meadows. Sedge meadows may also be components of mixed emergent marshes. (3) Seep fens are groundwater driven emergent wetlands that occur at breaks in slope or bases of floodplain slopes with many plants associated with calcareous fens (IIId) types but lacking in calciphile fen obligates like shrubby cinquefoil. Seep fens have many fen associates like *Carex stricta, Carex leptalea, Carex interior, Solidago patula, Aster puniceus,* as well as other sedge-meadow, marsh, and wet prairie plants. Communities with species assemblages similar to seep fens but without strong ground water inputs, should be classified as sedge meadows.
		c	Herbaceous Riverine Communities	Types of riverine communities: (1) submergent, (2) floating-leaved, (3) mixed emergent, and (4) water-willow	Characterized by perennial or nearly perennial surface water connection to streams or rivers and large annual sediment movements. Riverine communities may occur over the entire breadth of slow streams or may be restricted to the slower waters in shallower or more protected areas. Species assemblages may be similar to other non-riverine marsh communities and may also include a strong presence of shrub species. They are commonly bordered by deeper or more rapidly flowing water. Riverine communities include stands in water which flows either all or part (e.g. oxbows) of a year, usually every year. Headwater marshes which normally display very slow flowage are excluded but the distinction between a marsh and riverine systems is not always clear.
		d	Fens	(1) Cinquefoil-Sedge Fen, (2) Tamarack Fen, (3) Arbor Vitae Fen	Characterized by mineral-rich, nutrient poor groundwater inputs or on margins of glacial kettle lakes with strong presence of obligate calciphile plant species like *Cacalia plantaginea, Carex flava, Carex sterilis, Deschampsia flexuosa, Eleocharis rostellata, Eriophorum viridicarinatum, Parnassia glauca, Potentilla fruticosa, Rhynchospora capillacea, Solidago ohioensis, Triglochin* spp.
		e	Bogs	(1) Sphagnum bog, (2) Leatherleaf bog	Both bog communities are characterized by continuous carpets of *Sphagnum* and/or other acidophilic mosses. Large bog systems often include areas of floating-leaved marsh in peripheral moats or in the center as well as other marsh or shrub dominated areas. Refer to Anderson (1982) for discussion of these community types.

Table 7. Interim Hydrogeomorphic (HGM) classification system for Ohio wetlands v1.1 (October 2000) modified after Mack (Table 1, p. 5, 2000a) and adapted from Smith et al. (1995) and Cole et al. (1997). Note: the term isolated is used in an the context of hydrogeomorphic class or landscape position and should not be construed to have any bearing on legal definitions or jurisdiction.

	class	subclass	dominant soils	description
I	Isolated Depression	(A) closed (B) open	(1) organic soils, (2) mineral soils	Wetland is in an isolated landscape position and not associated with a stream, river, or lake. Wetland may be "closed" (without discernable surface water inlets or outlets) or "open" (with inlets or outlets), but precipitation, overland flow, and/or interflow are primary water sources and evapotranspiration in the growing season is the dominant hydrodynamic. Wetland may have organic (peat, muck) or mineral soils and may have shallow groundwater, surface water (including precipitation), or both as sources of hydrology
II	Impoundment	(A) beaver (B) human	(1) organic soils, (2) mineral soils	Wetland is impounded by beaver or human activity. Fringing wetlands around some reservoirs can be classified there.
III	Riparian Depression	(A) Headwater (1^{st} or 2^{nd} order) (B) Mainstem (3^{rd} order or larger)	(1) organic soils, (2) mineral soils	Wetland is associated with a stream or river in a headwater or mainstem floodplain position and receives hydrologic inputs from annual or regular flooding. If evapotranspiration in the growing season is the dominant hydrodynamic , wetland is "riparian-depression." If ground water is an important hydrologic input in addition to surface water, wetland is "riparian-groundwater. Wetland may have organic (peat, muck) or mineral soils.
IV	Riverine	(A) Headwater (1^{st} or 2^{nd} order) (B) Mainstem (3^{rd} order or larger)	(1) organic soils, (2) mineral soils	Wetland located within the defined banks or channel of a stream or river and is not a Riparian headwater wetland
V	Slope	(A) riparian (B) isolated (C) fringing	(1) organic soils, (2) mineral soils	Wetland located on a topographic slope with break-in-the slope ground water inputs with unidirectional flow of water and in isolated landscape position (isolated) OR associated with stream or river (riparian) OR associated with a lake, pond or reservoir (fringing)
VI	Fringing	(A) ground water (B) surface water (C) both	(1) organic soils, (2) mineral soils	Wetland associated with a kettle lake (other than Lake Erie), or large pond, divided into subclasses based on predominant hydrology (groundwater, surface water or both) and soil type
VII	Coastal	(A) unrestricted, (B) restricted (C) estuarine		Wetland is associated with the coast of Lake Erie and its hydrology is unrestricted by human activity, OR restricted by human activity, OR associated with the reaches of rivers and streams flowing into Lake Erie and affected by short and long term lake levels

2.4.2 Attribute evaluation and Metric selection

After initial classification and during classification iterations, potential ecological or biological a*ttributes* of the taxa group are identified and evaluated (Barbour et al. 1995).[5] Potential attributes are initially selected *a priori* and should include aspects of the community structure, taxonomic composition, individual condition, and biological processes (Table 8; Karr and Kerans 1992; Barbour et al. 1995).

Barbour et al. (1995) state that a useful attribute has five general characteristics:

1. Relevant to the biological community under study and to the specified program objectives;

2. Sensitive to stressors;

3. Able to provide a response that can be discriminated from natural variation;

4. Environmentally benign to measure in the aquatic environment; and

5. Cost-effective to sample.

Table 8. Types and characteristics of attributes which can be included in biological assessments using vascular plants as a taxa group. Adapted from Barbour et al. 1995.

type	possible attributes
community structure	taxa richness, relative cover, density, dominance
taxonomic composition	identity, floristic quality (FQAI), tolerance or intolerance of key taxa
individual condition	disease, anomalies, contaminant levels
biological processes	productivity, trophic dynamics, nutrient cycling

Ohio EPA evaluated sampling costs and sampling time (including travel to and from study sites) for vegetation sampling during the 2001 field season. One time equipment purchases to perform sampling describe in this report total approximately $12,000. Annual supply costs are approximately $2,000. During the 2001 field season, an experienced sampling team sampled 44 sites with 47 plots over 28 field days. A normal sampling team was comprised of one full time biologist and two interns. Average person hours per site and per plot was 6.5 and 6.1 hours, respectively for the biologist, and 11.6 and 10.8, hours, respectively for the interns. Cost per site and per plot, excluding soil and water sample analytical costs was approximately $402 and $376, respectively. Average lab costs for soil and water sample analysis at Ohio EPA's laboratory were $394 per plot for soil samples and $154 per plot for water samples (48 samples, and 36 water samples).

Ohio EPA evaluated a suite of potential attributes based on the biological information collected. The target taxa group (vascular plants) was classified into several categories (Table 9). Then possible changes

[5] In this report, "attribute" is defined as a measurable characteristic of the biological community, and “metric” is defined as an attribute that changes in some predictable way in response to increased human disturbance (Karr and Chu 1997). "Metric" is also used to refer to an attribute that has been included as a component of a multimetric IBI.

to disturbance (increase, decrease, etc.) and types of changes (linear, curvilinear, dose-response) were proposed. These constitute testable hypotheses and assumptions which go into making up the completed IBI (Table 10). Data from wetlands representing a range of disturbance were then evaluated for ecologically meaningful and explainable trends.

These procedures can be summarized as follows:

Step 1 Classify organisms such that attributes span range of types, trophic levels, strata (horizontal, vertical), reproductive strategies, ecological affinities, age classes

Step 2 Propose working hypotheses for potential attributes

Step 3 Use graphical techniques, descriptive statistics, regression analysis, etc. to evaluate attributes from data set of reference and nonreference wetlands.

Step 4 Select "successful" attributes

In general, successful attributes were those where ecologically meaningful linear or curvilinear dose-response or other ecologically meaningful relationships were observed across a gradient of human disturbance. *See* Results section for additional discussion.

Table 9. Categories used to classify vascular plants. Adapted from Karr and Kerans (1992).

#	category	type
1	Taxa group	dicots, monocots, certain genera (e.g. *Carex*), certain families or family groups (e.g. Poaceae, cryptograms), etc.
2	Life Form	forb, graminoid, shrub, tree, aquatic, etc.
3	Indicator Status	wetland indicator status, e.g. FAC, OBL, FACW, etc.
4	Age (size) class	what size, and presumably age, class a tree is a member of
5	Ecological affinity	Coefficient of conservatism assigned to plant species by Floristic Quality Assessment Index.

Table 10. Hypotheses and assumptions about changes in vascular plant community in wetlands from human disturbance. Adapted from Karr and Kerans (1992).

#	hypothesized changes caused by human disturbance of natural wetlands
1	number of species and those of specific taxa groups declines
2	abundance (dominance) or numbers of intolerant species declines
3	abundance (dominance) or numbers of tolerant species increases
4	proportions or abundance of plants with narrow ecological affinities declines
5	overall floristic quality of plant community declines
6	primary productivity increases
7	proportions or abundances of plants with particular wetland affinities (obligate, facultative) changes relative to reference conditions

Table 10. Hypotheses and assumptions about changes in vascular plant community in wetlands from human disturbance. Adapted from Karr and Kerans (1992).

#	hypothesized changes caused by human disturbance of natural wetlands
8	proportions or abundances of plants with certain life forms (e.g. forb, graminoid, shrub or tree) or reproductive classes changes relative to reference conditions
9	proportions of individuals (relative density) or relative dominance (basal area) in woody species age classes increases changes relative to reference conditions
10	changes in community heterogeneity relative to reference condition

2.4.3 Metric score and calibration

Once an ecological attribute is selected as a "metric", a score must be assigned based on the measurement of that attribute by a biological survey of the wetland. U.S. EPA (1998, 1999) outlines several methods for determining scoring criteria including an "all-sites" and "percentage of standard" method followed by trisection or quadrisection of the distribution. Karr et al. (1986) and Ohio EPA (1988a, 1988b) used trisection of data from reference sites to derive IBIs for fish in freshwater streams. Ohio EPA (1988a, 1988b) used quadrisection in the derivation of IBIs for macroinvertebrates in freshwater streams. Hughes et al. (1998) used the 95^{th} percentile of values from all sites as the most sensitive index. Mack et al. (2000) evaluated both trisection and quadrisection in developing the interim VIBI for Ohio wetlands. The relative position of the wetlands remained the same regardless whether the VIBI score distribution was trisected or quadrisected. Because of the clear advantages of quadrisection using a 0, 3, 7, 10 scoring scale (e.g. more intuitive 100 point scale, more graphical "spread", etc.), only quadrisection was used in this paper.

U.S. EPA (p. 9-10, 1999) states that recent data from various states is supportive of the "all-sites" approach and that ideally, a composite of all sites representing a gradient of conditions is used which represent a dose-response relationship; however, this approach depends on whether both reference and non-reference sites can be incorporated into the data set. Karr et al.(1986), Ohio EPA (1988a, 1988b), and others used a reference site approach followed by trisection or quadrisection. *Reference sites are defined as sites lacking obvious or discernible human cultural influence or the least-impacted systems available in particular landscape.* In the case of stream IBIs based on fish or macroinvertebrate assemblages, data from reference streams was plotted against stream drainage area to account for natural variability based on stream size and landscape position. A "maximum species richness line" (MSRL) is then fitted to the resulting distribution such that 95% of the data points fall below the line. The distribution is then trisected or quadrisected below this line (Ohio EPA 1988a, 1988b; Yoder and Rankin 1995; Barbour et al. 1995). Since no similar defining "x-axis" equivalent to stream drainage area has been identified for wetlands when vascular plants are being used as an indicator assemblage, the step of fitting the MSRL to the distribution can be omitted, and the 95% point identified numerically and the measurements below this point are quadrisected. The main difference is the omission, in the "reference-sites" method, of sites *with* human cultural influences.

Mack et al. (2000) calculated VIBI scores using an "all-sites" and a "reference-sites" method. The main effect was an overall suppression in the VIBI score when only least-impacted reference sites were used; the relative position of sites did not vary noticeably. Karr and Chu (1999) state that sectioning of data sets into approximately equal thirds or fourths is appropriate where monotonic or linear distributions are observed in the metric values. Where distributions are not monotonic or linear, they recommend using natural breaks in the distribution to determine scores

Low quality sites are often more difficult to locate and obtain access to than high quality sites. Many high quality wetlands are located on public lands where research access is easily obtained; low quality sites are often on private lands and locating them and obtaining access is more difficult. Because of this, low quality sites are under represented in the existing data set, especially for forested and shrub dominated communities. The difficulty in finding low quality forest or shrub wetlands is further compounded by the fact that forest or shrub wetlands, when very degraded, often lose their woody component altogether and resemble low quality emergent marshes.

Because of this problem, the "all-sites" and "reference sites" methods are further evaluated in this report to determine which is most appropriate. When the "all-sites" method was used, all the sites within the class representing a gradient of disturbance were analyzed together. When the "reference-sites" method was used, all the sites within the class representing least-impacted or "reference" conditions were analyzed together.

The measurement of a particular metric was made at each wetland and the 95th percentile of the measurement was calculated. The 95th percentile is used as the upper reference limit and the range of scores below this score was quadrisected. The 95th percentile was calculated using the PERCENTILE function of EXCEL. Two methods were used to quadrisect the distribution: mathematical quadrisection and graphically-fitted quadrisection. Mathematical quadrisection simply mathematically divides the distribution into four equal parts. Sites with measurements above the fourth quartile below the 95th percentile received a score of 10, sites within the third received a score of 7, sites within the second received a score of 3 and sites within the first quartile received a score of 0. Graphically-fitted quadrisection breaks the distribution into sections at points in the distribution that conform to observed changes in the attributes and assigns scores of 0, 3, 7, or 10 based on whether the attribute is in the first, second, third, or fourth section of the distribution. This method was used when the distribution was not linear or obvious breaks in metric values were apparent. The differences in the two methods are readily apparent when actual data and breakpoints are compared.

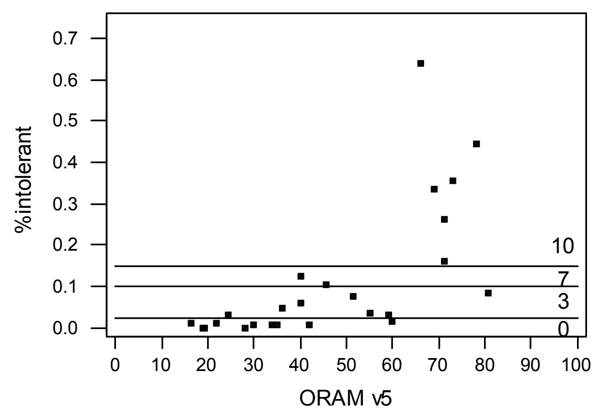

Figure 3. Relative cover of intolerant plant species (%intolerant) versus ORAM v. 5.0 score from %intolerant metric of VIBI-Emergent with metric score breakpoints established by graphical fitting technique.

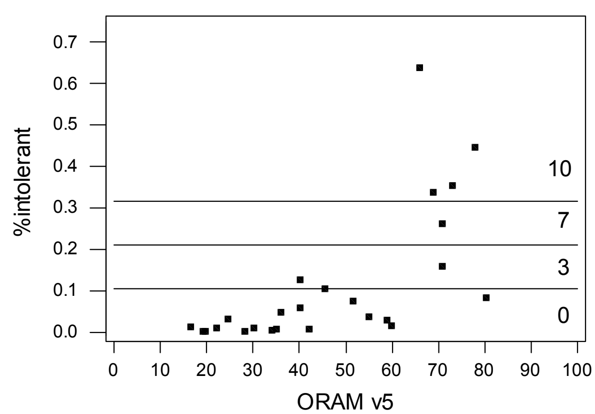

Figure 4. Relative cover of intolerant plant species versus ORAM v. 5.0 score from %intolerant metric of VIBI-Emergent with metric score breakpoints established by mathematical quadrisection technique.

Figures 3 and 4 show the values for the %intolerant metric in the VIBI-E where it was determined that graphical fitting was more appropriate than mathematical quadrisection. Figure 3 has graphically fitted breakpoints; Figure 4 has scoring mathematically quadrisected breakpoints. It is readily apparent that this distribution is not linear but rather represents a threshold where high to moderate disturbance results in scores of 0 to nearly 0 with an abrupt increase in scores as disturbance decreases. Mathematically derived breakpoints result in too many sites receiving a score of 0 when they are functioning at a higher level. Graphically fitting the breakpoints to the distribution considerably improves the metric's performance.

2.5 Floristic Quality Assessment Index

Ohio EPA has previously investigated the use of the Floristic Quality Assessment Index (FQAI) and its relationship to wetland disturbance and quality in Fennessy et al. (1998a and 1998b). Mack et al. 2000 found that the FQAI score and variants of that score were very strongly correlated with measures of wetland disturbance.

The FQAI was first devised by Swink and Wilhelm (1979) for plants in the Chicago region and later explored by Wilhelm and Ladd (1988) and Wilhelm and Masters (1995) and adapted to Michigan (Herman et al. 1993) and Northern Ohio (Andreas and Lichvar 1995). Its use is being explored in other parts of the United States (Ladd, in prep.). The principal concept underlying the FQAI is that the "quality" of a natural community can be objectively evaluated by examining the degree of ecological conservatism (or tolerance) of the plants species in that community, regardless of the type of community or the abundance, dominance, growth form, etc. of the plants that comprise it. Fennessy et al. (1998a, 1998b) found significant correlations between a wetland's FQAI score and the degree of human disturbance at the site.

A floristic quality index is developed by assigning a numeric score from 0 to 10 to the entire flora growing in a specified geographical region. This score is called a "coefficient of conservatism" or “C of C,” and represents the degree of conservatism (or tolerance) displayed by that species in relation to all other species of the region (Wilhelm and Ladd 1988; Wilhelm and Masters 1995; Andreas and Lichvar 1995). The C of C's of all the species identified as growing at a particular site are summed and divided by the square root of the total species identified, N, or

$$I = \sum(c_1+c_2+....c_n)/\sqrt{N} \qquad \text{Eqn. 1}$$

where I = the FQAI score, c_n = the coefficient of conservatism of a plant, and N = the total number of native species at the site being evaluated. Note that the FQAI excludes nonnative plants from the calculation of the index.

For the purposes of IBI development, the FQAI can be conceptualized as a weighted richness metric. Richness (total number of species, number of species in a taxa or functional group, etc.) is one of the oldest concepts used in ecology to distinguish communities (Krebs 1999), and is often used as a useful attribute in IBI development.

Although the assigning of the CofC is a subjective, although not arbitrary decision made by a person or group of persons intimately familiar with the flora of a region or state based on their knowledge of the narrowness or breadth of a plant's ecological tolerances, once this decision is made, the index is both objective and consistent. In effect, FQAI "front-loads" the subjectivity during the development of the system itself: users of the index are required to apply it objectively and consistently. Any inherent biases in assigning a particular CofC to particular plants, occur uniformly and the relative comparison of site A to Site B to Site C is not affected.

In using the FQAI to develop VIBIs, Ohio EPA has used the FQAI system developed by Andreas and Lichvar (1995) and the CofC's proposed by them for this regional flora. Most of the wetlands studied to date occur within or near this region and it was determined that until a statewide FQAI was developed, this is the best system presently available.

2.6 Disturbance scale

As was mentioned previously, no similar defining "x-axis" equivalent to stream drainage area has been identified for wetlands when vascular plants are being used as an indicator assemblage. Therefore, an important part of the development of the VIBI has been the concomitant development of a semi-quantitative "disturbance scale." Fennessy et al. (1998b) developed a qualitative 0 to 10 scale of degree of disturbance. Fennessy et al. (Figure 2.2, 1998a) developed a 4-tiered ranking system for evaluating the degree of human disturbance. In addition, Fennessy et al. (1998a) investigated the responsiveness of the score from ORAM v. 3.0 to disturbance and found significant correlations.

Gernes and Helgen (1999) classified sites by type of disturbance (none, agricultural, stormwater) and used a scoring scheme which assigned a 0, 2, 4, or 8 depending on the degree of human influence, 0 being equal to reference conditions and 8 being very disturbed. In addition, they considered three other disturbance factors (hydrologic alteration and miscellaneous influences, known historic influences, and the quality of the immediate buffer around the site). These factors were assigned scores of 0, 1, 2, or 3, with 3 being the most severely disturbed.

Carlisle et al. (1999) developed a multivariable habitat quality/disturbance ranking system for use in their development of IBIs for vascular plants and macroinvertebrates in Massachusetts coastal marshes. In addition, Ohio EPA has had considerable experience and success in developing a qualitative habitat evaluation index (QHEI) for streams and in correlating this index to IBIs (Rankin 1989; 1995).

The ORAM v. 5.0 is similar to these other ranking systems in that it functions as an ecological integrity and disturbance scale in addition to being a regulatory classification tool. It expressly addresses disturbances to wetland hydrology and habitat, presence or lack of buffers, intensity of surrounding land use, presence and abundance of invasive plant species, disturbances to substrates, and overall wetland quality. Finally, the ORAM v. 5.0 was designed to “relativize” differences in wetland type and HGM class during the assessment of the wetland and assigning of a score. Thus, the user is asked to evaluate a wetland in relation to other ecologically and hydrogeomorphically similar wetlands. Once a “score” is assigned to a particular wetland, it is comparable to other scores of other different types of wetlands. By “controlling” for these variables up-front in the disturbance scale, the number of wetland classes needed to develop an IBI can be limited. This results in wetlands occupying the same ranking “space” on the disturbance scale regardless of differences in hydrology and landscape position.

The ORAM v. 5.0 appears to be useful as a regulatory categorization tool as well as for evaluating the degree of human disturbance, or conversely, a qualitative assessment of the ecological integrity (intactness) of the wetland. Hence, the score has been used as the disturbance scale in the development of the vegetation IBIs presented here.

2.7 Statistical analyses

Minitab v. 12.0 for Windows was used to perform all statistical tests. Descriptive statistics, box and whisker plots, regression analysis, analysis of variance, multiple comparison tests, and t tests were used to explore and evaluate the biological attributes measured for VIBI development, the VIBIs, physical parameters, and the ORAM v. 5.0 scores.

3.0 Vegetation IBIs for Wetlands

Vegetation IBIs have been previously proposed for three dominant plant community types: emergent, forest, and shrub (Mack et al. (2000). These community types corresponded to the first broad community division of the Cowardin et al. (1979) classification scheme, e.g. the "palustrine" system was divided into palustrine forested, palustrine emergent, and palustrine shrub wetlands. There were several reasons these three broad classes were adopted. First, some metrics used in the Vegetation IBIs were specific to a particular type of wetland. For example, average standing biomass (g/m^2) data in the form of clip plots was only collected at emergent wetland types; forestry metrics like relative density of trees in the 10 to 25 cm size classes could only be collected in sites dominated by woody vegetation. Therefore, metrics based on these attributes were inapplicable to some types of wetlands.

Second, it is obvious that there is a large amount of natural variation in species composition and ecosystem functions between communities dominated by herbaceous vegetation versus communities dominated by woody vegetation (Cronk and Fennessy 2001). Classifying at this broad level helped to reduce the effect of this natural variability to identify community attributes that were varying due to human disturbances.

Finally, a statistical comparison was performed of the mean values of the shared metrics between emergent, forest, and shrub communities (Table 11). Significant differences were observed for 5 "core" metrics common to the vegetation IBIs (dicot, hydrophyte, FQAI, %tolerant, and %intolerant). The successionally and/or floristically intermediate position of shrub wetlands between emergent and forested wetlands is also suggested by this comparison of mean metric scores.

Each of the subsequent sections presents the Vegetation Index of Biotic Integrity (VIBI) for the emergent, forested, and shrub wetland vegetation classes. Figures and tables supporting each VIBI are presented after the text in §§3.1, 3.2, and 3.3. An overall analysis of the behavior of the three VIBIs is discussed in §4.0.

The individual metrics that make up the VIBI-E, VIBI-F, and VIBI-SH were selected to represent a number of taxa groups and taxa levels, plant life forms, tolerance or intolerance to disturbance, and community level variables. Metrics were selected that had linear, curvilinear, threshold, or other discernible relationship to the disturbance gradient. An important step in the development of an IBI is to test the metrics initially developed against data collected from additional sites, or from sites in different ecoregions, or from sites of a different HGM or plant community class, to determine whether the relationship observed between that metric and human disturbance continues to be present or was simply an artifact of the prior data set.

The Vegetation IBIs proposed in Mack et al. (2000) were based on data collected from wetlands located in the Eastern Corn Belt Plains (ECBP) Ecoregion of western and central Ohio. Since 1996, 509 vascular plant species have been identified in the quadrats and plots used in this study. Of these 509 species, 394 had relative cover values >1.0%. Wetlands in the Erie Ontario Lake Plains (EOLP) ecoregion (glaciated Allegheny Plateau and Lake Plains) were sampled during the 2000 field season.[6] Data from the EOLP wetlands were tested against the ECBP wetlands data for differences based on ecoregion. Graphical analysis, regression analysis, and analysis of variance and multiple comparison tests were used to test the previously developed Vegetation IBI.

[6] Wetlands in the Erie Ontario Drift and Lake Plains were also sampled during the 2001 field season, but this data was not able to be analyzed in time for this report.

Table 11. Mean, standard deviation (parenthesis) and ANOVA results for 3 primary vegetation community classes for metrics used in the vegetation IBI for "reference" condition wetlands, i.e. wetlands lacking in obvious human cultural influences. Means with shared letters were not significantly different after Tukey's Honest Significant Difference test. Metrics with asterisks were compared using 2-sample t-test. Means in bold face paired for purposes of developing VIBI-SH (See § 3.3 below).

metric	results	Emergent N=8	Forested N=13	Shrub N=12
no. carex spp.	df=32, F=1.73, p=0.690	3.9(1.6)	**3.2(2.7)**	**3.0(1.8)**
no. dicot spp.	df=32, F=3.56, p=0.041	**23.0(5.2)a**	30.6(6.9)b	**26.6(6.5)ab**
no. shrub spp	df=32, F=0.04, p=0.958	5.4(2.5)	**5.1(2.9)**	**5.1(1.9)**
no. hydrophyte spp.	df=32, F=8.59, p=0.001	32.0(7.3)a	**20.1(8.5)b**	**19.9(5.1)b**
no. Rosaceae spp.	df=32, F=1.51, p=0.238	1.9(1.0)	**2.9(1.6)**	**2.8(1.4)**
FQAI score	df=32, F=2.52, p=0.097	**23.4(4.8)ab**	25.9(3.9)a	**22.5(2.9)bc**
% tolerant spp.	df=32, F=5.27, p=0.011	0.19(0.14)a	0.17(0.08)a	0.06(0.05)b
% intolerant spp.	df=32, F=4.90, p=0.014	0.22(0.15)a	**0.41(0.22)b**	**0.50(0.19)b**
%invasive graminoids	df=32, F=3.56, p=0.041	0.030(0.055)a	0.00004 (0.00002)b	0.003(0.008)b
*shrub density	df=20, t=-0.82, p=0.42	na	**1533(1358)**	**2004(1404)**
*small tree	df=17, t=0.06, p=0.95	na	**0.101(0.05)**	**0.099(0.09)**
*maximum IV	df=19, t=-1.70, p=0.11	na	**1.14(0.28)**	**1.39(0.41)**

An important factor in the development of these IBIs has been the consistent use of certain decision rules. Even small wetlands can have more than one plant community even at the broad level of just three classes, emergent, forest, and shrub. Some of the "rules" for how data is analyzed and used are found in the sampling procedures for locating sample plots. These specify how to sample various wetlands and plant communities within them (Mack 2001b). Beyond these, certain methodological issues arise when deciding how to use the data to develop a vegetation-based wetland IBI. Additional and different issues arise when deciding how to use the same data to assess the level of "impairment" or to assign a regulatory category of a wetland.

For example, a wetland has two co-dominant plant communities, a shallowly inundated to saturated wet woods and a deeper buttonbush pool that has no forest canopy above it. Floristically and structurally the two communities are different but comprise a single "wetland" in the sense of drawing a boundary between wetland areas and upland areas. Several approaches to sampling this wetland are possible: sample only one of the two communities; sample each community separately with completely separated plots; sample each community separately with adjoining plots; sample mostly in one community but include a portion of the other in the sampling plot. Depending on how the community was sampled, additional issues arise as to how to use the data in the development of a vegetation IBI versus how to use the data to assess the wetland from a condition assessment/use attainment perspective. An answer to the IBI development issue may not answer the use attainment application issue.

Returning to the wetland above, suppose you choose to sample each community with two completely separated plots. Now you want to use this data to develop a vegetation IBI. Since this is a single wetland, should you combine the data sets? If you do, how do you graph or analyze the data? With the forest community data set or the shrub community data set? If the data is combined, doesn't this give this type of wetland an advantage over a wetland with only one of these communities in the IBI development process. If you analyze data from each community separately and only include the relevant portion in the relevant data set (forest and shrub), what happens if there are disturbances that have only degraded one but not the other community? Should there be a separate disturbance score for each community to reflect this? What if, instead of using this data to develop an IBI, you want to assess the condition of this wetland. Do you combine the data sets or keep them separate? Combining them may result in a higher IBI score. Do you calculate separate IBI scores and use the higher of the two scores to assess condition? Again, what if the disturbance is localized to one but not the other community/portion of the wetland?

Applying the use attainment paradigm to wetlands may also present some methodological difficulties that prevent a mechanical approach to its use when working in wetland versus stream systems. Streams are more defined and definable. Sampling is clearly confined within two banks and some linear reach. Attainment/nonattainment areas are defined by river miles. Wetlands come in very large to very small sizes. Single to multiple communities, gradients (physical, temporal) of inundation, saturation. Disturbances may only effect a portion of wetland or a portion of one community in a wetland. In this situation, is the wetland in attainment or nonattainment or partial attainment? How do you define an area of nonattainment?

In response to questions like this, certain "decision rules" have been adopted to ensure the consistent development and use of a vegetation IBI.

1. IBI Development Rule. Co-dominant communities within a single wetland should be sampled with completely separate plots, or at a minimum, adjoining plots that allow the data set to be kept separate, and data from each should be analyzed as if it were the only community present. Thus, forested wetland data sets should only be graphed and analyzed with other forested wetland data sets when developing and selecting metrics and metric scoring breakpoints to develop a vegetation IBI. Wetlands with a single dominant community with small amounts of other communities, e.g. the buttonbush swamp with a narrow forested margin, the emergent marsh with a narrow shrub margin or small pool with floating aquatic plants, should be sampled using the plot location rules in the Field Manual (Mack 2001b) which require that the marginal community be included in the plot but not be the focus of the intensive modules.

2. Assessment Rule. HOWEVER, from a bioassessment, use attainment, or antidegradation categorization perspective, a single wetland with two co-dominant communities should be assessed or categorized by looking at the result that gives you the best answer, e.g. the forested community has a Category 3 VIBI score while the buttonbush community has a Category 2 VIBI score: the wetland is categorized as a Category 3 wetland.

3. IBI Development and Assessment Rule. Large wetland complexes with multiple subcommunities should generally be sampled with multiple plots in order to reflect the overall diversity of the complex <u>and</u> the data from these plots should be added together and analyzed as if it were a single wetland. Note: rule 1 applies if there are codominant emergent, forest, or shrub classes; this rule addresses multiple communities within a class. For example, Singer Lake Bog[7] is a several hundred acre bog complex with areas of continuous Sphagnous carpets dominated by leatherleaf and cranberry,

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[7] Vegetation IBI scores Singer Lake Bog were as follows: Floating-leaved marsh/decodon marsh plot=66; Leatherleaf Bog plot=60, combined data set of both plots=80.

floating-leaved marshes, open water moats and channels, decodon marshes, mixed shrub communities, etc. A complete assessment of this complex would require data from most of these communities and would likely require two to several sampling plots.

4. Certain problems with codominant communities can be solved by using the scoring boundary rules developed for ORAM v. 5.0 regulatory categorization purposes (Mack 2001a). In order to use the ORAM as a rapid assessment tool, a "scoring boundary" needs to be established in order to determine what is being assessed and what is not. The main rule is that where strong changes in hydrology occur, wetland areas can be scored separately even if they are contiguous to each other. Thus, where a wetland can be split into separate scorable areas, separate sample plots should be established in each scoring area and the data evaluated, analyzed and used as if they were two geographically separated wetlands. For example, Watercress Marsh is a large wetland complex at the headwaters of the Mahoning River in Columbiana County. A large, sloped, tall shrub fen is present on one side of the complex; the rest of the marsh is primarily a cattail or floating leaved marsh with shrubby margins. The hydrology of the fen is driven by calcareous ground water expressing along the slope. The marsh areas receive this ground water but are also fed by run off from the watershed. The marsh is also very disturbed by nutrient enrichment from nearby farms and former road construction; the fen appears to be largely intact and very floristically diverse. Because of the hydrologic discontinuity at the base of the slope fen to the flat marsh, separate scoring boundaries can be established around these two hydrogeomorphically (and floristically) distinct communities.

With these preliminary matters addressed, the following sections present the Vegetation IBIs developed for three classes of wetland plant communities: emergent, forest, and shrub.

3.1 VIBI-EMERGENT

In Mack et al. (2000), a Vegetation IBI was proposed for "emergent" wetland types (VIBI-EMERGENT or VIBI-E) that included ten metrics: number of carex spp., number of dicot spp., number of shrub spp. divided by the total spp., FQAI score, % cover of tolerant spp. , % cover of intolerant spp., % cover of FAC spp., median % cover of graminoid spp., average standing biomass (g/m^2) and heterogeneity. Of these original ten metrics, 7 were determined to be still valid and usable, 6 unchanged and 1 with slight modifications; 3 metrics were rejected and replaced with new metrics.

Table 12. Metrics modified or replaced in Vegetation IBI for emergent wetlands from those initially proposed in Mack et al. 2000.

code	metric	description
%FAC	relative cover of plants with FAC wetland indicator status	Metric replaced. Overall Lack of discernible relationship between metric and disturbance gradient. Replaced with a richness metric of number of FACW and OBL species.
%graminoid	median of the relative cover of graminoid plant species	Metric replaced. Abrupt curvilinear relationship observable but natural variability and the large number of disturbed wetlands with low metric values resulted in too many scores of 7 or 10 and a skewing of overall VIBI scores. Replaced with relative cover of invasive graminoid species.
biomass	average standing biomass (g/m^2)	Metric modified. High quality graminoid dominated communities with relatively high standing biomass obscured predictable trend observed in this metric when initially adopted. Modified by using maximum standing biomass sampled instead of average of all biomass samples dampened this natural variability in productivity.
heterogeneity	heterogeneity index (Simpson's D)	Metric replaced. Only weak relationship between metric and disturbance gradient and the large number of disturbed wetlands with low metric values resulted in too many scores of 7 or 10 and a skewing of overall VIBI scores. Replaced with Rosaceae species richness metric.

The originally proposed metrics and replacement metrics were evaluated using the techniques outlined in the methods section and also for their continued robustness and sensitivity based on the inclusion in the data set of additional emergent wetlands from the EOLP ecoregion. None of the metrics were rejected solely based on obvious ecoregional differences.[8] Table 12 and Figure 5 summarize the rejected metrics and the reasons for rejection.

Table 15 describes the metrics currently included in the VIBI-E. The six metrics retained from the initial VIBI-E continue to perform strongly especially number of carex and dicot species, FQAI score, and relative cover of tolerant and intolerant plant species. Predictable and statistically significant linear and curvilinear relationships between human disturbance, as measured by the ORAM v. 5.0 score, and the current metrics continue to be observed (Figure 6, Table 13).

[8] The means of the rejected metrics for wetlands in the ECBP and EOLP were compared. None of the means were significantly different except the %graminoid metric: %FAC (df=17, t=1.53, p=0.14); %graminoid (df=17, t=2.25, p=0.038; biomass (df=6, t=0.72, p=0.50); heterogeneity (df=22, t=0.28, p=0.79).

Table 13. Summary table of regression analysis of metrics used to derive VIBI-E. N=25, df=24 for all metrics except maximum biomass (N=24, df=23). See Table 15 for descriptions of metrics.

	F	p	R^2
carex	11.71	0.002	33.7%
dicot	40.22	<0.001	63.6%
shrub/tot	11.8	0.002	33.9%
hydrophyte	82.99	<0.001	78.3%
rosaceae	12.41	0.002	35.0%
FQAI	79.25	<0.001	77.5%
%tolerant	18.66	<0.001	44.8%
%intolerant	18.17	<0.001	44.1%
%invasive graminoids	6.67	<0.017	22.5%
maximum biomass	8.82	0.007	28.6%

Results from an analysis of variance using ecoregion and reference condition as independent variables were mixed and should be considered preliminary given the small sample sizes for 3 of the 4 categories. Eight metrics had significant differences: carex, dicot, shrub/tot, hydrophyte, FQAI, %tolerant, %intolerant and %intolerant (Table 14, Figure 7). Most of these differences were due to differences between reference and nonreference wetlands and not to ecoregional differences.

For the dicot metric, the mean number of dicot species in reference wetlands in the ECBP region was significantly higher (by 4 species) than the EOLP region; there was no similar difference between nonreference wetlands in these ecoregions. It is unclear whether this is a true ecoregional difference or an artifact of the data set since the number of dicot species in reference wetlands was significantly higher than nonreference wetlands regardless of ecoregion.

For the shrub/tot metric, all four means were significantly different from each other with the means in both reference and nonreference ECBP wetlands being lower than the means of reference and nonreference wetlands in the EOLP region. This pattern could be problematic for the future use of this metric since alternate scoring breakpoints may need to be derived for each ecoregion. However, these differences may disappear as additional sites are added to the data set. Assuming the differences are real, the present use of this metric with a combined data set of EOLP and ECBP would result in a slight bias against ECBP wetlands since the EOLP wetlands might shift the scoring breakpoints up. The behavior of this metric will be investigated further as data from the 2001 field season is included.

For the hydrophyte metric, all means were again significantly different from each other, although ref-ECBP and ref-EOLP wetlands only differed by 5.5 species. A larger difference was observed between non-ECBP and non-EOLP wetlands (8.8 species) but this was likely an artifact of the data set since the non-reference EOLP wetlands were of considerably better quality than many of the non-reference ECBP wetlands in the data set. Again, assuming the differences are real, the present use of this metric with a combined data set of EOLP and ECBP would result in a slight bias against ECBP wetlands since the EOLP wetlands might shift the scoring breakpoints up. The behavior of this metric will be investigated further as data from the 2001 field season is included.

The differences in FQAI metric means can probably be discounted as an artifact of the current data set for the reasons discussed in the hydrophyte metric since the highly disturbed nonreference ECBP wetlands sampled had considerably lower FQAI scores than the non-EOLP sites sampled.

Table 14. Comparison of means (standard deviation in parenthesis) of VIBI-E metrics by ecoregion and reference condition using analysis of variance (N=25, df=24 for all metrics except maximum biomass (N=24, df=23)). Means without shared letters are significantly different at p<0.05 based on Tukey's Honest Significant Difference test.

	ANOVA results	non-ECBP N=13	non-EOLP N=3	ref-ECBP N=5	ref-EOLP N=4
carex	df=24, F=7.79, p=0.001	1.5(0.98)a	1.0(1.0)a	4.2(1.8)b	3.3(1.3)b
dicot	df=24, F=6.75, p=0.002	11.7(7.1)a	14.0(4.4)a	25.2(6.1)b	21.3(2.5)bc
shrub/tot	df=24, F=11.59, p<0.001	0.02(0.03)a	0.18(0.09)b	0.10(0.06)c	0.16(0.09)d
hydrophyte	df=24, F=15.06, p<0.001	13.2(6.6)a	22.0(1.7)b	29.0(8.4)c	34.5(4.0)d
rosaceae	df=24, F=2.45, p=0.092	0.6(0.96)	1.0(1.0)	1.8(1.3)	1.8(0.5)
FQAI	df=24, F=14.02, p<0.001	11.7(4.3)a	16.8(1.4)b	24.5(6.5)c	23.1(0.95)c
%tolerant	df=24, F=6.07, p=0.004	0.53(0.24)a	0.44(0.15)a	0.11(0.08)b	0.26(0.16)b
%intolerant	df=24, F=9.03, p<0.001	0.03(0.04)a	0.04(0.05)a	0.33(0.20)b	0.18(0.19)bc
%invasive graminoids	df=24, F=1.63, p=0.211	0.21(0.26)	0.23(0.16)	0.01(0.01)	0.05(0.08)
maximum biomass	df=23, F=2.24, p=0.115	1616(628)	1408(1054)	1231(758)	508(146)

For the %tolerant metric, only differences between reference and nonreference wetlands were significant. No significant ecoregional differences were present.

Finally, for the %intolerant metric the ref-ECBP wetlands had an average higher score than the ref-EOLP wetlands, the same pattern observed in the dicot metric. It is unclear whether this is a real difference or simply due to the relatively small sample sizes. No ecoregional differences were observed in the nonreference ECBP or EOLP classes. The behavior of this metric will be investigated further as data from the 2001 field season is included.

Metric values were converted to IBI scores by quadrisecting the 95th percentile of the values of that metric data. Table 16 lists the scoring breakpoints used to assign a score to a particular metric value.
The scores of each metric were evaluated (Table 17). Scores were distributed appropriately when the percentage of scores was calculated by qualitative categories (very poor, poor, fair, good, reference), reference versus nonreference, and ORAM v. 5.0 scoring categories (0-35, 36-59, 60+) (Table 18).

A Vegetation Index of Biotic Integrity for wetlands dominated by emergent vegetation communities was calculated by summing the individual metric scores. The VIBI scores for each wetland were replotted against the ORAM score (Figure 8) (df=24, F=106.49, p<0.001, R^2=82.2%). The overall behavior of the VIBI-Emergent is very satisfactory. Reference sites receive high to very high scores and the VIBI-E is able to distinguish a full range of sites from very highly disturbed (lowest score = 3) to very high quality sites (highest score = 97).

Although emergent fens and bogs were excluded from the data set during the derivation of the VIBI-E because of their exceptional floristic characteristics, calculating a VIBI score for these sites using the metrics and scoring criteria derived without them appeared to result in appropriate scores for the fen and bog sites, with the exception of Springville Marsh (Table 17). This was probably due to how Springville

Marsh was sampled since only very small relict areas of fen vegetation exist in a sea of narrow-leaved cattail, however, the sampling plot focused on this relict vegetation. Thus, until a separate fen/bog VIBI is developed, this technique appears to provide an adequate assessment method for these class of wetlands, since the VIBI-E appears to accurately assess their relative integrity/disturbance levels and rank them appropriately in the class of emergent wetlands.

Overall characteristics and behavior of the VIBI-E in relation to ecoregional, hydrogeomorphic, and plant community classes is found in §4.0. A important development in the study of emergent wetlands in this report has been the evaluation of the emergent class and whether "mixed emergent marsh" communities and sedge-grass communities (fens, seep fens, sedge meadows, wet prairies) can be grouped. This issue is explored in detail in §4.0 below.

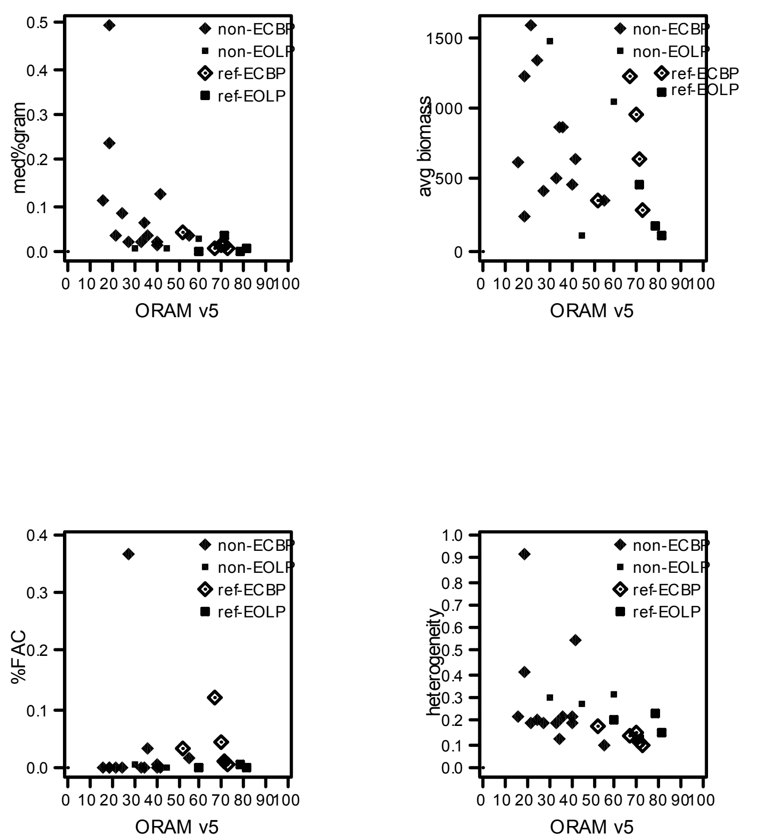

Figure 5. Scatterplots of metrics used initially in the Vegetation IBI-E proposed in Mack et al. (2000).

Table 15. Description of metrics for VIBI-EMERGENT in the State of Ohio.

metric	code	type	(+) or (-) as disturbance increases	description
number of carex spp.	carex	richness	decrease	Number of *Carex* spp. present at a site.
number of dicot spp.	dicot	richness	decrease	Number of dicot (dicotyledon) spp. present at a site.
shrub species/total species	shrub/tot	richness ratio	decrease	Number of shrub species divided by the total number of species.
number of FACW and OBL spp.	hydrophyte	richness	decrease	Number of plants with a Facultative Wet (FACW) or Obligate (OBL) wetland indicator status present at a site.
number of Rosaceae spp.	rosa	richness	decrease	Number of species in the Rose (Rosaceae) family present at the site.
FQAI score	FQAI	weighted richness index	decrease	The Floristic Quality Assessment Index score calculated in accordance with Andreas and Lichvar (1995). See §2.3 for description.
relative cover of intolerant plants	%intolerant	dominance ratio	decrease	Percent coverage of plants in herb and shrub stratums with a CofC of 6,7,8,9 and 10 divided by total percent coverage of all plants.
relative cover tolerant plant species	%tolerant	dominance ratio	increase	Percent coverage of plants in herb and shrub stratums with a CofC of 0, 1, and 2 divided by total percent coverage of all plants .
relative cover of invasive graminoid plant species	%gram	dominance	increase	The relative coverage of *Typha* sp., *Phalaris arundinacea,* and *Phragmites australis*.
maximum standing biomass	biomass	primary production	increase	The grams per square meter of largest clip plot sample collected at each emergent wetland.

Table 16. Scoring breakpoints for assigning metric scores to an emergent wetland. See Table 15 for descriptions of metric codes.

metric	95th percentile	quadrisection method	score 0	score 3	score 7	score 10
carex	5.7	mathematical quadrisection	0-1	2-3	4	≥5
dicot	26.7	graphical fitting	0-9	10-14	15-23	≥24
shrub/tot	0.225	mathematical quadrisection	0-0.056	0.0561-0.112	0.1121-0.169	0.1691-1.0
hydrophyte	40.0	mathematical quadrisection	0-10	11-20	21-30	≥31
rosa	3.0	mathematical quadrisection	0-1	2	3	≥4
FQAI	28.3	graphical fitting	0-9.9	10.0-14.3	14.4-21.4	≥21.5
%intolerant	0.423	mathematical quadrisection	0-0.106	0.1061-0.211	0.2111-0.317	0.3171-1.0
%tolerant	0.797	mathematical quadrisection	0.5981-1.0	0.3981-0.598	0.1991-0.398	0-0.199
%invasive graminoids	0.592	graphical fitting	0.31-1.0	0.151-0.3	0.031-0.15	0-0.03
biomass	2435	mathematical quadrisection	≥1827	1219-1826	610-1218	0-609

Table 17. Distribution of metric scores by site for VIBI-E. Sites in *italics* are fen or bog sites excluded from the derivation of the scoring breakpoints but then evaluated using the VIBI-E.

site	condition	ORAM v5.0	VIBI-E	no. of "0" scores	no. of "3" scores	no. of "7" scores	no. of "10" scores
American Legion	fair	40	41	3	2	4	1
Bates Creek	good	59	53	0	5	1	4
Beaver Creek	good	55	50	0	5	3	2
Berger Rd	poor	24.5	6	7	3	0	0
Birkner Pond	poor	30	27	5	2	2	1
Bloomville Swamp	fair	36	19	2	7	1	0
Calamus 1997	reference	73	67	1	2	2	5
County Rd 200	very poor	19	13	8	1	0	1
Daughmer	reference	69	87	0	1	0	9
Dever	fair	22	15	4	5	1	0
Eagle Cr Beaver	reference	71	64	0	1	5	4
Eagle Cr Bog	reference	81	67	1	2	2	5
Guilford Lake	good	45.5	51	2	0	6	2
Herrick Fen	fair	61	53	3	0	3	4
Keller Low	fair	35	26	3	5	1	1
Kinnikinnick	reference	66	60	1	3	1	5
Kiser Lake	reference	71	88	0	0	1	9
LaRue Emergent	fair	28	33	4	3	2	1
Lawrence Low 1	poor	34	29	4	4	1	1
Marsh Wetlands	reference	78	83	0	1	2	7
Mishne 1999	very poor	19.5	3	9	1	0	0
Mud Lake Bog	reference	91	78	0	1	3	6
Palmer Rd	very poor	16.5	9	7	3	0	0
Rickenbacker	reference	51.5	61	0	2	6	2
Scofield	fair	40	46	1	3	4	2
Silver Lake	fair	82	87	0	1	0	9
Singer Lake Bog	reference	86	77	0	2	1	7
Springville Marsh	fair	50	73	0	2	2	6
Stages Pond	poor	42	12	6	4	0	0
Tinkers Creek	reference	80.5	70	1	1	3	5
Watercress Marsh	fair	60	37	1	5	3	1
			total	73	77	60	100
			%total	23%	25%	19%	32%

Table 18. Percentage of metric scores by emergent wetland condition, reference versus nonreference, and ORAM v. 5.0 score.

	% of “0" scores	% of “3" scores	% of “7" scores	% of “10" scores
very poor	33%	6%	0%	1%
poor	30%	17%	5%	2%
fair	29%	42%	35%	16%
good	3%	16%	27%	10%
reference	5%	19%	33%	71%
nonreference	93%	71%	52%	36%
reference	7%	29%	48%	74%
0-35 ORAM score	70%	35%	12%	5%
26-59 ORAM score	19%	39%	45%	19%
60+ ORAM score	11%	26%	43%	76%

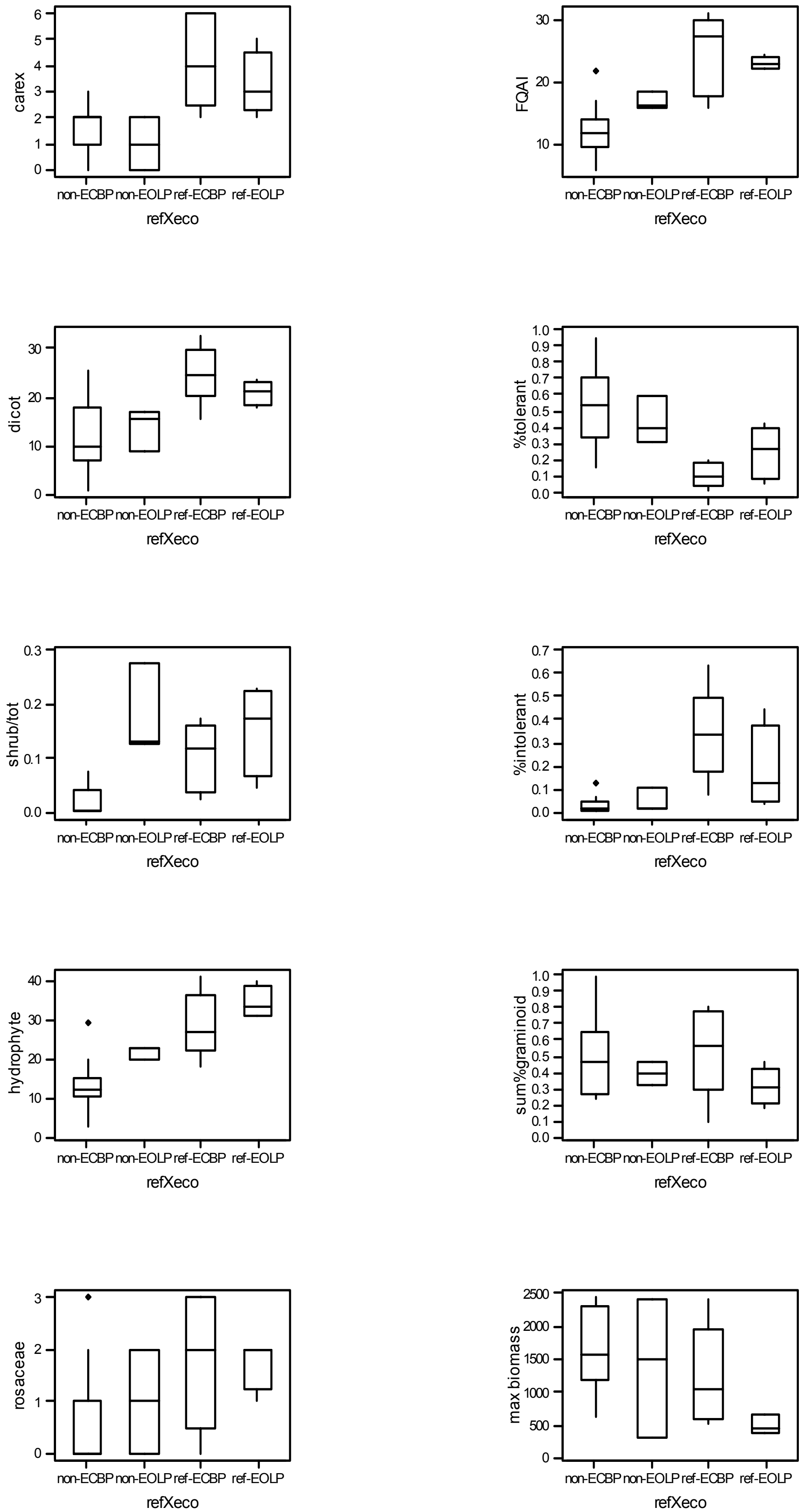

Figure 6. Box and whisker plots of ORAM v. 5.0 scores by vegetation community based on wetland classes. Refer to Table 6 for a description of these classes. A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and the highest observations that are still inside the region defined by the following limts: Lower Limit=Q1-1.5(Q3-Q1); Upper Limit=Q3+1.5(Q3-Q1).

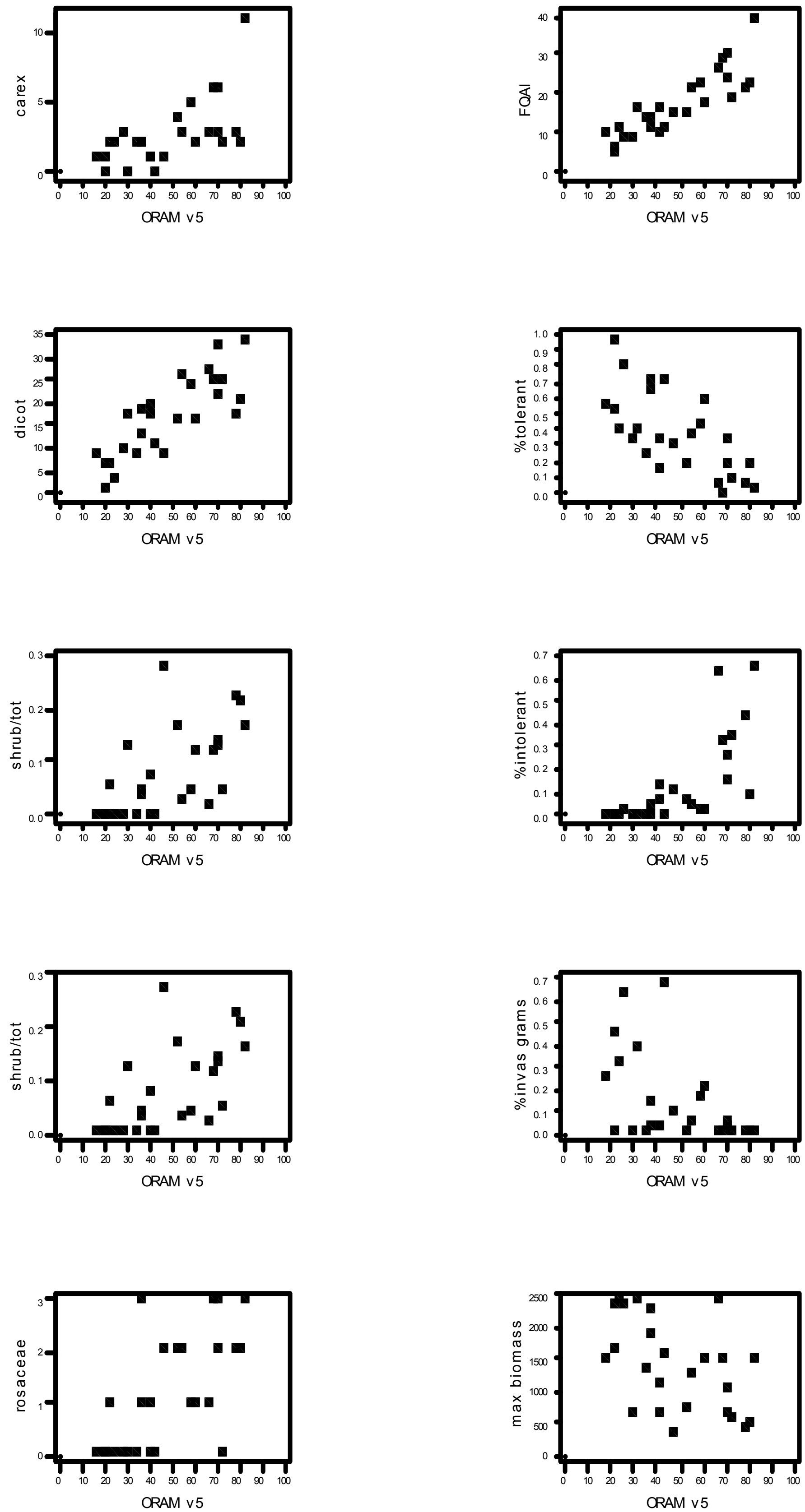

Figure 7. Scatterplots of metrics of wetlands used to derive the Vegetation IBI for emergent wetlands.

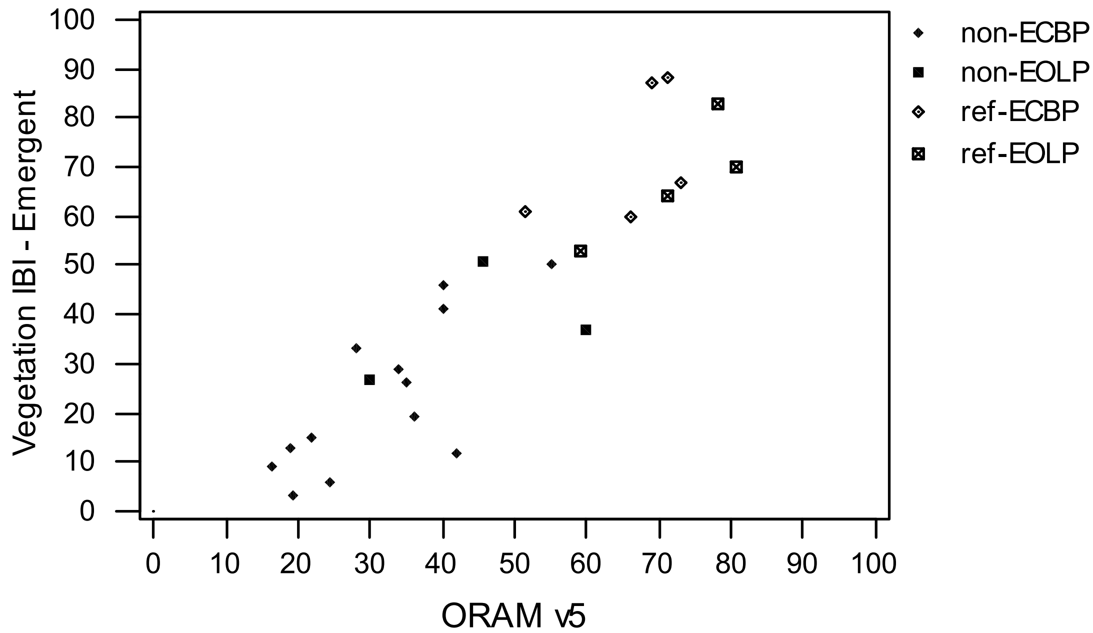

Figure 8. Scatterplot of Vegetation IBI scores for emergent wetlands used to derive the VIBI-E (df=24, F=106.49, $p<0.001$, R^2=82.2%). ECBP = Eastern Corn Belt Plains Ecoregion; EOLP = Erie Ontario Lake Plains Ecoregion; ref=reference wetlands, i.e. wetlands lacking in obvious human cultural influences; non=nonreference wetlands.

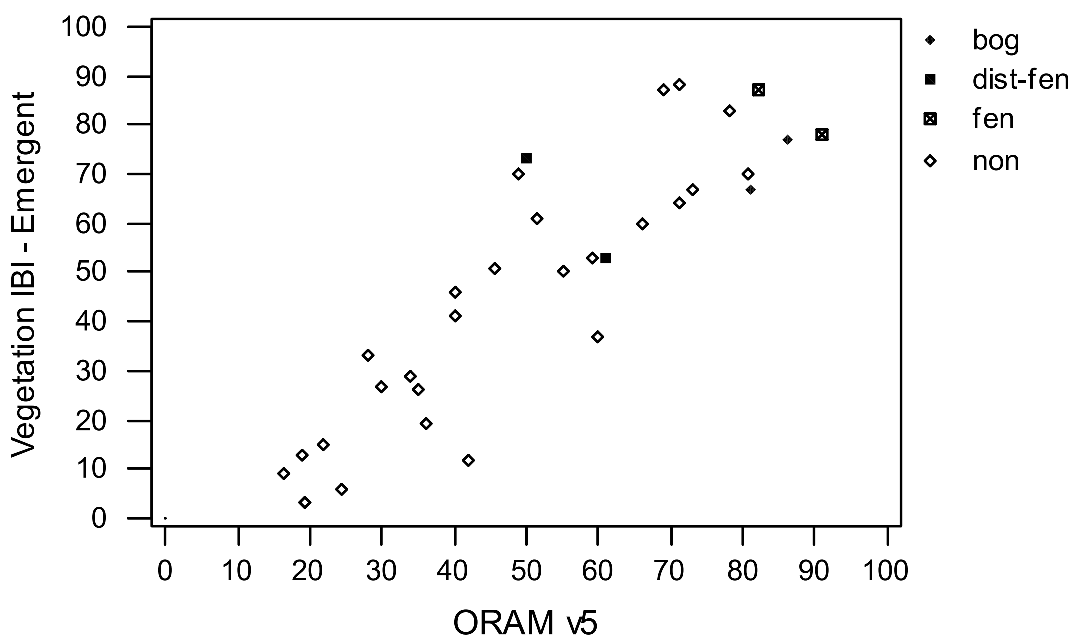

Figure 9. Scatterplot of vegetation IBI scores for emergent wetlands with fen and bog wetlands included. See Table 5 for plant community descriptions. bog=wetlands that are classified as bogs; fen=wetlands that are classified as fens, dist-fen=fens that have been disturbed by human activities; non=wetlands not classified as fens or bogs.

3.2 VIBI-FORESTED

In Mack et al. (2000), a Vegetation IBI was proposed for "forested" wetland types (VIBI-FOREST or VIBI-F) that included ten metrics: number of dicot spp., number of shrub spp. divided by number of tree spp., number of FAC spp. divided by the total number of spp., FQAI score, % cover of tolerant spp., % cover of intolerant spp., % cover of OBL spp., relative density of small trees, $\log_{10}$ of shrub density, and heterogeneity. Of these original ten metrics, 7 were determined to be still valid and usable, 5 unchanged and 2 with slight modifications, and 3 were rejected and replaced with new metrics.

The originally proposed metrics and replacement metrics were evaluated using the techniques outlined in the methods section and also for their continued robustness and sensitivity based on the inclusion in the data set of additional forested wetlands from the EOLP ecoregion. None of the metrics were rejected solely based on obvious ecoregional differences. Table 19 and Figure 10 summarize the modified or rejected metrics and the reasons for the change.

Table 22 describes the metrics currently included in the VIBI-F. The seven metrics retained from the initial VIBI-F continue to perform strongly, especially, number of dicot species, FQAI score, relative cover of tolerant and intolerant plant species, small tree, and shrub density. Predictable and statistically significant linear and curvilinear relationships between human disturbance, as measured by the ORAM v. 5.0 score, and the current metrics continued to be observed (Figure 11, Table 20).

Table 19. Metrics modified or replaced in Vegetation IBI for forested wetlands from those initially proposed in Mack et al. 2000.

code	metric	description
shrub/tree	ratio of number of shrub species divided by number of tree species	Metric modified. Better fit when simpler shrub species richness metric used instead of previously used ratio metric.
FAC/tot	ratio of number of plants with a FAC wetland indicator status divided by the total number of species at the site	Metric replaced. Overall Lack of discernible relationship between metric and disturbance gradient. Replaced with hydrophyte richness metric counting numbers of FACW and OBL plant species per site.
%OBL	relative cover of plants with an OBL wetland indicator status	Metric replaced. Determined to be too redundant with the hydrophyte metric (number of FACW and OBL spp.). Replaced with Rosaceae species richness metric.
shrub density	the $\log_{10}$ of shrub density	Metric modified. Better fit when simpler shrub density without $\log_{10}$ conversion used.
heterogeneity	heterogeneity index (Simpson's D) (see Krebs 1999)	Metric replaced. Only weak relationship between metric and disturbance gradient. Replaced with quantitative forestry metric of maximum importance value of a species at a site.

Table 20. Summary table of regression analysis of metrics used to derive VIBI-F. N=29, df=28 for all metrics. See Table 23 for descriptions of metrics.

	F	p	R^2
dicot	15.69	<0.001	36.8%
shrub	17.42	<0.001	39.2%
hydrophyte	10.71	0.003	28.4%
rosaceae	4.89	0.036	15.3%
FQAI	48.39	<0.001	64.2%
%tolerant	12.48	0.001	31.6%
%intolerant	9.74	0.004	26.5%
small tree	17.00	<0.001	38.6%
shrub density	12.40	0.002	31.5%
maximum IV	8.54	0.007	24.0%

Results from an analysis of variance using ecoregion and reference condition as independent variables should be considered preliminary given the small sample sizes for 3 of the 4 categories. Only four metrics had significant differences (FQAI, %intolerant, small tree and shrub density) while two other metrics showed marginally significant differences (dicot and hydrophyte) (Table 21). None of the significant or marginally significant mean differences, except for hydrophyte, were due to ecoregional differences in the mean metric values when only reference sites were compared. There were differences between nonreference wetlands based on ecoregion for the %intolerant, small tree, and shrub density metrics. It is unclear whether this is a real difference or simply due to wetlands sampled to date. The nonreference EOLP wetlands sampled in 2000 tended to be of overall better quality and an effort was made during the 2001 field season to sample the very worse type of wetlands in the EOLP ecoregion.

There were some graphical differences between means of the reference wetlands based on ecoregion but these differences did not trend consistently, i.e. one ecoregion consistently with better scores than the other. Thus, in conclusion, little clear ecoregional variation is apparent from an examination of mean values of the metrics that make up the vegetation IBI for forested wetlands.

Metric values were converted to IBI scores by quadrisecting the 95^{th} percentile of the values of that metric data. Table 23 lists the scoring breakpoints used to assign a score to a particular metric value.
The scores of each metric were evaluated (Tables 24 and 25). Scores were distributed appropriately when the percentage of scores was evaluated by qualitative categories (very poor, poor, fair, good, reference), reference versus nonreference, and ORAM v. 5.0 scoring categories (0-35, 36-59, 60+).

Table 21. Comparison of means of VIBI-F metrics by ecoregion and reference condition using analysis of variance (N=29). Means without shared letters are significantly different at p<0.05 based on Tukey's Honest Significant Difference test, except for dicot and hydrophyte.

	ANOVA results	non-ECBP N=11	non-EOLP N=5	ref-ECBP N=5	ref-EOLP N=8
dicot	df=28, F=2.93, p=0.053	24.8(8.1)ac	19.8(7.6)a	33.0(9.4)b	29.0(4.5)bc
shrub	df=28, F=2.20, p=0.113	2.5(2.2)	3.6(2.6)	5.3(3.2)	5.0(2.4)
hydrophyte	df=28, F=2.54, p=0.079	13.6(4.2)a	18.2(4.9)a	23.3(13.7)b	18.0(4.9)a
rosaceae	df=28, F=0.62, p=0.608	2.2(2.3)	1.8(1.1)	3.3(1.5)	2.8(1.4)
FQAI	df=28, F=6.73, p=0.002	17.7(4.9)a	18.6(5.6)a	24.2(4.5)b	26.7(4.0)b
%tolerant	df=28, F=2.19, p=0.114	0.31(0.18)	0.33(0.29)	0.18(0.03)	0.14(0.09)
%intolerant	df=28, F=5.75, p=0.004	0.06(0.09)a	0.34(0.36)b	0.32(0.06)b	0.43(0.25)b
small tree	df=28, F=3.91, p=0.020	0.26(0.13)a	0.17(0.17)b	0.08(0.05)b	0.11(0.05)b
shrub density	df=28, F=4.77, p=0.009	92(224)a	893(999)b	1798(1911)c	1402(1004)c
maximum IV	df=28, F=1.23, p=0.320	1.445(0.436)	1.498(0.467)	1.285(0.141)	1.148(0.337)

A Vegetation Index of Biotic Integrity for wetlands dominated by forest vegetation communities was calculated by summing the individual metric scores. The VIBI scores for each wetland were replotted against the ORAM score (Figure 11) (df=28, F=53.81, p<0.001, R^2=66.6%). The overall behavior of the VIBI-Emergent is very satisfactory. Reference sites receive high to very high scores and the VIBI-E is able to distinguish a full range of sites from very highly disturbed (lowest score = 6) to very high quality sites (highest score = 94).

Several points can be made in summarizing the characteristics of the VIBI-F. First, as a minor point, one site, Killdeer Plains, has been reclassified as a nonreference site for this report. This site is locate in a woodlot southwest of Harpster in the Killdeer Plains Wildlife Area. The wetland is located in the center of the woodlot on the east side and extends past the woodlot edge into a pasture/former farmer field. The woodlot itself has an overall, subtle degraded appearance being depauperate in spring wildflowers and with very high coverages of poison ivy. Given the lack of any blatantly obvious human disturbances, this site was classified as reference in Mack et al. (2000) even though it did not otherwise appear to be a reference site. Its very low VIBI score (33) is a definite outlier in the data set and therefore this site has been reclassified as a nonreference site.

Second, three sites that had mid-range ORAM v5.0 scores had very high VIBI scores (Hempelman, City of Mansfield, and Blackjack Rd front) (Table 24). All three sites had disturbances in or near the wetland which lowered their ORAM v. 5.0 score. City of Mansfield has a ditch and a pond dug into part of the wetland and a buried sewer line through part of the wetland; Blackjack Rd was a mature forest that was clearcut about 15 years ago and is located next to a road; Hempelman is located in a small woodlot with narrow buffers on two sides, a road next to or through the wetland, and intensive farming just outside the woodlot. Despite these disturbances City of Mansfield and Blackjack Rd. continue to exhibit very high levels of floral quality; during sampling of Blackjack Rd., a new population and Knox County record of the state endangered plant *Carex crus-corvi* was discovered. City of Mansfield has a very diverse open woodland canopy with rich shrub and herbaceous understory. The reason for the high VIBI score for Hempelman is less clear, but may be due to changes in sampling method: Hempelman was sampled in 1997 using the quadrat/transect method (*see* Mack et al. 2000 for a discussion of this), and this may have resulted in over-estimates of metric values.

Third, although very low quality forested wetlands exist, it is much more difficult to locate them on the landscape since when forested wetlands become very disturbed they tend to have had their trees completely removed and thus have the appearance of emergent marshes or shrub swamps. Given that the climatological climax landscape in Ohio is deciduous forest (Shane 1987; Webb et al. 1983), and that most of Ohio was forested at the time of settlement (Gordon 1966), it can be argued that degraded emergent marshes in known, previously forested areas constitute the bottom of the scale for forested wetlands. Such a site was actually sampled in 2000 (US 42 wetland). This was a riparian forested wetland impoundment area for the Charles Mills reservoir in Richland County that was clearcut about 15 years ago. Stumps with stump sprouts are present but the site has converted to an open water and reed canary grass (*Phalaris arundinacea*) dominated wetland: it looks like a very disturbed emergent marsh, but for the stumps and stump sprouts.

The continued existence of a forest canopy in the wetland, which is usually associated with some upland forest buffer, also likely ameliorates the effect of human disturbance and increases the overall integrity of even degraded forested systems. Thus, it is expected that, in general, the most highly disturbed, but still tree-covered, forested wetlands will on average exhibit higher degrees of quality than the most highly disturbed emergent wetlands.

Fourth, Mack et al. (2000) discussed the existence of unvegetated versus vegetated forested wetlands. Although not analyzed further in this report, this continues to be a difference observed in the field during sampling of forested wetlands. The metrics presently included in the VIBI-F were selected because they work in both types of systems. In sampling unvegetated forested wetlands, it is very important to include within the sampling plot a considerable portion of the edges of these wetlands (especially herbaceous and shrub vegetation) as well as vegetation growing on bases of trees and hummocks.

Table 22. Description of metrics for VIBI for forested wetlands.

metric	code	type	(+) or (-) as disturbance increases	description
number of dicot spp.	dicot	richness	decrease	Number of dicot (dicotyledon) spp. present at a site.
number of shrub spp.	shrub	richness	decrease	Number of shrub species present at a site.
number of FACW and OBL plant species	hydrophyte	richness	decrease	Number of plant species with a facultative-wet or obligate wetland indicator status at a site.
number of Rose family spp.	rosaceae	richness	decrease	Number of species in the Rose Family (Rosaceae) present at a site.
FQAI score	FQAI	weighted richness index	decrease	The Floristic Quality Assessment Index score calculated in accordance with Andreas and Ladd (1995). See §2.3 for discussion
relative cover of "intolerant" plants	%intol	dominance ratio	decrease	Percent coverage of plants in the herb and shrub stratum with CofCs of 6, 7, 8, 9, or 10 divided by the total percent coverage of all plants. "CofC" means the an individual plant species' "Coefficient of Conservatism".
relative cover of "tolerant plant species	%tol	dominance ratio	increase	Percent coverage of plants in the herb and shrub stratum with CofCs of 0, 1, or 2 divided by the total percent coverage of all plants. "CofC" means the an individual plant species' "Coefficient of Conservatism".
relative density of trees in 10-25cm size classes	small tree	density ratio	increase	The density (stems/ha) of a tree species in size classes between 10 and 25 cm dbh divided by the density of all trees.
shrub density (stems/ha)	shrub density	density	decrease	The density (stems/ha) of shrub species.
maximum modified importance value of a species at a site	max IV mod	importance value	increase	The maximum modified importance value of a species at a site calculated by summing relative size class frequency, relative density, and relative basal area of a species, but not dividing this sum by 3.

Table 23. Scoring breakpoints for assigning metric scores to a forested wetland. See Table 22 for descriptions of metric codes.

metric	95th percentile	quadrisection method	score 0	score 3	score 7	score 10
dicot	37.2	graphical fitting	0-15	16-25	26-29	30+
shrub	8.0	graphical fitting	0-1	2	3-4	5+
hydrophyte	24.6	graphical fitting	0-9	10-14	15-20	21+
rosaceae	5.6	graphical fitting	0	1	2-3	4+
FQAI	30.1	graphical fitting	0-14.0	14.1-19.0	19.1-24.0	24.1+
%intolerant	0.602	graphical fitting	0-0.035	0.0351-0.12	0.121-0.3	0.31-1.0
%tolerant	0.737	mathematical quadrisection	0.4511-1.0	0.3011-0.451	0.1501-0.301	0-0.150
small tree	0.411	mathematical quadrisection	0.3241-1.0	0.2161-0.324	0.1081-0.216	0-0.108
shrub density	2990	graphical fitting	0-99	100-399	400-999	1000+
max IV	2.033	graphical fitting	1.61+	1.31-1.6	1.21-1.3	0-1.2

Table 24. Distribution of metric scores by site for VIBI-F calculated. Sites in *italics* are bog or fen sites.

site	condition	ORAM v5.0	VIBI-F	no. of "0" scores	no. of "3" scores	no. of "7" scores	no. of "10" scores
Ackerman	poor	24	6	8	2	0	0
Big Woods	reference	68.5	68	0	2	6	2
Blackjack Rd (front)	fair	55.5	91	0	0	3	7
Brown Lake Bog	reference	79	90	0	1	1	8
City of Mansfield	good	53	91	0	0	3	7
Collier Woods	reference	73.5	64	0	3	5	2
Eagle Cr. Vernal	reference	64	76	0	0	8	2
Flowing Well	fair	46	23	5	3	2	0
Fowler Woods	reference	79	81	0	1	4	5
Gahanna Woods 4th	good	67.5	53	0	5	4	1
Graham Rd.	very poor	28.5	6	8	2	0	0
Hempelman	good	48	85	0	0	5	5
Johnson Rd.	very poor	21	6	8	2	0	0
Killbuck Creek	fair	33	32	2	6	2	0
Killdeer Plains	fair	53.5	33	3	4	3	0
LaRue Woods	fair	55	43	3	3	2	2
Lawrence Woods High	reference	73	87	0	1	2	7
Lawrence Woods Low 2	fair	43	71	2	3	5	0
Leafy Oak	reference	78	94	0	0	2	8
Mentor Marsh	fair	34	44	2	3	5	0
N. Kingsville S. Barr. Sw.	reference	67	77	0	2	3	5
Orange Rd.	fair	45	37	3	3	4	0
Oyer Tamarack	reference						
Pallister	reference	74	81	0	1	4	5
Pawnee Rd.	reference	70	79	0	3	0	7
Sawmill	good	52	63	1	3	2	4
Tipp-Elizabeth Rd.	poor	29	29	4	4	1	1
Townline Rd.	good	61	70	0	3	3	4
US42	poor	31	16	7	2	0	1
White Pine Bog	reference	83	88	0	0	4	6
			total	56	62	84	98
			%total	19%	21%	28%	33%

Table 25. Percentage of metric scores by forested wetland condition, reference versus nonreference, and ORAM v. 5.0 score.

	% of "0" scores	% of "3" scores	% of "7" scores	% of "10" scores
very poor	29%	6%	0%	0%
poor	34%	13%	1%	2%
fair	30%	34%	27%	9%
good	7%	24%	24%	21%
reference	0%	23%	48%	67%
nonreference	95%	66%	45%	29%
reference	5%	34%	55%	71%
0-35 ORAM score	30%	34%	27%	9%
36-59 ORAM score	64%	32%	18%	19%
60+ ORAM score	5%	34%	55%	71%

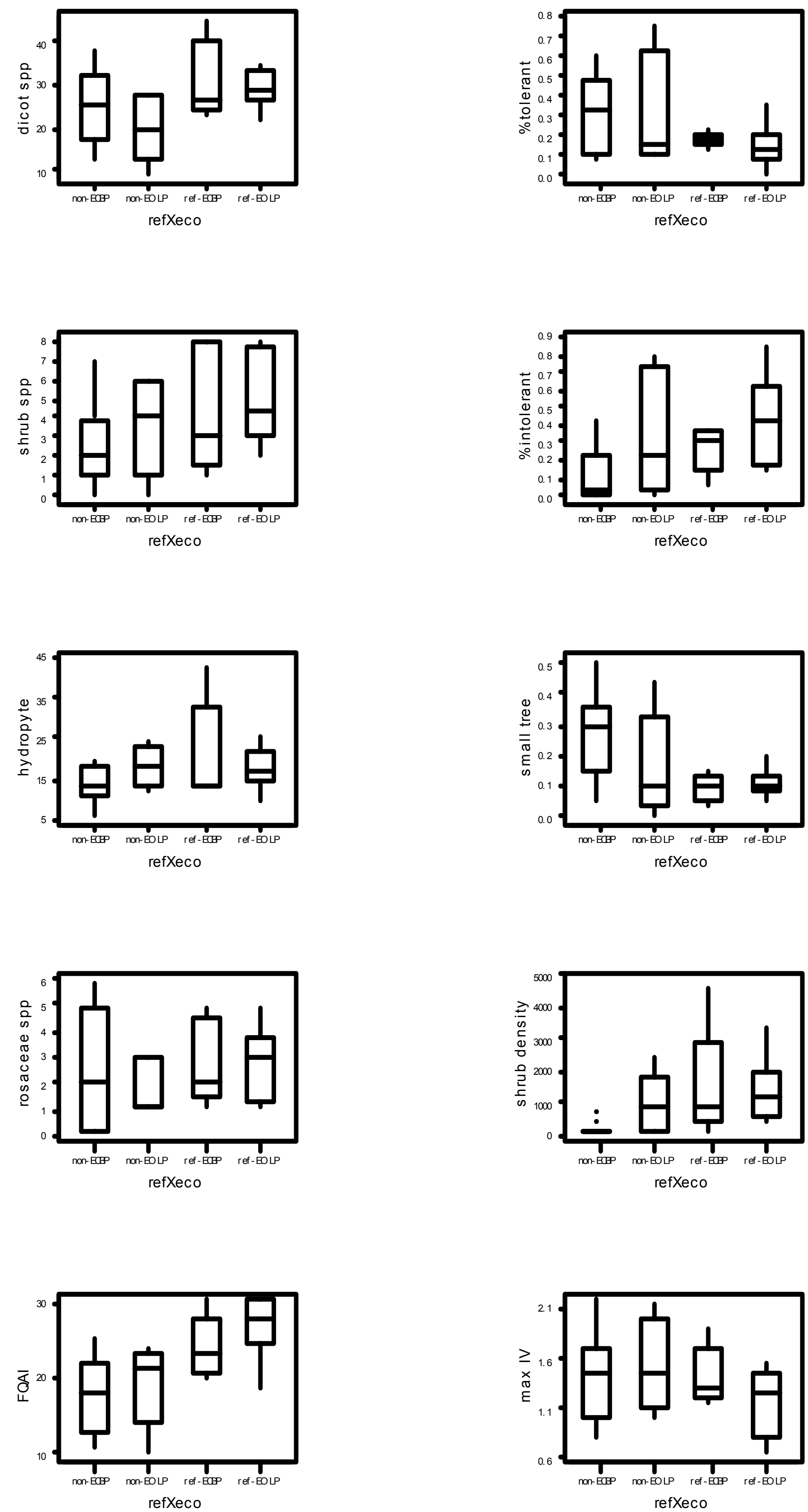

Figure 10. Box and whisker plots of individual metric values for the VIBI-forested by reference/nonreference and ecoregion (ECBP=Eastern Corn Belt Plains; EOLP=Erie Ontario Lake Plains). A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and the highest observations that are still inside the region defined by the following limits: Lower Limit=Q1-1.5(Q3-Q1); Upper Limit=Q3+1.5(Q3-Q1).

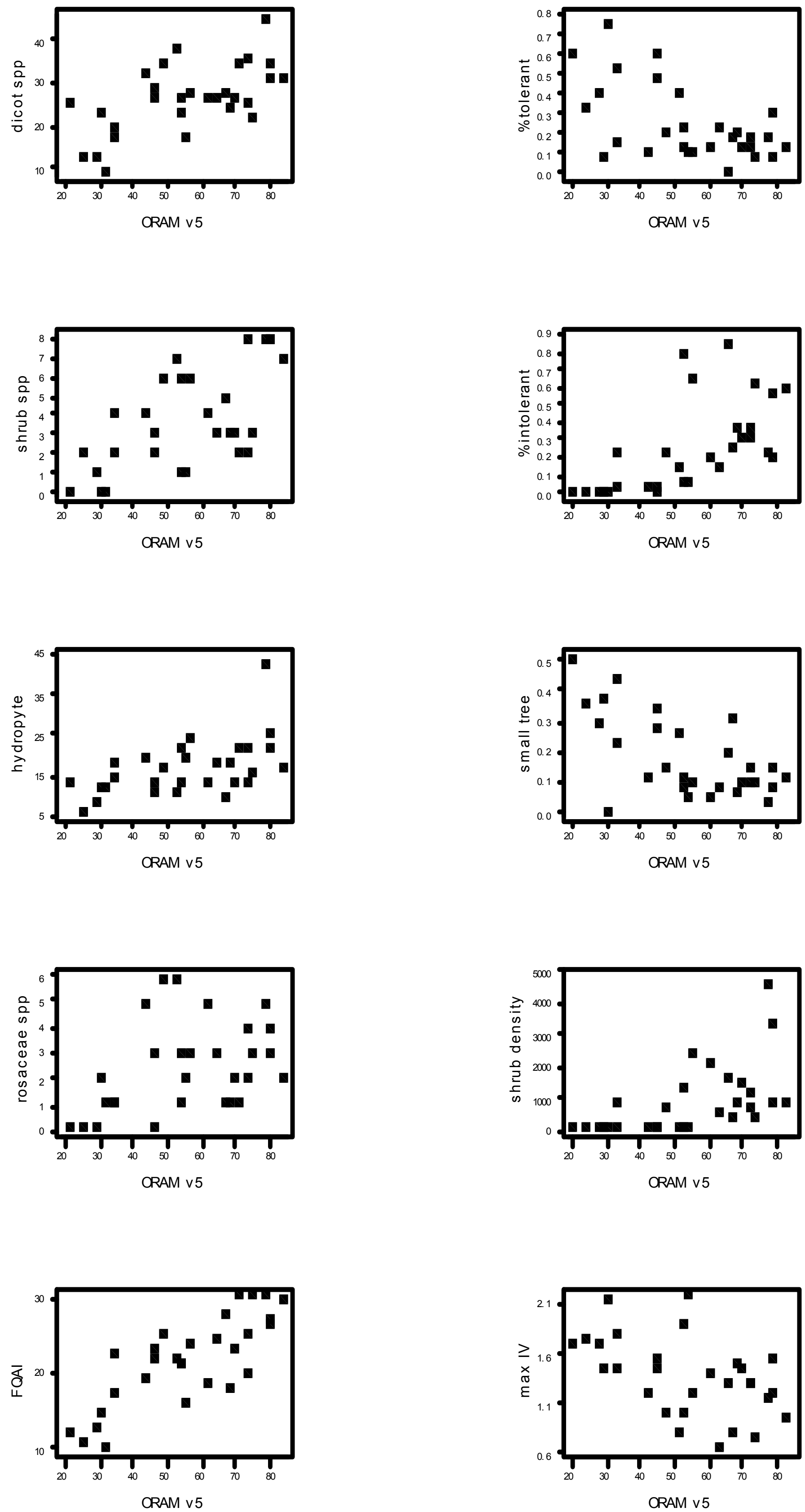

Figure 11. Scatterplots of metric values used in VIBI-Forested versus ORAM v. 5.0 score.

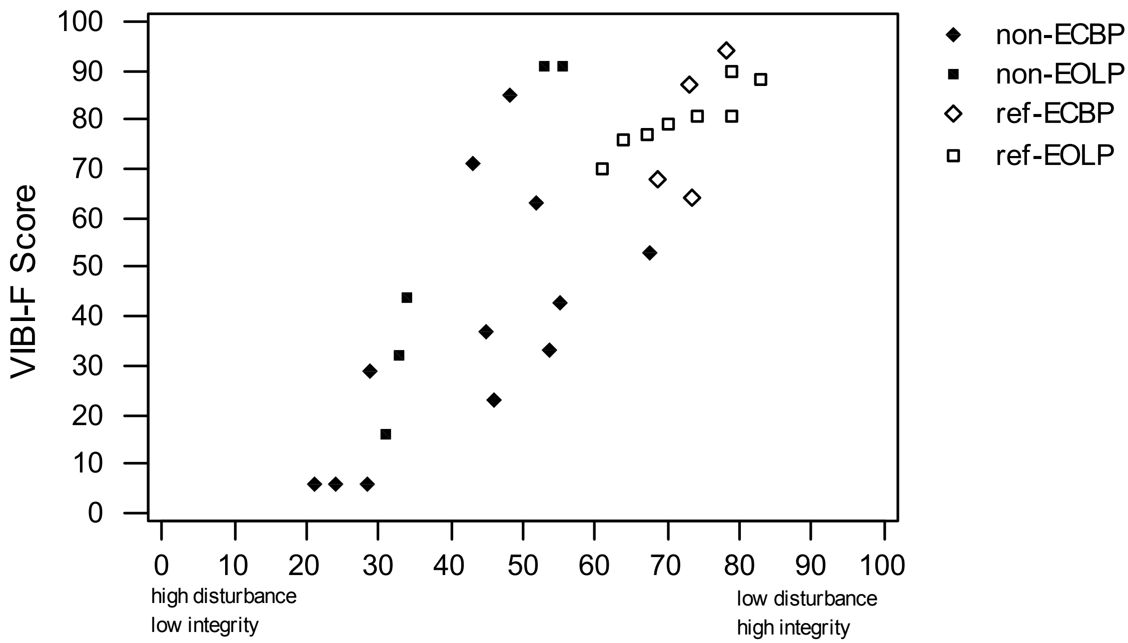

Figure 12. Scatterplot of Vegetation IBI score versus disturbance scale (ORAM v.5.0 score) for forested wetland (df=28, F=53.81, $p<0.001$, R^2=66.6%). non=nonreference wetlands; ref=reference wetlands; ECBP=Eastern Corn Belt Plains; EOLP=Erie Ontario Lake Plains.

3.3 VIBI-SHRUB

Development of the VIBI-SHRUB (VIBI-SH) (formerly VIBI-Scrub-Shrub or VIBI-SS) was complicated by the fact that initially many shrub communities were classified as forested since they were located entirely within upland or wetland forests. The scrub-shrub class did not begin to emerge until data exploration of potential attributes for forest IBIs revealed a group of sites which did not appear to "fit." The dominant character of the vegetation communities at these was reconsidered and it became apparent that they were more properly classified as shrub dominated communities without a closed canopy of trees, although a "forested" margin was often present and they were frequently located within tracts of forest.

Another complication was the lack of a suite of sites which represented the entire disturbance gradient form highly disturbed to very undisturbed. All of the shrub wetlands were in "good" or "reference" condition; the low end of the scale was missing in this data set which made it impossible to apply the attribute evaluation "rules" used to identify candidate metrics (i.e. linear or curvilinear relationships, etc.).

Shrub communities in Ohio are usually an intermediate successional step between herbaceous and forested communities, however they can be very stable (in time) and extensive (in area) features on the landscape and are generally treated as a distinct, identifiable community (Anderson 1982; Cowardin et al. 1979). Because shrub communities are intermediate between herbaceous and forested communities, a solution to the problems discussed above was to evaluate the shrub sites in conjunction with the metric values for forested and emergent communities. Thus, the shrub wetlands were compared with forested and emergent wetlands. Metrics where the shrub community sites "fit" into these other data sets were selected for use. "Fit" was determined by graphing shrub metric values with the emergent and forested data sets (Figure 13) and by comparing mean values of metrics for emergent, forest, and shrub communities to identify where significant differences between these classes occurred (refer to Table 11 in §3.0). This analysis resulted in the use of 5 forested (shrub, rosaceae, hydrophyte, small tree, shrub density) and 3 emergent metrics (carex, dicot, FQAI) (Table 26, Figure 13). Because the distributions and mean values for %tolerant and %intolerant metrics were so different for shrub wetlands, only the shrub wetland values for these two metrics were used to calculate the metric scoring breakpoints (Table 27).

Metric scores for shrub wetlands were calculated by using the scoring breakpoints derived for the emergent and forested metrics (Table 27). A Vegetation Index of Biotic Integrity for wetlands dominated by shrub vegetation communities was calculated by summing the individual metric scores (Table 28).

Table 26. Description of metrics for VIBI -shrub. Group refers to which data set (E=emergent, F=forested, SH=shrub) the shrub wetland data was included with to derive the VIBI-SH.

	code	type	group	(+) or (-) as disturbance increases	description
number of Carex spp.	carex	richness	E+SH	decrease	Number of Carex spp. present at a site.
number of dicot spp.	dicot	richness	E+SH	decrease	Number of dicot (dicotyledon) spp. present at a site.
number of shrub spp.	shrub	richness	F+SH	decrease	Number of shrub species present at a site.
number of FACW and OBL plant species	hydrophyte	richness	F+SH	decrease	Number of plant species with a facultative-wet or obligate wetland indicator status at a site.
number of Rose family spp.	rosaceae	richness	F+SH	decrease	Number of species in the Rose Family (Rosaceae) present at a site.
FQAI score	FQAI	weighted richness index	E+SH	decrease	The Floristic Quality Assessment Index score calculated in accordance with Andreas and Ladd (1995).
relative cover of "intolerant" plants	%intolerant	dominance ratio	SH	decrease	Percent coverage of plants in the herb and shrub stratum with CofCs of 6, 7, 8, 9, and 10 divided by the total percent coverage of all plants. "CofC" means the an individual plant species' "Coefficient of Conservatism".
relative cover of "tolerant plant species	%tol	dominance ratio	SH	increase	Percent coverage of plants in the herb and shrub stratum with CofCs of 0, 1, or 2 divided by the total percent coverage of all plants. "CofC" means the an individual plant species' "Coefficient of Conservatism".
relative density of trees in 10-25cm size classes	small tree	density ratio	F+SH	increase	The density (stems/ha) of tree species in size classes between 10 and 25 cm dbh divided by the total density of trees.
shrub density (stems/ha)	shrub density	density	F+SH	decrease	The density (stems/ha) of shrub species.

Table 27. Scoring breakpoints for assigning metric scores to a shrub wetland. See Table for descriptions of metric codes.

metric	95^{th} percentile	quadrisection method	score 0	score 3	score 7	score 10
carex	5.7	graphical fitting emergent distribution	0-1	2-3	4	≥5
dicot	26.7	graphical fitting emergent distribution	0-9	10-14	15-23	≥24
shrub	8.0	graphical fitting forest distribution	0-1	2	3-4	5+
hydrophyte	27.0	graphical fitting forest distribution	0-9	10-14	15-20	21+
rosaceae	5.6	graphical fitting forest distribution	0	1	2-3	4+
FQAI	28.3	graphical fitting emergent distribution	0-9.9	10.0-14.3	14.4-21.4	≥21.5
%intolerant	0.838	mathematical quadrisection only shrub site distribution	0-0.210	0.2101-0.419	0.4191-0.629	0.6291-1.0
%tolerant	0.206	mathematical quadrisection only shrub site distribution	0.1551-1.0	0.1031-0.155	0.0521-0.103	0-0.055
small tree	0.411	mathematical quadrisection forest distribution	0.3241-1.0	0.2161-0.324	0.1081-0.216	0-0.108
shrub density	2990	graphical fitting forest distribution	0-99	100-399	400-999	1000+

Table 28. Distribution of metric scores by site for VIBI-SH calculated. Sites in *italics* are bogs and fens

site	condition	ORAM v5.0	VIBI-SH	no. of “0" scores	no. of “3" scores	no. of “7" scores	no. of “10" scores
2 Meadows Swamp	good	49	71	0	2	5	3
Area K	reference	61.5	84	0	1	3	6
Blackjack Rd (back)	good	67	94	0	0	2	8
Blanchard Oxbow	fair	48	27	5	2	3	0
Burton Lakes Vernal	reference	67	77	1	1	2	6
Callahan	good	57.5	58	1	2	6	1
Cessna	reference	61	78	0	1	5	4
Drew Woods	reference	70	80	0	2	2	6
Fowler Woods BBS	reference	79	68	1	1	5	3
Frieds Bog	reference	76	86	0	2	0	8
Gahanna 1st	reference	82.5	94	0	0	2	8
Grand R. Terraces	reference	74	91	0	0	3	7
Keller High	reference	65.5	65	2	0	5	3
King Hollow Rd	poor	28	27	6	1	2	1
Koelliker Fen	reference	72	74	1	1	3	5
McKee Bog	good	56	94	0	0	2	8
McKinley	fair	37.5	33	4	3	2	1
Oyer Wood Frog	reference	69	68	1	1	5	3
Route 29	reference	59	75	1	0	5	4
Slate Run	reference	71	88	0	0	4	6
Swamp Cottonwood	reference	75	94	0	0	2	8
The Rookery	reference	69	71	0	2	5	3
Towners Woods	reference	74	54	3	1	3	3
Townline BBS	good	61	57	2	2	3	3
Watercress Marsh Fen	reference	77.5	85	0	3	3	4
Wilson Swamp	reference	77	66	1	3	1	5
			total	29	31	83	117
			%total	11%	12%	32%	45%

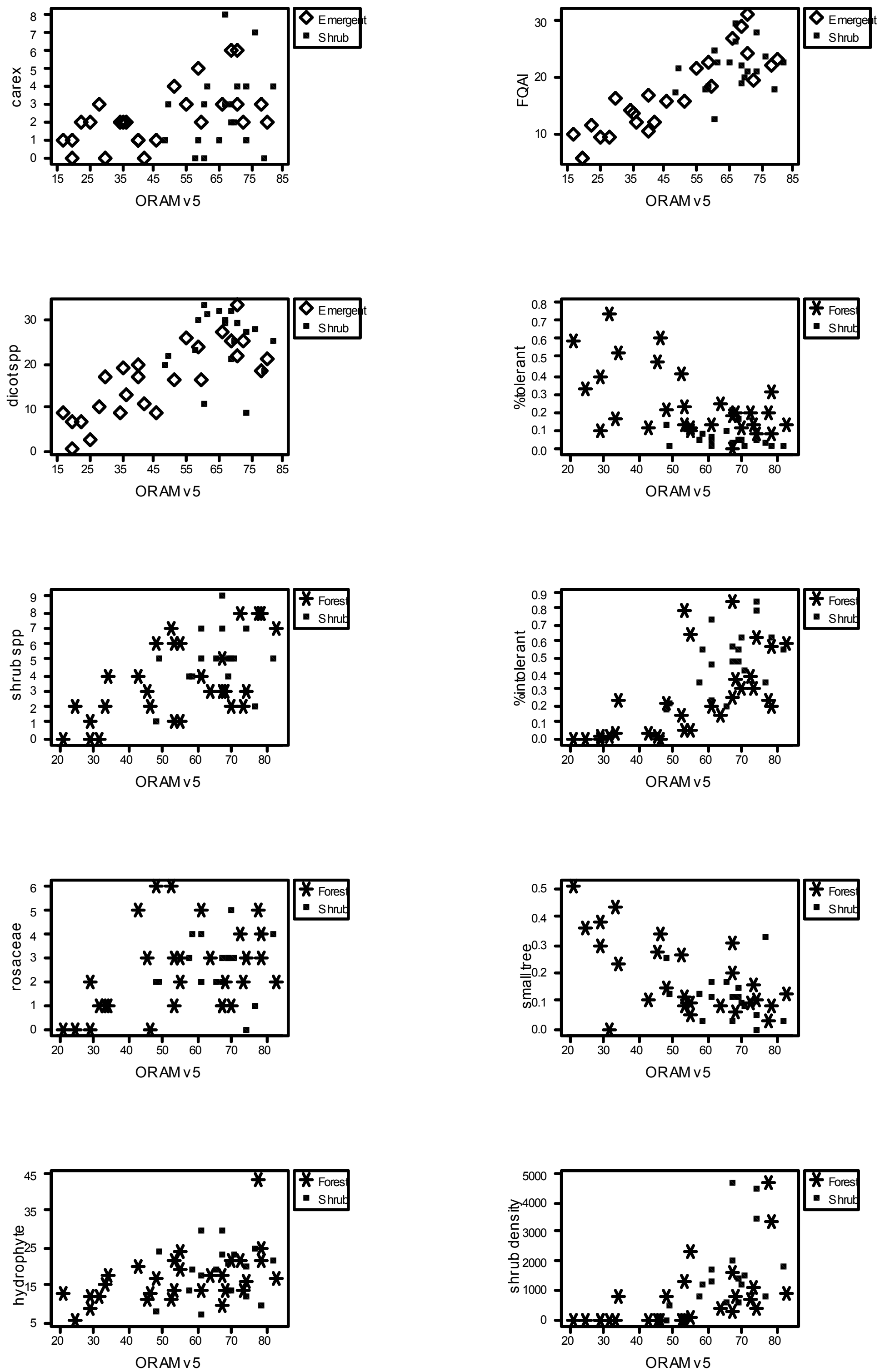

Figure 13. Scatterplots of metrics used for VIBI for shrub wetlands.

4.0 Analysis of the Vegetation IBI and ORAM scores: ecoregional, hydrogeomorphic, and plant community comparisons

4.1. Vegetation IBI

The characteristics of the Vegetation Indices of Biotic Integrity (VIBIs) were compared using ecoregional, hydrogeomorphic (HGM) and plant community classification schemes as major sorting variables. Only wetlands from the Eastern Corn Belt Plains or Erie Ontario Drift and Lake Plains ecoregions were included in this analysis (N=83), however, 3 sites from the Michigan Indiana Drift and Lake Plains, 1 coastal marsh, and 1 site from the Western Allegheny Plateau have been sampled. Table 29 summarizes the sites currently sampled (through the 20001 field season) for present or future use in developing vegetation IBIs.

Table 29. Summary of numbers of sites by major hydrogeomorphic and plant community classes. Numbers in parentheses are numbers including plots from 2001 field season. Data from 2001 field season was not analyzed in this report

Hydrogeomorphic Classes	N	Plant Community Classes	N
isolated depression	57(69)	various bog communities	6(7)
isolated flats	1(2)	various fen communities	6(11)
riparian mainstem depression	8(12)	marshes (all types)	23(36)
riparian headwater depression	5(8)	sedge-grass communities	3(6)
riparian headwater groundwater	3	shrub swamps	20(23)
slope (riparian and isolated)	8(17)	swamp forests	30(38)
fringing	3		
impoundment	2		
coastal	1(5)		
TOTAL	**88(121)**		**88(121)**

The Vegetation IBI scores for all wetlands and classes of wetlands in the Eastern Corn Belt Plains and Erie Ontario Drift and Lake Plains were plotted together (Figure 14). Very strong linear trends were observed (df=82, F=174.95, p<0.001, R^2=68.4%). While this is a not unexpected result given that the VIBI metrics were selected based on their relationship to the ORAM v. 5.0 score used as a disturbance scale, this graph can be considered a summation of the relationship each metric has had with the disturbance scale. The IBI scoring technique has a standardizing effect that dampens individual metric variability.

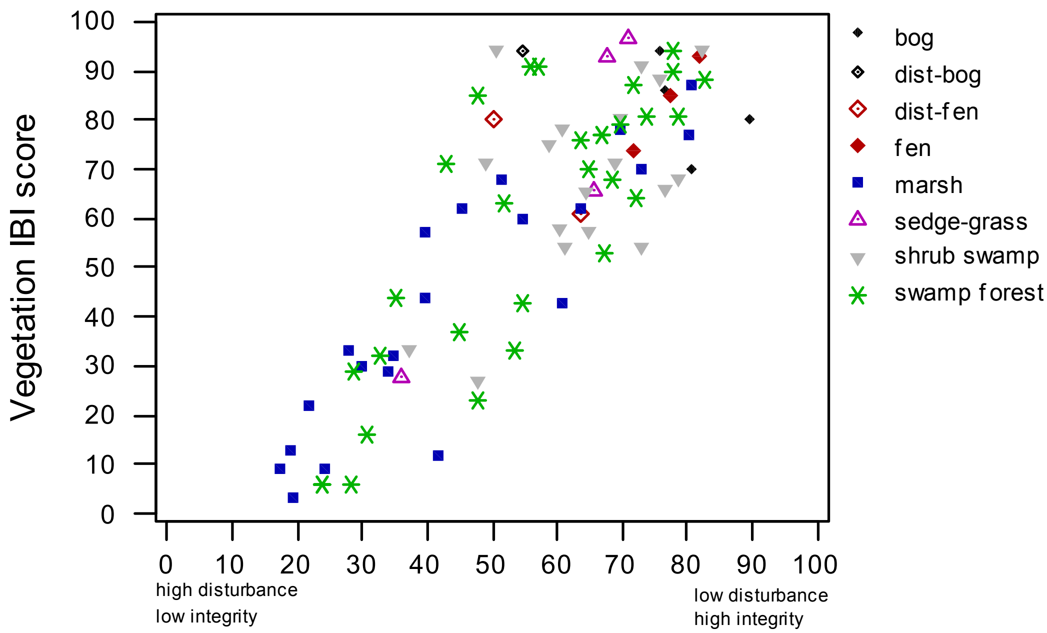

Figure 14. Vegetation IBI scores for wetlands in the Eastern Corn Belt Plains and Erie Ontario Lake Plains plotted against ORAM v.5.0 score. Refer to Table 6 for descriptions of the plant communities. "dist-fen" and dist-bog" refer to fens or bogs that have been disturbed by human activity. Results from linear regression of this distribution highly significant (df=82, F=174.95, p<0.001, R^2=68.4%).

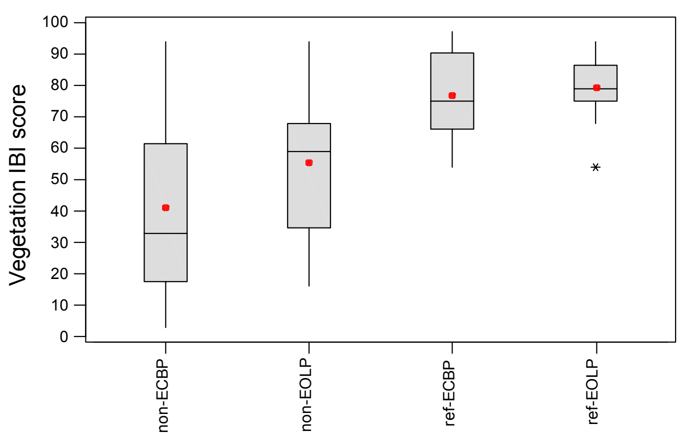

Figure 15. Box and whisker plots of Vegetation IBI scores for reference (ref) and nonreference (non) wetlands by ecoregion. ECBP= Eastern Corn Belt Plains, EOLP= Erie Ontario Lake Plains. Means are indicated by solid circles. A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits: Lower Limit = Q1 - 1.5 (Q3 - Q1); Upper Limit = Q3 + 1.5 (Q3 - Q1). Outliers are points outside of the lower and upper limits and are plotted with asterisks (*).

Comparisons of the mean Vegetation IBI scores for wetlands in the Eastern Corn Belt Plains (ECBP and Erie Ontario Drift and Lake Plains (EOLP) ecoregions showed scores were significantly different from each other based on reference condition, but ecoregional differences were only noted between the nonreference ECBP and nonreference EOLP categories (df=72, F=19.79, p<0.001) (Table 30, Figure 15). Thus, on average, there were no significant differences in mean scores for reference wetlands in this data set for the two ecoregions when VIBI scores for all classes are pooled. Only small differences were noted when the 95th percentiles of the two ecoregions were compared with ECBP distribution being slightly higher than the EOLP distribution. This is opposite what would be expected.

Table 30. Mean and standard deviation of Vegetation IBI scores for 2 ecoregions and 2 wetland classes (reference and nonreference sites). Bogs and calcareous fens from both ecoregions were excluded from the analysis. Means with shared letters were not significantly different at p<0.05 after analysis of variance followed by Tukey's HSD multiple comparison test.

	mean	stdev	N
nonreference ECBP	38.1a	26.3	31
nonreference EOLP	50.7b	22.1	10
reference ECBP	76.9c	13.1	17
reference EOLP	78.3c	9.4	15

The quadrisected distributions of the 95th percentile of each of the dominant vegetation communities (emergent, forest, shrub) was also evaluated. Little ecoregional variation was observed (Table 31) and very similar scores and breakpoints were calculate for each community type (Table 32). However, very marked ecoregional separation is present within the emergent class when only "marsh" communities in the two ecoregions are compared (Table 35 and see discussion below separating emergent marsh communities and emergent sedge-grass, fen, and bog communities). Considering only reference quality marshes in the two ecoregions, the following breakpoints were calculated when the 95th percentile was quadrisected:

ECBP Reference Marshes	0-16	17-34	35-51	52+
EOLP Reference Marshes	0-20	21-41	42-62	63+

Mean VIBI scores for emergent marshes were also different based on ecoregion (ECBP=69.0 n=2; EOLP=80.7 n=3) although these differences were not significant probably due to the admittedly small sample sizes.[9] In conclusion, within the limits of the current data set, there appear to be noticeable ecoregional differences in emergent marshes that should be accounted for when establishing numeric biological criteria.

[9] A review of Table 35 will also reveal that a similar discrepancy in breakpoints is also apparent when sedge-grass, fen, and bog communities are compared. It is felt that this difference is due to the lack of reference quality fen and sedge-grass sites in the EOLP region. Additional reference quality sites in the EOLP region were sampled in 2001. Also, similar large differences were not observed when ecoregional differences in the mean VIBI scores of reference forested and reference shrub wetlands were evaluated : mean VIBI-F scores: ref-ECBP=78.3, refEOLP=81.7, not significant at p<0.05; mean VIBI-SH scores: ref-ECBP=75.0, ref-EOLP=77.8, not significant at p<0.05.

Table 31. Comparison of 95th percentile and quadrisection of 95th percentile of Vegetation IBI scores by ecoregion for reference sites by ecoregion and all sites by ecoregion, excluding fen and bog wetlands.

	reference EOLP	reference ECBP	point difference	all sites EOLP	all sites ECBP	point difference
95th percentile	90.3	94.0	-3.7	90.8	93.0	-2.2
1st quarter	22.6	23.5	-0.9	22.7	23.3	-0.6
2nd quarter	45.2	47.0	-1.8	45.4	46.5	-1.1
3rd quarter	67.7	70.5	-2.8	68.1	69.8	-1.7

Table 32. Comparison of 95th percentile and mathematical quadrisection of 95th percentile for Vegetation IBI scores for emergent, forested, and shrub wetland IBIs.

		95th percentile	1st quarter	2nd quarter	3rd quarter
Emergent	**All Sites**	93	23	47	70
	All ECBP sites	93	23	47	70
	All EOLP sites	84	21	42	63
	Reference ECBP sites	96	24	48	72
	Reference EOLP sites	86	21	43	64
	average	90	23	45	68
Forest	**All Sites**	91	23	46	68
	All ECBP sites	92	23	46	69
	All EOLP sites	90	23	45	68
	Reference ECBP sites	93	23	46	69
	Reference EOLP sites	89	22	45	67
	average	91	23	46	68
Shrub	**All Sites**	91	23	47	68
	All ECBP sites	91	23	45	68
	All EOLP sites	89	22	45	67
	Reference ECBP sites	92	23	46	69
	Reference EOLP sites	89	22	45	67
	average	90	23	45	68

Individual metrics that make up the VIBI-E, VIBI-F, and VIBI-SH were also compared (Table 33). Of the ten metrics evaluated, 9 metrics showed significant differences between reference and nonreference wetlands. Only 4 metrics had apparent ecoregional differences (dicot, hydrophyte, %intolerant, shrub density). Of these 4 metrics, only the differences in %intolerant and shrub density appear to be possible ecoregionally-based differences. The difference in dicot and hydrophyte metrics is opposite the expected trend since the reference ECBP sites on average are higher than the reference EOLP sites. This is likely to be an artifact of the current data set.

The differences in the %intolerant metric may in fact be due to EOLP wetlands having higher relative cover of plants with coefficients of conservatism of 6 to 10; or at least this would not be an unexpected result, given the more "boreal" character of wetlands in northeast Ohio. The differences in shrub density between ref-ECBP and ref-EOLP wetlands is not as easily explainable. It may be a real difference or again an artifact of the current data set. The behavior of all the metrics used will continue to be evaluated as data from 2001 and subsequent years are incorporated into the VIBI data set.

The mean ORAM scores of reference wetlands of different dominant vegetation communities was also compared. While there were no significant differences between these classes when reference sites were compared (df=40, F=1.27, p=0.300), sites dominated by bog, fen, and sedge-grass communities had noticeably higher VIBI scores (Table 34). The lack of significance may be due to the very small sample sizes when only reference sites are considered, especially for the sedge-grass communities.

It has been expected throughout the development of the VIBI, that bogs and calcareous fens would likely need to be classified and treated separately, but the high scores for sedge-grass communities is a new factor. In order to further explore this classification issue, the 95th percentiles of the VIBI distributions for all emergent sites, marshes only, and fen/bog/sedge-grass communities were compared. Very stark differences in the 95th percentiles and the upper end of the quadrisected distribution were apparent (Table 35). Including fen, bog and sedge-grass communities in the distribution raises the 3rd quarter breakpoint for marshes by 12 points from 58 (marshes only) to 70 (all sites). The 3rd quarter breakpoint for just the fen, bog and sedge-grass communities is a score of 72, 14 points higher than the 3rd quarter breakpoint for marshes only. Therefore, separate numeric standards appear to be necessary for establishing wetland habitat uses for these two emergent community groups.

Table 33. Mean and standard deviation (parenthesis) and ANOVA results for metrics used in VIBI-E, VIBI-F, and VIBI-SH by reference (ref) and nonreference(non) and ecoregion categories (ECBP=Eastern Corn Belt Plains, EOLP= Erie Ontario Drift and Lake Plains. Means with shared letters were not significantly different after Tukey's HSD multiple comparison test. Results from biomass metric not reported because of insufficient sample size (n<4) in two of the four categories.

metric	ANOVA results	nonECBP	nonEOLP	refECBP	refEOLP
dicot spp.	df=72, F=7.58, p<0.001	18.7(9.6)a	17.4(6.5)a	28.9(6.2)b	24.7(6.9)c
hydrophyte spp.	df=72, F=6.39, p=0.001	14.4(6.4)a	19.4(8.9)b	24.0(9.0)c	20.5(7.8)d
rosaceae spp.	df=72, F=2.77, p=0.048	1.5(1.8)a	1.7(1.4)a	2.8(1.4)b	2.3(1.1)b
FQAI	df=72, F=16.32, p<0.001	15.7(5.9)a	17.4(4.2)a	23.2(4.2)b	25.1(3.9)b
%tolerant	df=72, F=9.49, p<0.001	0.36(0.26)a	0.35(0.23)a	0.10(0.07)b	0.13(0.10)b
%intolerant	df=72, F=10.10, p<0.001	0.13(0.19)a	0.22(0.30)a	0.37(0.15)b	0.48(0.25)c
%invasive graminoids	df=72, F=5.82, p=0.001	0.11(0.19)a	0.23(0.27)b	0.005(0.009)c	0.003(0.010)c
small tree density	df=43, F=3.40, p=0.027	0.21(0.13)a	0.18(0.19)a	0.11(0.08)b	0.09(0.06)b
shrub density	df=43, F=6.59, p=0.001	458(739)a	523(644)a	1433(1089)b	2305(1714)c
max importance value	df=45, F=1.72, p=0.178	1.41(0.46)	1.54(0.44)	1.43(0.30)	1.13(0.39)

Table 34. Mean and standard deviation of Vegetation IBI scores of reference wetlands for 5 dominant plant community classes in the Eastern Corn Belt Plains and Erie Ontario Drift and Lake Plains ecoregions. Sedge-grass meadow wetlands include wet prairies, seep fens and other sedge and grass dominated wetlands. Means were not significantly different (p=0.35) after analysis of variance.

	mean	stdev	N
bog	84.8	10.1	5
fen	83.0	8.0	4
sedge-grass	85.3	16.9	3
marsh	76.0	7.5	5
shrub swamp	73.7	13.2	12
swamp forest	80.1	8.8	12

Table 35. Comparison of 95th percentile for Vegetation IBI scores for EMERGENT wetlands.

description	Table 6 code	Grouped by	95th percentile	1st quarter	2nd quarter	3rd quarter
All Emergent	**III**	**All Sites**	**93**	23	47	**70**
		All ECBP sites	93	23	47	70
		All EOLP sites	84	21	42	63
		Reference ECBP sites	96	24	48	72
		Reference EOLP sites	86	21	43	64
		average	90	23	45	68
Marshes only	**IIIa**	**All Sites**	**78**	19	39	**58**
		All ECBP sites	69	17	34	51
		All EOLP sites	84	21	42	63
		Reference ECBP sites	70	17	35	52
		Reference EOLP sites	86	22	43	65
		average	77	19	39	58
Fen, bog, and	**IIIb, c, d, e**	**All Sites**	**96**	24	48	**72**
sedge-grass		**All ECBP sites**	96	24	48	72
communities		**All EOLP sites**	79	20	40	59
		Reference ECBP sites	96	24	48	72
		Reference EOLP sites	82	20	40	60
		average	89	22	45	67

Finally, the Vegetation IBI score of reference wetlands based on hydrogeomorphic class was analyzed. In order to ensure a large enough sample size, some classes were grouped together. With regards to HGM classes, no statistically significant differences in mean VIBI scores were observed for reference wetlands (df=40, F=1.25, p=0.304) and all wetlands (df=82, F=1.45, p=0.235) (Table 36). However, there is a very large difference in mean scores and noticeable graphical separation in box and whisker plots (Figure 16) for riparian mainstem depressions versus the other HGM classes. All of the riparian mainstem depression sites in the current data set are forest or shrub dominated communities.

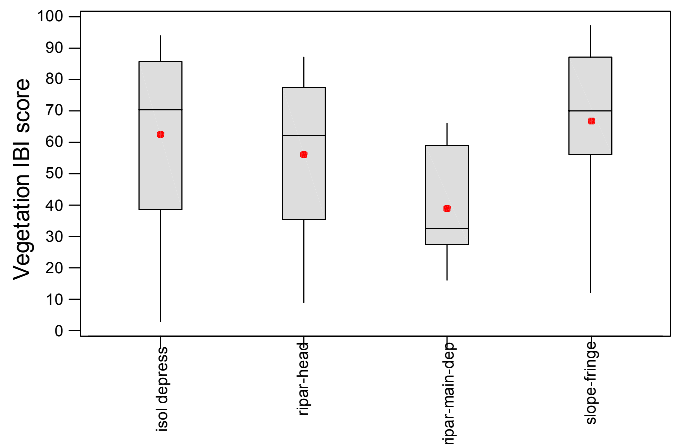

Figure 16. Box and whisker plots of Vegetation IBI scores for hydrogeomorophic classes. "isol depress"=isolated depressions; "ripar-head"= riparian headwater depressions; "ripar-main-dep"=riparian mainstem depressions; "slope-fringe"= slope or lacustrine fringe (primarily fens) wetlands. Means are indicated by solid circles. A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits: Lower Limit = Q1 - 1.5 (Q3 - Q1); Upper Limit = Q3 + 1.5 (Q3 - Q1). Outliers are points outside of the lower and upper limits and are plotted with asterisks (*).

Despite the lack of statistical significance, when means from all sites are considered the mean VIBI score for riparian mainstem depressions is17 to 28 points lower; for reference sites, it is 14 to 17 points lower. This difference is too large to ignore and may require separate VIBI breakpoints for this class. The 95th percentile of riparian mainstem depressions is 65.3 (n=8). Quadrisecting this distribution results in substantially lower breakpoints than for other forested and shrub wetlands (Table 32). The lower overall scores for riparian mainstem depressions are also amenable to an ecological explanation: these are communities which would often be subject to annual to multi-annual flood events such that there floras would have strong representation from plants tolerant of this recurring natural disturbance. In comparison to inland wetlands with more stable hydrologies, this shift to a high-quality, naturally-disturbance tolerant flora, may result in lower VIBI scores. The same situation may occur in the coastal marsh setting where wetland annuals with relatively low coefficients of conservatism can occur in diverse coastal marsh plant communities.

Table 36. Mean and standard deviation of Vegetation IBI scores of all wetlands for 4 dominant hydrogeomorphic classes including fen and bog sites. One headwater impoundment was grouped in the riparian headwater category. No means were significantly different (p<0.05) after analysis of variance.

	ALL SITES mean	ALL SITES N	REFERENCE mean	REFERENCE N
isolated depression	62.6(28.0)	56	79.1(11.3)	30
riparian mainstem depression	38.9(17.9)	8	65.0(1.4)	2
riparian-headwater-depression and riparian-headwater-groundwater	55.9(25.3)	9	80.7(5.5)	3
slope and fringing	66.9(25.1)	10	82.0(11.8)	6

In conclusion, there appear to be no ecoregional differences in Vegetation IBI scores of reference wetlands in the current data set with the exception of emergent marsh communities; ecoregional differences between nonreference wetlands are attributable to the current data set which is lacking very highly disturbed EOLP wetlands. Such sites were sampled during the 2001 field season and it is expected that nonreference wetlands in both regions will have similar scores once these new sites are incorporated into the data set. Vegetationally, emergent marshes, swamp forests (wet woods, vernal pools and other depressional wetlands) and shrub swamps have very similar average VIBI scores. Calcareous fens, bogs, and sedge-grass dominated emergent wetlands need to be separately classified. Considering hydrogeomorphic classes, little or no differences are apparent between classes except for riparian mainstem depression wetlands, which appear to require separate classification and numeric criteria breakpoints.

4.2 ORAM score comparison

The characteristics of the Ohio Rapid Assessment Method for Wetlands (ORAM) v. 5.0 scores were compared using ecoregional, hydrogeomorphic (HGM) and plant community classification schemes as major sorting variables.

Comparing mean ORAM v. 5.0 scores for wetlands in the Eastern Corn Belt Plains (ECBP and Erie Ontario Drift and Lake Plains (EOLP) ecoregions, scores were significantly different from each other reference versus nonreference categories, but only nonreference wetlands showed significant ecoregional differences (Table 37, Figure 17). Nonreference wetlands selected for sampling in the EOLP region during the 2000 field season tended to be of better quality; highly degraded sites were not sampled, and therefore, this difference may be an artifact of the current data set. Attempts were made to include highly degraded EOLP wetlands during the 2001 field season.

In addition to a comparison of mean differences in ORAM v. 5.0 scores, the 95th percentile of the ORAM score distributions was analyzed since the sectioning of this number is a standard IBI development technique for determining breaks between IBI classifications. In comparing reference sites between the ecoregions, differences in breakpoints were minor varying from 0.7 to 2.2 points for the quadrisected 95th percentile (Table 38). There was up to a 2.9 point difference in the 95th percentiles for the two regions. Assuming the ecoregional differences are real and not an artifact of the current data set, using these

Table 37. Mean and standard deviation of ORAM v. 5.0 scores for 2 ecoregions and 2 wetland classes (reference and nonreference sites). Fen and bog sites from both ecoregions were excluded from the analysis. Means with shared letters were not significantly different at p<0.05 after analysis of variance followed by Tukey's HSD multiple comparison test.

	mean	stdev	N
nonreference ECBP	39.8a	13.7	31
nonreference EOLP	48.6b	15.1	10
reference ECBP	68.9c	7.8	17
reference EOLP	73.8c	6.0	15

Table 38. Comparison of 95th percentile and quadrisection of 95th percentile of ORAM v. 5.0 scores by ecoregion for reference sites by ecoregion and all sites by ecoregion, excluding fen and bog wetlands.

	reference EOLP	reference ECBP	point difference	all sites EOLP	all sites ECBP	point difference
95th percentile	81.6	78.7	2.9	80.9	76.7	4.2
1st quarter	20.4	19.7	0.7	20.2	19.2	1.0
2nd quarter	40.8	38.4	2.4	40.5	38.4	2.1
3rd quarter	61.2	59.0	2.2	60.8	57.5	3.3
N	15	17		25	48	

Table 39. Mean and standard deviation of ORAM v. 5.0 scores of all wetlands for 4 dominant hydrogeomorphic classes. One headwater impoundment was grouped in the riparian headwater category. Means with shared letters were not significantly different at p<0.05 after analysis of variance followed by Tukey's HSD multiple comparison test.

	mean	stdev	N
isolated depression (includes 1 isolated flats)	57.5a	19.3	56
riparian mainstem depression	45.4a	19.0	8
riparian-headwater-depression and riparian-headwater-groundwater	55.3a	20.2	9
slope and fringing	63.7a	14.0	10

results to set ORAM scoring breakpoints[10] would result in the following:

ECBP 0-19.7 (Category 1) 19.8-59.0 (Category 2) 59.1+ (Category 3)
EOLP 0-20.4 (Category 1) 20.5-61.2 (Category 2) 61.2+ (Category 3)

Comparing these breakpoints to the ones proposed in Mack (2000), results in a 1 point lowering of the Category 2/3 breakpoint for ECBP wetlands and a 1 point increase in the Category 2/3 breakpoint for the EOLP wetlands. It should be noted that mechanical quadrisection of the ORAM v. 5.0 distribution was rejected in Mack et al. (2000) and breakpoints were graphically fitted since the 1st quarter breakpoint was too low and virtually no highly disturbed (category 1) wetlands would exist if mathematically quadrisected breakpoints were used.

The ORAM score of reference wetlands based on hydrogeomorphic and plant community classification scheme (Tables 5 and 6) was analyzed. In order to ensure a large enough sample size, some classes were grouped together. With regards to HGM classes, no statistically significant differences in mean ORAM

[10] ORAM breakpoints proposed in Mack et al. (2000) were as follows: 0-29.9 (Category 1), 30-34.9 (Category 1-2 "gray" zone, 35.0-59.9 (Category 2), 60.0-64.9 (Category 2-3 "gray" zone), 65.0-100 (Category 3).

scores were observed for reference wetlands (df=38, F=0.60, p=0.618) and all wetlands (df=82, F=1.45, p=0.235) (Table 39).

The mean ORAM scores of reference wetlands of different dominant vegetation communities were also compared. There were significant differences between each category when all sites (both reference and nonreference were compared (df=82, F=4.68, p=0.001); however, when only reference wetlands were compared, there were no significant differences, although bogs on average scored 4-6 points higher than the other classes (df=40, F=0.39, p=0.853) (Table 40).

The results of the HGM and plant community comparison make sense and were expected since the questions that make up the ORAM are either insensitive to such differences or, to be properly answered, require the rater to explicitly rate wetlands in relation to others with the same HGM or plant community

Table 40. Mean and standard deviation of ORAM v. 5.0 scores of reference wetlands for 4 dominant plant community classes. Several sedge-grass meadow wetlands were included in the marsh category. Means were not significantly different at (p=0.853) after analysis of variance.

	mean	stdev	N
bog	75.8	12.9	5
fen	70.5	13.9	4
sedge-grass	71.2	12.0	5
marsh	68.3	2.5	3
shrub swamp	69.4	7.0	11
swamp forest	71.3	7.7	13

classes. For example, some metrics in the ORAM (e.g. Metric 1 wetland size, Metric 2 buffers and intensity of surrounding land uses, Metric 4a substrate disturbance, Metric 6b plan view interspersion, Metric 6c invasive plant coverage) can be answered objectively without any reference to HGM or plant community class of the wetland being evaluated. Other Metrics (e.g. Metric 3e hydrologic intactness, Metric 4b habitat development, Metric 4c habitat intactness) expressly require the rater to rate the wetland only in relation to wetlands of the same type, region, class, etc., thus expressly standardizing the ORAM score such that wetlands of different types receive a similar score (Mack 2000).

In conclusion, ORAM v. 5.0 performed as it was intentionally designed to perform, with an overall *insensitivity* to regional, hydrogeomorphic, and plant community differences in wetlands. The method includes questions which by their nature are insensitive to these potential differences, or requires the user to explicitly compare the wetland being assessed to other wetlands with the same regional, hydrogeomorphic, or plant community characteristics. The only real exception to this are the "special wetland communities" listed in Metric 5 of ORAM v. 5.0, in particular the bog and fen communities, which showed a marked graphical separation in their box and whisker plots especially when both reference and nonreference sites were analyzed together. However, this was also an intended and expected result of the ORAM v. 5.0 which was designed to ensure that special communities of this type in Ohio consistently received high scores and were appropriately categorized. Significant ecoregional differences in mean scores of nonreference wetlands were observed in the current data set but this may be an artifact of the wetlands currently included in the data set. Significant differences in mean scores of references were not detected although there mean scores for reference wetlands in the EOLP were higher than reference wetlands in ECBP. This may be due to the fact that, on average, wetlands in the Eastern Corn Belt Plains ecoregion tend to be more disturbed. Regionally, the Eastern Corn Belt Plains tends to be a much more fragmented landscape overwhelming developed as active agricultural land. However, when the 95th percentiles of the ORAM distributions for the two ecoregions are compared the differences are much less apparent, such that the best quality wetlands in the ECBP ecoregion are as good as the best quality wetlands in the EOLP, there are just fewer intact systems in the ECBP ecoregion.

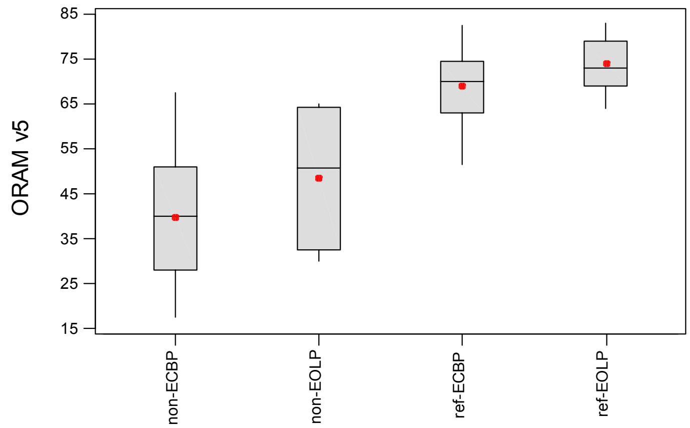

Figure 17. Box and whisker plots of ORAM v. 5.0 scores for reference (ref) and nonreference (non) wetlands by ecoregion. ECBP= Eastern Corn Belt Plains, EOLP= Erie Ontario Lake Plains. Means are indicated by solid circles. A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits: Lower Limit = Q1 - 1.5 (Q3 - Q1); Upper Limit = Q3 + 1.5 (Q3 - Q1). Outliers are points outside of the lower and upper limits and are plotted with asterisks (*).

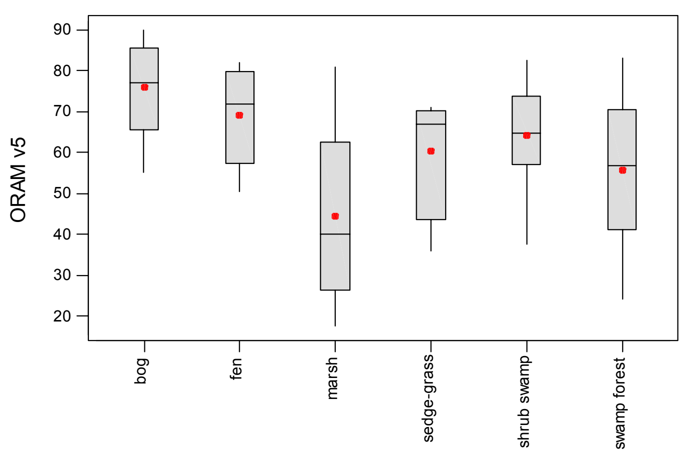

Figure 18. Box and whisker plots of ORAM v. 5.0 scores by vegetation community based wetland classes. Refer to Table 5 for a description of these classes. The mean is indicated by a solid dot. A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits: Lower Limit = Q1 - 1.5 (Q3 - Q1); Upper Limit = Q3 + 1.5 (Q3 - Q1).

5.0 Preliminary Wetland Aquatic Life Uses

A main purpose of developing wetland specific IBIs has been to specify numeric biological criteria for wetlands that correspond to various wetland designated uses. At the present time, Ohio law lists a single designated use for wetlands, the "wetland designated use" (OAC Rule 3745-1-52) which a wetland has merely by meeting the definition of a wetland in OAC Rule 3745-1-50. The development of a numeric IBI based on wetland vegetation is sufficiently advanced to attempt a preliminary outline of wetland aquatic life uses with associated numeric criteria. Ultimately, standards like these would be incorporated into the State of Ohio's water quality standards just as standards for streams have been previously promulgated.

The uses discussed below should be considered to be a preliminary attempt at developing specific wetland use designations. There should be every expectation that major or minor changes will be made as this topic is discussed and refined. The Wetland Aquatic Life Uses (ALUSs) follow a format equivalent to stream aquatic life uses. General use designations are defined in Table 41.

Table 41. General Wetland Aquatic Life Use Designations using Vegetation IBIs.

code	designation	definition
SWLH	Superior Wetland Habitat	Wetlands that are capable of supporting and maintaining a superior or unusual community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least3 times the quadrisected 95th percentile distribution as specified in Table 44 below.
WLH	Wetland Habitat	Wetlands that are capable of supporting and maintaining a balanced, integrated, adaptive community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 2 times the quadrisected 95th percentile distribution as specified in Table 44 below.
RWLH	Restorable Wetland Habitat	Wetlands which are degraded but have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 1 times the quadrisected 95th percentile distribution as specified in Table 44 below.
LWLH	Limited Wetland Habitat	Wetlands which are seriously degraded and which do not have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of less than 1 times the quadrisected 95th percentile distribution as specified in Table 44 below.

Once a general use designation is assigned, a specific Wetland Aquatic Life use is designated. This specific use incorporates aspects of the classification schemes in Table 6 and Table 7 and provides hydrogeomorphic and dominant vegetation characteristics of the range of wetlands present in the State of Ohio. The specific uses are summarized in Table 42. The specific uses correspond to the three dominant plant communities (forest, emergent, shrub), the seven main landscape positions (isolated, riparian, slope,[11] coastal (Lake Erie), lacustrine (non-Lake Erie), impoundment, and riverine). Most of the landscape position information is specified as a numeric specific use designation modifier in Table 42. Finally, in addition, to the general and specific uses, special uses are proposed in Table 43.

[11] There are five possible kinds of slope wetlands are forest seeps, seep fens, sedge-meadows, tall shrub fens, and fens.

Table 42. Specific wetland use designations.

Use code	specific use designation	Landscape position use designation modifier
Ia	Swamp forest	(1) riparian headwater depression, (2) riparian mainstem, depression (3) isolated depression, (4) lacustrine, (5) human impoundment, (6) beaver impoundment
Ib	Vernal pool	
Ic	Forest seeps	(1) riparian (2) isolated (3) lacustrine
Id	Tamarack-hardwood bog	
IIa	Mixed shrub swamp	(1) riparian headwater depression, (2) riparian mainstem, depression (3) isolated depression, (4) lacustrine, (5) human impoundment, (6) beaver impoundment
IIb	Buttonbush swamp	(1) riparian headwater depression, (2) riparian mainstem, depression (3) isolated depression, (4) lacustrine, (5) human impoundment, (6) beaver impoundment
IIc	Alder swamp	(1) riparian headwater depression, (2) riparian mainstem, depression (3) isolated depression, (4) lacustrine, (5) human impoundment, (6) beaver impoundment
IId	Tall shrub bog	
IIe	Tall shrub fen	(1) riparian (2) isolated (3) lacustrine
IIIa	Marshes (includes submergent, floating-leaved, mixed emergent, and cattail)	(1) riparian headwater depression, (2) riparian mainstem, depression (3) isolated depression, (4) lacustrine, (5) human impoundment, (6) beaver impoundment
IIIb	Sedge-grass communities (includes wet prairies, sedge meadows, and seep fens)	(1) riparian headwater depression, (2) riparian mainstem, depression (3) isolated depression, (4) lacustrine, (5) human impoundment, (6) beaver impoundment
IIIc	Riverine marsh communities (includes submergent, floating-leaved, mixed emergent and various intermixed shrub communities	
IIId	Fens (includes cinquefoil-fens, tamarack fens, arbor vitae fens)	(1) riparian (2) isolated (3) lacustrine
IIIe	Bogs (includes sphagnum bogs, leatherleaf bogs, but not tamarack-hardwood bogs (Ic) or tall shrub bogs (IId)	
IV	Coastal marshes	(1) restricted, (2) unrestricted, (3) estuarine

Table 43. Special wetland use designations.

subscript	special uses	description
A	recreation	wetlands with known recreational uses including hunting, fishing, birdwatching, etc. that are publicly available
B	education	wetlands with known educational uses, e.g. nature centers, schools, etc.
C	fish reproduction habitat	wetlands that provide important reproductive habitat for fish
D	bird habitat	wetlands that provide important breeding and nonbreeding habitat for birds
E	flood storage	wetlands located in landscape positions such that they have flood retention functions
F	water quality improvement	wetlands located in landscape positions such that they can perform water quality improvement functions for streams, lakes, or other wetlands

Table 44 provides pilot numeric biological criteria for wetlands based on Vegetation IBI scores for specific wetland plant communities and landscape positions (hydrogeomorphic class). Because no ecoregional differences in Vegetation IBIs appear to be present at this time, the numeric criteria apply to wetlands in all ecoregions of Ohio. However, as discussed in §4.0, differences have been noted based on landscape position and plant community type. Separate numeric criteria are proposed for classes where differences appear to be present as discussed in preceding sections.

An example in how to assign a Wetland Aquatic Life use with Tables 35-38 may be helpful. The wetland being evaluated is a pumpkin ash (*Fraxinus profunda*) swamp in Fowler Woods State Nature Preserve. This is a swamp forest in an non-riparian landscape position. After a detailed vegetation survey, a Vegetation IBI score of 81 is calculated. Referring to Table 36, this wetland receives a specific use designation of Ia3 (swamp forest-isolated depression). Referring to Table 38, a Vegetation IBI score of 81 is in the EWLH (Exceptional Wetland Habitat) use scoring range. Finally, Table 37 is consulted and it is determined that the wetland has educational uses as a state nature preserve that is open to the public. The Wetland Aquatic Life use designation can then summarized as,

$$\text{SWLP-Ia3}_B$$

where SWLH=means Superior Wetland Habitat, Ia3=Isolated Swamp Forest, and the subscript$_B$=education use.

The primary purpose of numeric wetland biocriteria is to assess the ecological integrity, or conversely the level of impairment, of a wetland. The primary purpose of the specific uses is to identify the type and landscape position of the wetland. This provides that wetlands within a class are compared for the purpose of assessing their relative quality and functions. It also allows the tracking of impacts to determine whether wetlands of certain types are being lost from the landscape of Ohio, and whether these wetlands are being replaced through creation or restoration. The Wetland ALUSs are designed to generally correspond to the antidegradation categories listed in OAC Rule 3745-1-54: Category 1, 2, and 3. However, there may be some instances where a wetland shows moderate to substantial impairment under the Wetland ALUSs but is still categorized as a Category 2 or 3 wetland under the antidegradation rule because it exhibits one or several valuable functions at moderate to superior levels, e.g. flood retention. Any confusion this situation might engender should be alleviated by the "special uses" listed in Table 43 since this should serve as an "alert" for antidegradation review purposes.

Table 44. Pilot numeric biological criteria for wetlands based on Vegetation IBI breakpoints for specific plant communities and landscape positions. "tbd"=to be developed.

Landscape position	plant community	specific use code(s)	LQWLH	RWLH	WLH	SWLH
Riparian mainstem depressions	swamp forests shrub swamps	Ia2, IIa2, IIb2, IIc2	0-16	17-33	34-50	51-100
All landscape positions except riparian mainstem depressions	swamp forests vernal pool shrub swamp	all use codes except Ia2, IIa2, IIb2, IIc2	0-22	23-45	46-66	67-100
All landscape positions except coastal and riverine	marshes	IIIa-ECBP	0-16	17-33	34-50	51-100
		IIIa-EOLP	0-20	21-41	42-62	63-100
All landscape positions	bog fen sedge-grass	Id, IId, IIe, IIIb, IIId, IIIe	0-23	24-47	48-71	72-100
Coastal	all	all use codes	tbd	tbd	tbd	tbd
Riverine	all	n/a	tbd	tbd	tbd	tbd

6.0 Quantitative vegetation characteristics of wetland types.

The final section of this report includes a series of tables summarizing quantitative characteristics of wetland plant communities. Since 1996, Ohio EPA has collected quantitative vegetation data in order to develop wetland specific IBIs using vascular plants. This data also has other uses. It provides numeric characteristics of the wetland plant communities sampled such that they can be compared to other types of wetland and terrestrial plant communities from a plant community ecology or phytosociological perspective.

Several of the tables below describe characteristics of wetland plant communities sorted by the wetlands's regulatory category under OAC Rule 3745-1-54. One of the requirements of this rule is that compensatory mitigation for unavoidable impacts to a wetland must restore or create a wetland of equal or higher category.[12] The following tables may be useful in providing quantitative ecological performance targets for mitigation projects or wetland mitigation banks. The variables summarized in these tables include the some of the component metrics that make up the Vegetation IBI as well as other vegetation and physical parameters.

With the exception of a few sites, the data summarized in these tables was collected using plots that were generally 0.1ha in area. Cover of plants found in the herb and shrub layer was estimated at the 100m^2 level (generally 10mX10m quadrats) and then converted to relative cover by dividing the total cover of a particular species by the cover of all species identified in the plot. Stand data for shrub and forest wetlands was derived from complete woody stem counts were made in these plots. Other vegetation sampling methods that have a similar sampling intensity and yield similar data should generally be comparable to these tables (Peet et al. 1998).

Tables 45, 46, 47, 48, 49, and 50 provided quantitative vegetation characteristics for several common wetland plant communities found in Ohio: emergent marshes, swamp forests (including vernal pools), shrub swamps, sedge-grass communities, calcareous fens, and various bog communities (leatherleaf bogs, sphagnum bogs, tall shrub bogs). Characteristics are sorted using the regulatory category of the wetlands in the current data set. Regulatory category was determined using the categorization rules found in Mack (2001). These tables should be useful in evaluating the success of mitigation projects, especially projects aimed at restoring or creating emergent marshes, swamp forests, and shrub swamps. They may also aid in evaluating the quality or regulatory category of a particular wetland.

Of note in these tables is the inclusion of several physical parameters found in natural wetlands including number of tussocks, hummocks, standing dead, and coarse woody debris, summer[13] depth of water and depth to saturated soils, litter depth, and average microtopographic score. Higher quality wetlands are heterogeneous at the microtopographic (sub-meter to sub-100m^2 level), a fact that is often overlooked in the design and construction of restoration and creation projects. They also often have very shallow (less than 30cm depth) water or saturated soils closer to the surface present during mid to late summer. Lower quality wetlands often have the depth to saturated soils >30cm or have no water or much deeper water (often an artificial impoundment effect) during mid-summer. A common flaw in restoration and creation projects is to have water that is too deep (in effect a pond) or saturated soil conditions that retreat too far below the soil surface during the growing season.

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12 In the case of Category 1 and Category 2 wetlands, the mitigation wetland must be Category 2 or 3 quality; in the case of Category 3 wetlands, the wetland must be of Category 3 quality.

13 Parameters generally measured between mid June to the end of August.

Table 51 provides mean importance values[14] for woody plant species (trees and shrubs) frequently observed in shrub or forest wetland plant communities. Several points can be readily made from this table. First, the presence and importance of red and silver maple (*Acer rubrum, A. saccarhinum*), elms (*Ulmus americana, U. rubra*), and green ash (*Fraxinus pensylvanica)* are not, by themselves, indicative of the relative quality of a forested wetland. Both low, medium and high quality forested wetlands can be dominated by these species, although a decline in importance, especially for green ash, appears to occur as quality increases.

Second, the presence and importance of certain species including red and swamp white oak (*Quercus rubra, Q. bicolor*), pumpkin ash (*Fraxinus profunda*), swamp cottonwood (*Populus heterophylla*) and other mesic forest species (*Carpinus caroliniana, Fagus grandifolia, Tilia americana)*[15] and hickory species (*Carya* spp.) appear to be indicative of higher quality forested wetland.

Third, the shrub strata within a forested wetland appears to be a sensitive indicator of quality with the shrub community largely disappearing in low quality forested wetlands and constituting a vary diverse subcanopy community in medium to high quality forested wetlands. Several species including chokeberry (*Aronia melanocarpa*), catberry (*Nemopanthus mucronata*), poison sumac (*Toxicodendron vernix*) and highbush blueberry (*Vaccinium corymbosum*) appear to be distinctive of Category 3 forested wetlands, especially in the Lake Plains and Glaciated Allegheny Plateau of northeast Ohio.

Tables 52 and 53 quantify stand characteristics of mature to old growth forested wetlands. Mature forested wetlands are defined in the Narrative Questions of the Ohio Rapid Assessment for Wetlands as forested wetlands with more the 50% of the canopy dominated by trees with diameters at breast height >45cm (Mack 2001). In preparing these tables, the stand characteristics of all forested wetlands with at least one tree >45cm dbh were analyzed (Table 52). In addition, the woody stem counts made in the plots are recorded for each 10mx10m module allowing the mapping of position of large trees across the plot (Figures 19 and 20). Because trees are very long-lived, a mature and diverse canopy of trees can persist in a forested wetland even after very substantial human disturbances have degraded the herb, shrub, and faunal communities.

Finally, Tables 54, 55, 56, and 57 provide lists of representative plant species for good quality emergent marsh, swamp forest, shrub swamps, and sedge-grass communities. These lists were compiled from the species list and the relative dominance of these species in wetlands sampled from 1996-2000. “Good quality” is a relative term but includes plant species found in wetlands that are capable of supporting and maintaining a balanced, integrated, adaptive community of vascular plants. It can be equated with Category 2 (excluding degraded Category 2s) and Category 3 wetlands as they are defined in OAC Rule 3745-1-54. These lists should not be considered inclusive or exclusive lists but typical lists of the plants often observed in these wetland plant communities sampled to date.

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[14] Importance value is calculated by summing the relative class frequency, relative density and relative basal area and dividing by 3. Relative class frequency (See §2.3.10) is substituted for relative frequency since relative frequency is not easily calculated using the plot based sampling method.

[15] Sometimes located near the wetland edges or on microtopographic rises within a wetland.

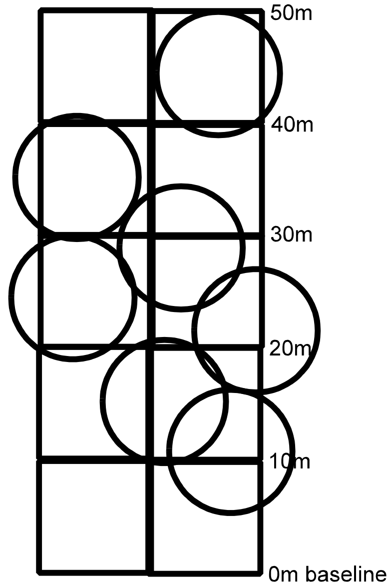

Figure 19. Approximate location of trees >45cm dbh in modules of 20mx50m plot at Big Woods Preserve, Miami County, Ohio. Big Woods is a category 3 vernal pool forested wetland.

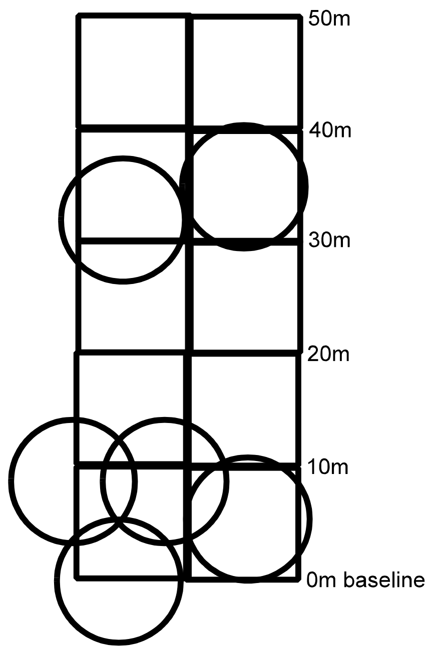

Figure 20. Approximate location of trees >45cm in modules of 20mx50m plot at Orange Road site, Delaware County, Ohio. Orange Road is a degraded category 2 forested wetland with a persistent mature canopy.

Table 45. Mean values (standard deviation in parenthesis) of vegetation and physical characteristics of EMERGENT MARSH communities by wetland category. Sampling intensity generally 0.1ha plot with 8 nested quadrats in accordance with methods in §2.0. Analysis of variance followed by Tukey's HSD test used to explore differences between categories. Means without shared letters significantly different at $p<0.05$.

parameter	Category 1	Restorable Category 2	Category 2	Category 3
Vegetation IBI score	15(10)a	34(8)b	50(19)b	78(7)c
FQAI score	9(2)a	16(2)b	16(4)b	22(2)c
Total species	13(5)a	21(4)b	30(9)c	38(3)d
Graminoid species	6(3)	5(2)	8(3)	10(1)
Forb species	6(3)a	14(4)b	17(8)bc	19(3)c
Shrub species	0.2(0.4)a	2(2)ab	2(2)b	6(3)c
Cryptogam species	0(0)a	0.3(0.6)a	0.3(0.5)a	1(0.8)b
Dicot species	6(3)a	14(4)b	18(6)bc	22(3)c
Monocot species	7(4)a	7(1)a	11(5)b	15(1)b
FACW and OBL species	9(4)a	18(6)b	22(9)b	31(3)c
relative cover forb species	0.28(0.28)a	0.70(0.10)bc	0.52(0.23)b	0.75(0.18)c
relative cover graminoid species	0.68(0.28)a	0.28(0.11)b	0.39(0.25)b	0.19(0.18)b
relative cover shrub species	0.002(0.006)a	0.01(0.02)a	0.06(0.05)b	0.05(0.008)c
relative cover tolerant species	0.61(0.24)a	0.42(0.17)b	0.41(0.21)b	0.17(0.12)c
relative cover intolerant species	0.008(0.01)a	0.009(0.005)a	0.05(0.04)b	0.26(0.17)c
relative cover invasive grass spp.	0.29(0.26)	0.31(0.28)	0.15(0.23)	0.01(0.02)
mean standing biomass ($g/m^{2)}$	903(551)a	1007(477)b	463(265)c	259(155)c
tussocks per are ($100m^2$)	0	0	0	29
hummocks per are ($100m^2$)	0	0	2.5	0.4
standing dead per hectare	0	0	6	125
woody debris per hectare	0	133	93	125
mean summer water depth (cm)	0	23	13	28
mean litter depth (cm)	6	nd	1.5	1
mean summer depth to saturated soils (cm)	>30	nd	20	nd
mean microhabitat interspersion score	nd	0.1	0.9	2.7

Table 46. Mean values (standard deviation in parenthesis) of vegetation and physical characteristics of SWAMP FOREST communities by wetland category. Sampling intensity generally 0.1ha plot with 8 nested quadrats in accordance with methods in §2.0. Analysis of variance followed by Tukey's HSD test used to explore differences between categories. Means without shared letters significantly different at p<0.05. There was only on 1 "restorable Category 2" swamp forest so this category was not analyzed separately.

parameter	Category 1	Category 2	Category 3
Vegetation IBI score	13(10)a	53(25)b	76(14)c
FQAI score	12(2)a	22(2)b	26(5)c
Total species	20(7)a	34(7)b	39(10)b
Graminoid species	2(2)	5(3)	6(4)
Forb species	10(6)a	13(3)b	17(5)c
Shrub species	0.6(0.9)a	4(2)b	5(3)b
Tree species	6(3)a	10(3)b	9(3)b
Cryptogam species	0(0)a	1(1)a	2(2)b
Dicot species	16(7)a	27(7)b	29(7)b
Monocot species	3(2)a	6(2)b	8(5)b
FACW and OBL species	10(3)a	16(4)b	20(7)c
relative cover forb species	0.52(0.17)	0.50(0.27)	0.45(0.19)
relative cover graminoid species	0.29(0.26)	0.15(0.14)	0.20(0.15)
relative cover shrub species	0.07(0.16)a	0.10(0.12)a	0.25(0.18)b
relative cover tolerant species	0.43(o.25)a	0.32(0.19)b	0.15(0.07)c
relative cover intolerant species	0.09(0.19)a	0.17(0.25)a	0.38(0.22)b
relative cover invasive grass spp.	0.22(0.30)a	0.07(0.15)b	<0.0001b
tussocks per are ($100m^2$)	0(0)	4(10)	28(37)
hummocks per are ($100m^2$)	0(0)	2(5)	5(5)
standing dead per hectare	75(66)	50(57)	25(39)
woody debris per hectare	208(95)	263(265)	256(217)
mean summer water depth (cm)	0(0)	0.4(0.8)	5.9(7.3)
mean litter depth (cm)	2.1(2.0)	1.2(1.1)	1.9(1.8)
mean summer depth to saturated soils (cm)	>30	22(13)	11(12)
mean microhabitat interspersion score	nd	2.7(2.5)	5.2(2.5)

Table 47. Mean values of vegetation and physical characteristics of SHRUB SWAMP communities by wetland category. Sampling intensity generally 0.1ha plot with 8 nested quadrats in accordance with methods in §2.0. "nd" = no data available.

parameter	Category 1	Restorable Category 2	Category 2	Category 3
Vegetation IBI score	nd	27	59	76
FQAI score	nd	17	19	22
Total species	nd	22	31	31
Graminoid species	nd	1	3	5
Forb species	nd	8	15	12
Shrub species	nd	1	4	5
Tree species	nd	9	7	6
Cryptogam species	nd	nd	0.3	1.4
Dicot species	nd	20	24	23
Monocot species	nd	2	6	7
FACW and OBL species	nd	8	19	18
relative cover forb species	nd	0.57	0.58	0.24
relative cover graminoid species	nd	0.02	0.05	0.13
relative cover shrub species	nd	0.17	0.32	0.52
relative cover tolerant species	nd	0.13	0.09	0.04
relative cover intolerant species	nd	0.18	0.36	0.58
relative cover invasive grass spp.	nd	nd	0.01	0.0004
tussocks per are ($100m^2$)	nd	nd	6	51
hummocks per are ($100m^2$)	nd	nd	10	6
standing dead per hectare	nd	nd	88	45
woody debris per hectare	nd	nd	269	350
mean summer water depth (cm)	nd	nd	7	10
mean litter depth (cm)	nd	nd	1.6	3.1
mean summer depth to saturated soils (cm)	nd	nd	26	18
mean microhabitat interspersion score	nd	nd	nd	4.9

Table 48. Mean values of vegetation and physical characteristics of CALCAREOUS FEN communities by wetland category. Sampling intensity generally 0.1ha plot with 8 nested quadrats in accordance with methods in §2.0. All calcareous fens are Category 3.

parameter	disturbed fen	high quality fen
Vegetation IBI score	71	84
FQAI score	31	34
Total species	48	56
Graminoid species	14	14
Forb species	23	27
Shrub species	7	12
Cryptogam species	2	2
Dicot species	30	36
Monocot species	16	18
FACW and OBL species	36	44
relative cover forb species	0.22	0.28
relative cover graminoid species	0.71	0.32
relative cover shrub species	0.05	0.35
relative cover tolerant species	0.47	0.10
relative cover intolerant species	0.32	0.52
relative cover invasive grass spp.	0.45	0.02
mean standing biomass (g/m^2)	981	798
tussocks per are ($100m^2$)	64	204
hummocks per are ($100m^2$)	0	0.7
standing dead per hectare	0	0
woody debris per hectare	0	0
mean summer water depth (cm)	9	0
mean litter depth (cm)	nd	0.3
mean summer depth to saturated soils (cm)	12	0
mean microhabitat interspersion score	nd	8.8

Table 49. Mean values of vegetation and physical characteristics of SEDGE-GRASS communities (includes sedge-grass meadows and seep fens) by wetland category. Sampling intensity generally 0.1ha plot with 8 nested quadrats in accordance with methods in §2.0. All calcareous fens are Category 3.

parameter	Restorable Category 2	Category 3
Vegetation IBI score	28	85
FQAI score	12	29
Total species	23	47
Graminoid species	9	16
Forb species	10	25
Shrub species	1	5
Cryptogam species	nd	0.3
Dicot species	13	28
Monocot species	10	18
FACW and OBL species	14	33
relative cover forb species	0.28	0.33
relative cover graminoid species	0.64	0.61
relative cover shrub species	0.04	0.03
relative cover tolerant species	0.67	0.09
relative cover intolerant species	0.05	0.41
relative cover invasive grass spp.	0.03	0.01
mean standing biomass (g/m^2)	861	944
tussocks per are ($100m^2$)	nd	32
hummocks per are ($100m^2$)	nd	46
standing dead per hectare	nd	13
woody debris per hectare	nd	0
mean summer water depth (cm)	nd	2
mean litter depth (cm)	nd	0.4
mean summer depth to saturated soils (cm)	nd	9
mean microhabitat interspersion score	nd	nd

Table 50. Mean values of vegetation and physical characteristics of BOG communities. Sampling intensity generally 0.1ha plot with 8 nested quadrats in accordance with methods in §2.0. All bogs were Category 3 wetlands.

parameter	Bog values
Vegetation IBI score	85
FQAI score	29
Total species	35
Graminoid species	7
Forb species	15
Shrub species	8
Cryptogam species	2
Dicot species	23
Monocot species	9
FACW and OBL species	26
relative cover forb species	0.43
relative cover graminoid species	0.18
relative cover shrub species	0.34
relative cover tolerant species	0.07
relative cover intolerant species	0.65
relative cover invasive grass spp.	0.0005
mean standing biomass (g/m^2)	256
tussocks per are (100m^2)	42
hummocks per are (100m^2)	15
standing dead per hectare	22
woody debris per hectare	53
mean summer water depth (cm)	6
mean litter depth (cm)	0.08
mean summer depth to saturated soils (cm)	0
mean microhabitat interspersion score	7

Table 51. Mean importance value for selected frequently observed tree and shrub species by category of forested wetland where species observed. *Carya* spp. include *C. cordiformis, C. glabra, C. laciniosa, C. ovalis, C. ovata,* and *C. tomentosa*. *Cornus* spp. include *C. amomum, C. drummondii,* and *C. racemosa.*

species	Category 1	Category 2	Category 3
TREES			
Acer rubrum	0.003	0.307	0.154
Acer saccarhinum	0.186	0.163	0.306
Carpinus caroliniana	---	0.035	0.019
Carya spp.*	---	0.039	0.008
Fagus grandifolia	---	0.003	0.083
Fraxinus nigra	0.288	0.067	0.021
Fraxinus pennsylvanica	0.442	0.184	0.126
Fraxinus profunda	---	---	0.107
Populus deltoides	0.351	0.127	0.158
Populus heterophylla	---	---	0.024
Quercus bicolor	---	0.102	0.057
Quercus palustris	0.066	0.107	0.018
Quercus rubra	---	0.003	0.007
Salix nigra	0.280	---	0.012
Tilia americana	---	0.022	0.009
Ulmus americana	0.051	0.098	0.075
Ulmus rubra	0.013	0.049	0.047
SHRUBS			
Alnus incana	---	0.120	0.008
Aronia melanocarpa	—	---	0.024
Cephalanthus occidentalis	---	0.153	0.122
Cornus spp.**	0.024	0.015	0.031
Ilex verticillata	---	0.098	0.136
Lindera benzoin	---	0.055	0.132
Nemopanthus mucronata	---	---	0.014
Rosa palustris	---	0.009	0.018
Sambucus canadensis	---	0.002	0.006
Toxicodendron vernix	---	---	0.007
Vaccinium corymbosum	---	---	0.064
Viburnum recognitum	---	0.067	0.100

Table 52. Density and dominance of trees >45cm in existing forested wetland data set. All wetlands with at least one tree >45cm included in this table. Sampling intensity generally 0.1ha plot in accordance with methods in §2.0. Site names in boldface type are mature forested wetlands.

site	density stems/ha >45cm dbh	ratio >45cm stems/all stems	dominance basal area m^2/ha	ratio >45cm basal/total basal	comments
Ackerman	33	0.004	0.5	0.029	
Big Woods	90	0.108	17.1	0.427	
Blackjack Rd (front)	0	---	0.0	---	
Brown Lake Bog	30	0.034	4.2	0.132	
City of Mansfield	20	0.042	3.3	0.125	
Collier Woods	70	0.089	14.6	0.348	
Eagle Cr. Vernal	50	0.096	8.4	0.454	
Flowing Well	57	0.076	11.3	0.375	
Fowler Woods	60	0.042	11.0	0.220	
Gahanna Woods 4th	10	0.038	2.1	0.139	
Graham Rd.	40	0.023	9.5	0.286	non-riparian, only large *Populus deltoides*
Hempelman	10	0.006	1.5	0.080	
Johnson Rd.	50	0.043	8.0	0.262	non-riparian, only large *Populus deltoides*
Killbuck Creek	10	0.007	1.8	0.059	
Killdeer Plains	100	0.097	19.6	0.474	
LaRue Woods	17	0.024	2.5	0.252	
Lawrence Woods High	37	0.085	6.9	0.422	
Lawrence Woods Low 2	40	0.321	14.1	0.429	
Leafy Oak	0	---	0.0	---	
Mentor Marsh	0	---	0.0	---	
N. Kingsville S. Barr. Sw.	10	0.007	1.6	0.046	
Orange Rd.	60	0.042	12.7	0.253	
Oyer Tamarack	10	0.005	1.5	0.182	
Pallister	100	0.049	15.0	0.334	
Pawnee Rd.	80	0.036	17.2	0.396	
Sawmill	0	---	0	---	
US42	0	---	0	---	
Tipp-Elizabeth Rd.	0	---	0	---	
Townline Rd.	0	---	0	---	
White Pine Bog	70	0.053	16.8	0.381	

Table 53. Stand characteristics of mature forested wetlands.

characteristic	range
density >45cm dbh trees (stems/ha)	50-100
density ratio (stems/ha >45cm trees to stems/ha of all trees)	0.04-0.11
dominance >45cm trees (basal area at breast height m^2/ha)	8.4-19.6
dominance ratio (basal area >45cm trees to basal area of all trees)	0.22-0.47
avg. no. of stems >45cm per plot (typically 20mx50m)	7.1
avg. no. of stems >45cm per 10mx10m module in plot	0.83

Table 54. Representative plant species of good quality emergent marshes.

species	family	life form	repro class
Alnus incana	Betulaceae	shrub	dicot
Amphicarpaea bracteata	Fabaceae	forb	dicot
Angelica atropurpurea	Apiaceae	forb	dicot
Asclepias incarnata	Asclepiadaceae	forb	dicot
Bidens cernua	Asteraceae	forb	dicot
Boehmeria cyclindrica	Urticaceae	forb	dicot
Carex alata	Cyperaceae	graminoid	monocot
Carex comosa	Cyperaceae	graminoid	monocot
Carex hystericina	Cyperaceae	graminoid	monocot
Carex lacustris	Cyperaceae	graminoid	monocot
Carex lurida	Cyperaceae	graminoid	monocot
Carex projecta	Cyperaceae	graminoid	monocot
Carex scoparia	Cyperaceae	graminoid	monocot
Carex tribuloides	Cyperaceae	graminoid	monocot
Carex vulpinoidea	Cyperaceae	graminoid	monocot
Cephalanthus occidentalis	Rubiaceae	shrub	dicot
Ceratophyllum echinatum	Ceratophyllaceae	forb	dicot
Chelone glabra	Scrophulariaceae	forb	dicot
Cicuta bulbifera	Apiaceae	forb	dicot
Cornus amomum	Cornaceae	shrub	dicot
Cornus sericea	Cornaceae	shrub	dicot
Cyperus erythrorhizos	Cyperaceae	graminoid	monocot
Cyperus odoratus	Cyperaceae	graminoid	monocot
Decodon verticillatus	Lythraceae	forb	dicot
Dulichium arundinaceum	Cyperaceae	graminoid	monocot
Eleocharis palustris	Cyperaceae	graminoid	monocot
Elodea canadensis	Hydrocharitaceae	forb	monocot
Eupatorium maculatum	Asteraceae	forb	dicot
Eupatorium perfoliatum	Asteraceae	forb	dicot
Galium tinctorium	Rubiaceae	forb	dicot
Hibiscus laevis	Malvaceae	forb	dicot
Hibiscus moscheutos	Malvaceae	forb	dicot
Iris versicolor	Iridaceae	forb	monocot
Juncus canadensis	Juncaceae	graminoid	monocot
Juncus interior	Juncaceae	graminoid	monocot
Juncus nodosus	Juncaceae	graminoid	monocot
Lemna trisulca	Lemnaceae	forb	monocot
Lycopus rubellus	Lamiaceae	forb	dicot
Lysimachia terrestris	Primulaceae	forb	dicot
Lysimachia thyrsiflora	Primulaceae	forb	dicot
Nuphar advena	Nymphaceae	forb	monocot
Nymphaea odorata	Nymphaceae	forb	monocot
Onoclea sensiblis	Aspleniaceae	fern	cryptogam
Peltandra virginica	Araceae	forb	monocot
Pilea fontana	Urticaceae	forb	dicot
Polygonum amphibium	Polygonaceae	forb	dicot
Polygonum arifolium	Polygonaceae	forb	dicot
Polygonum punctatum	Polygonaceae	forb	dicot
Pontederia cordata	Pontederiaceae	forb	monocot
Potamogeton epihydrus	Potamogetonaceae	forb	monocot
Potamogeton foliosus	Potamogetonaceae	forb	monocot
Potamogeton nodusus	Potamogetonaceae	forb	dicot
Ranunuculus longirostris	Ranunculaceae	forb	dicot
Rosa palustris	Rosaceae	shrub	dicot
Rumex orbiculatus	Polygonaceae	forb	dicot
Rumex verticillatus	Polygonaceae	forb	dicot
Sagittaria brevirostra	Alismataceae	forb	monocot
Sagittaria calycina	Alismataceae	forb	monocot
Sagittaria latifolia	Alismataceae	forb	monocot
Salix discolor	Salicaceae	shrub	dicot
Salix exigua	Salicaceae	shrub	dicot
Salix sericea	Salicaceae	shrub	dicot
Scirpus fluviatilis	Cyperaceae	graminoid	monocot
Scirpus validus	Cyperaceae	graminoid	monocot
Scutellaria galericulata	Lamiaceae	forb	dicot
Scutellaria lateriflora	Lamiaceae	forb	dicot
Sium suave	Apiaceae	forb	dicot
Sparganium americanum	Sparganiaceae	graminoid	monocot
Sparganium eurycarpum	Sparganiaceae	graminoid	monocot

Table 54. Representative plant species of good quality emergent marshes.

species	family	life form	repro class
Spirea alba	Rosaceae	shrub	dicot
Spirodela polyrhiza	Lemnaceae	forb	monocot
Stachys palustris	Lamiaceae	forb	dicot
Thelypteris palustris	Thelypteridaceae	fern	cryptogam
Toxicodendron vernix	Anacardiaceae	shrub	dicot
Typha latifolia	Typhaceae	graminoid	monocot
Urtica dioica	Urticaceae	forb	dicot
Utricularia vulgaris	Lentibulariaceae	forb	monocot
Vaccinium corymbosum	Ericaceae	shrub	dicot
Verbena hastata	Verbenaceae	forb	dicot
Veronica anagallis-aquatica	Scrophulariaceae	forb	dicot
Veronica scutellata	Scrophulariaceae	forb	dicot
Viburnum recognitum	Caprifoliaceae	shrub	dicot
Wolffia brasiliensis	Lemnaceae	forb	monocot
Wolffia columbiana	Lemnaceae	forb	monocot

Table 55. Representative plant species of good quality forested wetlands.

species	family	life form	repro class
Acer rubrum	Aceraceae	tree	dicot
Acer saccarhinum	Aceraceae	tree	dicot
Apios americana	Fabaceae	forb	dicot
Arisaema triphyllum	Araceae	forb	monocot
Aronia melanocarpa	Rosaceae	shrub	dicot
Betula alleghaniensis	Betulaceae	tree	dicot
Boehmeria cylindrica	Urticaceae	forb	dicot
Caltha palustris	Ranunculaceae	forb	dicot
Carex bromoides	Cyperaceae	graminoid	monocot
Carex crinita	Cyperaceae	graminoid	monocot
Carex crus-corvi	Cyperaceae	graminoid	monocot
Carex grayii	Cyperaceae	graminoid	monocot
Carex hyalinolepis	Cyperaceae	graminoid	monocot
Carex intumescens	Cyperaceae	graminoid	monocot
Carex lupulina	Cyperaceae	graminoid	monocot
Carex prasina	Cyperaceae	graminoid	monocot
Carex seorsa	Cyperaceae	graminoid	monocot
Carex stipata	Cyperaceae	graminoid	monocot
Carex tribuloides	Cyperaceae	graminoid	monocot
Carex tuckermanii	Cyperaceae	graminoid	monocot
Carex vesicaria	Cyperaceae	graminoid	monocot
Carpinus caroliniana	Betulaceae	tree	dicot
Carya laciniosa	Juglandaceae	tree	dicot
Carya ovata	Juglandaceae	tree	dicot
Cinna arundinacea	Poaceae	graminoid	monocot
Circaea lutetiana	Onagraceae	forb	dicot
Coptis trifolia	Ranunculaceae	forb	dicot
Dryopteris carthusiana	Aspleniaceae	forb	cryptogam
Dryopteris cristata	Aspleniaceae	forb	dicot
Festuca subverticillata	Poaceae	graminoid	monocot
Fraxinus nigra	Oleaceae	tree	dicot
Fraxinus pennsylvanica	Oleaceae	tree	dicot
Fraxinus profunda	Oleaceae	tree	dicot
Glyceria septentrionalis	Poaceae	graminoid	monocot
Hydrocotyle americanum	Apiaceae	forb	dicot
Hydrophyllum virginianum	Hydrophyllaceae	forb	dicot
Ilex verticillata	Aquifoliaceae	shrub	dicot
Laportea canadensis	Urticaceae	forb	dicot
Leersia virginica	Poaceae	graminoid	monocot
Lindera benzoin	Lauraceae	shrub	dicot
Lobelia cardinalis	Campanulaceae	forb	dicot
Lysimachia ciliata	Primulaceae	forb	dicot
Maianthemum canadense	Liliaceae	forb	monocot
Nemopanthus mucronatus	Aquifoliaceae	shrub	dicot
Nyssa sylvatica	Cornaceae	tree	dicot
Osmunda cinnamomea	Osmundaceae	forb	cryptogam
Osmunda regalis	Osmundaceae	forb	cryptogam
Pinus strobus	Pinaceae	tree	gymnosperm
Poa alsodes	Poaceae	graminoid	monocot
Polygonum hydropiperoides	Polygonaceae	forb	dicot
Polygonum punctatum	Polygonaceae	forb	dicot
Populus heterophylla	Salicaceae	tree	dicot
Quercus bicolor	Fagaceae	tree	dicot
Quercus rubra	Fagaceae	tree	dicot
Sambucus canadensis	Sambucaceae	shrub	dicot
Smilacina stellata	Liliaceae	forb	monocot
Symplocarpus foetidus	Araceae	forb	monocot
Trientalis borealis	Primulaceae	forb	dicot
Ulmus americana	Ulmaceae	tree	dicot
Vaccinium corymbosum	Ericaceae	shrub	dicot
Viburnum dentatum	Caprifoliaceae	shrub	dicot
Viola cucullata	Violaceae	forb	dicot

Table 56. Representative plant species of good quality shrub swamps.

species	family	life form	repro class
Acer rubrum	Aceraceae	tree	dicot
Acer saccarhinum	Aceraceae	tree	dicot
Aronia melanocarpa	Rosaceae	shrub	dicot
Betula alleghaniensis	Betulaceae	tree	dicot
Bidens connata	Asteraceae	forb	dicot
Bidens discoidea	Asteraceae	forb	dicot
Boehmeria cylindrica	Urticaceae	forb	dicot
Carex bromoides	Cyperaceae	graminoid	monocot
Carex crus-corvi	Cyperaceae	graminoid	monocot
Carex decomposita	Cyperaceae	graminoid	monocot
Carex grayii	Cyperaceae	graminoid	monocot
Carex hyalinolepis	Cyperaceae	graminoid	monocot
Carex intumescens	Cyperaceae	graminoid	monocot
Carex laevivaginata	Cyperaceae	graminoid	monocot
Carex muskingumensis	Cyperaceae	graminoid	monocot
Carex prasina	Cyperaceae	graminoid	monocot
Carex seorsa	Cyperaceae	graminoid	monocot
Carex tribuloides	Cyperaceae	graminoid	monocot
Carex typhina	Cyperaceae	graminoid	monocot
Carex vesicaria	Cyperaceae	graminoid	monocot
Carpinus caroliniana	Betulaceae	tree	dicot
Cephalanthus occidentalis	Rubiaceae	shrub	dicot
Chelone glabra	Scophulariaceae	forb	dicot
Cinna arundinacea	Poaceae	graminoid	monocot
Dryopteris carthusiana	Aspleniaceae	forb	cryptogam
Festuca subverticillata	Poaceae	graminoid	monocot
Fraxinus pennsylvanica	Oleaceae	tree	dicot
Galium asprellum	Rubiaceae	forb	dicot
Galium tinctorium	Rubiaceae	forb	dicot
Galium triflorum	Rubiaceae	forb	dicot
Glyceria septentrionalis	Poaceae	graminoid	monocot
Impatiens capensis	Balsaminaceae	forb	dicot
Iris versicolor	Iridaceae	forb	monocot
Lemna trisulca	Lemnaceae	forb	monocot
Lindera benzoin	Lauraceae	shrub	dicot
Lobelia cardinalis	Campanulaceae	forb	dicot
Lysimachia terrestris	Primulaceae	forb	dicot
Lysimachia thyrsiflora	Primulaceae	forb	dicot
Nyssa sylvatica	Cornaceae	tree	dicot
Osmunda cinnamomea	Osmundaceae	forb	cryptogam
Osmunda regalis	Osmundaceae	forb	cryptogam
Polygonum hydropiperoides	Polygonaceae	forb	dicot
Populus heterophylla	Salicaceae	tree	dicot
Quercus bicolor	Fagaceae	tree	dicot
Ranunculus flabellaris	Ranunculaceae	forb	dicot
Ranunculus hispidus nitidus	Ranunculaceae	forb	dicot
Ribes americanum	Grossulariaceae	shrub	dicot
Rosa palustris	Rosaceae	shrub	dicot
Rubus hispidus	Rosaceae	forb	dicot
Scutellaria lateriflora	Lamiaceae	forb	dicot
Sium suave	Apiaceae	forb	dicot
Symplocarpus foetidus	Araceae	forb	monocot
Ulmus americana	Ulmaceae	tree	dicot
Vaccinium corymbosum	Ericaceae	shrub	dicot
Viburnum dentatum	Caprifoliaceae	shrub	dicot

Table 57. Representative plant species of good quality sedge-grass communities.

species	family	life form	repro class
Agrimonia gryposepala	Rosaceae	forb	dicot
Angelica atropurpurea	Apiaceae	forb	dicot
Asclepias incarnata	Asclepiadaceae	forb	dicot
Aster novae-angliae	Asteraceae	forb	dicot
Aster puniceus	Asteraceae	forb	dicot
Bromus ciliatus	Poaceae	graminoid	monocot
Calamagrostis stricta	Poaceae	graminoid	monocot
Calamagrostis canadensis	Poaceae	graminoid	monocot
Campanula aperinoides	Campanulaceae	forb	dicot
Carex aquatilis	Cyperaceae	graminoid	monocot
Carex atherodes	Cyperaceae	graminoid	monocot
Carex hystericina	Cyperaceae	graminoid	monocot
Carex interior	Cyperaceae	graminoid	monocot
Carex lacustris	Cyperaceae	graminoid	monocot
Carex pellita	Cyperaceae	graminoid	monocot
Carex trichocarpa	Cyperaceae	graminoid	monocot
Carex sartwellii	Cyperaceae	graminoid	monocot
Carex scoparia	Cyperaceae	graminoid	monocot
Carex stricta	Cyperaceae	graminoid	monocot
Carex suberecta	Cyperaceae	graminoid	monocot
Carex tenera	Cyperaceae	graminoid	monocot
Carex tetanica	Cyperaceae	graminoid	monocot
Carex annectens	Cyperaceae	graminoid	monocot
Cephalanthus occidentalis	Rubiaceae	shrub	dicot
Cirsium muticum	Asteraceae	forb	dicot
Cornus amomum	Cornaceae	shrub	dicot
Cornus racemosa	Cornaceae	shrub	dicot
Cornus sericea	Cornaceae	shrub	dicot
Corylus americana	Betulaceae	shrub	dicot
Cyperus odoratus	Cyperaceae	graminoid	monocot
Eleocharis tenuis borealis	Cyperaceae	graminoid	monocot
Eupatorium maculatum	Asteraceae	forb	dicot
Filipendula rubra	Rosaceae	forb	dicot
Galium asprellum	Rubiaceae	forb	dicot
Galium obtusum	Rubiaceae	forb	dicot
Juncus acuminatus	Juncaceae	graminoid	monocot
Juncus brachycephalus	Juncaceae	graminoid	monocot
Juncus canadensis	Juncaceae	graminoid	monocot
Juncus dudleyi	Juncaceae	graminoid	monocot
Lathyrus palustris	Fabaceae	forb	dicot
Lobelia kalmii	Campanulaceae	forb	dicot
Lobelia siphilitica	Campanulaceae	forb	dicot
Lycopus americanus	Lamiaceae	forb	dicot
Lycopus uniflorus	Lamiaceae	forb	dicot
Lysimachia ciliata	Primulaceae	forb	dicot
Lythrum alatum	Lythraceae	forb	dicot
Mimulus ringens	Scrophulariaceae	forb	dicot
Osmunda regalis	Osmundaceae	forb	cryptogam
Pycnanthemum virginianum	Lamiaceae	forb	dicot
Rosa palustris	Rosaceae	shrub	dicot
Rudbeckia fulgida	Asteraceae	forb	dicot
Salix amygdaloides	Salicaceae	shrub	dicot
Salix bebbiana	Salicaceae	shrub	dicot
Salix discolor	Salicaceae	shrub	dicot
Salix eriocephala	Salicaceae	shrub	dicot
Salix exigua	Salicaceae	shrub	dicot
Salix humulis	Salicaceae	shrub	dicot
Salix sericea	Salicaceae	shrub	dicot
Sanguisorba canadenis	Rosaceae	forb	dicot
Saxifraga pennsylvanica	Saxifragaceae	forb	dicot
Scirpus acutus	Cyperaceae	graminoid	monocot
Scirpus pungens	Cyperaceae	graminoid	monocot
Scleria verticillata	Cyperaceae	graminoid	monocot
Solidago ohioensis	Asteraceae	forb	dicot
Solidago patula	Asteraceae	forb	dicot
Solidago rugosa	Asteraceae	forb	dicot
Sorghastrum nutans	Poaceae	graminoid	monocot
Spartina pectinata	Poaceae	graminoid	monocot
Spirea alba	Rosaceae	shrub	dicot

Table 57. Representative plant species of good quality sedge-grass communities.

species	family	life form	repro class
Stellaria longifolia	Caryophyllaceae	forb	dicot
Thelypteris palustris	Thelypteridaceae	forb	cryptogam
Tradescantia ohioensis	Commelinaceae	forb	monocot

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