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Wetland Ecology Unit
Division of Surface Water

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Volume 1:

Vegetation Indices of Biotic Integrity (VIBI) for Wetlands
and
Calibration of the Ohio Rapid Assessment Method for Wetlands v. 5.0

John J. Mack

with
Mick Micacchion
Lauren D. Augusta
Gregg R. Sablak

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122 South Front Street, P.O. Box 1049

Columbus, Ohio 43216-1049

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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).

More recently, Karr (1993) has used the term "*ecological integrity*" and defined it 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. 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 and lakes 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). The State of Ohio's system was based on methods and results first published by Karr et al. (1986). This type of system is often referred to as an "Index of Biotic Integrity" and 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).

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[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 1. Components of ecological (biological) integrity for wetlands. Adapted from Karr and Kerans (1992), 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 bio-sphere	

Table 2. Factors associated with wetlands that can be negatively impacted by human activities causing wetland degradation. 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 (Ohio EPA 1988a). 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 under federal and state law. *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 state's water quality standards. On May 1, 1998, the State of Ohio adopted wetland water quality standards and a wetland antidegradation rule. OAC Rules 3745-1-50 through 3745-1-54. The water quality standards specify narrative criteria for wetlands and created the "wetland designated use." All jurisdictional wetlands are assigned to the "wetland designated use." However, numeric criteria were not proposed since they had not yet been developed.

Ohio began working on the development of biological criteria for wetlands in 1996. To date, Ohio has sampled over 60 different wetlands located primarily in the Eastern Cornbelt Plains Ecoregion (Figure 1). These wetlands have included isolated wetlands and wetlands located in riparian settings, wetlands dominated by predominately emergent, forested, and scrub vegetation, wetlands located on the margins of kettle lakes, and wetlands which can be classified as fens and bogs. The wetlands being studied span the range of condition from ?impacted" (i.e., those that have sustained a relatively high level of human disturbance) to ?least-impaired" (i.e., the best quality sites available). This work has been funded since 1996 by several different U.S. EPA Region 5 Wetland Program Development Grants including CD995927, CD995761,

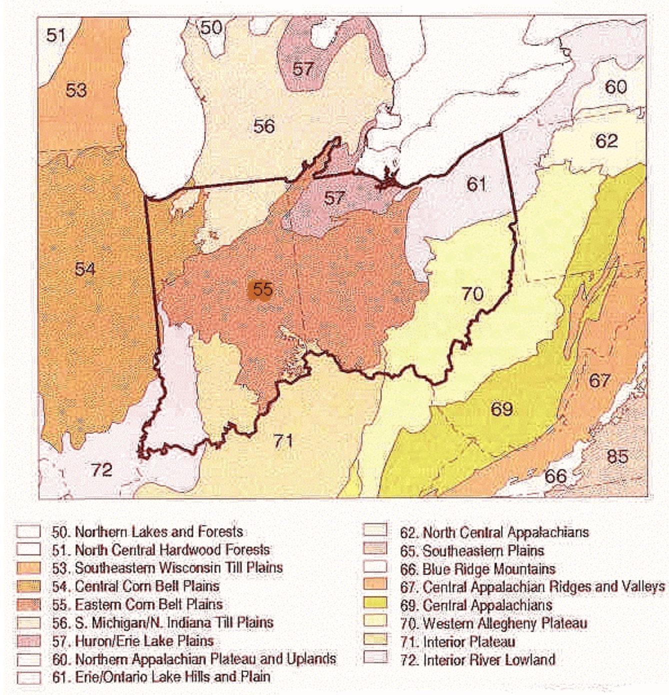

Figure 1. Ecoregions of Ohio, Indiana, and neighboring states. From Woods et al. 1998.

CD985277, CD985276, and CD985875. 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

The objectives of the wetland biocriteria development project are as follows:

1. 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.

2. To identify and describe reference wetlands in the Ohio's four main ecoregions Eastern Cornbelt Plains, Erie/Ontario Drift and Lake Plain, Huron-Erie Lake Plain, and Western Allegheny Plateau.

3. To continue to assess and calibrate the Ohio Rapid Assessment Method, and to test and refine breakpoints between the wetland categories required under the Wetland Antidegradation Rule (see below).

A key 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 were 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. A wetland is assigned to one of these three categories "...as determined by an appropriate wetland evaluation methodology acceptable to the director." OAC Rule 3745-1-54(C)(1)(a), (C)(2)(a), and (C)(3)(a). During the rule development process, Ohio EPA began developing its own wetland evaluation methodology known now as the Ohio Rapid Assessment Method (ORAM) for wetlands. The ORAM is a rapid, semiquantitative, wetland ranking tool. *See* discussion below and ORAM Manual (Mack 2000).

The ORAM is designed to categorize a wetland based on whether it is particular type of wetland (e.g. fen, bog, old growth forest, etc.) or contains threatened or endangered species, or based on its "score." Fennessy et al. (1998a) found significant correlations between a wetland's score on the ORAM and the wetlands biological quality and/or degree of disturbance. The initial scoring ranges proposed in Fennessy et al. (1998a) were descriptively derived from a sample of wetlands scored using the ORAM and the professional judgment of The Ohio Rapid Assessment Workgroup (Fennessy et al. 1998a). Recalibration of the scoring ranges 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 and the use of "draft" versions of the ORAM (versions 3.0, 4.0, and 4.1) in regulatory decision making.

This report discusses the development of and proposes:

1. An interim Vegetation Index of Biotic Integrity (VIBI) for forested, emergent, and scrub-shrub wetlands;

2. Scoring ranges for ORAM version 5.0 for determining Category 1, 2, and 3 wetlands when using the ORAM.

The interim VIBI and ORAM scoring ranges are based on vegetation data collected by Ohio EPA from wetlands located in the Eastern Corn Belt Plains Ecoregion of Ohio in 1996, 1997, 1998, and 1999 (Figure 1). Ohio EPA is sampling wetlands in the Erie-Ontario Lake Plains Ecoregion (Lake Plains and glaciated Allegheny Plateau) during the 2000 and 2001 field seasons, and the Western Allegheny Platiau (unglaciated Allegheny Plateau) and the Huron-Erie Lake Plains ecoregions in the following years.

2.0 Methods

2.1 Vegetation Sampling

The Ohio EPA began evaluating vegetation sampling methods in 1996. Major concerns in selecting a sampling method were ease of use, cost, reproducibility of results, and obtaining as complete a list plant species at a wetland as possible as well as determining the appropriate sampling window. This last concern related to Ohio's use of a Floristic Quality Assessment Index (FQAI) (Wilhelm and Masters 1995; Andreas and Lichvar1995) which requires a relatively complete flora of a site.

Ohio EPA sampled disturbed and undisturbed wetlands in western and central Ohio in 1996 and 1997. Initially, Ohio EPA adopted a fixed transect method with $1m^2$ and $10m^2$ circular nested quadrats spaced evenly along the transect. A minimum of 30 quadrats were sampled along 3 transects ($30m^2$ area sampled herbaceous vegetation and $300m^2$ woody vegetation), with at least one transect oriented perpendicular to the other two. In addition, plants located outside the quadrats but within a 5m wide "belt" along the transect were identified but no density or dominance information was recorded for these plants (hereafter transect-belt method). Within the quadrats, percent cover and stem counts (woody only) were recorded for each species. *See* Fennessy et al. (1998a) for more detailed description of this method. In addition, after sampling the same wetland in spring, summer and fall, Fennessy et al. (1998a) concluded that the best sampling window was between June 15th and August 30th.

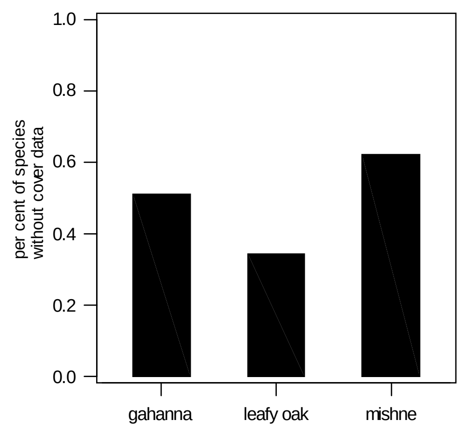

Figure 2 Percentage of plant species that were missing dominance or density data at three wetlands resampled in 1999 using releve method as described in Peet et al. (1998).

By 1998, it became apparent that many of the more successful attributes were associated with measures of dominance or abundance, e.g. percent cover, density (stems/ha), etc. However, using the transect-belt method, 30% to 60% of the plants observed had only presence/absence data associated with them (Figure 2). There were also other problems. One, area sampled to characterize forested communities appeared to be too small. The forestry literature recommends 400-$1000m^2$ as minimum area to adequately characterize eastern forest communities (Peet et al. 1998) and Ohio EPA was using thirty $10m^2$ plots ($300m^2$). Two, the transect method often passed through several different plant communities, homogenizing the vegetation data for wetlands with multiple plant communities. Finally, the transect method appeared to overemphasize wetland "edge" species.

In 1999, Ohio EPA reevaluated its sampling method and adopted a method used by the North Carolina Vegetation Survey (hereafter releve method) as described in Peet et al. (1997, 1998). This is a flexible, multipurpose sampling method that is appropriate for most types of vegetation, flexible in intensity and time commitment, compatible with other data types from other methods, and provides information on species composition across spatial scales (discussion below).

Out of the current data set of 45 wetlands used to derive the interim VIBIs, 26 wetlands had data collected under the releve method, 16 wetlands had data collected using the transect-belt method, 3 wetlands had data collected under both the transect-belt and releve methods (only the releve method data was used to derive the VIBI scores). Of the 16 wetlands with transect-belt method data, species observed outside of the quadrats in the "belt" area of the transect were excluded from the subsequent data analysis. *See* Section 3.0 below for a comparison of the two methods.

2.1.1 Releve Method - Rationale

Even if only three main classes are identified (forested, scrub-shrub, and emergent), a single wetland can have several co-dominant vegetation classes, or a single dominant class and several minor subclasses. Thus, a sampling method should be flexible enough to account for horizontal and vertical variation in vegetation.

Peet et al. (1998) describe 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 over 3000 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, compatible with other data types from other methods, 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 (Peet et al. 1998). Peet et al. (1998), state,

> Our solution to the problems of scale and spatial autocorrelation is to adopt a modular approach to plot layout, wherein all measurements are made in plots comprised of one or more 10 x 10m quadrats or "modules" (100 m^2 = 1 are = 0.01 hectare). The module size and shape were chosen to provide a convenient building block for larger plots, and because a body of data already exists for plots of some multiple of this size. The square shape is efficient to lay out, ensures the observation is typical for species interactions at that scale of observation, and avoids biases built into methods with distributed quadrats or high perimeter-to-area ratios.

(Peet et al. 1998, p. 264). The most typical application of the method employs a set of 10 modules in a 20 x 50m layout (Figure 3).

Once the plot is laid out, all species within the plot are identified. In addition, for forest and shrub communities, an aggregate woody stem count is made. In addition, four 10 x 10m modules are "intensively" sampled in a series of nested quadrats. Within these "intensive" modules, species cover class values 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. frequency, density, basal area, cover, etc.

2.1.1 Releve Method Definitions

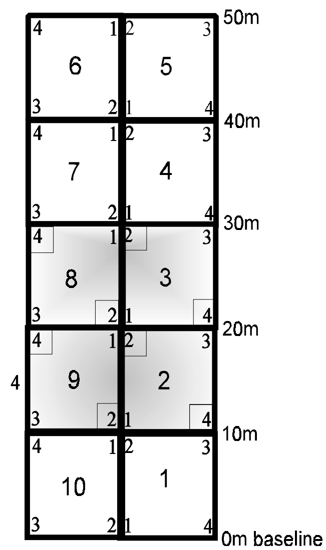

Figure 3. Standard 20x50m (2x5) plot used in vegetation sampling as recommended by Peet et al. (1998). Modules are numbered counterclockwise moving from the "front" of the plot to the "back," then from the back of the plot to the front. Module corners are numbered clockwise in the direction of movement along the centerline. Typical intensive modules are shaded and standard intensive module nested quadrats are indicated by small squares.

Module - A “module” is the basic unit of sampling under this method and consists of a 10 x 10m quadrat. Nested quadrats of $0.01m^2$, $0.1m^2$, $1m^2$, $10m^2$ are often 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 10x10m, then the module is also a "plot" or a "releve."

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 “releves.”

Releve - A synonym for “plot.”

Quadrat - Quadrat refers to the 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 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."

2.1.3 Releve Method Procedures

2.1..3.1 Step 1. Selecting the Plot location(s) and Configuration(s)

Plot size and shape and location. At most sites, a "standard" plot was established consisting of a 2x5 array of 10x10m modules, i.e. 20m wide by 50m long (equals $1000m^2$ = 1 are = 0.1 ha), within the jurisdictional boundary of the wetland and within each vegetation community of interest.[2] 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 single type of community, but had a minor presence of another, the plot was located such that at least a portion of 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 5x10m module by reducing the width 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

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[2] Peet et al. (1998) recommend $1000m^2$ area for forest inventory of rich mesic forests and numerous North American forest studies have employed a 1000m2 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.

vegetation is zoned in narrow bands.

2.1.3.2 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 20m 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 50m centerline of the plot was located perpendicular to the 20m baseline, and then the sides of the plot were similar located. Marker flags were placed at the corners of every 10x10m module. 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 1). Conversely, the corners of the modules were numbered *clockwise*, starting at the centerline and moving up or down the centerline, depending on which side of the centerline the module is located (Figure 1) to avoid having nested quadrats being placed side by side.

2.1.3.3 Step 4. 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.

2.1.3.4 Step 5. 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 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 graminoid #1, #2, etc. Nomenclature in this report follows Gleason and Cronquist (1990) unless otherwise noted.

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 contains 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 4 for every species, except canopy level trees where only basal area was measured (see Step 6 for woody vegetation below). The midpoint of the cover class was used in all subsequent analyses.

Table 4. 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
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2.2.3.5 Step 6. 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 1 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.

2.1.3.6 Step 7. 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 sample bags. Plants were oven dried at 105 ºC for at least 24 hours and samples were weighed and the weights recorded.

2.1.3.7 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 almost always collected. Vouchers were retained in the Ohio EPA herbarium as well as sent to regional herbariums.

2.1.3.9 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, cryptogram (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*) and small trees that never or rarely reach bottom of mature forest canopy, e.g. *Carpinus caroliniana*);

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

    e. woody/nonwoody - plants with woody versus nonwoody stems;

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

    g. aquatic/nonaquatic - plants that float in or on the water versus plants with do not. This category was further subdivided into aquatic plants that are rooted (rooted aquatic bed) versus aquatic plants which float (floating aquatic bed).

3. Wetland indicator status categories. The basic wetland indicator status of 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 §2.3.

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.

2.1.3.10 Step 10. Calculating vegetation community attributes

The following basic vegetation community attributes were calculated:

Number (Richness). The number of plants in various categories listed above 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 releve 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.

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

Heterogeneity. Simpson's Index of Heterogeneity (Simpson's Index or D) was calculated using relative cover values for all plants in the herb and shrub stratum as follows:

$$D = \sum p_i^2$$

where D = Simpson's Index of Heterogeneity, p_i^2 = relative cover of an individual plant species within the plot sampled at a wetland.[3]

FQAI Score and variants. The FQAI score and variants thereof was calculated. *See* §2.3.

2.2 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

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[3] This index is based on the concept that a plant community with 10 equally abundant species does not have the same diversity as a second plant community where one species comprises 99% of the total individuals and 9 other species comprise 1% of the total individuals. Simpson (1949) as cited in Krebs (1999) proposed a measure of heterogeneity that combined richness with evenness. In a wetland with 10 equally abundant species, 2 plants picked at random are likely to be different species. Simpson (1949) proposed that diversity was inversely related to the probability that two plants picked at random belong to the same species. Thus, the *higher* the probability that two plants picked at random belong to the same species, the *lower* the diversity of the community (Krebs 1999).

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

2.2.1 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.

Ohio EPA initially classified wetlands using a hydrogeomorphic criterion (depressional versus riparian) and a floristic criterion (forested versus emergent) (Table 5).

Table 5. Initial floristic and hydrogeomorphic wetland classification scheme employed by Ohio EPA during 1996-98 VIBI development.

criterion	categories	description
hydrogeomorphic	depressional	Generally corresponds to "depressional" HGM class in Brinson (p. 20, Table 3, 1993). Ohio EPA defined as isolated wetlands not hydrologically connected to streams or lakes; precipitation/evapotranspiration driven hydrology during growing season; typically seasonally-inundated or saturated.
	riparian	Closest analog to HGM Classes in Brinson (p. 22, Table 3, 1993) is "Riverine - Middle Gradient Landform." Ohio EPA defined as located on floodplain or adjacent to perennial stream where wetland receives annual to biannual surface water inputs from spring flooding.
floristic	emergent	Wetland does not have closed canopy of tree species, i.e. is dominated by herbaceous plant species. Generally equivalent to Cowardin et al. (1979) "emergent" class, but may include some "scrub-shrub" and "aquatic bed" also.
	forested	Wetland has a closed canopy of tree species or is located within a forest, although the canopy may be open above portions of the wetland, e.g. a buttonbush swamp located in a mature second growth forest. Generally equivalent to Cowardin et al. (1979) "forested" class, but may include "scrub-shrub" and "aquatic bed" also.

Current results are suggesting somewhat diverse wetland types may be "clumpable." The hypothesis currently being evaluated is that even though the floras of hydrogeomorphically or floristically distinct wetlands are different at the species level, the quality and/or responsiveness of their unique floras to human disturbance is equivalent. This is especially a concern where there are two few remaining examples of a particular class of wetlands to "fill out" a class, e.g., undisturbed wet prairies were once an abundant type of wetland that has now virtually disappeared from the landscape of Ohio.

More recently, Ohio EPA has adopted and modified plant community classification system originally developed by Anderson (1982) as an Ohio floristic classification system (Table 6). Three main vegetation communities are identified based on the dominant “canopy” plants: forested, emergent (or herbaceous) and scrub-shrub (or shrub). Within each class several subclasses are identified. In particular, bog and fen communities are singled out as well as emergent riverine communities. It is still being evaluated whether these communities deserve status as separate classes or can be considered under a broad “emergent” rubric. *See* discussion in results section.

Ohio EPA is also continuing to develop a hydrogeomorphic (HGM) based classification system. An important part in the development of an HGM scheme is the adaptation of the general scheme to local and regional conditions (Brinson 1993). Ohio EPA's current HGM classification scheme is summarized in Table 7. All of the wetlands used to derive the VIBI proposed in this report are in the first two categories. Ohio EPA has also sampled several kettle lakes, fens, and bogs and presents some preliminary conclusions in the results section.

A goal in the development of the vegetation IBI has been to focus on dominant floristic differences in classifying wetlands and to “control for” hydrologic differences by requiring that wetlands be rated in the Ohio Rapid Assessment Method in relation to other wetlands of similar type and hydrology (Mack 2000). This results in wetlands occupying the same ranking “space” on the disturbance/quality x-axis regardless of differences in hydrology and landscape position. For example a pristine bog system with undisturbed hydrology and habitat will score similarly to a pristine floodplain swamp forest. This issue is discussed further in §§2.4 and 3.1 and in the User's Manual of the Ohio Rapid Assessment for Wetlands (Mack 2000).

Table 6. Interim Ohio Vegetation Community Communities (modified after Anderson 1982). Refer to Anderson (1982) for a more detailed discussion of the community types listed below.

	class		community	type	description
I	Forested	a	Swamp forests	(1) maple-ash, (2) oak-maple, (3) mixed, (4) hemlock-hardwood, (5) white pine	Communities characterized by closed canopies of tree species. Includes swamp forests in isolated (depressional) settings (flats, wet woods, vernal pools), as well as swamp forests located on floodplains and subject to regular flooding and part of a floodplain forest matrix.
		b	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	Scrub-Shrub	a	Shrub Swamps	(1) mixed shrub swamp, (2) buttonbush shrub swamp, (3) alder shrub swamp	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.
		b	Bog Shrub Swamps	(1) tall shrub bog, (2) leatherleaf bog	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
III	Emergent	a	Marshes	(1) submergent marsh, (2) floating-leaved marsh, (3) mixed emergent marsh, (4) cattail, and (5) sedge-grass meadow	Characterized by herbaceous vegetation in isolated, depressional settings, adjacent to or part of lakes, and sometimes in proximity to or in headwater positions of streams but development and succession not influenced by perennial or nearly perennial surface connections and large annual sediment movements.
		b	Wet Prairies	(1) slough grass-bluejoint prairie, (2) mixed wet prairie	Characterized by *Calamogrostis* spp, *Spartina pectinata*, and *Carex* spp. as well as other “prairie” forbs and grasses.
		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. 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	Refer to Anderson (1982) for discussion of these community types.
		e	Bogs	(1) Sphagnum bog	Refer to Anderson (1982) for discussion of this community type.

Table 7. Interim hydrogeomorphic (HGM) classification system for Ohio wetlands used in vegetation IBI development.

	class		subclass	description
I	Depressional	A	Isolated	precipitation, high growing season Evapotranspiration (E/T) domininate hydrology, but also includes isolated break in slope (seep) wetlands and wetlands receiving or suspected of receiving shallow, subsurface groundwater inputs
		B	Riparian	precipitation, seasonal surface water, high growing season E/T dominate hydrology, but also includes break in slope (seep) wetlands located at bases of floodplain walls
II	Large Depressional	A	Headwater	large 10-100ha, wetland complexes at headwaters of river systems, or with headwater tributaries passing through them, depressional and riverine characteristics
		B	Kettle Lake	natural kettle lakes with aquatic beds, marginal marshes, shrub-swamps, but not including marginal fen and bog systems
III	Riverine			perennial or semiperennial surface water connection with stream or river
IV	Coastal	A	unrestricted	hydrology unrestricted by human activity
		B	restricted	hydrology controlled to restrict erosion of wetland vegetation
		C	estuarine	wetlands located in flooded river mouths with hydrology influenced by lake and river
V	Fen-Bog	A	marginal fen	margins of kettle lakes cf. Silver Lake, Mud Lake Bog. May also be classifiable as Large Depressional-Kettle Lake
		B	perched fen	seep fens located on floodplain terraces, isolated locations, above ordinary influence of river, lake levels, or in headwater position
		C	large fen	fen complexes like Cedar Bog, Springville Marsh
		D	bog	sphagnum bog, leatherleaf bog, tall shrub bog, tamarack-hardwood bog

2.2.2 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).[4] 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] In this report, "attribute" is defined as a measurable characteristic of the biological community, and "metric" is defined as and 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 component of a multimetric IBI.

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

With these principles in mind, 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 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 based on the type of wetland (forested, emergent, etc.)
8	proportions or abundances of plants with certain life forms (e.g. forb, graminoid, shrub or tree) changes relative to reference conditions
9	proportions of individuals (relative density) or relative dominance (basal area) in tree species age classes increases changes relative to reference conditions
10	proportions or numbers of non-native species or hybrids increases
11	changes in community heterogeneity relative to reference condition

2.2.3 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 methods for determining scoring criteria including an "all-sites" and "percentage of standard" methods 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 95th percentile of values from all sites as the most sensitive index.

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 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

Two scoring methods were evaluated in the development of a VIBI. The procedures for each are summarized below. Ultimately, it was determined that quadrisection using a 100 point scale worked better with the existing data set in addition to presenting obvious intuitive advantages.

Method 1 - "All-sites" trisection or quadrisection using 95th percentile

In this method, all the sites within the class representing a gradient of disturbance 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 were trisected and quadrisected. The 95th percentile was calculated using the PERCENTILE function of QuattroPro Spreadsheet software. Sites with measurements within the first third below the 95th percentile received a score of 5, sites within the second third received a score of 3, and sites within the third received a score of 1. Similarly, procedures were used to quadrisect data using scores of 0, 3, 7, and 10.

Method 2 - "Reference-sites" trisection or quadrisection using 95th percentile

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 trisected (and quadrisected). The main difference between Method 1 and Method 2 is the omission, in Method 2, of sites *with* human cultural influences.

2.3 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). 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 decision made by 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, are 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.[5]

2.4 Disturbance scale and the x-axis problem

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

[5] In addition to the FQAI as proposed by Andreas and Lichvar (1995) various variants of the score were also calculated and evaluated including proportion of plants with various CofCs, "sub-FQAI" scores, i.e. the FQAI score of graminoids, dicots, or Cyperaceae species, and weighted FQAI scores, i.e. the sum of CofC times the relative cover of that plant divided by the square root of N. None of these potential attributes was ultimately selected and this data is not presented here.

of disturbance.[6] Fennessy et al. (Figure 2.2, 1998a) developed a 4-tiered ranking system for evaluating the degree of human disturbance in a particular. 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).

After a reanalysis of plant community data at wetland sites in 1996 and 1997 (Mack, unpublished data), it appeared that the ORAM score might be a useful x-axis candidate. The Quantitative Rating of ORAM v.4.1 was revised using a format similar to the QHEI for streams. *See* Mack (2000) for the ORAM User's Manual and v. 4.1 and 5.0 rating forms. The score from the Quantitative Rating was revised to range from 0 to 100, whereas, under earlier versions of the ORAM the score ranged from 0 to some indeterminable limit (high 50s to low 60s). The 100 point scale provided several advantages: 1) it had a definite maximum, 2) it was a much more intuitive base 10 scale, and 3) it provided a greater range of scores, allowing for more visual “spread” when graphing the score versus quantitative biological data; and 4) each “metric” in ORAM v. 5.0 also had a definite maximum which allows the entire score to be easily partitioned and allows for a relative weighting of importance attributed to each metric.

One of the main shortcomings of earlier versions of the ORAM was a failure to expressly address the hydrology (and human modifications thereto) of a wetland and also human alterations to the wetlands natural habitat. These two factors account for much of the possible disturbances to a wetland, and to the wetlands perceived overall “quality.” Earlier versions of the ORAM addressed “human disturbance” in an indirect fashion, if at all, and did not expressly address all aspects of a wetland’s hydrology, except qualitatively as in Question 1 of the Qualitative Rating in ORAM v. 4.0. The revised Quantitative Rating expressly included an evaluation of the degree of alteration to a wetland's hydrology and habitats. In addition, the amount and type of buffers and surrounding land use, size, special community characteristics, and an evaluation of the structural quality of the community (interspersion, microhabitat, vegetative diversity and quality) are also expressly addressed.

Early versions of the ORAM also discriminated in the scoring based on wetland type, number of vegetation classes or proximity to surface waters. There was a clear preference for wetlands located near streams and discrimination against groundwater-driven or precipitation-driven depressional systems. In addition, earlier versions of the ORAM assigned 40-60% of the total points a wetland might obtain to an enumeration of the number of vegetation communities >0.25 acres in size and the number of species in those communities with an areal cover >10%. However, earlier versions of the ORAM did not include an express evaluation of the importance or quality of those vegetation communities for that wetland, or whether the species present were merely invasive weeds and disturbance-tolerant native plants. These

[6] In 1996, Fennessy et al. (1998b) investigated the ability of the Floristic Quality Assessment Index to detect human disturbance by performing floristic surveys in 10 riparian wetlands. However, the vegetation sampling methods were developed in order to evaluate the FQAI as an assessment tool and did not provide data comparable to the data collected for the 21 wetlands studied in Fennessy et al. (1998a), and therefore these 10 sites have not been used to derive the VIBIs.

problems led to both overscoring of low quality, highly disturbed wetlands that happened to have multiple vegetation classes and/or proximity to surface waters, as well as underscoring of high quality, undisturbed, depressional wetlands with a single vegetation class.

Finally, and most importantly, 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. Thus, an undisturbed, high quality bog will score similarly to a undisturbed, high quality floodplain swamp forest. By “controlling” for these variables up-front in the disturbance scale, the number of wetland classes needed to develop on IBI can be limited to classes based on differences in dominant vegetation.

Based on these revisions the ORAM v. 5.0 appears to be useful for the dual purpose of 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.

2.5 Statistical analyses

Minitab v. 12.0 for Windows was used to perform all statistical tests. Regression analysis, analysis of variance, Tukey's multiple comparison test, correlation coefficients, and t tests were used to explore and evaluate the biological attributes measured for VIBI development. Multivariate analysis of the data is being performed but was not completed at the time of report submission.

3.0 Results and Discussion

3.1 Classification

Appendix 1 lists the 49 wetlands (or separately evaluated plant community within a wetland) evaluated in the development of the Vegetation Indices of Biotic Integrity (VIBIs) and basic site information regarding those sites. Classifying by vegetation class, there were 21 emergent wetlands [7], 16 forested wetlands, and 12 scrub-shrub wetlands. Further classifying by vegetation community, there were 2 fens, 1 bog, 16 swamp forests, 18 marshes, 1 wet prairie, and 11 shrub swamps. Using the hydrogeomorphic classes listed in Table 7, there were 38 "depressional-isolated" wetlands, 4 "depressional-riparian" wetlands, 3 "large-depressional kettle lake"[8] wetlands, 2 "large depressional-headwater" wetlands, 1 "large fen" wetland, and 1 "bog" wetland.

Box and whisker plots of 8 community attributes are presented in Figures 5, 6, and 7 for vegetation class, vegetation community type, and HGM class for wetlands which were determined to represent "reference" conditions, i.e. lacking in obvious human cultural influences or as lacking in such influences as presently exists in the region. Only reference wetlands were used in order to control for variation caused by human (as opposed to natural) disturbances. Analysis of variance followed by Tukey's multiple comparison test was used to explore potential inter-class differences for these attributes (Tables 11, 12, and 13).

The Interim Ohio HGM classes listed in Table 7 were compared (Table 11, Figure 5). Among HGM classes, depressional-isolated and depressional-riparian wetlands were generally similar using these eight community attributes; conversely, the bog and large depressional-kettle lake classes appeared noticeably different from the depressional classes for several attributes (Table 11, Figure 5), including total species richness, relative coverage of tolerant plant species, FQAI score, shrub species richness ratio, total dicot species, and total *Carex species*. It should be noted that vegetation at the reference kettle lakes was dominated by marginal fen plant communities. Given the small sample sizes of the bog, kettle lake, and riparian classes, these conclusions should be regarded as tentative. However, it appears that bogs and fens may constitute separate HGM classes and were properly excluded from the data set for deriving IBIs for non-bog and non-fen systems.

In its interim HGM classification system for Ohio, evapotranspiration driven systems are classified as "depressional" regardless of their proximity to a stream or river. A review of the composition of the plant communities in riparian and depressional wetlands appears to indicate that, floristically, these sites are similar regardless of their landscape position. The driving force in the hydrology of these "riparian" wetlands appears to be evapotranspiration and precipitation during the growing season, not dormant season flooding (at least in regard to hydrologically related changes in the floral communities). Once the wetland receives its annual or semiannual "slug" of surface water it is hydrologically equivalent to an isolated, depressional wetland. Note that this conclusion may not apply to other taxa groups, in particular macroinvertebrate or amphibian communities.

Primary vegetation classes listed in Table 7 (emergent, forested, scrub-shrub) were compared (Table 12, Figure 6). Graphical variation was observable between two or more of the classes for ORAM v.5.0 score, total species, total *Carex* species, and FQAI score and statistically significant differences ($p<0.10$) were observed for relative cover of tolerant and intolerant plant species. The differences noted between

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[7] The kettle lake sites with marginal fens (Mud Lake Bog, Silver Lake), the degraded kettle lake (Stages Pond) and Springville Marsh (cattail marsh with relict fens) were not used to derive the VIBIs. These sites were classified as "emergent" wetlands.

[8] Of the large depressional-kettle lake sites, the vegetation communities of two (Mud Lake Bog and Silver Lake) were predominately fens .

these classes in this study are in accordance with classifications commonly employed in vegetation classification systems (e.g. Anderson 1982; Cowardin et al. 1979).

Finally, plant community types within each of the three main vegetation community classes were analyzed (Table 6, Table 13, Figure 4). Again, bog and fen communities appeared to stand out from the other community types for multiple attributes, suggesting separate class status for these now uncommon features in Ohio's landscape. More importantly, other communities, which could be easily separated, appear to share characteristic and thus may be able to be treated together. It is suspected that somewhat diverse wetland plant communities may be "clumpable" under a broad vegetation class rubric of forested, emergent, or scrub-shrub. Even though their floras are different at the species level, the quality or responsiveness of their unique floras to human disturbance is equivalent. Data from very different types of wetlands seems to bear this out, e.g. depressional bluejoint/sedge prairie (Daughmer Oak Savannah) versus sedge meadow wetland (Kiser Lake) versus floating-leaved marsh (Calamus). These sites are located in the same graphical “space” for many attributes, even though an *a priori* HGM classification would often "split" them into separate categories (Figure 4).

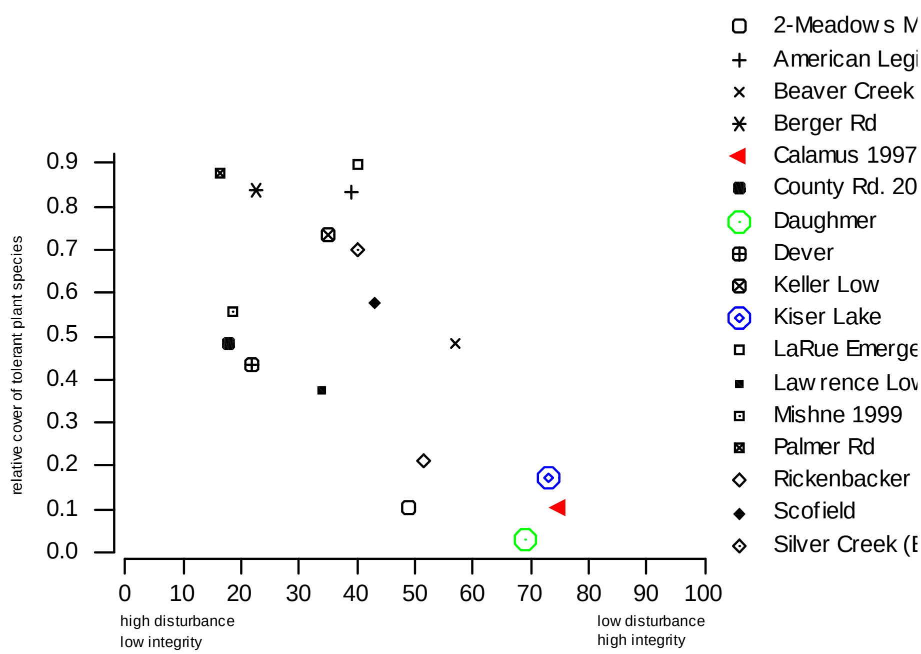

Figure 4. Relative cover of tolerant plant species for 17 emergent wetlands. Sites referred to in the text have larger symbols.

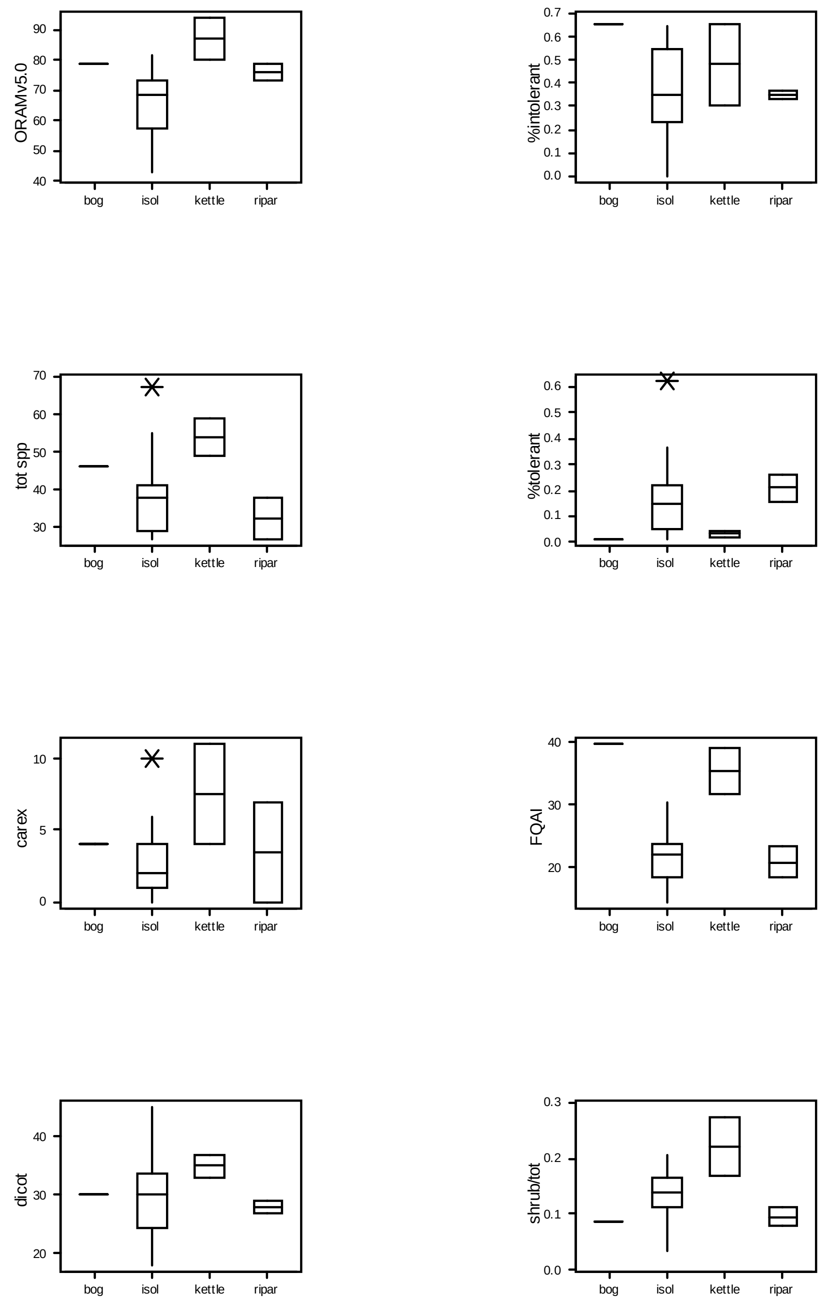

Figure 5. Box and whisker plots of selected community attributes for reference (undisturbed) wetlands versus interim Ohio hydrogeomorphic (HGM) classification. See Tables 14, 19, and 24 for descriptions of the parameter codes. "Bog" = a single Tamarack-hardwood bog forest, "isol" = depressional-isolated wetland, "kettle" = large depressional-kettle lake with marginal fens, and "ripar" = depressional-riparian wetland. There were no reference condition large depressional-headwater headwater wetlands in the data set. See Table 7 for descriptions of the HGM 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 (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 (*).

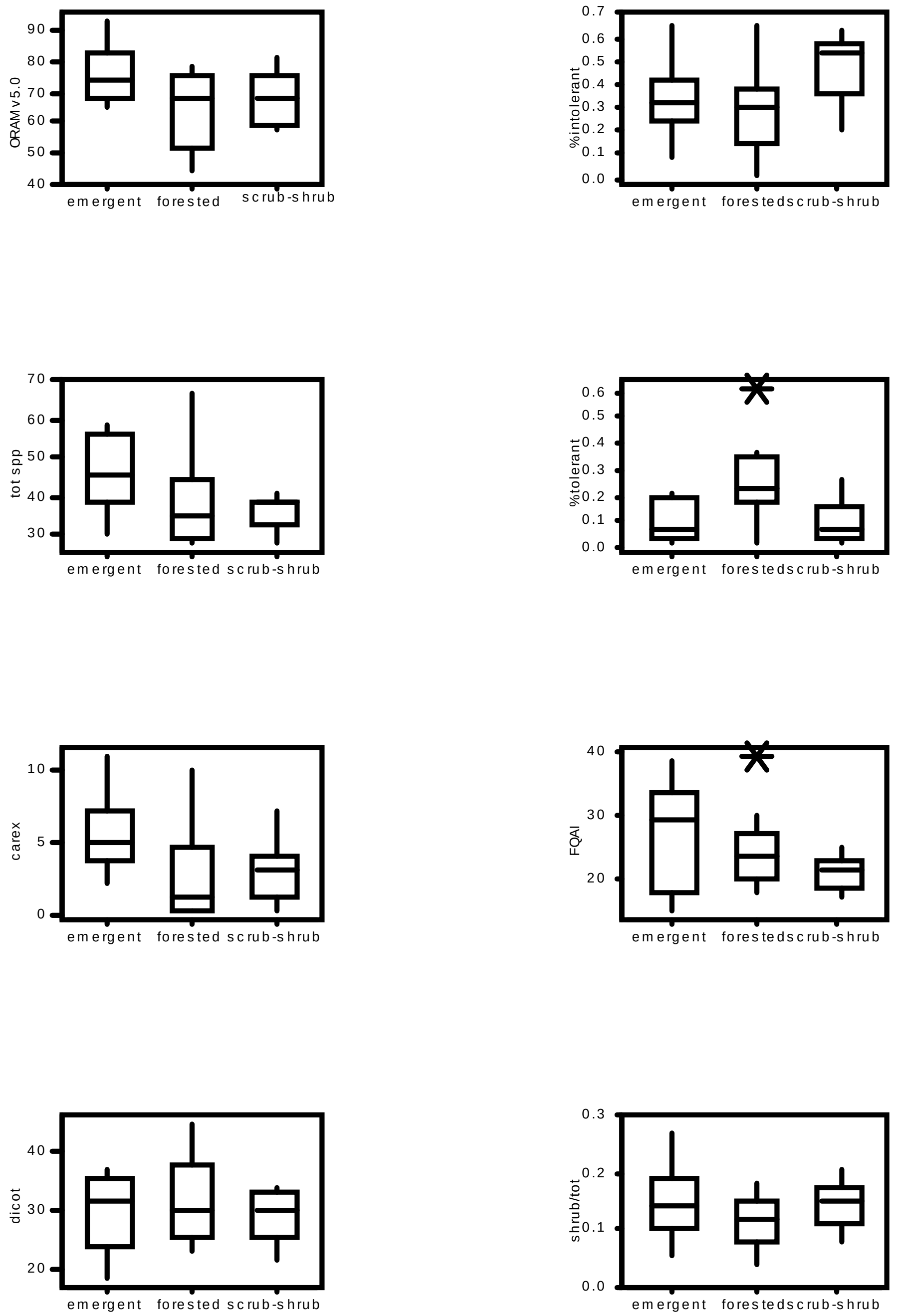

Figure 6. Box and whisker plots of selected community attributes for reference (undisturbed) wetlands versus interim Ohio vegetation community classes. See Tables 14, 19, and 24 for descriptions of the parameter codes (y-axis) and Table 6 for description of vegetation classes. A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (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 (*).

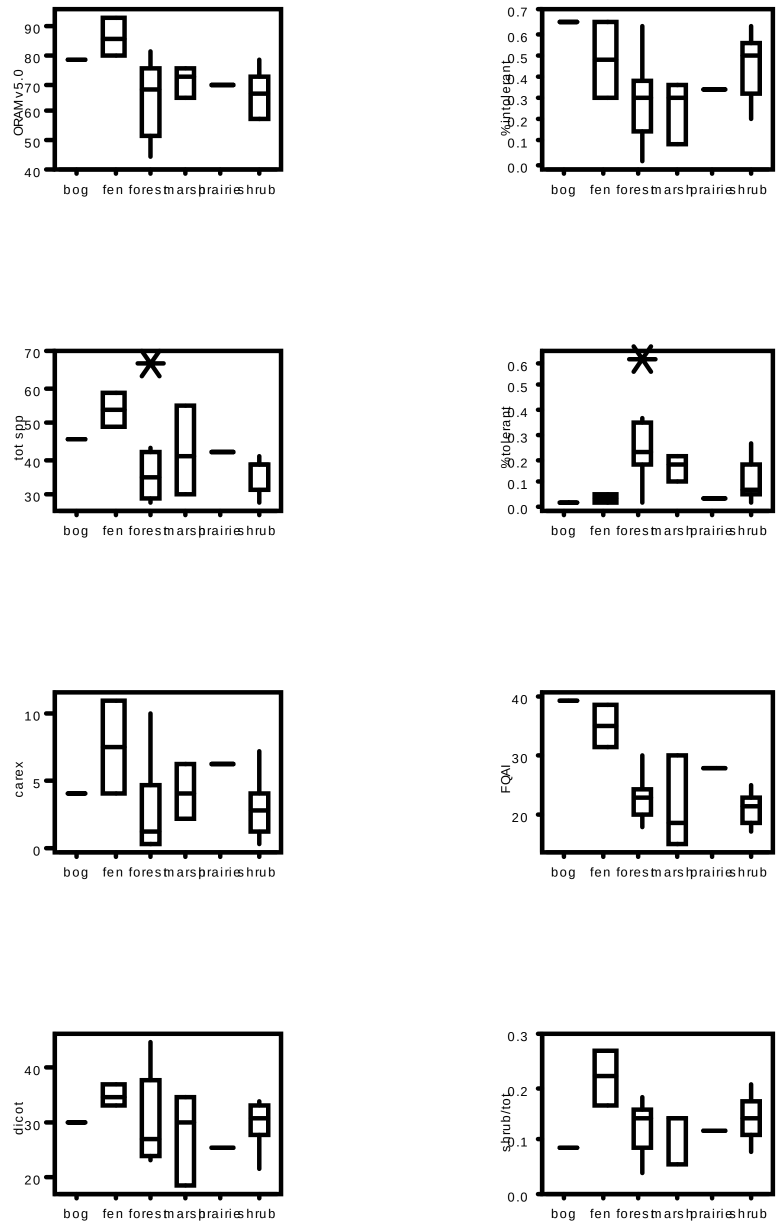

Figure 7. Box and whisker plots of selected community attributes for reference (undisturbed) wetlands versus interim Ohio vegetation communities. See Tables 14, 19, and 24 for descriptions of the parameter codes (y-axis) and Table 6 for description of vegetation communities. “Bog” = bog community (in this case a single Tamarack-hardwood bog forest), “fen” = fen communities (2 cinquefoil-fens and 1 tamarack fen), “forest” = swamp forests, “marsh” = emergent marshes of all types, “prairie” = wet prairies (in this case a single bluejoint/slough grass prairie), and “shrub” = shrub swamps. 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 (*).

Table 11. Mean and standard deviation (parenthesis) and p-values from exploratory analysis of variance for 4 HGM classes for selected community characteristics. Means that do not have shared letters following them were significantly different after Tukey's Multiple Comparison Test, e.g. the mean for total spp. for ISOL, RIPAR, and BOG were not significantly different from each other; the means for RIPAR, BOG, and KETTLE were not significantly different from each other; but, the means for ISOL and KETTLE were significantly different from each other.

attribute	p-value	ISOL depressional-isolated N=21	RIPAR depressional-riparian N=2	BOG tamarack-hardwood bog forest N=1	KETTLE lg depressional-kettle lake N=2
ORAM v. 5.0	0.023	65.3(10.1)a	76.3(3.9)ab	79.0( )ab	87.0(9.9)b
total spp.	0.096	37.6(9.5)a	32.5(7.8)ab	46.0( )ab	54.0(7.1)b
total *Carex* spp.	0.201	2.9(2.5)	3.5(5.0)	4.0( )	7.5(5.0)
total dicot spp.	0.685	29.8(6.5)	28.0(1.4)	30.0( )	35.0(2.8)
# shrub spp./total spp.	0.040	0.13(0.04)a	0.10(0.02)ab	0.09( )ab	0.22(0.07)b
FQAI score	<.001	21.9(4.1)a	20.8(3.5)a	39.6( )b	35.4(5.0)b
rel cover of tolerant spp.	0.410	0.17(0.15)	0.21(0.08)	0.01( )	0.03(0.02)
rel cover of intolerant spp.	0.370	0.35(0.19)	0.35(0.03)	0.66( )	0.48(0.25)

Table 12. Mean and standard deviation (parenthesis) and p-values from exploratory analysis of variance for 3 primary vegetation community classes for selected community characteristics. Means that do not have shared letters were significantly different after Tukey's Multiple Comparison Test.

attribute	p-value	Emergent N=6	Forested N=9	Scrub-Shrub N=11
ORAM v. 5.0	0.151	75.9(10.3)	64.3(13.3)	67.5(9.1)
total spp.	0.119	45.8(10.8)	38.2(12.9)	35.4(4.4)
total carex spp.	0.111	5.5(3.1)	2.6(3.3)	2.8(1.9)
total dicot spp.	0.697	29.7(7.1)	31.4(7.5)	29.1(4.4)
# shrub spp./total spp.	0.343	0.15(0.07)	0.11(0.05)	0.14(0.04)
FQAI score	0.135	27.1(9.0)	24.4(6.8)	20.9(2.5)
rel cover of tolerant spp.	0.007	0.10(0.08)a	0.27(0.17)ab	0.09(0.08)ac
rel cover of intolerant spp.	0.087	0.34(0.19)a	0.29(0.19)ab	0.47(0.15)ac

Table 13. Mean and standard deviation (parenthesis) and p-values from exploratory analysis of variance for 6 vegetation communities for selected community characteristics. Means that do not have shared letters were significantly different after Tukey's Multiple Comparison Test.

attribute	p-value	bog N=1	fen N=2	swamp forest N=9	marsh N=3	wet prairie N=1	shrub swamp N=10
ORAM v. 5.0	0.165	79.0(na)	87.0(9.9)	64.6(13.7)	70.8(5.6)	69.0(na)	66.1(8.3)
total spp.	0.234	46.0(na)	54.0(7.1)	37.0(12.6)	41.7(13.0)	42.0(na)	35.4(4.7)
total carex spp.	0.283	4.0(na)	7.5(5.0)	2.6(3.3)	4.0(2.0)	6.0(na)	2.7(2.0)
total dicot spp.	0.797	30.0(na)	35.0(2.8)	30.7(8.0)	27.7(8.7)	25.0(na)	29.7(4.1)
# shrub spp./total spp.	0.155	0.09(na)	0.22(0.07)	0.12(0.05)	0.11(0.05)	0.12(na)	0.14(0.04)
FQAI score	<0.001	39.6(na)a	35.4(5.0)a	22.5(3.6)b	21.1(8.2)b	28.1(na)ab	20.8(2.6)b
rel cover of tolerant spp.	0.040	0.01(na)a	0.03(0.02)a	0.27(0.17)b	0.16(0.06)ab	0.03(na)ab	0.10(0.08)a
rel cover of intolerant spp.	0.134	0.66(na)	0.48(0.25)	0.28(0.19)	0.24(0.14)	0.34(na)	0.45(0.15)

3.2 Comparison of quadrat versus plot sampling methods

Ohio EPA resampled several wetlands with the releve method that had previously been sampled with transect-belt method. These wetlands included a highly degraded emergent marsh, an unvegetated vernal pool, and a floristically rich forested wetland. The releve method clearly solved the problems discussed in §2.0 with regards to the transect-belt method. First, all plants had cover or density data associated with them. However, at all three sites, the transect-belt method had a larger species list (Figure 8), but this difference was most apparent at the floristically poor and good sites (Mishne and Gahanna, respectively). At the floristically rich wetland (Leafy Oak), the difference between the releve method and the transect-belt method was only 11 species (Figure 8). At the highly degraded emergent marsh (Mishne), substantially greater numbers of species were identified using the transect-belt method than the releve method. However, these were predominately upland weed species growing in narrow band along an edge of the wetland near a fence-row. Inclusion of these plants inflated the Floristic Quality Assessment Index scores for the Mishne site (Figure 9). But, at the floristically rich Leafy Oak site, the releve method performed as well as the transect-belt method with regards to FQAI scores (Figure 9).

A comparison of vegetation IBI scores of data from the transect-quadrat and releve methods yielded very similar results: the relative position of the wetlands sampled using both methods did not change (Figure 10).

The releve method appears to have several advantages over transect-quadrat methods: 1) it allows for an easy qualitative, stratified sampling of the dominant plant communities; 2) it provides a more complete forest inventory; 3) the quantitative data is intercomparable with other standard vegetation sampling methods; 4) it is relatively quick (2-3 sites per day with an experienced team); it is easily adaptable to unique situations and shapes of communities (the module system allows you to build up or down in plot size); 5) it provides the data for phytosociological analysis; 6) it requires a good site reconnaissance to identify the major plant communities and an express decision as to what the community of interest being sampled is; and 7) assures all plants identified have dominance data associated with them.

The releve method does not allow the mapping of the vegetation communities like a fixed transect method would and the releves are often hard to lay out in dense shrub communities. In addition, the flora of the wetland is somewhat less complete using the releve method, although this could be compensated for by doing a qualitative survey outside of the plot. Both the transect-quadrat and releve methods yielded equivalent results when the data resulting from these methods was used to calculate a vegetation IBI. Thus, data collected in 1996-98 using the transect-belt method can be safely combined with the data collected in 1999 and subsequent years in developing and deriving VIBIs.

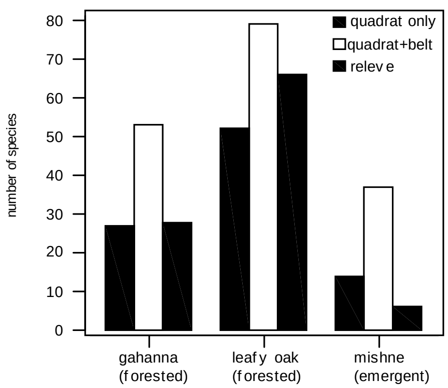

Figure 8. Number of species found at three wetlands sampled using transect-quadrat, transect-belt, and releve methods (see text) .

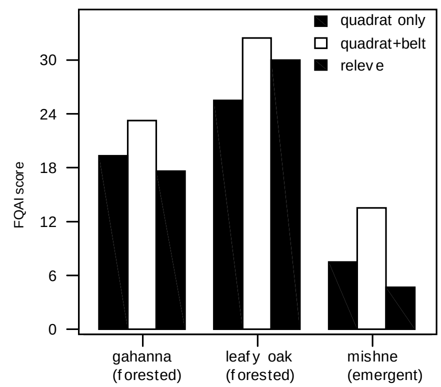

Figure 9. Floristic Quality Assessment Index (FQAI) score at three wetlands sampled using transect-quadrat, transect-belt, and releve methods (see text for description of FQAI score and box text for description of methods).

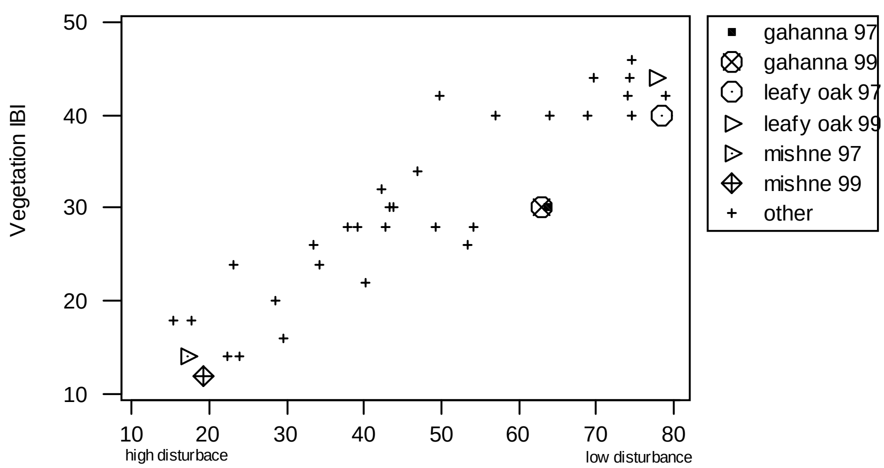

Figure 10. Vegetation Indices of Biotic Integrity (IBI) scores calculated using all-sites method and trisection of distribution for 45 wetlands in the Eastern Cornbelt Plains Ecoregion of Ohio. Comparison of IBI scores for three wetlands sampled using transect-quadrat and releve method.

3.3 VIBI general considerations.

In developing the VIBIs presented below, the decision was made to derive separate IBIs for the dominant plant communities: emergent, forested, and scrub-shrub. This conclusion was based on the following considerations:

1. An evaluation of existing classification schemes which classified separately vegetation communities dominated by herbaceous vegetation, shrubs, or trees, cf. Anderson (1982), Cowardin et al. 1979.

2. Analysis of results presented in §3.1 which suggested that riparian and isolated systems may be floristically equivalent such that they can be evaluated together. In addition, only a 4 riparian sites are in the current data set and it was felt that more was gained by including them than was lost. Likewise, the fen and kettle lake systems were excluded from the emergent data set because preliminary results suggested they may need to be dealt with separately.

3. The existing relatively small size of the data set prohibited the development of more than 3 classes.

4. The structure of the disturbance gradient (ORAM v. 5.0) which attempted to control for differences in hydrology and habitat ensuring sites with different HGM settings would score similarly.

Both quadrisection and trisection were evaluated and derivation of the VIBI score was calculated using the all-sites and reference-sites methods. The relative ranking of sites remained the same whether trisection or quadrisection was used (Figures 14, 15, 24 and 25). Since quadrisection had a more intuitive 100 point scale and also had advantages in Ohio's current wetland regulatory scheme (3 categories with an implied fourth category, i.e. degraded Category 2s), quadrisection was selected as the method of choice. Similarly, the relative ranking of wetlands did not change when using the "all-sites" versus the "reference-sites" methods; therefore, the all-sites method was selected since it removed a subjective step of assigning a wetland to reference or nonreference category and allowed for the use of the entire data set.

Each of the subsequent sections presents the Vegetation Index of Biotic Integrity (VIBI) for the emergent, forested, and scrub-shrub wetland vegetation classes. Figures and tables supporting each VIBI are presented after the text in §§3.3, 3.4, and 3.5

3.3 VIBI-EMERGENT

Ten attributes were selected as metrics for the VIBI-EMERGENT (VIBI-E) (Table 14). These were selected to represent a number of taxa groups and taxa levels, plant life forms, tolerance or intolerance to disturbance, and community level variables (productivity, heterogeneity). Metrics were selected that had linear, curvilinear, threshold, or other discernible relationship to the disturbance gradient (Figure 11). Descriptive statistics and results from linear regressions of metric values are presented in Appendix 2. All values except biomass were significant at $p < 0.01$ or lower.

Metric scores were calculated by trisecting and quadrisecting data using the "all-sites" and "reference-sites" methods discussed in the methods section. Table 15 lists the scoring breakpoints used to assign a score to a particular metric value. Individual metric scores for the all-sites/quadrisect method were evaluated using scatterplots and frequency histograms (Table 16; Figures 12 and 13)[9]. Appropriately, individual metric scores increased as the x-axis rank of ecological integrity of the wetland increased (Figure 12), and in general, were evenly distributed among the 4 scoring categories (Figure 13). The

[9] Because there was so little difference between the methods in the relative ranking of the sites, the scoring ranges and percentages for trisection and reference-sites methods are not presented in this report.

percentage of scores by qualitative categories (very poor, poor, fair, good, reference), reference versus nonreference, and ORAM v. 5.0 scoring categories (0-20, 20-40, 40-60, 60+) was calculated (Table 17).

A Vegetation Index of Biotic Integrity for wetlands dominated by emergent vegetation communities was calculated by summing the individual metric scores. Scores for each method used (all-sites and reference-sites) and each partitioning technique trisection and quadrisection) were replotted against the disturbance gradient (Figures 14 and 15). Very strong and statistically significant linear relationships for the VIBI-E were observed using each method with an R^2 between 80 to 93 percent (Figures16, 17, 18, and 19). Use of the reference-sites method did not change the relative position of the sites in relation to each other although it did suppress the maximum scores (Figures 11a versus 11b and 12a versus 12b). Using trisection versus quadrisection also did not affect the relative scores of the sites evaluated (Figures 11 and 12).

The quadrisection method with its 100 point scale better delineated the degraded category 2 wetland, the implied category in the wetland antidegradation rule. Using the all-sites method removed the need to subjectively determine reference-sites versus nonreference sites. There also were concerns that the number of reference sites (n=4) in this data set skewed certain results especially when frequency histograms and scatterplots of the reference method metric scores were evaluated (data not shown here). Therefore, the all-sites quadrisection VIBI-E was selected as the “best” method given the current data set (Figure 11a).

Two kettle lake fens (Mud Lake Bog, Silver Lake), a large fen (Springville Marsh) and a kettle lake without a fen (Stages Pond) were sampled and evaluated using the VIBI-E, although data from these sites was not used to derive the VIBI-E. Using the scoring breakpoints in Table 16, a VIBI-E score was calculated for each of these sites: Mud Lake Bog (VIBI-E = 81), Silver Lake (VIBI-E = 80), Springville Marsh (VIBI-E = 74) and Stages Pond (VIBI-E = 12) (Figure 20). Even though these sites were excluded from the data set used to derive the VIBI-E, sampling and scoring them to calculate the VIBI-E appears to accurately assess their relative integrity/disturbance levels and rank them appropriately in the class of emergent wetlands.

Table 14. Description of metrics for VIBI-EMERGENT in State of Ohio, Eastern Corn Belt Plains Ecoregion. "CofC" means the an individual plant species' "Coefficient of Conservatism" as described in Andreas and Lichvar (1995).

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.
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	%intol	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	%tol	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 plants with a facultative wetland indicator status	%FAC	dominance ratio	decrease	Percent coverage of all plants with a Facultative (FAC) wetland indicator status divided by total percent coverage of all plants.
median relative coverage of graminoid plant species	%gram	dominance	increase	The median relative coverage of all graminoid species. "Graminoid" plant species include all species in the Cyperaceae, Poaceae, Sparganiaceae, and Typhaceae.
average standing biomass	biomass	primary production	increase	The average grams per square meter of clip plot samples collected at each emergent wetland.
Heterogeneity	Heterogeneity	Simpson's index	decrease	A heterogeneity index proposed by Simpson (1949) as described in Krebs (1999). See §2.3.1.10 for discussion.

Table 15. Scoring breakpoints for assigning metric scores to emergent wetland metrics using quadrisection/all-sites method. See Table 15 for descriptions of metric codes.

metric	score 0	score 3	score 7	score 10
carex	0-2	3	4-5	≥6
dicot	0-8	9-15	16-23	≥24
shrub/tot	0-0.035	0.0351-0.070	0.0701-0.105	0.1051-1.0
FQAI	0-7.1	7.2-14.3	14.4-21.4	≥21.5
%intolerant	0-0.090	0.0901-0.179	0.1791-0.269	0.2691-1.0
%tolerant	0.6621-1.0	0.4411-0.662	0.2211-0.441	0-0.221
%FAC	0-0.065	0.0651-0.130	0.1301-0.195	0.1951-1.0
%graminoid	0.1331-1.0	0.0891-0.133	0.0441-0.089	0-0.044
biomass	≥1041	694-1040	348-693	0-347
heterogeneity	0.2891-1.0	0.1931-0.289	0.0961-0.193	0-0.096

Table 16. Distribution of metric scores by site for VIBI-E calculated using quadrisect/all-sites method.

site	condition	ORAM v5.0	VIBI-E	no. of "0" scores	no. of "3" scores	no. of "7" scores	no. of "10" scores
2- Meadows	good	49	64	1	2	4	3
American Legion	fair	39	34	5	1	3	1
Beaver Creek	good	57	53	2	3	2	2
Berger Rd	poor	22.5	6	8	2	0	0
Calamus 1997	reference	75	73	0	2	1	6
County Rd 200	very poor	18	20	7	1	1	1
Daughmer	reference	69	90	0	1	1	8
Dever	fair	22	29	4	4	1	1
Keller Low	fair	35	23	5	3	2	0
Kiser Lake	reference	73	94	0	0	2	8
LaRue Emergent	fair	40	36	3	4	2	1
Lawrence Low 1	poor	34	43	3	3	2	2
Mishne 1999	very poor	18.5	3	9	1	0	0
Palmer Rd	very poor	16.5	16	6	3	1	0
Rickenbacker	reference	51.5	64	1	1	5	3
Scofield	fair	43	50	1	4	4	1
Silver Creek (Bloomville)	fair	40	32	3	5	1	1
			total	58	40	32	38
			%total	35%	24%	19%	23%

Table 17. 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	38%	13%	6%	3%
poor	19%	13%	6%	5%
fair	36%	53%	41%	13%
good	5%	13%	19%	13%
reference	2%	10%	28%	66%
nonreference	98%	90%	72%	34%
reference	2%	10%	28%	66%
0-19 ORAM score	38%	13%	6%	3%
20-39 ORAM score	43%	33%	25%	11%
40-59 ORAM score	19%	45%	56%	21%
60+ ORAM score	0%	10%	13%	66%

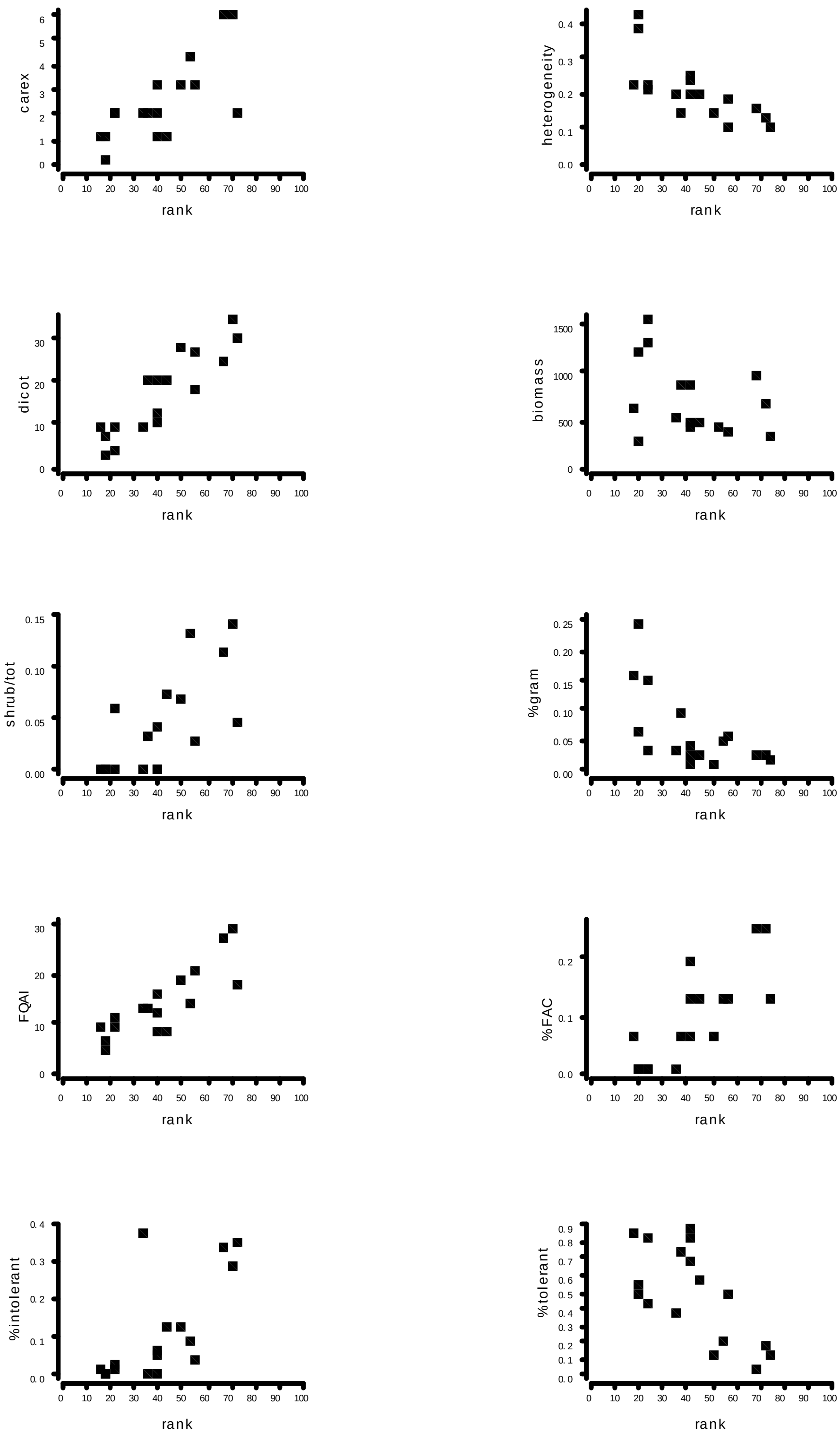

Figure 11. Scatterplots of individual metric values for each emergent wetland sampled versus rank (disturbance/quality scale) from ORAM v. 5.0). Rerer to Table 14 for descriptions of the metrics and metric codes.

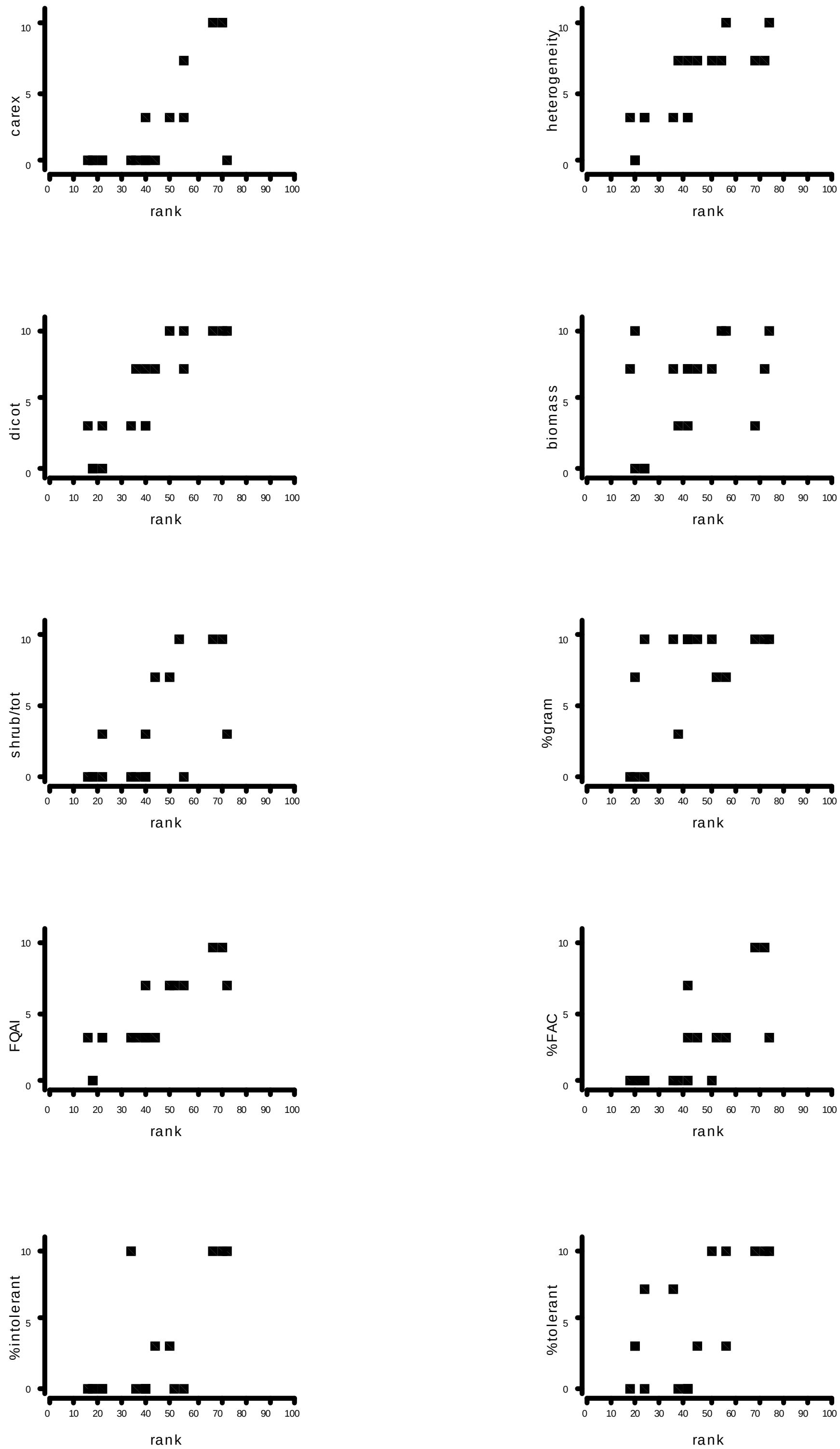

Figure 12. Scatterplots of individual metric scores for each emergent wetland sampled versus rank (disturbance/quality scale) from ORAM v. 5.0). Rerer to Table 14 for descriptions of the metrics and metric codes.

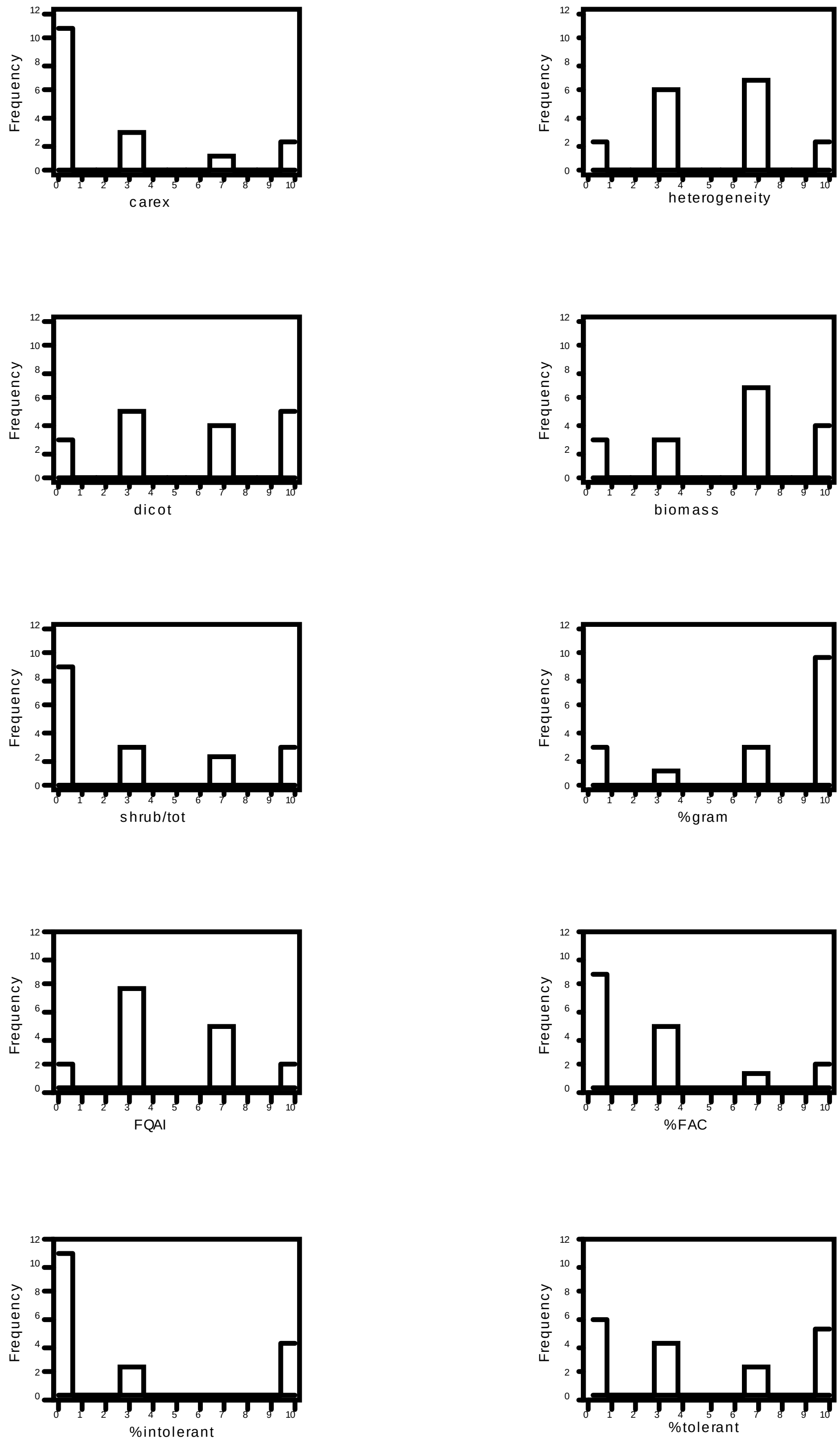

Figure 13. Frequency histograms of metric scores for emergent wetland metrics calculated using the all-sites method and quadrisection of the 95th percentile of the metric value. Refer to Table 14 for descriptions of metrics and metric codes.

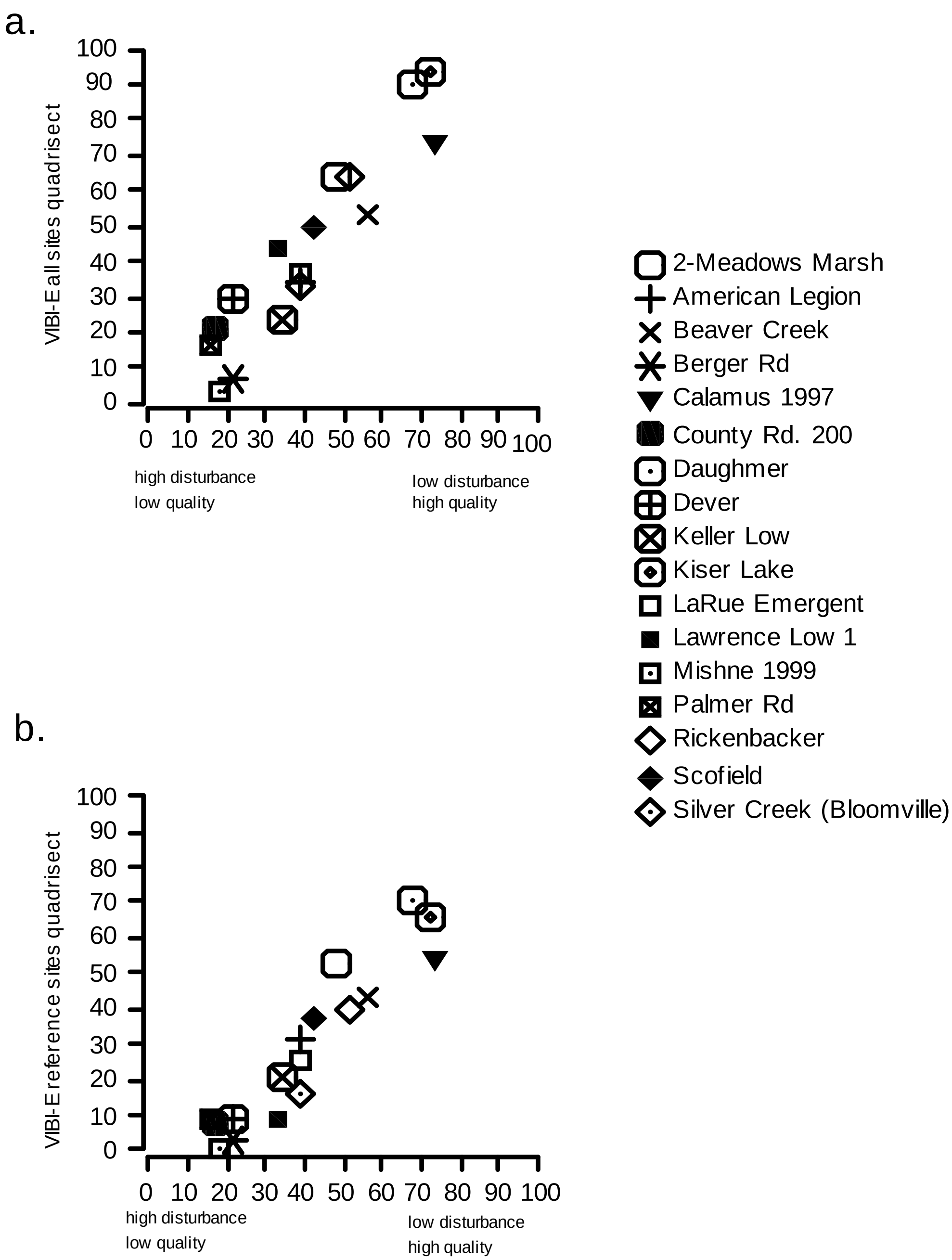

Figure 14. Vegetation IBI for EMERGENT wetland communities derived using "all-sites" (graph a) and "reference-sites" (graph b) methods with QUADRISECTION partitioning of metric values used for both methods.

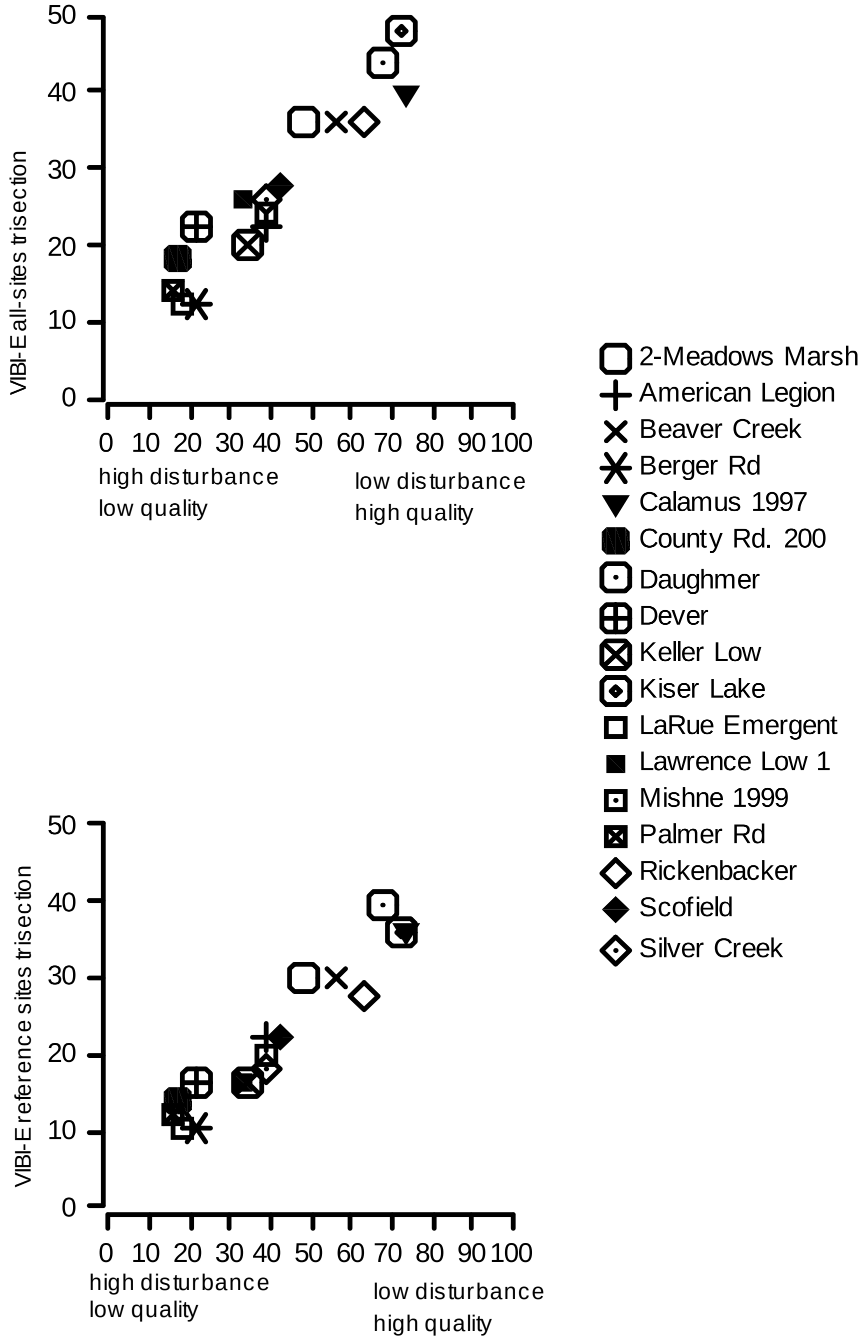

Figure 15. Vegetation IBI for EMERGENT wetland communities derived using "all-sites" (graph a) and "reference-sites" (graph b)methods with TRISECTION partitioning of metric values used for both methods.

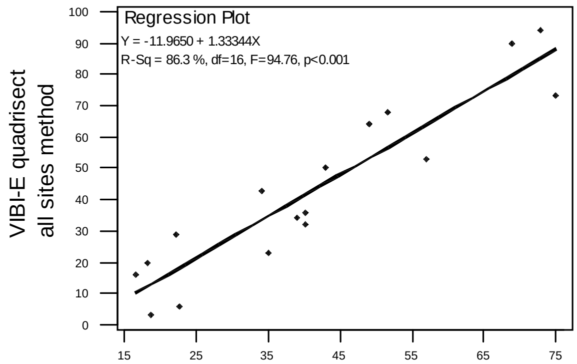

Figure 16. Linear regression of Vegetation IBI score for EMERGENT communities using all-sites method and quadrisection of metric values.

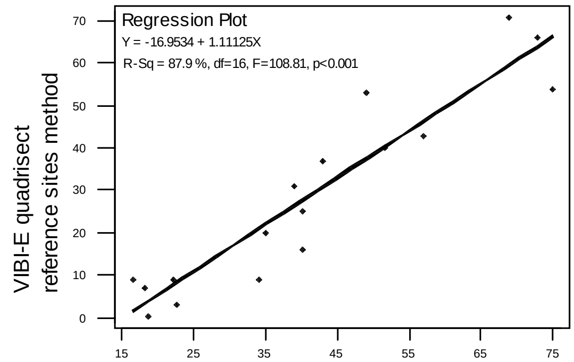

Figure 17. Linear regression of Vegetation IBI score for EMERGENT communities using reference-sites method and quadrisection of metric values.

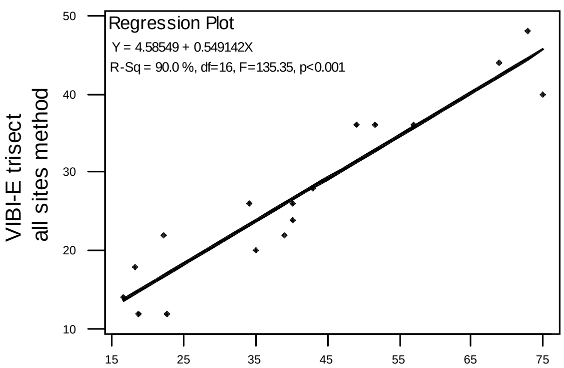

Figure 18. Linear regression of Vegetation IBI score for EMERGENT communities using all-sites method and trisection of metric values.

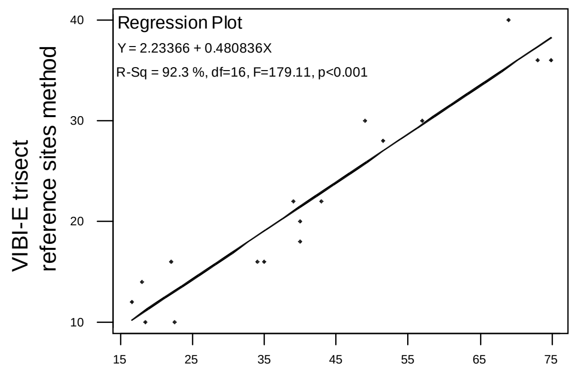

Figure 19. Linear regression of Vegetation IBI score for EMERGENT communities using reference-sites method and trisection of metric values.

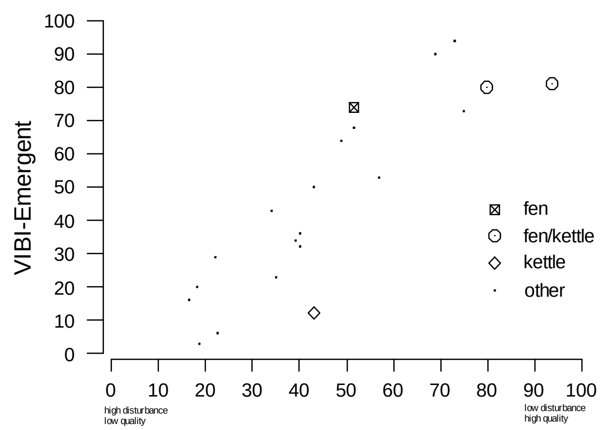

Figure 20. Scatterplot of non-fen or kettle lake emergent wetlands and 3 fens and 1 kettle lake site where VIBI-E scores were calculated using the scoring breakpoints in Table 16.

3.4 VIBI-FORESTED

Ten attributes were selected as metrics for the VIBI-FORESTED (VIBI-F) (Table 18). These were selected to represent a number of taxa groups and taxa levels, plant life forms, tolerance or intolerance to disturbance, and community level variables (productivity, heterogeneity). Metrics were selected that had linear, curvilinear, threshold, or other discernible relationship to the disturbance gradient (Figure 21). Descriptive statistics and results from linear regressions of metric values are presented in Appendix 2. All values were significant at p=0.003 or lower except for number of dicot species (p=0.087).

Metric scores were calculated by trisecting and quadrisecting data using the “all-sites” and “reference-sites” methods discussed in the methods section. Table 19 lists the scoring breakpoints used to assign a score to a particular metric value. Individual metric scores for the all-sites/quadrisect method were evaluated using scatterplots and frequency histograms (Table 20; Figures 22 and 23)[10]. Appropriately, Individual metric scores generally increased with as the x-axis rank of ecological integrity of the wetland increased (Figure 22) and in general, metric scores were evenly distributed among the 4 scoring categories (Figure 23). The percentage of scores by site and by qualitative categories (very poor, poor, fair, good, reference; reference versus nonreference) and by ORAM v. 5.0 scoring categories (0-20, 20-40, 40-60, 60+) was calculated (Tables 21 and 22). Low scores decreased with quality, and high scores increased with wetland quality.

A Vegetation Index of Biotic Integrity for wetlands dominated by emergent vegetation communities was calculated by summing the individual metric scores. Scores for each method used (all-sites trisection/quadrisection and reference-sites trisection/quadrisection were replotted against the disturbance gradient (Figures 24 and 25). Very strong and statistically significant linear relationships for the VIBI-E were observed using each method with an R^2 between 80 to 89 percent (Figures 26, 27, 28, and 29). Use of the reference-sites method did not change the relative position of the sites in relation to each other although it did suppress the maximum scores (Figures 24a versus 24b and 25a versus 25b). Using trisection versus quadrisection also did not affect the relative scores of the sites evaluated (Figures 24 and 25).

The quadrisection method with its 100 point scale will allow for better delineation of the degraded category 2 wetland, the implied category in the wetland antidegradation rule. Using the all-sites method removed the need to subjectively determine reference-sites versus nonreference sites. Therefore, the all-sites quadrisection VIBI-E was selected as the “best” method given the current data set (Figure 24a).

During analysis of the forest community data, two types of forested wetlands were noted. The first is often called a "vernal pool", a defined term in the Wetland Water Quality Standards (OAC Rule 3745-1-50). It is characterized by a closed canopy of tree species with sparse herbaceous and shrub vegetation on fallen logs, tree bases, or in a narrow margin around a largely unvegetated pool. The second type of forested wetland can have pools as deep as the vernal pool type, but is characterized by a extensive (in coverage) and diverse herb and shrub stratum. Absolute cover values (sum of %coverage of all herb and shrub species) were significantly different between "vegetated" and "unvegetated" forested wetlands (Figure 30). Forested wetlands with less than 100% absolute cover for all herb species can be characterized as unvegetated forested wetlands or vernal pools.

During evaluation and selection of metrics for the VIBI-FORESTED, only metrics which "worked" for both of these types of wetlands were selected although there were metrics which could have been used if they were treated as separate types. For example, number of carex species with C of Cs greater than 3

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[10] Because there was so little difference between the methods in the relative ranking of the sites, the scoring ranges and percentages for trisection and reference-sites methods are not presented in this report.

exhibited a very strong linear relationship for vegetated forested wetlands, but failed as a metric when both vegetated and unvegetated forested wetlands were analyzed together (Figure 31). This potential classification issue will be explored further in the future as the forested wetland data set expands.

Table 18. Description of metrics for VIBI for FORESTED wetlands in State of Ohio, Eastern Corn Belt Plains Ecoregion. "CofC" means the an individual plant species' "Coefficient of Conservatism" as described in Andreas and Ladd (1995).

metric	code	type	(+) or (-) as disturbance increases	description
number of dicot spp.	dicot	richness	decrease	Number of dicot (dicotyledon) spp. present at a site.
shrub species/tree species	shrub/tree	richness ratio	decrease	Number of shrub species divided by the number of tree species.
facultative species/total species	FAC/tot	richness ratio	decrease	Number of plant species with a facultative wetland indicator status divided by the total number of species.
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.
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.
relative cover of plants with obligate wetland indicator status	%OBL	dominance ratio	decrease	Percent coverage of plants in the herb and shrub stratum with an obligate wetland indicator status divided by the total percent coverage of all plants.
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.
$\log_{10}$ shrub density	shrub	density	decrease	The logarithm to base 10 of shrub density (stems/hectare).
Heterogeneity	heterogeneity	Simpson's index	decrease	A heterogeneity index as proposed by Simpson (1949) as described in Krebs (1999). See §2.3.1.10 for discussion.

Table 19. Scoring breakpoints for assigning metric scores to forested wetland metrics using quadrisection/all-sites method. See Table 20 for descriptions of metric codes.

metric	score 0	score 3	score 7	score 10
dicot	0-11	12-21	22-32	≥33
shrub/tree	0-0.18	0.181-0.36	0.361-0.54	0.541-1.0
FAC/tot	0.1531-1.0	0.1021-0.153	0.0511-0.102	0-0.051
FQAI	0-9.1	9.2-18.1	18.2-27.2	27.21-1.0
%intolerant	0-0.143	0.1431-0.286	0.2861-0.429	0.4291-1.0
%tolerant	0.1291-1.0	0.0861-0.129	0.0431-0.086	0-0.043
%OBL	0-0.169	0.1691-0.338	0.3381-0.506	0.5061-1.0
small tree	0.2321-1.0	0.1551-0.232	0.0771-0.155	0-0.077
shrub den	0-0.914	0.9141-1.827	1.8271-2.741	≥2.7411
heterogeneity	0.3101-1.0	0.2061-0.310	0.1031-0.206	0-0.103

Table 20. Distribution of metric scores by site for VIBI-F calculated using quadrisect/all-sites method.

site	condition	ORAM v5.0	VIBI-F	no. of "0" scores	no. of "3" scores	no. of "7" scores	no. of "10" scores
Big Woods	reference	68.5	77	0	2	3	5
Collier Woods	reference	73.5	65	1	1	6	2
Flowing Well	good	43	40	4	2	2	2
Gahanna 4th 1999	reference	62.5	61	0	3	6	1
Graham Rd	very poor	28.5	16	6	3	1	0
Hempelman	good	48	67	0	3	4	3
Johnson Rd	very poor	21	13	7	2	1	0
Killdeer Plains	reference	53.5	41	4	1	4	1
LaRue Woods	fair	55	49	1	5	2	2
Lawrence High	reference	73	88	0	0	4	6
Lawrence Low 2	poor	43	40	3	2	2	2
Leafy Oak 1999	reference	78	91	0	0	3	7
Orange Rd	fair	44	38	4	1	5	0
Oyer Tamarack	reference	79	78	1	0	4	5
Sawmill 1997	fair	50.5	50	2	3	3	2
Tipp-Elizabeth Rd	poor	29	23	5	3	2	0
			total	38	31	52	38
			%total	24%	19%	33%	24%

Table 21. 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	34%	16%	4%	0%
poor	21%	16%	8%	5%
fair	18%	29%	19%	11%
good	11%	16%	12%	13%
reference	16%	23%	58%	71%
nonreference	84%	77%	42%	29%
reference	16%	23%	58%	71%
0-19 ORAM score	0%	0%	0%	0%
20-39 ORAM score	47%	26%	8%	0%
40-59 ORAM score	47%	55%	42%	32%
60+ ORAM score	5%	19%	50%	68%

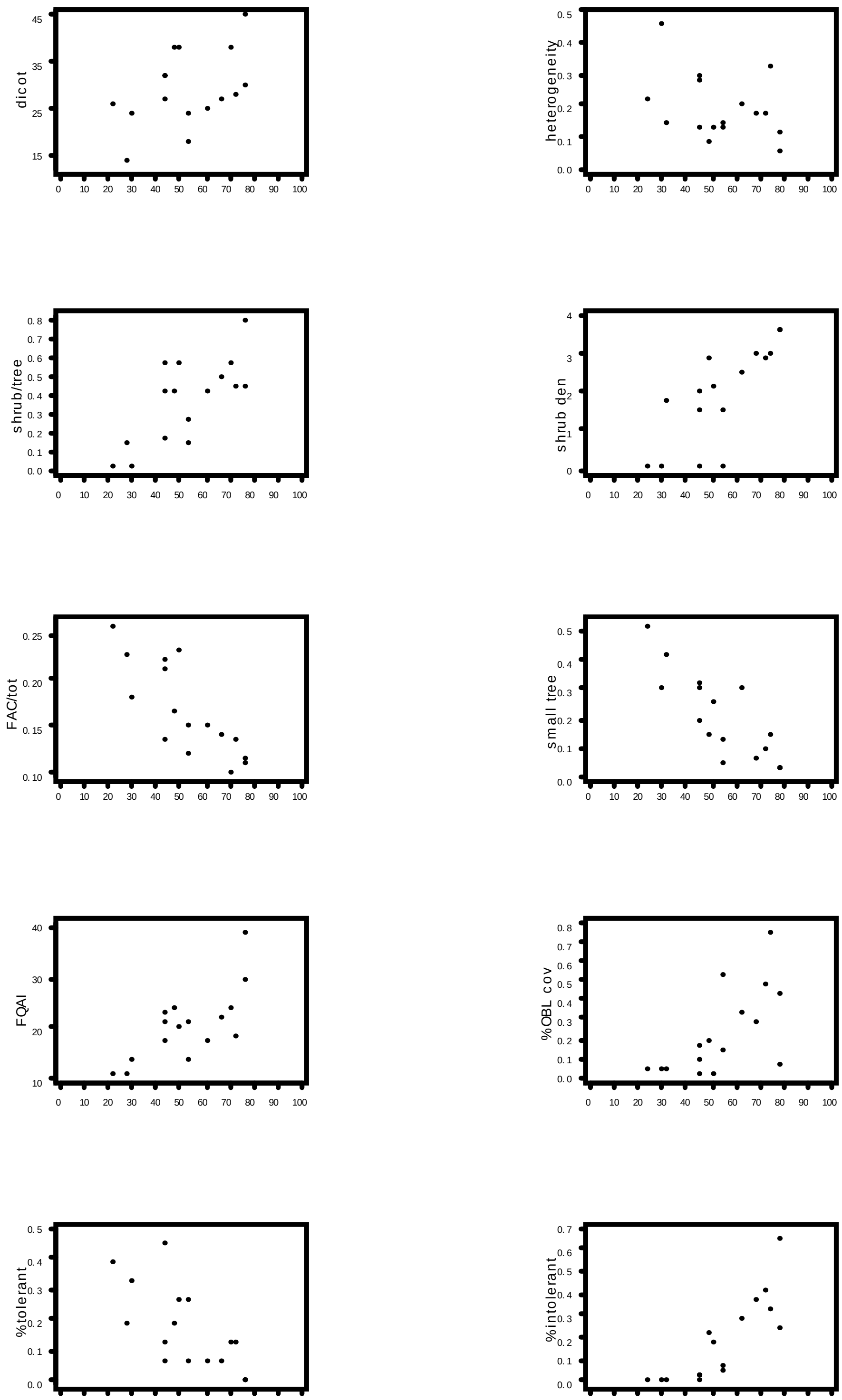

Figure 21. Scatterplots of individual metric values for each forested wetland sampled versus rank (disturbance/quality scale) from ORAM v. 5.0). Refer to Table 18 for descriptions of the metrics and metric codes.

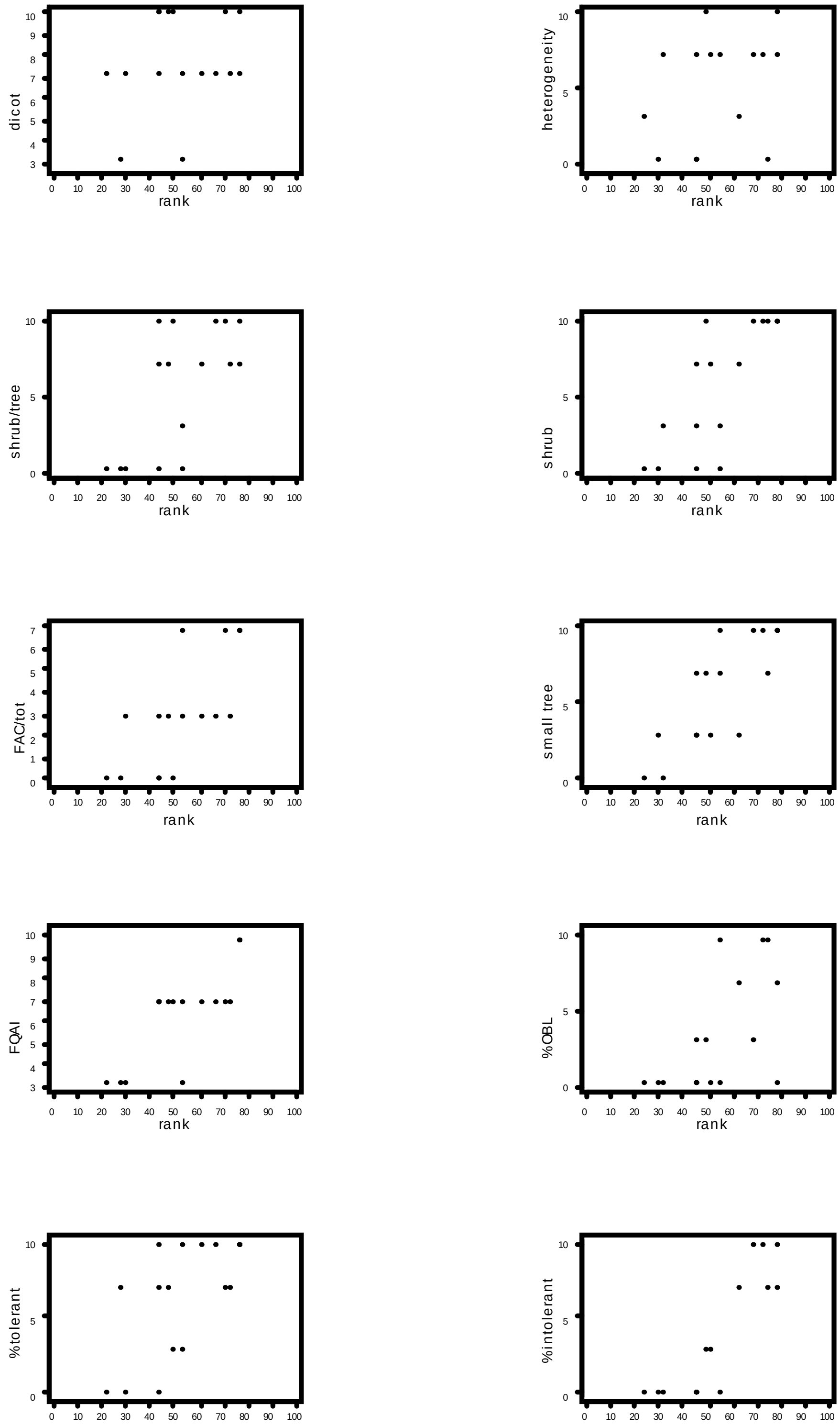

Figure 22. Scatterplots of individual metric scores for each FORESTED wetland sampled versus rank (disturbance/quality scale) from ORAM v. 5.0). Refer to Table 18 for descriptions of the metrics and metric codes.

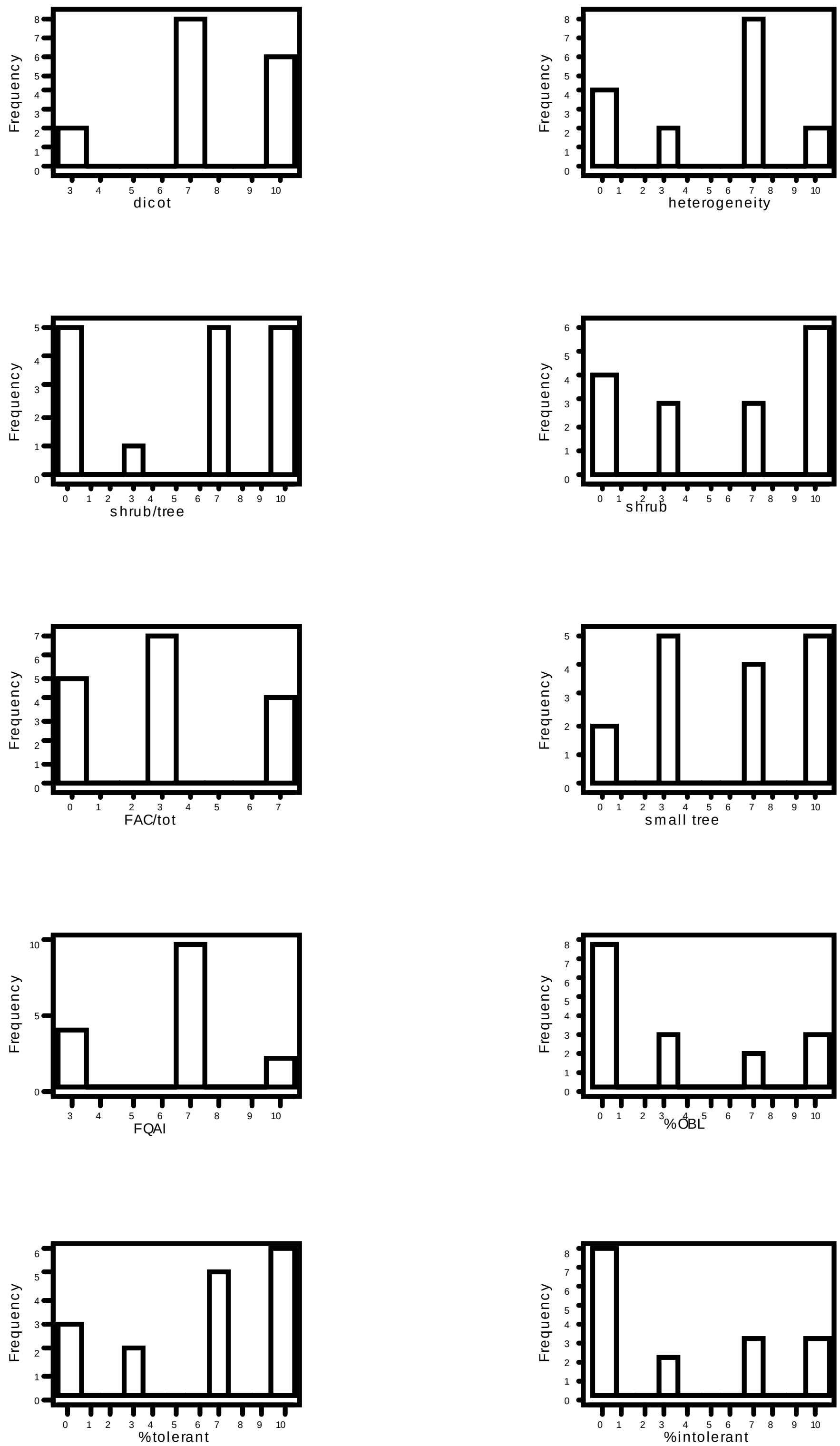

Figure 23. Frequency histograms of metric scores for FORESTED wetland metrics calculated using the all-sites method and quadrisection of the 95th percentile of the metric value. Refer to Table 18 for descriptions of metrics and metric codes.

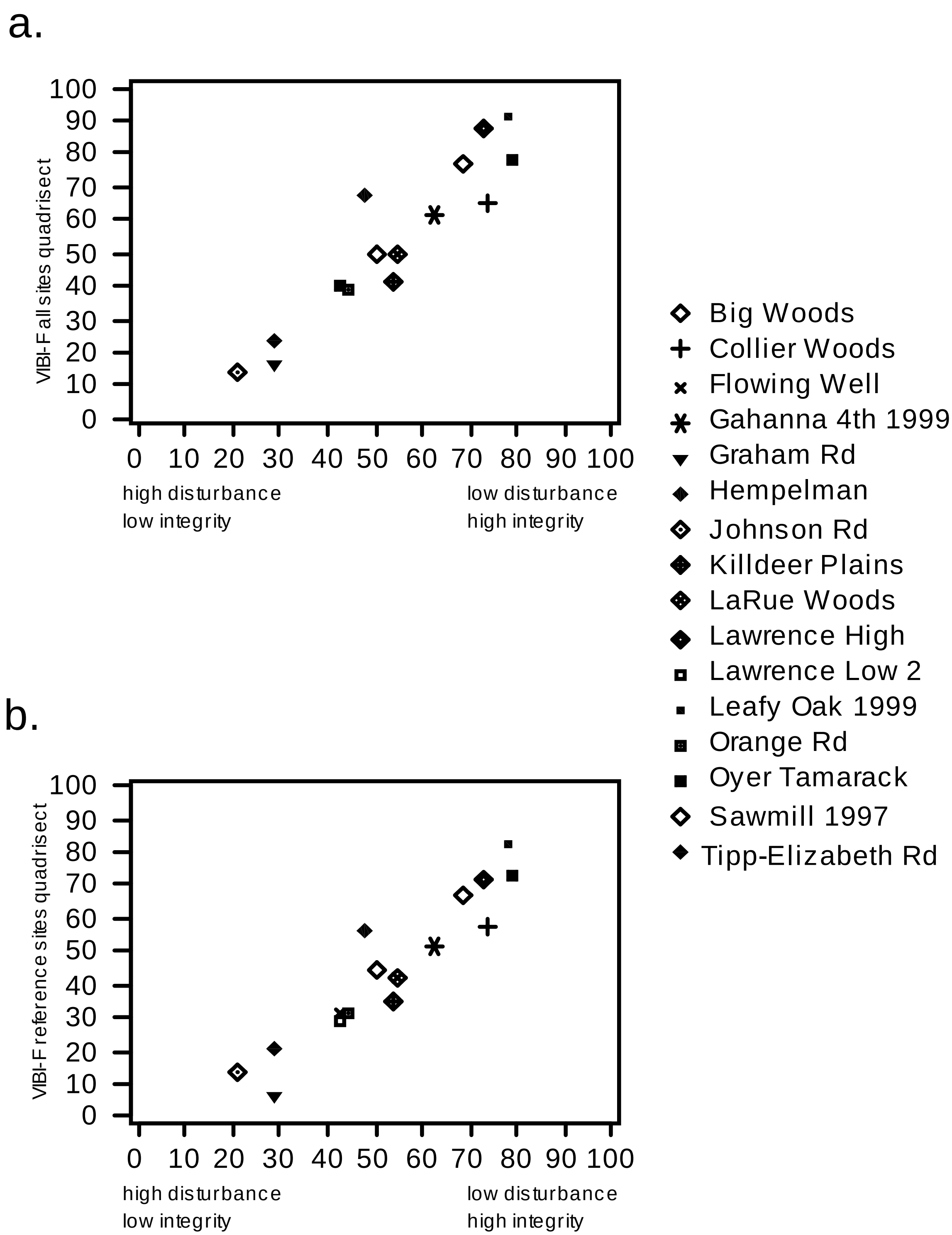

Figure 24. Vegetation IBI for FORESTED wetland communities derived using "all-sites" (graph a) and "reference-sites" (graph b) with QUADRISECTION partitioning of metric values used for both methods.

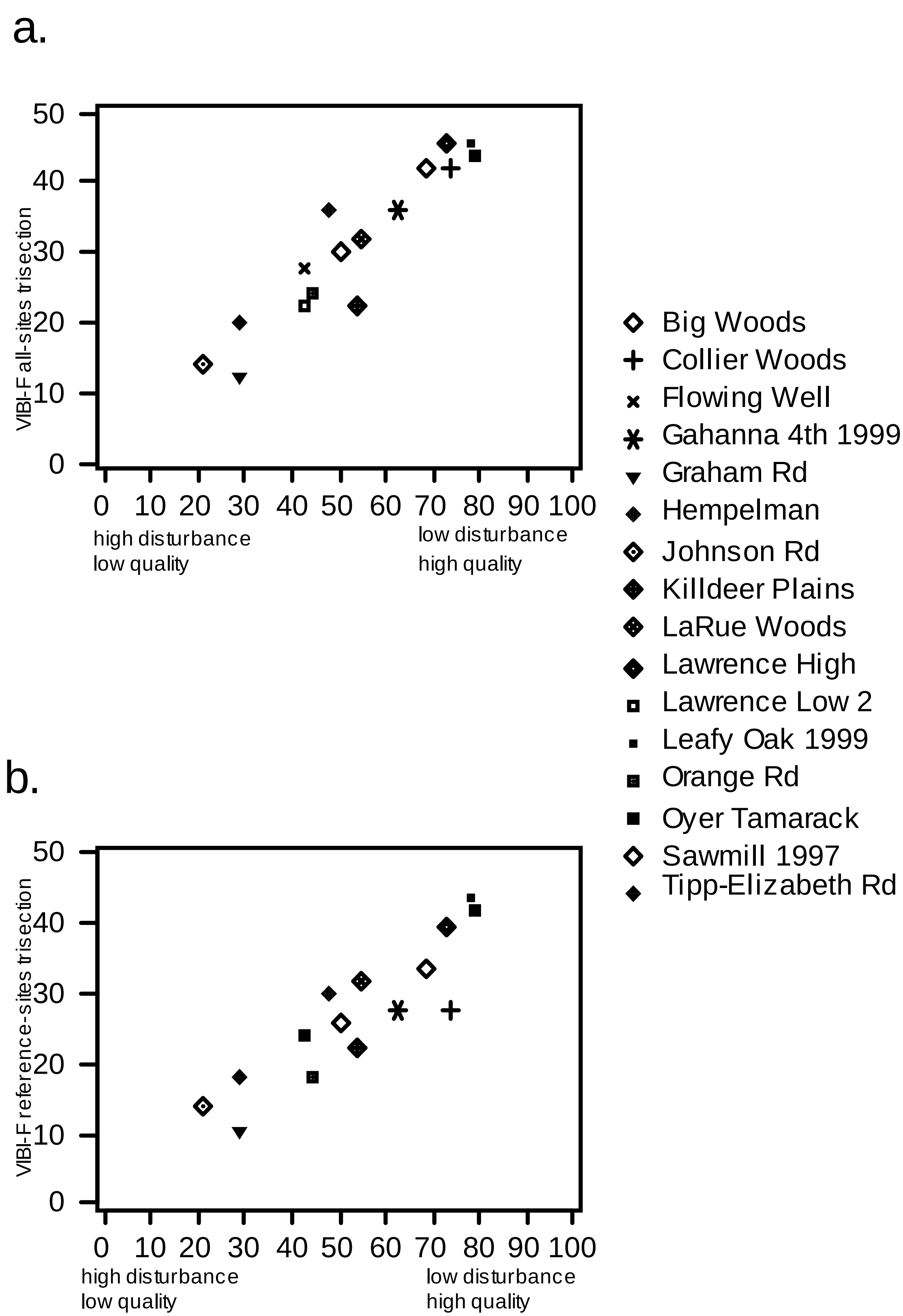

Figure 25. Vegetation IBI for FORESTED wetland communities derived using "all-sites" (graph a) and "reference-sites" (graph b) with TRISECTION partitioning of metric values used for both methods.

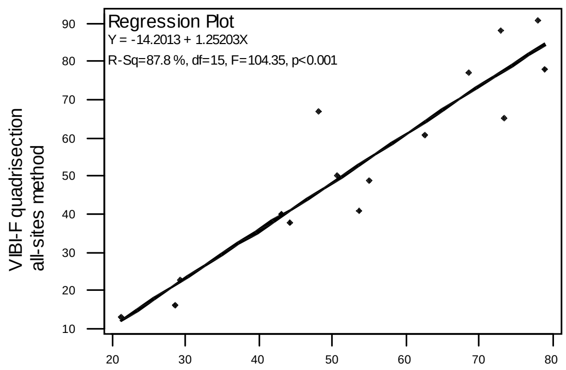

Figure 26. Linear regression of Vegetation IBI score for FORESTED communities using all-sites method and quadrisection of metric values.

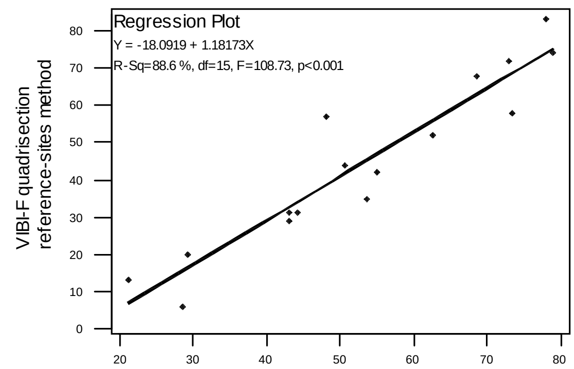

Figure 27. Linear regression of Vegetation IBI score for FORESTED communities using reference-sites method and quadrisection of metric values.

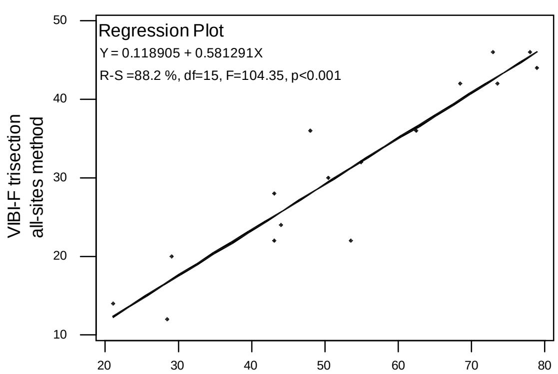

Figure 28. Linear regression of Vegetation IBI score for FORESTED communities using all-sites method and trisection of metric values.

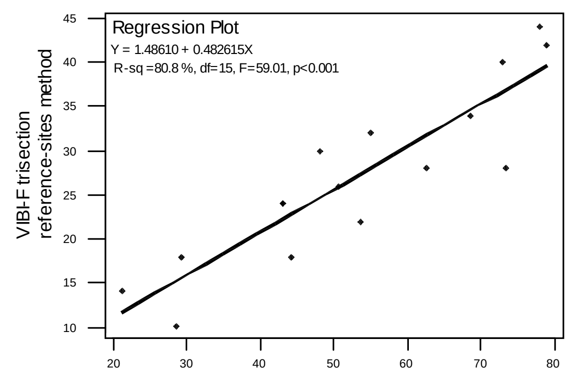

Figure 29. Linear regression of Vegetation IBI score for FORESTED communities using reference-sites method and trisection of metric values.

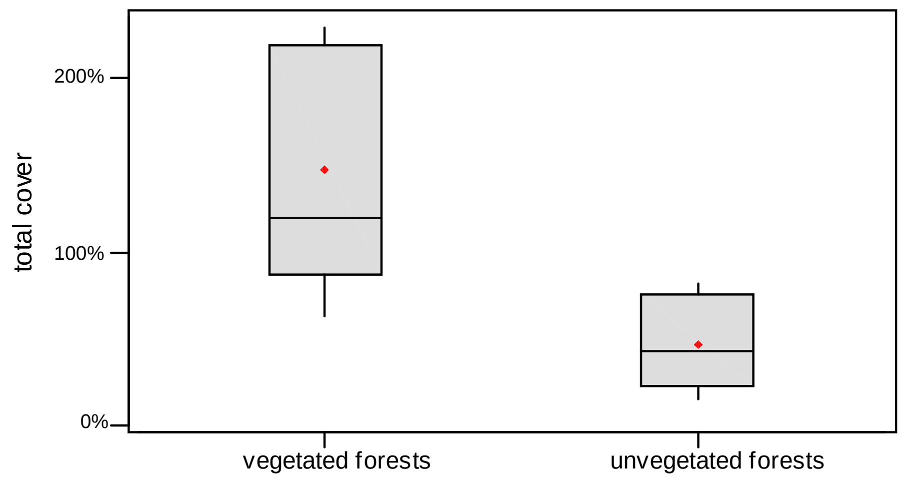

Figure 30. Box and whisker plots of vegetated and unvegetated forested wetlands. The dot is the mean. Means were signficantly different from each other (F=15.66, df=13, p=-.002). A line is drawn across the box at the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The

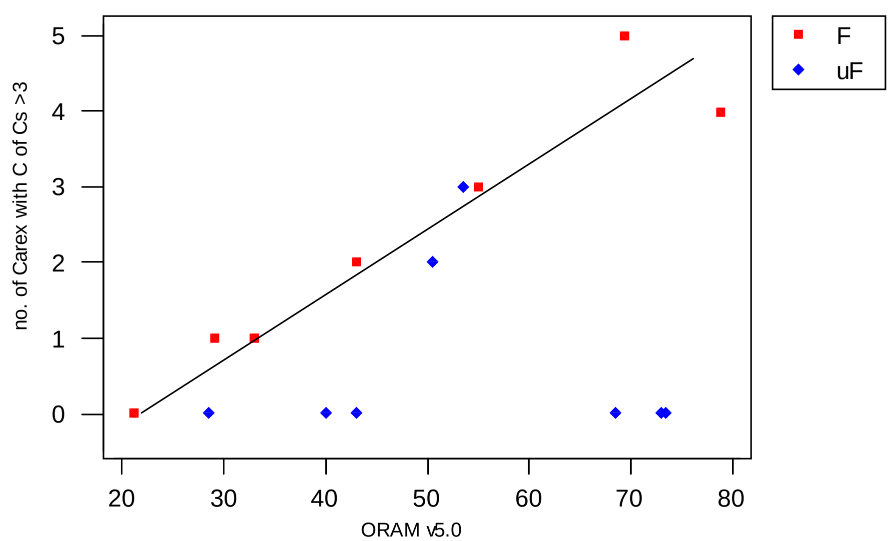

Figure 31. Number of *Carex* spp. with C of Cs greater than 3 versus ORAM v. 5.0 score for "vegetated" (F) and "unvegetated" (uF) forested wetlands. Fitted line is linear regression of vegetated forested wetlands points (R^2 = 91.5%, df =14, F=53.85, p=0.001).

3.5 VIBI-SCRUB-SHRUB

Development of the VIBI-SCRUB-SHRUB (VIBI-SS) was complicated by the fact that initially many scrub-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 conceptually, 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 sites were graphed with the forested sites and the emergent sites. Metrics where the shrub community sites "fit" into these other data sets were selected for use in the VIBI-SS (Figure 32). This resulted in the use of 3 forested (FQAI, %intolerant, small tree) and 7 emergent metrics (carex, dicot, shrub/tot, %tolerant, %FAC, %graminoid, heterogeneity) (Table 22). Descriptive statistics for scrub-shrub sites are presented in Appendix 2.

Metric scores for scrub-shrub wetlands were calculated by using the quadrisection scoring breakpoints derived for the emergent and forested metrics used (Tables 16 and 21). A Vegetation Index of Biotic Integrity for wetlands dominated by scrub-shrub vegetation communities was calculated by summing the individual metric scores. Scores were replotted against the disturbance gradient with the VIBI scores from the emergent and forested wetland data sets (Figure 33). A very strong and statistically significant linear relationship for the VIBI-SS was observed using with an R^2 of 84.5 percent (Figure 33).

Table 22. Description of metrics for VIBI for SCRUB-SHRUB wetlands in State of Ohio, Eastern Corn Belt Plains Ecoregion. "CofC" means the an individual plant species' "Coefficient of Conservatism" as described in Andreas and Ladd (1995).

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.
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	%intolerant	dominance ratio	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.
relative cover of "tolerant" plants	%tolerant	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.
relative cover of plants with a facultative wetland indicator status	%FAC	dominance ratio	decrease	Percent coverage of all plants in the herb and shrub stratum with a Facultative wetland indicator status divided by total percent coverage of all plants.
median relative cover of graminoid plant species	%gram	dominance ratio	increase	The median percent coverage of all graminoid species. "Graminoid" plant species include all species in the Cyperaceae, Poaceae, Sparganiaceae, and Typhaceae.
relative density of trees in 10-25cm size classes	small tree	density ratio	increase	The density (stems/ha) of tree species in size classes between 10 and 25 cm dbh divided by the total density of trees.
Heterogeneity	heterogeneity	heterogeneity index	decrease	A heterogeneity index based on Simpson's Index as described in Krebs (1999). See §2.3.1.10 for discussion.

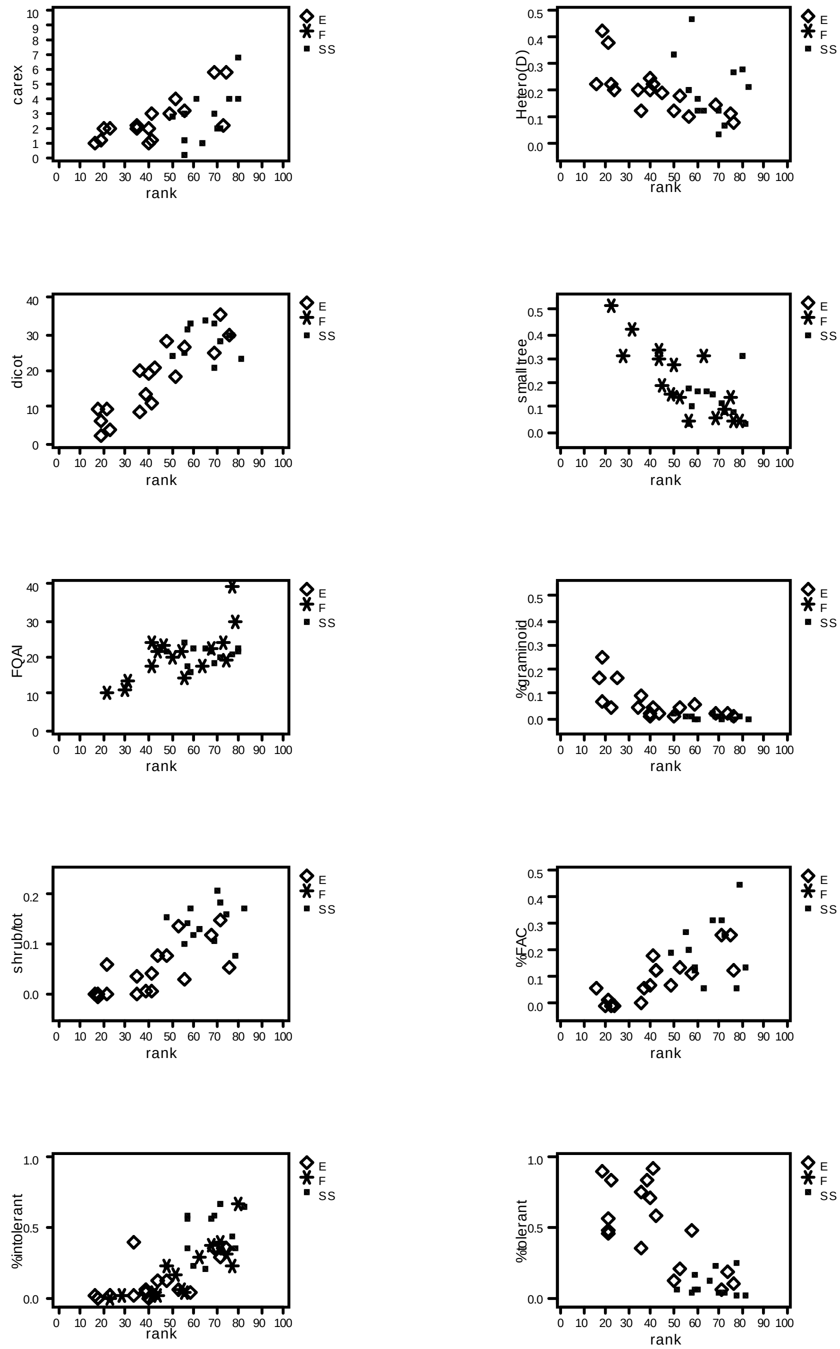

Figure 32. Scatterplots of individual metric values for each scrub-shrub wetland plotted with associated forested and emergent wetlands versus rank (disturbance/quality scale) from ORAM v. 5.0). Refer to Table 22 for descriptions of the metrics and metric codes.

3.6 VIBI general characteristics and calibration of the ORAM score and wetland categories.

The VIBI scores for wetland classes and condition were compared and evaluated. Very strong linear trends were observed when VIBI scores for all wetlands were compared to the disturbance/quality scale (Figure 31) (R^2=84.5%, df=44, F=235.23, p<0.001).

In a comparison of mean VIBI scores among emergent, forested, and scrub-shrub wetlands using analysis of variance followed by Tukey's multiple comparison test, the emergent and forested classes were not significantly different from each other, although the scrub-shrub class was significantly different from both emergent and forested classes (df=44, F=6.3, p=0.004) (Figure 32). However, this difference was caused by the lack of low and medium quality scrub-shrub communities in the data set. Thus, VIBI score appears to have a standardizing effect on natural variation caused by differences in dominant vegetation.

Significant differences were also observed between qualitatively assigned wetland “condition” categories (very poor, poor, fair, good, reference) as well as between reference and nonreference condition wetlands (Figures 33 and 34). Finally, very significant differences were observed between the VIBI score of Category 1, 2, and 3 wetlands (df=44, F=67.7, p<0.001). Therefore, the VIBI appears to be able to discriminate between at least three to four different categories of wetland quality/disturbance. This finding comports with the results of Fore, Karr, and Loveday (1993) who concluded that the state of Ohio's stream IBI could distinguish between five and six nonoverlapping categories of integrity.

The final step in development of the VIBI was using the biologically-derived index to calibrate the score for the Ohio Rapid Assessment Method for Wetlands, which is a qualitative habitat/functional assessment method. Recalibration of the scoring ranges using actual measures of a wetland's biology and functions has been a continuing need since the adoption of the State of Ohio's Wetland Water Quality Standards and Wetland Antidegradation rules and the use of "draft" versions of the ORAM (versions 3.0, 4.0, and 4.1) in regulatory decision making.

Figure 36 summarizes the results from calibrating the ORAM using the VIBI scores for forested, emergent, and scrub-shrub wetland vegetation community classes. Four wetland integrity categories are distinguished: Category 1, modified Category 2, Category 2, and Category 3. Because of the very strong linear, dose-response relationship observed in the VIBI scores, the 95^{th} percentile of the overall distribution of scores (89.6) was quadrisected resulting in the four IBI categories on the right side of the figure. Quadrisection of the 95^{th} percentile of the ORAM score (78.8) was evaluated but resulted in category breakpoints in which only one or two wetland s would have been categorized as Category 1. Because of this breakpoints for the ORAM score were visually assigned based on the VIBI score distribution and category breakpoints assigned by quadrisection. A 5% “gray zone” was placed below the cutoff for each main regulatory category. Scoring ranges are summarized in Table 23.

Comparing the IBI determined category to the ORAM determined category, 1 site was "overscored "by the ORAM (2.5%), 5 sites were "underscored" by the ORAM (11.1%, two in the category 1-2 (4.9%) and 3 in the category 2 to 3 (6.7%)). However, 3 of the underscored sites were scrub-shrub wetlands and this may be an artifact of the procedure for calculating scrub-shrub IBIs. Five sites (11.1%) were located in the gray zone.

It should be noted that scoring breakpoints have been developed based on the scoring and study of wetlands located primarily in the Eastern Corn Belt Plains (ECBP) Ecoregion (Figure 1; Omernik 1987; US EPA 1997). Ohio EPA will be studying wetlands in other ecoregions of Ohio in the coming years, but persons using these scoring ranges and breakpoints should keep in mind that they have been calibrated based on biological data obtained from predominately depressional wetlands located in the Eastern Corn Belt Plains Ecoregion. Thus, they should be applied with caution to wetlands located in other ecoregions of the state and to wetlands of other vegetation types and other landscape settings. Ohio

EPA has found significant ecoregional differences in streams, and this may also be the case for wetlands (Ohio EPA 1988a, 1988b, 1989). Ohio EPA will be studying wetlands in the Erie-Ontario Lake Plains (including the glaciated Allegheny Plateau) in 2001 and 2002, and in the Huron-Erie Lake Plains and Western Allegheny Plateau Ecoregions in subsequent years.

Table 23. Interim scoring breakpoints for wetland regulatory categories for ORAM and VIBI scores.

category	VIBI score	ORAM score
1	0 - 21	0 - 29.9
1 or 2 gray zone	----	30 - 34.9
modified 2	22 - 44	35 - 44.9
2	45 - 66	45 - 59.9
2 or 3	----	60 - 64.9
3	67 - 100	65 - 100

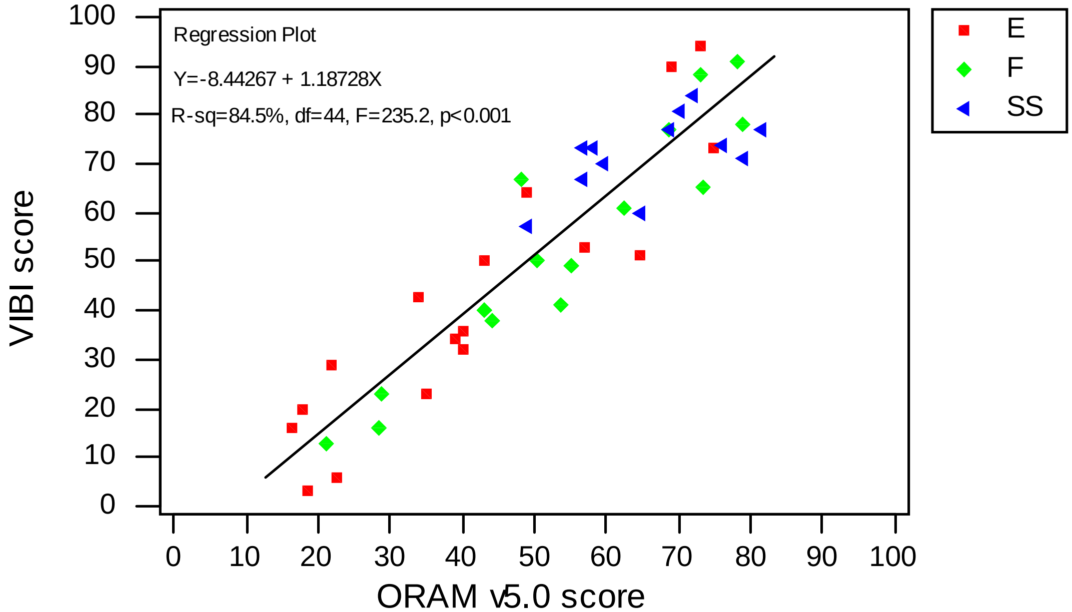

Figure 33. VIBI scores for emergent (E), forested (F) and scrub-shrub(SS) vegetation communities versus ORAM v. 5.0 score. Line is fitted line from linear regression of 45 wetland IBI scores.

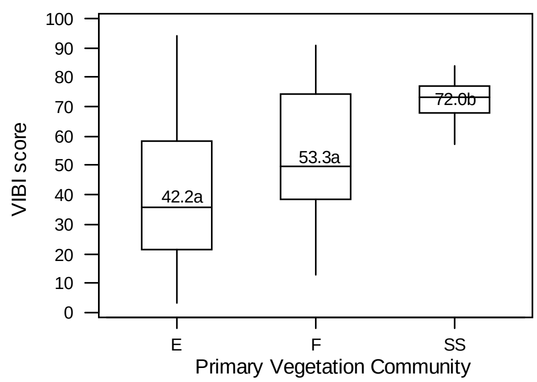

Figure 34. Box an whisker plots of emergent (E), forested (F), and scrub-shrub (SS) vegetation community VIBI scores. A line is drawn across the box at the median. Number on line is mean VIBI score. Means with different letters were significantly different. The bottom of the box is at the first quartile (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 (*).

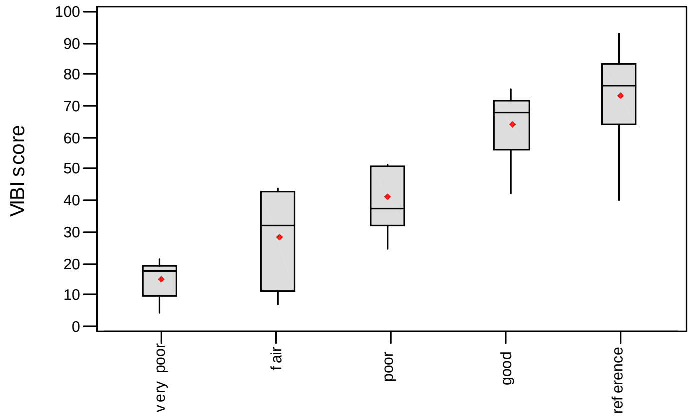

Figure 35. Box an whisker plots of all VIBI scores by wetland condtion. Dot is the mean score. All means were significantly different from one another except “very poor” versus “poor”, “poor” versus “fair,” and “good” versus “reference” (df=44, F=35.27, p=<0.001). A line is drawn across the box at the 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).

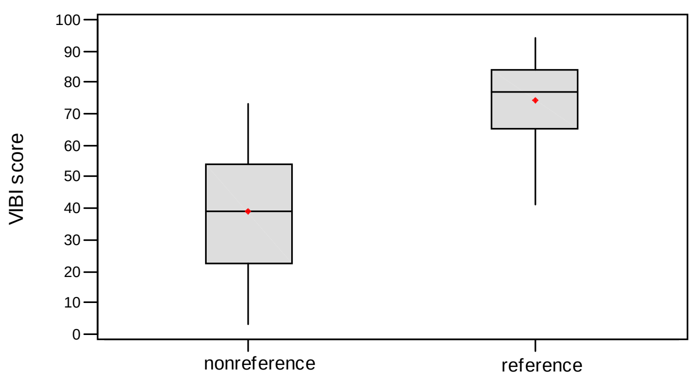

Figure 36. Box an whisker plots of all VIBI scores by wetland type (reference or nonreference condition, i.e. lacking in obvious human cultural influences). Dot is the mean score. Means were significantly different from one another (df=44, F=45.3, p=<0.001). A line is drawn across the box at the median. 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).

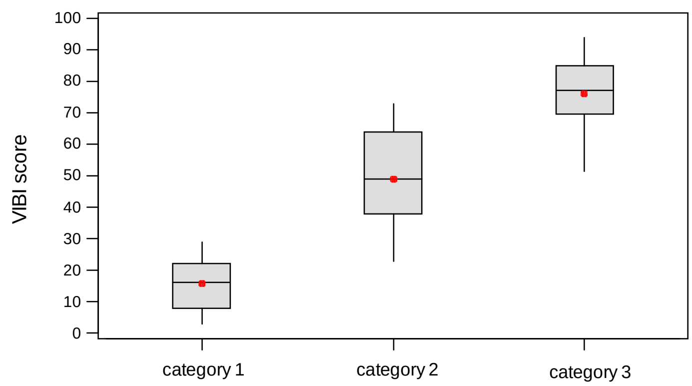

Figure 37. Box an whisker plots of all VIBI scores by wetland category Dot is the mean score. All means were significantly different from one another (df=44, F=67.7, p=<0.001). Line across the box is the median. The bottom of the box is at the first quartile (Q1), and the top is at the third quartile (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).

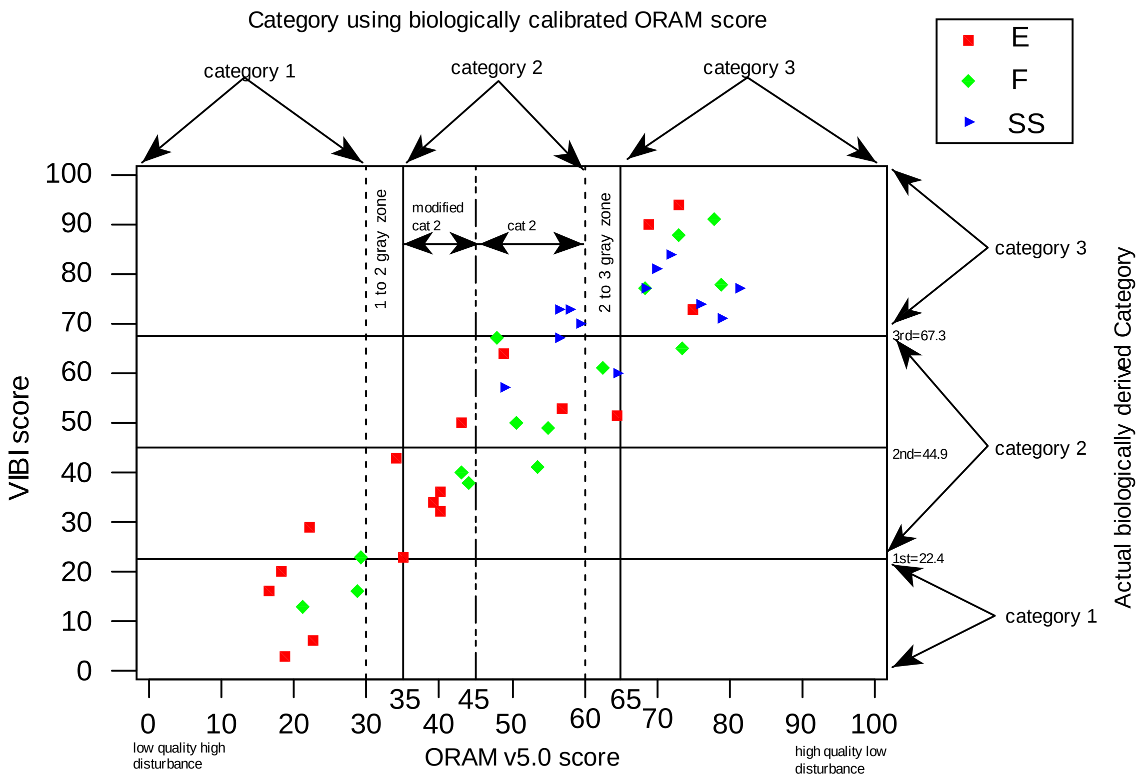

Figure 38. Interim VIBI scores and interim wetland categorization breakpoints for emergent, forested, and scrub-shrub wetland vegetation community classes and ORAM score for 45 wetlands in the Eastern Corn Belt Plains Ecoregion of the State of Ohio.

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Appendix 1
Site Characteristics

Appendix 2
Descriptive Statistics by Wetland Vegetation Class