DEALING WITH SOURCES OF VARIATION IN THE DEVELOPMENT OF WETLAND TIERED AQUATIC LIFE USES

Ohio EPA Technical Report WET/2007-6

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Appropriate Citation:

Mack, John J. 2007. Dealing with sources of variation in the development of wetland tiered aquatic life uses. Ohio EPA Technical Report WET/2007-6 Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

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DEALING WITH SOURCES OF VARIATION IN THE DEVELOPMENT OF WETLAND TIERED AQUATIC LIFE USES

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John J. Mack

ABSTRACT

The Vegetation Index of Biotic Integrity (VIBI) for Ohio wetlands was evaluated for significant differences due to ecological region, hydrogeomorphic (HGM) class, and dominant plant community. Significant ecoregional differences were observed for the first time. Marshes, swamp forests, and shrub swamps in depressional and riverine landscape positions in the glaciated Allegheny Plateau had higher VIBI scores than similar wetlands located in other ecoregions. But, ecoregion was not a significant variable for wet meadow communities (fens, wet prairies, prairie sedge meadows) and bog communities (tall shrub bogs, leatherleaf bogs, etc.) which had similar average VIBI scores across all ecoregions. Hydrogeomorphic class of reference standard wetlands was a significant variable with 5 non-overlapping groups: weakly ombrotophic bogs (96.7), strongly ombrotrophic bogs (67.8), riverine mainstem depressions (65.6), impoundments (78.3), slopes (82.1), and combined class of depressions (74.6), riverine headwater depressions (77.0) and coastal wetlands (75.5). Plant community class of reference standard wetlands was also a significant variable with four non-overlapping groups: fen meadows (85.5) and other wet meadow (wet prairie, sand prairies, etc.) communities (88.8), swamp forests (73.9), shrub swamps (67.1), and a combined group of forest seeps (78.7), marshes (78.1) and bogs (78.7). An analysis of average scores and 95th percentiles of classes defined by ecoregion, landscape position, and dominant vegetation resulted in 12 Tiered Aquatic Life Use (TALUs) categories with differing biological expectations. Numeric biocriteria were developed and this represents the first time wetland TALUs applicable to all wetlands in a state have been published.

INTRODUCTION

In most instances, Indices of Biotic Integrity (IBIs) are developed to be used in state or federal water resource programs. The Clean Water Act requires states to develop water quality standards for water resource protection and restoration. These standards typically include numeric chemical and/or biological criteria that are used to establish differing "uses" including aquatic life uses (e.g. Ohio Administrative Code Chapter 3745-1). These "tiered" uses are usually defined by the deviation of IBI scores or other biologically-based information from regional expectations, e.g. Ohio EPA (1988a, b, 1989a, b), Yoder and Rankin (1995).

A plant-based IBI for wetlands in the State of Ohio (Vegetation IBI) has been developed through multiple testing iterations for statewide use (Mack, 2004a, 2004b). As any plant ecologist of the last century would tell you, landscape position is a significant variable for determining plant community. Significant variation from ecoregion, landscape position (hydrogeomorphic or HGM class), or dominant vegetation can occur at multiple levels of community organization and data synthesis: at the community level with an analysis of species composition data; at the individual metric level with some types of wetlands scoring better or worse on average than other types; or at the level of composite index scores with significant differences in achievable biological expectations as measured by the IBI score. Ultimately, the variation that "matters," for the applied purposes that IBIs are developed, is variation that causes significant differences in the IBI score. Classification helps to control and partition variation into meaningful bundles of like sites; but wherever possible, the goal is to merge classes that have similar biological expectations: the working hypothesis being that while certain wetland types may differ in their floras at the species or community level, these species or communities behave in a similar manner in response to human disturbance (Karr and Chu 1999).

Ohio adopted wetland water quality standards in 1998 which narratively defined protection categories based on wetland quality and function (Ohio Administrative Code Rules 3745-1-50 to -54). A narrative approach was taken because data sets to define numeric criteria were not developed. Since 1998, reference wetland data sets have been collected and wetland IBIs using vascular plants (Mack, 2004b), amphibians (Micacchion, 2004), and macroinvertebrates (Knapp, 2004) have been developed. This paper evaluates differences in Vegetation IBI scores due to ecoregion, hydrogeomorphic class, and dominant vegetation, and proposes tiered aquatic life uses (TALUs) applicable to wetlands statewide. To the author's knowledge, this is the first time this has been done using a large reference wetland data set with ecoregion, landscape position (HGM or hydrogeomorphic class) and dominant plant community as TALU categories.

METHODS

A plot-based vegetation sampling method was used (Peet et al., 1998; Mack, 2004c), and a Vegetation IBI score was calculated for each sample site. Site selection, sampling methods, and VIBI development procedures are fully described in Mack (2004b) and are not recapitulated here. Sites were classified by hydrogeomorphic class and dominant plant community (Mack, 2004a) and by ecoregion (Omernik, 1987; Woods et al., 1998) (Figure 1).

Descriptive statistics, box and whisker plots, analysis of variance, and detrended correspondence analysis (DCA) (Hill and Gauch 1980; Gouch 1982) were used to evaluate variation in average and achievable VIBI scores. Minitab v. 12.0 was used for all analyses except DCA where PC-ORD was used (McCune and Mefford 1999). Even given the relatively large data set in this paper (n = 168), grouping by ecoregion, HGM class, and plant community resulted in many small sample groups. To address this, the data set was aggregated in order to compare mean VIBI scores by ecoregion (all HGM class and plant communities), then HGM class (all ecoregions, plant communities), and then plant community (all ecoregions and HGM classes). Because of uneven and/or small sample sizes, 5% scoring ranges (5 points out of 100 point maximum VIBI score) centered on mean values ($\pm$ 2 points of mean) were used instead of standard multiple comparison tests. Tiered Aquatic Life Uses were derived by calculating the 95th percentile of the VIBI score as recommended by USEPA (1990, 1998, 1999). The 95th percentile for sites grouped by ecoregion and HGM and plant community class were compared, and groups with similar percentiles were averaged and partitioned into sextiles and combined into TALU categories.

The starting point for this paper was the ordination and classification previously performed (Mack, 2004a) which demonstrated 1) the very strong effect of gross vegetation characteristics (forest, emergent, shrub), 2) multiple HGM classes and subclasses (depressions, impoundments, riverine mainstem, riverine headwater, slopes, fringing, bog, Lake Erie coastal), although there was poor definition of the depression and riverine mainstem classes, and 3) multiple plant community classes included swamp forests, bog communities, forest seeps, marshes, wet meadows (fens, wet prairies, etc.), and shrub swamp communities. The purpose of this analysis was to further define and/or combine classes by evaluating the effect of ecoregion, hydrogeomorophic class, and dominant vegetation on biological expectations.

RESULTS

Vegetation IBI scores varied significantly ($p < 0.001$) due to the ecological region of the wetland. Wetlands located in the glaciated Allegheny Plateau region (EOLP) (80.4) had, on average, significantly higher VIBI scores than wetlands located in the till plains (ECBP) (70.4) or the unglaciated Western Allegheny Plateau (WAP) region (63.8). There was a 6 point difference in average VIBI scores for ECBP and WAP wetlands, but this difference was not significant and is likely due to the fact that virtually all WAP wetlands are riverine systems which have lower VIBI scores (see below). However, the VIBI scores of certain plant communities and hydrogemorphic classes did not vary ecoregionally. The 95th percentiles for wet meadow communities (fens, wet prairies, sand prairies) were similar throughout Ohio (Table 1). Bog communities remaining in Ohio are nearly all confined to the EOLP, so ecoregion is not issue. Slopes (fens, forest seeps) also had similar biological expectations regardless of ecoregion (Table 1). Detrended correspondence analysis was used to evaluate differential performance on multiple metrics. Sites clustered based on metric values by ecological region (Figure 2). Sites in the EOLP clustered towards the left of Axis 1 and bottom of Axis 2, and sites in the ECBP did the opposite. Sites in the WAP were interspersed in the ECBP sites near the center of the metric vectors. Lake Erie coastal marshes clustered to the right of Axis 1 and bottom of Axis 2. The few HELP sites, mostly Lake Plains sand prairies were mostly scattered along the boundary between ECBP and EOLP sites.

Statistically significant differences due to hydromorphic class were observed (Table 2). VIBI scoring ranges of $\pm$ 2 points of mean (5% of maximum VIBI score of 100) were evaluated. Using this approach and comparing box and whisker plots (Figure 3), 5 non-overlapping HGM classes were observed: 1) weakly ombrotrophic bogs, 2) strongly ombrotrophic bogs, 3) riverine mainstem depressions, 4) slopes, and 5) a combined group (coastal, depression, riverine headwater depression, impoundment) (Table 2). Detrended correspondence analysis of shared metrics showed clustering based on HGM class indicating differential performance due to HGM class (Figure 4).

Dominant plant community was also a significant category (Table 2). Reference standard condition fens and wet meadow communities had higher, on average VIBI scores than marshes, swamp forests, bogs, forest seeps, and shrub swamps (Table 2). A comparison of box and whisker plots (Figure 5) and 5% VIBI scoring ranges, showed 4 non-overlapping plant community classes: 1) wet meadow communities (fens, wet prairies, sand prairies), 2) shrub swamps, 3) swamp forests, and 4) a combined class of forest seeps, bogs, and marshes (Table 2). Detrended correspondence analysis also showed differential metric performance across plant community types (Figure 6).

To summarize the results from the analyses discussed above: 1) ecoregion (EOLP v. all other regions) is an important additional category; 2) riverine mainstem depressions, although poorly defined in prior evaluations (Mack, 2004a), had lower VIBI scores than other classes; wet meadows, regardless of HGM class and ecoregion, had similar 95th percentile and average VIBI scores; 3) HGM and plant community class, in general, remained important categories for defining biological expectations.

The final step in developing tiered aquatic life uses (TALUs) for wetlands in Ohio was to synthesize the results from prior evaluations of wetland class (Mack, 2004a, b) and the results above, into numeric criteria. The 95th percentile of VIBI scores of wetlands in Table 1 were evaluated for similarities and combined into 12 TALU categories, and the 95th percentiles for groups comprising the category were averaged to obtain a composite score (Table 3). The development of separate VIBIs for emergent, forest, and shrub wetlands had the additional benefit of standardizing the VIBI scores for these plant communities and, with the exception of wet meadow communities, resulted in little or no significant difference in average or 95th percentile VIBI scores due to dominant vegetation. Thus, plant community classes were combined in Table 3. Wet meadow communities (slopes, depressions, etc.) were combined into a single TALU category since average scores and 95th percentiles of fens, wet prairies, and Lake Plain sand prairies were equivalent and showed little difference from HGM class or ecoregion. Although forest seeps had lower, on average, VIBI scores than fen meadows (emergent slopes) (Table 2), the 95th percentile of forest seeps and other slope wetlands was equivalent, and this distinct plant community was grouped with emergent slope communities (fens).

Separate depression TALU categories were defined for ECBP and EOLP wetlands because of large differences in average scores and 95th percentile scores. The WAP and HELP region were included in the ECBP class. Depressions are virtually absent as a hydrogeomorphic class in the WAP. Only 1 non-wet meadow depression in the HELP was included in this analysis. Additional data collected from wetlands in the HELP region, other than sand prairies in the Oak Openings, showed they are comprised of depressions in isolated woodlots or riverine mainstem systems very similar to depression and riverine ECBP wetlands (Mack, unpublished data).

Riverine mainstem sites from the ECBP, WAP, and HELP were combined into a single TALU category; EOLP riverine mainstem wetlands again comprised a separate group (Table 3). Reference standard impoundments and riverine headwater depressions were not able to be located (and may no longer exist) in the ECBP although they exist in the WAP. Impoundments and riverine headwater wetlands in the WAP were significantly different from EOLP wetlands, and these sites were used to define a combined WAP-ECBP-HELP category.

Although average and 95th percentile scores for Lake Erie coastal wetlands were not much different from many inland types, coastal wetlands were maintained as a separate TALU category based on the distinct character, geographic location and the results from earlier analyses (Mack, 2004). Finally, clear differences in average scores and 95th percentiles resulted in separate TALU categories for weakly ombrotrophic and strongly ombrotrophic bogs (Table 3).

Narrative TALU categories were previously described (Table 4) as well as special uses (values or ecological services) provided by wetlands (Table 5) (Mack, 2001; Mack 2004b). The average 95th percentiles of the TALU categories were partitioned into sextiles and combined into 4 aquatic life use categories proposed to define numeric biological criteria for Ohio wetlands: limited quality wetland habitat (LQWLH) (1st and 2nd sextiles), restorable wetland habitat (RWLH) (3rd and 4th sextiles), wetland habitat (5th sextile), and superior wetland habitat (SWLH) (6th sextile) (Table 6). Numeric TALUs (biological criteria) for Ohio wetlands were developed based on VIBI scores, ecoregion, landscape position, and plant community (Table 6). Using Tables 4 to 6, a wetland TALU can be assigned as described in the following example: the wetland being evaluated is a pumpkin ash (*Fraxinus profunda*) swamp in Fowler Woods State Nature Preserve. This is a swamp forest in a depression landscape position. After a detailed vegetation survey, a Vegetation IBI score of 76 is calculated. This wetland is classified as "IA1a" (depression, surface water/swamp forest) (Mack, 2004a). Referring to Tables 4 and 6, a Vegetation IBI score of 76 is in the SWLH (Superior Wetland Habitat) use range. Finally, Table 5 is consulted and it is determined that the wetland has educational uses as a state nature preserve that is open to the public. The Wetland Aquatic Life use designation can then summarized as "SWLH-IA1a$_B$", where

SWLH = means Superior Wetland Habitat, IA1a = surface water depression/swamp forest, and the subscript $_B$ = a special use of "educational."

DISCUSSION

Natural variation in biological expectations can be addressed in several ways during wetland IBI development. First, the data set can be partitioned *ab initio* by significant classes and completely separate IBIs developed, with unique metrics and metric scoring procedures. This was an approach taken here where the data set was partitioned into emergent, forest, and shrub dominated wetlands and separate IBIs were developed. The reason for this partition was both data-driven and pragmatic. Early analysis of reference wetland data revealed strong natural variation due to inherent differences in plant community characteristics from dominant vegetation (Mack et al., 2000; Mack, 2001). Pragmatically, some available attributes were just not available for some vegetation types. For example, metrics based on importance values of woody species do not make sense for emergent communities; productivity metrics like standing biomass do not make sense for forest communities with sparse herb layers. This division of the data set was later clearly demonstrated (Mack, 2004a) where community level data (species composition and relative abundance) was ordinated to evaluate the *a priori* classification scheme previously developed (Mack, 2004b). It confirmed the broad recognition of emergent, forest, and shrub dominated wetlands as well multiple plant community subclasses (Mack, 2004a). The ordination of community level data also confirmed differences due to hydrogeomorphic class (Mack, 2004a) including slopes, Lake Erie coastal, impoundments, bogs (including weakly to strongly ombrotrophic), riverine headwater, and a broad depression and riverine mainstem depression group. The distinction between riverine and non-riverine "depressional" systems was poorly defined at the level of community data (Mack, 2004a). This may be due to the fact that, after spring flooding is over, riverine mainstem depressions shift to a vertical hydrologic pathway dominated by evapotranspiration and precipitation similar to non-riverine depressions.

Second, natural variation can be addressed by setting different metric scoring expectations. For example if two different types of wetland are differentially performing on a metric, alternate scoring ranges can be established, or minor metric modifications or substitutions can be made. For example, the %sensitive species was modified for the VIBI-Shrub to exclude coverage of buttonbush (*Cephalanthus occidentalis*) from the metric calculation, or for Lake Erie coastal marshes, richness of Cyperaceae species was substituted for richness of *Carex* species (Mack, 2004b).

Finally, when attainable IBI scores vary due to ecoregion or other variables, e.g. hydrogeomorphic class, different set points for tiered aquatic life uses can be defined for those classes. Conversely, classes with similar biological expectations can be combined and the same IBI scoring range can be used. This last approach forms the basis of this paper.

Resolving the effect of HGM class is important for developing a valid IBI; but, it is also important from a public policy perspective since HGM functional assessments have been encouraged as the assessment approach for Section 404 wetland programs (Brinson, 1993, Smith et al., 1995 and others). But, the term HGM "functional" assessment is, at best, a misnomer since few, if any, HGM models measure functions (ecosystem processes) or even ecological services (values) directly (exceptions are functions like flood retention or water quality improvement where basically civil engineering or environmental chemistry modeling allow a reasonable quantification). A review of attempts at developing HGM functional assessments shows that structural parameters are far and away the most frequently measured variables and that HGM modesl attempt to infer functional level from structural variables (e.g. Rheinhardt et al., 1997, 2002; Stutheit et al. 2004). Stevenson and Hauer (2003) state that there is little difference between an IBI approach which measures "structural" variables and assumes that if the structure deviates little from "reference" condition, that the functions supporting that structure are also operating at reference levels; and an HGM approach, which measures structural variables and attempts to infer functional level directly by measuring the deviation of "structural" variables from "reference standard" condition.

While landscape is clearly a significant variable for IBI development not every conceivable landscape type is important. Hydrogeomorphic class, at least on its surface, appears to consider wetland vegetation to be "green stuff" on the ground. While hydrology and landscape position can determine what grows, what grows can be markedly different within the same HGM class, cf. slopes = calcareous fens, non-calcareous fens, forest seeps; cf. depressions = marshes, forests, sedge meadows, wet prairies, shrub swamps. A focus on HGM class alone can result in homogenization of very distinct wetland communities and create a likely insuperable problem in developing wetland assessment tools. This is true not just for a vegetation-based tool described here but also tools using faunal assemblages (e.g.

Micacchion 2004).

A main wetland program goal in developing wetland specific IBIs is to be able to specify numeric biological criteria for wetlands that correspond to various wetland designated uses. Standards like these will be incorporated into the State of Ohio's water quality standards just as standards for streams have been previously promulgated. The tiered aquatic life uses for wetlands are proposed with differing biological expectations based on landscape positions, plant communities, and ecoregions in Ohio. This represents the first time wetland TALUs applicable to all wetlands in a state have been published.

Far beyond meeting a mere legal mandate, the tiered aquatic life uses proposed here have multiple practical uses and form the foundation a complete wetland assessment program. Wetland TALUs and the reference data sets that they are based upon can be used in multiple ways including: defining numeric and narrative biological criteria for protecting wetland uses; developing and calibrating rapid wetland assessment methods (Mack, 2001); supporting wetland permitting and enforcement programs to define wetland protection categories and to determine what impacts if any should be allowed in application for wetland filling or modification; establishing ecologically-based performance criteria for wetland mitigation and restoration; and performing watershed or regional wetland condition assessments in support of Section 305(b) and 303(d) of the Clean Water Act.

This work was funded under Wetland Program Development Grants CD995927, CD995761, CD985277, CD985276, and CD985875.

REFERENCES

Brinson, M. M. 1993. A hydrogeomorphic classification for wetlands. U.S. Army Corps of Engineers Waterways Experiment Station. Wetlands Research Program Technical Report WRP-DE-4. Vicksburg, MS.

Gouch, H.G., Jr., 1982. Multivariate Analysis in Community Ecology. Cambridge University Press. 298 p.

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

Karr, J. R., and E.W. Chu, 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press, Washington, DC. 206 p.

Knapp, M., 2004. Integrated wetland assessment program. Part 8: wetland invertebrate community index (WICI). Ohio EPA Technical Report WET/2004-8. Ohio Environmental Protection Agency, Division of Surface Water, Ecological Assessment Section, Columbus, Ohio.

Mack, J.J., M. Micacchion, L. D. Augusta, and G. R. Sablak. 2000. Vegetation Indices of Biotic Integrity (VIBI) for Wetlands and Calibration of the Ohio Rapid Assessment Method for Wetlands v. 5.0. Final Report to U.S. EPA Grant No. CD985276, Interim Report to U.S. EPA Grant No. CD985875, Volume 1. Wetland Ecology Group, Division of Surface Water, Ohio Environmental Protection Agency, Columbus, Ohio.

Mack, J.J., 2001. Vegetation indices of biotic integrity (VIBI) for wetlands: ecoregional, hydrogeomorphic, and plant community comparison with preliminary wetland aquatic life use designations. Final Report to U.S. EPA for Grant No. CD985875, Volume 1. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Mack, J.J., 2004a. Integrated wetland assessment program. Part 2: an ordination and classification of wetlands in the Till and Lake Plains and Allegheny Plateau regions. Ohio EPA Technical Report WET/2004-2. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Mack, J.J., 2004b. Integrated wetland assessment program. Part 4: Vegetation Index of Biotic Integrity (VIBI) for Ohio Wetlands. Ohio EPA Technical Report WET/2004-4. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Mack, J.J., 2004c. Integrated wetland assessment program. Part 9: field manual for the vegetation index of biotic integrity for wetlands v. 1.3. Ohio EPA Technical Report WET/2004-9. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

McCune B. and M. J. Mefford, 1999.

Multivariate Analysis of Ecological Data v. 4.0. MjM Software. Glenenden Beach, Oregon, USA.

Micacchion, M., 2004. Integrated wetland assessment program. Part 7: amphibian index of biotic integrity for Ohio wetlands. Ohio EPA Technical Report WET/2004-7. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Ohio EPA, 1988a. Biological Criteria for the Protection of Aquatic Life: Volume I. The role of biological data in water quality assessment. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio EPA, 1988b. Biological Criteria for the Protection of Aquatic Life: Volume II. Users Manual for biological field assessment of Ohio surface waters. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio EPA,1989a. September 30, 1989 Addendum to Biological Criteria for the Protection of Aquatic Life: Volume II, 1988. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Assessment Section, Columbus, Ohio.

Ohio EPA,1989b. Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Assessment Section, Columbus, Ohio.

Omernik, J. M., 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77, 118-125.

Peet, R. K., T. R. Wentworth, and P. S. White, 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63, 262-274.

Smith R. D., A. Ammann, C. Bartoldus, and M. M. Brinson, 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical Report WRP-DE-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stevenson, R.J. and F. R. Hauer, 2002. Integrating hydrogeomorphic and index of biotic integrity approaches for environmental assessment of wetlands. Journal of North American Benthological Society 21, 502:513.

U.S. EPA. 1990. Biological Criteria. National Program Guidance for Surface Waters, Office of Water, Regulations and Standards (WH-585), U.S. Environmental Protection Agency, Washington, D.C., April 1990. EPA-440/5-90-004.

U.S. EPA. 1998. Lake and Reservoir

Bioassessment and Biocriteria. Technical Guidance Document. Office of Water, U.S. Environmental Protection Agency, Washington, D.C., August 1998. EPA 841-B-98-007.

U.S. EPA. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. Periphyton, Benthic Macroinvertebrates and Fish, 2nd Ed.. Office of Water, U.S. Environmental Protection Agency, Washington, D.C., July 1999. EPA 841-B-99-002.

Woods, A.J., J.M. Omernik, C.S. Brockman, T.D. Gerber, W.D. Hosteter, and S.H. Azevedo, 1998. Ecoregions of Indiana and Ohio (Map) and Supplementary text.

Table 1. Number of sites, 95th percentiles, and mean VIBI scores for all sites (reference standard and disturbed sites) by ecoregion, HGM class and subclass and plant community.

ecoregion	HGM class	HGM subclass	plant community	95th percentile	mean all/ref std	N	comment
ECBP[1]	depression	all	marsh	68	26.1/67.5	9	reference standard marshes virtually absent from ECBP.
			wet meadow	80	45.0/84.0	2	incl. highly degraded reed canary grass site
			shrub	79	54.5/60.8	11	
			forest	74	43.5/70.7	12	
	impoundment	all	marsh	19	19.0/--	1	no reference standard sites found
			wet meadow	---	---	---	no sites found
			shrub swamp	---	---	---	no sites sampled
	riverine	mainstem	marsh	56[2]	22.5/--	2	no reference standard sites
			wet meadow	56[2]	16.0/--	1	degraded reed canary grass meadow
			shrub	56[2]	33.3/64.0	3	
			forest	56[2]	27.5/46.0	2	
		headwater	marsh	56[2]	23.0/--	1	no reference standard sites
			wet meadow	56[2]	16.0/--	---	no reference standard sites
			shrub	---	---	---	no sites found
			forest	---	---	---	no sites found
	slope	all	marsh	---	86.0/86.0	1	incl. in wet meadow calculation
			wet meadow	96	77.5/85.8	7	all fens except one slope *Sparganium* marsh with marginal *Carex stricta* meadow
			tall shrub fen	---	---	---	no sites found
			forest seep	---	---	---	no sites sampled as of 2002
EOLP	depression	all	marsh	89	54.3/78.5	4	
			wet meadow	---	---	---	no sites found; all wet meadows in EOLP were slopes

[1] Including the following sites from the MIDP: buttonbush swamp, and 2 lacustrine fens (slopes).

[2] Percentile calculated from combined VIBI scores of all ECBP riverine mainstem sites (n = 8).

Table 1. Number of sites, 95th percentiles, and mean VIBI scores for all sites (reference standard and disturbed sites) by ecoregion, HGM class and subclass and plant community.

ecoregion	HGM class	HGM subclass	plant community	95th percentile	mean all/ref std	N	comment
			shrub	95	71.2/73.7	11	
			forest	91	74.0/83.0	11	
	impoundment	all	marsh	86	76.0/84.0	3	
			wet meadow	---	---	---	no sites found
			shrub	---	---	---	no sites found
	riverine	mainstem	marsh	87	45.1/81.3	9	incl. 3 highly degraded forests
			wet meadow	---	---	---	no sites sampled
			shrub	---	---	---	no sites sampled
			forest	---	13.0/--	3	incl. in marsh calculation
		headwater	marsh	84	51.5/83.0	5	incl. 1 highly degraded forest
			wet meadow	---	---	---	no sites sampled
			shrub	---	---	---	no sites sampled
			forest	---	16.0/--	1	incl. in marsh calculationt
	slope		marsh	---	69.0/69.0	1	incl. in wet meadow calculation
			wet meadow	92	84.7/84.6	8	all fens except one slope *Sparganium-Typha* marsh
			forest seep	92	77.0/81.5	6	
WAP	depression	---	---	---	---	---	extremely rare or nonexistent in ecoregion
	impoundment		marsh	75	71.6/--	3	
			wet meadow	---	---	---	no sites sampled
			shrub	64	46.0/67.0	2	
	riverine	mainstem	marsh	---	---	---	no sites sampled
			wet meadow	68	68.0/--	1	*Leerzia oryzoides* meadow developing on failed beaver imoundment with strong acid mine drainage groundwater input
			shrub	58	41.7/--	3	
			forest	73	63.3/64.0	4	

Table 1. Number of sites, 95th percentiles, and mean VIBI scores for all sites (reference standard and disturbed sites) by ecoregion, HGM class and subclass and plant community.

ecoregion	HGM class	HGM subclass	plant community	95th percentile	mean all/ref std	N	comment
		headwater	marsh	71	74.0/74.0	2	
			wet meadow	---	---	---	no sites found
			shrub	---	---	---	no sites sampled
			forest	---	---	---	no sites found
	slope		shrub	70	--/70.0	1	difficult to classify small headwater community with ground water input
	bog	weakly ombrotrophic	tamarack-hardwood, tall shrub bogs	100	92.0/96.0	5	incl. 1 highly degraded bog in ECBP, 1 tamarack hardwood bog in MIDP, 3 bogs in EOLP
		strongly ombrotrophic	leatherleaf, tamarack, open sphagnum bogs	72	67.8/67.8	4	
COASTAL[3]			marsh	72	53.3/70.5	12	
			shrub-forest	77	50.5/81.0	3	2 shrub sites, 1 forest site
HELP[4]	depression		wet meadow	96	90.5	4	All sites Lake Plains sand prairies
	riverine	mainstem	forest	67	67	1	

3 Lake Erie coastal marshes were located mostly in HELP region except for 5 sites in the EOLP.

4 Additional HELP sites sampled in 2003-2004 but data not presented here.

Table 2. Comparison of average VIBI scores by HGM class for reference standard sites (df = 79, F = 2.97, p = 0.009) and by dominant plant community for reference standard sites (df = 79, F = 4.12, p = 0.001). Because of uneven groups and small group sizes in some classes, multiple comparison test not performed. Classes with shared letters have overlapping 5% ranges.

HGM class	mean reference standard	n	5% range	plant community	mean reference standard	n	5% range
bog, weakly ombrotrophic	96.7 (3.5)	3	95 - 99a	wet meadow, fens	85.5 (8.3)	12	84 - 88a
bog, strongly ombrotrophic	65.3 (8.6)	4	63 - 67b	wet meadow, other	88.8 (7.5)	4	87 - 91a
coastal	75.5 (12.0)	2	74 - 78c	forest seep	79.8 (16.9)	3	78 - 82b
depression	74.6(15.2)	34	73 - 77c	bogs (all types)	78.7 (18.0)	7	77 - 81b
riverine, headwater	77.0 (6.0)	5	75 - 79c	marsh	78.1 (9.0)	18	76 - 80b
riverine, mainstem	65.6 (18.1)	11	64 - 68b	shrub swamp	64.7 (17.7)	19	63 - 67d
impoundment	78.3 (10.3)	3	76 - 80c	swamp forest	74.4 (12.4)	17	72 - 76e
slope	82.1 (11.6)	18	80 - 84d				
mitigation	---	---	---				

Table 3. Analysis of 95th percentiles of VIBI scores.

TALU group	ecoregion	HGM class	Plant community class	95th	N	avg 95th
1	COAST	Coastal	Marsh	72	12	74
			Shrub-Forest	77	2	
2	ECBP	Depression	Marsh	68	9	74
			Shrub Swamp	79	11	
			Swamp forest	74	12	
3	EOLP	Depression	Marsh	89	4	92
			Shrub Swamp	91	11	
			Swamp forest	95	11	
4	ECBP	Riverine mainstem depression	All (ECBP)	56	10	63
	WAP	Riverine mainstem depression	Shrub swamp	58	3	
	WAP	Riverine mainstem depression	Swamp forest	73	4	
	HELP	Riverine mainstem depression	Swamp forest	67	1	
5	EOLP	Riverine mainstem depression	Marsh	87	9	87
6	WAP	Riverine headwater depression	Marsh	77	2	73
		Slope, headwater	Shrub	70	1	
7	EOLP	Riverine headwater depression	Marsh	84	4	84
8	WAP	Impoundment	Marsh	75	3	69
			Wet meadow	68	1	
			Shrub swamp	64	2	
9	EOLP	Impoundment	Marsh	86	3	86
10	ALL	bog, strongly ombrotrophic	Leatherleaf,	72	4	72
			Sphagnum bogs	100	5	100
		bog, weakly ombrotrophic	Tall shrub,			
			Tamarack-hardwood			
11	ALL	Slope	Wet meadow, fen	96	7	91
		Slope	Forest seep	92	6	
		Slope	Wet meadow, fen	92	8	
		Slope	Tall shrub fen	85	2	
		Depression	Wet meadow, other	84	2	
		Depression	Wet meadow, other	96	4	

Table 4. Narrative descriptions of Wetland Tiered Aquatic Life Use Designations.

designation	definition
Superior Wetland Habitat (SWLH)	Wetlands that are capable of supporting and maintaining a high quality community with species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 83% (five-sixths) of the 95th percentile for the appropriate wetland type and region as specified in Table 11.
Wetland Habitat (WLH)	Wetlands that are capable of supporting and maintaining a balanced, integrated, adaptive community having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 66% (two-thirds) of the 95th percentile for the appropriate wetland type and region as specified in Table 11.
Restorable Wetland Habitat (RWLH)	Wetlands which are degraded but have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community of vascular plants having a species composition, diversity, and functional organization comparable to the vegetation IBI score of at least 33% (one-third) of the 95th percentile distribution for the appropriate wetland type and region as specified in Table 11.
Limited Quality Wetland Habitat (LQWLH)	Wetlands which are seriously degraded and which do not have a reasonable potential for regaining the capability of supporting and maintaining a balanced, integrated, adaptive community having a species composition, diversity, and functional organization comparable to the vegetation IBI score of less 33% (one-third) of the 95th percentile for the appropriate wetland type and region as specified in Table 11.

Table 5. Special wetland use designations.

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

Table 6. Wetland Tiered Aquatic Life Uses (WTALUs) for Ohio Wetlands. tbd = to be developed. LQWLH = limited quality wetland habitat, RWLH = restorable wetland habitat, WLH = wetland habitat, SWLH = superior wetland habitat. Equivalent antidegradation categories as specified in Ohio Administrative Code Rule 3745-1-54 are indicated in parentheses below the TALU category.

HGM class	HGM subclass	plant community	ecoregions	LQWLH (Category 1)	RWLH (modified Category 2)	WLH (Category 2)	SWLH (Category 3)
Depression	all	Swamp forest, Marsh, Shrub swamp	EOLP	0 - 30	30 - 60	61 - 75	76 - 100
			all other regions	0 - 24	25 - 50	51 - 62	63 - 100
	all	Wet Meadow (prairies, sedge-grass communities that are not slopes)	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Impoundment	all	Marsh, Shrub swamp	EOLP	0 - 26	27 - 52	53 - 66	67 - 100
			all other regions	0 - 24	25 - 47	48 - 63	64 - 100
		Wet Meadow (prairies, sedge-grass communities that are not slopes)	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Riverine	Headwater	all	EOLP	0 - 27	28 - 56	57 - 69	70 - 100
			all other regions	0 - 23	24 - 47	48 - 59	60 - 100
	Mainstem	all	EOLP	0 - 29	30 - 56	57 - 73	74 - 100
			all other regions	0 - 20	21 - 41	42 - 52	53 - 100
	Headwater or Mainstem	Wet Meadow (prairies, sedge-grass communities that are not slopes)	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Slope	all	Wet meadow (fen), tall shrub fen, forest seep	all regions	0 - 29	30 - 59	60 - 75	76 - 100
Fringing[1]	Natural Lakes (excluding lacustrine fens) and reservoirs (impoundments)	tbd	tbd	tbd	tbd	tbd	tbd
Coastal[2]	closed embayment, barrier-protected, river mouth	all	all regions	0 - 24	25 - 49	50 - 61	62 - 100
	open embayment, diked (managed, unmanaged, failed)	tbd	tbd	tbd	tbd	tbd	tbd
Bog	weakly ombrotrophic	Tamarack-hardwood bog, Tall shrub bog	all regions	0 - 32	33 - 65	66 - 82	83 - 100
	moderately to strongly ombrotrophic	Tamarack forest, Leatherleaf bog Sphagnum bog	all regions	0 - 23	24 - 47	48 - 59	60 - 100

1. Depending on the circumstances, scoring breaks for depression, impoundment, or riverine may be used.
2. Scoring breaks for coastal embayment, barrier-protected, and river mouth may be usable.

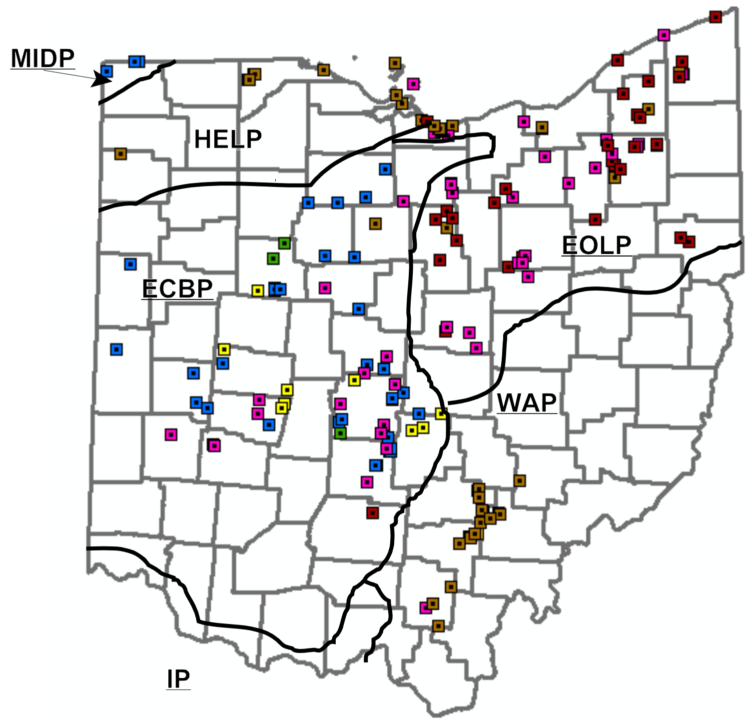
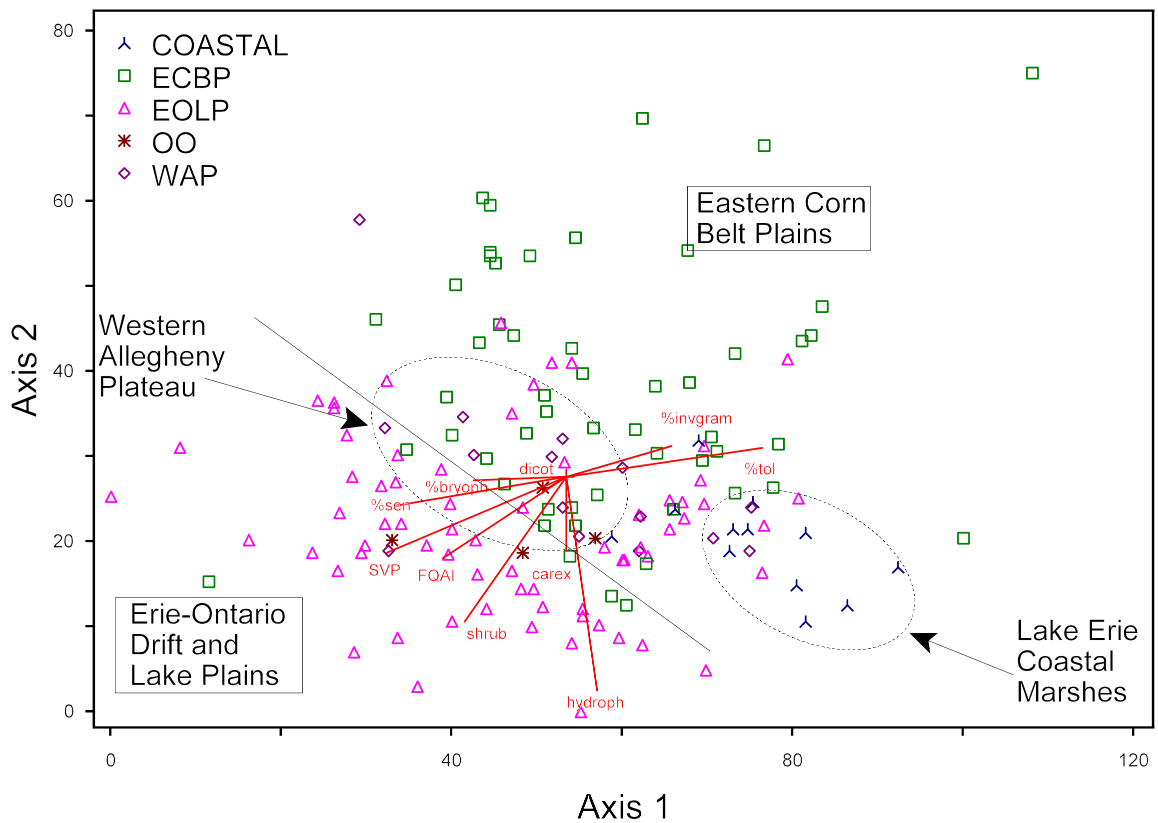


Figure 1. Wetland reference sites in Ohio and approximate ecoregional boundaries. MIDP = Michigan-Indiana Drift Plains, HELP = Huron-Erie Lake Plains, ECBP = Eastern Corn Belt Plains, EOLP = Erie-Ontario Drift and Lake Plains, WAP = Western Allegheny Plateau, IP= Interior Plateau (Woods, et al. 1998).



Figu
re 2. Detrended correspondence analysis of shared VIBI metrics for all sites excluding mitigation wetlands with ecological region of wetland location. COASTAL = Lake Erie coastal wetlands, ECBP = Eastern Corn Belt Plains, EOLP = Erie-Ontario Drift and Lake Plains, OO = Oak Openings subregion wetlands, WAP = Western Allegheny Plateau. Note general separation of ECBP wetlands from EOLP wetlands, although some better quality ECBP interspersed with EOLP wetlands. Also note, relatively distinct coastal wetland group. Four wetlands located in Michigan-Indiana Drift Plains (MIDP) included in ECBP.

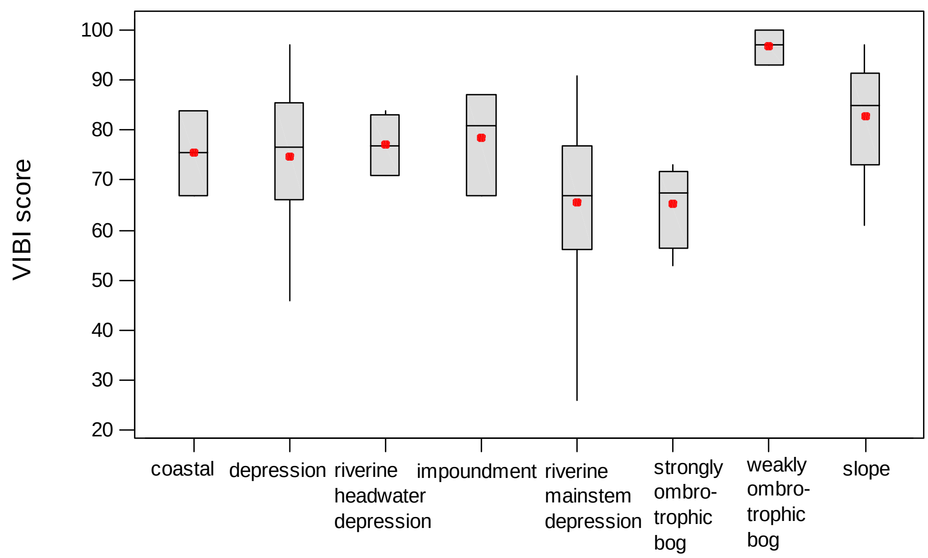


Figure 3. Box and whisker plots of Vegetation IBI scores for reference standard sites by hydrogeomorphic class (df = 79, F = 2.97, p = 0.009). Box represents 25th and 75th percentiles, bar = median, dot = mean. The whiskers are defined by the following limits: lower (Q1 - 1.5 *(Q3 - Q1)); upper (Q3 + 1.5 *(Q3 - Q1)). Outliers are points outside of the lower and upper limits (*).

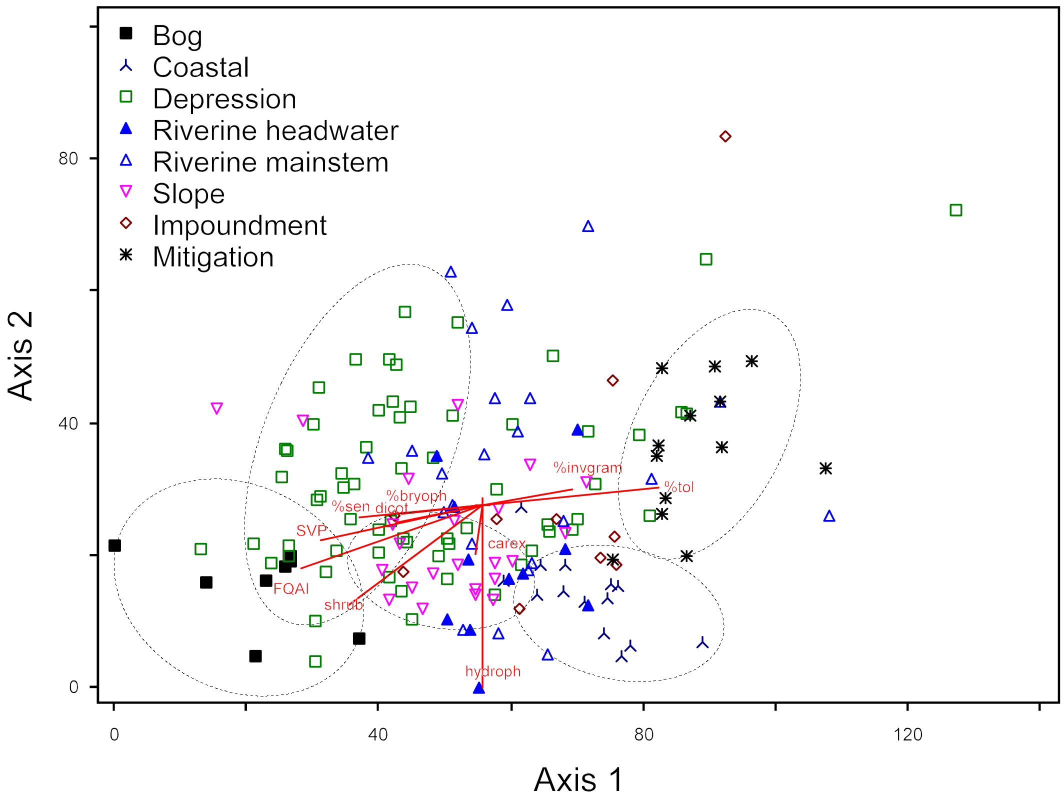


Figure 4. Detrended correspondence analysis of shared VIBI metrics for all sites by HGM class. Note differing metric performance due to HGM class from general grouping of bog, slope, coastal, depression, riverine, and mitigation classes.

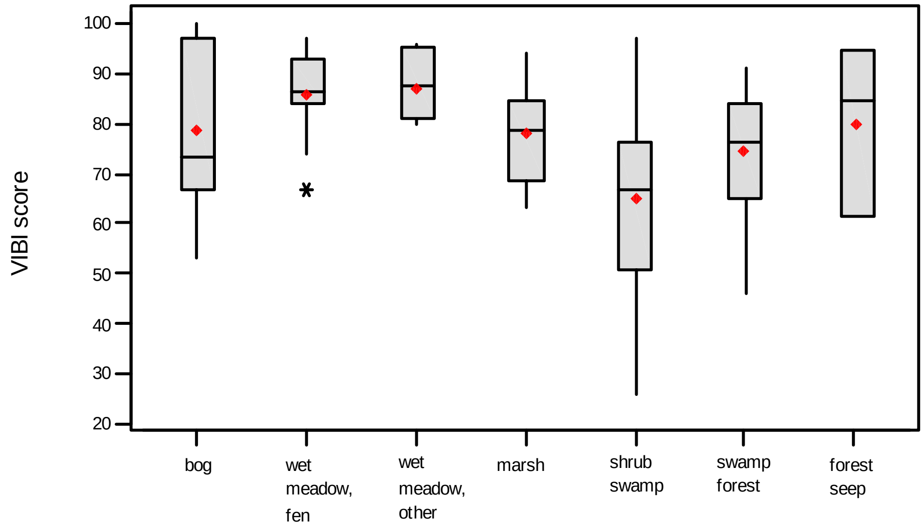


Figure 5. Box and whisker plots of Vegetation IBI scores for reference standard sites by plant community (df = 79, F = 5.73, p < 0.001). Box represents 25th and 75th percentiles, bar = median, dot = mean. The whiskers are defined by the following limits: lower (Q1 - 1.5 *(Q3 - Q1)); upper (Q3 + 1.5 *(Q3 - Q1)). Outliers are points outside of the lower and upper limits (*).

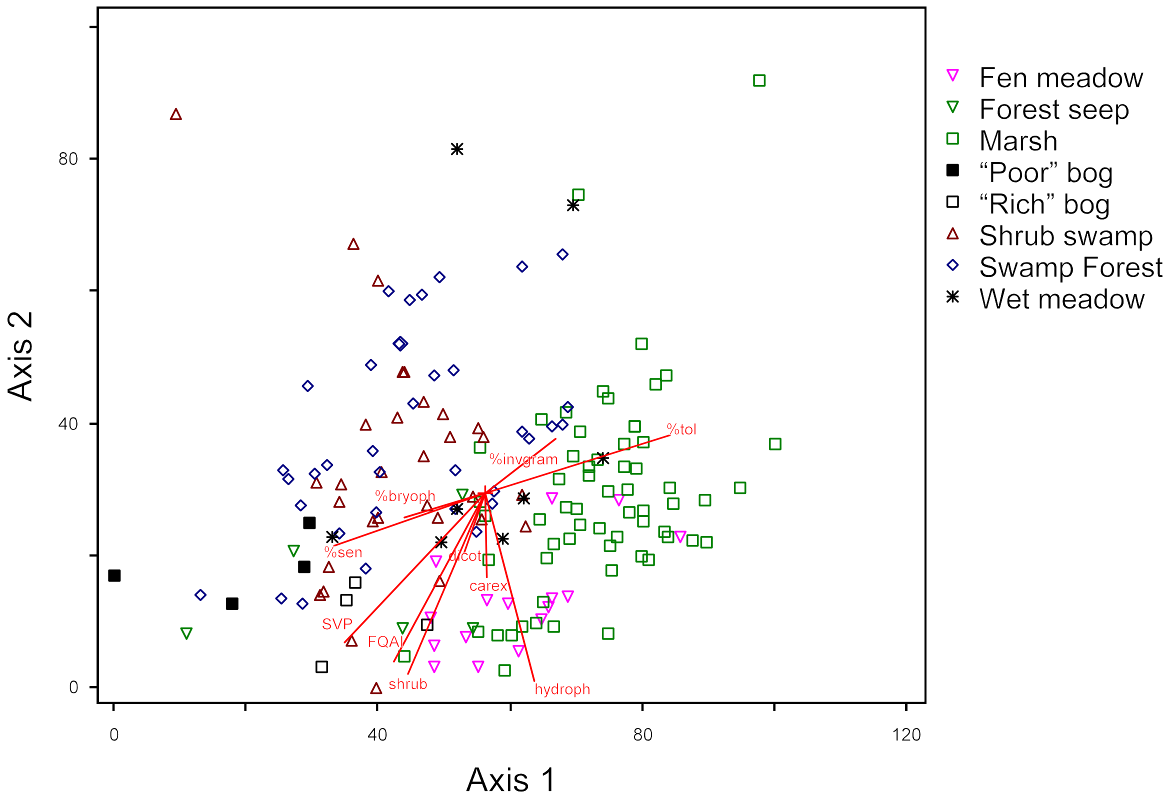


Figure 6. Detrended correspondence analysis of shared VIBI metrics for all sites excluding mitigation wetlands by dominant plant community. Fen meadow = all fens (slope wetlands with emegent sedge-grass communities), Forest seeps = slope wetlands with closed canopies of trees, Wet meadow = other grass/sedge dominated wetlands without significant ground water hydrologies (i.e. not slopes), Marsh = various mixed emergent marshes, Shrub swamp = shrub dominated wetlands that are not bogs or fens, and Swamp forest = wetlands with closed canopies of trees that are not bogs or fens.