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Development of volunteer-driven indices of biological integrity for wetlands in West Virginia

Walter Emil Veselka IV
West Virginia University

Development of Volunteer-Driven Indices of Biological Integrity for Wetlands in West Virginia

Walter Emil Veselka IV

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James T. Anderson, Ph.D., Major Advisor
James Rentch, Ph.D., Committee Member
Walter S. Kordek, Committee Member

Division of Forestry and Natural Resources

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ABSTRACT

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Walter Emil Veselka IV

Wetland indices of biological integrity (IBIs) are used to satisfy the water resources monitoring requirements of the Clean Water Act (CWA). However, debate still exists on what classification systems and taxa to base these IBIs upon. Our cumulative research, representing indices of biological integrity designed for regional HGM subclasses, designated HGM management classes and Cowardin et al. (1979) classes for West Virginia. The indices were derived from metrics calculated from anuran, avian, macroinvertebrate, and vegetation communities; each representing increasing levels of resources associated with gathering the necessary data. For example, avian and anuran data used to derive floodplain wetland IBI metrics can be collected by volunteers, but the disturbance scores only account for 46% and 18% of the variation in IBI scores, respectively. Alternatively, the disturbance scores account for 56% and 47% of the variation in vegetation and invertebrate IBI scores, respectively. However, if the floodplain wetland was also a scrub-shrub wetland, by adding the avian and anuran metrics of both floodplain and scrub-shrub IBIs, the resulting hybrid-class, multi-taxa IBI disturbance scores accounts for 89% of the variation in IBI scores. We evaluate each of these taxa groups alone and in combination, in single and hybrid classification schemes, to examine changes in sensitivities to the disturbance gradient. The result is a decision making tool that can assist resource managers by providing them with the opportunity to stretch finite resources; while still ensuring the monitoring captures changes in wetland communities due to human disturbance.

Keywords: *Indices of biological integrity, IBIs, wetlands, disturbance, anuran communities, avian communities, macroinvertebrate communities, vegetation communities, West Virginia.*

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Table of Contents

Chapter 1: List of Figures

Chapter 2: List of Tables

Chapter 2: List of Figures

Chapter 3: List of Tables

Chapter 3: List of Figures

Chapter 4: List of Tables

Chapter 4: List of Figures

Chapter 5: List of Tables

Chapter 5: List of Figures

Chapter 6: List of Tables

Chapter 6: List of Figures

List of Appendices

Chapter 1

West Virginia Wetland Indices of Biological Integrity

Introduction and Justification for the Development of Wetland Indices of Biological Integrity for Wetlands in West Virginia

Walter Veselka IV[1]
James T. Anderson[1, 3]
Walter S. Kordek[2]

[1] Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

[2] West Virginia Division of Natural Resources, Wildlife Resources Section, PO Box 67, Ward Road, Elkins, WV 26241

[3] address correspondence to James T. Anderson, Ph.D., Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506. *email:* wetland@wvu.edu*phone:* (304) 293-2941 ext. 2445, *fax:* (304) 293-2441

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1.0 Introduction

The Clean Water Act (CWA) of 1972 is the instrument by which water quality is protected within the United States. Through court decisions, the interpretation of this legislation has changed over time (Adler 1999; Downing et al. 2003; Murphy 2006). However, the CWA is generally considered to be effective in maintaining water quality, ensuring anti-degradation of water, and in slowing the rate of wetland loss.

The basis for the CWA focuses on "maintaining the chemical, biological, and physical integrity of waters within the United States." As this pertains to wetlands, the CWA has evolved into a process and structure by which the destruction of wetlands due to anthropogenic impacts must be mitigated, through either the creation of new wetlands, or the restoration of degraded ones. The wetlands created or restored as a result of mitigation have replicated the natural wetlands which they replaced with mixed success (Balcombe et al. 2005a,b,c; Brown and Veneman 2001; Cole and Brooks 2000a; Perry et al. 1996). However, as more research is being devoted to understanding the role wetlands play within a landscape, the prospects for successful mitigation are increasing (Brooks et al. 2005; Mitsch and Wilson 1996). Reference wetlands with minimal human impact are being used to evaluate mitigation success of wetlands with a landscape context (Bedford 1996; Brinson and Rheinhardt 1996). However, the true ecological success of these mitigated sites remains relative and subjective. For instance, mitigated wetlands are well-documented in improving water quality (Fleming-Singer and Horne 2006; Kovacic et al. 2006; Poe et al. 2003; White and Bayley 1999). However, the restoration of the biological flora and fauna, as well as the hydrologic and physical characteristics compared to natural wetlands, is questionable. Soil characteristics and hydrology of created wetlands are typically wetter than natural wetlands (Cole et al. 2006; Cole and Brooks 2000b), and lack variation in microtopography (Bruland and Richardson 2005; Stolt et al. 2000). Vegetation development and structure differ between natural and mitigated wetlands (Balcombe et al. 2005a; Brown and Veneman 2001); but this is not necessarily indicative of a mitigated wetland not performing the same ecosystem functions as natural wetlands (Wilson and Mitsch 1996). As may be expected, if differences in vegetation communities are not uncommon, neither are differences in invertebrate communities (Balcombe et al. 2005b; Stanczak and Keiper 2004), or avian (Brown and Smith 1998; Snell-Rood and Cristol 2003) and anuran assemblages (Balcombe et al. 2005c).

The process of determining whether wetland integrity is compromised has historically been through monitoring water chemistry. However, protecting wetlands in this manner does not ensure that the physical or biological integrity is being maintained. Chemical measurements are evidence of the condition at a point in time and the cumulative biotic effects of the chemical stressors may not be evident. Measuring physical parameters of a wetland can also overlook biological and chemical stressors affecting a system (Karr and Chu 1999; Yoder and Rankin 1995). Within the current federal wetland policy, despite the CWA mandate to protect water quality, wetland function and biotic integrity can be compromised from anthropogenic impacts in proximity to the wetlands (Harris 1988; Winter 1988; Yuan and Norton 2004). The functions that wetlands provide (e.g., the transfer and storage of water, production of plants and animals, biochemical transformation and storage, decomposition of organic materials, and provision of habitat) (Ehrenfeld 2004; Richardson 1994), occur on multiple spatial scales within a matrix of landscapes (Zedler 2003). Therefore evaluating the impacts and stressors that can influence wetlands also needs to be evaluated over time on a landscape basis (Bedford and Preston 1988; Hemond and Benoit 1988; Risser 1988; Whigham et al. 1988).

As the tools used to interpret and implement the CWA mandates have evolved, indices of biotic integrity (IBIs) have emerged as a cost-effective way of measuring the biological integrity of multiple systems both domestically and internationally (Karr and Chu 2000; Karr 1991; Miltner et al.2004; Moyle and Randall 1998; Simon et al. 2000; Teels et al. 2004; Veraat et al. 2004). Metrics, or biological attributes that respond minimally to natural disturbance while responding in a predictable and consistent manner to human impairment, are used to form IBIs. Biological integrity is specifically and operationally defined as the state of biota in systems with minimal human disturbance (Jackson and Davis 1995; Steedman 1995). A central premise to integrity is the assumption that all biological systems evolve towards a product of self organization resulting in community structure as a function of both positive and negative feedback (Campbell 2000). Community structure requires a prescribed amount of energy to maintain itself. With significant impacts via human impairment, the energy required to maintain this structural integrity is no longer attainable. As the system adapts, the shift will be represented by changes in biotic structure (Klopatek 1988). Changes in biotic structure should not be confused with differences in species' abundances and distributions due to differing wetland types (Brinson 1988), so a hierarchal approach to biological assessments that evaluates the community and population dynamics, within a regional landscape context, is best to detect losses in wetland function and regional biodiversity (Noss 1990). Deciphering the impairments of wetlands at multiple scales is important when seeking an understanding of open systems (Jacobson 2000); however, caution must be taken to consider *apropos* variables that are the stressors rather than symptoms or by-products of stressors. For example, the percent of impervious surface is the stressor, whereas roads and development are symptoms of the stressor (Brooks et al. 1998; Novotny et al. 2005).

A critical component in developing an IBI is the identification of an effective disturbance gradient that is sensitive enough to exhibit multiple levels of human disturbance (Mack, 2005, *personal communication*; U.S. EPA 2002). Local-level disturbance indices that require a site visit for assessment have been developed and used in Pennsylvania, Ohio, Minnesota, and Delaware to compare site-specific disturbance scores to biological attribute metric scores (Brooks et al. 2006;Helgen and Gernes 2002; Jacobs 2006; Mack 2001). Although each state has developed a disturbance assessment procedure, they are all based in-part on wetland stressors drawn from literature (Adamus and Brandt1990). In some of the above-mentioned states, the site level stressor gradient is augmented by data from spatial features to increase sensitivity of the disturbance index (Brooks et al. 2006). Using a geographic information system (GIS) is more cost-efficient than individual on-site visits (Brooks et al. 2004). Using only GIS derived data, a Landscape Disturbance Index (LDI) has served as the disturbance gradient in assessing human impairment (Brown and Vivas 2005). However, on-site assessments are generally more effective in demonstrating significant relations and explaining a greater part of the variability associated with metrics (Micacchion 2004).

States have developed IBIs for wetlands using multiple assemblages of species including algae, plants, fish, macroinvertebrates, and birds (U.S. EPA 2002). By sampling multiple taxonomic groups there can be numerous candidate metrics from which to evaluate impairment to better understand the full complexity of wetland systems (Dale and Beyeler 2001; O'Connor et al. 2000).

Wetlands are commonly classified by vegetation structure (Cowardin et al. 1979) and will be referred to as the "Cowardin" classification method in this document. The Cowardin classes have been demonstrated to be an effective categorization for an amphibian-based IBI in Ohio wetlands (Miccachion 2004). This scheme groups wetlands as emergent (EM) (Figure 1), scrub-shrub (SS) (Figure 2), and forested (FO) (Figure 3); and is used in mapping by the National Wetland Inventory (NWI). An alternative to using vegetation to classify wetlands is the hydrogeomorphic (HGM) approach (Brinson 1993). The HGM classification resolves many of the shortcomings of the Cowardin approach. For example, in the Cowardin classification system a palustrine emergent wetland may be found along a river floodplain, fringing a lake, or as a prairie pothole; all of which are functionally dissimilar (Stevenson and Hauer 2002). The HGM approach is based on physical determinants of wetland structure and function, according to the geologic setting and hydrologic regime; therefore, allowing the aggregation of wetlands that are functionally similar (Smith et al. 1995).

When interpreting biological studies within wetlands it is necessary to think in terms of the influence that climate and hydrologic settings have on biological communities. This continuum is most easily thought of as a two-dimensional gradient represented by groundwater and atmospheric water. By locating the position of any wetland along both axes of the continuum, the potential biological expression of the wetland community can be predicted (Euliss et al. 2004). However, determining this point of hydrologic variability for wetlands is difficult and can complicate matters when attempting to apply and interpret it in relation to an IBI (Wilcox et al. 2002). Appropriate classifications, especially relative to hydrologic regimes, are essential to developing an effective IBI (Karr and Chu 1999). By classifying wetlands according to HGM subclasses, the subclasses themselves can be used as surrogate categorical variables to characterize hydrologic variability (Cole and Brooks 2000b; Cole et al. 1997; Merkey 2006). The coupling of the HGM approach of classifying wetlands with the IBI approach for measuring wetland impairment has been called for to increase the effectiveness and sensitivity in detecting disturbance (Stevenson and Hauer 2002). This technique achieved success in North Carolina (Rheinhardt et al. 1999) and Pennsylvania (Brooks et al. 2006).

In developing IBIs or bioassessments, stratification by ecoregion is important to reduce variance in the final product (Klopatek 1988; Omernik 1995). In some cases, indices can be sufficiently robust for use in multiple ecoregions (Hill et al. 2003; McCormick et al. 2001); however, multiple IBI standards have been developed to account for detectable, predictable, ecoregion variation (Mack 2001). Level 3 ecoregions (Omernik 1987) are the level of resolution used in existing regional IBI programs (Mack 2004; Micacchion 2004; Miller et al. 2006; Miller et al. 2004).

2.0 West Virginia

Funding from the U.S. Environmental Protection Agency (EPA) and mandates under Section 316(b) of the CWA will enable West Virginia to develop monitoring standards and protocols that will ensure the protection of wetlands by 2011. Anticipating a shortage of future funding to support such programs, the West Virginia Division of Natural Resources (WVDNR) is focused on maximizing the effectiveness and efficiency of such a program. By borrowing lessons from other existing wetland monitoring programs, West Virginia's program development will be both time and cost-effective. Methods easily integrated into existing or planned West Virginia Wildlife Diversity Program (WDP) monitoring programs could cost less to drive this monitoring effort (Kordek, WVDNR, *personal communication*). West Virginia can maximize returns on expenditures, while maintaining or increasing surveying effort by selecting biological assemblages that can, at least in some capacity, be effectively surveyed by trained volunteers (Fore et al. 2001; Krzys et al. 2002; Witten 2005). Although methods implemented in this West Virginia study may differ from other monitoring programs, testing and evaluating existing IBI metrics and disturbance gradients can yield similar results (Herbst and Silldorff 2006).

The objectives in developing a wetland IBI for West Virginia are:

- Develop a protocol by which natural and mitigated wetlands can be monitored over time for changes and trends in biological integrity;
- Provide a tool by which the performance of mitigated wetlands can be compared to natural wetlands;

- Build a series of robust IBIs for Cowardin and HGM classifications that can be applied state-wide, will be responsive to a local disturbance gradient, and that will serve as a baseline for future researchers to develop a landscape-level "Sensitivity Index" to predict the effects of land-use changes on biotic assemblages, allowing for more focused monitoring and restoration efforts.

Accomplishing these objectives will occur over multiple stages. Sites will be selected across the state to represent the gradient of human impact to wetlands found in West Virginia. After intensive biological surveys at each site, a pool of potential metrics will be identified from the body of literature for each taxa group. Using the 75th and 25th percentile of a disturbance index, reference and stressed thresholds will be defined independently for the HGM and Cowardin classification schemes (Barbour et al. 1995). We will examine the relation between each taxa-specific suite of potential metrics and Cowardin and HGM classifications. Reference and stressed sites will then be plotted by potential metric using box-and-whisker plots. A rating system is used to examine the amount of overlap between reference and stressed sites that will generate a list of candidate metrics (Barbour et al. 1996). The candidate metrics will be tested for redundancy using Spearman's R statistic. Metrics with an r-value of >0.80 will be examined one-by-one to identify redundancy. The redundant candidate metrics that are least efficient in discriminating between the reference and stressed conditions will be discarded. An analysis of variance (ANOVA) will then test for an interaction between and among the remaining factors and the Level 3 aquatic ecoregion stratum within West Virginia (Barbour et al. 1999). After the elimination of metrics with an ecoregion or alternative classification scheme effect, we will examine the entire suite of metrics using a multivariate analysis of variance (MANOVA) to ensure the derived indices of biological integrity do not exhibit a cumulative ecoregion or alternative classification scheme effect. The resulting metrics will be included in the formation of a multimetric IBI. Each metric will be normalized to have a range of 0 to 10, which will give us consistent scaled response levels for each metric (Bryce et al. 2002). Metrics for each biological assemblage sampled can then be added to form a taxon-specific IBI (Gerritsen 1995). These taxon-specific IBIs will then be used to compose a multi-taxa IBI (Griffith et al. 2005; O'Connor et al. 2000). Moreover, we will examine the sensitivity of hybrid IBIs, formed by combining metrics from the Cowardin and HGM classification schemes, to disturbance scores. Comparisons can then be drawn contrasting the sensitivities of multi-taxa IBI and taxon-specific IBIs using individual or hybrid wetland classifications.

Once this IBI has been developed it will provide a method for comparing like wetlands, including mitigated (i.e., constructed), with a consistent scoring technique over time. This will allow the detection of wetland trends as well as provide ways to evaluate the success of mitigation.

The wetland IBI will be used in conjunction with the existing stream condition index (Gerritsen et al. 2000), to monitor the health and quality of the states' waters, as mandated by the CWA (Kordek, 2007, *personal communication*). The intention is to use the wetland IBI to validate the effectiveness of a rapid wetland assessment. Wetlands assessed by the rapid assessment method will, in turn, be used to validate landscape level wetland assessments. Landscape level assessments, calibrated and verified by rapid wetland assessment methods, are the only cost-effective means of assessing the status of the wetlands in the state. Areas selected for more intensive study may be regionally (or otherwise) stratified such that a complete statewide wetland resource assessment could be completed on a regular basis. A similar approach is used to monitor other water bodies such that each 8-digit hydrologic unit code (HUC) is assessed once every 5 years. Selected wetlands will be evaluated using a rapid assessment procedure, and a subset will receive intensive biological surveys leading to IBIs that validate the larger sample. The results of these surveys will be used to identify individual wetlands and watersheds at risk or in poor condition. The WVDNR will use the wetland IBI to gauge the improvement in the health of these impacted wetlands. Before purchasing or restoring wetlands within impacted watersheds, an IBI can determine what wetland or series of wetlands are most biologically "intact," to maximize the effect of resources directed to restoration.

3.0 Vegetation

Vegetation assemblages have historically been used as a component in identifying jurisdictional wetlands (USACOE 1987), and recently used in the formation of multimetric vegetative IBIs to assess the integrity of wetlands (Chipps et al. 2006; Gernes and Helgen 2002; Mack 2004; Miller et al. 2006; Witten 2005). Plants are immobile, making plant communities well-suited as indicator assemblages, as they are susceptible to influences within their environment. For instance, vegetation communities respond in a predictable manner to anthropogenic disturbances, such as sedimentation (Mahaney et al. 2004a), nutrient enrichment (Craft and Richardson 1997; Drohan et al. 2006), and changes in hydrology (Koning 2005; Magee and Kentula 2005).

Multiple researchers from various regions within the United States and abroad have determined that hydrology is often the primary driver in the expression of wetland plant communities (Aznar et al. 2003; Kirkman et al. 2000; Koning 2005; Magee and

Kentula 2005). There are other local effects that influence plant communities, but with varying degrees of magnitude. Age of constructed wetlands explains some variation in plant communities (Balcombe et al. 2005a). Wetland size is linked to wetland species richness, although this relation weakens from ~20% of the variance explained to ~10%, when upland plants are included in analysis of playas in the Southern High Plains of Texas (Smith and Haukos 2002). Natural disturbances or fire influences succession of plant communities in both Canadian sphagnum wetlands and Atlantic Coastal Plain depressional wetlands (DeSteven and Toner 2004; Lachance and Lavoie 2004). The colonization by invasive or exotic species has prevented the expression of some natural vegetation assemblages regionally and in West Virginia (Drohan et al. 2006; Mahaney et al. 2004a, 2004b).

Vegetation assemblages also have been evaluated in a landscape context using GIS technologies. In Texas playas, as the percentage of agricultural land within a wetland basin increases, there is a predictable increase in plant diversity, consisting of mostly exotics and few native perennial species (Smith and Haukos 2002). In Minnesota, the proportion of disturbed land within 500 m of a wetland, the number of storm water inputs and the degree of cultivation explained 32% of the variation associated with percent native and herbaceous perennials (Galatowitsch et al. 2000). Ditches, canals, and other hydrologic modifiers connecting wetlands have been linked to the increased dispersal and propagation of invasive species (Aznar et al. 2003).

Vegetation metrics were designed, in part, to evaluate the recovery process of wetlands (Galatowitsch et al. 1999). This recovery process is important to understand, and should be used to identify processes that occur naturally over time, and those that can be accelerated with human intervention (Palmer et al. 1997). Some wetland species' seeds can remain viable in soil that had been used for agriculture for up to 50 years (Middleton 2003). Natural recolonization of wetland plant species is an effective technique for restoring abandoned agricultural fields, but in a New York study, when the native soil has been removed it is less successful (Brown 1999). Establishing vegetation structure and diversity is a critical component for restoration success of other wetland taxa (Brown et al. 1997; Calhoun et al. 2005). Creating variations in microtopography in restored wetlands leads to significant differences in soil temperature and moisture that facilitates the development of multiple plant communities and increased aboveground biomass (Bruland and Richardson 2005).

4.0 Birds

Avian species are among the most conspicuous and charismatic wetland species, making them ideal for biological assessment and cultivating public interest (Weller 1988). There is an extensive body of literature that suggests birds as indicators of habitat quality in both non-wetlands (Bradford et al. 1998; Canterbury et al. 2000; Croonquist and Brooks 1991; O'Connell et al.1998), and wetlands (Bryce et al. 2002; DeLuca et al. 2004; Galatowitsch et al. 1999). Metrics derived from bird data can be formulated from guilds (Brown and Smith 1998; Croonquist and Brooks 1991), which were developed focusing on using inexpensive methods that could be used consistently over a region (Brooks et al. 1991). These guilds were effective in discriminating between disturbed and undisturbed sites (Croonquist and Brooks 1991). A guild is defined as a group of species that exploit a class of environmental resources in a similar way or respond similarly to perturbations in habitat conditions (Szaro 1986).

Many local factors, including anthropogenic stressors and natural variability, can influence the abundance and distribution of birds. The Ohio Rapid Assessment Method (ORAM) (Mack 2001) was initially developed to categorize natural wetlands for regulatory purposes and to contribute to the development of indicators of biological integrity. The robustness of ORAM was demonstrated by its effectiveness in predicting avian diversity, richness of species of concern, as well as richness of wetland dependent birds (Stapanian et al. 2004). Vehicular traffic, or proximity to roads, can alter the foraging behavior of wading birds (Stolen 2003). Other research found that even pedestrian traffic within 100 m of wetlands can have an influence on wetland bird communities (Francl and Schnell 2002). Moist-soil management techniques, though not a stressor and intended to maximize invertebrate and seed resources availability, affects timing and use of wetlands by waterfowl (Anderson and Smith 1999; Taft et al. 2002). Fish presence, and their affect on invertebrate populations, can limit food supply for hatchling waterfowl (Hornung and Foote 2006). Within bird communities of forested depressional wetlands, species richness and abundances of wetland associated birds were explained by the factors of forest characteristics and area (Riffell et al. 2006). The natural variability in wetland size and vegetation composition also can influence bird composition (Brown and Smith 1998; VanRees-Siewert and Dinsmore 1996), as some species are more susceptible to local influences than landscape factors, in part due to the mobility of the assemblage (Naugle et al. 2001).

Examining factors affecting wetland bird communities using GIS has been well-documented. Spatial statistics have been developed to quantify landscape patterns depending on the study scale (McGarigal and Marks 1995). Landscape metrics such as diversity, which is based on Shannon's diversity index (Shannon and Weaver 1949) or Simpson's diversity index (Simpson 1949), examine the probability that any 2 patches selected at random will be different types. Contagion is another raster based landscape metric measuring the mixing of patches in a landscape and the dispersion of a single patch type throughout that landscape. Landscape patterns of diversity, contagion, mean forest-wetland patch size, and proportion of forest cover are all effective in reflecting changes in guild composition due to disturbance levels (Miller et al. 1997). A 500 m radius zone of influence has been used to quantify patterns of disturbance for a central Appalachian Bird Community Index (BCI) (O'Connell et al. 2000). Wetland bird species richness has also been correlated with wetland connectivity within 3 km (Fairbairn and Dinsmore 2001). This research was further validated as exhibited by a negative response by marsh bird communities to artificial habitat fragmentation and suburban development (Benoit and Askins 2002; DeLuca et al. 2004). Depending on the size and type of roads, non-wetland and wetland bird communities are susceptible to community effects from roads ranging from 200 m to 800 m away (Forman 2000). High biotic integrity of bird communities in New York is associated with roadlessness (Glennon and Porter 2005). The importance of landscape attributes for effective conservation is reflected in multiple scales. The relation between wetland bird assemblages and roads is most pronounced within 500 m, whereas wetland connectivity influences assemblages up to distances of 2,500m (Whited et al. 2000). Yet we contend that for the purposes of an IBI, which can be used in a regulatory context, that wetlands should be evaluated based on local conditions. Regulation of activities on a broad, landscape level with multiple stakeholders is not logistically feasible. Landscape level characteristics may best be used for predicting wetland and watershed health when evaluated and modeled using local characteristics (Wardrop et al. 2007, Weller et al. 2007).

Efforts to restore avian habitat for migratory birds in forested floodplain ecosystems can be accelerated by planting early-successional tree species (Twedt et al. 2002). To continue to increase the conservation effort for wetland birds, it is important to provide regulatory recognition to small wetland complexes (Marzluff and Ewing 2001), despite the 2001 *Solid Waste Authority of Northern Cook County v. U.S. Army Corps of Engineers* (SWANCC) ruling (Christie and Hausmann 2003) and the 2006 Supreme Court *Rapanos* rulings (Murphy 2006).

5.0 Amphibians

The decline of amphibian populations is a well-documented trend attributed in-part to their sensitivity to human impacts (Wake 1991, Wyman 1990). Thin, permeable, unshelled eggs and life history characteristics including restrictive home ranges with requirements for both aquatic and terrestrial habitat, and limited dispersal capability make amphibians suitable subjects for bioassessments (Blaustein et al. 1994). The decline of amphibians has been linked to a number of anthropogenic sources such as habitat loss or fragmentation, acid deposition, increases in ultra-violet radiation, the spread of toxic substances, and introduction of predators and pathogens (Sparling et al. 2002). As such, it is often difficult to measure a direct cause-effect relation for amphibian declines. However, amphibian metrics have been derived and included in the making of wetland IBIs (Farr 2003; Micacchion 2004). The development of a consistent monitoring protocol, as well as an examination of amphibian IBI scores over time, may guide thinking relative to landscape level amphibian decline versus normal annual variation in numbers at a site (Pechmann et al. 1991).

Biotic influences on amphibian populations are a major component of amphibian community structure. For example, larval survival has been identified as the largest factor affecting population fluctuation in wood frogs (*Rana sylvatica*) (Berven 1990). Also, indirect competition for limited resources between species of tadpoles (i.e., those hatched early versus later) can affect the metamorphosed size and survival of the later-hatching species of amphibians (Morin 1987). Further, predation from other amphibians such as bullfrogs (*Rana catesbiena*) and red-spotted newts (*Notophthalmus viridescens*), as well as fish and odonates, can significantly affect the resulting amphibian community structure (Gascon and Travis 1992; Hecnar and M'Closkey 1997; Kurzava and Morin 1998).

Wetland size does not necessarily correlate with amphibian species richness (Semlitsch and Bodie 1998; Snodgrass et al. 2000a). However, the development of expected larval amphibian assemblages can be determined by hydroperiod, which has a weak relation to wetland size (Snodgrass et al. 2000b). The length of hydroperiod, as well as the spatial distribution of breeding pools, can impact amphibian species richness (Burne and Griffin 2005). Tree canopy cover of wetlands, which can be impacted by silvicultural treatments, may facilitate the drying of breeding pools. This can have a limiting effect on the distribution of species and can determine the outcome of amphibian community dynamics (DeMaynadier and Hunter 1998; Skelly et al. 1999). Impacts causing changes in water quality and pH, and the subsequent changes in vegetative structure, are critical to habitat use and expression of amphibian communities (Anderson et al. 1999, Pehek 1995).

Many amphibian species use adjacent upland area during some aspect of their life, and in doing so typically exist as metapopulations, using several nearby wetlands interchangeably (Dodd and Cade 1998; Joyal et al. 2001; Semlitsch 1998). Disturbances within this upland area influence amphibian population viability (Gibbons 2003; Trenham and Shaffer 2005). The amount of forest area surrounding a wetland, as well as the degree of isolation within the landscape matrix in which a wetland exists, explains some of the variability exhibited by amphibian populations (Hecnar and M'Closkey 1998; Kolozsvary and Swihart 1999). However, with aquatic or other species tolerant of human influence, like the American toad (*Bufo americanus*), the landscape matrix may not be a good predictor of amphibian species composition (Guerry and Hunter 2002). Road densities within500-2,500 m of a wetland are associated with lower amphibian species richness (Lehtinen et al. 1999). Land use changes at distances up to 10 km from a wetland were linked to changes in anuran population dynamics over a 30-year time-frame in New York (Gibbs et al. 2005).

Despite the literature suggesting that landscape indictors can negatively influence amphibian populations, these populations can recover. As the percent of forest cover increased in a previously predominately agriculture landscape, amphibian populations showed a remarkable ability to rebuild and recover (Gibbons et al. 2006). Best Management Practices (BMP) also can be implemented when amphibian habitat is impacted to mitigate many of the negative effects on these communities (Calhoun et al. 2005).

6.0 Invertebrates

Wetland invertebrates, as in streams, are sensitive to disturbances from multiple types of impairments ranging from sediment and chemical stressors to community impacts from habitat alteration or landscape disturbance (Barbour et al. 1999; Bendell-Young et al. 2000; Spieles and Mitsch 2000; Woodcock et al. 2005). As a result of the dynamic characteristics of wetlands, such as hydroperiod and vegetation succession, wetland invertebrate communities can represent the proliferation of multiple, diverse, ecological niches (Wissinger 1999). The multiple expressions of invertebrate communities within similar vegetation, as a function of anthropogenic impairment, has been used to form invertebrate based IBIs nationally (Burton et al. 1999; Helgen and Gernes 2002; Ohio EPA 2004) and internationally (Ortega et al. 2004). Land use disturbances quantified with GIS tools within a wetland catchment basin do not affect invertebrate metrics in the Prairie Pothole Region (Tangen et al. 2003) because invertebrate communities are often a function of more local effects that may not be adequately addressed using landscape level data alone (Johnson and Goedkoop 2002).

Invertebrate abundance and composition have been manipulated by moist-soil management techniques, a function of controlling the hydrology of a site, in wetlands as diverse as playas in Texas (Anderson and Smith 2000) and the lowland fields of England (Ausden et al. 2000). Within forested vernal pools, hydrology drives the expression of macroinvertebrate composition (Brooks 2000). As wetlands dry, terrestrial invertebrates will often colonize the site, affecting the survival of aestivating aquatic invertebrates (Batzer 2004). Woody debris and the rate of its decomposition, which is affected by saturation, is an important component of wetland invertebrate habitat (Braccia and Batzer

2004). Vegetative structure, which affects water chemistry and is often a function of hydrology, explained macroinvertebrate community structure in emergent Maine wetlands (Woodcock et al. 2005).

The level of identification for wetland invertebrate specimens can influence the usefulness of data. Identifying specimens to the family level is faster and less prone to error than genus identification (Hilsenhoff 1988). In fact, for bioassessments, family level identification is sufficient in some cases (Gerritsen et al. 2000). Genus level identification is still important for understanding life histories and when attempting to identify environmental conditions with indicator species (King and Richardson 2002). However, using genus level identification for bioassessments can lead to added costs and increased ecological noise (Bailey et al. 2001).

Invertebrate communities have been shown to be structurally similar in comparisons between mitigated and natural wetland sites in multiple studies. However, the reasons for some of the degree of variation has been attributed to wetland age (Stanczak and Keiper 2004), a function of wetland age and vegetation structure (Balcombe et al. 2005b), and a function of wetland depth and the ability to sustain fish populations (Fairchild et al. 2000, Zimmer et al. 2000). The restoration of invertebrate communities in created wetlands can be stimulated by using vegetation plugs from natural wetlands to facilitate the colonization of some slower dispersing wetland invertebrates (Brady et al. 2002, Brown et al. 1997). The remains of wetland invertebrates, as well as drought-resistant eggs, can persist in soils even after they have been tilled (Euliss et al. 2002, 2001). This provides proof of prior wetland existence, as well as providing a potential source for the recolonization of the natural invertebrate communities.

7.0 Quality control

Quality control was conducted at every stage of data collection and analysis. Anuran and avian species' calls were learned using various audiotapes and confirmed by field technicians knowledgeable in respective taxa. Plant identification was performed by experts in field botany: William N. Grafton and Dr. James S. Rentch. Aquatic macroinvertebrate familial taxonomy was performed by myself and confirmed by Sarah McClurg, Donna Hartman, and Drs. Linda Butler and John Strazanac. Dr. James T. Anderson reviewed all methodologies and techniques incorporated into data collection for this project. Dr. George Seidel and James T. Anderson assisted in all statistical analyses.

8.0 Conclusion

Compromising wetland biological integrity by mismanaging the resource can have the same effect within the landscape as not managing wetlands at all. By not mitigating human impairments to wetlands, there can be broad devastating ecological effects such as the loss of biodiversity (Gibbs 2000) and changes in the health of flora and fauna populations resulting in changes in species niche-width and range boundaries (Swihart et al. 2003). Fragmentation as a result of human impacts can have far-reaching biological effects, including the rapid decline of endemic waterfowl and plant species (Liu et al. 2004; Miller et al. 1997; Saunders et al. 1991). The restoration of natural wetland ecosystems could provide ecosystem services, among them water supply and treatment, worth up to $33 trillion per year worldwide (Costanza et al. 1997). It would be irrational to think that it is possible or desirable to return all North American wetlands, to pre-European settlement conditions. What are considered to be natural and pristine wetlands may actually be recovery relicts of wetlands that recovered from human impacts naturally from over a century ago (Thorson and Harris 1991). Wetland conservation, management, and mitigation strategies need to be based on realistic goals adapted to accomplishing specific objectives (Ehrenfeld 2000). Powerful tools exist to help prioritize and select areas with the greatest potential for restoration success (Russell et al. 1997). However, the process of restoring these habitats is, in and of itself, an experiment-in-progress (Mitsch et al. 1998).

The development of working wetland IBIs within West Virginia will allow resource managers the ability to consistently and effectively measure the current state of wetland ecosystems, identify potential restoration sites, and establish criteria for evaluating successful restoration (Hobbs and Harris 2001). Additionally, with the recent EPA ruling on "Compensatory Mitigation for Losses of Aquatic Resources" (40 CFR Part 230), mitigation banking becomes the preferred alternative to remedy wetland impacts. In the future, resource managers will be able to use the West Virginia wetland IBIs to ascertain, catalogue, and ensure the quality of these mitigation banks by comparing mitigation banking IBI scores to the IBI scores of wetlands found throughout the state. This represents another tool that can be used to gauge the effectiveness of "no net loss" in regards to biological integrity, and bring a measure of accountability to determine the relative success or failure of mitigation banks.

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Figure 1. An example of an emergent wetland site in Wyoming county, West Virginia, used to develop indices of biological integrity for wetlands in West Virginia, USA, from 2005-2006.

Figure 2. An example of a scrub-shrub wetland site in Pocahontas county, West Virginia, used to develop indices of biological integrity for wetlands in West Virginia, USA, from 2005-2006.

Figure 3. An example of a forested wetland site in Cabell county, West Virginia, used to develop indices of biological integrity for wetlands in West Virginia, USA, from 2005-2006.

Chapter 2

Avian Wetland Indices of Biological Integrity

Using Dual Classifications in the Development of Avian Wetland Indices of Biological Integrity for Wetlands in West Virginia, USA

Walter Veselka IV[1]
James T. Anderson[1, 3]
Walter S. Kordek[2]

[1] Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

[2] West Virginia Division of Natural Resources, Wildlife Resources Section, PO Box 67, Ward Road, Elkins, WV 26241

[3] address correspondence to James T. Anderson, Ph.D., Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506. *email:* wetland@wvu.edu*phone:* (304) 293-2941 ext. 2445, *fax:* (304) 293-2441

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Abstract

Considerable resources are being used to develop and implement bioassessment methods for wetlands to ensure "biological integrity" is maintained under the Clean Water Act. Previous research has demonstrated avian composition is susceptible to human impairments at multiple spatial scales. Using only a local site specific disturbance gradient, we built Avian Wetland Indices of Biological Integrity (AW-IBI) specific to the Cowardin et al. (1979) and hydrogeomorphic (HGM) wetland classification schemes. The resulting class-specific AW-IBI were comprised of 1-4 metrics that varied in their sensitivity to the disturbance gradient. Sensitivity to the disturbance gradient increased, in some instances, when the metrics of each class-specific AW-IBI were combined. For example, the relation of the variability between an emergent headwater floodplain wetland and the disturbance gradient was greater when metrics sensitive to disturbance for headwater floodplain wetlands were combined (added) to those metrics sensitive to disturbance in emergent wetlands. Overall, all of the derived biological indices specific to Cowardin et al. (1979) classes of wetlands had a significant relation with the disturbance gradient; however, the biological index derived for floodplain wetlands exhibited a more consistent response to a local disturbance gradient. We suspect the consistency of this response is due to the inherent nature of the connectivity of available habitat in floodplain wetlands.

Keywords: *avian composition, birds, disturbance, index of biological integrity, metrics, West Virginia, wetlands*

1.0 Introduction

Wetland function and biotic integrity can be compromised by anthropogenic impacts in proximity to a wetland (Harris 1988; Winter 1988; Yuan and Norton 2004). Functions that wetlands provide occur on multiple spatial scales within a matrix of landscapes (Zedler 2003). Therefore evaluating the impacts and stressors that can influence wetlands should focus on using site-specific criteria that reveal patterns within the landscape context (Bedford and Preston 1988). The mobility of avian assemblages infers that birds would be ideal candidates for assessing wetland condition from a landscape perspective (Naugle et al. 2001).Because birds are conspicuous and charismatic, the results of avian bioassessments can be easily related to the general public to help drive public policy and awareness (Weller 1988).

Using avian assemblages as indicators of impairment within riparian areas has demonstrated measurable differences in assemblage composition between minimally disturbed and agriculturally dominated watersheds in Pennsylvania (Croonquist and Brooks 1991). Bird data are formulated into response guilds that are effective indicators of human disturbance (Canterbury et al. 2000; O'Connell et al. 1998a). Guilds are better for assessment procedures than using individual species presence/ absence or abundance because no 2 species occupy the same niche, so using indicator species cannot be expected to ensure the maintenance of all other species (Hutto et al. 1987). This guild approach has been validated in numerous studies evaluating the quality of wetland habitat (Bryce et al. 2002; DeLuca et al. 2004; Galatowitsch et al. 1999). Guilds can be categorized by the nature of response to either structural, functional, or compositional changes. Structural guilds are groupings of species based on their response to site specific habitat characteristics, such as presence of cavity trees (Verner 1984). A functional guild is characterized by its response to changes in trophic structure (O'Connell et al. 1998a). Compositional guilds are based on population characteristics that change according to the responses and changes to the abundance and distribution of other species (O'Connell et al. 1998a). Using a combination of guilds that explore multiple elements of avian community dynamics will increase the detection probability of an ecosystem's changes in response to human impairment (Bayer and Porter 1988; Canterbury et al. 2000).

With an extensive body of potential metrics derived from previous literature (Bradford et al. 1998; Croonquist and Brooks 1991; Galatowitsch et al. 1999; O'Connell et el. 1998a), we systematically evaluated potential avian metrics for inclusion into an Avian Wetland Index of Biotic Integrity (AW-IBI) that could be used to evaluate the condition of wetlands across West Virginia. Biotic indices measuring wetland health have been based on both the Cowardin et al. (1979) system (Mack 2004) and the hydrogeomorphic (HGM) (Brinson 1993) classification system (Gernes and Helgen 2002, Galatowitsch et al. 1999). The Cowardin et al. (1979) system is used to classify the wetlands mapped by the National Wetland Inventory (NWI), and henceforth will be referred to as the Cowardin classification. Using the HGM approach to compare wetlands has been advocated because it compares wetlands that are functionally similar (Stevenson and Hauer 2002). However, its use has not been used to contrast or augment the Cowardin system, which is relatively straightforward to non-biologist resource managers and used in West Virginia for regulatory purposes (West Virginia State Code Chapter 22-11, 22-26).

Our objective was to assess the classification systems for use in an AW-IBI that will be able to quantify the differences in bird communities between wetlands that are anthropogenically impaired and those in a natural state. In doing so we will be able to monitor the biological integrity of wetlands over time and to establish and ensure antidegradation standards are met, as well as compare the effectiveness of mitigated wetlands in replacing natural wetlands lost to development. Further, we explored using metric scores derived independently within the Cowardin and HGM-based AW-IBI to determine if a finer resolution of predicting the disturbance in wetlands can be ascertained by summing the metrics used in each classification system and comparing it to the disturbance gradient. For example, summing the resulting metric scores of the emergent AW-IBI with those of the floodplain AW-IBI gives us a greater number of metrics that are influenced by the disturbance gradient in an emergent wetland that is also a floodplain. This analysis was drawn from Gerritsen's (1995) argument that additive models are simple to understand which would make bioassessments more likely to be adopted by resource managers. Our methods reflect an attempt to construct a West Virginia avian community wetland index of biotic integrity within the parameters of existing or planned West Virginia Division of Natural Resources (WVDNR) programs and resources.

2.0 Methods

2.1 Study Area

Study sites were selected across the U.S. Environmental Protection Agency's Level 3 aquatic ecoregions within West Virginia, USA: the Central Appalachians, the Ridge and Valley, and the Western Allegheny Plateau (Omernik 1987), as revised by

Woods et al. (1999). Efforts were made to stratify sites across ecoregions and the Cowardin scheme by selecting random 7.5 minute quadrangles from a Geographic Information System (GIS) database. Statewide maps of wetlands according to the HGM scheme were not available and therefore could not be used to stratify according to this classification. On the ground field reconnaissance was then conducted to ascertain access to wetlands. This allowed us to maximize the number of sites (151) used in this study; 68 in 2005 and 83 in 2006, while efficiently sampling across the entire state (Figure 1). Sites were located ≥ 300 m from one another, and no 2 sites adjacent to one another had the same Cowardin subclass classification. Our sampling regime included individual wetlands and 20 wetland complexes in which we sampled from 2-5 sites per complex. However, each site was analyzed independently. Site location was recorded with a Geographic Positioning System (GPS) to establish a permanent survey station.

Wetlands were categorized by both the Cowardin classification system and by regional HGM subclasses (Cole et al. 1997), meaning each wetland site was categorized by both systems and that they were not mutually exclusive. For example, a palustrine emergent wetland may have been classified as a headwater floodplain or a surface water depression depending on its position in the landscape. Likewise, a headwater impoundment wetland could be either a palustrine emergent or scrub-shrub wetland, depending on vegetation development. To increase the efficiency and applicability of the AW-IBI, a guiding principle for developing a regional IBI (Brooks et al. 1998), some subclass designations were combined (Table 1). This was done to represent realistic management designations of wetland HGM subclasses and to increase sample size for statistical validity. However, enough wetlands of the regional HGM subclasses (Cole et al. 1997) were sampled to build headwater floodplain and riparian depression AW-IBI (Table 2). This allowed us to evaluate the difference between true HGM subclasses and our designated HGM management classes. Human-made wetlands, created as mitigation or otherwise, were designated according to the HGM designation the design mimics, in this study either depression, impoundment, or fringing wetlands.

2.2 Bird Surveys

Avian communities were surveyed at 1 point, twice per individual site using 5 minute single-observer 50-m radius point count surveys between 15 May and 1 July, 2005 or 2006 (Ralph et al. 1995). Surveys occurred between 30 minutes before sunrise and 1000 hours, under acceptable weather conditions (Ralph et al. 1995). All surveys were conducted at least 10 days apart. Metrics were calculated using the high count of species abundance numbers between the 2 site visits. The first visit also included a callback survey following the point count for secretive waterbirds, which were completed before 1 June to follow methods in use by the WVDNR Wildlife Diversity Program. These call-response surveys were used to detect the presence of Virginia rails (*Rallus limicola*), king rails (*R. elegans),* soras (*Porzana carolina*), American bitterns (*Botaurus lentiginosus*), least bitterns (*Ixobrychus exilis*), and pied-billed grebes (*Podilymbus podiceps*) following Gibbs and Melvin (1993). The waterbird surveys followed the methods of Balcombe et al. (2005), in which the playbacks broadcasted the target species calls for 50 seconds, followed by40 seconds of silence, before the next call would begin. These calls were broadcasted using a portable cassette player located 0.75 m above ground with a maximum sound pressure of 80 dB 1 m from the recorder. These surveys increased the likelihood of detecting these secretive waterbirds and can be used to monitor changes in the population over time (Gibbs and Melvin 1997).

2.3 Disturbance Gradient

Defining a consistent and applicable disturbance gradient that metrics respond predictably to, is a critical step towards building an IBI (John Mack, Ohio EPA, personal *communication*, 2005). The Ohio Rapid Assessment Method, version 5.0 (ORAM) was developed to assess the quality of natural wetlands in Ohio (Mack 2001). It has been used in Ohio as the disturbance gradient in wetland amphibian and plant IBIs, as well as a predictor of avian diversity (Mack 2004; Micacchion 2004; Stapanian et al. 2004). The ORAM not only examines disturbances, but the habitat and landscape characteristics associated with each wetland. It is a wetland equivalent of the Rapid Bioassessment Procedure (RBP)that is used in stream research and monitoring (Barbour et al.1999).Our disturbance gradient was drawn from specific metrics and sub-metrics from the ORAM that are directly related to human disturbance on a local scale (Table 3). These metrics and submetrics formed a disturbance score that had a maximum of 39, indicating no visible impact from human impairment. The minimum score of 4 indicated severe human impacts. The metrics selected for inclusion into the AW-IBI were based on the metrics' responses to the disturbance score. By selecting a disturbance gradient that is straightforward and easy to use, the stressors that comprise it can be manipulated by resource managers (Brooks et al. 1998). For example, if we are able to implement best management practices that minimize local stressors within the vicinity of wetlands, we would expect a demonstrable effect on the expression of biological communities within these wetlands (Calhoun et al. 2005).

2.4 Reference and Stressed Sites Designations

The designation of reference and stressed sites is critical to metric testing and the formation of an IBI. We chose reference sites based on the concept of least-disturbed conditions. These sites were not intended to be pristine or free from any evidence of human manipulation, but to represent examples of what can be realistically expected from a minimally impacted wetland in West Virginia (Omernik 1995). Disturbance gradient scores in the 75th and 25th percentile were used to categorize reference and stressed conditions, respectively (Barbour et al. 1995). Reference and stressed designations were developed independently for Cowardin and designated HGM management class across all Level 3 ecoregions (Omernik 1987; Woods et al. 1999) because these designations were based on human impairment characteristics throughout West Virginia rather than the ecological basis of the ecoregions.

2.5 Data Analysis

The presence and abundance of each avian species was recorded using the high count of each species of the 2 survey periods and categorized in response guilds (Croonquist and Brooks 1991; O'Connell et al. 1998a). These response guild classifications (Appendix A) were then used to derive a list of 23 candidate metrics that have been used to detect levels of human impairment in previous studies (Table 4). These guilds were categorized according to their relation with ecosystem integrity as more or less responsive to the individual wetland characteristics of structure, function, and composition, or in some cases a combination of these characters (O'Connell et al. 1998a).

An objective in building the AW-IBI was to ensure that like-wetlands were being compared. To develop an applicable, statewide,avian community IBI, we analyzed the data in a series of elimination steps for each candidate metric. This process enabled us to build indices of biotic integrity specific to individual HGM or Cowardin classes, which then allowed us to compare and contrast the 2 classification systems to augment one another to increase sensitivity to disturbance scores. By evaluating AW-IBIs across wetland types with an individualized approach, rather than a "one size fits all" approach, we were able to detect and characterize subtle AW-IBI differences resulting from impairments to different wetland types.

Metrics were tested for responsiveness to the human disturbance index using box-and-whisker plots. The metric values for reference sites and stressed sites for each categorization were plotted side by side. A visual comparison examining the interquartile range and median of each metric was used to designate a narrative rating of discriminatory power (Barbour et al. 1996). Metrics were classified as excellent, good, fair, or poor (Figure 2). Fair and poor metrics were removed from further analysis.

The discrimination efficiency, or effectiveness of the metric values to discriminate between reference and stressed sites, was calculated for metrics rated good and excellent (Equation 1). Those with a discrimination efficiency value below 60% were discarded from further analysis because of their inability to consistently differentiate between reference and stressed conditions.

Equation 1:

Discrimination Efficiency = $100 \times (\boldsymbol{a} / \boldsymbol{b})$
where, ***a***= the number of stressed sites scoring below 25th percentile of reference
b = the total number of stressed sites.

The remaining metrics were tested for redundancy using Spearman's R correlation (Hughes et al. 1998). Metrics with an R-value > 0.80 were considered highly correlated (Table 5).Of the correlated pairs of metrics, the one with the greatest discrimination efficiency between reference and stressed sites was retained for inclusion into the AW-IBI (Table 4).If correlated metrics had the same discrimination efficiency, then both metrics were retained for further ecoregion and classification scheme screening to determine which metric was best suited for inclusion in the AW-IBIs.

Class-specific AW-IBIs were not developed for wetland classes with fewer than 5 referenceand5 stressed sites (Chipps et al. 2006). Sites were designated by sampling year. However, this effect was not tested because an individual wetland was only sampled during1 year of the study period, not both (O'Connell et al. 1998b; Reiss 2006). All statistical tests were conducted at an *a priori* alpha level of 0.05 (Mack 2004; Micacchion 2004).

Within the remaining suite of metrics for each of the resulting class-specific AW-IBI, we tested for an ecoregion effect or alternative classification effect using a series of 2-wayanalyses of variances (ANOVA). The data were not transformed based on the observation that the violation of normality, in our case, was small and inconsequential to the overall association we measured (Miller et al. 2006). The metric values from each site (dependent variables) were individually examined for an interaction with the ecoregion, Cowardin class, and designated HGM management class (Table 6). This test was conducted to screen the remaining metrics for ecoregion or classification bias without the excess "noise" generated by redundant metrics, or those not capable of discriminating between reference and stressed conditions. Reference and stressed sites were used because we expected the marginally impacted wetland values to vary in their response depending on the specific stressors in each wetland. Stressed sites represent the cumulative impact of multiple stressors, whereas reference sites are those with minimal disturbances. Using both reference and stressed sites to look for differences among ecoregions and classes is one of the guidelines for implementing regional indices of biological integrity (Brooks et al. 1998).

The metrics that were significantly influenced by the ecoregion or alternative wetland classification effect were omitted as metrics capable of discriminating between reference and stressed conditions throughout West Virginia. When multiple metrics were used to derive the class-specific AW-IBI, the metrics were evaluated a final time with a multivariate analysis of variance (MANOVA), testing for a cumulative effect on the metric values at both reference and stressed sites from ecoregion or classification scheme influences (Table 7). This *post-hoc* analysis was meant to ensure the derived AW-IBI was appropriately classified, resulting in applicable and robust indices of biological integrity.

After the series of tests finalizing the metrics used in the resulting AW-IBI were conducted, the integer metrics, such as richness, were then normalized (0-1) to allow scoring comparisons to be made (Equation 2).

Equation 2:

Normalized value = metric value/ maximum metric value

Metrics responding positively to human impairment were inversed (Equation 3) to enable a consistent response for all metric values.

Equation 3:

Inverted metric value = |1-(metric responding positively to human impairment)|

Metrics included in the AW-IBI were scored on a continuous 0-10 scale (Blocksom 2003; Bryce et al. 2002). The influence of outlier values was mitigated by using the best standard value (BSV) of each metric, which was determined to be the 95th percentile of the highest values (Blocksom 2003). This scoring technique is consistent with the West Virginia Stream Condition Index (Gerritsen et al. 2000). This scoring technique performed better in comparisons with discrete scoring methods for metrics (Blocksom 2003). Metric scores were standardized by dividing the raw metric value by the range in that metric (Hill et al. 2003) and multiplying by 10 (Equation 4).

Equation 4:

Metric score = 10 ×(raw metric value / (95th percentile – low metric value))

Using the metrics appropriate for each classification, AW-IBIs were formed by summing all metrics selected for inclusion. The total number of metrics included in the AW-IBI varied by each classification. For example, the number of suitable metrics that could consistently discriminate between reference and stressed conditions in a depressional wetland was 2, whereas 4 metrics were used to discriminate between reference and stressed sites in a floodplain wetland.

The disturbance gradient and the distribution of the AW-IBI scores for the reference sites were used to set numeric thresholds describing wetland condition (Gerritsen et al. 2000). Categorical threshold limits for AW-IBI scores were set using the 75th, 25th, and 5th percentiles for reference sites (Table 8). Sites scoring above the 75th percentile were designated as excellent, those between the 25th and 75th percentile were considered good, below the 25th percentile and above the 5th percentile were fair, and those below the 5th percentile represented poor wetland conditions (Hill et al. 2003; McCormick et al. 2001).

The relation between AW-IBI scores and the disturbance score were examined and plotted using simple linear regression specific to each classification. This enabled us to interpret and compare the results of our derived AW-IBI accordingly.

In addition to scoring each wetland with an individual designated HGM management and Cowardin class AW-IBI score, we used the additive properties of metrics to form a specific hybrid AW-IBI that combined the classification schemes, pending large enough sample sizes (Brinson 1993; Cole et al. 1997; Cowardin et al. 1979). This method of adding the individual metric scores of the different classes of resulting AW-IBI has not been documented in the prevailing literature, and was adopted out of an argument for implementing additive indices for resource management (Gerritsen 1995). As an example, this novel approach examines a palustrine scrub-shrub floodplain wetland using all the suitable metrics in both the scrub-shrub and floodplain AW-IBI that were not duplicated. If a metric was selected for inclusion in both classes of AW-IBI the value used in the calculation was the average metric score between the 2 classes. Hence, by increasing the number of metrics applicable to a particular wetland we will be able to determine if more metrics enabled us to ascertain wetland condition with a stronger degree of certainty.

3.0 Results

3.1 Ecoregions and site classifications

Site classification by Cowardin, designated HGM management classes, and regional HGM subclasses (Cole et al. 1997) by ecoregion led us to remove all but 2 classes of regional HGM subclasses (riparian depression and headwater floodplain) because inadequate sample sizes did not allow comparing 5 reference to 5 stressed sites (Chipps et al. 2005). In addition, the aquatic bed (Cowardin et al. 1979) and fringing and slope (HGM) classes were also excluded due to low sample size (Table 2). A complete list of all sites and corresponding attribute data (e.g., ecoregion, location, class, etc.) can be found in Appendix B. The disturbance scores were normally distributed for all sites (Figure 3) (*Skewness = -0.04, Kurtosis = -0.39*).

After the initial series of 2-way ANOVA screenings, we eliminated some metrics due to a significant ecoregion or alternative classification scheme effect (Table 7). The only metric capable of discriminating between reference and stressed sites in riparian depression wetlands, the percentage of residential and edge-tolerant species, was omitted because of a significant 2-way interaction between ecoregion and the Cowardin class. This resulted in a failure to develop a wetland AW-IBI for the riparian depression HGM subclass. The percent of single-brood species was eliminated in our floodplain AW-IBI because of a significant Cowardin classification effect. In the Cowardin-based AW-IBIs, 5 of the 6 metrics selected for inclusion in the emergent class AW-IBI were eliminated due to a significant HGM effect on metric scores. These metrics included the percent of residential and edge-tolerant species, the percentage of neotropical migrants, the percentage of habitat-specific neotropical migrants, the percentage of habitat specific birds, as well as the percentage of insectivorous species. Additionally, the abundance of wetland bird species and the percent of single-brooded species were eliminated from the scrub-shrub AW-IBI. Of the metrics comprising the forested AW-IBI, 2 metrics, the percentage of neotropical habitat specific species and the percentage of habitat specific species were eliminated so that there was not a significant cumulative HGM effect (Table 8).

3.2 Avian community results

A total of 118 bird species was recorded in this study (Table 9). Site richness ranged from 5 to 28 species. A total of 2,297 birds was counted. A site by site record of species and abundance data can be found in Appendix C. Further, individual metric values for each site can be found in Appendix D, as well as summary statistics for each metric value by ecoregion (Appendix E). On average, birds with at least a facultative use of wetlands or greater made up the majority of surveyed individuals (Table 10).Of the top 6 most frequently occurring species, the most common (common yellowthroat, *Geothlypis trichas*) and the third most common species (red-winged blackbird, *Agelaius phoeniceus*), were wetland associated. The remaining 3 species in the top 5 most frequently occurring (song sparrow, *Melospiza melodia*, yellow warbler, *Dendroica petechia,* and gray catbird, *Dumetella carolinensis*) were facultative wetland species. The northern cardinal (*Cardinalis cardinalis)* was the sixth most frequently occurring bird species, and is not considered to have an affinity for wetlands (Croonquist and Brooks 1991).

3.3 Metric performance

All metrics were subject to an initial visual screening, redundancy testing, and discrimination efficiency testing before inclusion into a class specific AW-IBI (Appendices F-M). Ten metrics were excluded from all of the resulting AW-IBI due to redundancy or the inability to discriminate between reference and stressed sites (Table 4). A complete list of sites and corresponding disturbance scores used to designate reference and stressed conditions can be found in Appendix B.

Avian wetland indices of biotic integrity were built with acceptable metrics for the Cowardin classifications, designated HGM management classes, and 1 of the 2 regional HGM subclasses (Cole et al. 1997). These indices were composed of 1 to 4 metrics dependent upon classification system (Table 4). Scoring thresholds for each class-specific avian community wetland IBI were derived from the 75th, 25th, and 5th percentile of reference site AW-IBI scores (Hill et al. 2003). Each class specific AW-IBI was able to discriminate between reference and stressed conditions > 60% of the time (Table 6).

The resultant class-specific AW-IBIs varied in their relation to and degree of response to the disturbance index (Table 10). Six of the 7 derived AW-IBIs had a significant relation to the disturbance scores. The disturbance gradient explained 11% and 49% of the variability in AW-IBI scores in depressional wetlands and headwater floodplain wetlands, respectively. The relation between the disturbance gradient and impoundment AW-IBI scores was not significant. Cowardin based AW-IBIs scores were more consistent in their response to the disturbance gradient as it explained between 11% and 25% of the variability in these AW-IBI scores. The AW-IBI scores in headwater floodplains explained 49% of the variation associated with the disturbance gradient, whereas, due to a significant ecoregion and Cowardin classification scheme interaction, we could not create a robust, statewide riparian depression AW-IBI.

3.4 Additive properties of metrics in the classification system

When metrics from the Cowardin classification scheme were combined with metrics used in designated HGM management classes and regional HGM subclasses, results were mixed in their response to the disturbance gradient (Table 11). The depression and impoundment designated HGM management class wetlands did not exhibit a significant relation with the disturbance gradient when combined with metrics of the corresponding Cowardin classes.

The relation between the metrics in headwater floodplain and designated floodplain management class AW-IBI, combined with their Cowardin counterpart AW-IBI metrics did have a significant relation with the disturbance gradient; with the exception of the headwater floodplain-emergent hybrid AW-IBI. These combined AW-IBIs increased the amount of variation the disturbance gradient accounted for in all of the Cowardin based AW-IBIs. However, the results were mixed as far as the accountability of the disturbance gradient and the relation between headwater floodplain and the floodplain designated HGM management class AW-IBIs. In the case of headwater floodplain wetlands, the metrics from the scrub-shrub and forested class-specific AW-IBIs increased the sensitivity to the disturbance gradient to 94% and 76%, respectively. In the case of the floodplain designated HGM management class, metrics from the forested AW-IBI decreased the accountability of the disturbance gradient from 46% to

42%, whereas metrics from the scrub-shrub and emergent AW-IBIs increased the disturbance gradient's accountability to 85% and 52%, respectively.

4.0 Discussion

4.1 Study design

The principles outlined by Brooks et al. (1998) intended to guide the development of regional indices of biotic integrity provide an excellent example of achievable goals to consider when designing an index of biotic integrity. Bird communities with high biological integrity are the desired endpoint representing least impaired wetland conditions. The elimination of an ecoregion effect on our avian wetland community indices of biotic integrity enabled us to examine and contrast the more recent and regionally specific HGM approach (Brinson 1993) with the Cowardin approach because of ample sample sizes. Our decision to combine the regional subclasses (Cole et al. 1997) into designated HGM management classes was based on the intended applicability and management implications within the objectives of developing an avian community wetland index of biotic integrity. We included analysis of regional HGM subclasses (Cole et al. 1997), if sample size permitted, which allowed evaluation of the efficacy of our designated HGM management class.

The classifications and methods were adopted so that this monitoring protocol could be easily integrated into existing WVDNR programs. For example, with limited wetland training, resource managers can differentiate between depression, floodplain, impoundment, fringing, and slope wetlands. Indeed, practicality exerted considerable leverage on design considerations for this study. For instance, sites were clustered such that sampling could be portioned into discrete "routes" which then could be assigned with reasonable expectation of completion by volunteers, such as conducting breeding bird point count surveys. Additionally, the local disturbance index, adopted from a modified ORAM (Mack 2001), was straightforward and was completed consistently under guidance of the scoring manual. The stressors contributing to our disturbance gradient we reassessed intuitively and represent conditions that could be quantitatively improved with a realistic expectation of improved bioassessment scores. The expectation is that this body of work will act as a baseline from which to initiate a statewide West Virginia wetland monitoring program, capable of detecting impairment and recognizing improvement and degradation in natural and mitigated wetland conditions.

4.2 Classifications for Avian Wetland Indices of Biotic Integrity

The significant relation between the local disturbance score and the Cowardin classification schemes indicated that independent suites of suitable metrics needed to be derived for each of these vegetation driven classifications. This indicated that bird community metrics that were used to detect human impairment would differ depending on vegetative structure. Different metrics were selected to detect impairment levels that were specific to each *vegetation structure* class. This result was based on strong evidence supporting the relation between vegetation development and avian communities (Brown and Smith 1998; Murkin et al. 1997; Snell-Rood and Cristol 2003; Twedt et al. 2002). The consistency of this relation is exhibited in the resulting AW-IBIs. Although only a minority of the scoring variation was explained by the disturbance gradient for many of the wetland types (Table 11), it is still measurable and reflected in the ability of all AW-IBIs to discriminate between reference and stressed sites (Table 6).

Examining the characteristics of guilds within the Cowardin classifications explains the consistency of the relation between the disturbance scores and the AW-IBI scores. These guilds were predominately based on structural components of the ecosystem. For example, it stands to reason that the percent forest area sensitive species metric would differentiate between reference and stressed sites within the forested classification. However, an examination of factors that drive wetland vegetation structure enabled us to see why the designated HGM subclass AW-IBIs performed in the manner they did. Hydrology is the primary driver in the expressions of wetland plant communities (Aznar et al. 2003; Kirkman et al. 2000; Koning 2005; Magee and Kentula 2005). Anthropogenic effects within wetlands are not always apparent by visual reconnaissance. However, altering the hydrology of a wetland, even if the impact site is not physically located within the wetland, has measurable impacts on wetland function. In turn, an altered hydrologic regime will ultimately lead to changes in the expression of the vegetative community (Drohan et al. 2006). Furthermore, vegetative communities play a critical role in how a wetland functions within an ecosystem. For example, floodplains are more surface water driven with a deeper depth to the water table, compared to groundwater driven riparian depressions (Cole et al. 1997). As a result, plant communities are expected to differ between these 2 classes, simply based upon hydrology. Therefore, further comparisons of regional HGM subclasses would be useful for researching the effect of hydrologic variation on avian communities.

The percent of insectivorous species, and the percent year-round edge tolerant species are robust metrics that discriminated between reference and stressed conditions in all classification schemes, with the exception of the regional HGM subclass riparian depression. Functional trophic levels are revealed within the percent of insectivorous species metric. Year-round residential and edge tolerant species is a hybrid composition and structural metric that responds to increasing levels of human impairment. In addition to the habitat specific and neotropical migratory species metric, it further illustrates the "generalist versus specialist" approach that was successful in deriving appropriate metrics for other regional bioassessment cases (O'Connell et al. 1998a).

Impoundment wetlands are, by default, a product of altered hydrology. However, wetlands formed as a result of hydrologic change, whether natural or human-induced, still provide some ecosystem services such as water retention, water purification, refugia etc. (Hemond and Benoit 1988). Regional HGM subclasses of impounded wetlands include mainstem and headwater impoundments (Cole et al. 1997). These two impoundment HGM subclasses could also be a result of beaver (*Castor canadensis*) activity, inadvertent human activity, or even human attempts at creating natural wetlands. A study of wetland bird integrity in Montana found the neotropical migrants guild metrics were significantly influenced by beaver activity. This is consistent with our finding which excluded all of the neotropical migratory bird based metrics from the impoundment designated HGM management class based AW-IBI. Small sample sizes prevented us from evaluating these subclasses individually. Despite a non-significant relation with our disturbance gradient, the resultant AW-IBI was able to discriminate between reference and stressed impoundment sites. For example, metrics that measured trophic structure, percent insectivorous and percent omnivorous individuals and year-round edge tolerant birds, were effective despite variability in hydrology and vegetative structure within impoundment wetlands.

Variability in hydrology has been identified as the cause of failure in some cases of indices of biotic integrity (Wilcox et al. 2002). Our data seems to support the conclusion that appropriate classifications, comparing apples to apples, or in our case, hydrologic regimes, are essential to developing an effective IBI (Karr 1999). The hydrologic regime of floodplain designated HGM management class wetlands, either mainstem or headwater floodplains (Cole et al. 1997), exhibits a high degree of consistency (Cole et al. 2006; Cole and Brooks 2000). Isolating this hydrologic variability through an appropriate classification, and based on previous literature, we would expect a floodplain AW-IBI to be highly responsive to a disturbance gradient (Croonquist and Brooks 1991).

Floodplain AW-IBIs differed from all of our other class specific IBIs because of a built-in measure of bias that is a product of its classification. For instance, floodplain wetlands, by definition, are linked to a water source and are always connected to a corridor that connects patches of suitable habitat (Croonquist and Brooks 1991). Alternatively, emergent, scrub-shrub, forested, and depressional wetlands can all be isolated from other wetlands, water sources and patches of suitable habitat. The connectivity of wetland floodplain ecosystems is inherent, and the connectivity and patterns of wetlands within a landscape are proven predictors of avian and other biotic communities (Galatowitsch et al. 1999; Miller et al. 1997; Whited et al. 2000). Floodplain AW-IBI scores demonstrated a strong relation with the disturbance gradient. This may be a result of stable hydrology and a degree of inherent connectivity that is a product of this classification approach.

In this study, Shannon-Weiner's diversity index was able to differentiate between reference and stressed floodplain sites. This metric, based on evenness and richness (Magurran 1988), is an expression of higher diversity scores with decreasing levels of impairment. Richness metrics were shown to be responsive to components of the ORAM score (Stapanian et al,.2004). Birds have been identified as a group where species composition reaches "equilibrium" in predictable environments (Tramer 1969). When this predictability shifts, changes in species abundances shift to favor "opportunistic" species (Tramer 1969). As impairment increases, we would expect to see greater numbers of tolerant species that would decrease evenness and be reflected in diversity scores.

4.3 Comparison with other Avian Wetland Indices of Biological Integrity

Our AW-IBI results varied expectedly with other avian indices of biological integrity. Some variation is to be expected from regional differences. Additionally, the differences in scale and attributes of a disturbance gradient will always change the relation to a resulting index of biological integrity.

Research from 14 wetlands in Ohio that examined ORAM scores (Mack 2001), as well as components of the ORAM scores and avian composition were comparable to our results (Stapanian et al. 2004). This research did not directly examine the relation between the ORAM-derived factors in our disturbance gradient and combined metrics representing avian integrity composition. However a significant relation was found between the variations in a disturbance gradient and species of concern, species richness, and wetland dependent birds. The variability accounted for by these variables ranged from 24% to 51%. These relations were relatively consistent with the variability accounted for in our derived AW-IBI based on a local impairment disturbance gradient.

The regional Bird Community Index (BCI) (O'Connell et al. 1998b) was developed with a different methodology intended for the Mid-Atlantic Highlands, although many of the metrics that were incorporated into the BCI were incorporated into our class-specific AW-IBI. The disturbance gradient used in the BCI accounted for more of the variability in BCI scores than in our study; however, it was derived from both vegetation and land cover variables (O'Connell et al. 1998b). These are a function of, but not of direct measure of local impairment. Selecting metrics that are responsive to local disturbances was our objective and will enable us to use the AW-IBI to detect trends during long-term monitoring efforts.

In addition to disturbance, other sources such as hydrology and connectivity can account for the variability in AW-IBI scores. Furthermore, studies examining bird communities at larger spatial scales reveal that the intensity of surrounding land use and road densities play a large role in influencing both wetland and non-wetland avian communities (DeLuca et al. 2004; Forman 2000; Glennon and Porter 2005). These influences are more complex than simply altering hydrology. Not only does proximity to multiple land types influence the expression of bird communities, but so does the shape and pattern of natural and anthropogenic land uses relative to areas sampled (Miller et al. 1997; O'Connell et al. 2000; Whited et al. 2000).

4.4 Avian Communities

As expected, the majority of individual birds per site had at least some degree of affinity for wetlands. However, conspicuously absent from our point count surveys were large numbers of waterfowl and other waterbirds. This may be due to the lack of open-water in many natural wetlands in West Virginia (Balcombe et al. 2005). Yet West Virginia wetlands support many more species than waterfowl and waterbirds. The metrics derived from avian bird communities demonstrate that birds can be used to detect local levels of human impairment quantified in our wetlands, as indicated by the discriminatory capability across all class-specific AW-IBI. This does not come as a surprise since birds have been used for bioassessments in both wetland and non-wetland circumstances, although not regionally across multiple wetland classifications (Bradford et al. 1998; DeLuca et al. 2004; O'Connell et al. 2000).

4.5 Regional HGM subclasses and Designated HGM management classes

Small sample size prevented independent analysis of all the regional HGM subclasses (Cole et al. 1997). However, conclusions from the resulting AW-IBI can still be made. Based upon our results, it may be that combining of isolated depression, surface water depression, and riparian depression into the depressional designated HGM management class failed to account for the complex hydrology unique to each of these systems, which is supported by other regional findings (Cole et al. 1997). Riparian and isolated depressions are groundwater-driven, which is not the case, by definition, for surface-water depressions.

When we examined riparian depressions independently, the only metric that could consistently differentiate between reference and stressed conditions was the percent of residential and edge tolerant species. However, due to a significant ecoregion and alternative classification scheme effect, we could not create a riparian depression AW-IBI. This is in contrast to our depression designated HGM management class that exhibited a significant (albeit weak) relation between the disturbance gradient and depression AW-IBI scores as a whole. This is despite the riparian depression subclass composing 59 of the 72 sample sites used to form the depression designated HGM subclass. This result suggests further research is needed to understand the relation between human impacts on bird communities in isolated depressions, surface-water depressions, and riparian depressions.

Headwater floodplains, responded similarly to the disturbance gradient as the floodplain designated HGM management class. This is partially explained by the high proportion (29 of 35) of headwater floodplain wetlands that composed this management class. The metric that was the exception in differentiating reference and stressed conditions between these 2 classes was the Shannon-Weaver diversity index. However, the total variation of bird communities explained by the disturbance gradient in both classes differed by <4%. These 2 classes exhibited the strongest relation with the disturbance gradient of any classifications, perhaps due to the inherent nature of floodplains discussed previously.

The consistency between our testing of regional HGM subclasses and our designated HGM management classes indicate that with further validation it may be appropriate in AW-IBI to use designated HGM management classes as a unit for comparing the biological integrity of avian communities within wetlands. If this consistency withstands the rigor of further scientific testing, it would prove beneficial to assisting resource managers in making comparisons and understanding the relation between bird communities and human impairment in wetlands. However, we must caution that all regional HGM subclasses should to be tested for congruity with the designated HGM management classes in West Virginia before adopting this strategy.

4.6 Metrics

The majority of metrics involving facultative wetland, wetland associated and wetland dependent birds failed to differentiate reference from stressed sites in every instance and therefore were not included in a resulting IBI. An examination of the prevailing literature helps to explain the lack of performance by what we collectively term, wetland "affinity" avian metrics. Both disturbance tolerant and intolerant species are captured in these metrics, which may be why they were not successful at differentiating stressed from reference conditions. For example, red-winged blackbirds (*Agelaius phoeniceus*) are a ubiquitous wetland associated species that are tolerant of human impairments, whereas prothonotary warblers (*Protonotaria citrea*) are also a wetland associated species that are sensitive to negative anthropogenic disturbances (Petit 1991). Furthermore, waterfowl and other birds that require wetlands for survival are responsive to changes in wetland hydroperiods and correspond to wetland area (Brown and Smith 1998; Kantrud and Stewart 1977; Murkin et al. 1997; VanRees-Siewert and Dinsmore 1996). However, West Virginia's terrain is not conducive to the large wetland complexes that support large numbers of these types of birds. In fact, West Virginia has less wetland area than any other state east of the Mississippi River, and is second only to Rhode Island as far as least amount of wetland area (Dahl 1990).

Some metrics are generated based on restoration expectations. However, these expectations often fall within vague goals. For example, it may no longer be appropriate to define a target for species richness as a restoration goal (Ehrenfeld 2000). Also, some metrics, such as proportion shrub nesters become challenging as it is difficult to explain how they may be responsive to human influence (Dale and Beyeler 2001). Further, this metric is ambiguous as both tolerant and sensitive species will nest in shrubs.

The percent carnivorous habitat-specific species metric, and the percent edge species metric were both shown to be effective in discriminating between reference and stressed sites in some classes. Yet both were rejected from inclusion from most of the class specific AW-IBIs. The percent of carnivorous habitat-specific species was often redundant with the percent habitat-specific neotropical migratory bird metric. In addition, a carnivorous habitat-specific bird species, such as the belted kingfisher (*Ceryle alcyon*) (10 occurrences of 2,297) or an osprey (*Pandion haliaetus*) (3 occurrences of 2,297), is a relatively uncommon find for our study. The importance of rare and minor species for bioassessments and ecosystem processes is still subject to debate (Boeken and Shachek 2006; Cao et al. 1998). Finally, the percent of edge species was redundant and inferior to the percent year-round residential and edge species metrics as both of these metrics discriminated between reference and stressed sites in every case.

Compositional metrics based on richness and abundance were not acceptable for inclusion into designated HGM management classes because of the inconsistent relation these metrics have with disturbance. The abundance of wetland affinity birds was removed from inclusion in the scrub-shrub AW-IBI after exhibiting an HGM effect. The omission of this metric is consistent with research noting densities of species can be misleading indicators of habitat quality (VanHorn 1983).

Compositional metrics that were incorporated into AW-IBIs could be explained by the “generalists versus specialist” nature of each metric (O’Connell et al. 2000). The compositional metrics that were effective for Cowardin classifications were based on this approach. For example, the percent of species that lay a single brood of eggs per year is a compositional metric that characterizes these single brood species as specialists because they are often restricted to patches that are relatively free of nest predators and brood parasites (Freemark and Collins 1992; O'Connell et al. 2000). This metric was capable of distinguishing between reference and stressed conditions in most classes.

4.7 Combining of AW-IBI Metrics across Classes

Combining metrics from the HGM based and Cowardin classification schemes showed promising signs in some cases, but not all, by increasing the amount of variability explained by the disturbance gradient. A lack of a significant relation between depression and impoundment designated HGM management class and riparian depression HGM subclass (Cole et al. 1997) wetlands when combined with the Cowardin counterpart metrics was not to be unexpected. It should be noted that the impoundment AW-IBI did not have a significant relation with the disturbance gradient alone, and the depression relation was significant but did not account for a substantial part of the AW-IBI variation.

The response of the designated floodplain HGM management class metrics and the headwater floodplain metrics with the Cowardin counterparts is promising as it increased the amount of variation accounted for by the disturbance gradient in scrub-shrub floodplain wetlands and in headwater floodplain forested and scrub-shrub wetlands. It should be noted that for these combined classes the amount of variation accounted for is greater than that captured in the backwards stepwise regression models for headwater floodplain wetlands and the floodplain designated management class wetlands that was intended to maximize the R^2 values. However, because of relatively smaller sample sizes, more study sites are needed to separate the effects of natural variability in bird populations and the effect of human impairment in these wetlands.

4.8 Scoring thresholds

The generation of thresholds that indicate wetland quality is necessary to account for some degree of stochasticity in sampling from year to year. Examining categorical values of site AW-IBI scores will enable monitoring to discount small changes in AW-IBI scoring to determine if the integrity of a wetland is being maintained or is succumbing to the effects of impairments. The biological basis for these scoring categories is based on tested principles that have been used in previous regional studies (Hill et al. 2003; McCormick et al. 2001). However, the legitimacy and applicability of these scoring thresholds will need to be explored in future work. For example, increased sample sizes would, in theory, generate a larger variation in scoring values, for which we would need to recalibrate these proposed thresholds. Additionally, when we combine the class-specific AW-IBI to form addititive hybrid classification indices, the reference and stressed sites' designations were based on within class-specific parameters. That is to say a reference site for a Cowardin classification may not be a reference site for our designated HGM management classes. Increasing sample sizes would provide a more consistent context of what constitutes reference condition regardless of classification schemes. Therefore, these derived scoring thresholds should be regularly re-examined to refine and calibrate these thresholds, increasing their validity and interpretability.

5.0 Management Implications

The objective of designing avian wetland indices of biotic integrity that can be broadly applied and integrated quickly into management action was successfully demonstrated by our methodology. New sites to validate the effectiveness of these AW-IBIs can be added opportunistically. Our stressor gradient is not a theoretical principle component of chemical, physical, and/or biological stressors. Rather, this gradient is tangible and can be realistically managed and quantified by non-experts with limited training. A systematic scoring and testing protocol, based on existing methods, will allow future researchers to "append" data to our existing dataset to increase validity and test more HGM subclasses (Cole et al. 1997) or designated HGM management classes. Further, summing the metrics used in each wetland classification system has shown promise as a novel method that may increase the sensitivity of AW-IBI to a disturbance gradient. In the future, additional surveys of multiple taxonomic groups can be examined for sensitive metrics responsive to our disturbance score. These metrics could be evaluated with metrics from these resulting AW-IBI to establish multiple taxa IBIs. This approach would increase the sensitivity of our bioassessment efforts in diagnosing wetland stressors at multiple scales (Griffith et al. 2005; O'Connor et al. 2000).

Future analyses coupling site specific results with landscape patterns using Geographic Information Systems (GIS) will assist in landscape planning and will ensure wetland resources are maintained (Haig et al. 1998; Marzluff and Ewing 2001). The scoring threshold categories can be evaluated based on the capability to predict these wetland categories using landscape variables, which in turn will help guide both wetland and avian community conservation strategies (Glennon and Porter 2005; Whited et al.

2000). In essence, our research in wetlands of West Virginia represents the beginning of an expansion in the understanding of the components that characterize the provision of wetland services and functions within the state. Furthermore, waters from West Virginia drain into both the Chesapeake Bay and the Gulf of Mexico. Protecting this state's wetlands and water resources is critically important to protecting against downstream effects of poor water quality. By maintaining healthy and functional wetlands, West Virginia will be proactive in protecting avian communities within our state while ensuring downstream water quality.

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Table 1. Designated hydrogeomorphic (HGM) management classes derived from regional hydrogeomorphic (HGM) subclasses[a] for use in developing class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

Designated Management HGM subclass	Hydrogeomorphic subclass[a]
Depression	Surface water depression
	Riparian depression
	Isolated depression
Floodplain	Headwater floodplain
	Mainstem floodplain
Impoundment	Headwater impoundment
	Mainstem impoundment
Fringing	Fringing
Slope	Slope

[a] Cole et al. (1997).

Table 2. Total number of sites by regional hydrogeomorphic (HGM) subclass, designated HGM management class, and Cowardin class by ecoregion for use in developing class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

	Level 3 U.S. Environmental Protection Agency aquatic ecoregion[a]			
	Ridge and Valley	**Central Appalachian**	**Western Alleghany Plateau**	**Total**
Hydrogeomorphic subclass[b]				
Surface water depression[c]	0	2	5	7
Riparian depression	10	24	25	59
Isolated depression[c]	0	2	4	6
Headwater floodplain	10	15	4	29
Mainstem floodplain[c]	2	2	1	5
Headwater impoundment[c]	1	12	4	17
Mainstem impoundment[c]	0	2	4	6
Fringing[c]	0	2	11	13
Slope[c]	4	4	0	8
Floodplain-in-stream[c]	0	0	1	1
Designated HGM Management Class				
Depression	10	28	34	72
Floodplain	12	17	6	35
Impoundment	1	14	8	23
Fringing[c]	0	2	11	13
Slope[c]	4	4	0	8
Cowardin Class				
Emergent	15	34	26	75
Scrub-shrub	6	17	21	44
Forested	6	14	11	31
Aquatic bed[c]	0	0	1	1
Total	27	65	59	151

[a] Omernik (1987), modified by Woods et al. (1999).

[b] Cole et al. (1997).

[c] Removed from analysis due to small sample size.

Table 3. Metrics and sub-metrics selected from the Ohio Rapid Assessment Method (Mack 2001) used to define the disturbance gradient for use in developing class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

Scoring value		Disturbance component
		Upland buffers and surrounding land use
		Calculate the average buffer width. Select only one and assign score.
7		WIDE. Buffers average 50m or more around wetland perimeter
4		MEDIUM. Buffers average 25m to <50m around wetland perimeter
1		NARROW. Buffers average 10m to <25m around wetland perimeter
0		VERY NARROW. Buffers average <10m around wetland perimeter
		Intensity of surrounding land use. Select one or double check and average.
7		VERY LOW. 2nd growth or older forest, prairie, savannah, wildlife area, etc.
5		LOW. Old field (>10 years), shrubland, young second growth forest.
3		MODERATELY HIGH. Residential, fenced pasture, park, conservation tillage, new fallow field.
1		HIGH. Urban, industrial, open pasture, row cropping, mining, construction.
		Hydrology
		Modifications to natural, hydrologic regime. Score one or double check and average.
12		None or none apparent. There are no modifications or no modifications that are apparent to the rater.
7		Recovered. The wetland appears to have recovered from past modifications which altered the wetland's natural hydrologic regime.
3		Recovering. The wetland appears to be in the process of recovering from past modifications, which altered the wetland's natural hydrologic regime.
1		Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past modifications and / or the modifications are ongoing.
		Habitat alteration and development
		Substrate disturbance. Score one or double check and average.
4		None or none apparent. There are no modifications or no modifications that are apparent to the rater.
3		Recovered. The wetland appears to have recovered from past disturbances.
2		Recovering. The wetland appears to be in the process of recovering from past disturbances.
1		Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past disturbances and/ or the disturbances are ongoing.
		Habitat alteration. Score one or double check and average.
9		None or none apparent. There are no alterations or no alterations that are apparent to the rater.
6		Recovered. The wetland appears to have recovered from past alterations.
3		Recovering. The wetland appears to be in the process of recovering from past alterations.
1		Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past alterations and/ or the alterations are ongoing.

Table 4. Candidate avian community biological metrics evaluated by class according to regional Hydrogeomorphic (HGM) subclass, designated HGM management class, and the Cowardin classification schemes in building avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

			Classification system[a]							
			HGM subclass		Designated HGM management class			Cowardin classification		
Candidate avian metrics[a]	Guild type	Expected Response to Disturbance	Riparian Depression	Headwater Floodplain	Depression	Floodplain	Impoundment	Emergent	Scrub-Shrub	Forested
Percent neotropical migrants[b]	composition	-	*	R	*	R	*	E	*	R
Percent habitat specific and neotropical migrants[b]	composition and structure	-	*	R	*	R	*	E	I	E
Percent habitat specific[b]	structure	-	*	R	*	R	*	E	R	E
Percent permanent resident and edge birds[b]	composition and structure	+	E	I	I	I	I	E	I	I
Percent carnivore and habitat specific[b]	function and structure	-	*	I	*	R	*	R	*	*
Shannon-Weaver diversity index[c]	composition	-	*	*	*	I	*	*	*	*
Percent of omnivorous birds[d]	function	+	*	I	*	I	I	I	I	F
Percent single brood[d]	composition	-	*	I	*	E	*	*	E	I
Percent forest area sensitive[d]	structure	-	*	*	*	*	*	*	*	I
Percent of insectivorous birds[d,e]	function	-	*	R	I	I	I	E	I	R
Wetland bird abundance	composition	-	*	*	*	*	*	*	E	*
Percent wetland dependent[b,f]	structure	-	*	*	*	*	*	*	*	*
Percent wetland dependent and associated[b,f]	structure	-	*	*	*	*	*	*	*	*
Percent facultative wetland species[b,f]	structure	-	*	*	*	*	*	*	*	*
Wetland species richness[f]	composition	-	*	*	*	*	*	*	*	*
Wetland bird Shannon-Weaver diversity[f]	composition	+	*	*	*	*	*	*	*	*
Species richness[c,f]	composition	+	*	*	*	*	*	*	*	*
Total bird abundancec[,f]	composition	+	*	*	*	*	*	*	R	*
Percent edge species[b,f]	structure	+	*	R	*	R	*	R	*	*
Shannon's Evenness index[f]	composition	-	*	*	*	*	*	*	F	*
Percent nest parasite/ predator[d,f]	composition	-	*	*	*	*	*	*	*	F
Percent shrub nesters[d,f]	structure	+	*	*	*	*	*	*	*	*

[a] I = included into class-specific AW-IBI; R = redundancy with other metrics; F = failure due to lack of scoring range; E = failure due to significant ecoregion or alternative classification scheme effect;
* = failure to discriminate between reference and stressed sites.

[b] Croonquist and Brooks (1991).

[c] Bradford et al. (1998).

[d] O'Connell et al. (1998a).

[e] Galatowitsch et al. (1999).

[f] metrics excluded from all of the resullting class-specific AW-IBI due to redundancy, failure in scoring range, or inability to discriminate between reference and stressed sites.

Table 5. Correlated metrics based on Spearman's R (R> 0.80) selected based on discrimination efficiency in differentiating between reference and stressed sites metrics used in developing class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

Classification/ Metric	Discrimination Efficiency	Spearman's R Correlation	Correlated Metric	Discrimination Efficiency
Headwater Floodplain				
Residential Edge[a]	100	-0.828	Insectivorous	100
Residential Edge[a]	100	-0.861	neotropical Habitat Specific	88
Residential Edge[a]	100	0.864	Edge	88
Residential Edge[a]	100	-0.862	Habitat Specific	75
Residential Edge[a]	100	-0.830	neotropical Migrant	63
Carnivorous Habitat Specific[a]	88	0.853	Insectivorous[b]	100
Carnivorous Habitat Specific[a]	88	0.925	neotropical Habitat Specific[b]	88
Carnivorous Habitat Specific[a]	88	-0.823	Edge[b]	88
Carnivorous Habitat Specific[a]	88	0.864	Habitat Specific[b]	75
Omnivorous[a]	75	0.861	Insectivorous	100
Insectivorous[b]	88	0.866	neotropical Habitat Specific[b]	88
Insectivorous[b]	100	-0.861	neotropical Migrant[b]	63
neotropical Habitat Specific[b]	88	0.856	Habitat Specific[b]	75
neotropical Habitat Specific[b]	88	-0.825	Edge[b]	88
neotropical Habitat Specific[b]	88	0.872	neotropical Migrant[b]	63
Edge[b]	88	-0.987	Habitat Specific	75
Floodplain				
Residential Edge[a]	100	-0.893	Carnivorous Habitat Specific	89
Residential Edge[a]	100	-0.846	neotropical	67
Residential Edge[a]	100	-0.887	Habitat Specific	78
Residential Edge[a]	100	0.887	Edge	89
Insectivorous[a]	89	0.805	neotropical Habitat Specific	89
Insectivorous[a]	89	0.820	neotropical	67
neotropical Habitat Specific[b]	89	0.889	neotropical[b]	67
neotropical Habitat Specific[b]	89	0.851	Habitat Specific[b]	78
neotropical Habitat Specific[b]	89	-0.839	Edge[b]	89
neotropical Habitat Specific[b]	89	0.893	Carnivorous Habitat Specific[b]	89
Edge[b]	89	-0.989	Habitat Specific[b]	78
Edge[b]	89	-0.881	Carnivorous Habitat Specific[b]	89
Carnivorous Habitat Specific[b]	89	0.890	Habitat Specific[b]	78

Table 5. Continued.

Classification/ Metric	Discrimination Efficiency	Spearman's R Correlation	Correlated Metric	Discrimination Efficiency
Emergent				
Habitat Specific[a]	84	-0.966	Edge	79
Habitat Specific[a]	84	0.844	Carnivorous Habitat Specific	73
neotropical Habitat Specific[a]	84	0.903	Carnivorous Habitat Specific	73
Edge[b]	79	-0.832	Carnivorous Habitat Specific[b]	73
Scrub-Shrub				
Residential Edge[a]	100	-0.828	Habitat Specific	67
Residential Edge[a]	100	0.825	Edge	58
Wetland Species Abundance[a]	75	0.873	Abundance	75
Shannon's Evenness[a]	67	-0.886	Abundance[b]	67
Habitat Specific[b]	67	-0.999	Edge[b]	58
Forested				
Residential Edge[a]	88	-0.867	neotropical	88
Residential Edge[a]	88	-0.834	Insectivorous	75
Omnivorous[a]	88	-0.803	Insectivorous	75
neotropical[b]	88	0.837	Insectivorous[b]	75

[a]Selected for inclusion into class-specific AW-IBI.
[b]Not included into AW-IBI due to redundancy with metric with higher discrimination efficiency.

Table 6. Analysis of variance (ANOVA) results of reference and stressed sites' metric values compared to Level 3 ecoregions (Omernik 1987; Wood et al. 1999) and the alternative classification scheme used in developing avian wetland indices of biological integrity (AW-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Riparian Depression AW-IBI (n=27)				
Percent residential and edge tolerant species[a]	Cowardin class	2,26	1.86	0.2150
	Level 3 ecoregion	2,26	0.88	0.4288
	Cowardinclass x Level 3 ecoregion	2,26	3.76	0.0410
Headwater Floodplain AW-IBI (n=16)				
Percent residential and edge tolerant species	Cowardinclass	2,15	1.28	0.3202
	Level 3 ecoregion	2,15	0.89	0.4414
	Cowardinclass x Level 3 ecoregion	1,15	0.30	0.5939
Percent carnivorous and habitat specific species	Cowardinclass	2,15	0.20	0.8215
	Level 3 ecoregion	2,15	0.35	0.7106
	Cowardinclass x Level 3 ecoregion	1,15	0.01	0.9076
Percent single-brood species	Cowardinclass	2,15	0.25	0.7845
	Level 3 ecoregion	2,15	0.25	0.7820
	Cowardinclass x Level 3 ecoregion	1,15	1.88	0.2001
Percent omnivorous species	Cowardinclass	2,15	0.82	0.4685
	Level 3 ecoregion	2,15	0.15	0.8627
	Cowardinclass x Level 3 ecoregion	1,15	0.15	0.7037
Depression AW-IBI (n=37)				
Percent residential and edge tolerant species	Cowardinclass	3,36	2.22	0.1076
	Level 3 ecoregion	2,36	0.26	0.7757
	Cowardinclass x Level 3 ecoregion	3,36	0.64	0.5953
Percent insectivorous species	Cowardinclass	3,36	2.36	0.0925
	Level 3 ecoregion	2,36	0.16	0.8522
	Cowardinclass x Level 3 ecoregion	3,36	0.43	0.7345
Floodplain AW-IBI (n=19)				
Percent residential and edge tolerant species	Cowardinclass	2,18	1.38	0.2958
	Level 3 ecoregion	2,18	0.63	0.5521
	Cowardinclass x Level 3 ecoregion	4,18	1.43	0.2936
Avian diversity	Cowardinclass	2,18	0.03	0.9716
	Level 3 ecoregion	2,18	0.25	0.7815
	Cowardinclass x Level 3 ecoregion	4,18	1.55	0.2612
Percent omnivorous species	Cowardinclass	2,18	1.55	0.2592
	Level 3 ecoregion	2,18	1.19	0.3439
	Cowardinclass x Level 3 ecoregion	4,18	1.82	0.2012
Percent single-brood species[a]	Cowardinclass	2,18	7.61	0.0098
	Level 3 ecoregion	2,18	1.03	0.3912
	Cowardinclass x Level 3 ecoregion	4,18	0.91	0.4933
Percent insectivorous species	Cowardinclass	2,18	1.69	0.2333
	Level 3 ecoregion	2,18	1.16	0.2535
	Cowardinclass x Level 3 ecoregion	4,18	2.41	0.1182

Table 6. Continued.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Impoundment AW-IBI (n=13)				
Percent residential and edge tolerant species	Cowardinclass	2,12	0.98	0.4202
	Level 3 ecoregion	2,12	2.86	0.1233
	Cowardinclass x Level 3 ecoregion	1,12	1.50	0.2606
Percent omnivorous species	Cowardinclass	2,12	0.56	0.5936
	Level 3 ecoregion	2,12	0.68	0.5353
	Cowardinclass x Level 3 ecoregion	1,12	0.57	0.4735
Percent insectivorous species	Cowardinclass	2,12	0.21	0.8135
	Level 3 ecoregion	2,12	1.50	0.2878
	Cowardinclass x Level 3 ecoregion	1,12	2.57	0.1532
Emergent AW-IBI (n=38)				
Percent residential and edge tolerant species[a]	Designated HGM[b] management class	4,37	3.29	0.0267
	Level 3 ecoregion	2,37	0.86	0.4352
	Designated HGM[b] management class x Level 3 ecoregion	6,37	3.33	0.0151
Percent neotropical migrant[a]	Designated HGM[b] management class	4,37	4.22	0.0095
	Level 3 ecoregion	2,37	0.81	0.4583
	Designated HGM[b] management class x Level 3 ecoregion	6,37	1.21	0.3330
Percent habitat specific and neotropical migrant[a]	Designated HGM[b] management class	4,37	6.28	0.0012
	Level 3 ecoregion	2,37	0.04	0.9594
	Designated HGM[b] management class x Level 3 ecoregion	6,37	1.35	0.2744
Percent habitat specific[a]	Designated HGM[b] management class	4,37	6.73	0.0008
	Level 3 ecoregion	2,37	0.37	0.6952
	Designated HGM[b] management class x Level 3 ecoregion	6,37	1.87	0.1255
Percent omnivorous species	Designated HGM[b] management class	4,37	2.61	0.0595
	Level 3 ecoregion	2,37	0.03	0.9702
	Designated HGM[b] management class x Level 3 ecoregion	6,37	1.50	0.2200
Percent insectivorous species[a]	Designated HGM[b] management class	4,37	5.82	0.0019
	Level 3 ecoregion	2,37	0.03	0.9738
	Designated HGM[b] management class x Level 3 ecoregion	6,37	1.07	0.4054
Scrub-Shrub AW-IBI (n=23)				
Wetland bird abundance[a]	Designated HGM[b] management class	4,22	3.42	0.0377
	Level 3 ecoregion	2,22	0.33	0.7256
	Designated HGM[b] management class x Level 3 ecoregion	2,22	1.09	0.3626
Percent residential and edge tolerant species	Designated HGM[b] management class	4,22	1.00	0.4403
	Level 3 ecoregion	2,22	0.44	0.6521
	Designated HGM[b] management class x Level 3 ecoregion	2,22	1.77	0.2058
Percent habitat specific and neotropical migrant	Designated HGM[b] management class	4,22	2.64	0.0785
	Level 3 ecoregion	2,22	1.46	0.2657
	Designated HGM[b] management class x Level 3 ecoregion	2,22	2.01	0.1705
Percent single-brood species[a]	Designated HGM[b] management class	4,22	3.63	0.0314
	Level 3 ecoregion	2,22	0.02	0.9761
	Designated HGM[b] management class x Level 3 ecoregion	2,22	0.23	0.8011
Percent omnivorous species	Designated HGM[b] management class	4,22	0.54	0.7101
	Level 3 ecoregion	2,22	0.91	0.4260
	Designated HGM[b] management class x Level 3 ecoregion	2,22	3.52	0.0579
Percent insectivorous species	Designated HGM[b] management class	4,22	1.20	0.3525
	Level 3 ecoregion	2,22	1.00	0.3918
	Designated HGM[b] management class x Level 3 ecoregion	2,22	1.83	0.1974

Table 6. Continued.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Forested AW-IBI (n=16)				
Percent habitat specific and neotropical migrant	Designated HGM[b] management class	4,15	0.43	0.7838
	Level 3 ecoregion	2,15	0.17	0.8443
	Designated HGM[b] management class x Level 3 ecoregion	2,15	0.66	0.5468
Percent habitat specific	Designated HGM[b] management class	4,15	2.48	0.1390
	Level 3 ecoregion	2,15	0.16	0.8559
	Designated HGM[b] management class x Level 3 ecoregion	2,15	0.86	0.4653
Percent residential and edge tolerant species	Designated HGM[b] management class	4,15	1.15	0.4082
	Level 3 ecoregion	2,15	0.11	0.8993
	Designated HGM[b] management class x Level 3 ecoregion	2,15	1.34	0.3218
Percent single-brood species	Designated HGM[b] management class	4,15	2.32	0.1563
	Level 3 ecoregion	2,15	2.67	0.1376
	Designated HGM[b] management class x Level 3 ecoregion	2,15	1.94	0.2134
Percent forest-area sensitive	Designated HGM[b] management class	4,15	3.33	0.0792
	Level 3 ecoregion	2,15	0.19	0.8280
	Designated HGM[b] management class x Level 3 ecoregion	2,15	0.09	0.9137

[a] Metric excluded from inclusion into class-specific AW-IBI due to a significant ecoregion, alternative classification scheme, or cumulative 2-way interaction.

[b] Hydrogeomorphic (Brinson 1993).

Table 7. Wilks' Lambda statistic for *posthoc* validation of reference and stressed sites' metric values of class-specific avian wetland indices of biological integrity (AW-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification scheme and interaction	Wilks' Lambda	F-value	df	p-value
Headwater Floodplain AW-IBI (n=16)				
Cowardin class	0.4292	0.92	8, 14	0.5278
Level 3 ecoregion	0.7291	0.30	8, 14	0.9541
Cowardinx Level 3 ecoregion	0.7037	0.74	4, 7	0.5954
Floodplain AW-IBI (n=19)				
Cowardinclass	0.6504	0.42	8, 14	0.8903
Level 3 ecoregion	0.7253	0.30	8, 14	0.9518
Cowardinx Level 3 ecoregion	0.2491	0.79	16, 20.02	0.6788
Depression AW-IBI (n=37)				
Cowardinclass	0.7838	1.17	6, 54	0.3382
Level 3 ecoregion	0.9798	0.14	4, 54	0.9673
Cowardinx Level 3 ecoregion	0.9009	0.48	6, 54	0.8187
Impoundment AW-IBI (n=13)				
Cowardinclass	0.4067	0.95	6, 10	0.5042
Level 3 ecoregion	0.3989	0.97	6, 10	0.4902
Cowardinx Level 3 ecoregion	0.6255	1.00	3, 5	0.4656
Scrub-Shrub AW-IBI (n=23)				
Designated HGM[a] management class	0.4102	0.72	16, 34.23	0.7504
Level 3 ecoregion	0.5362	1.01	8, 22	0.4598
Designated HGM[a] management class x Level 3 ecoregion	0.5878	0.84	8, 22	0.5806
Forested AW-IBI (n=19)				
Designated HGM[a] management class	0.0636	2.06	12, 13.52	0.1013
Level 3 ecoregion	0.4643	0.78	6, 10	0.6045
Designated HGM[a] management class x Level 3 ecoregion	0.4952	0.70	6, 10	0.6554

[a] Hydrogreomorphic (Brinson 1993).

Table 8. Reference site scoring summary used to derive scoring thresholds, and discrimination efficiency (D.E.) in developing class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

	Reference Site Scoring Summary							Means (SE)	
	N	Max IBI score	75th	25th	5th	Median	D.E.[a]	Reference[b]	Stressed
Headwater Floodplain	8	40	37.54	30.54	24.73	33.29	100	33.18 (2.07)	21.16 (2.09)
Depression	19	20	19.79	16.15	9.69	19.18	78	17.18 (0.86)	12.95 (1.15)
Floodplain	10	40	38.21	32.50	27.93	36.83	100	35.17 (1.40)	24.98 (2.05)
Impoundment	6	30	27.70	22.36	20.91	24.86	86	24.78 (1.39)	20.64 (0.68)
Emergent	19	10	10.00	9.47	6.33	10.00	68	9.22 (0.32)	7.50 (0.57)
Scrub-shrub	11	40	39.55	35.58	25.62	38.19	92	36.07 (1.86)	26.69 (2.14)
Forested	8	30	29.07	19.06	16.15	24.57	75	23.74 (2.01)	14.87 (1.58)

[a] Effectiveness of AW-IBI scores to effectively discriminate between reference and stressed sites.
[b]All means statistically different (Tukey $\alpha = 0.05$).

Table 9. Avian species recorded and used in the formation of class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

Common Name	*Scientific Name*
Acadian flycatcher	*Empidonax virescens*
Alder flycatcher	*Empidonax alnorum*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Carduelis tristis*
American kestrel	*Falco sparverius*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*
American woodcock	*Scolopax minor*
Baltimore oriole	*Icterus galbula*
Bank swallow	*Riparia riparia*
Barn swallow	*Hirundo rustica*
Barred owl	*Strix varia*
Belted kingfisher	*Ceryle alcyon*
Black-and-white warbler	*Mniotilta varia*
Black-capped chickadee	*Poecile atricapilla*
Black-throated blue warbler	*Dendroica caerulescens*
Black-throated green warbler	*Dendroica virens*
Blue jay	*Cyanocitta cristata*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue-headed vireo	*Vireo solitarius*
Blue-winged warbler	*Vermivora pinus*
Brown thrasher	*Toxostoma rufum*
Brown-headed cowbird	*Molothrus ater*
Canada goose	*Branta canadensis*
Carolina chickadee	*Poecile carolinensis*
Carolina wren	*Thryothorus ludovicianus*
Cedar waxwing	*Bombycilla cedrorum*
Cerulean warbler	*Dendroica cerulea*
Chestnut-sided warbler	*Dendroica pensylvanica*
Chimney swift	*Chaetura pelagica*
Chipping sparrow	*Spizella passerina*
Common grackle	*Quiscalus quiscula*
Common yellowthroat	*Geothlypis trichas*
Cooper's hawk	*Accipiter cooperii*
Dark-eyed junco	*Junco hyemalis*
Domestic duck	*not applicable*
Downy woodpecker	*Picoides pubescens*
Eastern bluebird	*Sialia sialis*
Eastern kingbird	*Tyrannus tyrannus*
Eastern meadowlark	*Sturnella magna*
Eastern phoebe	*Sayornis phoebe*
Eastern towhee	*Pipilo erythrophthalmus*
Eastern wood-pewee	*Contopus virens*
European starling	*Sturnus vulgaris*

Table 9. Continued.

Common Name	*Scientific Name*
Field sparrow	*Spizella pusilla*
Golden-crowned kinglet	*Regulus satrapa*
Golden-winged warbler	*Vermivora chrysoptera*
Grasshopper sparrow	*Ammodramus savannarum*
Gray catbird	*Dumetella carolinensis*
Great blue heron	*Ardea herodias*
Great crested flycatcher	*Myiarchus crinitus*
Green heron	*Butorides virescens*
Hairy woodpecker	*Picoides villosus*
Henslow's sparrow	*Ammodramus henslowii*
Hermit thrush	*Catharus guttatus*
Hooded merganser	*Lophodytes cucullatus*
Hooded warbler	*Wilsonia citrina*
House wren	*Troglodytes aedon*
Indigo Bbnting	*Passerina cyanea*
Kentucky warbler	*Oporornis formosus*
Killdeer	*Charadrius vociferus*
Louisiana waterthrush	*Seiurus motacilla*
Magnolia warbler	*Dendroica magnolia*
Mallard	*Anas platyrhynchos*
Marsh wren	*Cistothorus palustris*
Mourning dove	*Zenaida macroura*
Mourning warbler	*Oporornis philadelphia*
Nashville warbler	*Vermivora ruficapilla*
Northern cardinal	*Cardinalis cardinalis*
Northern flicker	*Colaptes auratus*
Northern mockingbird	*Mimus polyglottos*
Northern parula	*Parula americana*
Northern rough-winged swallow	*Stelgidopteryx serripennis*
Northern waterthrush	*Northern Waterthrush*
Orchard oriole	*Icterus spurius*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapillus*
Philadelphia vireo	*Vireo philadelphicus*
Pileated woodpecker	*Dryocopus pileatus*
Pine warbler	*Dendroica pinus*
Prothonotary warbler	*Protonotaria citrea*
Purple finch	*Carpodacus purpureus*
Purple martin	*Progne subis*
Red-bellied woodpecker	*Melanerpes carolinus*
Red-breasted nuthatch	*Sitta canadensis*
Red-eyed vireo	*Vireo olivaceus*
Red-tailed hawk	*Buteo jamaicensis*

Table 9. Continued.

Common Name	*Scientific Name*
Red-winged blackbird	*Agelaius phoeniceus*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Ruby-crowned kinglet	*Regulus calendula*
Ruby-throated hummingbird	*Archilochus colubris*
Savannah sparrow	*Passerculus sandwichensis*
Scarlet tanager	*Piranga olivacea*
Sedge wren	*Cistothorus platensis*
Solitary sandpiper	*Tringa solitaria*
Song sparrow	*Melospiza melodia*
Spotted sandpiper	*Actitis macularia*
Swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Vermivora peregrina*
Tree swallow	*Tachycineta bicolor*
Tufted titmouse	*Parus bicolor*
Turkey vulture	*Cathartes aura*
Veery	*Catharus fuscescens*
Virginia rail	*Rallus limicola*
Warbling vireo	*Vireo gilvus*
Whip-poor-will	*Caprimulgus vociferus*
White-breasted nuthatch	*Sitta carolinensis*
White-eyed vireo	*Vireo griseus*
Willow flycatcher	*Empidonax traillii*
Winter wren	*Troglodytes troglodytes*
Wood duck	*Aix sponsa*
Wood thrush	*Hylocichla mustelina*
Yellow warbler	*Dendroica petechia*
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-breasted chat	*Icteria virens*
Yellow-rumped warbler	*Dendroica coronata*

Table 10. Summary statistics of proportion of wetland affiliated birds by classification used in developing class specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

	Facultative[a]	Associated [b]	Dependent	Shannon-Weaver Diversity	Wetland Bird Richness[c]	Wetland Bird Abundance[c]
Headwater Floodplain	0.52	0.33	0.12	2.69	7.31	13.24
Riparian Depression	0.57	0.30	0.11	2.69	7.54	14.98
Depression	0.57	0.31	0.11	2.66	7.42	14.93
Floodplain	0.52	0.31	0.13	2.68	7.23	13.11
Impoundment	0.60	0.37	0.16	3.06	7.96	19.61
Emergent	0.60	0.35	0.14	2.79	7.89	16.92
Scrub-Shrub	0.56	0.34	0.11	2.77	7.59	15.45
Forested	0.41	0.18	0.10	2.36	5.87	9.26

[a] Includes wetland associated and dependent birds.

[b] Includes wetland dependent birds.

[c] Includes all birds with affiliated with facultative wetland use and greater.

Table 11. Relations between the resulting hydrogeomorphic (HGM) and Cowardin class-specific and combined avian wetland indices of biological integrity (AW-IBI) for West Virginia, USA and the disturbance gradient from 2005-2006.

	Number of metrics	N	df	F-value	P-value	R^2	Equation
HGM subclass							
Headwater Floodplain	4	29	1, 27	25.44	<0.0001	0.49	y = 11.97 + 0.62 (Disturbance score)
Designated HGM management class							
Depression	2	72	1, 70	9.71	0.0027	0.12	y = 9.52 + 0.23 (Disturbance score)
Floodplain	4	35	1, 33	32.74	<0.0001	0.46	y = 18.14 + 0.50 (Disturbance score)
Impoundment	3	23	1, 21	1.14	0.2982	0.05	y = 18.15 + 0.15 (Disturbance score)
Cowardin class							
Emergent	1	75	1, 73	8.71	0.0042	0.11	y = 6.47 + 0.09 (Disturbance score)
Scrub-Shrub	4	44	1, 42	13.71	0.0006	0.25	y = 17.54 + 0.54 (Disturbance score)
Forested	3	31	1, 29	8.48	0.0056	0.24	y = 6.07 + 0.47 (Disturbance score)
Hybrid class							
Headwater Floodplain / Emergent	4	15	1, 13	4.59	0.0517	0.26	y = 16.48 + 0.45 (Disturbance score)
Headwater Floodplain / Scrub-Shrub	6	7	1, 5	79.93	0.0003	0.94	y = -2.96 + 1.54 (Disturbance score)
Headwater Floodplain / Forested	5	7	1, 5	15.66	0.0108	0.76	y = -2.84 + 1.20 (Disturbance score)
Depression / Emergent	3	38	1, 36	3.43	0.0723	0.09	y = 15.82 + 0.30 (Disturbance score)
Depression / Scrub-Shrub	4	19	1, 17	0.1656	0.6891	0.01	y = 23.88 + 0.11 (Disturbance score)
Depression / Forested	4	14	1, 12	1.4	0.2601	0.1	y = 18.77 + 0.31 (Disturbance score)
Floodplain / Emergent	4	16	1, 14	15.41	0.0015	0.52	y = 21.20 + 0.44 (Disturbance score)
Floodplain / Scrub-Shrub	5	8	1, 6	33.95	0.0011	0.85	y = 0.50 + 1.27 (Disturbance score)
Floodplain / Forested	6	11	1, 9	6.43	0.0319	0.42	y= 14.43 + 0.95 (Disturbance score)
Impoundment / Emergent	3	14	1, 12	0.63	0.4421	0.05	y = 19.27 + 0.14 (Disturbance score)
Impoundment / Scrub-Shrub	4	7	1, 5	1.11	0.3395	0.18	y = 6.13 + 0.77 (Disturbance score)
Impoundment / Forested	5	2					inadequate sample size

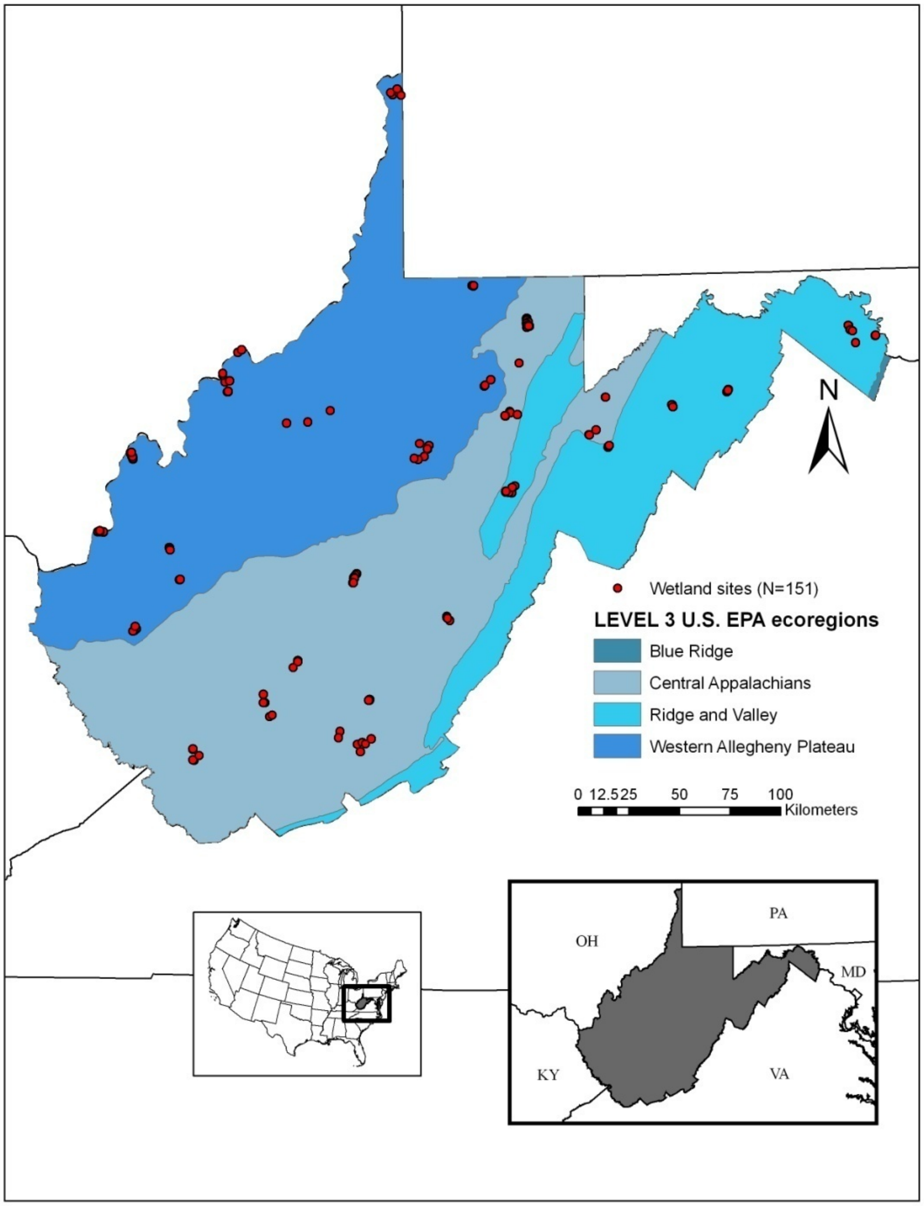

Figure 1. Site locations of wetlands and ecoregions (Woods et al. 1999, Omernik 1987) used in developing class-specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006. Wetland sites were clustered; scale of map prevents all sites from being marked individually. Legend may indicate 1-4 wetlands per mark.

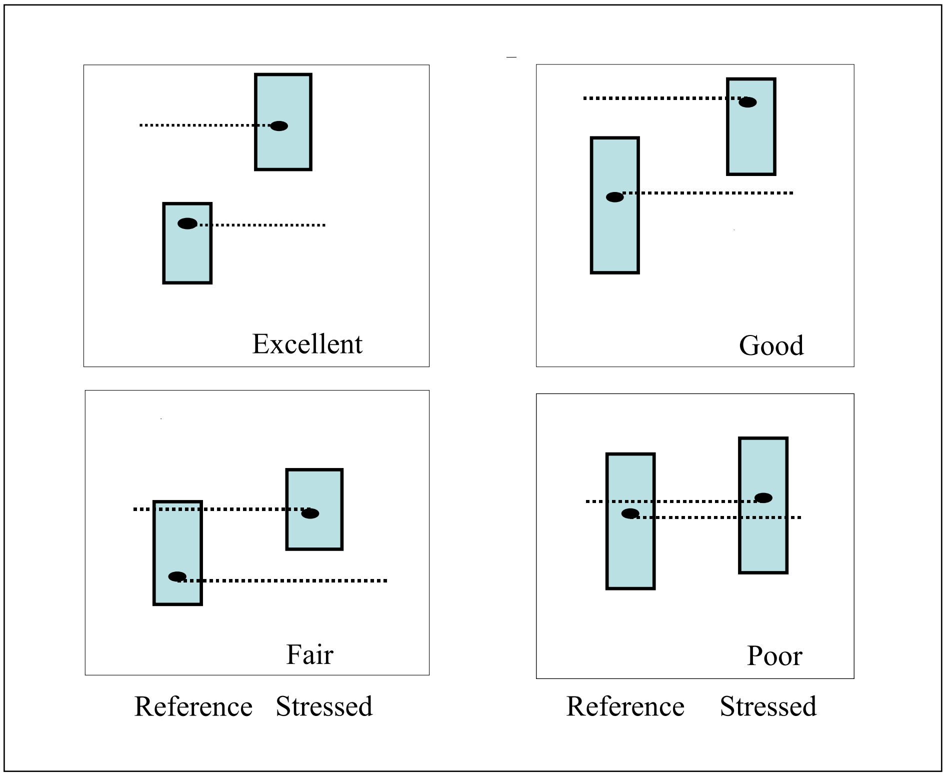

Figure 2. Box-and-whisker plot characteristics and resulting narrative description of reference and stressed sites' distribution of a biological metric value considered for inclusion into class-specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006. Solid ovals represent the median of metric value (courtesy of Greg Pond, U.S. EPA).

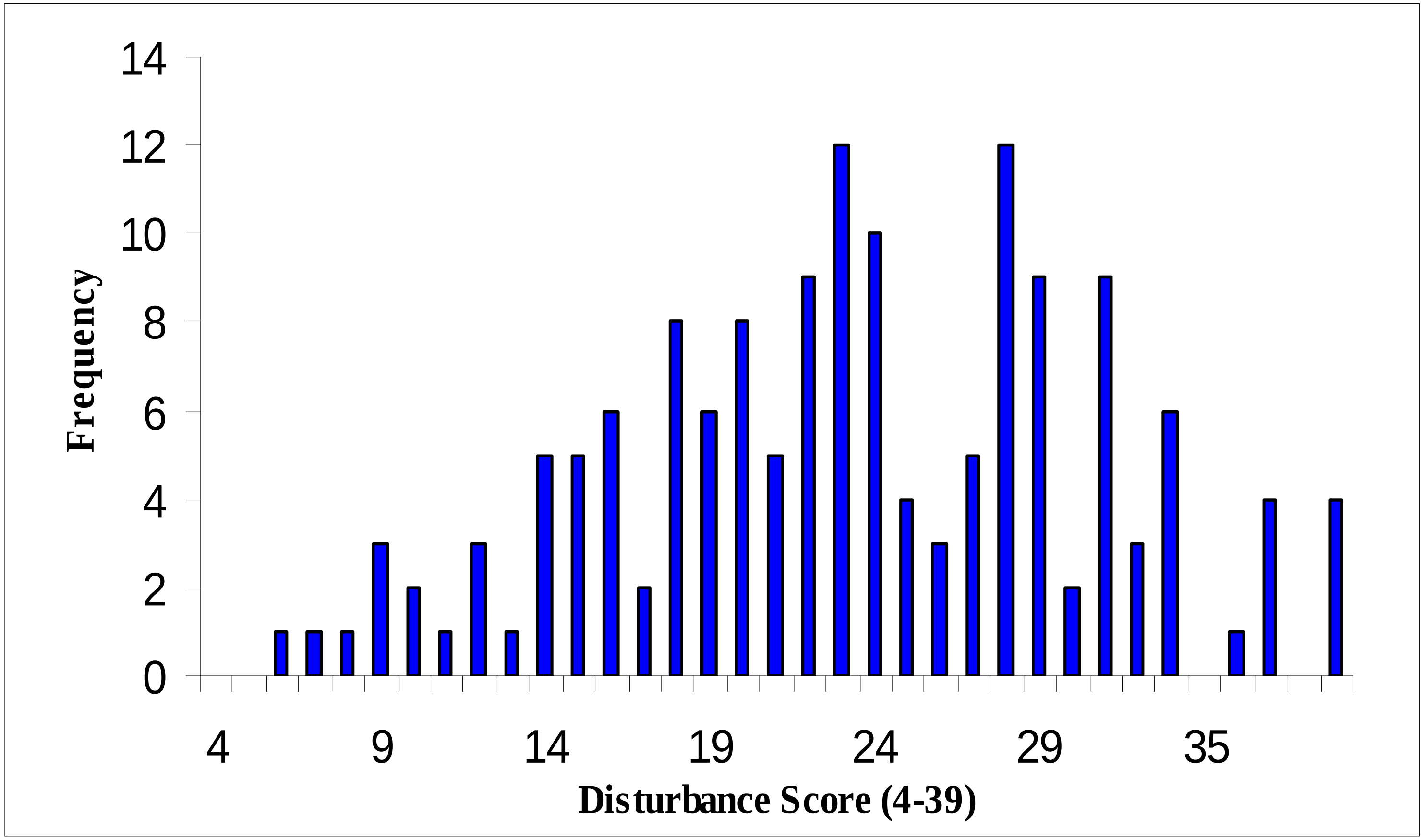

Figure 3. Frequency distribution of disturbance scores for sites used to develop class-specific avian wetland indices of biological integrity (AW-IBI) for wetlands in West Virginia, USA from 2005-2006.

Chapter 3

Acoustically-based Anuran Indices of Biological Integrity

Development and Evaluation of Acoustically-based Anuran Indices of Biological Integrity for Wetlands in West Virginia, USA

Walter Veselka IV[1]
James T. Anderson[1, 3]
Walter S. Kordek[2]

[1] Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

[2] West Virginia Division of Natural Resources, Wildlife Resources Section, PO Box 67, Ward Road, Elkins, WV 26241

[3] address correspondence to James T. Anderson, Ph.D., Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506. email: wetland@wvu.edu phone: (304) 293-2941 ext. 2445, fax: (304) 293-2441

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Abstract

Across the United States there has been a recent push to monitor biological integrity of wetlands. This study examined using anuran call surveys, a common methodology used in many states, to derive metrics that exhibit a consistent response to levels of human impairment. These methods resulted in only 2 anuran metrics capable of consistently discriminating between reference and stressed sites. However, the resulting anuran acoustically-based indices of biological integrity (AA-IBI) exhibited a relation with the local disturbance gradient, developed regionally by the state of Ohio's Environmental Protection Agency. In addition to deriving and testing these anuran metrics against a local disturbance gradient, we combined the AA-IBI scores with metric scores from an avian wetland index of biological integrity (AW-IBI). This allowed us to compare the effectiveness of a single taxon IBI with that of a multi-metric IBI. In some cases, when metrics from avian and anuran assemblages were combined, the relation with the disturbance gradient was more consistent than with the individual taxon-specific IBI composed of these metrics. In general, the addition of anuran call-survey derived metrics provided limited additional discriminatory value beyond that provided by the AW-IBI metrics. However, anuran call-surveys should not be discontinued as they provide a relatively straight-forward introductory avenue for public participation in wetland monitoring programs, which is critical to protecting our state's wetland resources.

Keywords*: anuran call surveys, indices of biological integrity, IBI, human impairment, metrics, avian wetland indices of biological integrity*

1.0 Introduction

Amphibians are a conspicuous taxon whose populations are responsive to changes in environmental conditions (Wake 1991; Wyman 1990). Identifying the specific causes behind the changes in amphibian populations can be difficult to ascertain (Blaustein et al. 1994; Pechmann et al. 1991). Large scale, difficult to quantify causes such as acid deposition, global warming, increases in UV radiation, the spread of toxic substances, and the introduction of predators have been suggested as factors playing a role in population fluctuations, and may affect amphibian metapopulations on a global scale (Houlahan et al. 2000; Sparling et al. 2002). Silvicultural practices, roads, and both aquatic and terrestrial habitat alterations have been suggested as factors affecting local amphibian population numbers in many areas including Maine, Minnesota, and Ontario (Houlahan and Findlay 2003; Lehtinen et al. 1999; Patrick et al. 2006; Trenham and Shaffer 2005; Trombulak and Frissel 2000).

The Clean Water Act (CWA) charges the United States Environmental Protection Agency's Office of Water with the responsibility "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Methods for ensuring and quantifying biological integrity have advanced as more types of water bodies are being evaluated using multiple taxa groups(Gerritsen et al. 2000; Guntenspergen et al. 2002; Hill et al. 2003; Karr et al. 1986). Amphibians tend to display the characteristics suitable for developing bioassessments due to their restricted home ranges and their varying needs for both terrestrial and aquatic habitat components (Blaustein et al. 1994).

Ohio has developed an Amphibian Index of Biotic Integrity (Amph-IBI) in which greater than 50% of the variability of IBI scores can be attributed to the characteristics within and immediately surrounding a wetland (Micacchion 2004; Micacchion 2002). In addition to anthropogenic impacts, amphibian breeding success may be influenced by biotic factors such as predatory dragonflies and fish, and even the breeding or presence of other amphibians (Hecnar and M'Closkey 1997; Kiesecker and Blaustein 1998;Morin 1987; Skelly and Werner 1990). These biotic influences may be influenced by a wetland's hydroperiod which, in addition to wetland size and canopy cover, has been shown to explain a portion of the variation associated with amphibian species richness in South Carolina, Massachusetts, and Michigan (Burne and Griffin 2005;Skelly et al. 1999; Snodgrass et al. 2000a; Snodgrass et al. 2000b). While the habitat within and surrounding amphibian breeding areas is associated with the likelihood of species occurrence, the responses exhibited by amphibian communities are complex. For example, a previous study in West Virginia that used call surveys to compare amphibian communities between natural and mitigated wetlands revealed patterns that may be considered, by some, to be counterintuitive (Balcombe et al. 2005). Within this work, anuran species richness, abundance, and diversity were all greater in mitigated wetlands than in the natural wetlands.

Our study assessed the potential of using the commonly used protocol of the North American Amphibian Monitoring Program (NAAMP) protocol to develop anuran metrics that are able to differentiate between wetlands that are anthropogenically impaired and those in a natural state (Genet and Sargent 2003; Mossman 1994). West Virginia already uses volunteer surveyors to monitor anuran populations, so this study was intended to ascertain the possibility of creating anuran acoustically-based indices of biological integrity (AA-IBI) easily integrated into existing programs.

The resulting AA-IBIs were designed to compare anuran community responses to disturbance within different wetland classification schemes (Cowardin et al. 1979). The Cowardin et al. system (1979) is based upon vegetative structure, and will be referred to as “Cowardin” hereafter. This classification scheme is used for mapping by the National Wetland Inventory (NWI).The hydrogeomorphic (HGM) approach of classifying wetlands is based upon a wetland’s position in the landscape and hydrology (Brinson 1993). These HGM classifications have been subdivided into regional HGM subclasses (Cole et al. 1997) based upon regional wetland conditions. Stratifying IBIs by HGM class for measuring wetland impairment has been identified as a means of increasing effectiveness and sensitivity because it compares wetlands that are functionally similar (Stevenson and Hauer 2002). However, its use has not been used to contrast or augment the Cowardin system, which is relatively straightforward and used in West Virginia for regulatory purposes (West Virginia State Code Chapter 22-11, 22-26).

Our objective was to assess the classification systems for use in an AA-IBI to quantify the differences in anuran communities between wetlands that are anthropogenically impaired and those in a natural state. In doing so we will be able to monitor the biological integrity of wetlands over time, ensure antidegradation standards are met, and compare the effectiveness of mitigated wetlands in replacing natural wetlands lost to development. Further, we explored summing avian wetland-indices of biological integrity (AW-IBI) (Veselka 2008: Chapter 2) with those derived in this research to determine if multi-taxa IBIs are more responsive to the disturbance gradient than an IBI based on a single taxon. This exploratory analysis is based on the argument that additive models are simple and easy to apply (Gerritsen 1995), and that a multi-taxa approach can increase sensitivity to environmental stressors (Griffith et al. 2005; O'Connor et al. 2000). In doing so we will be able to monitor the biological integrity of wetlands over time, ensure antidegradation standards are met, and compare the effectiveness of mitigated wetlands in replacing natural wetlands lost to development.

2. 0 Methods

2.1 Study Area

Most of West Virginia falls into 1 of 3 U.S. Environmental Protection Agency Level 3 aquatic ecoregions: the Central Appalachians, the Ridge and Valley, and the Western Allegheny Plateau (Omernik 1987; Woods et al. 1999).Efforts were made to stratify these study sites by ecoregion and Cowardin classification scheme; as there is no statewide HGM mapping of wetlands(Table 1) (Veselka 2008: Chapter 2). Final site selection was based on wetland accessibility, as well as efficiency considerations aimed at maximizing sampling efforts in localized areas (Figure 1) (Veselka 2008: Chapter 2). Upon selection, wetlands were identified by the Cowardin system, and further classified by regional HGM subclasses (Cole et al. 1997), meaning each site was categorized by both systems and that they were not mutually exclusive. In an effort to increase sample sizes, some subclasses were combined (Table 2) (Veselka 2008: Chapter 2). Moreover, combining regional HGM subclasses into designated HGM management classes allowed us to compare the efficacy of IBIs derived from the original HGM subclasses with the newly designated HGM management classes (Veselka 2008: Chapter 2).

2.2 Anuran Surveys

Anuran communities at each site were surveyed 3 times each year according to the North American Amphibian Monitoring Program (NAAMP) guidelines (Mossman

1994). The survey consisted of a 2 minute settling period, followed by a 5 minute listening period in which a Wisconsin Index (WI) value and species abundance estimate was assigned to each species heard according to call intensity (Balcombe et al. 2005). This index ranged from 1 to 3 and was representative of the relative abundance of species heard at each site. An index value of 1 was assigned to species with non-overlapping calls and when an exact count of individuals could be made, an index value of 2 was assigned to species whose calls overlapped and only estimations of numbers could be made, and an index value of 3 was assigned to species that were calling in full chorus. If a WI value of 3 was assigned to a species, an arbitrary abundance estimate of 50 was assigned (Balcombe et al. 2005). The highest index value recorded across the 3 survey periods for each species was used to calculate metric values at each site.

2.3 Disturbance Gradient

The Ohio Rapid Assessment Method, version 5.0 (ORAM) (Mack 2001) was used to assign a disturbance value directly related to human disturbance at each site (Table 3).The disturbance score has a maximum value of 39, indicating no visible impact of human impairment, and a minimum score of 4 indicating severe human impact. Metrics selected for inclusion into the AA-IBI were based on their responses to the disturbance score. This disturbance gradient was composed of stressors that are intuitive and can be reasonably mitigated by resource mangers (Brooks et al. 1998). By choosing a disturbance gradient that would be reflective of changes brought about by the implementation of approved best management practices, we can expect a change in anuran communities based on these changes (Calhoun et al. 2005).

2.4 Reference and Stressed Sites Designations

Each site was classed as a reference or stressed wetland based on ambient condition (Omernik 1995). Disturbance gradient scores in the 75th and 25th percentile were used to categorize reference and stressed conditions, respectively (Barbour et al. 1995). Reference and stressed designations were developed independently for Cowardin, HGM subclass (Cole et al. 1997), and designated HGM management class across all Level 3 ecoregions (Omernik 1987, Woods et al. 1999) because these designations were based on human impairment characteristics rather than any ecological basis.

2.5 Data Analysis

Presence, relative abundance, and an abundance estimate of each anuran species was recorded by site (Appendix N). The relative abundance of each species, or WI value, was used to estimate species' population numbers and used in calculating metrics. The expressions of the anuran communities were used to develop a list of 12 candidate metrics, based on existing IBI metrics and literature suggesting predictable responses to human impairment (Table 4)(Balcombe et al. 2005; Micacchion 2002; Wilson 1995). Species were assigned a Coefficient of Conservatism (C of C) value from 1-10 based on their sensitivity to disturbance that was used in formulating metrics such as the percent of sensitive species (Table 5) (Micacchion 2002). The species data were first screened to exclude sites where no anurans were detected (4 sites) or only 1 species at the site during only 1 sampling period (14 sites). This analysis is meant to provide a measure of consistency in building the resulting AA-IBI, indicating minimum criteria for detection needed to be incorporated into an AA-IBI.

To develop a statewide IBI using anuran communities, we analyzed the data in a series of elimination steps for each candidate metric (Veselka 2008: Chapter 2). For groups with adequate sample sizes, metrics were tested for responsiveness to the human disturbance index using box-and-whisker plots (Barbour et al. 1996; Chipps et al. 2005) (Figure 2). Metrics failing to discriminate between reference and stressed sites were discarded (Veselka 2008: Chapter 2). The remaining metrics were tested for redundancy using Spearman's R correlation statistic (Hughes et al. 1998; Veselka 2008: Chapter 2). Metrics with an R-value > 0.80 were considered highly correlated (Table 6). Of the correlated pairs of metrics, the one with the greatest discrimination efficiency between reference and stressed sites was retained for inclusion into the AA-IBI (Table 7). If correlated metrics had the same discrimination efficiency, then both metrics were retained for further ecoregion and classification scheme screening to determine which metric was best suited for retention (Veselka 2008: Chapter 2).

Within the remaining suite of metrics for each of the resulting class-specific AA-IBIs, we tested for an ecoregion effect or alternative classification effect using a series of 2-way analyses of variance (ANOVA) (Table 8). Metric values represented the dependent variables and ecoregion and wetland classification scheme were the independent variables. When multiple metrics were used to derive the class-specific AA-IBI, the metrics were evaluated a final time with a multivariate analyses of variance (MANOVA), testing for a cumulative effect of the metric values of reference and stressed site to ecoregion or classification scheme influences (Veselka 2008: Chapter 2) (Table 9). After the series of tests finalizing the metrics used in the resulting AA-IBI were conducted, the metrics were then normalized (0-1)and values inversed as needed to provide a consistent response to disturbance by all metrics (Veselka 2008: Chapter 2).

Metrics included in the AA-IBI were scored by multiplying by a factor of 10 to form a continuous 0-10 scale (Blocksom 2003; Bryce et al. 2002; Veselka 2008: Chapter 2). Using the metrics appropriate for each classification, AA-IBIs were formed by summing all metrics selected for inclusion (Veselka 2008: Chapter 2).

The disturbance gradient and the distribution of the AA-IBI scores for the reference sites were used to set numeric thresholds describing wetland condition (Gerritsen et al. 2000; Hill et al. 2003; McCormick et al. 2001; Veselka 2008: Chapter 2). The relation between AA-IBI scores and the disturbance score were examined using simple linear regression specific to each classification. This enabled us to interpret and compare the results of our derived AA-IBI accordingly (Veselka 2008: Chapter 2).

After scoring each wetland with its derived designated HGM management class and HGM subclass (Cole et al. 1997) AA-IBI score, we continued to test the additive properties of metrics by combining the metrics of the AA-IBI with the corresponding class-specific scores of the West Virginia avian wetland index of biological integrity (AW-IBI) (Veselka2008: Chapter 2). We wished to determine if adding the individual metric scores of multiple taxa would provide a higher level of correlation between an IBI and the disturbance gradient. Adding of the IBI metrics was facilitated because all metric scores are on the same 0-10 scale. Using anuran and avian metrics is cost-effective as both indices of biological integrity could be derived from volunteer-collected data. For example, the 4 metric scores that make up the headwater floodplain AW-IBI were added to the single of the headwater floodplain AA-IBI metric to create a multi-taxa IBI of 5 metrics for comparison with the disturbance gradient. The relation between the combined metrics and the disturbance gradient were then re-examined using simple linear regression and compared to the results of the single-taxa derived wetland IBI.

3.0 Results

3.1 Ecoregions and site classifications

For groups with adequate sample size, we evaluated by ecoregion emergent and scrub-shrub Cowardin wetland classes, floodplain, depression, and impoundment designated HGM management classes, and riparian depression and headwater floodplain HGM subclasses (Cole et al. 1997) (Table 1). A complete list of all sites and corresponding attribute data (e.g., ecoregion, location, class, etc.) can be found in Appendix B. A frequency distribution indicated normal distribution of disturbance scores (Figure 3) (*Skewness = -0.04, Kurtosis = -0.39*).

After screening sites to eliminate sites from consideration in the development of the AA-IBI where no anurans where detected (4 sites) or only 1 species was detected at 1 sampling period (14 sites); the sample size of reference and stressed sites in forested wetlands was reduced so that we were unable to evaluate metrics suitable for inclusion into a forested AA-IBI. We were not able to distinguish between reference and impacted sites in the emergent, depression, or impoundment class wetlands so we were not able to derive AA-IBIs for these wetland classes. In the remaining wetland classifications, headwater floodplain, riparian depression, floodplain and scrub-shrub wetlands, redundant metrics were eliminated (Table 6). Richness, abundance, and the Shannon-Weaver diversity metrics were often correlated when able to discriminate between reference and stressed sites. For these instances, the Shannon-Weaver diversity metric was retained if discrimination efficiency of each of the metrics were equal, because the diversity score is a function of both species richness and abundance (Magurran 1988). The remaining metrics were scrutinized with a series of 2-way ANOVAs (Table 8). Two metrics contributing to the scrub-shrub AA-IBI, anuran relative diversity and percentage of fish-tolerant anurans, were significantly affected by the HGM classification, resulting in an absence of any Cowardin based AA-IBIs. The percentage of fish-tolerant anurans metric of the floodplain AA-IBI was significantly influenced by the Cowardin expression of the wetland, which resulted in the elimination of this metric in a floodplain AA-IBI. The cumulative MANOVA test of the remaining 2 metrics of the floodplain AA-IBI, anuran relative diversity and total relative abundance of anurans, was not significant. As a result, the class-specific AA-IBIs were sufficiently robust to consistently discriminate between reference and stressed sites throughout West Virginia, although the headwater floodplain and riparian depression AA-IBI were composed of only 1 metric.

3.2 Anuran Communities

Our surveys detected the presence of 12 of the 15 anuran species documented in West Virginia that can be detected by call surveys. Northern spring peepers (*Hyla crucifer*) and northern green frogs (*Rana clamitans*) were the most frequently detected species, respectively, whereas Fowler's toad (*Bufo woodhousei fowleri*) was only detected at 1 site (Table 11). The Blanchards cricket frog (*Acris crepitans blanchardi*), eastern cricket frog (*Acris crepitans crepitans*), and eastern spadefoot toad (*Scaphiopus holbrookii*) were not detected in our study. Species richness ranged from 0 species detected at 4 sites, to 8 species detected at 2 sites. The mean number of species found per site was 3.45 (SE = 1.86).

A list of species detected and corresponding WI chorus values has been included in Appendix N. The individual metric values for each site are in Appendix O, summary statistics of metric scores statewide and by ecoregion are in Appendix P.

3.3 Metric Performance

All metrics were initially screened based on their ability to discriminate between reference and stressed sites independently for each classification (HGM subclass, designated HGM management class or Cowardin class) based upon the disparity among the interquartile ranges of metric values for reference and stressed conditions (Appendix Q-X). Within these classifications, only the regional HGM subclasses (Cole et al. 1997) headwater floodplain and riparian depression; the floodplain designated HGM management class, and scrub-shrub wetlands within the Cowardin class were found to have metrics capable of discriminating between reference and stressed sites statewide.

The majority of metrics were discarded before being included into ecoregion-specific AA-IBI due to an inability to discriminate between reference and stressed conditions and redundancy with other metrics (Table 7). The resulting AA-IBIs were limited in the number of remaining suitable metrics. For example, at most, only 2 metrics were suitable for inclusion into the suite of resulting class-specific AA-IBIs. The relation between the class-specific AA-IBIs and our disturbance scores were significant in all remaining cases (Table 12). However, the variation attributed to disturbance in riparian depression AA-IBI scores is essentially of no value ($R^2 = 0.08$). The variation accounted for by the disturbance score peaked at 27% in the headwater floodplain AA-IBI, and was 18% in the broader floodplain AA-IBI classification.

Relative diversity was the metric most often retained by the majority of the classes (Table 7). There was 1 case (floodplain designated HGM management class) in which relative abundance was retained along with relative diversity, but these metrics were not correlated enough to lead to 1 metric being excluded by the other (Table 6).

3.4 Scoring Thresholds

The scoring thresholds for each class of derived AA-IBI were based on the 75th, 25th, and 5th percentile of reference AA-IBI scores (Table 10). Of the 3 classes of derived AA-IBI, 2 were able to discriminate between reference and stressed sites greater than 80% of the time. Riparian depression-based AA-IBI discriminated between reference and stressed conditions 67% of the time, although there was a significant difference between the mean reference and stressed sites' scores according to Tukey's Honestly Significance Difference test. The headwater floodplain AA-IBI was the only class in which mean scores between reference and stressed sites did not statistically differ.

3.5Hybrid Classification Capacity of AA-IBI metrics

There was a lack of suitable metrics capable of discriminating between reference and stressed sites in Cowardin based AA-IBIs. This resulted in an inability to combine metrics from the HGM-based IBIs and the Cowardin based IBIs. As a result, we were not able to evaluate any potential effect of integrating these 2 classes of IBIs on the sensitivity to the disturbance score.

3.6 Combining AA-IBI metric scores to form multi-taxa wetland IBIs

Combining the class-specific AA-IBI metric scores with corresponding metric scores from the avian wetland indices of biological integrity (AW-IBI) increased the number of metrics that were responsive to the disturbance gradient and could be added to form multi-taxa IBI. We were able to examine class-specific multi-taxa IBIs for headwater floodplain and floodplain wetlands using metrics derived from the AA-IBIs and AW-IBIs. Increasing the number of metrics did not always produce an increase in disturbance score sensitivity (Table 13). In headwater floodplain wetlands, combining metric scores of the anuran and avian taxa groups resulted in increases in the variation attributed to the disturbance gradient. However, the percentage of increase, although statistically significant, was only 1%. In floodplain wetlands, 5 metrics comprised the AW-IBI score, and 2 metrics made up the AA-IBI score. The resulting relation with the disturbance score was significant, and 43% of the variation in multi-taxa IBI scores was a result of the disturbance gradient. This is a decrease of 7% from the floodplain designated HGM management class AW-IBI relation with the disturbance gradient and an increase of 25% from the same classification AA-IBI.

We also examined multi-taxa hybrid-classes of IBI that were a result of combining Cowardin and HGM-based metrics from the AA-IBIs and AW-IBIs (Table 13). Combining the Cowardin based AW-IBI metrics with the riparian depression AA-IBI metrics to form a multi-taxa hybrid IBI did not result in any significant relation with the disturbance gradient. In addition the multi-taxa hybrid emergent-headwater floodplain, forested-headwater floodplain, forested-floodplain, and scrub-shrub-floodplain IBIs did not show a significant relation with the disturbance gradient. Only 2 multi-taxa hybrid IBIs, the emergent-floodplain and scrub-shrub-headwater floodplain, were significantly related to the disturbance gradient. In both cases, the amount of variation attributed to the disturbance gradient decreased slightly from the corresponding AW-IBI metrics-only hybrid classifications.

4.0 Discussion

4.1 Study design

This study represented, in part, an effort to develop a taxa-specific IBI that could quantify changes in levels of disturbance. Additionally, it enabled us to evaluate the potential of combining taxon-specific IBIs to construct multi-taxa IBIsmore sensitive to the disturbance gradient. Each taxon-specific IBI varies relative to sensitivity, ease of data collection, and cost. Upon completion, wetland resource managers will be able to measure wetland biological integrity and its relation to human disturbance cost-effectively and efficiently.

Anuran communities with high biological integrity are the desired endpoint representing least impaired wetland conditions. Contrasting the more recent and regionally specific HGM classification (Brinson 1993) with the Cowardin classification allowed us to identify the classification best suited to base an IBI upon. Our decision to combine the regional subclasses (Cole et al. 1997) into designated HGM management classes was based on the intended applicability and management implications within the objectives of developing an anuran community wetland index of biotic integrity. For comparison, we included analyses of regional HGM subclasses (Cole et al. 1997), if sample size permitted, which allowed us to look at the efficacy of our designated HGM management class.

The methodology used in our research was intended to be straight-forward and intuitive to enable users with various levels of expertise the opportunity to participate in wetland monitoring programs administered by the WVDNR or other groups. The redaction of regional HGM subclasses (Cole et al. 1997) to designated HGM management classes was designed not only to increase sample size, but also for ease of classification by non-professionals. For example, with minimal instruction, we expect volunteers to be able to differentiate between depression, floodplain, impoundment, fringing, and slope wetlands. Moreover, the local disturbance gradient, adopted from a modified ORAM (Mack 2001) has already been shown to be scientifically defensible and undergone numerous changes and revisions. As a result of this development process, a scoring manual, as well as workshops, are already being offered to standardize the scoring process. The scoring consistency achieved demonstrates that stressor conditions can be quantified, and improvement or rehabilitation of these stressors can be expected to produce quantifiable changes in biological communities asreflected in IBI scores.

The expectation is that this body of work can be used independently to examine the relation between anuran communities and disturbances; and further, augment the existing AW-IBI when applicable. It is the baseline from which to initiate a state-wide West Virginia wetland monitoring program, capable of detecting impairment and recognizing improvement and degradation in natural and constructed wetlands.

4.2 Classifications of Anuran Acoustically-based Indices of Biological Integrity

Developing an applicable IBI that can be scientifically defended represents a challenging endeavor. Using best professional judgment, it seems intuitive that there would be differences in anuran communities based on wetland classifications, regardless of whether those classifications are based on HGM setting or Cowardin classes. It is also plausible that there may be some differences in the data due to ecoregion (Omernik 1995). However, if the data are sensitive to ecoregion and wetland classification differences, the overall sample size must be increased to address these effects. The capacity to quickly and easily apply the results of this research to monitoring the changes in wetland biological integrity is deferred until additional data are assembled. Our objective was to find metrics that could be part of a robust state-wide wetland IBI immune to ecoregion variation. By addressing this possibility of variation, we are confident that the resulting AA-IBIs were constructed using consistent, scientific rigor.

After selecting metrics based on their ability to discriminate between reference and stressed sites and eliminating redundant metrics, we evaluated the reference and stressed sites' metric values using a series of 2-way ANOVAs. These tests were intended to identify metrics prone to ecoregion and/ or alternative classification effects. In the 3 derived HGM or HGM subclass-based AA-IBI, the majority of metrics, with the exception of percentage of fish-tolerant species in floodplain wetlands, were capable of discriminating between reference and stressed sites statewide, in spite of ecoregion or Cowardin class differences. Alternatively, the metrics of the scrub-shrub AA-IBI were subject to significant differences in values based on HGM expression, resulting in a failing AA-IBI not capable of consistently scoring scrub-shrub wetlands regardless of HGM expression. Although disappointing, this was not altogether unexpected. The wetlands that were used to develop the scrub-shrub-based AA-IBIswere developed on data from scrub-shrub wetlands. HGM and HGM subclass-based AA-IBI were based on wetland sharing similar hydrologic characteristics. Research from South Carolina, Michigan, Massachusetts, and Maine suggest that hydroperiod is the major, determining factor dictating the expression of amphibian communities (Baldwin et al. 2006; Burne and Griffin 2005;Skelly et al. 1999; Snodgrass et al. 2000a). The scrub-shrub AA-IBI did not inherently capture some of the variation in hydrology, resulting in inconsistent scores between HGM expressions, which led to the elimination of this class of AA-IBI.

Comparing the AA-IBI of the designated HGM management classes to the regional HGM subclasses (Cole et al. 1997), our results indicate the regional HGM subclasses seem to be better suited for detecting disturbance using anuran assemblages. However, there is a trade-off between the suitability of using HGM classes and ease with which categories can be identified. Designated HGM management classes represent broad categories easily identified with minimal training, whereas the regional HGM subclasses (Cole et al. 1997) require choices from more numerous and less intuitive categories. The regional HGM subclasses (Cole et al. 1997) are driven by water source, rather than general landscape position, that in-turn, determines hydroperiod. Therefore, because regional HGM subclasses (Cole et al. 1997) give us a better idea of the influence of hydrology and length of hydroperiod, it is not surprising that the AA-IBI developed for these subclasses perform more consistently than the designated HGM management classes.

Unfortunately, we were not able to derive AA-IBI for impounded, depressional, or emergent wetlands. Impounded wetlands are inherently products of disturbed hydrology; therefore it is not surprising that we would not be able to develop metrics capable of discriminating between reference and stressed conditions in such a system. The lack of metrics suitable for depressional wetlands is more difficult to interpret. The majority of the depressional wetlands in this study were riparian depressions (Cole et al. 1997), so it stands to reason that if a riparian depression AA-IBI was derived, a depressional AA-IBI would be similar. However, as the riparian depression AA-IBI was composed of only 1 metric, relative diversity, the variation associated with this metric in surface-water or isolated depressions was enough to elicit an inconsistent response between this metric and the disturbance score. Moreover, the lack of anuran metrics capable of consistently discriminating between reference and stressed conditions in emergent wetlands was not altogether unexpected. Ohio's amphibian IBI (Micacchion 2002) also failed to develop metrics suitable for an emergent wetland IBI, despite much-more quantified data generated by their labor-intensive methodology. The variation between types of emergent wetlands in our study may have been excessive for any single, metric based on anuran call surveys to discriminate between levels of human impairment. High-elevation wetlands, bogs, high and low order floodplain wetlands, and mitigated impoundments were all represented within the Cowardin class of emergent wetlands in this study. Further research, examining these wetlands as subsets of the emergent class may identify metrics suitable for discriminating between reference and stressed conditions within emergent wetlands.

4.3 Anuran Communities and Data

The species and relative abundance of each species was not surprising. Northern spring peepers, the most frequently occurring species, are the most commonly occurring anuran in the state; and the species we did not encounter are not common in West Virginia (Pauley 2001). The anuran community data were gathered using methods that are being used in at least 24 states as part of the NAAMP (Genet and Sargent 2003). Our decision to adopt these methods is a reflection of the effort to design an IBI that can be applied to existing WVDNR programs, despite counsel that the NAAMP protocol is best used to determine species presence/ absence because of the observer bias associated with relative abundance estimates (Genet and Sargent 2003). Of our 12 candidate metrics we selected for evaluation, only 2 did not rely on abundance data. However, previous work in West Virginia using call survey methodology indicate the relative abundance data can be used to derive consistent comparisons between sites (Balcombe et al. 2005). Moreover, other research considers manual call surveys effective at estimating relative abundance of certain species (Corn et al. 2000), so the relative abundances of the species at each wetland were used to derive metric values. Other concerns with call-surveys include capturing the presence of species that call infrequently and the temporal variation of species calls, by which species may vocalize outside NAAMP hours (Crouch and Paton 2002, Bridges and Dorcas 2000). Alternative methods, such as intensive surveys or using an acoustic Frog-logger® are expensive, of limited utility, and can be logistically difficult over a large sampling region (Corn et al. 2000). Research in Maine has shown that the presence of seasonal pools is not always an indication of breeding success (Vasconcelos and Calhoun 2006). However, egg mass surveys for some species, such as wood frogs (*Rana sylvatica*), within these seasonal pools, is a cost-effective and relatively accurate and precise alternative to anuran call counts (Crouch and Paton 2000).

4.4 Metric Performance

Of the original 12 metrics considered for inclusion into AA-IBI, 9 metrics were discarded due to inability to discriminate between reference and stressed conditions, redundancy, or a lack of adequate scoring variation between reference and stressed conditions. Of the remaining 3 metrics, the percentage of fish-tolerant species was eliminated from both the scrub-shrub and floodplain AA-IBI due to an alternative classification scheme effect (Table 8). We also eliminated the anuran relative diversity metric from the scrub-shrub AA-IBI due to differences in scoring attributed to the HGM expression.

The relative diversity metric most often discriminated between reference and stressed sites. In many cases, relative abundance was found to be redundant with relative diversity. However, based on the results of Spearman's R correlation matrix, it was retained for inclusion into the floodplain designated HGM management class AA-IBI (Table 6). Understanding the relation between disturbance and anuran community diversity is currently subject to debate(Schurbon and Fauth 2004; Schurbon and Fauth 2003). The argument revolves around the intermediate disturbance hypothesis that states the impact of disturbance on diversity is complex and may deviate from the linear-like relationwe assume is representative of metrics reflecting disturbance(Connell 1978; Johst and Huth 2005; Mackey and Currie 2000). Regardless of the outcome of this debate, in the context of our study in West Virginia, relative diversity remains as a metric suitable of discriminating between reference and stressed conditions using anuran call surveys.

Metric performance may have been improved by selecting a more inclusive disturbance gradient. Our disturbance gradient represented site-specific conditions and did not incorporate many of the factors determined to be important to the management of amphibians. These factors include local population dynamics, the availability of amphibian breeding habitat, and metapopulation dynamics (Semlitsch 2000). Our gross population estimates, rather than quantifiable abundance counts,were a result of our attempt to create a volunteer-friendlyAA-IBI. Moreover, we did not examine the context or matrix of wetlands from which our sampled wetlands occurred in the landscape. Wetland connectivity has been cited in numerous studies as driving factor in the expression of amphibian assemblages (Guerry and Hunter 2002; Kolozsvary and Swihart 1999). However, this deliberation was not an oversight, but rather a product of the study design in which the same local disturbance score is used to derive metrics from avian, anuran, vegetation, and macroinvertebrate communities. We suggest that the successful development of headwater floodplain and floodplain AA-IBIs may, in part, incorporate measures of this inherent connectivity associated with these classes.

4.5 Combining Anuran and Avian Metric Scores

By keeping the formation of taxa-specific indices of biological integrity consistent and normalized, we were able to combine the anuran metrics with those of the AW-IBI (Veselka 2008: Chapter 2). Exploring this combined relation allowed us to identify differences in sensitivity to the disturbance gradient, as demonstrated by the successful use of multi-taxa indices of biological integrity in wetlands, lakes, and streams(Griffith et al. 2005; Guntenspergen et al. 2002, O'Connor et al. 2000).

We summed the metric scores from the resulting AA-IBIs with the previous AW-IBI metric scores (Veselka 2008: Chapter 2) within the same classes and compared the composite multi-taxa IBI scores to the disturbance score using simple linear regression. The results of this analysis are promising for future research, but combining anuran and avian metrics from data collected using methods appropriate for volunteers added minimal utility value above what had been provided using only avian assemblages. The addition of 1 anuran metric score to the 4 avian metric scores within the headwater floodplain regional HGM subclass (Cole et al. 1997) resulted in an increase of only 1% in the amount of variation explained by the disturbance score; whereas the addition of 2 anuran metrics to 5 avian metrics in the composite, multi-taxa floodplain wetland IBI actually decreased the amount of variation explained by 7%. Additionally, the anuran and avian hybrid multi-taxa IBIs results were similar to those arrived at by combining the multiple taxa within the same classes: promising but of limited value.

Changes in the amount of variation accounted for by the disturbance score as a result of combining anuran and avian metrics did not increase IBI sensitivity to the disturbance score. However, the results validate our methods and show the potential of using multiple taxa groups *en masse* to detect changes in biological communities due to human impairment. As more data are analyzed, more combinations of multiple taxa groups, including vegetation and macroinvertebrates, may increase the sensitivity of these composite, multi-taxa wetland IBIs. Additionally, as further research increases our sample size, we will be able to build on our initial success of evaluating hybridized IBIs built from metrics showing a consistent response to disturbance in both the Cowardin classes and designated HGM management classes.

4.6 Comparisons with other Studies

The metrics derived from the AA-IBI were successful at discriminating between reference and stressed conditions. However, the number of anuran metrics limits the effectiveness of anuran call surveys to monitor the biological integrity of wetlands. Many of our metrics were drawn from Ohio's state-wide Amphibian Index of Biotic Integrity (Amph-IBI) for natural forested and shrub-scrub wetlands (Micacchion 2002). However, Ohio's methods used provided more quantitative data to discriminate between reference and stressed conditions. Ohio used the Cowardin classifications to test the metric responses to disturbance. The study was based on the combined forested/ scrub-shrub class of wetlands, as they did not discern a predictable relation between amphibian communities and disturbance in emergent wetlands. Using the same factors used to construct our disturbance gradient, 62.3% of the variation in the 5 metric AmphIBI scoresfor forested and scrub-shrub wetlands, was attributed to the disturbance level(Micacchion 2002).

The difference in results between our research and Ohio's AmphIBI is partly due to the quantitative methodology. However, the costs associated with this quantitative data collection are high (Corn et al. 2000). Our results are valuable because they show the potential to be combined with other volunteer-driven survey methods, while still obtaining similar responses to the disturbance gradient as with other bioassessment methods (Herbst and Silldorff 2006).

4.7 Scoring Thresholds

The generation of scoring thresholds that indicate wetland biological integrity is necessary to account for some degree of stochasticity in sampling from year to year. Categorizing site-specific AA-IBI scores will discount minor variations in annual AA-IBI scores and focus on the larger question of whether the integrity of the wetland is being maintained or is succumbing to the effects of impairments. However, applying these scoring thresholds based on our initial results may be premature. Riparian depression and headwater floodplain AA-IBIs are based on only 1 metric score, and therefore may be better served as supplements to existing indices of biological integrity. By basing the integrity of a wetland on only 1 metric, there exists a greater chance that random anomalies in the data will influence the results. This might be mitigated by combining multiple metric scores, if not from the same taxon, then from other taxa capable of discriminating between levels of integrity in wetlands. The biological basis for these scoring categories is based on principles that have been used in previous regional studies (Hill et al. 2003, McCormick et al. 2001). However, the legitimacy and applicability of these scoring thresholds will need to be examined in future works. For example, increased sample sizes, would, in theory, generate a larger variation in scoring values, for which we would need to recalibrate these proposed thresholds. Additionally, when we combine class-specific AA-IBIs with others to form additive hybrid classification indices or add IBIs with different taxa, such as the AW-IBI, values must be recalculated. The reference and stressed sites' designations were based on within class-specific parameters. That is to say a reference site for a Cowardin classification may not be a reference site for our designated HGM management classes. The increased sample sizes would provide a more consistent context of what constitutes a reference condition regardless of classification scheme. Therefore these derived scoring thresholds should be re-examined on a consistent schedule as to calibrate these thresholds, increase their validity and add interpretable biological meaning.

5.0 Management Implications

The importance of using volunteers to collect anuran data should not be discounted because of a lack of sensitive anuran community responses to the disturbance score. Although results were mixed, combining IBI scores of multiple taxa in both the HGM and Cowardin classifications suggests further research is warranted and we continue to expect that multi-taxa wetland IBIs, as well as hybrid IBIs, will respond predictably to human disturbances.

Our disturbance gradient represents a site-specific scale. The changes in variation explained by combining IBI scores of multiple taxa may reflect a calibration effect. The number of metrics included in multi-taxa indices of biological integrity changes the influence of each individual metric score on an IBI. Each metric within the IBI, in theory, exhibits the greatest response to a unique, scale-specific disturbance gradient. However, metrics are included in our combined IBI because they responded to our site-specific disturbance gradient. Knowing that these metrics respond to different scales of disturbance but remain “loyal” to the local disturbance gradient has profound effects in monitoring applicability. As additional groups and metrics are evaluated for bioassessment potential, wetland resource managers will be able to select more metrics for inclusion into a multi-taxa wetland IBI.These metrics will be responsive to stressors at multiple scales, while still exhibiting a significant relation with the local disturbance gradient. To public policy makers, wetland monitoring often occurs on this site-specific basis within a mitigation, protection, or restoration context. Monitoring changes and protecting the biological integrity of wetlands has always been mandated by the Clean Water Act, but questions remained on how to define, monitor and quantify changes in impairment. By tying the disturbance gradient to site-specific, easily-recognizable stressors, we found that combining metrics from multiple communities can reveal local-level biological community patterns representative of impairment. Further, we used methods already used by WVDNR and others that are often volunteer-driven to gather the avian and anuran species data. These methods can be used in the future to conduct cost-effective and response oriented wetland monitoring plans to evaluate the measures taken to protect or replace our wetland resources.

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Table 1. Total number of sites by regional hydrogeomorphic (HGM) subclass, designated HGM management class, and Cowardin classby ecoregion for use in developing anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

	Level 3 U.S. Environmental Protection Agency aquatic ecoregion[a]			
	Ridge and Valley	**Central Appalachian**	**Western Alleghany Plateau**	**Total**
Hydrogeomorphic subclass[b]				
Riparian depression	10	24	25	59
Headwater floodplain	10	15	4	29
Designated HGM Management Class				
Depression	10	28	34	72
Floodplain	12	17	6	35
Impoundment	1	14	8	23
Cowardin Class				
Emergent	15	34	26	75
Scrub-shrub	6	17	21	44
Forested	6	14	11	31

[a] Omernik (1987), modified by Woods et al. (1999).

[b] Cole et al. (1997).

Table 2. Designated hydrogeomorphic (HGM) management classes derived from regional HGM subclasses for use in developing class specific anuran acoustically-based wetland indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

Designated HGM Management Class	Hydrogeomorphic subclass[a]
Depression	Surface water depression
	Riparian depression
	Isolated depression
Floodplain	Headwater floodplain
	Mainstem floodplain
Impoundment	Headwater impoundment
	Mainstem impoundment
Fringing	Fringing
Slope	Slope

[a] Cole et al. (1997).

Table 3. Metrics and sub-metrics selected from the Ohio Rapid Assessment Method (Mack 2001) used to define the disturbance gradient for use in developing class specific anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

Scoring value	Disturbance component	
	Upland buffers and surrounding land use	
		Calculate the average buffer width. Select only one and assign score.
7		WIDE. Buffers average 50m or more around wetland perimeter
4		MEDIUM. Buffers average 25m to <50m around wetland perimeter
1		NARROW. Buffers average 10m to <25m around wetland perimeter
0		VERY NARROW. Buffers average <10m around wetland perimeter
		Intensity of surrounding land use. Select one or double check and average.
7		VERY LOW. 2nd growth or older forest, prairie, savannah, wildlife area, etc.
5		LOW. Old field (>10 years), shrubland, young second growth forest.
3		MODERATELY HIGH. Residential, fenced pasture, park, conservation tillage, new fallow field.
1		HIGH. Urban, industrial, open pasture, row cropping, mining, construction.
	Hydrology	
		Modifications to natural, hydrologic regime. Score one or double check and average.
12		None or none apparent. There are no modifications or no modifications that are apparent to the rater.
7		Recovered. The wetland appears to have recovered from past modifications which altered the wetland's natural hydrologic regime.
3		Recovering. The wetland appears to be in the process of recovering from past modifications which altered the wetland's natural hydrologic regime.
1		Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past modifications and / or the modifications are ongoing.
	Habitat alteration and development	
		Substrate disturbance. Score one or double check and average.
4		None or none apparent. There are no modifications or no modifications that are apparent to the rater.
3		Recovered. The wetland appears to have recovered from past disturbances.
2		Recovering. The wetland appears to be in the process of recovering from past disturbances.
1		Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past disturbances and/ or the disturbances are ongoing.
		Habitat alteration. Score one or double check and average.
9		None or none apparent. There are no alterations or no alterations that are apparent to the rater.
6		Recovered. The wetland appears to have recovered from past alterations.
3		Recovering. The wetland appears to be in the process of recovering from past alterations.
1		Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past alterations and/ or the alterations are ongoing.

Table 4. List of 12 candidate metrics evaluated for inclusion into anuran acoustically-based indices of biological integrity (AA-IBI) for West Virginia, USA in 2005-2006.

Metrics	Expected Response to Disturbance	Components of Metrics
Anuran relative diversity[a]	+	Shannon-Weaver diversity index score
Percent sensitive anurans[b]	-	Proportion of anurans with C of C ≥ 6
Anuran percent species of concern	-	Proportion of anurans listed as a West Virginia Species of Concern
Percent tolerant anurans[b]	+	Proportion of anurans with C of C ≤ 3
Percent of wood frog abundance[b]	-	Proportion of relative abundance that were wood frogs (*Rana sylvatica*)
Anuran richness[a]	+	Total anuran richness
Total anuran relative abundance[a]	+	Total anuran relative abundance
Modified amphibian quality assessment index (AQAI)[b]	-	A weighted index based on C of C values and relative abundance
Average coefficient of conservatism	-	The average C of C based on species presence/ absence
Percent upland sensitive species[c]	-	Proportion of wood frogs and mountain chorus frogs
Percent upland tolerant species[c]	+	Proportion of northern spring peepers and eastern American toads
Percent species tolerant offish[c]	+	Proportion of northern green frogs and American bullfrogs

[a] Balcombe et al. (2005).

[b] Micacchion (2002).

[c] Wilson (1995).

Table 5. Anuran species and corresponding coefficients of conservatism (CoC) used in analysis for deriving anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

Species	Scientific name	CoC[a]	West Virginia Species of Concern[b]
Eastern American toad	*Bufo americanus*	1	
Fowler's toad	*Bufo woodhousii fowleri*	1	
Northern spring peeper	*Pseudacris crucifer*	2	
Leopard frog	*Rana pipiens*	2	x
Northern green frog	*Rana clamitans*	2	
Bullfrog	*Rana catesbeiana*	2	
Mountain chorus frog	*Pseudacris brachyphona*	3	
Upland chorus frog	*Pseudacris triseriata*	3	x
Gray treefrog	*Hyla versicolor*	5	
Cope's gray treefrog	*Hyla chrysoscelis*	5	
Wood frog	*Rana sylvatica*	7	
Pickerel frog	*Rana palustris*	7	

[a] Micacchion (2002) sensitivity to disturbance from 1 (tolerant) to 10 (most sensitive).

[b] West VirginiaWildlife Diversity Program.

Table 6. Spearman's R correlation matrices of metrics by classification scheme able to discriminate between reference and stressed sites metrics used in developing anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006. Metrics with Spearman's R values > 0.80 were considered highly correlated.

Headwater Floodplain

	Relative diversity	Richness	Abundance
Relative diversity[a]	1		
Richness	0.985	1	
Abundance	0.867	0.913	1

Floodplain

	Relative diversity	Richness	Abundance	Percent fish tolerant
Relative diversity[a]	1			
Richness	0.977	1		
Abundance[a]	0.77	0.863	1	
Percent fish tolerant	0.469	0.491	0.465	1

Scrub-Shrub

	Relative diversity	Richness	Abundance	Percent fish tolerant
Relative diversity[a]	1			
Richness	0.989	1		
Abundance	0.885	0.91	1	
Percent fish tolerant[a]	0.693	0.7	0.638	1

[a] Metric selected for inclusion into class-specific AA-IBI.

Table 7. Candidate anuran community biological metrics evaluated by class according to regional Hydrogeomorphic (HGM) subclass, designated HGM management class, and the Cowardin classification schemes in building acoustically-based anuran wetland indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

	HGM subclass		Designated HGM management class			Cowardin class		
Candidate anuran metrics[a]	Riparian Depression	Headwater Floodplain	Depression	Floodplain	Impoundment	Emergent	Scrub-Shrub	Forested[b]
Anuran relative diversity[c]	I	I	*	I	"	*	E	
Percent sensitive anurans[d]	*	*	*	*	*	*	*	
Anuran percent Species of Concern	*	*	*	*	*	*	*	
Percent tolerant anurans[d]	*	*	*	*	*	*	*	
Percent of wood frog abundance[d]	*	*	*	*	*	*	*	
Anuran richness[c]	*	R	*	R	*	*	*	
Total anuran relative abundance[c]	*	R	*	I	*	*	*	
Modified amphibian quality assessment index (AQAI)[d]	*	*	*	*	*	*	*	
Average coefficient of conservatism	*	*	*	*	*	*	*	
Percent upland sensitive species[e]	*	*	*	*	*	*	*	
Percent upland tolerant species[e]	*	*	*	*	*	*	*	
Percent species tolerant to fish[e]	*	*	*	E	*	*	E	

[a] I = included in class-specific AA-IBI; R = redundancy with other metrics; E = excluded due to significant ecoregion or classification effect; * = failure to discriminate between reference and stressed sites.

[b] Inadequate sample size.

[c] Balcombe et al. (2005).

[d] Micacchion (2002).

[e] Wilson (1995).

Table 8. Analysis of variance (ANOVA) results of reference and stressed sites' metric values compared to Level 3 ecoregions (Omernik 1987, Wood et al. 1999) and the alternative classification scheme used in developing anuran acoustically-based wetland indices of biological integrity (AA-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Riparian Depression AA-IBI (n=24)				
Anuran relative diversity	Cowardin class	2,23	1.75	0.2839
	Level 3 ecoregion	2,23	0.34	0.7310
	Cowardinclass x Level 3 ecoregion	3,23	0.85	0.4931
Headwater Floodplain AW-IBI (n=11)				
Anuran relative diversity	Cowardinclass	2,10	1.75	0.2839
	Level 3 ecoregion	2,10	0.34	0.7310
	Cowardinclass x Level 3 ecoregion	2,10	0.85	0.4931
Floodplain AA-IBI (n=14)				
Anuran relative diversity	Cowardinclass	2,13	1.59	0.2786
	Level 3 ecoregion	2,13	0.58	0.5867
	Cowardinclass x Level 3 ecoregion	3,13	0.21	0.8882
Percent Fish tolerant species[a]	Cowardinclass	2,13	5.24	0.0482
	Level 3 ecoregion	2,13	2.09	0.2044
	Cowardinclass x Level 3 ecoregion	3,13	1.55	0.2969
Total relative abundance	Cowardinclass	2,13	3.06	0.1215
	Level 3 ecoregion	2,13	0.11	0.8952
	Cowardinclass x Level 3 ecoregion	3,13	0.03	0.9916
Scrub-shrub AA-IBI (n=18)				
Anuran relative diversity[a]	Designated HGM[b] management class	4,17	5.90	0.0130
	Level 3 ecoregion	2,17	0.84	0.4630
	Designated HGM[b] management class x Level 3 ecoregion	2,17	0.50	0.6219
Percent Fish tolerant species[a]	Designated HGM[b] management class	4,17	4.30	0.0324
	Level 3 ecoregion	2,17	0.69	0.5279
	Designated HGM[b] management class x Level 3 ecoregion	2,17	0.69	0.5279

[a] Metric excluded from inclusion into class-specific AA-IBI due to a significant ecoregion, alternative classification scheme, or cumulative 2-way interaction.

[b] Hydrogeomorphic (Brinson 1993).

Table 9. Wilks' Lambda statistic for *posthoc* validation of reference and stressed sites' metric values of class-specific anuran acoustically-based wetland indices of biological integrity (AA-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification scheme and interaction	Wilks' Lambda	F-value	df	p-value
Floodplain AA-IBI (n=14)				
Cowardin class	0.4219	1.35	4, 10	0.3182
Level 3 ecoregion	0.6471	0.61	4, 10	0.6663
Cowardin x Level 3 ecoregion	0.7374	0.27	6, 10	0.9366

Table 10. Discrimination efficiency (D.E.) and reference site scoring summary used to derive scoring thresholds in developing class specific anuran acoustically-based wetland indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

	Reference Site Scoring Summary							Means (SE)	
	N	Max possible IBI score	75th percentile	25th percentile	5th percentile	Median	D.E.[a]	Reference[b]	Stressed
Riparian Depression	15	10	8.14	3.68	2.37	5.51	67	5.69 (0.66)	3.15 (0.67)
Headwater Floodplain	5	10	10	6.33	5.24	6.63	83	7.59 (1.02)	4.13 (1.25)
Floodplain	7	20	17.45	13.98	11.31	16.33	86	15.49 (1.10)	8.63 (2.19)

[a] Effectiveness of AA-IBI scores to effectively discriminate between reference and stressed sites.

[b]All means, except riparian depression, statistically significantly different (Tukey α = 0.05).

Table 11. Frequency of species occurrences (number of wetland occur/ number of wetlands surveyed)in the 151 sites used to develop acoustically-based anuran indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

Species	Number of Sites Present	Percent Occurrence
Northern spring peeper	140	92.72%
Northerngreen frog	89	58.94%
Wood frog	56	37.09%
Gray treefrog	54	35.76%
Pickerel frog	48	31.79%
Eastern American toad	43	28.48%
Bullfrog	39	25.83%
Mountain chorus frog	19	12.58%
Cope's gray treefrog	14	9.27%
Upland chorus frog	11	7.28%
Northern leopard frog	7	4.64%
Fowler's toad	1	0.66%

Table 12. Metrics comprising each anuran acoustically-based indices of biological integrity (AA-IBI) as per designated hydrogeomorphic (HGM) management class, regional HGM subclass, and Cowardin classifications; the discrimination efficiency (D.E.) of each AA-IBI, and the resulting relations of the AA-IBI with disturbance scores for wetlands in West Virginia, USA from 2005-2006.

Wetland type	Metrics in AA-IBI	N	D.E.[a]	df	F-value	p-value	R^2	Equation
Regional HGM subclass[b]								
Riparian Depression	Relative Diversity	52	67	1, 50	4.32	0.0429	0.08	y = 1.53 + 0.12 (Disturbance score)
Headwater Floodplain	Relative Diversity	22	83	1, 21	7.49	0.0127	0.27	y = -0.52 + 0.20 (Disturbance score)
Designated HGM management class								
Floodplain	Relative Diversity, Relative Abundance	28	86	1, 26	5.76	0.0238	0.18	y = 3.37 + 0.30 (Disturbance score)

[a] Effectiveness of AA-IBI scores to discriminate between reference and stressed sites.

[b] Cole et al. (1997).

Table 13. Relations between the disturbance scores and multi-taxa IBI that resulted from combining the anuran acoustically-based indices of biological integrity (AA-IBI) metric scores with the avian wetland indices of biological integrity (AW-IBI) metric scores from wetlands of West Virginia, USA from 2005-2006. AW-IBI-only scores are provided for comparison.

Wetland classifications	IBI groups	Number of metrics	N	df	F-value	p-value	R^2	Equation
Headwater Floodplain	*Multi-taxa IBI*	5	22	1, 20	19.74	0.0003	0.50	y = 14.50 + 0.73 (Disturbance score)
	AW-IBI only	4	29	1, 27	25.44	<0.0001	0.49	y = 11.98 + 0.62 (Disturbance score)
Floodplain	*Multi-taxa IBI*	7	28	1, 16	19.8	0.0001	0.43	y = 26.30 + 0.65 (Disturbance score)
	AW-IBI only	5	35	1, 33	32.74	<0.0001	0.50	y = 21.94 + 0.64 (Disturbance score)
Hybrid classifications[a]								
Emergent/ Riparian Depression	*Multi-taxa IBI*	2	28	1, 26	2.12	0.1568	0.08	y = 8.54 + 0.17 (Disturbance score)
Emergent/ Headwater Floodplain	*Multi-taxa IBI*	5	13	1, 11	4.79	0.0510	0.30	y = 17.63 + 0.58 (Disturbance score)
	AW-IBI only	4	15	1, 13	4.59	0.0517	0.26	y = 16.48 + 0.45 (Disturbance score)
Emergent/ Floodplain	*Multi-taxa IBI*	6	14	1,12	8.69	0.0122	0.42	y = 27.68 + 0.54 (Disturbance score)
	AW-IBI only	4	16	1, 14	15.41	0.0015	0.52	y = 21.20 + 0.44 (Disturbance score)
Scrub-shrub/ Riparian Depression	*Multi-taxa IBI*	5	16	1, 14	0.6621	0.4294	0.05	y = 29.99 + 0.24 (Disturbance score)
Scrub-Shrub/ Headwater Floodplain	*Multi-taxa IBI*	7	5	1,3	23.46	0.0168	0.89	y = 0.55 + 1.61 (Disturbance score)
	AW-IBI only	6	7	1, 5	79.93	0.0003	0.94	y = -2.96 + 1.54 (Disturbance score)
Scrub-Shrub/ Floodplain	*Multi-taxa IBI*	6	6	1, 4	7.39	0.0531	0.65	y = -1.30 + 1.74 (Disturbance score)
	AW-IBI only	5	8	1, 6	33.95	0.0011	0.85	y = 0.50 + 1.27 (Disturbance score)
Forested/ Riparian Depression	*Multi-taxa IBI*	4	8	1, 6	0.0404	0.8473	0.01	y = 24.92 - 0.09 (Disturbance score)
Forested/ Headwater Floodplain	*Multi-taxa IBI*	6	4	1, 2	7.66	0.1094	0.79	y = -56.47 + 3.10 (Disturbance score)
	AW-IBI only	5	7	1, 5	15.66	0.0108	0.76	y = -2.84 + 1.20 (Disturbance score)
	Multi-taxa IBI	8	8	1, 6	0.10	0.7542	0.02	y = 50.31 + 0.28 (Disturbance score)
Forested/ Floodplain	*AW-IBI only*	6	11	1, 9	6.43	0.0319	0.42	y= 14.43 + 0.95 (Disturbance score)

[a]Couldnot compare to hybrid AW-IBI because riparian depression AW-IBI does not exist.

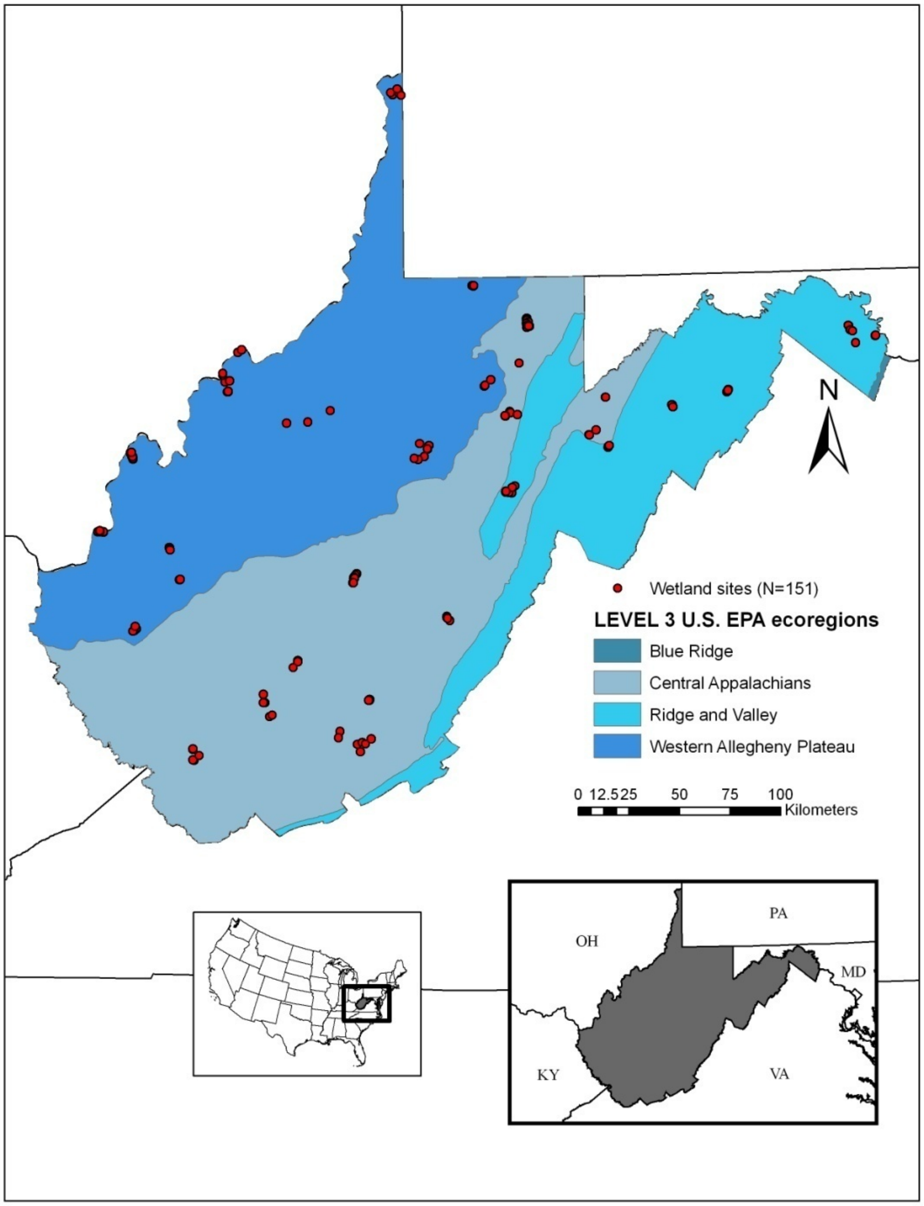

Figure 1. Site locations of wetlands and ecoregions(Woods et al. 1999; Omernik 1987) used in developing anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006. Wetland sites were clustered; scale of map prevents all sites from being marked individually. Legend may indicate 1-4 wetlands per mark.

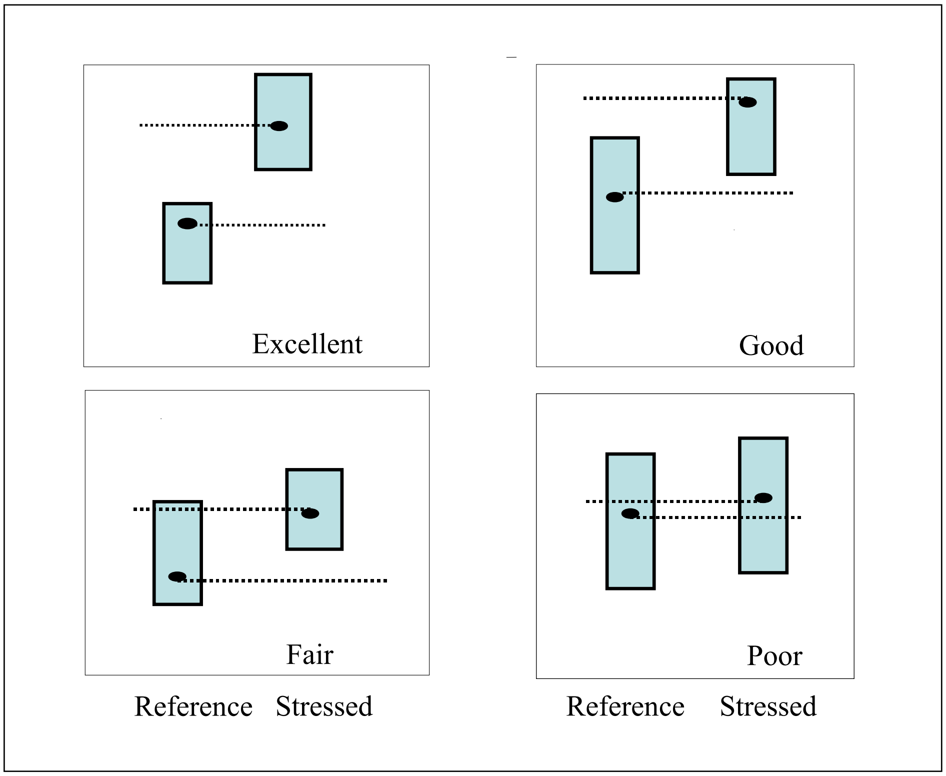

Figure 2. Box-and-whisker plot characteristics and resulting narrative description of reference and stressed sites' distribution of a biological metric value considered for inclusion into anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006. Solid ovals represent the median of metric value (courtesy of Greg Pond, U.S. EPA).

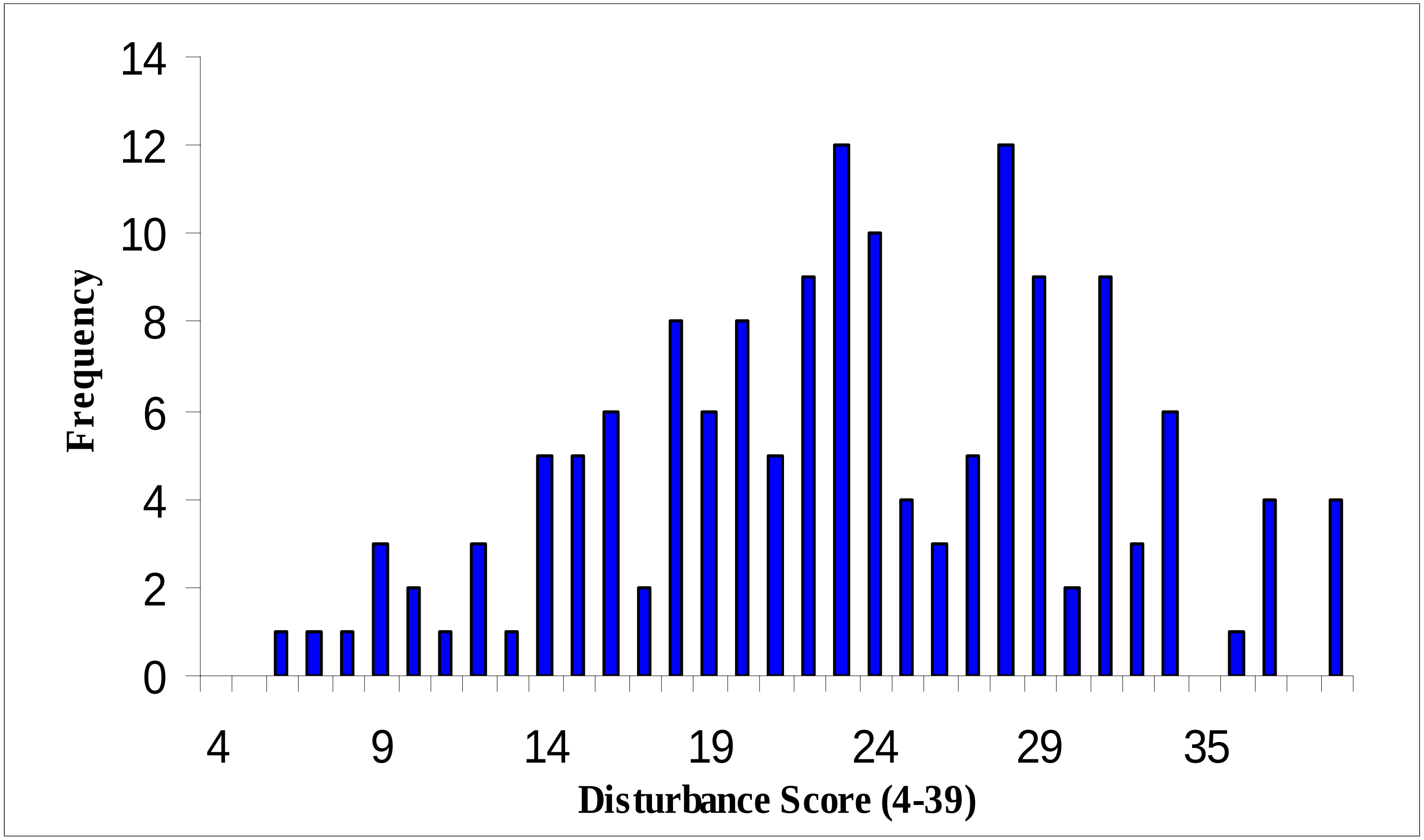

Figure 3. Frequency distribution of disturbance scores for sites used to develop class-specific anuran acoustically-based indices of biological integrity (AA-IBI) for wetlands in West Virginia, USA from 2005-2006.

Chapter 4

Vegetation Indices of Biological Integrity

Development of Vegetation Indices of Biological Integrity for Wetlands in West Virginia, USA

Walter Veselka IV[1]
James Rentch[1]
William Grafton[1]
Walter S. Kordek[2]
James T. Anderson[1, 3]

[1] Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

[2] West Virginia Division of Natural Resources, Wildlife Resources Section, PO Box 67, Ward Road, Elkins, WV 26241

[3] address correspondence to James T. Anderson, Ph.D., Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506. *email:* wetland@wvu.edu*phone:* (304) 293-2941 ext. 2445, *fax:* (304) 293-2441

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Abstract

Bioassessment methods for wetlands, and other bodies of water, have been developed worldwide, to measure and quantify changes in "biological integrity." These assessments are based on a classification system, meant to ensure appropriate comparisons between various wetland types. Using only a local site specific disturbance gradient, we built vegetation indices of biological integrity (Veg-IBIs) based on 2 commonly used wetland classification systems in the United States: the Cowardin et al. (1979) and hydrogeomorphic (HGM) wetland classification systems. The resulting class-specific Veg-IBIs were comprised of 1-5 metrics that varied in their sensitivity to the disturbance gradient (R^2 = 0.14 -0.65). Additionally, like previous West Virginia derived taxa-specific IBIs, the sensitivity to the disturbance gradient increased as metrics from each of the 2 classification schemes were combined (added). The sensitivity to the disturbance gradient also increased when metrics from the avian wetland indices of biological integrity (AW-IBIs) were added to those from the Veg-IBI. For example, the disturbance score explained more variation in floodplain wetlands (R^2 = 0.72) using metrics from both the AW-IBI and Veg-IBI, compared to either index alone (R^2 = 0.46 and R^2 = 0.56, respectively). Using this information to monitor natural wetlands, created wetlands, as well as wetland mitigation banks can help natural resource managers track the changes of the biological integrity of all wetlands in response to anthropogenic disturbance.

Keywords: *macroinvertebrate communities, disturbance, index of biological integrity, metrics, West Virginia, wetlands*

1.0 Introduction

Vegetative communities have historically been used as a component in identifying jurisdictional wetlands (USACOE 1987). The expression of plant communities reflect the hydrologic processes that occurred while the community was developing (Kirkman et al. 2000; Magee and Kentula 2005; Rentch et al. 2008). The resulting plant communities within and around wetlands reflect hydrologic conditions, and can indicate anthropogenic disturbances such as sedimentation (Mahaney et al. 2004a,b), nutrient enrichment (Craft and Richardson 1997; Drohan et al. 2006), and changes in hydrology (Koning 2005). Identifying and quantifying changes in plant communities resulting from human impairment is one way to measure the biological integrity of wetlands (Miller et al. 2006), one of the mandates charged to the U.S. Environmental Protection Agency (US EPA) under the Federal Clean Water Act (33 U.S.C. §1251).

Identifying metrics, or attributes, of a biological community that respond consistently and predictably to human disturbance is necessary to create indices of biological integrity (Karr and Chu 1999). These indices can be used to detect change and monitor trends in wetland condition, providing a basis of comparison that can be used to prioritize wetland protection, management, or restoration efforts. Wetland indices of biological integrity (IBI) based on vegetative communities have been developed according to Cowardin et al. (1979) classes (Galatowitsch et al. 2000; Mack 2004) or the hydrogeomorphic (HGM) (Brinson 1993) approach (Gernes and Helgen 2002; Miller et al. 2006). A study from Florida integrated both approaches to form a vegetative IBI specifically for forested, depressional wetlands (Reiss 2006). Researchers have advocated using the HGM approach for bioassessments because it compares wetlands that are functionally similar (Stevenson and Hauer 2002). However, in constructing an IBI, augmenting one approach with the alternative may increase sensitivity to human impairment (Veselka2008: Chapter 2). Currently the Cowardin et al. (1979) system is used in West Virginia for regulatory purposes (West Virginia State Code Chapter 22-11, 22-26), and will be referred to as "Cowardin" in this document from here after. However, this study uses both the NWI classifications and a variation of the HGM classes (Brinson 1993) that is meant to be clear and straight-forward for use by policy makers and resource managers.

The objectives of our study were to identify plant community metrics suitable for inclusion into robust, statewide, vegetative indices of biological integrity (Veg-IBI) for West Virginia. These indices will have the capacity to detect and quantify changes in the vegetative community that are reflective of varying levels and types of human impairment. The metrics we evaluated for inclusion into the Veg-IBI were drawn from previous research (Chipps et al. 2006;Gernes and Helgen 2002; Mack 2004; Miller et al. 2006; Miller and Wardrop 2006). As West Virginia-specific Veg-IBIs were developed, we were able to contrast and compare the classification strategies most often used in indices of biological integrity and evaluate the effectiveness of combining metric scores from other IBIs to form a multi-metric, multi-taxa composite IBI. Combining metric scores from multiple taxa groups enabled us to determine the efficacy of combining metric scores to increase the sensitivity and consistency of the IBI response to human impairment.

2.0 Methods

2.1 Study Area

Efforts were made to stratify sampling across both wetland Cowardin classes and the major U.S. Environmental Protection Agency's Level 3 aquatic ecoregions within West Virginia, USA: the Central Appalachians, the Ridge and Valley, and the Western Allegheny Plateau (Woods et al. 1999, Omernik 1987) (Table 1) (Veselka 2008: Chapter 2). Because of a lack of a comprehensive wetland map by HGM classification, stratification by this scheme was not possible. However, due the number of sites used in this study (151) we are confident we adequately sampled the major HGM subclasses (Cole et al. 1997) found in West Virginia (Figure 1) (Veselka 2008: Chapter 2). All sites were analyzed independently, although our sampling regime included single wetlands (48 of 151) and 20 wetland complexes in which we sampled from 2-5 sites per complex; all located ≥ 300 m from one another (Veselka 2008: Chapter 2).

After categorizing wetlands by both the Cowardin and regional HGM subclass (Cole et al. 1997) type, some subclass designations were combined into designated HGM management classes (Table 2) (Veselka 2008: Chapter 2). These categorizations increased our sample size and were meant to be more intuitive and applicable for use by natural resource managers and regulators. However, enough wetlands of the regional HGM subclasses (Cole et al. 1997) were sampled to build headwater floodplain and riparian depression Veg-IBIs. This allowed us to evaluate the difference between true HGM subclasses and our designated HGM management classes (Veselka 2008: Chapter 2).

2.2 Vegetation Surveys

Our vegetation survey methodology was designed to quickly and efficiently quantify the percent cover of the dominant species within our vegetation plot. Quantitative vegetation sampling was conducted once per wetland site in July or early August of 2005 or 2006. Vegetation sampling was conducted using a nested quadrat design to match the relative size of each vegetation stratum (Balcombe et al.2005). The dominant plant community, as determined by relative size (height), was identified in each wetland and sampled. Vegetation strata were classified into tree, shrub, and herbaceous layers(USACOE 1987). Trees were sampled using a 10-m radius circular plot; the shrub layer was sampled in a 6-m radius circular plot using the same center point nested within the tree stratum; and a minimum of 40.5-m radius herbaceous plots were randomly sampled within the 10-m radius plot.

The diameter at breast height (DBH) of trees that were > 12.0 cm for 1 stem, or a cumulative DBH > 20 cm for 2 stems, was measured to calculate basal area per species (Beltz et al. 1992). Woody vegetation between 10-cm and 6-m in height were considered shrubs. Each shrub species was recorded, and the diameter of each shrub's canopy was estimated and converted into percent cover. Herbaceous plants and woody vegetation (< 10 cm), exposed substrate, woody debris, bare ground, open water, and bryophytes were recorded and percent cover estimated using a modified Daubenmire (1968) cover class scale (Table 3) (Tiner 1999). The midpoints of each cover class were used to identify candidate metric values. Herbaceous quadrats were scattered randomly and sampled until ≤2 new species were detected after the initial 4 quadrats.

Additionally, we augmented the quantitative data collection by conducting a qualitative visual walk-through the wetland community to document the presence of species not detected in the initial vegetation survey (Balcombe et al. 2005). The walk-through allowed us to evaluate other metrics that may have been limited in their effectiveness because of non-detection using the previously discussed methodology. For example, the Floristic Quality Assessment Index scores are based on the presence of plant species and are immune to the influence of the abundance of any single plant species (Rentch and Anderson 2006). The quantitative and qualitative data of each stratum were then used to derive the candidate metrics that were tested for inclusion into the Veg-IBI (Table 4), allowing a greater number of candidate metrics.

2.3 Disturbance Gradient

Our disturbance gradient was based on metrics characterizing surrounding land-use activity, width and condition of the natural wetland buffer zone, and alteration to the hydrology, habitat, or substrate; adopted from the Ohio Rapid Assessment Method version 5.0 (ORAM) (Table 5) (Mack 2001). These metrics and submetrics formed a disturbance score that ranged from 4-39, the lower the score the more apparent the evidence of human impairment. The metrics selected for inclusion into the Veg-IBI were based on their responses to the disturbance score (Veselka 2008: Chapter 2).

2.4 Reference and Stressed Sites Designations

Reference and stressed designations were developed independently for Cowardin, HGM subclasses (Cole et al. 1997), and designated HGM management classes across Level 3 ecoregions (Woods et al. 1999, Omernik 1987) because these designations were based on human impairment characteristics throughout West Virginia rather than the ecological basis of the ecoregions. Disturbance index scores in the 75th and 25th percentile were used to categorize reference and stressed conditions, respectively (Barbour et al. 1995). Reference sites were based on least-disturbed conditions. These sites were not intended to be pristine or free from any evidence of human manipulation, but to represent examples of what can be realistically expected from a minimally impacted wetland in West Virginia (Omernik 1995).

<u>2.5 Data Analysis</u>

Class-specific Veg-IBIs were developed for wetland classes with ≥5 referenceand5 stressed sites (Chipps et al. 2006).   Sites were identified (in part) by sampling year. However, this effect was not tested because an individual wetland was only sampled during1 year of the study period, not both (Reiss 2006, O'Connell et al. 1998). All statistical tests were conducted at an *a priori* alpha level of 0.05 (Mack 2004, Micacchion 2004).

The vegetation plot measurements were used to derive candidate metric values that were evaluated for their capacity to discriminate between reference and stressed sites. After analyzing our data in a series of elimination steps specific to individual HGM or Cowardin classifications, we were able to contrast and use the 2 classification systems and use them to augment one another to increase sensitivity to disturbance scores (Veselka 2008: Chapter 2).

Potentially responsive metrics were identified, specific to each classification scheme, across the state of West Virginia using box-and-whisker plots (Barbour et al. 1996). After screening for redundant metrics (Hughes et al. 1998), remaining metrics were evaluated using an analyses of variance (ANOVA) test for an ecoregion interaction, a classification scheme interaction, and the 2-way interaction of both (Veselka 2008: Chapter 2). The resulting suite of metrics was evaluated a final time with a series of class-specific MANOVAs, testing for the cumulative effect of the metric values of reference and stressed sites to ecoregion or classification scheme influences (Veselka 2008: Chapter 2). Metrics were then normalized, inversed (when necessary) to ensure a consistent response to disturbance, and scored on a continuous 0-10 scale (Blocksom 2003; Bryce et al. 2002; Veselka 2008: Chapter 2). This scoring technique is consistent with the West Virginia Stream Condition Index (Gerritsen et al. 2000).

Using the metrics appropriate for each classification, Veg-IBIs were formed by summing all metrics selected for inclusion. The disturbance gradient and the distribution of the Veg-IBI scores for the reference sites were used to set numeric thresholds describing wetland condition (Gerritsen et al. 2000). Categorical threshold limits for Veg-IBI scores were set using the 75^{th}, 25^{th}, and 5^{th} percentiles for reference sites (Hill et al. 2003; McCormick et al. 2001; Veselka 2008: Chapter 2).The relation between Veg-IBI scores and the disturbance score were examined and plotted using simple linear regression specific to each Veg-IBI classification (Veselka 2008: Chapter 2).

In addition to scoring each wetland with an individual designated HGM management and Cowardin class Veg-IBI score, we used the additive properties of metrics to form specific hybrid Veg-IBIs that combined the 2 classification schemes, contingent on adequately large sample sizes.

A final analysis compared the derived class-specific and hybrid Veg-IBI with other wetland indices of biological integrity in West Virginia developed for other species assemblages. Using the same sample of wetland sites, a series of avian wetland indices of biological integrity (AW-IBI) and anuran acoustically-based indices of biological integrity (AA-IBI) were previously developed that characterized the species assemblages' responses to disturbance. This allowed the indices to be both compared, and integrated by adding metric scores. This determined if the sensitivity to the disturbance gradient increased as metrics from other biological assemblages were added.

3.0 Results

3.1 Ecoregions and site classifications

An *apriori* decision had been made to partition and build statewide specific Veg-IBI for both the designated HGM management class and Cowardin classification schemes (Maxted et al. 2000, Barbour et al. 1996).Adequate sample size permitted the formation of statewide Veg-IBIs for emergent, scrub-shrub, and forested wetlands, depression, floodplain, and impoundment designated HGM management class wetlands, and riparian depression and headwater floodplain HGM subclass (Cole et al. 1997) wetlands (Table 6) (Veselka 2008: Chapter 2).A complete list of sites and corresponding attribute data (e.g., ecoregion, location, class, etc.) can be found in Appendix B. The disturbance scores of sites were normally distributed (Figure 3) (*Skewness = -0.04, Kurtosis = -0.39*).

After eliminating redundant metrics (Table 7), remaining metrics were screened for ecoregion and alternate classification scheme interactions using a series of ANOVA tests (Table 8). Metric values with a significant ecoregion, classification scheme, or ecoregion x classification effect were subsequently removed from inclusion into the class-specific Veg-IBIs (Table 6).

Using only reference and stressed conditions, the suite of remaining metrics for each class-specific Veg-IBI were then evaluated again for a cumulative ecoregion, alternative classification scheme, or 2-way interaction with a MANOVA test (Table 9). This ensured that each class-specific Veg-IBI was robust and independent of ecoregion or classification scheme influences.

3.2 Metric Performance

Twenty-two candidate metrics were screened based on their ability to discriminate between reference and stressed sites independent of classification (HGM subclass, designated HGM management class or Cowardin class) within each ecoregion, based upon the disparity of the interquartile ranges of metric values for reference and stressed conditions (Appendix Y-AF). Six of the 22 metrics were discarded before being included into any of the class-specific Veg-IBI due to an inability to discriminate between reference and stressed conditions, not enough scoring variation between reference and stressed conditions, and/or redundancy with other metrics (Table 6). Additionally, 3 metrics were excluded from all Veg-IBIs after the *posthoc* analysis revealed a significant ecoregion or classification scheme effect. All metric scores and summary statistics by ecoregion are found in Appendices AF-AL.

The Mean Coefficient of Conservatism, adjusted Floristic Quality Assessment Index (adjusted FQAI), and non-native plant richness were most often correlated to one another. If discrimination efficiency among these metrics were equal, the FQAI metric was included because it incorporates measures of both the Coefficient of Conservatism and non-native plant richness (Miller and Wardrop 2006).

The resulting class-specific Veg-IBIs included between 1 and 5 metrics capable of discriminating between reference and stressed sites, although only 7 of the 8 derived indices were significantly related to disturbance scores (Table 10). Only the impoundment designated HGM management class Veg-IBI scores failed to exhibit a significant relation with the disturbance gradient, despite being able to discriminate between reference and stressed sites greater than 70% of the time.

The Veg-IBI based on Cowardin classifications all exhibited a significant relation with the disturbance gradient. Within the emergent class Veg-IBI, only the adjusted FQAI metric consistently discriminated between reference and stressed sites. The disturbance scores accounted for 14% of the variation in scores.

The scrub-shrub Veg-IBI was composed of 2 metrics; the relative cover of *Carex* species and, the relative cover of tolerant plant species. The disturbance scores accounted for 20% of the variation in the scrub-shrub Veg-IBI scores resulting from these metrics. The adjusted FQAI metric was removed from inclusion in the scrub-shrub Veg-IBI after a significant ecoregion and classification effect was found. The percent cover of native hydrophytic shrubs metric was also removed because of a significant ecoregion effect.

Five metrics formed the forested Veg-IBI. These metrics were the adjusted FQAI score, the relative cover of ferns and fern allies, the relative cover of *Carex* species, the relative cover of native hydrophytic herbaceous vegetation, and the relative cover of invasive graminoids including *Phalaris arundinacea*. The disturbance gradient accounted for 35% of the variation in the forested Veg-IBI scores. The relative cover of native graminoid species and relative cover of tolerant species were eliminated from consideration as suitable metrics because of a significant 2-way interaction effect between the designated HGM management class and ecoregion.

Among regional HGM subclasses (Cole et al. 1997),2 (riparian depression and headwater floodplain) for which specific Veg-IBIs were derived, exhibited significant relations with disturbance scores. The riparian depression Veg-IBI was built from 3 metrics; the adjusted FQAI score, the relative cover of tolerant species, and the percent cover of native shrubs. The disturbance gradient accounted for 26% of the variation in riparian depression Veg-IBI scores. Shrub richness was not included in the riparian depression Veg-IBI because it was significantly influenced by Cowardin classification.

The headwater floodplain Veg-IBI was composed of 4 metrics; the adjusted FQAI scores, the relative cover of *Carex* species, the mean importance value (IV) of tree species, and native shrub species richness. Based on the metrics included in the headwater floodplain Veg-IBI, 65% of the variation in scores can be attributed to the disturbance gradient. The metric discerning the mean IV of tree species with a wetland dependency rating of facultative or greater was eliminated from inclusion because it was significantly related to Cowardin classification.

As noted, with the exception of the impoundment designated HGM management class, both the floodplain and depression Veg-IBIs were significantly related to the disturbance scores. Five metrics were included in the floodplain Veg-IBI. These metrics were the mean Coefficient of Conservatism, the relative cover of *Carex* species, the mean IV of tree species, non-native plants from walk-through richness, and native shrub richness. Our disturbance gradient accounted for 56% of the variation in the floodplain Veg-IBI scores. As in the headwater floodplain Veg-IBI, the mean IV of tree species with a facultative or greater rating was eliminated due to a Cowardin effect. The percent cover of native shrub species displayed a Cowardin effect, an ecoregion effect, and an interaction effect.

With regards to the depression Veg-IBI scores, 31% of the variation in scores was attributed to the disturbance gradient. The scores of the depression Veg-IBI consisted of 2 metrics; the adjusted FQAI and the percent cover of native shrubs. As with the riparian depression Veg-IBI, the native shrub richness metric was removed after determining it exhibited a significant Cowardin classification effect.

The metrics making up the impoundment Veg-IBI, which did not exhibit a significant relation (p = 0.4308) included 2 metrics capable of discriminating between reference and stressed sites, the relative cover of monocot species and the relative cover of *Carex* species. The robust adjusted FQAI metric was excluded after the *posthoc* ANOVA showed a significant relation to both Cowardin class and ecoregion classification in impoundment wetlands.

Scoring thresholds based on the reference percentiles were calculated for each of the Veg-IBI classes (Table 11). All the means of Veg-IBIs that were related to the disturbance gradient varied significantly between reference and stressed sites.

3.3 Dual classification approaches for the Veg-IBI

The emergent Veg-IBI was only drawn from the adjusted FQAI metric; in relation to this metric, the disturbance gradient accounted for 14% of the variation in emergent Veg-IBI scores (Table 10). The sensitivity to disturbance increased in some instances when metric scores of the corresponding HGM classification were added. The emergent Veg-IBI sensitivity to disturbance increased when metrics from the HGM subclass of headwater floodplain (Cole et al. 1997) and floodplain designated HGM management classes were combined with the emergent Veg-IBI (Table 12). However, the amount of variation attributed to the disturbance gradient was actually less in the hybrid IBI than it would have been in a headwater floodplain or floodplain specific Veg-IBI.

Alternatively, when the metric scores from the scrub-shrub and forested Veg-IBI were combined with the corresponding designated HGM management class or HGM subclass (Cole et al. 1997) metric scores, the sensitivity to disturbance gradient increased in relation to both the Cowardin class Veg-IBI and the designated HGM management class Veg-IBI (Table 12). Impoundment Veg-IBI metrics, when evaluated with the scrub-shrub and forested Veg-IBI metrics, were not significantly influenced by the disturbance gradient.

3.4 Contrasting with other West Virginia wetland indices of biological integrity

The series of class-specific Veg-IBI are meant to be used as a stand-alone index for measuring biological integrity; yet we have also developed alternative indices using avian and anuran assemblages in the same sample of wetlands. This provided us with the opportunity to compare sensitivity to the disturbance gradient among the different species assemblages (Table 13). Examining the indices of biological integrity specific to HGM subclasses (i.e., riparian depression and headwater floodplain) (Cole et al. 1997), the Veg-IBI were more sensitive to the disturbance gradient than either the AA-IBI or AW-IBI. In riparian depression wetlands, adding the AW-IBI metrics actually decreased sensitivity to disturbance, whereas adding both the AW-IBI and AA-IBI metrics to the Veg-IBI metrics changed the sensitivity to the disturbance gradient only slightly. Alternatively, within headwater floodplain wetlands, adding metrics from other taxonomic groups increased sensitivity to the disturbance gradient more with the addition of AW-IBI metrics (n= 29, $F_{1, 27}$ = 86.47, p = <0.0001, R^2 = 0.76) than with both the AA-IBI and AW-IBI metrics (n = 22, $F_{1, 20}$ = 53.87, p = <0.0001, R^2 = 0.73).

Impoundment wetlands did not reveal any significant relation to the disturbance gradient relative to any of the taxa-specific or combined taxa IBI metrics. However, as with the HGM subclasses' specific IBIs, the Veg-IBI was more sensitive to the disturbance gradient in depression and floodplain wetlands than the AW-IBI or AA-IBI (Table 13). The combination of Veg-IBI and AW-IBI metrics of depression wetlands did not greatly change the relation to the disturbance gradient. In floodplain wetlands, adding metric scores to the Veg-IBI metrics from the AW-IBI alone and the AW-IBI and AA-IBI together both increased sensitivity to the disturbance gradient. However, the combination of AW-IBI and Veg-IBI metric scores were more sensitive (n = 35, $F_{1, 33}$ = 86.63, p = <0.0001, R^2 = 0.72) to the disturbance gradient than all 3 taxa-group metrics combined (n = 28, $F_{1, 26}$ = 44.44, p = <0.0001, R^2 = 0.63).

The Veg-IBI was more sensitive to the disturbance gradient within HGM classes than within Cowardin classes (Table 13). In emergent and scrub-shrub wetlands, the AW-IBI proved to be the most responsive to the disturbance gradient. When the Veg-IBI metrics were combined with the AW-IBI metric scores, both the emergent (n=75, $F_{1, 73}$ = 19.66, p = <0.0001, R^2 = 0.21) and scrub-shrub (n=44, $F_{1, 42}$ = 22.00, p = <0.0001, R^2 = 0.34) Cowardin classes produced more sensitive multi-taxa IBIs than any single species assemblage. Alternatively, the Veg-IBI was most sensitive to the disturbance gradient in forested wetlands in comparison to the AW-IBI; however, sensitivity still increased with the addition of AW-IBI and Veg-IBI metrics (n = 31, $F_{1, 29}$ = 26.90, p = <0.0001, R^2 = 0.48).

4.0 Discussion

4.1 Study design

Vegetation communities with high biological integrity are the desired endpoint representing least impaired wetland conditions (Brooks et al. 1998). Based on our objectives and analysis, the elimination of an ecoregion effect on the series of class-specific Veg-IBI enabled us to have a sufficient sample size to examine and contrast the more recent HGM approach (Brinson 1993) with the Cowardin approach. Our decision to combine the regional subclasses (Cole et al. 1997) into designated HGM management classes was based both a need to increase sample size, and to make IBI classifications intuitive to resource managers, rather than solely wetland specialists.

Each metric was evaluated based on its discrimination efficiency, and eliminating redundant metrics. The *posthoc* analysis of metric values included within the derived class-specific Veg-IBI was intended to validate our *apriori* classifications. The series of ANOVA tests of the metric values of reference and stressed sites for all vegetation classes was able to identify specific metrics within each classification scheme that did not respond consistently depending on ecoregion or classification scheme. After these metrics were removed, those remaining in each class were evaluated cumulatively, thus confirming that we had achieved our objective of building a series of statewide, wetland class-specific, vegetation-based indices of biological integrity. We believe our verification of no ecoregion or classification influences resulted in a series of intuitive and scientifically defensible Veg-IBIs that can be used to evaluate the effectiveness of pollution controls and to measure progress towards meeting the CWA objective of biological integrity (Jackson and Davis 1994). Moreover, the methods used to derive the

Veg-IBI incorporate measures of multivariate analysis that are presentable in an accessible and practical format (Courtemanch 1994).

4.2 Metric Performance by Classification Scheme

Vegetation indices of biological integrity were composed of1 to 5 metrics depending on classification schemes. The most common metric was the adjusted FQAI that was included in 5 of the 8 resulting class-specific Veg-IBIs. The formula for this metric was revised from other floristic quality indices (Miller and Wardrop 2006), but the robustness is not unexpected as it was essentially based on an established lineage of plant indices (Lopez and Fennessy 2002; Mack 2004; Nichols et al. 2006; Rentch and Anderson 2006). Integrating the Coefficients of Conservatism from West Virginia's FQI (Rentch and Anderson 2006) into the adjusted FQAI metric formula (Miller and Wardrop 2006) resulted in increasing discrimination efficiencies; potentially because the calculation incorporates a penalty for non-native plant richness.

Although the adjusted FQAI metric was able to discriminate between reference and impaired (impoundments and scrub-shrub wetlands) conditions, both visually and based upon discrimination efficiencies, it was not included in either classification's final Veg-IBI. This was, in part, due to a significant influence of metric values due to ecoregion classification effects. Additionally, both classifications were significantly influenced by the alternate classification scheme; meaning adjusted FQAI values in scrub-shrub wetlands are influenced by the type of HGM settings they are found in, as impoundment wetland adjusted FQAI scores are influenced by the Cowardin classes. The variation of impoundment wetlands, in our study ranging from forested beaver (*Castor canadensis*) impoundments to emergent mitigation impoundments, limited the number and effectiveness of metrics that could discriminate between reference and stressed conditions. Understanding how the value of the adjusted FQAI metric is calculated (with a penalty factor for exotic species), a recently constructed beaver impoundment may have a higher score than a decades-old, man-made impoundment; despite the beaver impoundment receiving a higher substrate and habitat alteration disturbance score.

With the exception of the scrub-shrub Veg-IBI, the floodplain Veg-IBI was the only other vegetation index significantly related to the disturbance gradient that does not include the adjusted FQAI as a metric. This was not because the adjusted FQAI did not discriminate between reference and stressed sites, but rather because the mean Coefficient of Conservatism metric facilitated efficient discrimination between the reference and stressed sites. We suspect the penalty factor associated with the adjusted FQAI influenced the interquartile distribution of the metric scores of reference sites, resulting in some of our reference sites scoring similar to that of the disturbed sites. These sites were deemed reference sites because they lacked characteristics of habitat, hydrology, or substrate alterations which can support the proliferation of non-native species in many instances (Drohan et al. 2006; Kercher and Zedler 2004; Galatowitsch et al. 1999). However, due to the nature of floodplains, they are already inherently prone to invasions by non-native species (Planty-Tabacchi et al. 1996). As a result, the mean Coefficient of Conservatism of plant species in each site is a better indicator of disturbed conditions as it doesn't overtly penalize for the proportion of non-native richness. However, a separate metric measuring the non-native richness was still included in the floodplain Veg-IBI. This metric was simply the non-native species richness counted in the walk-through of the plant community, without adjusting for the ratio of non-native to native species mean Coefficient of Conservatism.

The forested Veg-IBI was composed of 5 metrics, 3 of them unique to this classification; the relative cover of fern allies, the relative cover of hydrophytic herbaceous herbs, and the relative cover of *Phalaris arundinacae* and other invasive grasses. These metrics are similar to the "specialist" versus "generalist" nature of metrics described for avian species guilds (O'Connell et al. 2000). Forested wetlands are considerably different both structurally, and often hydrologically, than other Cowardin classes, therefore the majority of the metrics capable of discriminating between reference and stressed conditions would be unique.

Other unique specialist and generalist metrics included the relative cover of the monocot species metric for the impoundment Veg-IBI, as well as the mean IV for headwater floodplain and floodplain Veg-IBI. These 2 metrics are a further example of the "specialist" nature of metrics we described for the 4 metrics unique to the forested Veg-IBI. The relative cover of the monocot species metric increased with disturbance in impoundment wetlands. The impoundment Veg-IBI was not found to be significantly related to the disturbance scores, although it was capable of discriminating between reference and stressed conditions. Impoundment wetlands are inherently products of altered hydrology, so in a sense, they are unique as they represent a transition somewhere between the gradient of highly disturbed sites and those reaching a stable recovery point until natural hydrology can be restored. Identifying metrics that are significantly related to the disturbance gradient for impoundment wetlands has also been problematic using avian and anuran species assemblages (Veselka2008: Chapter 2, 3). Therefore, as impoundment wetlands are themselves an anomaly in comparison to the other wetlands types, it is not altogether surprising that a metric not found in any of the other IBIs would be included in the impoundment Veg-IBI.

The mean IV metric is derived from the tree stratum and used in both the headwater floodplain and floodplain Veg-IBIs. Logic may dictate that this metric may be included in the forested Veg-IBI rather than the headwater floodplain and floodplain Veg-IBI; however, the data directed us differently. Forested wetlands can occur in multiple hydrogeomorphic contexts, including depressional vernal pools, recent beaver ponds, and floodplains. The tree species occurring in such contexts will vary depending on hydroperiod, although to be considered a forested wetland community, at least 30% of the plant community must be under the forests' canopy (Cowardin et al. 1979). The plant communities we encountered in forested wetlands included high elevation beech-hemlock (*Fagus grandifolia- Tsuga canadensis*) forests, floodplain silver maple (*Acer saccharinum*) and red maple (*Acer rubrum)* swamps, and green ash (*Fraxinus pennsylvanica*) dominated mesophytic forests. The mean IV of tree species was unable to discriminate between reference and stressed sites because the number and type of tree species was inconsistent within our forested wetlands. Floodplain and headwater floodplain wetlands would often have < 20% canopy cover, although our methodology dictated we sample every vegetation stratum. Any tree included in our survey of floodplain wetlands was typically indicative of both minimal habitat alteration and low to very low surrounding land use impact; 2 factors used in calculating our disturbance score for each wetland. The IV of tree species for each sampling point must add up to 100; so a single tree species or lower numbers of trees species in each plot results in higher mean

IV. The presence of any tree within floodplain wetlands often coincided with a lesser level of disturbance and, as these disturbance scores were used to determine reference and stressed wetlands, the higher mean IVs were indicative of lesser impacted wetlands resulting in the inclusion of the IV metrics in headwater floodplain and floodplain Veg-IBIs.

Other general metrics were capable of discriminating between reference and stressed sites in multiple expressions of wetland types. Besides the previously noted adjusted FQAI, 4 other metrics appeared in 2 or more classes of Veg-IBI: the relative cover of *Carex* species, the relative cover of tolerant species, percent cover of native shrubs, and native shrub richness. The relative cover of *Carex* species was included as a metric in the headwater floodplain, floodplain, impoundment, scrub-shrub, and forested Veg-IBI. The relative cover of tolerant species was included in our riparian depression and scrub-shrub Veg-IBIs. Both of these metrics were included in vegetation-based IBIs of emergent and scrub-shrub wetlands in Ohio (Mack 2004), headwater wetland complexes in Pennsylvania (Miller et al. 2006), and depressional wetlands in Minnesota (Gernes and Helgen 2002). However, the relative cover of *Carex* species as a metric for scrub-shrub Veg-IBI is not intuitively biologically meaningful and may be representative of the transition from emergent wetlands to scrub shrub and forested wetlands. Nevertheless, the robustness of these metrics, spanning both Cowardin and designated HGM management classes within our study was not altogether surprising. In our study, the percent cover of native shrubs was included as a metric in the riparian depression and depression Veg-IBIs; native shrub richness was included in headwater floodplain and floodplain Veg-IBI. The percent cover of native shrubs was drawn from a vegetation IBI for headwater wetlands in Pennsylvania, although it was not included in the final IBI (Miller et al. 2006). The Ohio vegetation IBI for emergent and scrub-shrub wetlands included a metric for native shrub richness (Mack 2004). In our study, this metric applied to HGM class-specific Veg-IBI rather than the Cowardin classification used in Ohio. Despite the success of these metrics in discriminating between reference and stressed sites, future work should reevaluate the inclusion of these metrics as they were not found effective in the aforementioned regional works.

The emergent Veg-IBI was composed of only 1 metric able to discriminate between reference and stressed conditions, the adjusted FQAI metric. This sole metric did exhibit a significant response to the disturbance gradient that accounted for a portion of the variation in the scores ($R^2 = 0.14$), although we expected more metrics suitable for inclusion into the emergent Veg-IBI. One explanation could lie in the variability of emergent wetlands. In our study, emergent wetlands were composed of high-elevation fens, high and low order floodplains, mitigated impoundment cells, and areas of poor drainage as a result of road or railroad tracks. We postulate that the variation in plant communities in the above-described wetlands throughout West Virginia was the primary reason more candidate metrics did not adequately identify the stressed and reference conditions in emergent wetlands throughout the entire state.

4.3 Hybrid capacity of the Veg-IBI

With the exception of emergent wetlands, all other Veg-IBIs exhibited an increased sensitivity to the disturbance gradient by combining metrics from the alternate classification scheme. By combining metrics from the Cowardin class-specific and the designated HGM management class Veg-IBI, the number of metrics increased; however, the emergent Veg-IBI was comprised of only 1 metric, the adjusted FQAI metric. This metric was the most common metric discriminating between reference and stressed sites, resulting in the emergent Veg-IBI often overwhelming other adjusted FQAI scores rather than bolstering the other vegetative indices. Regardless, the ability of the entire suite of both the hybrid scrub-shrub and forested Veg-IBIs to respond with greater sensitivity to disturbance validates the approach and the need for continual research into integrating both classification systems from both a biological and regulatory perspective.

4.4 Comparisons with other Vegetation Indices of Biological Integrity

Our study's objective was to derive baseline data for a multitude of wetland expressions for use in a statewide wetland monitoring program integrating volunteers with professionals. Our metrics were drawn from previous studies, all of which used different disturbance gradients and sampling methods (Miller at al. 2006, Mack 2004). Although these comparisons were not all biologically meaningful (wetland depressions in Minnesota to wetland depressions in West Virginia), it allows us to contrast the sensitivity of each respective IBI to its disturbance gradient.

Minnesota developed a statewide vegetation IBI for large, depressional wetlands within the emergent plant community (Gernes and Helgen 2002). The disturbance gradient accounted for 49% of the variation in the 10 metric plant IBI scores. The 2 metric depression-class Veg-IBI for West Virginia had a significant, but comparatively weaker relation with the local disturbance gradient ($R^2 = 0.31$) as did the single metric emergent Veg-IBI ($R^2 = 0.14$).Yet by augmenting the depression Veg-IBI with a Cowardin class Veg- IBI, 2 of the 3 resulting hybrid-class indices had a stronger relation to the disturbance gradient than the depression-specific metrics. The 3 metric scrub-shrub - depression Veg-IBI had a significant relation with the disturbance gradient (R^2 = 0.46), as well the 6 metric forested - depression Veg-IBI (R^2 = 0.42); although combining emergent and depression metrics resulted in an insignificant relation (R^2 = 0.06). Both studies encompassed multiple ecoregions, but methods varied. The Minnesota disturbance gradient was composed of similar disturbance characteristics, although it included a factor based on water chemistry and sediment concentrations. The scoring method also implemented discrete scoring (Karr et al. 1986), rather than the continuous scale we employed (Blocksom 2003; Gerritsen et al. 2000; Hill et al. 2003).

A regional study of headwater wetlands in the Ridge and Valley ecoregion in Pennsylvania developed an 8 metric, plant-based IBI which is highly responsive to their disturbance gradient (Miller et al. 2006). This study combined the HGM subclasses of slope, riparian depression, and headwater floodplain wetlands associated with streams of the second order or less fed by surface or groundwater into a group termed headwater complexes (Cole et al. 1997). The disturbance gradient, which was composed of both a GIS-analysis of a 1-km radius circle and buffer zone stressor checklist, accounted for 51.8% of the variation of plant community scores. Our study developed Veg-IBIs for 2 of the 3 HGM subclasses (Cole et al. 1997) used in the Pennsylvania study, riparian depression and headwater floodplain wetlands. However, only the headwater floodplain wetlands were consistently associated with low-order streams, as our riparian depression wetlands were comparatively more variable throughout the entire state. Our local disturbance gradient accounted for 65% and 26% of the variation in headwater floodplain and riparian depression Veg-IBI scores, respectively.

The headwater floodplain Veg-IBI was comprised of 4 metrics, whereas the riparian depression consisted of 3. If the corresponding Cowardin class Veg-IBI metrics are also considered, the disturbance gradient may explain an even greater part of the variation in plant community metrics. Within headwater floodplain wetlands, incorporating the Cowardin class metrics resulted in a greater sensitivity to the disturbance gradient in 2 of the 3 classes. Emergent headwater floodplain scores were significant (R^2 = 0.61); although the combined 5-metric scrub-shrub-headwater floodplain (R^2 = 0.66) and 7 metric, forested-headwater floodplain (R^2 = 0.84) explained more variance than the class-specific headwater floodplain Veg-IBI (R^2 = 0.65). The statewide class-specific riparian depression Veg-IBI scores were significant in relation to the disturbance gradient (R^2 = 0.26), although not when combined with the emergent Veg-IBI adjusted FQAI metric score (R^2 = 0.00). However, when the riparian depression Veg-IBI metrics were combined with scrub-shrub and forested Veg-IBI metrics, the variation accounted for by the disturbance gradient increased to 50% and 41%, respectively.

Pennsylvania research was focused on a particular wetland system of 1 ecoregion (Miller et al. 2006), hence the results would predictably involve less geographic and wetland type variability than a study encompassing multiple ecoregions. Nonetheless, our approach of combining class-specific Cowardin and HGM metric scores resulted in a series of statewide hybrid Veg-IBIs with significant portions of variation attributed directly to a local disturbance gradient.

Another regional study from Ohio, from which some metrics were drawn, developed vegetation IBIs using Cowardin classes rather than a set of HGM subclasses

(Mack 2004). The disturbance gradient used in our research is a subset of the metrics from the Ohio Rapid Assessment Method (ORAM) version 5.0 (Mack 2001); which in its entirety, includes measures that don't directly measure human impacts such as size and connectivity to other wetlands, to deduce a wetland disturbance score. Variations of IBI scores due to the disturbance score will change as multiple iterations of each IBI are developed to match a statewide dataset (Mack 2007). However citing the initial stages of the Ohio research, the complete version of ORAM accounted for 72.5% of the variation in the 10 metric, emergent vegetation IBI, 48% in the 10 metric, scrub-shrub vegetation IBI, and 49.7% in the 10 metric, forested vegetation IBI (Mack 2004).Major differences in study methodologies include scoring the metrics, as the Ohio metric scores were calculated using an interval scoring method (Karr et al. 1986), and sampling strategies where Ohio commonly sampled a plant community using a 20 m by 50 m transect; which if used in West Virginia, would likely encompass more than 1 wetland vegetation community or take us out of the wetland area, confounding our results and interpretation. The Cowardin class Veg-IBIs developed for West Virginia included fewer metrics for each classification and, although drawn in part from the ORAM, were less responsive to the disturbance gradient. This may be due, in part, to the *apriori* decision to include only local components of ORAM reflecting human stressors rather than other "natural" proximity factors that can influence plant communities. The emergent Veg-IBI we developed for West Virginia was comprised of only 1 metric (the adjusted FQAI) and, although significantly related to the disturbance gradient, did not explain more than 14% of the variation in IBI scores. The disturbance score accounted for 20% and 35% of the variation in the 2 metric scrub-shrub and 5 metric forested Veg-IBI scores, respectively.

However, the relation between the disturbance gradient and the Cowardin class Veg-IBI scores can be considerably strengthened when augmented by corresponding designated HGM management class Veg-IBI metrics. For example, in the hybrid Veg-IBI for emergent wetlands in a floodplain setting, the disturbance gradient accounts for 55% of the variation in scores. However, in emergent-depression and emergent-impoundment wetlands, the relation between Veg-IBI scores and the disturbance gradient is not significant. In fact, both the scrub-shrub and forested Veg-IBI metrics were not significant when combined with impoundment Veg-IBI metrics, although the relations with depression and floodplain Veg-IBI metrics were significant. The disturbance score accounted for 46% and 59% of the variation in scrub-shrub-depression and scrub shrub-floodplain Veg-IBI scores, respectively. The relation between forested-depression Veg-IBI scores ($R^2 = 0.41$) and the disturbance gradient was weaker than the scrub-shrub-depression Veg-IBI; however, the disturbance gradient accounted for more variation in the forested-floodplain Veg-IBI than any other hybrid Cowardin-designated HGM management class combination ($R^2 = 0.68$).

The resulting relations generated by the West Virginia statewide class-specific vegetation IBIs are comparable to many of the results from surrounding regional studies, despite developing these indices using a site-specific disturbance gradient representing only human stressors. We have demonstrated, in some instances, that combining the Cowardin and HGM classification schemes can increase the sensitivity to the disturbance gradient. Developing the dual classifications for monitoring the biological integrity of wetlands allowed us to simultaneously contrast and compare wetlands based on criteria more specific than the most prevalent stratum of vegetation or geomorphic setting. We examined all expressions of wetlands across the state and used the additive properties of metrics to evaluate the possibility of strengthening the relation with disturbance scores. However, some wetlands categorized by 1 or 2 of the classification systems, may still result in relatively minor or no variation attributed to the disturbance gradient as we have seen in our studies combining Cowardin class metrics with metrics from the impoundment designated HGM management class.

4.5 Integration with other wetland indices of biological integrity in West Virginia

Our study collected data from different biological communities that were used to develop different taxa-specific IBIs in the same manner (Veselka 2008: Chapters 2, 3). These studies included evaluating avian and anuran assemblages to form avian wetland indices of biological integrity (AW-IBI) and acoustically-based anuran indices of biological integrity (AA-IBI). The Veg-IBI can be a stand-alone index that is capable of evaluating wetland biological condition with 1 site visit. Alternatively, the AW-IBI and AA-IBI are composed of cumulative data recorded from 2 and 3 site visits, respectively. These methods, resulting in the AW-IBI and AA-IBI metric scores, are intended to be useful within to volunteer-driven programs. Alternatively, the Veg-IBI requires considerable plant taxonomic skill and a commitment of time that may exceed most volunteer-dependent programs.

Although capable of being used independently, metrics from each taxa-class are all based upon the same scoring regime, and can be used to bolster sensitivity to the disturbance gradient by combining IBIs between taxa. For example, combining the Veg-IBI metrics for emergent wetlands ($R^2 = 0.14$) with the metric scores from the corresponding emergent AW-IBI results in a multi-taxa multi-metric wetland index in which 21% of the variation in scores is attributable to the disturbance gradient. This was greater than the variation described by the emergent AW-IBI alone ($R^2 = 0.11$). Additionally, different combinations of taxa groups used in the IBI combinations can be used to ascertain which groups of species would be best to characterize the level of biological integrity or track changes. For example, the relation between floodplain wetlands and the disturbance gradient is significant based on Veg-IBI scores, AW-IBI scores, and acoustically-based anuran indices of biological integrity (AA-IBI) scores. However the combination of floodplain AW-IBI and Veg-IBI metrics are better explained by the disturbance gradient ($R^2 = 0.72$) than when all 3 taxa IBI metrics are combined ($R^2 = 0.63$) or the single taxa floodplain IBI is used alone (R^2 ranged from 0.18 to 0.56).

An obvious intuitive question is raised when more metrics do not necessarily result in greater sensitivities to the disturbance gradient. The addition of AA-IBI metrics, in 4 of 5 cases, resulted in lower sensitivities to disturbance compared to when the Veg-IBI and AW-IBI are used alone. We discuss the shortcomings of the AA-IBI in previous works (Veselka 2008: Chapter 3); however, in summary, the AA-IBI is based upon methods that are more qualitative than quantitative. Additionally, a minimum criterion was to develop AA-IBI metrics based upon having 2 or more species of anurans vocalizing at 1site. Contrasting the sensitivities to the disturbance gradient will allow natural resource managers to selectively monitor the group or groups most sensitive to human impacts in wetlands, increasing wetland monitoring efficiency and cost-effectiveness.

5.0 Implications for Future Monitoring Programs

Flexibility in choosing which groups of taxa can best explain the relation between biological integrity of wetlands and the local disturbance gradient is important in planning future wetland monitoring programs. Based on the Cowardin or HGM classification of a particular wetland, we can identify which biological assemblages would most likely reflect impacts resulting from human activities in the immediate vicinity. Statewide monitoring programs are intended to describe statewide wetland status, prioritize and plan wetland restoration or preservation, as well as identify areas susceptible to degradation (Wardrop et al. 2007).

Integrating rapid-based bioassessments into spatial probability modeling can identify wetlands most at-risk from anthropogenic activities (Wardrop et al. 2007). By identifying these sites, we can prioritize the protection of the most functionally significant wetlands with regards to water quality improvement, floodwater regulation, and biological integrity to ensure the conditions and functions of wetlands within watersheds throughout West Virginia are maintained (Cedfeldt et al. 2000; Weller et al. 2007).

Wetland regulations are implemented at the local scale, as the filling and dredging of larger wetlands is generally permitted on a case-by-case basis. The CWA mandates that these activities should be conducted in a manner that maintains the biological integrity of the wetland, as long as the wetland in question meets the jurisdictional requirements of the Army Corps of Engineers (USACOE 1987). The success or failure of mitigation projects resulting from the permitted activities typically hinges on a surrogate of biological integrity such as the survival rate of a prescribed number of plants per acre. With the advent of the recent EPA ruling on "Compensatory Mitigation for Losses of Aquatic Resources" (40 CFR Part 230) which advocates mitigation banks as the preferred mitigation alternative, the statewide Veg-IBI should be used as the benchmark to define successful mitigation. The use of the Veg-IBI for this purpose will provide an in-depth level of accountability as to the relative success of a mitigation project, better ensuring "no-net loss" of wetlands in West Virginia as it pertains to biological integrity.

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Table 1. Number of sites by Cowardin and hydrogeomorphic (HGM) classification schemes and ecoregions for use in developinguse in developing vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Level 3 U.S. Environmental Protection Agency aquatic ecoregion[a]			
	Ridge and Valley	**Central Appalachian**	**Western Alleghany Plateau**	**Total**
Hydrogeomorphic subclass[b]				
Riparian Depression	10	24	25	59
Headwater Floodplain	10	15	4	29
Designated HGM Management Class				
Depression	10	28	34	72
Floodplain	12	17	6	35
Impoundment	1	14	8	23
Cowardin Class				
Emergent	15	34	26	75
Scrub-shrub	6	17	21	44
Forested	6	14	11	31

[a] Omernik (1987), modified by Woods et al. (1999).

[b] Cole et al. (1997).

Table 2. Designated hydrogeomorphic (HGM) management classes derived from regional hydrogeomorphic (HGM) subclasses[a] for use in developing vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Designated HGM Management class	Hydrogeomorphic subclass[a]
Depression	Surface water depression
	Riparian depression
	Isolated depression
Floodplain	Headwater floodplain
	Mainstem floodplain
Impoundment	Headwater impoundment
	Mainstem impoundment
Fringing	Fringing
Slope	Slope

[a] Cole et al. (1997).

Table 3. Cover class scales for herbaceous vegetation plots used to derive candidate metric values for developing vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Cover Class	Range of Cover	Midpoint value
Trace	<1	0.0%
1	1-4%	2.5%
2	5-15%	10.0%
3	16-25%	20.5%
4	26-39%	32.5%
5	40-60%	50.0%
6	61-74%	67.5%
7	75-84%	79.5%
8	85-95%	90.0%
9	96-99%	97.5%
10	100%	100.0%

Table 4. Candidate metrics, the survey plot the metrics were derived from, the expected response to disturbance, and descriptions tested for inclusion into vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Candidate vegetation metrics	Survey Plot[a]	Expected Response to Disturbance	Description of metric
MeanC[b, d]	WT	-	Average coefficient of conservatism per wetland
AdjFQAI[b, c, d]	WT	-	Adjusted Floristic Quality Assessment Index
FernRC[b]	Herbaceous	-	Relative cover of fern allies
MonoRC[b]	Herbaceous	+	Relative cover of monocot species
NativeGramRC[b]	Herbaceous	-	Relative Cover of native graminoids
InvGrassRC[b, c]	Herbaceous	+	Relative Cover of invasive graminoids
NativeDicotRC[c]	Herbaceous	-	Relative cover of native dicots
DicotRC[b]	Herbaceous	-	Relative cover of dicots
CarexRC[b, c]	Herbaceous	-	Relative cover of *Carex* species
TolerantRC[b, c]	Herbaceous	+	Relative cover of tolerant species (Coefficient of Conservatism ≥ 2)
NativeHydroHrbRC[b, c]	Herbaceous	-	Relative cover of native species with facultative wetness rating or greater
PhaInvGrassRC[b]	Herbaceous	+	Relative cover of *Phalaris* species and invasive graminoids
ShrubNativePC[c]	Shrub	-	Percent cover of native shrubs
FAConlyHrbRC[b]	Herbaceous	+	Relative cover of facultative-only rated species
ShrNativeHydroPC[c]	Shrub	-	Percent cover of native hydrophytic shrub species
MeanIV[c]	Tree	-	Mean Importance Value (IV) of trees in plot
TreeFACupMeanIV	Tree	-	Mean Importance Value (IV) of facultative or greater rated trees
TreeFACWupMeanIV	Tree	-	Mean Importance Value (IV) of facultative -wet or greater rated trees
MeanDBH[b]	Tree	-	Mean diameter-at-breast height of trees
InvGramWTRich	WT	+	Richness of invasive graminoid species
NonNativePlantWTRich[b]	WT	+	Richness of non-native plant species
ShrubRich[b]	Shrub	-	Richness of shrub species
NativeShrubRich[b]	Shrub	-	Richness of native shrub species

[a] Herbaceous layer 1/2 m radius, shrub layer 6 m radius, tree layer 10 m radius, WT = walk-through of wetland community and all species detected in other survey methods.

[b] Miller et al. (2006).

[c] Mack (2004).

[d] Rentch and Anderson (2006).

Table 5. Metrics and sub-metrics selected from the Ohio Rapid Assessment Method (Mack 2001) used to define the disturbance gradient for use in developing vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Scoring value		Disturbance component
	Upland buffers and surrounding land use	
		Calculate the average buffer width. Select only one and assign score.
7	☐	WIDE. Buffers average 50m or more around wetland perimeter
4	☐	MEDIUM. Buffers average 25m to <50m around wetland perimeter
1	☐	NARROW. Buffers average 10m to <25m around wetland perimeter
0	☐	VERY NARROW. Buffers average <10m around wetland perimeter
		Intensity of surrounding land use. Select one or double check and average.
7	☐	VERY LOW. 2nd growth or older forest, prairie, savannah, wildlife area, etc.
5	☐	LOW. Old field (>10 years), shrubland, young second growth forest.
3	☐	MODERATELY HIGH. Residential, fenced pasture, park, conservation tillage, new fallow field.
1	☐	HIGH. Urban, industrial, open pasture, row cropping, mining, construction.
	Hydrology	
		Modifications to natural, hydrologic regime. Score one or double check and average.
12	☐	None or none apparent. There are no modifications or no modifications that are apparent to the rater.
7	☐	Recovered. The wetland appears to have recovered from past modifications which altered the wetland's natural hydrologic regime.
3	☐	Recovering. The wetland appears to be in the process of recovering from past modifications which altered the wetland's natural hydrologic regime.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past modifications and / or the modifications are ongoing.
	Habitat alteration and development	
		Substrate disturbance. Score one or double check and average.
4	☐	None or none apparent. There are no modifications or no modifications that are apparent to the rater.
3	☐	Recovered. The wetland appears to have recovered from past disturbances.
2	☐	Recovering. The wetland appears to be in the process of recovering from past disturbances.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past disturbances and/ or the disturbances are ongoing.
		Habitat alteration. Score one or double check and average.
9	☐	None or none apparent. There are no alterations or no alterations that are apparent to the rater.
6	☐	Recovered. The wetland appears to have recovered from past alterations.
3	☐	Recovering. The wetland appears to be in the process of recovering from past alterations.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past alterations and/ or the alterations are ongoing.

Table 6. Candidate vegetation community metrics evaluated by class according to regional Hydrogeomorphic (HGM) subclass, designated HGM management class, and the Cowardin classification schemes in building vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Wetland Classification[a]							
	HGM subclass		**Designated HGM management class**			**Cowardin classification**		
Candidate vegetation metrics	**Riparian Depression**	**Headwater Floodplain**	**Depression**	**Floodplain**	**Impoundment**	**Emergent**	**Scrub-Shrub**	**Forested**
MeanC[b, d]	R	R	R	I	R	R	R	R
AdjFQAI[b, c, d]	I	I	I	*	E	I	E	I
FernRC[b]	*	*	*	*	*	*	*	I
MonoRC[b]	*	*	*	*	I	*	*	*
CarexRC[b, c]	*	I	*	I	I	*	I	I
TolerantRC[b, c]	I	*	*	*	*	*	I	E
NativeHydroHrbRC[b, c]	*	*	*	*	*	*	*	I
PhaInvGrassRC[b]	*	*	*	*	*	*	*	I
ShrubNativePC[c]	I	*	I	E	*	*	R	*
ShrNativeHydroPC[c]	*	*	R	*	*	*	E	*
MeanIV[c]	*	I	*	I	*	*	*	*
NonNativePlantWTRich[b]	R	R	R	I	*	*	R	F
NativeShrubRich[b]	E	I	E	I	*	*	*	F
NativeGramRC[b, e]	*	*	*	*	*	*	*	E
TreeFACupMeanIV[e]	*	E	*	E	*	*	*	*
TreeFACWupMeanIV[e]	*	R	*	*	*	*	*	*
MeanDBH[b, e]	*	R	*	R	*	*	*	*
NativeDicotRC[c, e]	*	*	*	*	*	*	*	*
DicotRC[b, e]	*	*	*	*	*	*	*	*
FAConlyHrbRC[b, e]	*	*	*	*	*	*	*	*
InvGramWTRich[e]	*	*	*	*	*	*	*	*
ShrubRich[b, e]	*	*	*	*	*	*	*	F

[a] I = included in class-specific Veg-IBI; R = redundancy with other metrics; F = failure due to lack of scoring range; E = excluded due to significant ecoregion or classification effect; * = failure to discriminate between reference and stressed sites.

[b] Derived fromMiller et al. (2006)

[c] Derived from Mack (2004)

[d] Rentch and Anderson (2006).

[e]Metrics excluded from all of the resulting class-specific Veg-IBI due to redundancy, failure in scoring range, significant ecoregion or classification scheme effect, inability to discriminate between reference and stressed sites.

Table 7. Correlated metrics (R> 0.80) selected based on discrimination efficiency (D.E.) in differentiating between reference and stressed sites' metrics used in developing vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification/ metric	**D.E.**	Metrics				
Riparian Depression		Mean C	AdjFQAI	Tolerant RC	Shrub Native PC	NonNative PlantWTRich
Mean C[a]	82	1				
AdjFQAI[b]	82	0.991	1			
Tolerant RC[b]	82	-0.477	-0.492	1		
Shrub Native PC[b]	64	0.166	0.162	-0.063	1	
NonNativePlantWTRich[a]	72	-0.827	-0.868	0.349	-0.025	1

Headwater Floodplain		Mean C	AdjFQAI	Carex RC	Mean IV	TreeFACup Mean IV	Mean DBH	NonNative PlantWTRich	Native Shrub Richness
Mean C[a]	88	1							
AdjFQAI[b]	88	0.985	1						
Carex RC[b]	75	0.267	0.213	1					
Mean IV[b]	88	-0.145	-0.215	0.123	1				
TreeFACupMean IV[c]	88	-0.069	-0.112	0.125	0.765	1			
Mean DBH[a]	88	-0.216	-0.264	-0.032	0.937	0.788	1		
NonNativePlantWTRich[a]	75	-0.762	-0.829	-0.014	0.379	0.199	0.316	1	
Native Shrub Richness[b]	62	0.14	0.154	0.077	0.421	0.509	0.436	-0.168	1

Table 7. Continued.

Classification/ metric	**D.E.**	Metrics							
Depression		Mean C	AdjFQAI	Shrub Native PC	ShrNativeHydroPC	NonNative PlantWTRich	Native Shrub Richness		
Mean C[a]	78	1							
AdjFQAI[b]	78	0.99	1						
Shrub Native PC[b]	72	0.119	0.104	1					
ShrNativeHydroPC[a]	67	0.126	0.108	0.951	1				
NonNativePlantWTRich[a]	67	-0.823	-0.873	0.049	0.063	1			
Native Shrub Richness[c]	67	0.026	0.003	0.754	0.698	0.166	1		
Floodplain		Mean C	Carex RC	Shrub Native PC	Mean IV	TreeFACup Mean IV	Mean DBH	NonNative PlantWTRich	Native Shrub Richness
Mean C[b]	66	1							
Carex RC[b]	89	0.181	1						
Shrub Native PC[c]	78	-0.061	0.123	1					
Mean IV[b]	89	-0.24	0.089	0.328	1				
TreeFACupMean IV[c]	89	-0.133	0.018	0.297	0.778	1			
Mean DBH[a]	89	-0.29	-0.144	0.384	0.887	0.83	1		
NonNativePlantWTRich[b]	78	-0.797	-0.009	-0.102	0.446	0.268	0.387	1	
Native Shrub Richness[b]	66	0.063	0.009	0.623	0.433	0.504	0.438	-0.06	1
Impoundment		Mean C	AdjFQAI	Mono RC	Carex RC				
Mean C[a]	86	1							
AdjFQAI[c]	86	0.984	1						
Mono RC[b]	71	-0.204	-0.175	1					
Carex RC[b]	71	-0.036	0.011	0.231	1				

Table 7. Continued.

Classification/ metric	D.E.	Mean C	AdjFQAI
Emergent			
Mean C[a]	68	1	
AdjFQAI[b]	74	0.992	1

Scrub Shrub	D.E.	Mean C	AdjFQAI	Carex RC	Tolerant RC	Shrub Native PC	ShrNative HydroPC	NonNative Plant WTRich
Mean C[a]	83	1						
AdjFQAI[c]	83	0.994	1					
Carex RC[b]	83	0.067	0.063	1				
Tolerant RC[b]	66	-0.562	-0.568	-0.119	1			
Shrub Native PC[a]	66	0.327	0.311	0.236	-0.394	1		
ShrNativeHydroPC[c]	66	0.29	0.266	0.222	-0.343	0.895	1	
NonNativePlantWTRich[a]	83	-0.864	-0.894	-0.007	0.437	-0.198	-0.142	1

Forested	D.E.	Mean C	AdjFQAI	FernRC	Native GramRC	Carex RC	Tolerant RC	NativeHydro HrbRC	PhaInv GrassRC	InvGram WTRich	NonNative PlantWTRich	Shrub Rich	Native Shrub Richness
Mean C[a]	88	1											
AdjFQAI[b]	88	0.982	1										
FernRC[b]	100	0.468	0.475	1									
NativeGramRC[c]	88	0.065	0.012	-0.098	1								
Carex RC[b]	63	-0.093	-0.128	-0.028	0.631	1							
Tolerant RC[c]	88	-0.615	-0.66	-0.249	0.021	0.352	1						
NativeHydroHrbRC[b]	63	0.238	0.288	0.16	0.226	-0.152	-0.646	1					
PhaInvGrassRC[b]	63	-0.389	-0.412	-0.145	0.206	0.322	0.56	-0.308	1				
InvGramWTRich[c]	75	-0.47	-0.489	-0.357	0.119	0.095	0.394	-0.088	0.783	1			
NonNativePlantWTRich[a]	75	-0.749	-0.818	-0.511	0.206	0.173	0.685	-0.395	0.555	0.618	1		
ShrubRich[c]	88	0.116	0.067	0.137	0.259	0.138	0.069	0.12	0.213	0.091	0.085	1	
Native Shrub Richness[c]	75	0.144	0.091	0.186	0.292	0.149	0.067	0.167	0.143	0.083	0.043	0.953	1

[a] Metric not included due to redundancy with other metrics with greater discrimination efficiency.

[b] Metric selected for inclusion into Veg-IBI.

[c] Metric selected for inclusion into Veg-IBI, but removed in later analysis due to lack of scoring variability, significant ecoregion or alternate classification scheme effect.

Table 8. Analysis of variance (ANOVA) results of reference and stressed sites' metric values compared to Level 3 ecoregions (Woods et al. 1999, Omernik 1987) and the alternative classification scheme used in developing vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Riparian Depression Veg-IBI (n=27)				
Adjusted FQAI	Cowardin class	2,26	0.92	0.4168
	Level 3 ecoregion	2,26	2.13	0.1464
	Cowardinclass x Level 3 ecoregion	3,26	0.36	0.7847
Native Shrub Richness[a]	Cowardin[b]class	2,26	4.68	0.0223
	Level 3 ecoregion	2,26	0.27	0.7627
	Cowardinclass x Level 3 ecoregion	3,26	0.38	0.7696
Tolerant relative cover	Cowardinclass	2,26	0.06	0.9377
	Level 3 ecoregion	2,26	1.92	0.1746
	Cowardinclass x Level 3 ecoregion	3,26	0.81	0.5058
Native Shrub percent cover	Cowardinclass	2,26	0.88	0.4328
	Level 3 ecoregion	2,26	1.06	0.3668
	Cowardinclass x Level 3 ecoregion	3,26	2.92	0.0604
Headwater Floodplain Veg-IBI (n=16)				
Adjusted FQAI	Cowardinclass	2,15	0.03	0.9675
	Level 3 ecoregion	2,15	1.34	0.3152
	Cowardinclass x Level 3 ecoregion	3,15	0.20	0.8922
Native Shrub Richness	Cowardinclass	2,15	3.23	0.0939
	Level 3 ecoregion	2,15	1.43	0.2948
	Cowardinclass x Level 3 ecoregion	3,15	0.11	0.9531
Mean IV	Cowardinclass	2,15	0.65	0.5473
	Level 3 ecoregion	2,15	0.87	0.4548
	Cowardinclass x Level 3 ecoregion	3,15	0.02	0.9968
Tree Facultative or greater Mean IV[a]	Cowardinclass	2,15	5.45	0.0321
	Level 3 ecoregion	2,15	3.64	0.0751
	Cowardinclass x Level 3 ecoregion	3,15	1.97	0.1976
Carex spp. relative cover	Cowardinclass	2,15	0.50	0.6254
	Level 3 ecoregion	2,15	0.07	0.9292
	Cowardinclass x Level 3 ecoregion	3,15	0.21	0.8884

Table 8. Continued.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Depression Veg-IBI (n=37)				
Adjusted FQAI	Cowardinclass	3,36	0.95	0.4296
	Level 3 ecoregion	2,36	1.96	0.1602
	Cowardinclass x Level 3 ecoregion	3,36	0.42	0.7367
Native Shrub Richness[a]	Cowardinclass	3,36	4.00	0.0172
	Level 3 ecoregion	2,36	0.57	0.5715
	Cowardinclass x Level 3 ecoregion	3,36	1.16	0.3443
Native Shrub percent cover	Cowardinclass	3,36	0.62	0.6093
	Level 3 ecoregion	2,36	1.07	0.3557
	Cowardinclass x Level 3 ecoregion	3,36	2.92	0.0516
Floodplain Veg-IBI (n=19)				
Mean C	Cowardinclass	2,18	0.24	0.7875
	Level 3 ecoregion	2,18	2.16	0.1664
	Cowardinclass x Level 3 ecoregion	4,18	0.32	0.8584
Non-Native Plant Walk-thru Richness	Cowardinclass	2,18	0.24	0.7899
	Level 3 ecoregion	2,18	2.63	0.1206
	Cowardinclass x Level 3 ecoregion	4,18	0.88	0.5075
Native Shrub Richness	Cowardinclass	2,18	3.03	0.0938
	Level 3 ecoregion	2,18	0.67	0.5338
	Cowardinclass x Level 3 ecoregion	4,18	0.21	0.9263
Tree Mean IV	Cowardinclass	2,18	1.46	0.2774
	Level 3 ecoregion	2,18	0.84	0.4595
	Cowardinclass x Level 3 ecoregion	4,18	0.41	0.7973
Tree Facultative or greater Mean IV[a]	Cowardinclass	2,18	9.39	0.0051
	Level 3 ecoregion	2,18	2.07	0.1775
	Cowardinclass x Level 3 ecoregion	4,18	2.12	0.1531
Carex spp. relative cover	Cowardinclass	2,18	0.45	0.6487
	Level 3 ecoregion	2,18	0.31	0.7372
	Cowardinclass x Level 3 ecoregion	4,18	0.22	0.9199
Native Shrub percent cover[a]	Cowardinclass	2,18	57.01	<0.0001
	Level 3 ecoregion	2,18	19.99	0.0003
	Cowardinclass x Level 3 ecoregion	4,18	20.32	<0.0001
Impoundment Veg-IBI (n=13)				
Adjusted FQAI[a]	Cowardinclass	2,12	5.91	0.0314
	Level 3 ecoregion	2,12	6.07	0.0296
	Cowardinclass x Level 3 ecoregion	1,12	0.47	0.4688
Monocot relative cover	Cowardinclass	2,12	1.29	0.3330
	Level 3 ecoregion	2,12	0.43	0.6690
	Cowardinclass x Level 3 ecoregion	1,12	0.00	0.9914
Carex spp. relative cover	Cowardinclass	2,12	0.01	0.9915
	Level 3 ecoregion	2,12	0.80	0.4885
	Cowardinclass x Level 3 ecoregion	1,12	0.02	0.8998

Table 8. Continued.

Classification (number of reference and impacted sites)	Validation test	df	F-value	p-value
Emergent Veg-IBI (n=38)				
Adjusted FQAI	Designated HGM[b] management class	4,37	1.17	0.3491
	Level 3 ecoregion	2,37	2.65	0.0900
	Designated HGM[b] management class x Level 3 ecoregion	6,37	1.11	0.3853
Scrub-Shrub Veg-IBI (n=23)				
Adjusted FQAI[a]	Designated HGM[b] management class	4,22	4.52	0.0149
	Level 3 ecoregion	2,22	6.34	0.0109
	Designated HGM[b] management class x Level 3 ecoregion	2,22	0.84	0.4541
Carex spp. relative cover	Designated HGM[b] management class	4,22	0.56	0.6922
	Level 3 ecoregion	2,22	0.60	0.5636
	Designated HGM[b] management class x Level 3 ecoregion	2,22	0.25	0.7794
Tolerant relative cover	Designated HGM[b] management class	4,22	1.17	0.3672
	Level 3 ecoregion	2,22	2.59	0.1106
	Designated HGM[b] management class x Level 3 ecoregion	2,22	0.01	0.9938
Native Hydrophytic Shrub percent cover[a]	Designated HGM[b] management class	4,22	0.16	0.9552
	Level 3 ecoregion	2,22	8.87	0.0033
	Designated HGM[b] management class x Level 3 ecoregion	2,22	0.16	0.8517
Forested Veg-IBI (n=16)				
Adjusted FQAI	Designated HGM[b] management class	4,15	0.66	0.6414
	Level 3 ecoregion	2,15	0.81	0.4841
	Designated HGM[b] management class x Level 3 ecoregion	2,15	1.06	0.3970
Fern relative cover	Designated HGM[b] management class	4,15	0.43	0.7866
	Level 3 ecoregion	2,15	0.30	0.6929
	Designated HGM[b] management class x Level 3 ecoregion	2,15	0.43	0.6694
Native Graminoid relative cover[a]	Designated HGM[b] management class	4,15	4.82	0.1100
	Level 3 ecoregion	2,15	4.30	0.0606
	Designated HGM[b] management class x Level 3 ecoregion	2,15	7.74	0.0169
Carex spp. relative cover	Designated HGM[b] management class	4,15	1.71	0.2511
	Level 3 ecoregion	2,15	1.50	0.2866
	Designated HGM[b] management class x Level 3 ecoregion	2,15	0.09	0.9153
Tolerant relative cover[a]	Designated HGM[b] management class	4,15	1.21	0.3845
	Level 3 ecoregion	2,15	3.28	0.0990
	Designated HGM[b] management class x Level 3 ecoregion	2,15	5.61	0.0351
Native Hydrophytic Herbaceous relative cover	Designated HGM[b] management class	4,15	1.70	0.2530
	Level 3 ecoregion	2,15	2.36	0.1645
	Designated HGM[b] management class x Level 3 ecoregion	2,15	2.12	0.1909
Phalaris spp. and Invasive Grasses relative cover	Designated HGM[b] management class	4,15	0.42	0.7878
	Level 3 ecoregion	2,15	0.43	0.6650
	Designated HGM[b] management class x Level 3 ecoregion	2,15	1.43	0.3011

[a] Metric excluded from inclusion into class-specific Veg-IBI due to a significant ecoregion, alternative classification scheme, or cumulative 2-way interaction.

[b] Hydrogeomorphic (Brinson 1993).

Table 9. Wilks' Lambda statistic for *posthoc* validation of reference and stressed sites' metric values of class-specific vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification scheme and interaction	Wilks' Lambda	F-value	df	p-value
Headwater Floodplain Veg-IBI (n=16)				
Cowardin class	0.2074	1.49	8, 10	0.2709
Level 3 ecoregion	0.3608	0.83	8, 10	0.5957
Cowardinx Level 3 ecoregion	0.6293	0.22	12, 13.52	0.9942
Riparian Depression Veg-IBI (n=27)				
Cowardinclass	0.8512	0.48	6, 34	0.8220
Level 3 ecoregion	0.567	1.86	6, 34	0.1168
Cowardinx Level 3 ecoregion	0.4483	1.80	9, 41.52	0.0969
Floodplain Veg-IBI (n=19)				
Cowardinclass	0.167	1.74	10, 12	0.1811
Level 3 ecoregion	0.4791	0.53	10, 12	0.8360
Cowardinx Level 3 ecoregion	0.3275	0.42	20, 20.85	0.9722
Depression Veg-IBI (n=37)				
Cowardinclass	0.8702	0.65	6, 54	0.6919
Level 3 ecoregion	0.7951	1.64	4, 54	0.1777
Cowardinx Level 3 ecoregion	0.7466	1.42	6, 54	0.2255
Impoundment Veg-IBI (n=13)				
Cowardinclass	0.7179	0.54	4, 12	0.7089
Level 3 ecoregion	0.7601	0.44	4, 12	0.7769
Cowardinx Level 3 ecoregion	0.9974	0.01	2, 6	0.9921
Scrub-Shrub Veg-IBI (n=23)				
Designated HGM[a] management class	0.6394	0.81	8, 26	0.5967
Level 3 ecoregion	0.6925	1.31	4, 26	0.2920
Designated HGM[a] management class x Level 3 ecoregion	0.9636	0.12	4, 26	0.9735
Forested Veg-IBI (n=19)				
Designated HGM[a] management class	0.0559	0.76	20, 10.9	0.7183
Level 3 ecoregion	0.1641	0.88	10, 6	0.5911
Designated HGM[a] management class x Level 3 ecoregion	0.341	0.43	10, 6	0.8874

[a] Hydrogreomorphic (Brinson 1993).

Table 10.Relations between the resulting class-specific vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA and the disturbance gradient from 2005-2006.

Vegetation IBI	Metrics in Veg-IBI	N	D.E.[a]	df	F-value	p-value	R^2	Equation
Riparian Depression	3	59	100%	1,57	19.87	<0.0001	0.26	y = 4.16 + 0.50 (Disturbance score)
Headwater Floodplain	4	29	100%	1, 27	50.00	<0.0001	0.65	y = -7.21 + 0.76 (Disturbance score)
Depression	2	72	78%	1, 70	31.79	<0.0001	0.31	y = 0.32 + 0.34 (Disturbance score)
Floodplain	5	35	100%	1, 33	42.16	<0.0001	0.56	y = -0.78 + 0.81 (Disturbance score)
Impoundment	2	23	71%	1, 21	0.65	0.4308	0.03	y = 3.48 + 0.10 (Disturbance score)
Emergent	1	75	74%	1, 73	11.91	0.0009	0.14	y = 3.47 + 0.12 (Disturbance score)
Scrub-shrub	2	44	92%	1, 42	10.33	0.0025	0.20	y = 3.13 + 0.66 (Disturbance score)
Forested	5	31	100%	1, 29	16.62	0.0005	0.35	y = 3.50 + 0.79 (Disturbance score)

[a] Effectiveness of Veg-IBI scores to discriminate between reference and stressed sites.

Table 11. Reference site scoring summary used to derive scoring thresholds, and discrimination efficiency (D.E.) in developing class specific vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Reference Site Scoring Summary							Means (SE)	
	N	Max possible Veg-IBI score	75th percentile	25th percentile	5th percentile	Median	D.E.[a]	Reference[b]	Stressed
Riparian Depression	16	30	21.88	17.40	14.40	19.78	100%	20.60 (1.09)	12.83 (1.31)
Headwater Floodplain	8	30	21.40	19.88	19.09	20.57	100%	20.72 (0.49)	5.39 (1.44)
Depression	19	20	12.41	7.52	5.73	10.17	78%	11.06 (1.04)	5.57 (0.68)
Floodplain	10	50	33.28	27.78	12.53	30.40	100%	27.70 (2.61)	11.60 (2.21)
Impoundment	6	20	6.09	4.05	2.99	5.36	71%	5.25 (1.24)	3.41 (1.15)
Emergent	19	10	8.44	6.13	3.66	7.00	74%	7.05 (0.48)	4.99 (0.51)
Scrub-shrub	11	20	16.00	10.75	10.06		92%	13.71 (0.89)	8.87 (0.85)
Forested	8	50	36.60	27.59	20.70	32.03	100%	31.39 (2.62)	17.34 (2.27)

[a]Effectiveness of Veg-IBI scores to effectively discriminate between reference and stressed sites.

[b] All means, except impoundment, statistically significantly different (Tukey $\alpha = 0.05$).

Table 12.Relations between the resulting hybrid-class vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA and the disturbance gradient from 2005-2006.

Vegetation IBI	Metrics in Veg-IBI	N	df	F-value	p-value	R^2	Equation
Emergent	1	75	1, 73	11.91	0.0009	0.14	y = 3.47 + 0.12 (Disturbance score)
Emergent/ Riparian depression	3	29	1, 27	0.09	0.7707	0.00	y = 12.67 + 0.05 (Disturbance score)
Emergent/ Headwater floodplain	4	15	1, 13	20.21	0.0003	0.61	y = -8.75 + 0.82 (Disturbance score)
Emergent/ Depression	2	38	1, 36	2.28	0.1396	0.06	y = 4.23 + 0.10 (Disturbance score)
Emergent/ Floodplain	6	16	1, 14	16.96	0.0010	0.55	y = 2.30 + 0.94 (Disturbance score)
Emergent/ Impoundment	3	14	1, 12	3.16	0.4828	0.04	y = 10.45 + 0.12 (Disturbance score)
Scrub-shrub	2	44	1, 42	10.33	0.0025	0.2	y = 3.13 + 0.66 (Disturbance score)
Scrub-shrub/ Riparian depression	3	18	1, 16	15.85	0.0011	0.50	y = 1.05 + 0.83 (Disturbance score)
Scrub-shrub/ Headwater floodplain	5	7	1, 5	9.77	0.0261	0.66	y = -1.70 + 0.89 (Disturbance score)
Scrub-shrub/ Depression	4	19	1, 17	14.64	0.0014	0.46	y = 2.70 + 0.78 (Disturbance score)
Scrub-shrub/ Floodplain	6	8	1, 6	8.52	0.0267	0.59	y = -3.53 + 1.36 (Disturbance score)
Scrub-shrub/ Impoundment	3	7	1, 5	0.29	0.6128	0.05	y = 11.41 + 0.18 (Disturbance score)
Forested	5	31	1, 29	16.62	0.0005	0.35	y = 3.50 + 0.79 (Disturbance score)
Forested/ Riparian depression	7	12	1,10	6.88	0.0255	0.41	y = 8.50 + 0.97 (Disturbance score)
Forested/ Headwater floodplain	7	7	1, 5	26.16	0.0037	0.84	y =0.30 + 1.23 (Disturbance score)
Forested/ Depression	6	14	1, 12	8.56	0.0127	0.42	y = 6.17 + 0.89 (Disturbance score)
Forested/ Floodplain	9	11	1, 9	18.74	0.0019	0.68	y = 1.35 + 1.59 (Disturbance score)
Forested/ Impoundment[a]		2					

[a] Insufficient sample size

Table 13. A comparison of the R^2 values of derived single and combined vegetation indices of biological integrity (Veg-IBI), avian wetland indices of biological integrity (AW-IBI), and anuran acoustically-based indices of biological integrity (AA-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Indices of Biological Integrity					
Classification	Veg-IBI	AW-IBI	AA-IBI[a]	Veg-IBI x AW-IBI	Veg-IBI x AA-IBI	Veg-IBI x AW-IBI x AA-IBI[a]
Riparian Depression	0.26	0.04*	0.08		0.28	
Headwater Floodplain	0.65	0.49	0.27	0.76	0.65	0.73
Depression	0.31	0.12		0.32		
Floodplain	0.56	0.46	0.18	0.72	0.50	0.63
Impoundment	0.03*	0.05*		0.09*		
Emergent	0.14	0.11		0.21		
Scrub-shrub	0.20	0.25		0.34		
Forested	0.35	0.24		0.48		

[a] Not able to discriminate between reference and stressed sites in all classes.
* Indicates a non-significant relation.

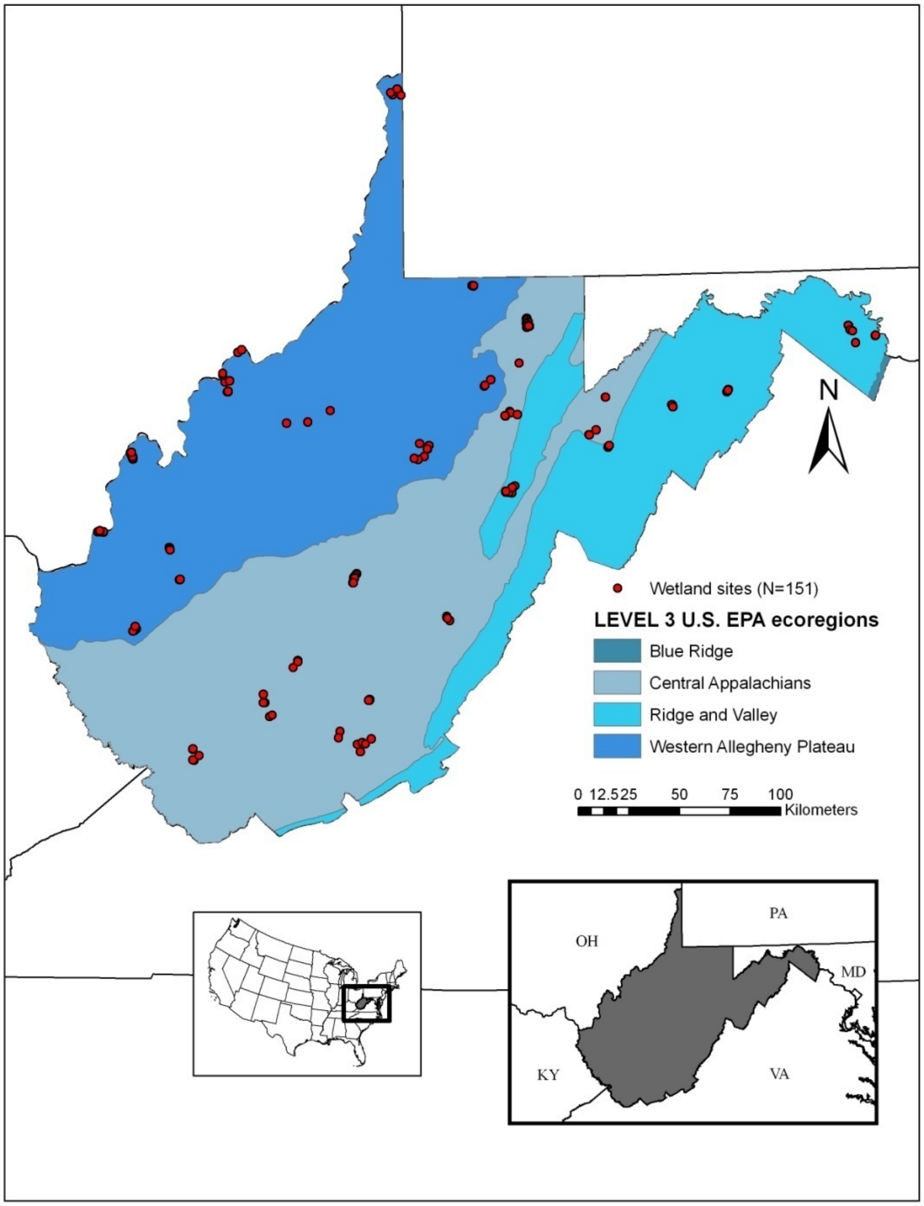

Figure 1. Site locations of wetlands and ecoregions (Omernik 1987, Woods et al. 1999) used in developing class-specific vegetation indices of biological integrity (Veg-IBI) in West Virginia, USA from 2005-2006. Wetland sites were clustered; scale of map prevents all sites from being marked individually. Legend may indicate 1-4 wetlands per mark.

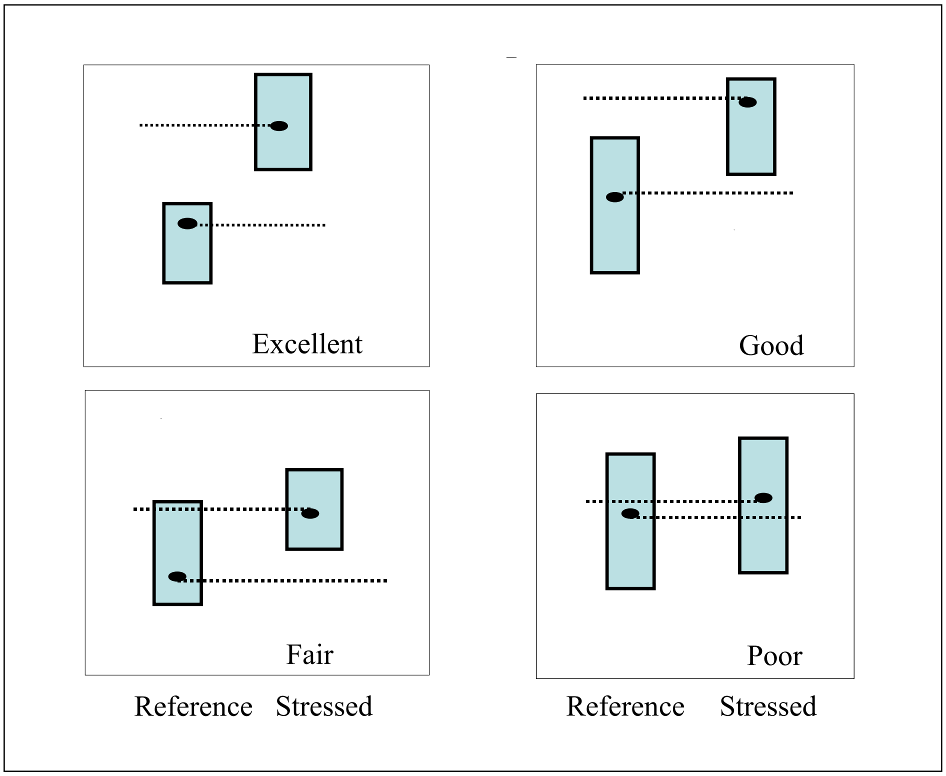

Figure 2. Box-and-whisker plot characteristics and resulting narrative description of reference and stressed sites' distribution of a biological metric value considered for inclusion into class-specific vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006Solid ovals represent the median of metric value (courtesy of Greg Pond, US EPA).

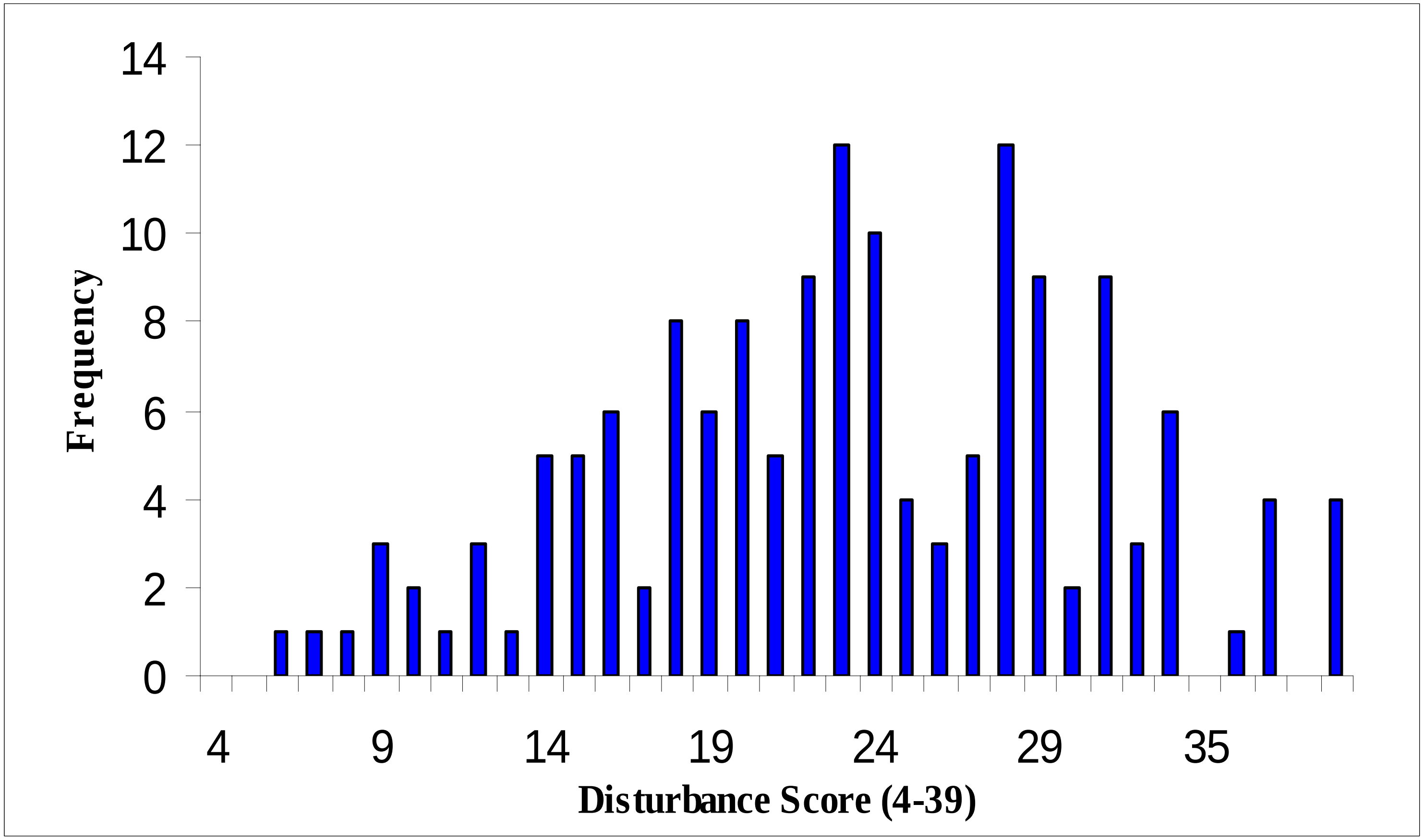

Figure 3. Frequency distribution of disturbance scores for sites used to develop class-specific vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006.

Chapter 5

Macroinvertebrate Indices of Biological Integrity (Mac-IBI)

Dual Classifications Used in Developing Macroinvertebrate Indices of Biological Integrity for Wetlands in West Virginia, USA

Walter Veselka IV[1]
James T. Anderson[1, 3]
Walter S. Kordek[2]

[1] Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

[2] West Virginia Division of Natural Resources, Wildlife Resources Section, PO Box 67, Ward Road, Elkins, WV 26241

[3] address correspondence to James T. Anderson, Ph.D., Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506. *email:* wetland@wvu.edu*phone:* (304) 293-2941 ext. 2445, *fax:* (304) 293-2441

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Abstract

Bioassessments of wetland habitats are based, in part, on consistent comparisons between wetland types. Typically, these wetland classifications are based on either the Cowardin et al. (1979) or hydrogeomorphic (HGM) wetland classification systems. By using both classification systems, we were able to derive a series of macroinvertebrate indices of biological integrity (Mac-IBI) that were compared to determine their sensitivity in detecting anthropogenic disturbance and to further determine their utility in augmenting other wetland indices of biological integrity. The resulting class-specific Mac-IBIs utilized 1-2 metrics that varied in their sensitivity to the disturbance gradient (R^2 = 0.11-0.47). However, unlike previous West Virginia derived taxa-specific IBIs, the sensitivity to the disturbance gradient did not increase as metrics from each of the 2 classification schemes were combined (added). Yet, sensitivity to the disturbance gradient increased when the metrics of other class-specific taxa group IBIs were added to those from the Mac-IBI. For example, the disturbance score explained more variation in floodplain wetlands (R^2 = 0.66) using a cumulative multi-metric, multi-taxa wetland IBI, than any of the individual taxa IBIs alone. The ramifications for policy makers in charge of designating wetland monitoring strategies include choosing which species taxa to monitor to yield the most information while maximizing efficiency and the number of wetlands monitored.

Keywords: *macroinvertebrate communities, disturbance, index of biological integrity, metrics, West Virginia, wetlands*

1.0 Introduction

The use of aquatic invertebrates to measure the integrity, or condition of water resources in relation to pollutants, has been used extensively in lotic environments (Gerritsen et al. 2000; Hill et al. 2003; McCormick et al. 2001; Miltner et al. 2004). These actions were prompted by the U.S. Environmental Protection Agency, which has charged states with developing criteria intended to ensure and maintain "the physical, chemical, and biological integrity" of the Nation's waters under the Clean Water Act (33 U.S.C. §1251). The development and subsequent validation of indices of biological integrity (IBIs) for running waters (Karr 1999; 1991; Karr et al. 1986) is now a well accepted part of water resource monitoring. These indices have more recently been developed to measure natural wetland health and to evaluate mitigation success (Miller et al. 2006; Teels et al. 2004).

The development of wetland IBIs will allow resource managers to monitor trends in wetland conditions and provide a quantifiable basis for comparison that can be used to prioritize wetlands for conservation, management, or restoration activities. Previous work in West Virginia focused on developing wetland IBIs using anuran, avian, or vegetation assemblages (Veselka 2008: Chapter 2, 3, 4) consistent with research underway in other states (Mack 2004; Micacchion 2002; Miller et al. 2006, O'Connell et al. 2000; Stapanian et al. 2004). Macroinvertebrate assemblages also have been used to ascertain wetland condition. This approach has been tested previously, primarily in ponded freshwater wetlands (Gernes and Helgen 2002; Hicks and Nedeau 2000; Knapp 2004); however, we evaluated multiple expressions of wetland classifications, using a consistent series of steps (U.S. EPA 2002).

Aquatic invertebrates are common and widely distributed in many types of wetlands (Batzer et al. 1999), and are good candidates for use in wetland bioassessments due to a number of inherent characteristics that lend themselves to the assessment procedure. The importance of invertebrates as both a food resource and agents in the transfer of nutrients in detritus within wetland food webs (Batzer and Wissinger 1996) suggests that macroinvertebrates can play a major role in comparing wetlands (Streever et al. 1996). The human disturbance gradient, a critical component used in developing an IBI, must be able to quantify impairments that may manifest in the biological assemblages used to drive the IBI. It should be based on local factors, such as changes in habitat, hydrology, and substrate alteration (Anderson and Smith 2000; Mack 2001); as research has indicated that landscape level Geographic Information System (GIS) tools used to quantify disturbances are not well suited for invertebrate metrics (Johnson and Goedkoop 2002; Tangen et al. 2003). Aquatic macroinvertebrates are sensitive to many stressors and pollutants, including sedimentation, changes in hydrology, and certain toxins (Barbour et al. 1999; Bendell-Young et al. 2000; Brooks 2000; Euliss and Mushnet 1999; King and Richardson 2007; Spieles and Mitsch 2000). Additionally, macroinvertebrate communities can often vary with differences in the vegetation community due to the use of macrophytes as a food source, attachment sites, refugia, or plant species-specific sites for egg-laying (Burton et al. 1999;Corbet 1999;Wissinger 1999).

However, in comparison to riverine bioassessments, wetland aquatic invertebrate bioassessments can be problematic due to a lack of habitat-specific information pertaining to each species or family, especially in regards to changes in hydrology and hydroperiod length (Batzer et al. 2001). Aquatic macroinvertebrate communities often are linked to hydroperiod length (Brooks 2000; Schneider and Frost 1996; Zimmer et al. 2000). This can confound baseline bioassessment data as colonization by terrestrial macroinvertebrates in wetlands occurs shortly after surface water has dried up (Batzer 2004). Moreover, there are also many different methods for sampling aquatic macroinvertebrates, some quantitative and others qualitative that, on a cost-per-unit effort basis, have relative advantages and disadvantages (Anderson and Smith 1996; Batzer et al. 1999; Brinkman and Duffy 1996; Cheal et al. 1993; Fairchild et al. 1987).

The objective of this research was to use both nektonic and benthic macroinvertebrate sampling to derive a series of macroinvertebrate indices of biological integrity (Mac-IBI) specific to Cowardin et al. (1979) wetland classes (hereafter known as “Cowardin”) and hydrogeomorphic (HGM) wetland classes (Brinson 1993). These indices will have the capacity to detect and quantify changes in macroinvertebrate communities reflective of the changing levels of human impairment affecting a wetland. The metrics that compose each of the series of derived indices were drawn from previous research (Balcombe et al. 2005a; Bennet 1999; Conklin 2003; Gernes and Helgen 1999; Knapp 2004; U.S. EPA 2002). Using the Mac-IBI, developed specifically for West Virginia wetlands, we were able to contrast and compare their sensitivity to a human disturbance in commonly used wetland classification systems. Additionally, we evaluated the ability to combine scores from other taxa-specific IBIs to form a multi-taxa, multi-metric composite IBI examining any changes in sensitivity to the human disturbance gradient.

2.0 Methods

2.1 Study Area

Study sites were stratified across West Virginia according to ecoregion (Omernik 1987; Woods et al. 1999) and Cowardin classifications (Table 1) (Veselka 2008: Chapter 2). Geographical and logistical constraints limited sampling to a total of 151 sites in this study, (68 in 2005 and 83 in 2006) (Figure 1). Each site was analyzed independently because all sites were located ≥ 300 m from one another, and no 2 adjacent sites had the same Cowardin classification. Our sampling regime included single wetlands (48 of 151) and 20 wetland complexes in which we sampled from 2-5 sites per complex. Nektonic organisms were not sampled if standing water was not present, and benthic organisms were not sampled if the surface of the ground was not saturated. As a result, 111 sites were used to evaluate nektonic invertebrate metrics (40 in 2005 and 71 in 2006) and 140 sites were used to consider benthic invertebrate metrics (59 in 2005, 81 in 2006). Site location was recorded with a Geographic Positioning System (GPS) to establish a permanent survey station.

Each wetland was categorized by both the Cowardin and HGM classification systems(Cole et al. 1997), although some HGM subclass class designations were consolidated to boost sample size and applicability of the resulting Mac-IBIs (Table 2) (Brooks et al. 1998; Veselka 2008: Chapter 2). However, the efficacy of HGM subclasses derived Mac-IBIs versus designated HGM management classes was evaluated given adequate sample size (Chipps et al. 2006; Veselka 2008: Chapter 2).

2.2 Macroinvertebrate Surveys

We sampled macroinvertebrates between June 1 and 15 July of 2005 or 2006 (Anderson and Smith 2004; 2000; 1996). Data were collected at 10 randomly placed 5 cm diameter benthic core samples (15 cm deep) and by use of a 7.5 cm diameter water-column sampler (Swanson 1983). The 2 sampling methods allowed us to examine the organisms from each sampled stratum separately and together (Balcombe et al. 2005a; Euliss et al. 1992). Nektonic samples were sieved in the field using a 500 micron screen (Huener and Kadlec 1992) and preserved for identification in 70% ethanol. Core samples were kept on ice until transported back to a laboratory and refrigerated (Balcombe et al. 2005a). Organic matter was separated from soil particles within 10 days of collection (Anderson and Smith 2000) using an elutriator (Magdych 1981). The remaining particulate was stored in 70% ethanol solution and dyed with rose bengal to help sort individual macroinvertebrates from the organic matter (Balcombe et al. 2005a; Mason and Yevich 1967). The number of individuals for each family was tallied, and biomass was obtained by oven-drying samples between 50-60 °C for at least 48 hours to a constant mass (0.0001 g) determined by using an analytical scale (Balcombe et al. 2005a). The macroinvertebrates were sorted and identified to family-level (McCafferty 1981; Merrit and Cummins 1984; Pennak 1989); or in some cases taxonomic Order if familial identification proved problematic. Functional feeding groups were assigned to families (Cummins and Merritt 2001). Using the relative abundance and percent biomass of each family by site, metrics were derived from the literature (Balcombe et al. 2005a; Bennet 1999; Conklin 2003; U.S. EPA 2002; Gernes and Helgen 2002; Knapp 2004), and each metric value was determined with and without the Order Oligochaeta and the Dipteran family Chironomidae to examine the effect of using different levels of resolution (Conklin 2003).

2.3 Disturbance Gradient

Our disturbance gradient was based on local factors directly attributable to anthropogenic sources, derived from portions of the Ohio Rapid Assessment Method version 5.0 (ORAM) (Table 3) (Mack 2001). These factors included surrounding land-use activity, width and condition of the natural wetland buffer zone, and alteration to the hydrology, habitat, or substrate. These metrics and submetrics formed a disturbance score that ranged from 4 to 39, the numbers representing less human impairment as they increase. The metrics selected for inclusion into the Mac-IBI were based on their responses to the disturbance score.

2.4 Reference and Stressed Sites Designations

Designated reference and stressed sites were used to evaluate a metrics' response to disturbance and are critical to the formation of an IBI. However, locating reference sites that are free from any signs of human impact is not feasible (Omernik 1995). Our reference conditions were based on realistic expectations of conditions indicating minimal or least disturbed conditions, of wetlands in West Virginia (Omernik 1995). Disturbance gradient scores above and below the 75^{th} and 25^{th} percentile were used to categorize reference and stressed conditions, respectively (Barbour et al. 1995). Reference and stressed designations were developed independently for Cowardin classes, HGM subclasses (Cole et al. 1997), and designated HGM management classes across Level 3 aquatic ecoregions (Omernik 1987;Woods et al. 1999) because these designations were based on human impairment characteristics throughout West Virginia rather than the ecological basis of the ecoregions.

2.5 Data Analysis

Nektonic and benthic macroinvertebrate data were used to derive candidate metric values that were evaluated for their capacity to discriminate between reference and stressed sites. We analyzed the benthic and nektonic community metrics data in 2 ways; by calculating the metric values separately according to sampling strategy, as well as cumulatively to contrast the results. Analyzing the benthic and nektonic metrics separately (Balcombe et al. 2005a; Euliss et al. 1992) allowed for the measurement and comparison of wetlands based on benthic community metrics even in the absence of standing water. Alternatively, when the data were combined, only sites for which both benthic and nektonic samples were collected were used to develop metrics; resulting in a decreased sample size. To develop an applicable, statewide, IBI using macroinvertebrate communities we analyzed the data in a series of elimination steps for each candidate metric. This process enabled us to build indices of biotic integrity, specific to individual HGM or Cowardin classes, which then allowed us to contrast and use the 2 classification systems to augment each other to increase sensitivity to disturbance scores (Veselka 2008: Chapter 2).

Class-specific Mac-IBIs were not developed for wetland classes with fewer than 5 reference and 5 stressed sites (Chipps et al. 2006). Metrics were initially tested for responsiveness to the human disturbance index using box-and-whisker plots (Barbour et al. 1996; Veselka 2008: Chapter 2). Metrics were classified as excellent, good, fair, or poor (Figure 2). Excellent and good metrics were retained, after further screening determined the discrimination efficiency of each metric (Veselka 2008: Chapter 2). Fair and poor metrics, as well as those not capable of discriminating between reference and stressed conditions ≥ 60%, were removed from further analysis. The remaining metrics were tested for redundancy using Spearman's R correlation statistic (Hughes et al. 1998); of the correlated pairs of metrics, the one with the greatest discrimination efficiency between reference and stressed sites was retained for inclusion in the Mac-IBI (Veselka 2008: Chapter 2).

The remaining sets of metrics for each of the resulting class-specific Mac-IBI were tested for an ecoregion effect or alternative classification effect using a series of 2-way analyses of variance (ANOVA) (Veselka 2008: Chapter 2). The metrics that were significantly influenced by the ecoregion or alternative wetland classification effect were omitted as metrics capable of discriminating between reference and stressed conditions throughout West Virginia (Veselka 2008: Chapter 2). However, in a case in which 2 redundant metrics remained with equal discrimination efficiencies and neither exhibited a significant ecoregion or classification scheme effect, the metric that utilized relative abundance was selected because the time to process and derive relative abundance was significantly less than the time needed to derive biomass. If more than 1 metric was used to derive the class-specific Mac-IBI, the metrics were evaluated a final time with a multivariate analysis of variance (MANOVA), testing for a cumulative effect of the metric values of reference and stressed site to ecoregion or classification scheme influences. This *posthoc* analysis was meant to ensure the derived Mac-IBI resulted in applicable and robust indices of biological integrity not subject to ecoregion or classification scheme influences.

After metrics were selected for each class-specific Mac-IBI, the metrics were scored on a continuous 0-10 scale (Blocksom 2003; Bryce et al. 2002; Gerritsen et al. 2000; Hill et al. 2003); and Mac-IBIs formed by summing all metrics selected for inclusion (Veselka 2008: Chapter 2).

The disturbance gradient and the distribution of the Mac-IBI scores for the reference sites were used to set numeric thresholds describing wetland condition (Gerritsen et al. 2000; Hill et al. 2003; McCormick et al. 2001; Veselka 2008: Chapter 2).The relation between Mac-IBI scores and the disturbance scores were examined and plotted using simple linear regression specific to each Mac-IBI classification (Veselka 2008: Chapter 2). This enabled us to interpret and compare the results of our derived Mac-IBI accordingly.

In addition to scoring each wetland with an individual designated HGM management and Cowardinclass Mac-IBI score, we used the additive properties of metrics to form a specific hybrid Mac-IBI that combined the classification schemes (Veselka 2008: Chapter 2).Moreover, we compared the derived class-specific Mac-IBI with wetland indices of biological integrity in West Virginia developed for other species assemblages. Using the same sample of wetland sites, a series of avian wetland indices of biological integrity (AW-IBI), anuran acoustically-based indices of biological integrity (AA-IBI), and vegetation-based indices of biological integrity (Veg-IBI) have characterized the species assemblages' responses to disturbance (Veselka 2008: Chapters 2, 3, 4). The metrics in these indices are based on the same disturbance scale, as well as the same metric scoring system in which values range from 0 to 10. This allowed the indices to be not only compared, but also integrated by adding metric scores. This determined if the sensitivity to the disturbance gradient increased as metrics from other biological assemblages increased.

Additionally, we evaluated adding the metrics from each taxa group to form the multi-taxa hybrid Cowardin- HGM wetland IBIs to ascertain if sensitivity to the disturbance score increased by attempting to classify wetlands using multiple classification schemes (Veselka 2008: Chapter 2). Because each of these IBIs were subjected to the same screening techniques (Veselka 2008: Chapter 2), the resulting multi-taxa, hybrid wetland IBI could be compared to the multi-taxa, class-specific approach.

3.0 Results

3.1 Ecoregion and site classifications

Due to the number of reference and stressed sites, we evaluated 97 metrics for inclusion into class-specific Mac-IBIs for riparian depression, headwater floodplain, depression, floodplain, emergent, scrub-shrub, and forested wetlands (Table 4). A complete list of all sites and corresponding attribute data (e.g., ecoregion, location, class, etc.) can be found in Appendix B. A frequency distribution indicated normal distribution of disturbance scores (Figure 3) (*Skewness = -0.04, Kurtosis = -0.39*).

Analyzing the benthic and nektonic samples separately resulted in 16 of 97 metrics being initially selected based on the ability to discriminate between reference and stressed sites across all ecoregions among 1 or more classifications of wetlands (Table 5). Four of these metrics were redundant and eliminated by selecting the metric with the greater discrimination efficiency of the 2 that were highly correlated (Table 6).Six of the remaining metrics were eliminated because of significant ecoregion or alternate classification scheme interactions after screening by a series of analysis of variance (ANOVA) tests (Table 7). This resulted in 4 of the 5 metrics making up the impoundment Mac-IBI, as well as 2 of the 3 metrics of the scrub-shrub Mac-IBI being eliminated. Only the forested and floodplain Mac-IBI were comprised of more than 1 metric. Using only reference and stressed conditions, the 2metrics of the forested and floodplain class-specific Mac-IBIs were evaluated for a cumulative ecoregion, alternative classification scheme, or interaction effect between the 2 with a MANOVA test. Both the floodplain and forested class-specific Mac-IBIs were not significantly affected (Table 8). This ensured that each class-specific Mac-IBI was robust and independent of ecoregion or classification scheme influences.

When the data were analyzed using the combined dataset from benthic and nektonic sampling, we were not able to develop a forested Mac-IBI because there was not consistent standing water from which to collect nektonic samples; resulting in only 2 reference sites and 4 stressed sites. Only 3 wetland classification schemes were found to consistently discriminate between reference and stressed sites; the headwater floodplain, floodplain, and emergent class-specific Mac-IBIs. All of these class-specific Mac-IBIs were composed of the metric, the percent of collector biomass (Table 5). The percent biomass of collectors, not including Oligochaete or Chironomid biomass was also capable of discriminating between reference and stressed sites in the floodplain Mac-IBI. Because these metrics were highly correlated (R = 0.98) and had the same discrimination efficiency, we conducted a complete analysis using both metrics (Table 6).

3.2 Metric Performance

There were 13,925 and 15,532 individual macroinvertebrates in the benthic and nektonic samples collected, respectively. The benthic individuals had a dry weight mass of 54.12 grams, whereas the nektonic individuals weighted 76.35 grams. These represented a total of 42 Orders and 75 Families. Only 6 of the 28 Orders, and 19 of 57 Families in benthic samples were found exclusively in benthic situations. In the nektonic samples, 9 of the 29 Orders and 39 of the 75 families were found only in the water column.

Ninety-seven candidate metrics were screened based on their ability to discriminate between reference and stressed sites independently for each classification (HGM subclass, designated HGM management class or Cowardinclass) within each ecoregion, based upon the disparity of the interquartile ranges of metric values for reference and stressed conditions (Appendix AL-BA). Macroinvertebrate abundance, biomass and richness for all sites can be found in Appendices BB-BC. Of these 97 metrics, only 19 remained after metrics were discarded due to an inability to discriminate between reference and stressed conditions (Table 5). These 19 metrics were then reduced to 9 class-specific Mac-IBI metrics because 10 were either redundant with other metrics, exhibited a significant interaction with ecoregion and classification scheme, or failed to have enough scoring variation to calculate metric values (Table 5).

Analyzing the benthic and nektonic communities independently, we were able to derive Mac-IBIs for all but the emergent Cowardin class. One or 2 metrics were included in each of the class-specific indices. Five of the 7 derived class-specific indices were significantly related to the disturbance score, although each of the indices discriminated between reference and stressed sites greater than 60% of the time (Table 9).

The riparian depression and depression Mac-IBIs were composed of the same metric derived from nektonic sampling: the percent biomass of the Coleopteran family Dytiscidae. Although the overall relation with the disturbance score was weak, the metric accounted for more variation in the riparian depressions HGM subclass (13%) than the depression designated HGM management class (11%).

The headwater floodplain Mac-IBI consisted of only 1 metric, the percent biomass of collectors, not including Oligochaete or Chironomid biomass in the calculation, drawn from benthic core samples. This metric accounted for 20% of the variation of disturbance scores in our headwater floodplain dataset. This metric was excluded from the larger classification of floodplain designated HGM management class due to redundancy with the benthic relative abundance of collectors, not including Oligochaete or Chironomid abundance. This metric, and the nektonic relative abundance of stressed taxa, accounted for 47% of the variation in disturbance scores of floodplain wetlands. The metric, percent biomass of stressed taxa had the same discrimination efficiency (71%) in discriminating between reference and stressed sites as relative abundance of stressed taxa, but was excluded in favor of relative abundance because of the additional time requirements and equipment needed to ascertain biomass.

The impoundment designated HGM management class Mac-IBI was formed using 1 metric, nektonic percent biomass of Odonata excluding Oligochaete and Chironomid biomass, and was not significantly related to the disturbance gradient despite being capable of discriminating between reference and stressed sites greater than 86% of the time. Five other metrics were initially included because of their capacity to discriminate between reference and stressed sites. These included the nektonic percent biomass of stressed taxa, the nektonic relative abundance of the Odonate family Libellulidae not counting the Oligochaete or Chironomid abundance, the nektonic percent biomass of Odonata not counting Oligochaete or Chironomid biomass, the benthic percent biomass of collectors, and benthic familial richness. These metrics were later excluded as they all exhibited a significant Cowardin class-ecoregion interaction (Table 7).

The Cowardin based Mac-IBI did not perform as well as those based on the HGM approach. With independent analysis of the benthic and nektonic macroinvertebrate communities, a palustrine emergent Mac-IBI was not developed because of a failure to identify a metric capable of discriminating between reference and stressed sites. Only 1 metric, the percent biomass of stressed taxa from nektonic sampling, was included in the scrub-shrub Mac-IBI, after the benthic relative abundance of collectors was determined to be significantly affected by the expression of the HGM class (Table 7). The resulting index failed to exhibit a significant relation with the disturbance gradient (Table 9).

Within the Cowardin classes, only the forested Mac-IBI scores were significantly related to disturbance. Two benthic metrics, the relative abundance of predators excluding Oligochaete and Chironomid abundance, and the relative abundance of collectors excluding Oligochaete and Chironomid abundance, made up the index, which was capable of discriminating between reference and stressed scores 71% of the time. However, despite the significant relation, only 14% of the variation in scores was attributed to disturbance scores.

Results did not improve upon analyzing benthic and nektonic communities together. Using the combined dataset, Mac-IBIs were derived for 3 wetland classes, emergent, headwater floodplain, and floodplain; and consisted of 1 metric, the percent biomass of collectors. An alternative to this metric in floodplain wetlands was the percent biomass of collectors, excluding Oligochaete or Chironomid biomass; however, discrimination efficiency (71%) remained the same and did not significantly improve the relation with the disturbance score (Table 10). In emergent and headwater floodplain wetlands, the disturbance scores accounted for 9% and 13% of the variation in Mac-IBI scores, respectively; and although statistically significant, are essentially biologically meaningless due to the minimal amount of variation accounted for by the disturbance scores. In the floodplain designated HGM management class wetland Mac-IBI, the sensitivity of the Mac-IBI scores ranged from 17-22% of variation attributed to the disturbance gradient. However, this is considerably less than the 47% of variation that can be attributed to disturbance scores in floodplain wetlands when nektonic and benthic metrics are derived separately. As a result, all future analyses used metrics from the stratified benthic and nektonic data because of the more consistent nature of the response to our disturbance gradient.

Scoring thresholds were derived for each of class-specific IBIs based on percentile scores of the reference sites (Table 11). The mean Mac-IBI scores of reference and stressed sites were significantly different, with the exception of the depression and impoundment designated HGM management class.

<u>3.3 Dual classification approaches for the Mac-IBI</u>

In an effort to increase sensitivity to the disturbance gradient, we combined the metrics from both the Cowardin and HGM classification schemes to form hybrid Mac-IBIs. In most instances, with the exception of the scrub-shrub-impoundment Mac-IBI, this increased the number of metrics, and therefore the IBI score, in relation to the disturbance score. Despite this, none of the integrated hybrid Mac-IBIs resulted in a significant relation with the disturbance scores (Table 12).

<u>3.4 Contrasting and augmenting with other West Virginia wetland IBIs</u>

The series of class-specific Mac-IBI were meant to be used as a standalone index for measuring biological integrity; yet we have developed alternative indices using avian, anuran, and vegetation assemblages in the same sample of wetlands. This allowed for comparisons between the sensitivities of each of the taxa-specific IBIs. The IBIs exhibiting a significant relation with the disturbance score were compared based on the amount of variation attributed to disturbance (Table 14). Using the Mac-IBIs derived from separate benthic and nektonic analysis, the relation between the Mac-IBI scores and the disturbance gradient were weaker than all of the corresponding Veg-IBI scores. In comparison to the suite of AW-IBIs, the Mac-IBIs were outperformed in every class with the exception of floodplain designated HGM management class, in which only slightly more variation (47% versus 46%) in floodplain IBI scores was a result of the disturbance scores. Additionally, there were more class-specific IBIs, 7 Veg-IBIs and 6 AW-IBIs, that exhibited a significant relation with the disturbance gradient in comparison to macroinvertebrate communities. Of the 3 AA-IBIs significantly related to disturbance scores, the Mac-IBI was more responsive in riparian depression and floodplain wetlands. However, within headwater floodplain wetlands, more variation in AA-IBI scores (27%) was a result of disturbance scores than in the Mac-IBI (20%).

Upon completion of the Mac-IBIs derived from separate benthic and nektonic samples, we combined all the metric scores from the resulting class-specific wetland IBIs to form a multi-taxa wetland IBI. The resulting class-specific multi-taxa IBI included between 5 and 12 metrics depending on classification scheme (Table 13). With the exception of impoundment wetlands, in which none of the derived IBIs exhibited a significant relation with disturbance, the variation in the multi-taxa IBI scores resulting from the disturbance scores was greater than each of the best individual taxa-specific wetland IBIs (Table 15).

The final analysis using the metrics from each taxa group and each classification scheme involved creating a series of hybrid IBIs. Because we had 3Cowardinclassifications, and a total of 5 HGM classifications (3 designated HGM management classes and 2 HGM subclasses), there could have been a total of 15 possible hybrid IBI categories. Of these 15, the forested-impoundment class was eliminated due to insufficient sample size. A total of 4 hybrid multi-taxa IBIs were significantly related to disturbance (Table 15). These included emergent-headwater floodplain, emergent-depression, emergent-floodplain, and forested-headwater floodplain. The amount of variation in scores attributed to the disturbance gradient ranged from 33-99%. However, we must caution that sample sizes were smaller as our dataset was partitioned.

4.0 Discussion

4.1 Study Design

Candidate metrics used to derive Mac-IBIs were extensively evaluated by analyzing benthic and nektonic community data separately (Balcombe et al. 2005a), as well as cumulatively (Anderson and Smith 1996). This approach allowed us to determine which of these 2 methods was most sensitive to disturbance. Additionally, by stratifying the analysis between benthic and nektonic communities, we were able to determine that macroinvertebrate communities could be sampled for bioassessments in the absence of standing water (i.e., forested and headwater floodplain wetlands); as well as conclude benthic samples were not necessary to differentiate between reference and stressed conditions in others (i.e., scrub-shrub and depression wetlands). The lack of sensitivity and applicable metrics responsive to the disturbance gradient in the combined benthic and nektonic community metrics' analysis was unexpected. However, the resulting conclusion suggests that when comparing macroinvertebrate communities to our current disturbance gradient in West Virginia wetlands, the analysis of macroinvertebrates should remain stratified to exhibit the greatest response to the disturbance scores.

Each candidate metric, either from the cumulative or stratified benthic and nektonic samples, was evaluated based on its discrimination efficiency. Redundant metrics with lower discrimination efficiencies were eliminated. The *posthoc* analysis of metric values included within the derived class-specific Mac-IBI was intended to validate our *apriori* wetland classifications. Inconsistent metrics were screened using ANOVA tests of the metric values of reference and stressed sites for all classes. This process identified specific metrics within each classification scheme that were then omitted because they did not respond consistently to ecoregion or the alternative classification scheme differences. After these metrics were removed, those remaining in each class were evaluated cumulatively by a MANOVA, confirming we had achieved our objective of building a series of statewide wetland class-specific macroinvertebrate-based indices of biological integrity. By taking steps intended to verify that the intended application of the resulting Mac-IBIs are not subject to ecoregion or classification influences; we believe our analysis resulted in a series of intuitive, but not necessarily strong, defensible Mac-IBIs that can be used to ascertain biological integrity. We suggest that our efficient methodology has scientific merit; however, with the exception of the floodplain Mac-IBI, the inconsistent response to the disturbance gradient suggests that a familial-level macroinvertebrate IBI does not respond to our current disturbance gradient.

4.2 Metric Performance

We tested 97 metrics in each classification scheme to identify metrics capable of consistently discriminating between reference and stressed sites. However, in relation to the total number of metrics evaluated, relatively few (8) proved to be suitable for inclusion into a macroinvertebrate-based IBI. We suspect a strong ecoregion effect demonstrated in macroinvertebrate communities, as 6 other metrics were eliminated because of differing ecoregion responses. This low number of suitable metrics responsive across the entire state of West Virginia demonstrates that macroinvertebrates do respond predictably to human impairment, as is evident by the prevalent literature from which our metrics were drawn (Balcombe et al. 2005a; Bennet 1999; Conklin 2003;

U.S. EPA 2003; Gernes and Helgen 1999; Knapp 2004). However, more research directed at the ecoregion level may strengthen these relations.

Understanding our results and why some metrics were effective and others were not will allow us to adapt and improve the efficacy of future wetland monitoring using macroinvertebrate communities. Previous research in West Virginia has indicated that wetlands having similar characteristics exhibit large variation in macroinvertebrate communities (Balcombe et al. 2005a). The variation in our metric scores is evident in the relatively large standard errors (Appendix BD). This may be suggestive that family-level identification may not be sufficient for use in bioassessments and that genus-level identification may result in improvement (Bailey et al. 2001; King and Richardson 2002). Literature from the Ohio EPA, from which our disturbance gradient was adopted, suggests that macroinvertebrates respond in a more predictable manner to water and soil characteristics, rather than the local disturbance scale we used in our evaluation of metrics (Knapp 2006). Literature supports the viewpoint that macroinvertebrate community structure is heavily dependent on both hydroperiod and vegetation community (Brooks 2000; Burton et al. 1999; Corbet 1999;Wissinger 1999; Zimmer et al. 2000). The omission of water chemistry data and hydroperiod characteristics from consideration in our disturbance gradients and classifications may have contributed to weaker correlations than the previously derived wetland IBIs for West Virginia (Veselka 2008: Chapters 2,4), suggesting macroinvertebrate communities may be more responsive to these variables than avian or vegetation communities. As a result, we were unable to derive any significant hybrid macroinvertebrate IBIs despite previous successes at integrating metrics from each of the class-specific Cowardin and the HGM based IBIs to form hybrid IBIs that were more sensitive to disturbances than individual classes

(Veselka 2008: Chapters 2-4). A disturbance gradient, more sensitive to the types of impairment affecting macroinvertebrate groups, derived from water and soil characteristics such as pollutant concentrations, levels of sedimentation and turbidity (Knapp 2006) may have allowed identification of a larger suite of discriminatory metrics.

Our macroinvertebrate community data were gathered using water column and core samplers (Balcombe et al. 2005a). Within the context of this study, a crucial element for using this method of sampling was time constraints. Due to the number of wetlands sampled, as well as the sampling regime in which multiple taxa were sampled throughout the field season (Veselka 2008: Chapter 2-4), it was necessary to select a macroinvertebrate sampling strategy in which collection could be completed in 1 day and samples preserved for later identification. Based on the diversity of families and orders in our samples, we believe the sampling methods were adequate.

We cannot conclusively say if our disturbance gradient was inappropriate, or if the differences in macroinvertebrate communities between ecoregions, or the taxonomic level of identification resulted in the weak relations between IBIs and the disturbance scores. We expect that all factors affected our results to some degree. Ecoregions in West Virginia follow an altitudinal gradient, suggesting that, although we sampled macroinvertebrates during the same time period, the wetlands may not have been at the same stage of phenological development due to the differences in the seasonal weather between ecoregions. Anuran sampling is conducted during different seasonal "windows" depending on physiographic region in West Virginia (Balcombe et al. 2005b); hence the development of macroinvertebrate sampling dates may provide us with more consistent data reflective of macroinvertebrate communities.

4.3Comparisons with Other Macroinvertebrate Indices of Biological Integrity

Our objective was to derive baseline data that could be used to develop a series of class-specific Mac-IBIs that could be used in a statewide monitoring program. Our metrics, and the resulting class-specific Mac-IBIs could then be compared to other macroinvertebrate indices of biological integrity. It should be noted that we are comparing sensitivity and responsiveness of our derived Mac-IBI to our disturbance gradient to other states' IBIs and disturbance gradients. These studies did not use the same disturbance gradient, or the same methods, making the comparisons less meaningful and useful in confirming that our results are similar to those of other programs.

The invertebrate IBI for Minnesota large depressional wetlands was composed of 8 metrics, encompassed multiple ecoregions, and was derived from both dip-netting and activity traps (Gernes and Helgen 2002). The Minnesota invertebrate IBI was correlated to their human disturbance score (R = 0.715). This variation is considerably more than is accounted for in the West Virginia 1 metric depression class Mac-IBI ($R^2 = 0.11$), despite a significant relation with the disturbance gradient and ability to discriminate between reference and stressed sites 60% of the time. Using all 5 of the multi-taxa metrics suitable for depression wetlands in West Virginia (Veselka 2008: Chapters 2-4), the amount of variation attributed to the disturbance score is only 35%. The Minnesota study's disturbance gradient included a factor for water chemistry and sediment concentrations, which may have resulted in a greater sensitivity to disturbance scores. Additionally, metrics were scored in Minnesota using a discrete scoring system (Karr et al. 1986), rather than the continuous method we employed (Blocksom 2003, Hill et al.

2003, Gerritsen et al. 2000). These factors and West Virginia's lack of equivalent large depressional wetlands may have contributed to the disparity in results.

The initial invertebrate IBI for Ohio wetlands did not separate IBIs for each Cowardin or HGM (Brinson 1993) classification (Knapp 2004). Despite this intended omission, a set of preliminary 6 and 8 metric invertebrate IBIs, using the same metrics from the ORAM v. 5.0 (Mack 2001) to represent human disturbance, was significantly related to disturbance. In this initial report researchers evaluated different discrete scoring strategies to assign metric values. Without removing outliers, the results ranged from 18 to 37% of the amount of variation in IBI scores being attributed to the disturbance gradient; with outliers removed, the results improved to 33% to 42%. These results seem to be comparable with those of our derived class-specific Mac-IBIs, despite only the West Virginia wetland derived 2 metric floodplain designated HGM management class having more variation explained by our disturbance scores. In addition to differences in scoring techniques, the Ohio research used 24 hour activity traps to sample macroinvertebrate communities (Knapp 2004). Although Ohio's results were preliminary, they were not consistent with other wetland IBIs developed in the state because they included all classes of wetlands rather than formulating an IBI according to the wetland Cowardin class (Mack 2004, Micacchion 2002). This approach differed from what we accomplished in West Virginia, which was a series of class-specific wetland IBIs, designed for individual taxa groups that were intended to be used as standalone indices, capable of integration with and augmenting of others according to the state's need.

4.4 Integration with other West Virginia wetland indices of biological integrity

Our study developed different taxa-specific IBIs in the same manner (Veselka 2008: Chapters 2-4). These studies included utilizing anuran, avian, and vegetation assemblage characteristics to form avian wetland indices of biological integrity (AW-IBI), acoustically-based anuran indices of biological integrity (AA-IBI), and vegetation indices of biological integrity (Veg-IBI). Although the Mac-IBI is intended to be a stand-alone index that is capable of evaluating wetland biological condition with a single site visit, adding the metric scores from each of the class-specific taxa produces better results than any 1 taxa-group alone. This result should be noted by wetland resource managers, as decisions involving the allocation of resources will dictate the number of taxa groups that can be efficiently monitored while producing results that are biologically meaningful and related to the disturbance gradient.

When we compare all of the cumulative multi-taxa class-specific results to the cumulative multi-taxa hybrid wetland IBIs, we must caution that small sample size must be considered. Regardless, with the exception of forested-headwater floodplain wetlands (n=4), every instance of using a class-specific multi-taxa approach proved more responsive to the disturbance gradient than the hybrid classification multi-taxa approach. For example, although 70% of the variation in scores of the emergent-headwater floodplain hybrid IBI was attributed to the disturbance gradient, 81% of the multi-taxa metrics that compose the headwater-floodplain wetland IBI can be traced to disturbance scores. The integration of all 4 taxa groups leads to more consistent class-specific results; however, the logistical coordination and effort required to sample all taxa groups in any 1 wetland throughout a given year is considerable.

5.0 Implications for Future Monitoring Programs

Future work will examine all the possible combinations of taxa groups in all class-specific and hybrid IBI combinations. Results will allow resource managers to make informed choices regarding the allocation of resources. Depending on results, the use of hybridized IBIs may, in some circumstances, be better suited for actual field work when resources are limited. The dilemma for wetland resource managers will be how to choose the best monitoring approach. In a scenario with infinite resources, it would undoubtedly be better to monitor the avian, anuran, vegetation, and macroinvertebrate communities of every wetland. However, the chances of this occurring are highly unlikely. Of the series of IBIs developed for West Virginia, some data used to drive the indices can be collected by volunteers; for example, bird and anuran surveys. This can be done relatively inexpensively compared to professional surveys. Invertebrates can even be collected by volunteers, but then must be identified by individuals with taxonomic training to classify the specimens to family or genus. This will increase cost, but at least time is not charged for collecting the data. Finally, detailed vegetation surveys require professionals to be at each wetland site, incurring transportation and time associated with data collection costs. This will force wetland resource managers to decide which taxonomic groups should be used to cost-effectively monitor wetlands. Eventually, after evaluating the benefit derived from sampling each taxon, a tiered approach that uses volunteer-gathered data augmented by professionals in certain circumstances may be best to efficiently and definitively monitor the status and trends of the state's wetlands. In this approach, the use of hybrid IBIs, in instances where not all taxonomic groups are evaluated, may still be the more responsive to a disturbance gradient (Veselka 2008: Chapter 2-4). This strategy can be used to conserve resources expended to measure wetland health by measuring only the species characteristics of wetland health most responsive to disturbance rather than expend the resources to measure all taxonomic groups in a wetland.

Our research in developing a series of statewide wetland IBIs gives water resource policy makers more tools than ever before in West Virginia regarding the best way to implement and initiate a wetland IBI program. Using these tools, and augmenting IBIs with a spatial analysis component that can be used to prioritize sites slated for management action (Wardrop et al. 2007, Weller et al. 2007), West Virginia will be in a position to implement a proactive, scientifically-based program to conserve, restore, and enhance the biological integrity of our wetlands, under the Clean Water Act. However, the decision to use the baseline data to start wetland monitoring and the initiative to implement a program capable of ensuring wetland health over the long-term ultimately rests with the natural resource policy makers in the state government.

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Table 1. Number of sites by Cowardin and hydrogeomorphic (HGM) classification schemes and ecoregions for use in developing macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Level 3 U.S. Environmental Protection Agency aquatic ecoregion[a]			
Wetland type	Ridge and Valley	Central Appalachian	Western Alleghany Plateau	Total
Hydrogeomorphic subclass[b]				
Riparian Depression	10	24	25	59
Headwater Floodplain	10	15	4	29
Designated HGM Management Class				
Depression	10	28	34	72
Floodplain	12	17	6	35
Impoundment	1	14	8	23
Cowardin Class				
Emergent	15	34	26	75
Scrub-shrub	6	17	21	44
Forested	6	14	11	31

[a] Omernik (1987), modified by Woods et al. (1999).

[b] Cole et al. (1997).

Table 2. Designated hydrogeomorphic (HGM) management classes derived from regional hydrogeomorphic (HGM) subclasses for use in developing macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

Designated HGM Management class	Hydrogeomorphic subclass[a]
Depression	Surface water depression
	Riparian depression
	Isolated depression
Floodplain	Headwater floodplain
	Mainstem floodplain
Impoundment	Headwater impoundment
	Mainstem impoundment
Fringing	Fringing
Slope	Slope

[a] Cole et al. (1997).

Table 3. Metrics and sub-metrics selected from the Ohio Rapid Assessment Method (Mack 2001) used to define the disturbance gradient for use in developing macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

Scoring value		Disturbance component
		Upland buffers and surrounding land use
		Calculate the average buffer width. Select only one and assign score.
7	☐	WIDE. Buffers average 50m or more around wetland perimeter
4	☐	MEDIUM. Buffers average 25m to <50m around wetland perimeter
1	☐	NARROW. Buffers average 10m to <25m around wetland perimeter
0	☐	VERY NARROW. Buffers average <10m around wetland perimeter
		Intensity of surrounding land use. Select one or double check and average.
7	☐	VERY LOW. 2nd growth or older forest, prairie, savannah, wildlife area, etc.
5	☐	LOW. Old field (>10 years), shrubland, young second growth forest.
3	☐	MODERATELY HIGH. Residential, fenced pasture, park, conservation tillage, new fallow field.
1	☐	HIGH. Urban, industrial, open pasture, row cropping, mining, construction.
		Hydrology
		Modifications to natural, hydrologic regime. Score one or double check and average.
12	☐	None or none apparent. There are no modifications or no modifications that are apparent to the rater.
7	☐	Recovered. The wetland appears to have recovered from past modifications which altered the wetland's natural hydrologic regime.
3	☐	Recovering. The wetland appears to be in the process of recovering from past modifications which altered the wetland's natural hydrologic regime.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past modifications and / or the modifications are ongoing.
		Habitat alteration and development
		Substrate disturbance. Score one or double check and average.
4	☐	None or none apparent. There are no modifications or no modifications that are apparent to the rater.
3	☐	Recovered. The wetland appears to have recovered from past disturbances.
2	☐	Recovering. The wetland appears to be in the process of recovering from past disturbances.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past disturbances and/ or the disturbances are ongoing.
		Habitat alteration. Score one or double check and average.
9	☐	None or none apparent. There are no alterations or no alterations that are apparent to the rater.
6	☐	Recovered. The wetland appears to have recovered from past alterations.
3	☐	Recovering. The wetland appears to be in the process of recovering from past alterations.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past alterations and/ or the alterations are ongoing.

Table 4. Candidate macroinvertebrate community biological metrics evaluated for inclusion into macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

Sampling Unit Used to Calculate Metrics*		
Nektonic	**Benthic**	**Benthic and Nektonic Combined**
% Biomass EPA Stressed[a]	% Biomass EPA Stressed[a]	% Biomass EPA Stressed[a]
Relative Abundance EPA Stressed[a]	Relative Abundance EPA Stressed[a]	Relative Abundance EPA Stressed[a]
% Biomass Chironomidae[b]	% Biomass Chironomidae [b]	% Biomass Chironomidae[b]
Relative Abundance Chironomidae[b]	Relative Abundance Chironomidae [b]	Relative Abundance Chironomidae[b]
% Biomass Corixidae[c,d]	% Biomass Collector [e]	% Biomass Corixidae[c,d]
% Biomass Corixidae*[c,d,e]	% Biomass Collector* [e]	% Biomass Corixidae*[c,d,e]
Relative Abundance Corixidae[c,d]	% Biomass Predator [b]	Relative Abundance Corixidae[c,d]
Relative Abundance Corixidae*[c,d,e]	% Biomass Predator* [b,e]	Relative Abundance Corixidae*[c,d,e]
% Biomass Coleoptera[d,e]	% Biomass Shredder [e]	% Biomass Coleoptera[d,e]
% Biomass Coleoptera*[d,e]	% Biomass Shredder* [e]	% Biomass Coleoptera*[d,e]
Relative Abundance Coleoptera[d,e]	Relative Abundance Collector [e]	Relative Abundance Coleoptera[d,e]
Relative Abundance Coleoptera*[d,e]	Relative Abundance Collector* [e]	Relative Abundance Coleoptera*[d,e]
% Biomass Coleoptera + Corixidae*[c,e]	Relative Abundance Predator [b]	% Biomass Coleoptera + Corixidae*[c,e]
% Biomass Coleoptera + Corixidae*[c,e]	Relative Abundance Predator* [b,e]	% Biomass Coleoptera + Corixidae*[c,e]
Relative Abundance Coleoptera + Corixidae[c,e]	Relative Abundance Shredder [e]	Relative Abundance Coleoptera + Corixidae[c,e]
Relative Abundance Coleoptera + Corixidae*[c,e]	Relative Abundance Shredder* [e]	Relative Abundance Coleoptera + Corixidae*[c,e]
% Biomass Dytiscidae[d]	% Biomass Coleoptera [d]	% Biomass Dytiscidae[d]
% Biomass Dytiscidae*[d,e]	% Biomass Coleoptera* [d,e]	% Biomass Dytiscidae*[d,e]
Relative Abundance Dytiscidae[d]	Relative Abundance Coleoptera [d]	Relative Abundance Dytiscidae[d]
Relative Abundance Dytiscidae*[d,e]	Relative Abundance Coleoptera* [d,e]	Relative Abundance Dytiscidae*[d,e]
% Biomass Collector[e]	Familial Richness [f]	% Biomass Collector[e]
% Biomass Collector* [e]		% Biomass Collector* [e]
% Biomass Predator[b,e]		% Biomass Predator[b,e]
% Biomass Predator*[b,e]		% Biomass Predator*[b,e]
% Biomass Shredder[e]		% Biomass Shredder[e]
% Biomass Shredder* [e]		% Biomass Shredder* [e]
Relative Abundance Collector[e]		Relative Abundance Collector[e]
Relative Abundance Collector* [e]		Relative Abundance Collector* [e]
Relative AbundancePredator[b,e]		Relative AbundancePredator[b,e]
Relative Abundance Predator*[b,e]		Relative Abundance Predator*[b,e]
Relative Abundance Shredder[e]		Relative Abundance Shredder[e]
Relative Abundance Shredder* [e]		Relative Abundance Shredder* [e]
Familial richness[f,]		Familial richness[f]
% Biomass Libellulidae[a]		% Biomass Libellulidae[a]
% Biomass Libellulidae*[a,e]		% Biomass Libellulidae*[a,e]
Relative Abundance Libellulidae [a]		Relative Abundance Libellulidae [a]
Relative Abundance Libellulidae*[a,e]		Relative Abundance Libellulidae*[a,e]
% Biomass Odonata[d,]		% Biomass Odonata[d]
% Biomass Odonata*[d,e]		% Biomass Odonata*[d,e]
Relative Abundance Odonata [d]		Relative Abundance Odonata [d]
Relative Abundance Odonata*[d,e]		Relative Abundance Odonata*[d,e]
% Biomass Odonata - Libellulidae [a]		% Biomass Odonata - Libellulidae [a]
% Biomass Odonata - Libellulidae*[a,e]		% Biomass Odonata - Libellulidae*[a,e]
Relative Abundance Odonata - Libellulidae [a]		Relative Abundance Odonata - Libellulidae [a]
Relative Abundance Odonata - Libellulidae [a,e]		Relative Abundance Odonata - Libellulidae [a,e]

* Indicates chironomid and/or oligochaete abundance/ biomass not included in metric calculation.
[a] U.S. EPA (2002).
[b] Bennet (1999).
[c] Gernes and Helgen (1999).
[d] Knapp (2004).
[e] Conklin (2003).
[f] Balcombe et al. (2005a).

Table 5.Candidate macroinvertebrate community biological metrics that were able to discriminate between reference and stressed sites; evaluated by class according to regional Hydrogeomorphic (HGM) subclass, designated HGM management class, and the Cowardin classification schemes in building macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Wetland Classification[h]							
	HGM Subclass		Designated HGM Management Class			Cowardin Classification		
Candidate Macroinvertebrate Metrics*	**Riparian Depression**	**Headwater Floodplain**	**Depression**	**Floodplain**	**Impoundment**	**Emergent**	**Scrub-shrub**	**Forested**
Nektonic community								
% Biomass EPA Stressed[a]	-	-	-	N	E	-	I	-
Relative Abundance EPA Stressed[a]	-	-	-	I	-	-	-	-
Relative Abundance Coleoptera[d,e,g]	-	-	-	-	E	-	-	-
% Biomass Dytiscidae[d]	I	-	I	-	-	-	-	-
Relative Abundance Libellulidae*[a,e,g]	-	F	-	-	E	-	-	-
% Biomass Odonata* [d,e]	-	-	-	-	I	-	-	-
Relative Abundance Odonata [d,g]	-	F	-	-	-	-	-	-
Relative Abundance Odonata*[d,e,g]	-	F	-	-	R	-	-	-
Benthic community								
% Biomass Collector [e,g]	-	-	-	-	E	-	-	-
% Biomass Collector* [e]	-	I	-	R	-	-	-	-
% Biomass Predator [b,g]	-	-	-	-	-	-	-	R
% Biomass Predator* [b,e,g]	-	-	-	-	-	-	-	R
Relative Abundance Collector [e,g]	-	R	-	R	-	-	E	-
Relative Abundance Collector* [e]	-	-	-	I	-	-	E	I
Relative Abundance Predator [b,g]	-	-	-	-	-	-	-	R
Relative Abundance Predator* [b,e]	-	-	-	-	-	-	-	I
Familial Richness [f,g]	-	-	-	-	E	-	-	-
Combined nektonic and benthic communities								
% Biomass Collector[e,g]	-	I	-	I	-	I	-	-
% Biomass Collector*[e,g]	-		-	I	-	-	-	-

* Indicates chironomid and/or oligochaete abundance/ biomass not included in metric calculation.

[a] U.S. EPA (2002).

[b] Bennet (1999).

[c] Gernes and Helgen (1999).

[d] Knapp (2004).

[e] Conklin (2003).

[f] Balcombe et al. (2005a).

[g] Metrics excluded from all of the resulting class-specific Mac-IBI due to redundancy, failure in scoring range, significant ecoregion or classification scheme effect, inability to discriminate between reference and stressed sites.

[h] I = included in class-specific Mac-IBI; R = redundancy with other metrics; F = failure due to lack of scoring range; E = excluded due to significant ecoregion or classification effect; N = not selected due to logistical requirements; - = failure to discriminate between reference and stressed sites.

Table 6. Correlation matrix of benthic and nektonic macroinvertebrate metrics used in developing macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006. Metrics with R> 0.80 were considered correlated and selected for inclusion into the Mac-IBI based on discrimination efficiency (D.E.).

Classification/ Metrics*	D.E.	Metrics*		
Headwater Floodplain		Benthic % Biomass of Collectors*	Benthic Relative Abundance of Collectors	
Benthic % Biomass of Collectors* [a]	67	1		
Benthic Relative Abundance of Collectors	67	0.991	1	
Floodplain		Nektonic % Biomass EPA Stressed	Nektonic Relative Abundance EPA Stressed	
Nektonic % Biomass EPA Stressed	71	1		
Nektonic Relative Abundance EPA Stressed[a]	71	0.848	1	
		Benthic % Biomass of Collectors*	Benthic Relative Abundance of Collectors	Benthic Relative Abundance of Collectors*
Benthic % Biomass of Collectors* [b]	71	1		
Benthic Relative Abundance of Collectors [b]	71	0.984	1	
Benthic Relative Abundance of Collectors* [a]	86	0.988	0.986	1
Benthic and Nektonic combined dataset		% Biomass of Collectors	% Biomass of Collectors*	
% Biomass of Collectors	71	1		
% Biomass of Collectors*	71	0.98	1	

Table 6. Continued.

Classification/ metrics*	D.E.	Metrics*				
Impoundment		Nektonic % Biomass EPA Stressed	Nektonic Relative Abundance of Coleoptera	Nektonic Relative Abundance Libellulidae*	Nektonic % Biomass of Odonata*	Nektonic Relative Abundance of Odonata*
Nektonic % Biomass EPA Stressed[c]	86	1				
Nektonic Relative Abundance of Coleoptera[c]	86	-0.398	1			
Nektonic Relative Abundance Libellulidae* [b]	71	0.671	-0.176	1		
Nektonic % Biomass of Odonata* [c]	86	0.612	-0.273	0.743	1	
Nektonic Relative Abundance of Odonata* [a]	71	0.295	-0.174	0.645	0.827	1
		Benthic % Biomass of Collectors	Benthic family richness			
Benthic % Biomass of Collectors [c]	71	1				
Benthic Family Richness[c]	86	0.482	1			
Scrub-Shrub		Benthic Relative Abundance of Collectors	Benthic Relative Abundance of Collectors*			
Benthic Relative Abundance of Collectors [c]	63	1				
Benthic Relative Abundance of Collectors* [c]	63	0.885	1			
Forested		Benthic % Biomass of Predators	Benthic % Biomass of Predators*	Benthic Relative Abundance of Collectors*	Benthic Relative Abundance of Predators	Benthic Relative Abundance of Predators*
Benthic % Biomass of Predators [b]	72	1				
Benthic % Biomass of Predators* [b]	72	0.908	1			
Benthic Relative Abundance of Collectors* [a]	72	-0.119	-0.28	1		
Benthic Relative Abundance of Predators [b]	72	0.951	0.884	-0.129	1	
Benthic Relative Abundance of Predators* [a]	85	0.918	0.963	-0.251	0.952	1

* Indicates chironomid and/or oligochaete abundance/ biomass not included in metric calculation.

[a] Metric selected for inclusion into Mac-IBI.

[b] Metric excluded due to redundancy with other metric with greater discrimination efficiency.

[c] Metric initially selected for inclusion into Mac-IBI, but removed in later analysis due to significant ecoregion or alternative classification scheme effect.

Table 7. Analysis of variance (ANOVA) results of reference and stressed sites' metric values compared to Level 3 ecoregions (Omernik 1987; Woods et al. 1999) and the alternative classification scheme used in developing macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification (number of reference and stressed sites)	Validation tests	df	F-value	p-value
Riparian Depression Mac-IBI (n=16)				
Nektonic % Biomass of Dytiscidae	Cowardin class	2,15	2.58	0.1451
	Level 3 ecoregion	2,15	0.02	0.9818
	Cowardin class x Level 3 ecoregion	1,15	0.01	0.9210
Headwater Floodplain Mac-IBI (n=14)				
Benthic Collectors % Biomass*	Cowardin class	2,13	1.04	0.4020
	Level 3 ecoregion	2,13	0.02	0.9800
	Cowardin class x Level 3 ecoregion	2,13	0.17	0.8455
Benthic and Nektonic Collectors % Biomass[e]	Cowardin class	2,13	0.79	0.4955
	Level 3 ecoregion	2,13	1.10	0.3920
	Cowardin class x Level 3 ecoregion	1,13	0.54	0.4910
Depression Mac-IBI (n=22)				
Nektonic % Biomass of Dytiscidae	Cowardin class	3,21	0.36	0.7833
	Level 3 ecoregion	2,21	0.39	0.6855
	Cowardin class x Level 3 ecoregion	3,21	0.12	0.9485
Floodplain Mac-IBI (n=17)				
Nektonic Relative Abundance EPA Stressed	Cowardin class	2,16	2.02	0.2131
	Level 3 ecoregion	2,16	0.64	0.5601
	Cowardin class x Level 3 ecoregion	4,16	1.11	0.4308
Nektonic % Biomass EPA Stressed	Cowardin class	2,16	2.59	0.1549
	Level 3 ecoregion	2,16	0.35	0.7184
	Cowardin class x Level 3 ecoregion	4,16	0.36	0.8259
Benthic Relative Abundance of Collectors*	Cowardin class	2,16	4.09	0.0596
	Level 3 ecoregion	2,16	0.7	0.5261
	Cowardin class x Level 3 ecoregion	4,16	0.69	0.6188
Benthic and Nektonic Collectors % Biomass[c]	Cowardin class	2,16	1.38	0.3217
	Level 3 ecoregion	2,16	0.96	0.4349
	Cowardin class x Level 3 ecoregion	3,16	0.58	0.6481
Benthic and Nektomic Collectors % Biomass*[c]	Cowardin class	2,16	1.97	0.2200
	Level 3 ecoregion	2,16	1.14	0.3808
	Cowardin class x Level 3 ecoregion	3,16	0.52	0.6839

Table 7. Continued.

Classification (number of reference and stressed sites)	Validation tests	df	F-value	p-value
Impoundment Mac-IBI (n=13)				
Benthic Family Richness[b]	Cowardin class	2,12	2.49	0.1525
	Level 3 ecoregion	2,12	1.39	0.3105
	Cowardin class x Level 3 ecoregion	1,12	7.01	0.033
Nektonic % Biomass EPA Stressed[b]	Cowardin class	2,12	1.47	0.2926
	Level 3 ecoregion	2,12	2.28	0.1731
	Cowardin class x Level 3 ecoregion	1,12	12.37	0.0098
Nektonic Relative Abundance of Libellulidae*[b]	Cowardin class	2,12	0.67	0.5399
	Level 3 ecoregion	2,12	1.97	0.2098
	Cowardin class x Level 3 ecoregion	1,12	6.08	0.0431
Nektonic Relative Abundance of Coleopterans[b]	Cowardin class	2,12	5.21	0.0411
	Level 3 ecoregion	2,12	0.66	0.5481
	Cowardin class x Level 3 ecoregion	1,12	0.7	0.4302
Nektonic % Biomass of Odonata*	Cowardin class	2,12	0.24	0.7958
	Level 3 ecoregion	2,12	1.85	0.2266
	Cowardin class x Level 3 ecoregion	1,12	5.28	0.0551
Emergent Mac-IBI (n=28)				
Benthic and Nektonic Collectors % Biomass[c]	Designated HGM[a] management class	4,27	0.85	0.5158
	Level 3 ecoregion	2,27	0.7	0.5114
	Designated HGM[a] management class x Level 3 ecoregion	4,27	0.72	0.5925
Scrub-shrub Mac-IBI (n=22)				
Benthic Relative Abundance of Collectors[b]	Designated HGM[a] management class	4,21	9.17	0.001
	Level 3 ecoregion	2,21	0.96	0.4095
	Designated HGM[a] management class x Level 3 ecoregion	2,21	2.55	0.1161
Benthic Relative Abundance of Collectors*[b]	Designated HGM[a] management class	4,21	4.63	0.0152
	Level 3 ecoregion	2,21	0.04	0.9567
	Designated HGM[a] management class x Level 3 ecoregion	2,21	1.23	0.3249
Nektonic % Biomass EPA Stressed	Designated HGM[a] management class	4,21	1.5	0.2452
	Level 3 ecoregion	2,21	0.07	0.9359
	Designated HGM[a] management class x Level 3 ecoregion	2,21	0.31	0.7421
Forested Mac-IBI (n=14)				
Benthic Relative Abundance of Predators*	Designated HGM[a] management class	3,13	0.75	0.5618
	Level 3 ecoregion	2,13	0.59	0.5856
	Designated HGM[a] management class x Level 3 ecoregion	2,13	3.13	0.1171

Table 7. Continued.

Classification (number of reference and stressed sites)	Validation tests	df	F-value	p-value
Benthic Relative Abundance of Collectors*	Designated HGM[a] management class	3,13	1.62	0.2808
	Level 3 ecoregion	2,13	0.17	0.8497
	Designated HGM[a] management class x Level 3 ecoregion	2,13	0.64	0.5595

* Indicates chironomid and/or oligocheate abundance/ biomass not included in metric calculation.

[a] Hydrogeomorphic (Brinson 1993).

[b] Metric excluded from inclusion into class-specific Mac-IBI due to a significant ecoregion, alternative classification scheme, or cumulative 2-way interaction.

[c]Metric for the combined analysis of benthic and nektonic data.

Table 8. Wilks' Lambda statistic for *posthoc* validation of reference and stressed sites' metric values of class-specific macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

Classification scheme and interaction	Wilks' Lambda	F-value	df	p-value
Floodplain Mac-IBI (n=15)				
Cowardin class	0.4238	1.34	4, 10	0.3210
Level 3 ecoregion	0.6932	0.50	4, 10	0.7349
Cowardin class x Level 3 ecoregion	0.4509	0.61	8,10	0.7512
Forested Mac-IBI (n=14)				
Designated HGM[a] management class	0.3968	0.98	6, 10	0.4864
Level 3 ecoregion	0.7693	0.35	4, 10	0.8380
Designated HGM[a] management class x Level 3 ecoregion	0.3986	1.46	4, 10	0.2852

[a]Hydrogeomorphic (Brinson 1993).

Table 9. Relations between the resulting class-specific macroinvertebrate indices of biological integrity (Mac-IBI) derived from separate analysis of benthic and nektonic samples for wetlands in West Virginia, USA and the disturbance gradient from 2005-2006.

Macroinvertebrate IBI	Nektonic Metrics	Benthic Metrics	N	D.E[a]	df	F-value	p-value	R^2	Equation
Riparian Depression	1	0	39	67%	1.37	5.58	0.0238	0.13	y = -2.36 + 0.17 (Disturbance score)
Headwater Floodplain	0	1	26	67%	1,24	6.06	0.0214	0.20	y = 0.85 + 0.23 (Disturbance score)
Depression	1	0	46	60%	1,44	5.17	0.028	0.11	y = -1.44 + 0.13 (Disturbance score)
Floodplain	1	1	28	71%	1,26	23.21	<0.0001	0.47	y = 2.92 + 0.41 (Disturbance score)
Impoundment	1	0	23	86%	1,21	1.54	0.2286	0.07	y = 3.99 + 0.13 (Disturbance score)
Scrub-Shrub	1	0	36	60%	1,34	3.37	0.075	0.09	y = 3.66 + 0.13 (Disturbance score)
Forested	0	2	29	71%	1,27	4.22	0.0497	0.14	y = 0.56 + 0.33 (Disturbance score)

[a] Discrimination efficiency, or ability to discriminate between reference and stressed sites.

Table 10. Relations between the resulting class-specific macroinvertebrate indices of biological integrity (Mac-IBI) derived from combined analysis of benthic and nektonic samples for wetlands in West Virginia, USA and the disturbance gradient from 2005-2006.

Macroinvertebrate IBI	N	D.E.[a]	df	F-value	p-value	R^2	Equation
Headwater Floodplain	23	67	1, 21	3.24	0.0863	0.13	y = 0.77 + 0.19 (Disturbance score)
Floodplain	27	71	1, 25	5.13	0.0325	0.17	y = 1.83 + 0.19 (Disturbance score)
	27	71	1, 25	7.09	0.0133	0.22	y = -0.11 + 0.23 (Disturbance score)
Emergent	58	66	1, 56	5.48	0.0228	0.09	y = 3.98 + 0.12 (Disturbance score)

[a] Discrimination efficiency, or ability to discriminate between reference and stressed sites.

Table 11. Reference site scoring summary used to derive scoring thresholds, and discrimination efficiency (D.E.) in developing class-specific macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Reference Site Scoring Summary								Means (SE)	
Wetland type	N	Max possible IBI score	75th percentile	25th percentile	5th percentile	Median	D.E.[a]		Reference[b]	Stressed
Riparian Depression	39	10	5.79	0.02	0	0.62	67		3.22 (1.76)	0.30 (0.27)
Headwater Floodplain	26	10	10	8.33	7.85	10.00	67		9.27 (0.36)[b]	6.80 (1.13)
Depression	46	10	3.8	0	0	0.25	60		2.75 (1.27)	0.49 (0.32)
Floodplain	28	20	18.91	14.75	12.95	16.25	71		16.55 (0.99)[b]	8.97 (2.20)
Impoundment	23	10	9.85	8.31	3.79	9.03	86		8.09 (1.19)	5.72 (1.07)
Scrub-shrub	36	10	10	7.14	6.59	10.00	60		8.72 (0.53)[b]	5.68 (1.23)
Forested	29	20	16..35	9.99	8.39	12.89	71		12.99 (1.47)[b]	6.33 (1.68)

[a] Effectiveness of Mac-IBI scores to effectively discriminate between reference and stressed sites.

[b] Means statistically significantly different (Tukey α = 0.05).

Table 12. Relations between resulting hybrid-class macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA and the disturbance gradient from 2005-2006.

Hybrid Macroinvertebrate IBI	Nektonic Metrics	Benthic Metrics	N	df	F-value	p-value	R^2	Equation
Riparian Depression / Scrub-shrub	1	1	13	1,11	0.48	0.5026	0.04	y = 6.75 + 0.09 (Disturbance score)
Riparian Depression / Forested	1	2	5	1, 3	0.44	0.5547	0.13	y = 12.50 - 0.27 (Disturbance score)
Headwater Floodplain/ Scrub-shrub	1	1	5	1,3	0.72	0.4577	0.19	y = 4.05 + 0.36 (Disturbance score)
Headwater Floodplain/ Forested	0	3	6	1,4	0.12	0.7466	0.03	y = 14.02 + 0.19 (Disturbance score)
Depression/ Scrub-shrub	2	0	14	1,12	0.61	0.4506	0.05	y = 6.68 + 0.10 (Disturbance score)
Depression/ Forested	1	2	5	1,3	0.44	0.5556	0.13	y = 12.49 - 0.27 (Disturbance score)
Floodplain/ Scrub-shrub	2	1	6	1,4	0.41	0.5571	0.09	y = 13.78 + 0.30 (Disturbance score)
Floodplain/ Forested	1	2	7	1,5	0.63	0.4629	0.11	y = 11.02 + 0.30 (Disturbance score)
Impoundment/ Scrub-shrub	2	0	7	1,5	2.00	0.2165	0.29	y = -9.50 + 0.93 (Disturbance score)

Table 13. Relations between a class-specific multi-metric, multi-taxa IBI and the disturbance gradient derived from the avian wetland indices of biological integrity (AW-IBI), anuran acoustically-based index of biological integrity (AA-IBI), the vegetation index of biological integrity (Veg-IBI) and the macroinvertebrate index of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Number of metrics by taxa group									
Wetland type	Anurans	Birds	Vegetation	Macro invertebrates	N	df	F-value	p-value	R^2	Equation
Riparian Depression	1	0	3	1	37	1,35	14.90	0.0005	0.3	y = 7.07 + 0.62 (Disturbance score)
Headwater Floodplain	1	4	4	1	21	1,19	79.25	<0.0001	0.81	y = -2.70 + 2.10 (Disturbance score)
Depression	0	2	2	1	46	1,44	23.97	<0.0001	0.35	y = 9.96 + 0.63 (Disturbance score)
Floodplain	1	4	5	2	24	1,22	43.10	<0.0001	0.66	y = 26.25 + 1.97 (Disturbance score)
Impoundment	0	3	2	1	23	1, 21	3.47	0.0766	0.14	y =25.63 + 0.37 (Disturbance score)
Emergent	0	1	1	0	75	1, 73	19.66	<0.0001	0.21	y = 9.93 + 0.21(Disturbance score)
Scrub-shrub	0	4	2	1	36	1,34	18.23	<0.0001	0.35	y = 29.79 + 0.79 (Disturbance score)
Forested	0	3	5	2	29	1,27	29.05	<0.0001	0.52	y = 13.61 + 1.44 (Disturbance score)

Table 14. A comparison of class-specific significant R^2 values of the scores and the disturbance gradient resulting from the avian wetland indices of biological integrity (AW-IBI), anuran acoustically-based index of biological integrity (AA-IBI), the vegetation index of biological integrity (Veg-IBI), the macroinvertebrate index of biological integrity (Mac-IBI), and the cumulative multi-taxa, multi-metric IBI for wetlands in West Virginia, USA from 2005-2006.

Wetland type	AW-IBI	AA-IBI	Veg-IBI	Mac-IBI	Cumulative Wetland IBI
Hydrogeomorphic subclass[a]					
Riparian Depression		0.08	0.26	0.13	0.30
Headwater Floodplain	0.49	0.27	0.65	0.20	0.81
Hydrogeomorphic class[b]					
Depression	0.12		0.31	0.11	0.35
Floodplain	0.46	0.18	0.56	0.47	0.66
Impoundment					
Cowardin class					
Emergent	0.11		0.14		0.21
Scrub-shrub	0.25		0.20		0.35
Forested	0.24		0.35	0.14	0.52

[a]Cole et al. (1997).
[b]Brinson (1993).

Table 15. Relations between hybrid multi-metric, multi-taxa IBI and the disturbance gradient derived from the avian wetland indices of biological integrity (AW-IBI), anuran acoustically-based index of biological integrity (AA-IBI), the vegetation index of biological integrity (Veg-IBI) and the macroinvertebrate index of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

	Number of metrics by taxa- group									
Wetland type	Anurans	Birds	Vegetation	Macro invertebrates	N	df	F-value	p-value	R^2	Equation
Emergent/ Headwater floodplain	1	4	4	1	12	1,10	22.83	0.0007	0.70	y = -2.32 + 2.10 (Disturbance score)
Emergent/ Riparian depression	1	1	3	1	21	1,19	4.27	0.0528	0.18	y = 16.34 + 0.56 (Disturbance score)
Emergent/ Depression	0	3	2	1	26	1,24	12.00	0.0020	0.33	y = 16.29 + 0.67 (Disturbance score)
Emergent/ Floodplain	1	4	6	2	13	1,11	18.22	0.0013	0.62	y = 31.50 + 1.95 (Disturbance score)
Emergent/ Impoundment	0	3	3	3	14	1,12	3.03	0.1071	0.20	y = 39.85 + 0.65 (Disturbance score)
Scrub-shrub/ Headwater floodplain	1	6	5	2	4	1,2	12.77	0.0702	0.86	y = 15.16 + 2.52 (Disturbance score)
Scrub-shrub/ Riparian depression	1	4	4	2	12	1,10	3.97	0.0744	0.28	y = 42.45 + 0.91 (Disturbance score)
Scrub-shrub/ Depression	0	4	4	2	14	1,12	2.94	0.1120	0.20	y = 40.85 + 0.67 (Disturbance score)
Scrub-shrub/ Floodplain	1	5	6	3	5	1,3	6.18	0.0889	0.67	y = 31.07 + 2.67 (Disturbance score)
Scrub-shrub/ Impoundment	0	4	3	1	7	1, 5	2.42	0.1805	0.33	y = 8.05 + 1.88 (Disturbance score)
Forested/ Headwater floodplain	1	5	7	3	4	1,2	137.07	0.0072	0.99	y = --37.60 + 4.53 (Disturbance score)
Forested/ Riparian depression	1	3	7	3	4	1,3	0.26	0.6619	0.11	y = 67.54 - 0.33 (Disturbance score)
Forested/ Depression	0	4	6	3	5	1,3	0.28	0.6287	0.09	y = 40.12 + 0.64 (Disturbance score)
Forested/ Floodplain	1	6	9	3	6	1,4	3.97	0.1170	0.50	y = 50.04 + 2.78 (Disturbance score)
Forested/ Impoundment[a]	0	5	6	5	2					

[a] Insufficient sample size.

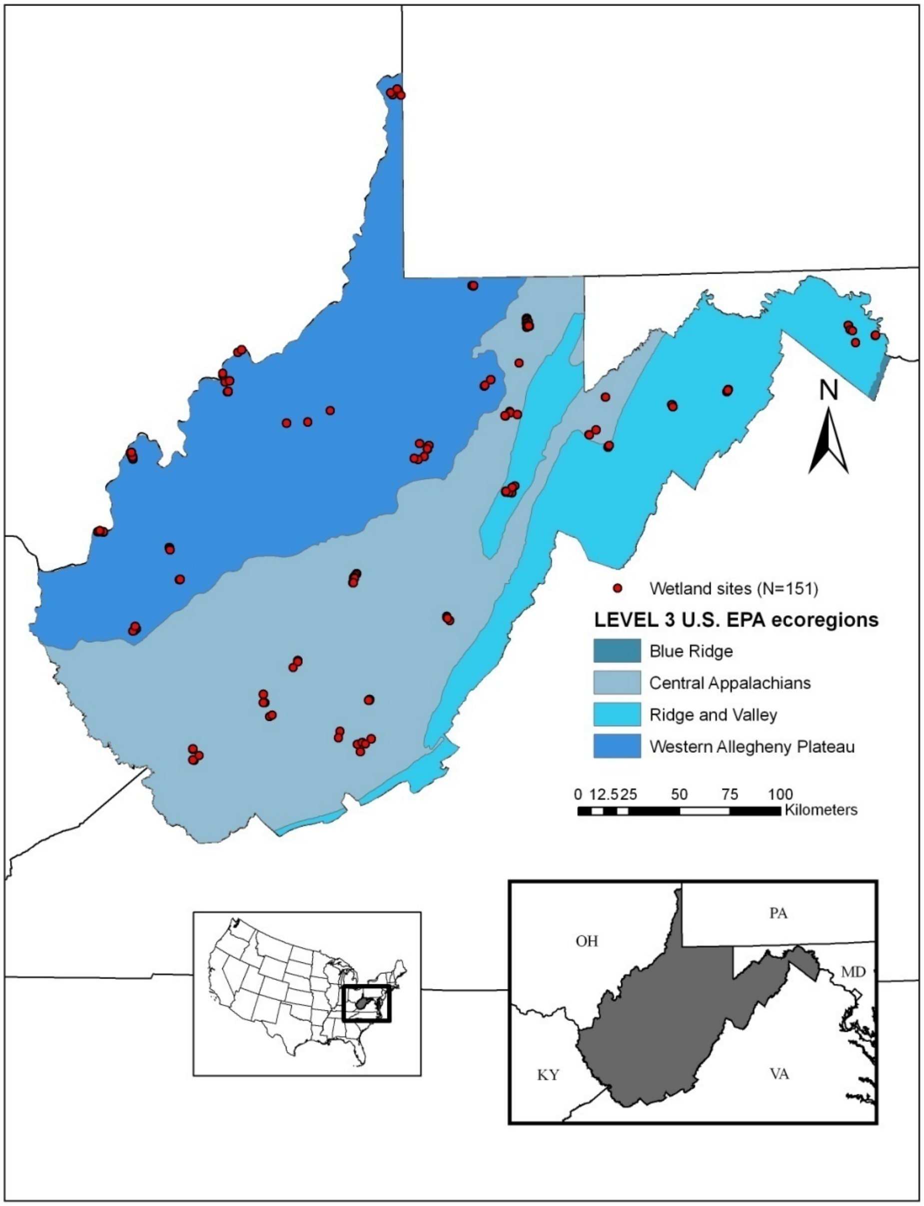

Figure 1. Site locations of wetlands and ecoregions (Omernik 1987, Woods et al. 1999) used in developing class-specific macroinvertebrate indices of biological integrity (Mac-IBI) in West Virginia, USA from 2005-2006. One or more wetlands may be represented by dots due to map scale.

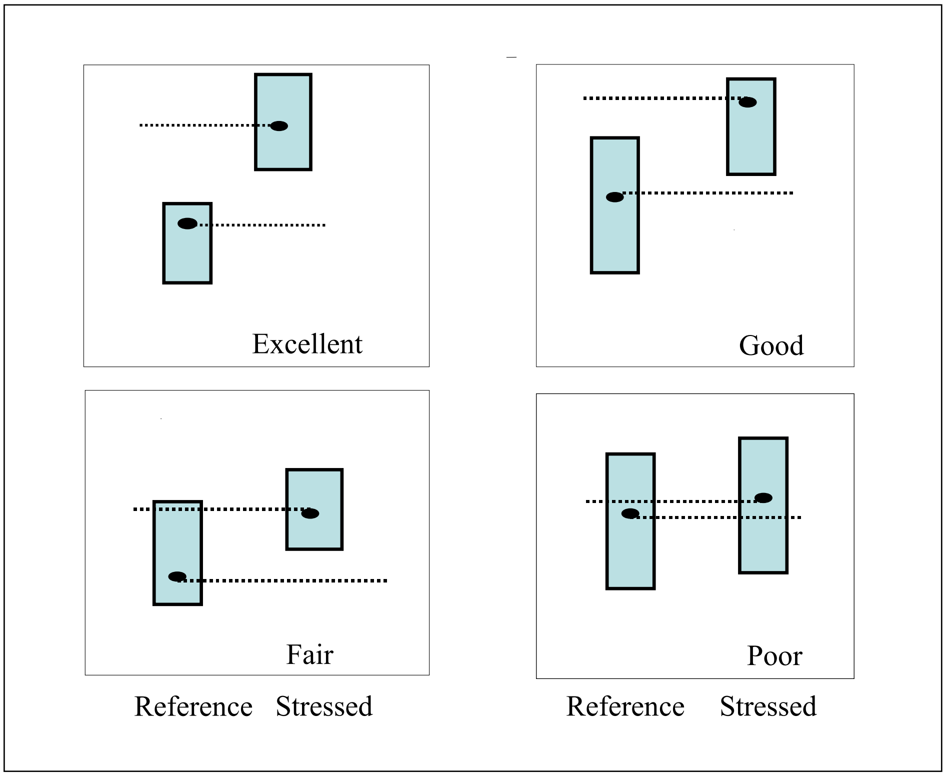

Figure 2. Box-and-whisker plot characteristics and resulting narrative description of reference and stressed sites' distribution of a biological metric value considered for inclusion into class-specific macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006. Solid ovals represent the median of metric value (courtesy of Greg Pond, US EPA).

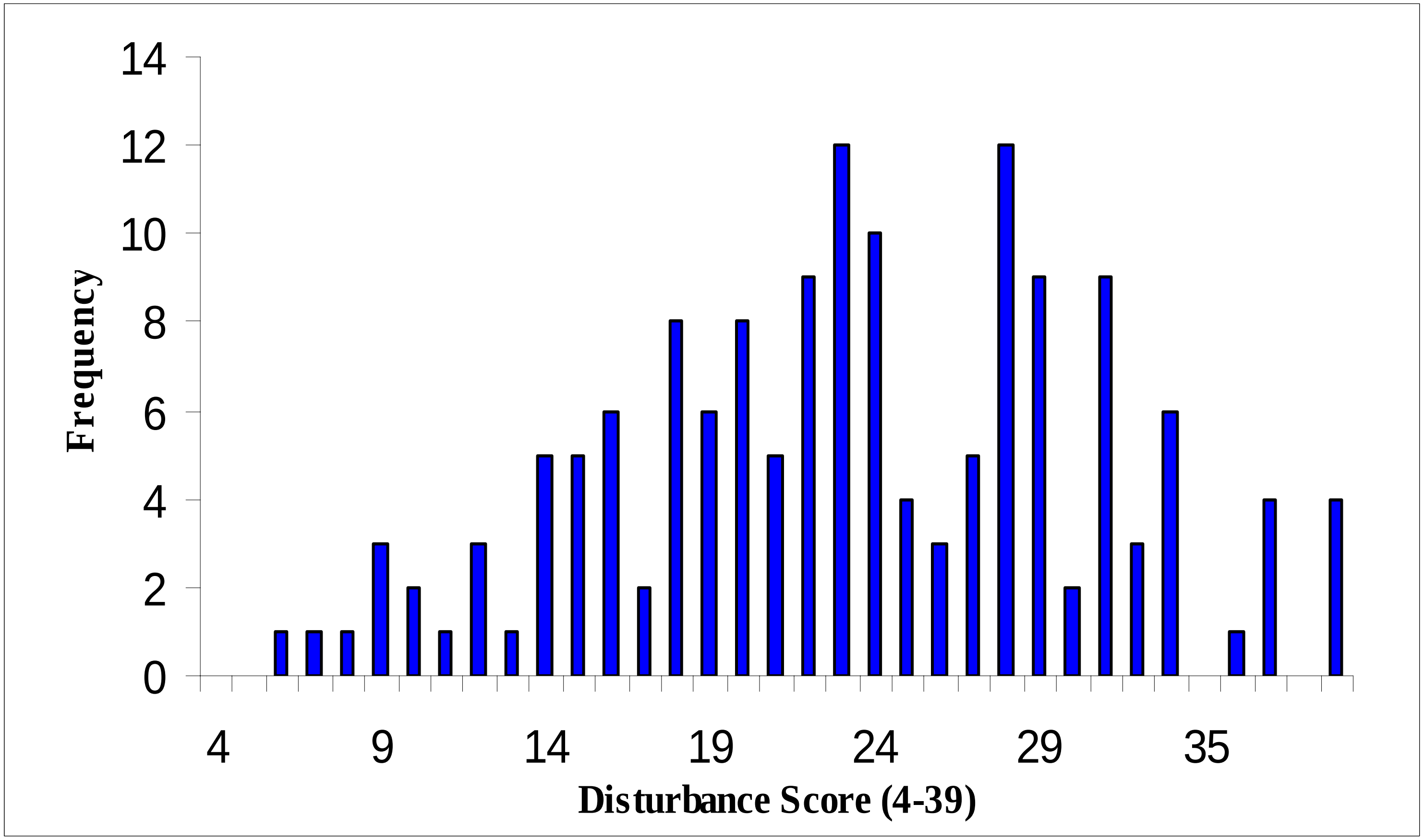

Figure 3. Frequency distribution of disturbance scores for sites used to develop class-specific macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA from 2005-2006.

Chapter 6

Indices of Biological Integrity Applications

Uses for Indices of Biological Integrity for Wetlands in West Virginia, USA

Walter Veselka IV[1]
James T. Anderson[1, 3]
Walter S. Kordek[2]

[1] Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506

[2] West Virginia Division of Natural Resources, Wildlife Resources Section, PO Box 67, Ward Road, Elkins, WV 26241

[3] address correspondence to James T. Anderson, Ph.D., Division of Forestry and Natural Resources, Wildlife and Fisheries Resources Program, West Virginia University, PO Box 6125, Percival Hall, Morgantown, WV 26506. *email:* wetland@wvu.edu *phone:* (304) 293-2941 ext. 2445, *fax:* (304) 293-2441

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Abstract

The use of wetland indices of biological integrity (IBIs) to satisfy the water resources monitoring requirements of the Clean Water Act (CWA) are beginning to become as accepted as IBIs used to monitor lotic environments. However, debate still exists on what classification systems to base these IBIs upon, as well as which taxa are most sensitive to disturbance. We present the results of our cumulative body of research, representing indices of biological integrity designed for regional HGM subclasses, designated HGM management classes and Cowardin et al. (1979) classes. The indices were derived from metrics calculated from anuran, avian, macroinvertebrate, and vegetation communities; each representing increasing levels of resources associated with gathering the necessary data. For example, avian and anuran data used to derive floodplain wetland IBI metrics can be collected by volunteers, but the disturbance scores only account for 46% and 18% of the variation in IBI scores, respectively. Alternatively, the disturbance scores account for 56% and 47% of the variation in vegetation and invertebrate IBI scores, respectively. However, if the floodplain wetland was also a scrub-shrub wetland, by adding the avian and anuran metrics of both floodplain and scrub-shrub IBIs, we form a hybrid class, multi-taxa IBI where the disturbance scores account for 89% of the variation in IBI scores. In this work, we evaluate each of these taxonomic groups alone and in combination, in single and hybrid classification schemes, to examine changes in sensitivities to the disturbance gradient. The result is decision making tool that can assist water resource managers by providing them with the opportunity to stretch finite resources while ensuring the monitoring captures changes in wetland communities due to human disturbance. We also propose a new initiative to use

these tools in a manner to ensure the biological integrity of wetlands is maintained while providing an opportunity for state agencies to generate much-needed wetland restoration and creation funds.

Key words: *Indices of biological integrity, IBIs, wetlands, disturbance, anuran communities, avian communities, macroinvertebrate communities, vegetation communities, West Virginia.*

1.0 Introduction

We have developed a series of state-wide indices that measure the biological integrity of wetlands in West Virginia. This research will allow policy makers to understand and anticipate the changes of avian, anuran, macroinvertebrate, and vegetation communities in response to increasing levels of localized human disturbance. As such, West Virginia could effectively evaluate wetlands throughout the state over time and quantify trends by measuring the changes, or lack thereof, in biological integrity. Monitoring and assessment are a requirement of the Clean Water Act (CWA). Section 303 of the CWA directs states to adopt assessment criteria. Section 304 requires the U.S. Environmental Protection Agency (EPA) to provide guidance on how to conduct biological monitoring; and Section 305(b) requires biennial state-level reports on the condition of water bodies and aquatic ecosystems as described in previous sections. Thus, the reason for and function of indices of biological integrity is to provide regulators with the means to biologically evaluate these aquatic systems (Jackson and Davis 1994; Paulsen et al. 1998). The creation of a wetland index of biological integrity (IBI) could also be used to measure the effectiveness of mitigated wetlands in supporting biological communities; however, we must caution that, in the case of mitigated wetlands, intact biological communities are not completely indicative of functional replacement of the wetlands lost (Brown and Veneman 2001)

The Clean Water Act directive to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. §1251- Section 101(a)) has for years, been unenforceable relative to West Virginia wetlands with regards to biological integrity because no quantitative criteria had been developed to measure this parameter.

The use of chemical monitoring for wetlands has been largely ignored due to costs and the ambiguity and understanding what is an acceptable threshold level of particular chemical stressors. For example, if a primary function of a particular wetland is to trap non-point source pollutants and retain sediments from entering flowing water, as in the case of some floodplain wetlands, chemical levels may not be an appropriate indication of the health of a wetland (Paulsen et al. 1998). Additionally, chemical monitoring is simply a snap-shot in time and not always indicative of aquatic ecosystem health (Karr et al. 1986). It does not capture the physical changes that can affect wetland health, such as sedimentation, and vegetation and hydrologic alterations (Karr and Dudley 1981). Measuring the physical integrity of a wetland is, like chemical monitoring, also not necessarily a viable indication of wetland health. In the broadest sense, maintaining physical integrity is, in essence, ensuring wetlands are not paved over or filled in. We can delineate a wetland's edge jurisdictionally (USACOE 1987), essentially drawing a line for future landuse plans that they cannot cross. However, altering areas around a wetland will change the natural hydrology and water dynamics within a wetland, even if the physical size of a wetland remains intact (Hemond and Benoit 1988; Whigham et al. 1988; Winter 1988). It is these alterations and changes that can occur in proximity to wetlands, as well as in wetlands, that biological monitoring has been shown to be suited for capturing (Mack 2004; Micacchion 2004; Miller et al. 2006; Stapanian et al. 2004).

In selecting and evaluating a collection of biological assemblages and corresponding metrics that respond to a local site-specific disturbance gradient, it is inherent that no 1 biological assemblage or metric is capable of being the definitive rule on what is impaired and what is not, nor do biological communities respond to impairment at the same rates. Our disturbance gradient was based on a suite of site characteristics (Table 1) that will affect species assemblages in different ways. For example, disturbances to the natural hydrology of a wetland will likely express themselves in the macroinvertebrate and vegetation communities before becoming evident in avian communities (Brooks 2000; Koning 2005; Magee and Kentula 2005; Zimmer et al. 2000); whereas alterations to the area adjacent to wetlands may first be detected by amphibian and avian communities (Houlahan and Findlay 2003; O'Connell et al. 1998; Trombulak and Frissel 2000). However, if the disturbance continues and worsens, all communities will eventually reflect the disturbance. The changes in hydrology may lead to the expression of different plant communities, which, in turn will support changes in the avian community (Brown and Smith 1998; Twedt et al. 2000). The shift in macroinvertebrate communities may be followed by a shift in amphibian communities. As adjacent uplands are modified by landuse changes, the vegetative community may be prone to invasion by exotic and noxious species (Galatowitsch et al. 2000). The decreased cover of adjacent uplands may lead to increases in sedimentation that can cover benthic macroinvertebrate habitat and stifle macrophytic transpiration, resulting in wetland functioning in a diluted capacity with regards to filtering out and trapping pollutants (Hemond and Benoit 1988; Mahaney et al. 2004).

It is precisely because disturbances express themselves in different rates upon different biological assemblages that we chose to develop wetland IBIs for avian, anuran, vegetation, and macroinvertebrate communities. These assemblages were used to develop wetland IBIs specific to wetland type as described by the Cowardin et al. (1979) class (here after referred to as "Cowardin"), and the hydrogeomorphic (HGM) setting of a wetland (Brinson 1993). Additionally, we examined developing IBIs for the regionally defined HGM subclasses of wetland (Cole et al. 1997) to ascertain if this level of classification increases the sensitivity of our IBIs. The assemblages chosen for developing wetland IBIs were done to maximize the amount of information collected with the least expenditure of resources. State agencies are often limited by budgets, so each taxon group represents a different level of commitment of resources, allowing policy-makers to make cost-effective decisions in regards to monitoring wetlands (Figure 1). For example, our anuran acoustically-based indices of biological integrity (AA-IBI) was derived from methods used by existing amphibian monitoring programs (Casey and Record 1999) and is the easiest data to collect. The avian wetland indices of biological integrity (AW-IBI) are next in terms of resources needed to evaluate wetlands. Birds can be identified by sight and sound, but is a more difficult and time-consuming commitment for people to learn. Data can be collected by volunteers, but these volunteers must be trained and checked to ensure the quality of their data. Macroinvertebrate collection can be conducted by volunteers, and IBIs have been based on macroinvertebrates collected by volunteers in other states (Hicks and Nedeau 2000); but the identification of macroinvertebrates is professional-level work. The macroinvertebrate indices of biological integrity (Mac-IBI) were based on data collection methods that could be completed by volunteers in 1 day, but identification requires significantly more resources than avian and anuran assemblages with regards to actually deriving the macroinvertebrate data that make up the metrics. The vegetation based indices of biological integrity (Veg-IBI) are based on data which are the most laborious and require professional skill. Identifying plants to the species level, especially grasses and other monocots, is maybe necessary to develop the metrics from the raw data. Alternatively, some metrics can be derived from volunteer-gathered data and has been used to evaluate wetland condition (Witten 2005).

Our objective is to present the results of all of these indices of biological integrity in a format that can be used to make cost-effective decisions with regard to evaluating wetland health and integrity. We present the relation between each individual species assemblage and the disturbance gradient. Additionally, we combine the metrics from each IBI in combinations to reflect the different possibilities of resource commitment in order to evaluate the most cost-effective way to detect changes in wetland condition due to human impairment. For example, the Veg-IBI may be the best single taxa indicator of human disturbance; but combining the AW-IBI metrics and AA-IBI metrics (via addition) may result in a multi-taxa IBI that is more sensitive and cost-effective than the single taxa Veg-IBI. This would enable a better allocation of wetland monitoring resources, potentially resulting in more wetlands being evaluated with a greater degree of statistical certainty of identifying wetland trends. This concept was adopted from a call for the use of additive indices for resource management (Gerritsen 1995). In addition to combining metrics from different taxonomic groups to increase the sensitivity to the disturbance gradient in a class of wetlands; we take this notion one step further by integrating the wetland classification schemes. Our metrics have been tested for robustness not only throughout West Virginia, but also under different classification schemes. This means metrics developed for the emergent class of wetlands can be used in any HGM setting; alternatively, the metrics identified as effective in a floodplain setting will work regardless of that floodplain's Cowardin class. This has led us to develop hybrid indices of biological integrity that in some cases may be more sensitive to the disturbance gradient than the individual class-specific IBIs. With this approach, we not only can decide what is the most cost-effective way to measure disturbance in a wetland; but also the class or combination of classes to use to evaluate a wetland effectively. For example, combining the metrics from a scrub-shrub IBI and a floodplain IBI may be more sensitive to disturbance in a scrub shrub-floodplain wetland than either one alone.

2.0 Methods

In previous works, we developed a series of wetland indices of biological integrity using anuran, avian, macroinvertebrate, and vegetative communities (Veselka 2008: Chapters 2-5). The metrics included in each of these indices were extensively evaluated to ensure the capability to discriminate between reference and stressed sites throughout the state of West Virginia; and at the same time able to provide consistent scores for each class-specific (Cowardin or HGM-based) IBI regardless of the wetland's alternative classification. Each metric was scaled from 0-10, and the cumulative total of all the metrics for each taxa group was used to create a final IBI score, which was then evaluated in relation to the disturbance score using simple linear regression (Veselka 2008: Chapter 2-5).

First, using only the class-specific wetland IBIs that exhibited a significant relation with the disturbance scores, we added the metric scores from each taxa-specific IBI in combinations to reflect different levels of committed resources to wetland monitoring. None of the single taxa group IBIs were significantly related to the disturbance scores in the impoundment designated HGM management class, resulting in the omission of the impoundment classification scheme. The resulting class-specific, multi-taxa IBIs were each evaluated against the disturbance scores using simple linear regression to provide a measurement of sensitivity that was used to compare against other class-specific combinations of taxa groups.

In our second analysis, we still evaluated only the wetland metrics from the class-specific wetland IBIs that were significantly related to disturbance scores; but in this approach we combined metric scores from different classification schemes to evaluate all the possible hybrid IBI sensitivities to disturbance scores. By using simple linear regression, our results enabled us to compare the effectiveness of using metrics from both classification schemes to our class-specific multi-taxa IBIs relative to disturbance sensitivity.

3.0 Results

Combining the significant singular taxa group IBIs into multi-taxa class-specific IBIs resulted in significant relations for every combination (Table 2). The resulting sensitivities varied but, in every case, the sensitivity of the combined multi-taxa IBIs were greater than the lowest single taxa IBI although not always greater than the IBI with the most variation attributed to the disturbance gradient (Table 3). For each classification, combinations of taxa groups that included vegetation metrics were the most sensitive to the disturbance score. When we examined single taxa IBIs and combination IBIs that did not include vegetation metrics, the sensitivities decreased the most in riparian depression IBIs (including vegetation metrics R^2 = 0.32, not inclusive of vegetation metrics R^2 = 0.13) and the least in floodplain IBIs (including vegetation metrics R^2 = 0.77, not inclusive of vegetation metrics R^2 = 0.72).

Combining the Cowardin and HGM classification schemes to form hybrid IBIs with multiple taxa, we found 49 of the 94 combinations we evaluated were significant to our disturbance scores (Table 4). We were able to evaluate the relations with the disturbance gradient based on these hybrid classifications to determine if an increase in variation can be attributed to the disturbance gradient (Table 5). We compared the class-specific IBIs with the highest sensitivities that included vegetation metrics, with those without the vegetation metrics, as an avenue to compare IBI sensitivity. We found the hybrid IBIs to be more sensitive to disturbance in 8 of the 12 classifications we evaluated. Only in the emergent-riparian depression, emergent-headwater floodplain, forested-riparian depression, and forested-depression hybrid IBIs could a greater amount of variation be attributed to the disturbance gradient by using the riparian depression, headwater floodplain, in the case of the emergent hybrid IBIs; or the forested class-specific IBIs as an alternative. In some cases, the increases in sensitivity were greater than 10%. For example, the emergent-depression IBI that used avian and invertebrate metrics (n = 26, $F_{1,24}$ = 10.12, p = 0.0040, R^2 = 0.30) was 14% more sensitive than the depression IBI using avian and invertebrate metrics (n = 46, $F_{1,44}$ = 8.37, p = 0.0059, R^2 = 0.16); although less than the invertebrate and vegetation class-specific depression IBI (n = 46, $F_{1,44}$ = 26.03, p = <0.0001, R^2 = 0.37). However, in scrub shrub-headwater floodplain wetlands, hybrid IBI scores were more sensitive than even the most sensitive headwater floodplain IBI that was formed by combining metrics from all taxa groups (n = 21, $F_{1,19}$ = 79.25, p <0.0001, R^2 = 0.81). The scrub shrub-headwater floodplain, avian and anuran IBI (n = 5, $F_{1,3}$ = 23.46, p = 0.0168, R^2 = 0.89) and avian, macroinvertebrate, and vegetation IBI (n = 6, $F_{1,4}$ = 83.28, p = 0.0008, R^2 = 0.95) were both more sensitive and would require fewer resources to evaluate a wetland fitting these 2 classifications. The scrub shrub-riparian depression IBI was most sensitive if made up of macroinvertebrate and vegetation metrics (n = 13, $F_{1,11}$ = 11.44, p = 0.0061, R^2 = 0.51), but other depression hybrid IBIs were not significantly related to the disturbance gradient if vegetation metrics were not included. If we were to evaluate this wetland without using vegetation metrics, the class-specific avian scrub shrub IBI exhibits the next highest relation with the disturbance gradient (n = 44, $F_{1,42}$ = 13.71, p = 0.0006, R^2 = 0.25) applicable to this wetland.

The mean, standard error, minimum and maximum of metric values statewide and for each ecoregion, by taxa, are listed so future researchers have a reference as to the typical variability associated with each metric throughout the state (Tables 6-9).

4.0 Discussion

These results are intended to give wetland resource managers in West Virginia an opportunity to make a proactive choice in regards to committing resources to wetland monitoring. All wetlands can't be monitored effectively using the same criteria, and the results of our research attempts to provide a measure of clarity regarding that choice. We envision this system being used as part of a decision making process that can be implemented by making realistic choices. For example, the location of resources is a major logistical challenge in many types of field work. Wetlands in one portion of the state could never realistically be monitored extensively using vegetation surveys if the botanists are located in another. Using our results, wetland resource managers could determine that it would be a more efficient allocation of resources to send volunteers capable of collecting avian and macroinvertebrate data to 10 floodplain wetlands as opposed to a professional botanist to fewer wetlands. This decision could be validated knowing that 72% of the variation in avian and invertebrate combined floodplain IBI scores is attributable to disturbance scores, compared to only 56% of the variation in vegetation IBI scores. Additionally, the combining of Cowardin and HGM classes to form hybrid IBIs could allow researchers to draw stronger conclusions from the same data. For example, if the floodplain wetland used in the last example was also a scrub shrub wetland, by incorporating scrub-shrub metrics we could evaluate the wetland based only on avian and anuran assemblages, rather than collecting macroinvertebrates, resulting in 89% of the variation in IBI scores being on account of human impairment. This would save expense associated with preserving, identifying, and processing the macroinvertebrates by professional staff.

The creation of HGM subclass (Cole et al. 1997) and the designated HGM management class IBIs provide us with more tools to use than traditional Cowardin classification techniques. Basing IBIs on these HGM approaches has been called for by previous researchers (Stevenson and Hauer 2002), but the significant gains we see in sensitivity to disturbance is profound. The strong relations between floodplain and headwater floodplain based IBIs to the local disturbance score is especially important for wetland monitoring in West Virginia, which is typified by steep terrain. In fact, this terrain was carved by nearly 63,300 km of streams and 10,000 named streams in the state, resulting in approximately 1.03km of stream for every square km of land, one of the highest stream densities in North America (Petty 2006). Because of this, flat land in West Virginia is a valuable commodity, and is more commonly found in the valleys of the mountainous terrain (and the tops of mountain top removal sites). Most wetlands associated with streams and rivers are typically small and linear, and literature suggests that they are often difficult to identify; leading to many wetlands not being included on maps such as the NWI(Anderson and Rentch 2007;Stolt and Baker 1995; Tiner 1997). As a result, we can assume in some capacity that floodplain wetlands are being lost in West Virginia to land-use changes brought on by human impacts, especially if they were never mapped or documented. Many historical floodplain wetlands, no doubt, have been lost in West Virginia prior to wetland protection as rivers were channeled and dredged to facilitate commerce. Floodplain wetlands provide many functions such as the regulation of floodwaters, sediment control, and biogeochemical transformations of nutrients and pathogens (Richardson 1994). According to the West Virginia Department of Environmental Protection (WVDEP), every major river in West Virginia has been impaired as a result of human activities (WVDEP 2004). The causes of impairment vary, but many are a result of heavy metals released from mining activities, increased fecal coliform levels, and sedimentation (WVDEP 2004). An intact floodplain wetland can only help mitigate some of the effects of these impacts. Floodplain wetlands trap sediment, filter out pollutants, and research has indicated on many levels that wetlands improve water quality (Fleming-Singer and Horne 2006; Kovacic et al. 2006; Whigham and Jordan 2003; Wilson and Mitsch 1996). Therefore, the development of highly responsive floodplain wetland IBIs that use multiple species as indicators of impairment provides an avenue from which the protection of these wetlands may be approached. As seen from our research, the sensitivity to disturbance scores can even be improved in headwater floodplain and floodplain wetlands when combined with metrics derived using the Cowardin classes.

The remaining class-specific IBIs, based on Cowardin class, depressional designated HGM management class, and the riparian depression HGM subclass, in many cases exhibit a significant relation to the disturbance scores. However the strength of these relations are consistently below 50% of the variation in scores attributed to the local disturbance score; with the exception of the avian, macroinvertebrate, and vegetation based forested IBI, and a macroinvertebrate and vegetation based scrub-shrub-riparian depression IBI. As a result, the usefulness of these IBIs may be better served when coupled with GIS modeling of landscape variables. Because these IBIs are significantly related to the disturbance scores on a local scale, we know they respond predictably to human impairment. Other researchers have developed and tested disturbance gradients using GIS variables alone (Brown and Vivas 2005), from which IBIs have been based, as well as being integrated with local disturbance factors (Miller et al. 2006; Micacchion 2004). The use of GIS has been used to identify functionally significant wetlands, as well as prioritize restoration efforts to improve water quality (Almendinger 1999; Cedfeldt et al. 2000; Russell et al. 1997). Coupling the GIS approach with the responses of biological assemblages in response to local disturbances could be used to develop predictive models used to report on overall wetland condition in a watershed (Wardrop et al. 2007; Weller et al. 2007); enabling West Virginia to report the findings on wetland health as mandated by Section 305 (b) of the Clean Water Act.

Based on the results of our research and recognizing finite monitoring resources, we suggest that future studies should focus on floodplain wetlands. These wetlands are directly tied to one of West Virginia's greatest and most imperiled natural resources, the extensive network of streams and rivers. Our results were most consistently attributed to disturbance scores in floodplain wetlands, resulting in some cases where ≥ 80% of the variation of IBI scores was attributed to the local disturbance gradient. In emphasizing floodplain wetlands, we will also continue to simultaneously collect data that can be used to refine corresponding Cowardin class-specific IBIs, which were designed to be independent of HGM expression. Upon reiterations and further development of data, the Cowardin based IBIs can be used to ascertain the condition of wetlands not associated with rivers and streams. These wetlands would not be considered floodplain wetlands, resulting in the capability to modify and refine IBIs for both the Cowardin and other HGM classification schemes. In monitoring wetlands in this manner, West Virginia would begin fulfilling CWA mandates using floodplain wetlands, then expand upon an increasing knowledge base to all wetland expressions located throughout the state.

5.0 Management Implications

Our research provides wetland resource managers with more tools and resources than previously available to monitor wetlands in West Virginia. No doubt the most effective of these tools is the ability for managers to allocate resources to monitoring individual wetlands, drawing connections between the results of the monitoring and the link to impairment. In constructing a wetland monitoring program for the entire state while being flexible as to its potential for uses, it is important to maximize the information acquisition using the least amount of resources. Public involvement in the monitoring of wetlands should be maximized, resulting in a greater sense of public empathy for the plight of wetlands; and a larger sampling of wetland characteristics that can serve to update and strengthen the relation between monitoring and ecological research (Courtemanch 1994; Hart 1994). As previously substantiated, more research integrating IBI scores with landscape variables may be used to model probable wetland condition and functions; however, these models need to be constructed and tested and are not ready for immediate application.

Alternatively, with the creation of responsive IBIs, the effectiveness of mitigated wetlands in replacing natural wetlands can be compared, at least biologically. Bioassessments have, on occasion, been used as a basis for litigation (Paulsen et al. 1998) which may provide some measure of accountability ensuring mitigated wetlands are created in a manner conducive to providing biological habitat. In fact, the recently issued EPA guidelines on "Compensatory Mitigation for Losses of Aquatic Resources" (40 CFR Part 230), which calls for mitigation banks becoming the preferred mitigation alternative, specifies a need for "…measurable, enforceable ecological performance standards and regular monitoring for all types of compensation and specifying components of a complete, compensatory mitigation plan..." The series of statewide West Virginia wetland IBIs fulfills this need by establishing numeric criteria for excellent, good, marginal, or poor quality wetlands based upon biological integrity measures derived from wetland characteristics from a statewide sampling regime. In essence, the use of these IBIs in this manner will provide a new tool to gauge the success of mitigation and to hold parties accountable for failing mitigation projects.

Additionally our research could result in, with the support of the state legislature, an opportunity for West Virginia to establish a pro-active policy aimed at conserving more than just the wetland water resources of the state. We know that floodplain wetlands are sometimes not captured on Cowardin and topographic maps, but provide valuable functions to human society such as floodwater retention, the removal of pathogens, the immobilization of metals, and sediment control. If state government mandated that all permitted development activities within 100-m of a river or stream be surveyed for the presence of wetlands, we would undoubtedly discover and conserve more of the existing wetland resources supporting improvements to the state's water quality just by ensuring these wetlands are not eliminated. Furthermore, we can protect against the degradation of these wetlands, as mandated by the Clean Water Act, because of the highly responsive nature of floodplain IBI scores within 50-m of disturbance. By requiring preconstruction biological monitoring to establish a measure of the biological integrity of a wetland in proximity to an area slated for permitted land use change, we could ensure state permitted land-use activities follow best-management practices, which can protect biological communities against stressor impacts (Calhoun et al. 2005), by requiring companies to post bonds prior to land-use transformation. A set of reference wetlands within the same watershed would also be measured at the same time to compare with watershed wetland degradation with that of the wetland in proximity to the land use change. This bond would then be placed into a fund, similar to that established by the Surface Mining Control and Reclamation Act of 1977, which the state manages and for which it collects interest. After a set time period, the wetland in proximity to the land-use transformation, as well as the reference wetlands, can be evaluated using the same IBI criteria, and the money released (*sans* interest) if the wetland was not impaired biologically, or if it degraded in the same amount as the reference wetlands. If the wetland was impaired the bond would be forfeited, and the state would be responsible for creating or restoring wetlands using the bond money. A similar system would apply to mitigation banking companies to ensure the created or restored wetlands are maintained.

Additionally, the interest from these bonds, upon maturation, could be used to restore or create wetlands where they would do the most good increasing water quality, as identified by future research. Although this would represent a bold initiative, the protection of wetlands in proximity to land-use alterations is not unprecedented; the state of Maine goes so far as to protect vernal pools, which are commonly not considered jurisdictional wetlands, from activities up to ~75 m away (Maine Natural Resources Protection Act: Chapter 310, 335). Furthermore, this method would actually be suited to measuring the impact of riparian landuse changes because our floodplain wetland IBIs are responsive to a local disturbance gradient; whereas it is difficult to identify and locate single sources that cause stream impairment over acceptable thresholds. Thus, by protecting the wetlands and ensuring their continued capacity to immobilize heavy metals, trap sediments, and eliminate pathogens, West Virginia also would be protecting its rivers from these same impairments that are responsible for the listing of many streams on the West Virginia 303(d) list of impaired streams. This protection would ensure that West Virginia, whose rivers flow to the Chesapeake Bay and the Gulf of Mexico, would not only be known as the "birthplace of rivers" but also as a national leader and pioneer of innovative, proactive, water quality assurances.

6.0 Acknowledgements

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Table 1. Metrics and sub-metrics of the Ohio Rapid Assessment Method (Mack 2001) used to define the disturbance gradient for use in developing multimetric indices of biological integrity for wetlands in West Virginia, USA from 2005-2006.

Scoring value		Disturbance component
		Upland buffers and surrounding land use
		Calculate the average buffer width. Select only one and assign score.
7	☐	WIDE. Buffers average 50m or more around wetland perimeter
4	☐	MEDIUM. Buffers average 25m to <50m around wetland perimeter
1	☐	NARROW. Buffers average 10m to <25m around wetland perimeter
0	☐	VERY NARROW. Buffers average <10m around wetland perimeter
		Intensity of surrounding land use. Select one or double check and average.
7	☐	VERY LOW. 2nd growth or older forest, prairie, savannah, wildlife area, etc.
5	☐	LOW. Old field (>10 years), shrubland, young second growth forest.
3	☐	MODERATELY HIGH. Residential, fenced pasture, park, conservation tillage, new fallow field.
1	☐	HIGH. Urban, industrial, open pasture, row cropping, mining, construction.
		Hydrology
		Modifications to natural, hydrologic regime. Score one or double check and average.
12	☐	None or none apparent. There are no modifications or no modifications that are apparent to the rater.
7	☐	Recovered. The wetland appears to have recovered from past modifications which altered the wetland's natural hydrologic regime.
3	☐	Recovering. The wetland appears to be in the process of recovering from past modifications which altered the wetland's natural hydrologic regime.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past modifications and / or the modifications are ongoing.
		Habitat alteration and development
		Substrate disturbance. Score one or double check and average.
4	☐	None or none apparent. There are no modifications or no modifications that are apparent to the rater.
3	☐	Recovered. The wetland appears to have recovered from past disturbances.
2	☐	Recovering. The wetland appears to be in the process of recovering from past disturbances.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past disturbances and/ or the disturbances are ongoing.
		Habitat alteration. Score one or double check and average.
9	☐	None or none apparent. There are no alterations or no alterations that are apparent to the rater.
6	☐	Recovered. The wetland appears to have recovered from past alterations.
3	☐	Recovering. The wetland appears to be in the process of recovering from past alterations.
1	☐	Recent or no recovery. The modifications have occurred recently, and / or the wetland has not recovered from past alterations and/ or the alterations are ongoing.

Table 2. Single and multi-taxa wetland indices of biological integrity and resulting relation with the disturbance score for wetlands in West Virginia, USA in 2005-2006.

Wetland Classification								
Taxa group(s) IBI			N	df	F-value	p-value	R^2	Equation
Riparian Depression								
Anurans			52	1,50	4.32	0.0429	0.08	y = 1.53 + 0.12 (Disturbance score)
Invertebrates			39	1,37	5.58	0.0238	0.13	y = -2.36 + 0.17 (Disturbance score)
Vegetation			59	1,57	19.87	<0.0001	0.26	y = 4.16 + 0.50 (Disturbance score)
Anurans	Invertebrates		37	1,35	4.48	0.0416	0.11	y = 0.92 + 0.20 (Disturbance score)
Anurans	Invertebrates	Vegetation	37	1,35	14.90	0.0005	0.30	y = 7.07 + 0.62 (Disturbance score)
Anurans	Vegetation		52	1,50	19.61	<0.0001	0.28	y = 6.92 + 0.58 (Disturbance score)
Invertebrates	Vegetation		39	1,37	17.52	0.0002	0.32	y = 3.27 + 0.61 (Disturbance score)
Cumulative Wetland IBI			37	1,35	14.90	0.0005	0.30	y = 7.07 + 0.62 (Disturbance score)
Headwater Floodplain								
Anurans			22	1,21	7.49	0.0127	0.27	y = -0.52 + 0.20 (Disturbance score)
Birds			29	1,27	25.44	<0.0001	0.49	y = 11.97 + 0.62 (Disturbance score)
Invertebrates			26	1,24	6.06	0.0214	0.20	y = 0.85 + 0.23 (Disturbance score)
Vegetation			29	1,27	50.00	<0.0001	0.65	y = -7.21 + 0.76 (Disturbance score)
Anurans	Birds		22	1,20	19.74	0.0003	0.50	y = 14.50 + 0.73 (Disturbance score)
Anurans	Birds	Invertebrates	21	1,19	41.76	<0.0001	0.69	y = 8.11 + 1.21 (Disturbance score)
Anurans	Birds	Vegetation	22	1,20	53.87	<0.0001	0.73	y = 4.48 + 1.58 (Disturbance score)
Anurans	Invertebrates		21	1,19	19.81	0.0003	0.51	y = -3.15 + 0.56 (Disturbance score)
Anurans	Invertebrates	Vegetation	21	1,19	46.62	<0.0001	0.71	y = -13.95 + 1.45 (Disturbance score)
Anurans	Vegetation		22	1,20	37.69	<0.0001	0.65	y = -10.54 + 1.06 (Disturbance score)
Birds	Invertebrates		26	1,24	36.34	<0.0001	0.60	y = 10.71+ 0.91 (Disturbance score)
Birds	Vegetation		29	1,27	86.47	<0.0001	0.76	y = 4.75 + 1.38 (Disturbance score)
Birds	Invertebrates	Vegetation	26	1,24	85.77	<0.0001	0.78	y = 3.40 + 1.68 (Disturbance score)
Invertebrates	Vegetation		26	1,24	40.11	<0.0001	0.63	y = -6.46 + 0.99 (Disturbance score)
Cumulative Wetland IBI			21	1,19	79.25	<0.0001	0.81	y = -2.70 + 2.10 (Disturbance score)
Depression								
Anurans								
Birds			72	1,70	9.71	0.0027	0.12	y = 9.52 + 0.23 (Disturbance score)
Invertebrates			46	1,44	5.17	0.028	0.11	y = -1.44 + 0.13 (Disturbance score)
Vegetation			72	1,70	31.79	<0.0001	0.31	y = 0.32 + 0.34 (Disturbance score)
Birds	Invertebrates		46	1,44	8.37	0.0059	0.16	y = 8.62 + 0.33 (Disturbance score)
Birds	Vegetation		72	1,70	33.32	<0.0001	0.32	y = 9.84 + 0.58 (Disturbance score)
Birds	Invertebrates	Vegetation	46	1,44	23.96	<0.0001	0.35	y = 9.96 + 0.3 (Disturbance score)
Invertebrates	Vegetation		46	1,44	26.03	<0.0001	0.37	y = -0.11 + 0.43 (Disturbance score)
Cumulative Wetland IBI			46	1,44	23.97	<0.0001	0.35	y = 9.96 + 0.63 (Disturbance score)

Table 2. Continued.

Wetland Classification Taxa group(s) IBI			N	df	F-value	p-value	R^2	Equation
Floodplain								
Anurans			28	1, 26	5.76	0.0238	0.18	y = 3.37 + 0.30 (Disturbance score)
Birds			35	1,33	32.74	<0.0001	0.46	y = 18.14 + 0.50 (Disturbance score)
Invertebrates			28	1,26	23.21	<0.0001	0.47	y = 2.92 + 0.41 (Disturbance score)
Vegetation			35	1,33	42.16	<0.0001	0.56	y = -0.78 + 0.81 (Disturbance score)
Anurans	Birds		28	1,26	19.81	0.0001	0.43	y = 26.30 + 0.65 (Disturbance score)
Anurans	Birds	Invertebrates	24	1,22	31.35	<0.0001	0.59	y = 26.15 + 1.18 (Disturbance score)
Anurans	Birds	Vegetation	28	1,26	44.44	<0.0001	0.63	y = 24.41 + 1.51 (Disturbance score)
Anurans	Invertebrates		24	1,22	14.87	0.0009	0.40	y = 5.27 + 0.74 (Disturbance score)
Anurans	Invertebrates	Vegetation	24	1,22	25.35	<0.0001	0.54	y = 5.37 + 1.53 (Disturbance score)
Anurans	Vegetation		28	1,26	25.55	<0.0001	0.50	y = 1.48 + 1.16 (Disturbance score)
Birds	Invertebrates		28	1,26	66.50	<0.0001	0.72	y = 21.03 + 0.93 (Disturbance score)
Birds	Vegetation		35	1,33	86.63	<0.0001	0.72	y = 17.35 + 1.31 (Disturbance score)
Birds	Invertebrates	Vegetation	28	1,26	88.38	<0.0001	0.77	y = 22.25 + 1.66 (Disturbance score)
Invertebrates	Vegetation		28	1,26	41.17	<0.0001	0.61	y = 4.14 + 1.13 (Disturbance score)
Cumulative Wetland IBI			24	1,22	43.10	<0.0001	0.66	y = 26.25 + 1.97 (Disturbance score)
Emergent								
Birds			75	1,73	8.71	0.0042	0.11	y = 6.47 + 0.09 (Disturbance score)
Vegetation			75	1,73	11.91	0.0009	0.14	y = 3.47 + 0.12 (Disturbance score)
Birds	Vegetation		75	1,73	19.66	<0.0001	0.21	y = 9.93 + 0.21 (Disturbance score)
Cumulative Wetland IBI			75	1,73	19.66	<0.0001	0.21	y = 9.93 + 0.21(Disturbance score)
Scrub-shrub								
Birds			44	1,42	13.71	0.0006	0.25	y = 17.54 + 0.54 (Disturbance score)
Invertebrates			36	1,34	3.37	0.075	0.09	y = 3.66 + 0.13 (Disturbance score)
Vegetation			44	1,42	10.33	0.0025	0.20	y = 3.13 + 0.66 (Disturbance score)
Birds	Vegetation		44	1,42	22.00	<0.0001	0.34	y = 22.53 + 0.78 (Disturbance score)
Cumulative Wetland IBI			36	1,34	18.23	<0.0001	0.35	y = 29.79 + 0.79 (Disturbance score)
Forested								
Birds			31	1,29	8.48	0.0056	0.24	y = 6.07 + 0.47 (Disturbance score)
Invertebrates			29	1,27	4.22	0.0497	0.14	y = 0.56 + 0.33 (Disturbance score)
Vegetation			31	1, 29	16.62	0.0005	0.35	y = 3.50 + 0.79 (Disturbance score)
Birds	Invertebrates		29	1,27	14.29	0.0008	0.35	y = 7.60 + 0.76 (Disturbance score)
Birds	Vegetation		31	1,29	26.90	<0.0001	0.48	y = 9.57 + 1.25 (Disturbance score)
Birds	Invertebrates	Vegetation	29	1,27	29.05	<0.0001	0.52	y = 13.61 + 1.44 (Disturbance score)
Invertebrates	Vegetation		29	1,27	15.19	0.0006	0.36	y = 6.57 + 1.01 (Disturbance score)
Cumulative Wetland IBI			29	1,27	29.05	<0.0001	0.52	y = 13.61 + 1.44 (Disturbance score)

Table 3. Significant R^2 for class-specific single and multi-taxa indices of biological integrity (IBIs) for hydrogeomorphic (HGM) subclasses, designated HGM management classes, and Cowardin classes for wetlands of West Virginia, USA from 2005-2006.

			HGM subclass[a]		Designated HGM management class		Cowardin classification		
Taxa groups in multi-taxa wetland IBIs			Riparian Depression	Headwater Floodplain	Depression	Floodplain	Emergent	Scrub-shrub	Forested
Anurans			0.08	0.27		0.18			
Birds				0.49	0.12	0.46	0.11	0.25	0.24
Invertebrates			0.13	0.20	0.11	0.47			0.14
Vegetation			0.26	0.65	0.31	0.56	0.14	0.20	0.35
Anurans	Birds			0.5		0.43			
Anurans	Birds	Invertebrates		0.69		0.59			
Anurans	Birds	Vegetation		0.73		0.63			
Anurans	Invertebrates		0.11	0.51		0.40			
Anurans	Invertebrates	Vegetation	0.30	0.71		0.54			
Anurans	Vegetation		0.28	0.65		0.50			
Birds	Invertebrates			0.60	0.16	0.72			0.35
Birds	Vegetation			0.76	0.32	0.72	0.21	0.34	0.48
Birds	Invertebrates	Vegetation		0.78	0.35	0.77			0.52
Invertebrates	Vegetation		0.32	0.63	0.37	0.61			0.36
Cumulative Wetland IBI			0.30	0.81	0.35	0.66	0.21	0.35	0.52

[a] Cole et al. (1997).

Table 4. Multi-taxa, hybrid classification scheme wetland indices of biological integrity and resulting relation with the disturbance score for wetlands in West Virginia, USA in 2005-2006.

Wetland Classification								
Taxa group in hybrid IBI			N	df	F-value	p-value	R^2	Equation
Emergent- Riparian Depression								
Anurans	Birds		28	1,26	2.13	0.1568	0.08	y = 8.54 + 0.17 (Disturbance score)
Anurans	Birds	Invertebrates	21	1,19	7.06	0.0156	0.27	y = 4.96 + 0.43 (Disturbance score)
Anurans	Birds	Vegetation	28	1,26	0.92	0.3472	0.03	y = 21.48 + 0.20 (Disturbance score)
Anurans	Invertebrates	Vegetation	21	1,19	4.69	0.0433	0.20	y = 7.97 + 0.56 (Disturbance score)
Anurans	Vegetation		28	1,26	1.23	0.2772	0.05	y = 13.00 + 0.21 (Disturbance score)
Birds	Invertebrates		21	1,19	6.38	0.0206	0.25	y = 3.60 + 0.31 (Disturbance score)
Birds	Vegetation		29	1,27	0.07	0.7947	0.00	y = 21.02 + 0.05 (Disturbance score)
Birds	Invertebrates	Vegetation	21	1,19	3.27	0.0864	0.15	y = 14.99 + 0.44 (Disturbance score)
Invertebrates	Vegetation		21	1,19	3.56	0.0747	0.16	y = 6.62 + 0.44 (Disturbance score)
Emergent- Headwater Floodplain								
Anurans	Birds		13	1,11	4.79	0.0510	0.30	y = 17.64 + 0.58 (Disturbance score)
Anurans	Birds	Invertebrates	12	1,10	12.59	0.0053	0.56	y = 8.58 + 1.20 (Disturbance score)
Anurans	Birds	Vegetation	13	1,11	14.96	0.0026	0.58	y = 8.23 + 1.43 (Disturbance score)
Anurans	Invertebrates	Vegetation	12	1,10	14.97	0.0031	0.60	y = -12.66 + 1.41 (Disturbance score)
Anurans	Vegetation		13	1,11	11.09	0.0067	0.50	y = -7.35 + 0.93 (Disturbance score)
Birds	Invertebrates		14	1,12	13.21	0.0034	0.52	y = 9.71 + 0.95 (Disturbance score)
Birds	Vegetation		15	1,13	20.66	0.0005	0.61	y = 7.73 + 1.27 (Disturbance score)
Birds	Invertebrates	Vegetation	14	1,12	30.16	<0.0001	0.72	y = -0.03 + 1.81 (Disturbance score)
Invertebrates	Vegetation		14	1,12	26.38	0.0002	0.69	y = -12.67 + 1.22 (Disturbance score)
Emergent- Depression								
Birds	Invertebrates		26	1,24	10.12	0.0040	0.30	y = 11.72 + 0.58 (Disturbance score)
Birds	Vegetation		38	1,36	4.63	0.0382	0.11	y = 20.06 + 0.41 (Disturbance score)
Birds	Invertebrates	Vegetation	26	1,24	12.00	0.0020	0.33	y = 16.29 + 0.67 (Disturbance score)
Invertebrates	Vegetation		26	1,24	8.13	0.0088	0.25	y = 1.79 + 0.32 (Disturbance score)
Emergent- Floodplain								
Anurans	Birds		14	1,12	8.69	0.0122	0.42	y = 27.68 + 0.54 (Disturbance score)
Anurans	Birds	Invertebrates	13	1,11	16.01	0.0020	0.59	y = 26.76 + 1.09 (Disturbance score)
Anurans	Birds	Vegetation	14	1,12	16.63	0.0015	0.58	y = 29.75 + 1.50 (Disturbance score)
Anurans	Invertebrates	Vegetation	13	1,11	8.79	0.0129	0.44	y = 12.48 + 1.43 (Disturbance score)
Anurans	Vegetation		14	1,12	6.58	0.0248	0.35	y = 8.58 + 1.06 (Disturbance score)
Birds	Invertebrates		15	1,13	38.82	<0.0001	0.75	y = 19.28 + 1.00 (Disturbance score)
Birds	Vegetation		16	1,14	42.86	<0.0001	0.75	y = 23.50 + 1.38 (Disturbance score)
Birds	Invertebrates	Vegetation	15	1,13	46.24	<0.0001	0.78	y = 23.91 + 1.87 (Disturbance score)
Invertebrates	Vegetation		15	1,13	23.99	0.0003	0.65	y = 4.56 + 1.37 (Disturbance score)

Table 4. Continued.

Wetland Classification								
Taxa group in hybrid IBI			N	df	F-value	p-value	R^2	Equation
Scrub shrub- Riparian Depression								
Anurans	Birds		16	1,14	0.66	0.4294	0.05	y = 29.99 + 0.24 (Disturbance score)
Anurans	Birds	Invertebrates	12	1,10	0.39	0.5468	0.04	y = 30.85 + 0.24 (Disturbance score)
Anurans	Birds	Vegetation	16	1,14	6.62	0.0221	0.32	y = 32.03 + 1.03 (Disturbance score)
Anurans	Invertebrates	Vegetation	12	1,10	7.70	0.0196	0.43	y = 7.27 + 0.77 (Disturbance score)
Anurans	Vegetation		16	1,14	10.00	0.0069	0.42	y = 5.63 + 0.85 (Disturbance score)
Birds	Invertebrates		13	1,11	0.61	0.4505	0.05	y = 26.16 + 0.26 (Disturbance score)
Birds	Vegetation		18	1,16	10.21	0.0056	0.39	y = 23.85 + 1.13 (Disturbance score)
Birds	Invertebrates	Vegetation	13	1,11	6.10	0.0312	0.36	y = 30.02 + 0.94 (Disturbance score)
Invertebrates	Vegetation		13	1,11	11.44	0.0061	0.51	y = 2.69 + 0.79 (Disturbance score)
Scrub shrub- Headwater Floodplain								
Anurans	Birds		5	1,3	23.46	0.0168	0.89	y = 0.55 + 1.61 (Disturbance score)
Anurans	Birds	Invertebrates	5	1,3	41.92	0.0075	0.93	y = 0.50 + 1.85 (Disturbance score)
Anurans	Birds	Vegetation	5	1,3	11.14	0.0445	0.79	y = 10.20 + 2.19 (Disturbance score)
Anurans	Invertebrates	Vegetation	5	1,3	3.80	0.1462	0.56	y = 0.55 + 1.28 (Disturbance score)
Anurans	Vegetation		5	1,3	2.17	0.2372	0.42	y = 0.61 + 1.05 (Disturbance score)
Birds	Invertebrates		6	1,4	30.78	0.0052	0.88	y = 5.63 + 1.52 (Disturbance score)
Birds	Vegetation		7	1,5	56.29	0.0007	0.92	y = -4.66 + 2.44 (Disturbance score)
Birds	Invertebrates	Vegetation	6	1,4	83.28	0.0008	0.95	y = 17.58 + 2.02 (Disturbance score)
Invertebrates	Vegetation		6	1,4	2.84	0.1674	0.42	y = 13.62 + 0.68 (Disturbance score)
Scrub shrub- Depression								
Birds	Invertebrates		14	1,12	0.00	0.9451	0.00	y = 27.69 + 0.03 (Disturbance score)
Birds	Vegetation		19	1,17	6.00	0.0255	0.26	y = 26.57 + 0.89 (Disturbance score)
Birds	Invertebrates	Vegetation	14	1,12	2.77	0.1221	0.19	y = 33.10 + 0.67 (Disturbance score)
Invertebrates	Vegetation		14	1,12	10.40	0.0073	0.46	y = 4.33 + 0.73 (Disturbance score)
Scrub shrub- Floodplain								
Anurans	Birds		6	1,4	7.39	0.0531	0.65	y = -1.30 + 1.75 (Disturbance score)
Anurans	Birds	Invertebrates	5	1,3	2.18	0.2364	0.42	y = 7.11 + 1.95 (Disturbance score)
Anurans	Birds	Vegetation	6	1,4	8.53	0.0432	0.68	y = 4.51 + 2.82 (Disturbance score)
Anurans	Invertebrates	Vegetation	5	1,3	2.10	0.2430	0.41	y = 3.91 + 1.97 (Disturbance score)
Anurans	Vegetation		6	1,4	3.22	0.1471	0.45	y = -10.73 + 1.98 (Disturbance score)
Birds	Invertebrates		6	1,4	2.82	0.1681	0.41	y = 24.41 + 1.01 (Disturbance score)
Birds	Vegetation		8	1,6	38.37	0.0008	0.86	y = -3.04 + 2.62 (Disturbance score)
Birds	Invertebrates	Vegetation	6	1,4	25.30	0.0073	0.86	y = 30.31 + 2.08 (Disturbance score)
Invertebrates	Vegetation		6	1,4	3.89	0.1200	0.49	y = 14.76 + 1.26 (Disturbance score)
Cumulative Wetland IBI								

Table 4. Continued.

Wetland Classification								
Taxa group in hybrid IBI			N	df	F-value	p-value	R^2	Equation
Forested- Riparian Depression								
Anurans	Birds		8	1,6	0.04	0.8473	0.01	y = 24.92 - 0.09 (Disturbance score)
Anurans	Birds	Invertebrates	4	1,2	0.82	0.4611	0.29	y = 31.03 +- 0.41 (Disturbance score)
Anurans	Birds	Vegetation	8	1,6	0.42	0.5415	0.07	y = 45.88 + 0.46 (Disturbance score)
Anurans	Invertebrates	Vegetation	4	1,2	0.85	0.4532	0.30	y = 33.87 + 0.13 (Disturbance score)
Anurans	Vegetation		8	1,6	1.64	0.2470	0.22	y = 25.90 + 0.56 (Disturbance score)
Birds	Invertebrates		5	1,3	0.20	0.6838	0.06	y = 28.58 - 0.28 (Disturbance score)
Birds	Vegetation		12	1,10	4.39	0.0625	0.31	y = 22.56 + 1.10 (Disturbance score)
Birds	Invertebrates	Vegetation	5	1,3	0.27	0.6379	0.08	y = 39.81 + 0.51 (Disturbance score)
Invertebrates	Vegetation		5	1,3	0.43	0.8175	0.21	y = 23.73 + 0.52 (Disturbance score)
Forested- Headwater Floodplain								
Anurans	Birds		4	1,2	7.67	0.1094	0.79	y = -56.47 + 3.10 (Disturbance score)
Anurans	Birds	Invertebrates	4	1,2	7.67	0.1094	0.79	y = -46.47 + 3.10 (Disturbance score)
Anurans	Birds	Vegetation	4	1,2	19.83	0.0469	0.91	y = -74.90 + 4.95 (Disturbance score)
Anurans	Invertebrates	Vegetation	4	1,2	11.41	0.0776	0.85	y = -22.87 + 2.52 (Disturbance score)
Anurans	Vegetation		4	1,2	11.41	0.0776	0.85	y = -32.87 + 2.52 (Disturbance score)
Birds	Invertebrates		6	1,4	6.01	0.0703	0.60	y = 12.24 + 1.36 (Disturbance score)
Birds	Vegetation		7	1,5	32.60	0.0023	0.87	y = -2.54 + 2.42 (Disturbance score)
Birds	Invertebrates	Vegetation	6	1,4	12.22	0.0250	0.75	y = 15.36 + 2.51 (Disturbance score)
Invertebrates	Vegetation		6	1,4	3.68	0.1277	0.48	y = 17.14 + 1.34 (Disturbance score)
Forested-Depression								
Birds	Invertebrates		5	1,3	0.09	0.7817	0.03	y = 36.40 - 0.23 (Disturbance score)
Birds	Vegetation		14	1,12	5.72	0.0340	0.32	y = 24.94 + 1.20 (Disturbance score)
Birds	Invertebrates	Vegetation	5	1,3	0.29	0.6287	0.09	y = 40.12 + 0.64 (Disturbance score)
Invertebrates	Vegetation		5	1,3	1.06	0.3787	0.26	y = 16.21 + 0.61 (Disturbance score)
Forested-Floodplain								
Anurans	Birds		8	1,6	0.11	0.7542	0.02	y = 50.31 + 0.28 (Disturbance score)
Anurans	Birds	Invertebrates	6	1,4	2.42	0.1945	0.38	y = 44.11 + 1.15 (Disturbance score)
Anurans	Birds	Vegetation	8	1,6	2.18	0.1905	0.27	y = 55.92 + 1.76 (Disturbance score)
Anurans	Invertebrates	Vegetation	6	1,4	4.41	0.1037	0.52	y = 11.42 + 2.39 (Disturbance score)
Anurans	Vegetation		8	1,6	3.63	0.1054	0.38	y = 18.12 + 1.56 (Disturbance score)
Birds	Invertebrates		7	1,5	15.65	0.0108	0.76	y = 23.15 + 1.44 (Disturbance score)
Birds	Vegetation		11	1,9	21.00	0.0013	0.70	y = 15.79 + 2.55 (Disturbance score)
Birds	Invertebrates	Vegetation	7	1,5	18.29	0.0079	0.79	y = 25.32 + 3.07 (Disturbance score)
Invertebrates	Vegetation		7	1,5	6.97	0.0460	0.58	y = 13.18 + 1.93 (Disturbance score)

Table 5. Significant R^2 for multi-taxa, hybrid classification schemes of indices of biological integrity (IBIs) for wetlands of West Virginia, USA from 2005-2006.

			Hybrid classification							
Taxa groups in multi-taxa, hybrid classification wetland IBIs			Emergent-Riparian Depression	Emergent-Headwater Floodplain	Emergent-Depression	Emergent-Floodplain	Scrub shrub-Riparian Depression	Scrub shrub-Headwater Floodplain	Scrub shrub-Depression	Scrub shrub-Floodplain
Birds						0.52		0.94		0.85
Vegetation				0.61		0.55	0.5	0.66	0.46	0.59
Anurans	Birds		*	*		0.42	*	0.89		*
Anurans	Birds	Invertebrates	0.27	0.56		0.59	*	0.93		*
Anurans	Birds	Vegetation	*	0.58		0.58	0.32	0.79		0.68
Anurans	Invertebrates	Vegetation	0.2	0.6		0.44	0.43	*		*
Anurans	Vegetation		*	0.5		0.35	0.42	*		*
Birds	Invertebrates		0.25	0.52	0.3	0.75	*	0.88	*	*
Birds	Vegetation		*	0.61	0.11	0.75	0.39	0.92	0.26	0.86
Birds	Invertebrates	Vegetation	*	0.72	0.33	0.78	0.36	0.95	*	0.86
Invertebrates	Vegetation		*	0.69	0.25	0.65	0.51	*	0.46	*

Table 5. Continued.

Taxa groups in multi-taxa, hybrid classification wetland IBIs			Hybrid classification: Forested-Riparian Depression	Forested-Headwater Floodplain	Forested-Depression	Forested-Floodplain
Birds				0.76		0.42
Vegetation			0.41	0.84	0.42	0.68
Anurans	Birds		*	*		*
Anurans	Birds	Invertebrates	*	*		*
Anurans	Birds	Vegetation	*	0.91		*
Anurans	Invertebrates	Vegetation	*	*		*
Anurans	Vegetation		*	*		*
Birds	Invertebrates		*	*	*	0.76
Birds	Vegetation		*	0.87	0.32	0.7
Birds	Invertebrates	Vegetation	*	0.75	*	0.79
Invertebrates	Vegetation		*	*	*	0.58

* Indicates not a significant relation with disturbance score.

Table 6. Avian community sampling summary statistics of metric scores statewide and by ecoregion used to form acoustically-based avian wetland indices of biological integrity (AW-IBI) for wetlands in West Virginia, USA 2005-2006.

Ecoregion/ metric				
Statewide (N=151)	Mean	Std. Error	Minimum	Maximum
Proportion of neotropical migrants	0.30	0.01	0.05	0.71
Proportion of habitat specific birds	0.27	0.01	0.00	0.71
Proportion of neotropical migrants- habitat specific birds	0.17	0.01	0.00	0.57
Proportion of forest-area sensitive birds	0.10	0.01	0.00	0.74
Proportion of year-round residential and edge-tolerant birds	0.49	0.02	0.05	0.88
Shannon-Weaver diversity index	5.77	0.06	2.49	7.35
Proportion of carnivorous-habitat specific species	0.18	0.01	0.00	0.62
Proportion of single-brood species	0.39	0.01	0.00	0.76
Proportion of insectivorous species	0.35	0.01	0.04	0.79
Proportion of omnivorous species	0.52	0.01	0.19	0.88
Bird abundance	14.85	0.64	1.00	40.00
Allegheny Highlands (N=65)				
Proportion of neotropical migrants	0.30	0.02	0.05	0.68
Proportion of habitat specific birds	0.25	0.02	0.00	0.71
Proportion of neotropical migrants- habitat specific birds	0.17	0.02	0.00	0.53
Proportion of forest-area sensitive birds	0.11	0.02	0.00	0.74
Proportion of year-round residential and edge-tolerant birds	0.48	0.02	0.11	0.88
Shannon-Weaver diversity index	5.68	0.08	3.63	7.05
Proportion of carnivorous-habitat specific species	0.17	0.01	0.00	0.62
Proportion of single-brood species	0.40	0.02	0.00	0.70
Proportion of insectivorous species	0.35	0.02	0.04	0.76
Proportion of omnivorous species	0.53	0.02	0.19	0.88
Bird abundance	13.05	0.72	4.00	26.00

Table 6. Continued.

Ecoregion/ metric				
Ridge and Valley (N=27)	Mean	Std. Error	Minimum	Maximum
Proportion of neotropical migrants	0.25	0.03	0.07	0.63
Proportion of habitat specific birds	0.26	0.03	0.00	0.57
Proportion of neotropical migrants- habitat specific birds	0.14	0.02	0.00	0.40
Proportion of forest-area sensitive birds	0.09	0.02	0.00	0.36
Proportion of year-round residential and edge-tolerant birds	0.52	0.04	0.05	0.87
Shannon-Weaver diversity index	5.48	0.17	2.49	6.55
Proportion of carnivorous-habitat specific species	0.16	0.02	0.00	0.47
Proportion of single-brood species	0.37	0.04	0.04	0.76
Proportion of insectivorous species	0.34	0.03	0.09	0.73
Proportion of omnivorous species	0.51	0.03	0.25	0.85
Bird abundance	14.93	2.00	1.00	40.00
Western Allegheny Plateau (N=59)	Mean	Std. Error	Minimum	Maximum
Proportion of neotropical migrants	0.31	0.02	0.05	0.71
Proportion of habitat specific birds	0.29	0.02	0.07	0.64
Proportion of neotropical migrants- habitat specific birds	0.18	0.02	0.00	0.57
Proportion of forest-area sensitive birds	0.09	0.01	0.00	0.50
Proportion of year-round residential and edge-tolerant birds	0.48	0.02	0.11	0.86
Shannon-Weaver diversity index	6.00	0.09	3.86	7.35
Proportion of carnivorous-habitat specific species	0.19	0.01	0.03	0.57
Proportion of single-brood species	0.39	0.02	0.10	0.74
Proportion of insectivorous species	0.35	0.02	0.07	0.79
Proportion of omnivorous species	0.52	0.02	0.21	0.76
Bird abundance	16.80	1.08	4.00	38.00

Table 7. Anuran community sampling summary statistics of metric scores statewide and by ecoregion used to form acoustically-based anuran indices of biological integrity (AA-IBI) for wetlands in West Virginia, USA 2005-2006.

Ecoregion/ metric				
Statewide (N=133)	Mean	Std. Error	Minimum	Maximum
Anuran relative Shannon-Weaver diversity	2.67	0.10	0.00	4.68
Proportion of sensitive anurans	0.16	0.01	0.00	0.57
Proportion of anuran species-of-concern	0.03	0.01	0.00	0.50
Proportion of tolerant anurans	0.74	0.02	0.20	1.00
Proportion of wood frog chorus	0.10	0.01	0.00	0.40
Anuran richness	3.81	0.15	1.00	8.00
Total anuran abundance	6.13	0.24	2.00	14.00
Shannon's evenness	0.30	0.01	0.00	0.37
Anuran quality assessment index	3.08	0.07	1.50	5.20
Anuran mean coefficient of conservatism	3.22	0.08	1.50	5.25
Proportion of upland sensitive anurans	0.13	0.01	0.00	0.43
Proportion of upland tolerant anurans	0.51	0.02	0.00	1.00
Proportion of fish-tolerant anurans	0.17	0.01	0.00	1.00
Allegheny Highlands (N=59)				
Anuran relative Shannon-Weaver diversity	2.27	0.16	0.00	4.68
Proportion of sensitive anurans	0.11	0.02	0.00	0.50
Proportion of anuran species-of-concern	0.03	0.01	0.00	0.50
Proportion of tolerant anurans	0.80	0.03	0.44	1.00
Proportion of wood frog chorus	0.08	0.02	0.00	0.33
Anuran richness	3.27	0.21	1.00	8.00
Total anuran abundance	5.37	0.33	2.00	13.00
Shannon's evenness	0.28	0.02	0.00	0.37
Anuran quality assessment index	2.82	0.11	1.50	4.50
Anuran mean coefficient of conservatism	2.94	0.13	1.50	5.25
Proportion of upland sensitive anurans	0.11	0.02	0.00	0.43
Proportion of upland tolerant anurans	0.60	0.03	0.22	1.00
Proportion of fish-tolerant anurans	0.13	0.02	0.00	0.50

Table 7. Continued.

Ecoregion/ metric *Ridge and Valley (N=21)*	Mean	Std. Error	Minimum	Maximum
Anuran relative Shannon-Weaver diversity	2.39	0.20	0.00	3.85
Proportion of sensitive anurans	0.22	0.03	0.00	0.43
Proportion of anuran species-of-concern	0.01	0.01	0.00	0.20
Proportion of tolerant anurans	0.73	0.03	0.50	1.00
Proportion of wood frog chorus	0.14	0.03	0.00	0.40
Anuran richness	3.24	0.27	1.00	6.00
Total anuran abundance	5.29	0.51	2.00	11.00
Shannon's evenness	0.31	0.02	0.00	0.37
Anuran quality assessment index	3.16	0.16	1.67	4.17
Anuran mean coefficient of conservatism	3.43	0.20	1.50	4.67
Proportion of upland sensitive anurans	0.14	0.03	0.00	0.40
Proportion of upland tolerant anurans	0.58	0.04	0.33	1.00
Proportion of fish-tolerant anurans	0.14	0.03	0.00	0.50
Western Allegheny Plateau (N=53)				
Anuran relative Shannon-Weaver diversity	3.23	0.11	1.47	4.56
Proportion of sensitive anurans	0.19	0.02	0.00	0.57
Proportion of anuran species-of-concern	0.03	0.01	0.00	0.50
Proportion of tolerant anurans	0.67	0.03	0.20	1.00
Proportion of wood frog chorus	0.10	0.02	0.00	0.40
Anuran richness	4.64	0.21	2.00	8.00
Total anuran abundance	7.30	0.39	2.00	14.00
Shannon's evenness	0.31	0.00	0.25	0.37
Anuran quality assessment index	3.33	0.11	1.60	5.20
Anuran mean coefficient of conservatism	3.44	0.12	1.67	4.67
Proportion of upland sensitive anurans	0.14	0.02	0.00	0.40
Proportion of upland tolerant anurans	0.38	0.02	0.00	0.80
Proportion of fish-tolerant anurans	0.23	0.02	0.00	1.00

Table 8. Vegetation community sampling summary statistics of metric scores statewide and by ecoregion used to form vegetation indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA 2005-2006.

Ecoregion/ metric				
Statewide (N=151)	Mean	Std. Error	Minimum	Maximum
West Virginia floristic quality index	25.47	0.44	10.17	40.85
Pennsylvania-formula floristic quality index	22.71	0.43	10.17	34.26
Mean coefficient of conservatism	4.39	0.05	2.83	6.46
Adjusted-formula floristic quality index	42.17	0.63	23.59	64.59
Obligate species herbaceous relative cover	0.50	0.03	0.00	1.00
Facultative wet and wetter species herbaceous relative cover	0.78	0.02	0.00	1.00
Facultative wetter species herbaceous relative cover	0.81	0.02	0.00	1.00
Facultative-only species herbaceous relative cover	0.03	0.01	0.00	0.33
Native shrub hydrophyte proportionate cover	0.21	0.03	0.00	1.70
Carex spp. walk-through richness	2.93	0.17	0.00	8.00
Invasive graminoid walk-through richness	0.50	0.07	0.00	4.00
Native plant walk-through richness	28.36	0.91	5.00	64.00
Non-native plant walk-through richness	3.03	0.26	0.00	14.00
Native hydrophyte walk-through richness	23.02	0.72	5.00	48.00
Native hydrophyte herbaceous richness	9.68	0.39	0.00	23.00
Native dicot walk-through richness	16.96	0.63	2.00	48.00
Native dicot herbaceous richness	5.91	0.31	0.00	16.00
Shrub richness	2.66	0.21	0.00	15.00
Native shrub richness	2.33	0.19	0.00	14.00
Non-native shrub richness	0.21	0.04	0.00	3.00
Tree richness	3.34	0.57	0.00	36.00
Mean IV	17.46	2.58	0.00	100.00
Facultative trees and wetter Mean IV	14.93	2.43	0.00	100.00
Facultative-wet trees and wetter Mean IV	12.23	2.31	0.00	100.00
Mean dbh	6.84	0.90	0.00	40.15
Fern and fern allies relative cover	0.02	0.01	0.00	0.77
Monocots relative cover	0.51	0.02	0.00	1.00
Native graminoid relative cover	0.41	0.02	0.00	1.00
Invasive graminoid relative cover	0.02	0.00	0.00	0.35
Native dicot relative cover	0.32	0.02	0.00	1.00
Dicot relative cover	0.37	0.02	0.00	1.00
Carex spp. relative cover	0.07	0.01	0.00	0.77
Non-native plant relative cover	0.06	0.01	0.00	0.60
Phalaris relative cover	0.06	0.02	0.00	0.99
Sensitive species relative cover	0.08	0.01	0.00	1.00
Tolerant species relative cover	0.13	0.02	0.00	0.99
Bryophyte relative cover	0.05	0.01	0.00	0.54
Native hydrophyte herbaceous relative cover	0.78	0.02	0.00	1.00
Phalaris and invasive graminoid relative cover	0.08	0.02	0.00	0.99
Native shrub proportionate cover	0.26	0.03	0.00	1.70
Non-native shrub proportionate cover	0.01	0.00	0.00	0.25

Table 8. Continued.

Ecoregion/ metric *Allegheny Highlands (N=65)*	Mean	Std. Error	Minimum	Maximum
West Virginia floristic quality index	27.37	0.71	10.17	40.85
Pennsylvania-formula floristic quality index	24.98	0.65	10.17	34.26
Mean coefficient of conservatism	4.48	0.07	2.83	5.62
Adjusted-formula floristic quality index	43.50	0.80	23.59	56.24
Obligate species herbaceous relative cover	0.45	0.04	0.00	1.00
Facultative wet and wetter species herbaceous relative cover	0.77	0.03	0.11	1.00
Facultative wetter species herbaceous relative cover	0.81	0.03	0.25	1.00
Facultative-only species herbaceous relative cover	0.04	0.01	0.00	0.33
Native shrub hydrophyte proportionate cover	0.26	0.05	0.00	1.65
Carex spp. walk-through richness	3.35	0.24	0.00	8.00
Invasive graminoid walk-through richness	0.59	0.12	0.00	4.00
Native plant walk-through richness	32.31	1.46	6.00	64.00
Non-native plant walk-through richness	2.62	0.38	0.00	14.00
Native hydrophyte walk-through richness	26.63	1.11	6.00	48.00
Native hydrophyte herbaceous richness	11.02	0.63	1.00	23.00
Native dicot walk-through richness	19.59	1.07	4.00	48.00
Native dicot herbaceous richness	6.85	0.54	0.00	16.00
Shrub richness	2.99	0.38	0.00	15.00
Native shrub richness	2.65	0.34	0.00	14.00
Non-native shrub richness	0.20	0.06	0.00	3.00
Tree richness	3.71	0.99	0.00	36.00
Mean IV	17.30	3.86	0.00	100.00
Facultative trees and wetter Mean IV	14.59	3.55	0.00	100.00
Facultative-wet trees and wetter Mean IV	10.63	3.31	0.00	100.00
Mean dbh	7.10	1.41	0.00	40.15
Fern and fern allies relative cover	0.02	0.01	0.00	0.23
Monocots relative cover	0.49	0.04	0.06	1.00
Native graminoid relative cover	0.45	0.04	0.01	1.00
Invasive graminoid relative cover	0.01	0.00	0.00	0.23
Native dicot relative cover	0.35	0.03	0.00	0.91
Dicot relative cover	0.37	0.03	0.00	0.91
Carex spp. relative cover	0.08	0.01	0.00	0.53
Non-native plant relative cover	0.03	0.01	0.00	0.33
Phalaris relative cover	0.05	0.02	0.00	0.99
Sensitive species relative cover	0.04	0.01	0.00	0.40
Tolerant species relative cover	0.09	0.02	0.00	0.99
Bryophyte relative cover	0.07	0.02	0.00	0.54
Native hydrophyte herbaceous relative cover	0.80	0.03	0.25	1.00
Phalaris and invasive graminoid relative cover	0.07	0.02	0.00	0.99
Native shrub proportionate cover	0.31	0.05	0.00	1.65
Non-native shrub proportionate cover	0.01	0.00	0.00	0.19

Table 8. Continued.

Ecoregion/ metric *Ridge and Valley (N=27)*	Mean	Std. Error	Minimum	Maximum
West Virginia floristic quality index	23.97	1.01	15.41	33.66
Pennsylvania-formula floristic quality index	21.11	1.05	12.66	32.82
Mean coefficient of conservatism	4.56	0.18	3.16	6.46
Adjusted-formula floristic quality index	43.79	2.07	28.47	64.59
Obligate species herbaceous relative cover	0.46	0.07	0.00	1.00
Facultative wet and wetter species herbaceous relative cover	0.75	0.04	0.30	1.00
Facultative wetter species herbaceous relative cover	0.79	0.04	0.41	1.00
Facultative-only species herbaceous relative cover	0.04	0.02	0.00	0.31
Native shrub hydrophyte proportionate cover	0.09	0.03	0.00	0.68
Carex spp. walk-through richness	1.93	0.30	0.00	6.00
Invasive graminoid walk-through richness	0.30	0.13	0.00	3.00
Native plant walk-through richness	22.41	1.63	10.00	40.00
Non-native plant walk-through richness	2.70	0.65	0.00	14.00
Native hydrophyte walk-through richness	17.96	1.47	6.00	35.00
Native hydrophyte herbaceous richness	7.19	0.60	1.00	13.00
Native dicot walk-through richness	12.74	1.10	3.00	25.00
Native dicot herbaceous richness	4.63	0.49	0.00	9.00
Shrub richness	1.74	0.33	0.00	5.00
Native shrub richness	1.56	0.29	0.00	5.00
Non-native shrub richness	0.19	0.09	0.00	2.00
Tree richness	3.00	1.21	0.00	21.00
Mean IV	7.75	3.18	0.00	50.00
Facultative trees and wetter Mean IV	6.19	2.68	0.00	50.00
Facultative-wet trees and wetter Mean IV	5.30	2.60	0.00	50.00
Mean dbh	5.50	2.09	0.00	34.73
Fern and fern allies relative cover	0.05	0.03	0.00	0.77
Monocots relative cover	0.45	0.06	0.00	1.00
Native graminoid relative cover	0.36	0.06	0.00	1.00
Invasive graminoid relative cover	0.02	0.02	0.00	0.35
Native dicot relative cover	0.31	0.05	0.00	0.78
Dicot relative cover	0.40	0.06	0.00	0.98
Carex spp. relative cover	0.06	0.03	0.00	0.60
Non-native plant relative cover	0.12	0.04	0.00	0.58
Phalaris relative cover	0.06	0.03	0.00	0.72
Sensitive species relative cover	0.06	0.02	0.00	0.34
Tolerant species relative cover	0.18	0.05	0.00	0.73
Bryophyte relative cover	0.07	0.03	0.00	0.49
Native hydrophyte herbaceous relative cover	0.72	0.05	0.25	1.00
Phalaris and invasive graminoid relative cover	0.09	0.04	0.00	0.72
Native shrub proportionate cover	0.12	0.03	0.00	0.68
Non-native shrub proportionate cover	0.01	0.01	0.00	0.25

Table 8. Continued.

Ecoregion/ metric *Western Allegheny Plateau (N=59)*	Mean	Std. Error	Minimum	Maximum
West Virginia floristic quality index	24.06	0.58	14.22	34.17
Pennsylvania-formula floristic quality index	20.95	0.53	12.55	31.17
Mean coefficient of conservatism	4.20	0.08	3.20	6.36
Adjusted-formula floristic quality index	39.97	0.90	26.94	63.57
Obligate species herbaceous relative cover	0.56	0.05	0.00	1.00
Facultative wet and wetter species herbaceous relative cover	0.80	0.03	0.00	1.00
Facultative wetter species herbaceous relative cover	0.83	0.03	0.00	1.00
Facultative-only species herbaceous relative cover	0.03	0.01	0.00	0.22
Native shrub hydrophyte proportionate cover	0.21	0.04	0.00	1.70
Carex spp. walk-through richness	2.92	0.28	0.00	7.00
Invasive graminoid walk-through richness	0.49	0.10	0.00	3.00
Native plant walk-through richness	26.75	1.29	5.00	52.00
Non-native plant walk-through richness	3.63	0.40	0.00	13.00
Native hydrophyte walk-through richness	21.36	0.97	5.00	37.00
Native hydrophyte herbaceous richness	9.34	0.61	0.00	20.00
Native dicot walk-through richness	16.00	0.85	2.00	30.00
Native dicot herbaceous richness	5.46	0.43	0.00	14.00
Shrub richness	2.73	0.32	0.00	9.00
Native shrub richness	2.32	0.27	0.00	7.00
Non-native shrub richness	0.22	0.06	0.00	2.00
Tree richness	3.10	0.82	0.00	29.00
Mean IV	22.09	4.75	0.00	100.00
Facultative trees and wetter Mean IV	19.29	4.63	0.00	100.00
Facultative-wet trees and wetter Mean IV	17.17	4.45	0.00	100.00
Mean dbh	7.15	1.41	0.00	35.44
Fern and fern allies relative cover	0.01	0.01	0.00	0.22
Monocots relative cover	0.56	0.04	0.00	0.98
Native graminoid relative cover	0.37	0.04	0.00	0.95
Invasive graminoid relative cover	0.02	0.01	0.00	0.28
Native dicot relative cover	0.29	0.03	0.00	1.00
Dicot relative cover	0.36	0.04	0.00	1.00
Carex spp. relative cover	0.06	0.02	0.00	0.77
Non-native plant relative cover	0.07	0.02	0.00	0.60
Phalaris relative cover	0.07	0.03	0.00	0.93
Sensitive species relative cover	0.12	0.03	0.00	1.00
Tolerant species relative cover	0.15	0.03	0.00	0.93
Bryophyte relative cover	0.01	0.01	0.00	0.36
Native hydrophyte herbaceous relative cover	0.79	0.03	0.00	1.00
Phalaris and invasive graminoid relative cover	0.09	0.03	0.00	0.93
Native shrub proportionate cover	0.25	0.05	0.00	1.70
Non-native shrub proportionate cover	0.01	0.01	0.00	0.19

Table 9. Macroinvertebrate community sampling summary statistics of metric scores statewide and by ecoregion used to form macroinvertebrate indices of biological integrity (Mac-IBI) for wetlands in West Virginia, USA 2005-2006.

Ecoregion/ metric				
Benthic and Nektonic Sampling Statewide (N=106)	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.25	0.03	0.00	0.99
% Biomass collectors	0.33	0.03	0.00	0.98
% Biomass collectors *	0.40	0.03	0.00	0.98
% Biomass predators	0.24	0.03	0.00	0.98
% Biomass predators *	0.31	0.03	0.00	1.00
% Biomass shredders	0.07	0.01	0.00	0.78
% Biomass shredders *	0.08	0.02	0.00	0.90
% Biomass Chironomidae	0.05	0.01	0.00	0.89
% Biomass Coleoptera	0.10	0.02	0.00	0.97
% Biomass Coleoptera *	0.11	0.02	0.00	0.99
% Biomass Dytiscidae	0.03	0.01	0.00	0.76
% Biomass Corixidae	0.03	0.01	0.00	0.78
% Biomass Corixidae *	0.03	0.01	0.00	0.78
% Biomass Coleoptera and Corixidae	0.03	0.01	0.00	0.97
% Biomass Libellulidae	0.13	0.02	0.00	0.97
% Biomass Libellulidae *	0.15	0.02	0.00	0.99
% Biomass Odonata - Libellulidae	0.07	0.02	0.00	0.73
% Biomass Odonata - Libellulidae *	0.09	0.02	0.00	0.76
% Biomass Odonata	0.04	0.01	0.00	0.50
% Biomass Odonata *	0.06	0.01	0.00	0.87
Relative abundance EPA stressed	0.11	0.02	0.00	0.95
Relative abundance collector	0.14	0.02	0.00	0.96
Relative abundance collector *	0.29	0.02	0.00	0.88
Relative abundance predator	0.24	0.02	0.00	0.81
Relative abundance predator *	0.34	0.02	0.00	0.97
Relative abundance shredder	0.19	0.02	0.00	0.80
Relative abundance shredder *	0.29	0.02	0.00	1.00
Relative abundance Chironomidae	0.08	0.01	0.00	0.61
Relative abundance Coleoptera	0.11	0.02	0.00	0.76
Relative abundance Coleoptera *	0.19	0.02	0.00	0.77
Relative abundance Dytiscidae	0.08	0.01	0.00	0.70
Relative abundance Dytiscidae *	0.12	0.02	0.00	0.85
Relative abundance Coleoptera and Corixidae	0.04	0.01	0.00	0.63
Relative abundance Corixidae	0.05	0.01	0.00	0.76
Relative abundance Corixidae *	0.12	0.01	0.00	0.80
Relative abundance Libellulidae	0.17	0.02	0.00	0.95
Relative abundance Libellulidae *	0.04	0.01	0.00	0.80
Relative abundance Libellulidae	0.06	0.01	0.00	0.95
Relative abundance Libellulidae *	0.02	0.00	0.00	0.20
Relative abundance Odonata	0.03	0.01	0.00	0.29
Relative abundance Odonata *	0.04	0.01	0.00	0.50

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric *Allegheny Highlands Benthic and Nektonic Sampling (N=46)*	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.23	0.04	0.00	0.89
% Biomass collectors	0.30	0.05	0.00	0.88
% Biomass collectors *	0.37	0.05	0.00	0.90
% Biomass predators	0.23	0.04	0.00	0.97
% Biomass predators *	0.31	0.05	0.00	0.99
% Biomass shredders	0.07	0.02	0.00	0.67
% Biomass shredders *	0.09	0.02	0.00	0.69
% Biomass Chironomidae	0.08	0.02	0.00	0.89
% Biomass Coleoptera	0.10	0.03	0.00	0.86
% Biomass Coleoptera *	0.12	0.03	0.00	0.89
% Biomass Dytiscidae	0.03	0.01	0.00	0.29
% Biomass Corixidae	0.03	0.01	0.00	0.32
% Biomass Corixidae *	0.03	0.01	0.00	0.25
% Biomass Coleoptera and Corixidae	0.04	0.01	0.00	0.28
% Biomass Libellulidae	0.13	0.03	0.00	0.86
% Biomass Libellulidae *	0.16	0.03	0.00	0.89
% Biomass Odonata - Libellulidae	0.08	0.02	0.00	0.73
% Biomass Odonata - Libellulidae *	0.11	0.03	0.00	0.76
% Biomass Odonata	0.04	0.01	0.00	0.50
% Biomass Odonata *	0.05	0.02	0.00	0.53
Relative abundance EPA stressed	0.11	0.03	0.00	0.73
Relative abundance collector	0.15	0.03	0.00	0.81
Relative abundance collector *	0.34	0.03	0.00	0.80
Relative abundance predator	0.19	0.03	0.00	0.74
Relative abundance predator *	0.31	0.03	0.00	0.89
Relative abundance shredder	0.16	0.02	0.00	0.80
Relative abundance shredder *	0.27	0.03	0.00	0.80
Relative abundance Chironomidae	0.10	0.02	0.00	0.61
Relative abundance Coleoptera	0.14	0.03	0.00	0.76
Relative abundance Coleoptera *	0.25	0.03	0.00	0.77
Relative abundance Dytiscidae	0.07	0.01	0.00	0.47
Relative abundance Dytiscidae *	0.12	0.02	0.00	0.81
Relative abundance Coleoptera and Corixidae	0.03	0.01	0.00	0.20
Relative abundance Corixidae	0.04	0.01	0.00	0.21
Relative abundance Corixidae *	0.11	0.02	0.00	0.47
Relative abundance Libellulidae	0.18	0.03	0.00	0.81
Relative abundance Libellulidae *	0.04	0.01	0.00	0.33
Relative abundance Libellulidae	0.07	0.02	0.00	0.50
Relative abundance Libellulidae *	0.03	0.01	0.00	0.20
Relative abundance Odonata	0.04	0.01	0.00	0.29
Relative abundance Odonata *	0.04	0.01	0.00	0.50

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric				
Ridge and Valley Benthic and Nektonic Sampling (N=21)	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.24	0.06	0.00	0.99
% Biomass collectors	0.38	0.07	0.00	0.98
% Biomass collectors *	0.40	0.08	0.00	0.98
% Biomass predators	0.19	0.04	0.00	0.76
% Biomass predators *	0.24	0.06	0.00	1.00
% Biomass shredders	0.08	0.04	0.00	0.78
% Biomass shredders *	0.11	0.05	0.00	0.90
% Biomass Chironomidae	0.05	0.03	0.00	0.54
% Biomass Coleoptera	0.10	0.03	0.00	0.63
% Biomass Coleoptera *	0.11	0.04	0.00	0.74
% Biomass Dytiscidae	0.02	0.01	0.00	0.23
% Biomass Corixidae	0.02	0.01	0.00	0.24
% Biomass Corixidae *	0.01	0.01	0.00	0.10
% Biomass Coleoptera and Corixidae	0.01	0.01	0.00	0.10
% Biomass Libellulidae	0.11	0.03	0.00	0.63
% Biomass Libellulidae *	0.12	0.04	0.00	0.74
% Biomass Odonata - Libellulidae	0.04	0.03	0.00	0.68
% Biomass Odonata - Libellulidae *	0.04	0.03	0.00	0.68
% Biomass Odonata	0.03	0.01	0.00	0.28
% Biomass Odonata *	0.03	0.01	0.00	0.28
Relative abundance EPA stressed	0.07	0.04	0.00	0.73
Relative abundance collector	0.07	0.04	0.00	0.73
Relative abundance collector *	0.30	0.05	0.00	0.83
Relative abundance predator	0.29	0.05	0.00	0.79
Relative abundance predator *	0.38	0.06	0.00	0.80
Relative abundance shredder	0.17	0.03	0.00	0.54
Relative abundance shredder *	0.28	0.06	0.00	1.00
Relative abundance Chironomidae	0.12	0.04	0.00	0.55
Relative abundance Coleoptera	0.15	0.04	0.00	0.62
Relative abundance Coleoptera *	0.21	0.04	0.00	0.65
Relative abundance Dytiscidae	0.09	0.02	0.00	0.38
Relative abundance Dytiscidae *	0.11	0.03	0.00	0.55
Relative abundance Coleoptera and Corixidae	0.04	0.01	0.00	0.21
Relative abundance Corixidae	0.05	0.02	0.00	0.22
Relative abundance Corixidae *	0.12	0.03	0.00	0.52
Relative abundance Libellulidae	0.15	0.04	0.00	0.63
Relative abundance Libellulidae *	0.03	0.02	0.00	0.48
Relative abundance Libellulidae	0.04	0.03	0.00	0.58
Relative abundance Libellulidae *	0.01	0.01	0.00	0.17
Relative abundance Odonata	0.02	0.01	0.00	0.21
Relative abundance Odonata *	0.03	0.01	0.00	0.28

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric *Western Allegheny Plateau Benthic and Nektonic Sampling (N=39)*	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.27	0.05	0.00	0.85
% Biomass collectors	0.35	0.05	0.00	0.97
% Biomass collectors *	0.43	0.05	0.00	0.97
% Biomass predators	0.28	0.05	0.00	0.98
% Biomass predators *	0.34	0.06	0.00	1.00
% Biomass shredders	0.05	0.02	0.00	0.63
% Biomass shredders *	0.07	0.02	0.00	0.63
% Biomass Chironomidae	0.02	0.01	0.00	0.27
% Biomass Coleoptera	0.10	0.03	0.00	0.97
% Biomass Coleoptera *	0.11	0.03	0.00	0.99
% Biomass Dytiscidae	0.05	0.02	0.00	0.76
% Biomass Corixidae	0.05	0.02	0.00	0.78
% Biomass Corixidae *	0.04	0.02	0.00	0.78
% Biomass Coleoptera and Corixidae	0.04	0.03	0.00	0.97
% Biomass Libellulidae	0.14	0.04	0.00	0.97
% Biomass Libellulidae *	0.15	0.04	0.00	0.99
% Biomass Odonata - Libellulidae	0.07	0.03	0.00	0.67
% Biomass Odonata - Libellulidae *	0.09	0.03	0.00	0.67
% Biomass Odonata	0.06	0.02	0.00	0.30
% Biomass Odonata *	0.08	0.03	0.00	0.87
Relative abundance EPA stressed	0.13	0.03	0.00	0.95
Relative abundance collector	0.17	0.04	0.00	0.96
Relative abundance collector *	0.24	0.03	0.00	0.88
Relative abundance predator	0.26	0.03	0.00	0.81
Relative abundance predator *	0.35	0.04	0.00	0.97
Relative abundance shredder	0.22	0.03	0.00	0.70
Relative abundance shredder *	0.32	0.04	0.00	1.00
Relative abundance Chironomidae	0.05	0.01	0.00	0.31
Relative abundance Coleoptera	0.06	0.02	0.00	0.36
Relative abundance Coleoptera *	0.12	0.02	0.00	0.60
Relative abundance Dytiscidae	0.10	0.02	0.00	0.70
Relative abundance Dytiscidae *	0.12	0.03	0.00	0.85
Relative abundance Coleoptera and Corixidae	0.05	0.02	0.00	0.63
Relative abundance Corixidae	0.06	0.02	0.00	0.76
Relative abundance Corixidae *	0.14	0.03	0.00	0.80
Relative abundance Libellulidae	0.17	0.03	0.00	0.95
Relative abundance Libellulidae *	0.04	0.02	0.00	0.80
Relative abundance Libellulidae	0.05	0.03	0.00	0.95
Relative abundance Libellulidae *	0.01	0.00	0.00	0.10
Relative abundance Odonata	0.02	0.01	0.00	0.17
Relative abundance Odonata *	0.06	0.02	0.00	0.30

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric				
Benthic Sampling Statewide (N=140)	Mean	Std. Error	Minimum	Maximum
% Biomass collector	0.35	0.03	0.00	1.34
% Biomass collector *	0.51	0.04	0.00	1.65
% Biomass predator	0.07	0.02	0.00	1.00
% Biomass predator *	0.13	0.02	0.00	1.00
% Biomass shredder	0.07	0.02	0.00	1.00
% Biomass shredder *	0.09	0.02	0.00	1.00
Relative abundance collector	0.26	0.02	0.00	1.00
Relative abundance collector *	0.42	0.03	0.00	1.00
Relative abundance predator	0.11	0.01	0.00	1.00
Relative abundance predator *	0.19	0.02	0.00	1.00
Relative abundance shredder	0.04	0.01	0.00	1.00
Relative abundance shredder *	0.07	0.01	0.00	1.00
% Biomass EPA stressed	0.13	0.02	0.00	1.00
Relative abundance EPA stressed	0.13	0.02	0.00	1.00
% Biomass Chironomidae	0.05	0.02	0.00	1.00
Relative abundance of Chironomidae	0.09	0.01	0.00	0.83
% Biomass Coleoptera	0.06	0.01	0.00	0.84
% Biomass Coleoptera *	0.10	0.02	0.00	1.00
Relative abundance Coleoptera	0.04	0.01	0.00	0.50
Relative abundance Coleoptera *	0.08	0.01	0.00	1.00
Family Richness	4.31	0.23	1.00	14.00
Allegheny Highlands Benthic Sampling (N=62)	Mean	Std. Error	Minimum	Maximum
% Biomass collector	0.25	0.04	0.00	1.00
% Biomass collector *	0.40	0.05	0.00	1.00
% Biomass predator	0.07	0.02	0.00	1.00
% Biomass predator *	0.16	0.04	0.00	1.00
% Biomass shredder	0.10	0.03	0.00	1.00
% Biomass shredder *	0.14	0.04	0.00	1.00
Relative abundance collector	0.17	0.03	0.00	1.00
Relative abundance collector *	0.31	0.04	0.00	1.00
Relative abundance predator	0.12	0.02	0.00	1.00
Relative abundance predator *	0.24	0.04	0.00	1.00
Relative abundance shredder	0.07	0.02	0.00	1.00
Relative abundance shredder *	0.12	0.03	0.00	1.00
% Biomass EPA stressed	0.08	0.02	0.00	1.00
Relative abundance EPA stressed	0.12	0.02	0.00	0.69
% Biomass Chironomidae	0.04	0.02	0.00	1.00
Relative abundance of Chironomidae	0.10	0.02	0.00	0.69
% Biomass Coleoptera	0.06	0.02	0.00	0.84
% Biomass Coleoptera *	0.13	0.04	0.00	1.00
Relative abundance Coleoptera	0.05	0.01	0.00	0.50
Relative abundance Coleoptera *	0.11	0.03	0.00	1.00
Family Richness	4.60	0.38	1.00	14.00

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric	Mean	Std. Error	Minimum	Maximum
Ridge and Valley Benthic Sampling (N=25)				
% Biomass collector	0.40	0.08	0.00	1.01
% Biomass collector *	0.48	0.09	0.00	1.02
% Biomass predator	0.02	0.01	0.00	0.13
% Biomass predator *	0.08	0.04	0.00	1.00
% Biomass shredder	0.05	0.04	0.00	0.98
% Biomass shredder *	0.05	0.04	0.00	0.98
Relative abundance collector	0.35	0.07	0.00	1.00
Relative abundance collector *	0.50	0.09	0.00	1.25
Relative abundance predator	0.12	0.04	0.00	0.75
Relative abundance predator *	0.20	0.06	0.00	1.00
Relative abundance shredder	0.02	0.02	0.00	0.36
Relative abundance shredder *	0.03	0.02	0.00	0.36
% Biomass EPA stressed	0.25	0.07	0.00	1.00
Relative abundance EPA stressed	0.17	0.04	0.00	0.63
% Biomass Chironomidae	0.11	0.06	0.00	1.00
Relative abundance of Chironomidae	0.11	0.04	0.00	0.63
% Biomass Coleoptera	0.09	0.04	0.00	0.78
% Biomass Coleoptera *	0.10	0.05	0.00	0.95
Relative abundance Coleoptera	0.04	0.02	0.00	0.50
Relative abundance Coleoptera *	0.05	0.03	0.00	0.67
Family Richness	4.04	0.54	1.00	9.00
Western Allegheny Plateau Benthic Sampling (N=53)		Std. Error	Minimum	Maximum
% Biomass collector	0.44	0.06	0.00	1.34
% Biomass collector *	0.64	0.06	0.00	1.65
% Biomass predator	0.08	0.03	0.00	0.98
% Biomass predator *	0.11	0.04	0.00	1.00
% Biomass shredder	0.03	0.02	0.00	0.82
% Biomass shredder *	0.04	0.02	0.00	0.84
Relative abundance collector	0.32	0.04	0.00	1.00
Relative abundance collector *	0.51	0.05	0.00	1.00
Relative abundance predator	0.08	0.02	0.00	0.60
Relative abundance predator *	0.14	0.03	0.00	1.00
Relative abundance shredder	0.01	0.01	0.00	0.20
Relative abundance shredder *	0.02	0.01	0.00	0.20
% Biomass EPA stressed	0.15	0.04	0.00	1.00
Relative abundance EPA stressed	0.13	0.03	0.00	1.00
% Biomass Chironomidae	0.04	0.02	0.00	0.80
Relative abundance of Chironomidae	0.07	0.02	0.00	0.83
% Biomass Coleoptera	0.04	0.02	0.00	0.75
% Biomass Coleoptera *	0.07	0.03	0.00	0.90
Relative abundance Coleoptera	0.04	0.01	0.00	0.50
Relative abundance Coleoptera *	0.05	0.02	0.00	0.50
Family Richness	4.09	0.32	1.00	11.00

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric *Nektonic Sampling Statewide (N=111)*	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed[a]	0.29	0.03	0.00	1.00
Relative abundance EPA stressed	0.32	0.03	0.00	1.00
% Biomass of Chironomidae	0.06	0.01	0.00	0.97
Relative abundance of Chironomidae	0.20	0.02	0.00	0.93
% Biomass of Corixidae	0.05	0.01	0.00	1.00
% Biomass of Corixidae *	0.05	0.01	0.00	1.00
Relative abundance of Corixidae	0.05	0.01	0.00	1.00
Relative abundance of Corixidae *	0.07	0.02	0.00	1.00
Percent Biomass of Coleoptera	0.09	0.02	0.00	0.98
Percent Biomass of Coleoptera *	0.10	0.02	0.00	1.00
Relative abundance of Coleoptera	0.10	0.01	0.00	0.80
Relative abundance of Coleoptera *	0.13	0.02	0.00	1.00
% Biomass of Coleoptera and Corixidae	0.14	0.02	0.00	1.00
Relative abundance of Coleoptera and Corixidae	0.15	0.02	0.00	1.00
Relative abundance of Coleoptera and Corixidae *	0.15	0.02	0.00	1.00
% Biomass of Dytiscidae	0.20	0.02	0.00	1.00
% Biomass of Dytiscidae *	0.04	0.01	0.00	0.83
Relative abundance of Dytiscidae	0.04	0.01	0.00	0.92
Relative abundance of Dytiscidae *	0.05	0.01	0.00	0.71
% Biomass of collectors	0.06	0.01	0.00	0.89
% Biomass of collectors *	0.47	0.03	0.00	1.00
% Biomass of predators	0.50	0.04	0.00	1.09
% Biomass of predators *	0.31	0.03	0.00	1.00
% Biomass of shredders	0.35	0.03	0.00	1.00
% Biomass of shredders *	0.06	0.01	0.00	0.68
Relative abundance of collectors	0.07	0.01	0.00	1.00
Relative abundance of collectors *	0.37	0.03	0.00	1.00
Relative abundance of predators	0.47	0.03	0.00	1.40
Relative abundance of predators *	0.23	0.02	0.00	1.00
Relative abundance of shredders	0.33	0.03	0.00	1.00
Relative abundance of shredders *	0.09	0.02	0.00	0.73
Family Richness	8.21	0.48	0.00	23.00
Relative abundance of Lestidae	0.00	0.00	0.00	0.24
Relative abundance of Lestidae *	0.01	0.01	0.00	0.63
% Biomass of Libellulidae	0.00	0.00	0.00	0.06
% Biomass of Libellulidae *	0.00	0.00	0.00	0.20
Relative abundance of Libellulidae	0.08	0.02	0.00	0.76
Relative abundance of Libellulidae *	0.09	0.02	0.00	0.77
% Biomass Odonata	0.02	0.01	0.00	0.23
% Biomass Odonata *	0.03	0.01	0.00	0.29
Relative abundance of Odonata	0.14	0.02	0.00	0.98
Relative abundance of Odonata *	0.15	0.02	0.00	1.00
% Biomass of Odonata - Libellulidae	0.07	0.01	0.00	0.52
% Biomass of Odonata - Libellulidae *	0.09	0.02	0.00	1.00
Relative abundance of Odonata - Libellulidae	0.06	0.01	0.00	0.98
Relative abundance of Odonata - Libellulidae *	0.07	0.01	0.00	1.00

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric *Allegheny Highlands Nektonic Sampling(N=46)*	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.31	0.04	0.00	0.97
Relative abundance EPA stressed	0.40	0.04	0.00	0.93
% Biomass of Chironomidae	0.09	0.03	0.00	0.97
Relative abundance of Chironomidae	0.28	0.04	0.00	0.93
% Biomass of Corixidae	0.04	0.01	0.00	0.32
% Biomass of Corixidae *	0.04	0.01	0.00	0.33
Relative abundance of Corixidae	0.05	0.01	0.00	0.37
Relative abundance of Corixidae *	0.08	0.02	0.00	0.57
Percent Biomass of Coleoptera	0.09	0.02	0.00	0.90
Percent Biomass of Coleoptera *	0.10	0.03	0.00	1.00
Relative abundance of Coleoptera	0.09	0.02	0.00	0.40
Relative abundance of Coleoptera *	0.14	0.03	0.00	1.00
% Biomass of Coleoptera and Corixidae	0.12	0.03	0.00	0.90
Relative abundance of Coleoptera and Corixidae	0.14	0.03	0.00	1.00
Relative abundance of Coleoptera and Corixidae *	0.14	0.02	0.00	0.40
% Biomass of Dytiscidae	0.22	0.03	0.00	1.00
% Biomass of Dytiscidae *	0.04	0.02	0.00	0.83
Relative abundance of Dytiscidae	0.04	0.02	0.00	0.92
Relative abundance of Dytiscidae *	0.04	0.01	0.00	0.21
% Biomass of collectors	0.06	0.02	0.00	0.50
% Biomass of collectors *	0.47	0.05	0.00	1.00
% Biomass of predators	0.51	0.06	0.00	1.09
% Biomass of predators *	0.29	0.05	0.00	0.97
% Biomass of shredders	0.36	0.06	0.00	1.00
% Biomass of shredders *	0.05	0.01	0.00	0.35
Relative abundance of collectors	0.06	0.02	0.00	0.39
Relative abundance of collectors *	0.35	0.04	0.00	1.00
Relative abundance of predators	0.50	0.05	0.00	1.40
Relative abundance of predators *	0.18	0.03	0.00	0.80
Relative abundance of shredders	0.30	0.04	0.00	1.00
Relative abundance of shredders *	0.11	0.03	0.00	0.73
Family Richness	7.35	0.62	0.00	21.00
Relative abundance of Lestidae	0.00	0.00	0.00	0.05
Relative abundance of Lestidae *	0.00	0.00	0.00	0.05
% Biomass of Libellulidae	0.00	0.00	0.00	0.05
% Biomass of Libellulidae *	0.00	0.00	0.00	0.06
Relative abundance of Libellulidae	0.10	0.03	0.00	0.76
Relative abundance of Libellulidae *	0.12	0.03	0.00	0.77
% Biomass Odonata	0.03	0.01	0.00	0.23
% Biomass Odonata *	0.05	0.01	0.00	0.29
Relative abundance of Odonata	0.15	0.04	0.00	0.91
Relative abundance of Odonata *	0.17	0.04	0.00	0.93
% Biomass of Odonata - Libellulidae	0.06	0.02	0.00	0.50
% Biomass of Odonata - Libellulidae *	0.08	0.02	0.00	0.60
Relative abundance of Odonata - Libellulidae	0.05	0.02	0.00	0.50
Relative abundance of Odonata - Libellulidae *	0.05	0.02	0.00	0.53

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric *Ridge and Valley Nektonic Sampling (N= 22)*	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.23	0.06	0.00	0.99
Relative abundance EPA stressed	0.27	0.06	0.00	0.85
% Biomass of Chironomidae	0.05	0.03	0.00	0.60
Relative abundance of Chironomidae	0.18	0.05	0.00	0.75
% Biomass of Corixidae	0.01	0.01	0.00	0.10
% Biomass of Corixidae *	0.01	0.01	0.00	0.11
Relative abundance of Corixidae	0.03	0.02	0.00	0.52
Relative abundance of Corixidae *	0.04	0.03	0.00	0.61
Percent Biomass of Coleoptera	0.10	0.03	0.00	0.63
Percent Biomass of Coleoptera *	0.11	0.04	0.00	0.74
Relative abundance of Coleoptera	0.09	0.02	0.00	0.43
Relative abundance of Coleoptera *	0.11	0.03	0.00	0.55
% Biomass of Coleoptera and Corixidae	0.11	0.04	0.00	0.63
Relative abundance of Coleoptera and Corixidae	0.12	0.04	0.00	0.74
Relative abundance of Coleoptera and Corixidae *	0.12	0.03	0.00	0.56
% Biomass of Dytiscidae	0.15	0.04	0.00	0.65
% Biomass of Dytiscidae *	0.02	0.01	0.00	0.24
Relative abundance of Dytiscidae	0.03	0.01	0.00	0.25
Relative abundance of Dytiscidae *	0.04	0.01	0.00	0.23
% Biomass of collectors	0.06	0.02	0.00	0.24
% Biomass of collectors *	0.46	0.08	0.00	0.97
% Biomass of predators	0.48	0.08	0.00	0.97
% Biomass of predators *	0.29	0.07	0.00	1.00
% Biomass of shredders	0.34	0.08	0.00	1.00
% Biomass of shredders *	0.06	0.02	0.00	0.29
Relative abundance of collectors	0.10	0.05	0.00	1.00
Relative abundance of collectors *	0.34	0.06	0.00	0.84
Relative abundance of predators	0.44	0.07	0.00	1.26
Relative abundance of predators *	0.21	0.05	0.00	1.00
Relative abundance of shredders	0.30	0.07	0.00	1.00
Relative abundance of shredders *	0.13	0.04	0.00	0.56
Family Richness	8.73	1.29	0.00	23.00
Relative abundance of Lestidae	0.02	0.01	0.00	0.24
Relative abundance of Lestidae *	0.04	0.03	0.00	0.63
% Biomass of Libellulidae	0.01	0.00	0.00	0.06
% Biomass of Libellulidae *	0.01	0.01	0.00	0.20
Relative abundance of Libellulidae	0.04	0.03	0.00	0.68
Relative abundance of Libellulidae *	0.04	0.03	0.00	0.69
% Biomass Odonata	0.01	0.01	0.00	0.19
% Biomass Odonata *	0.02	0.01	0.00	0.22
Relative abundance of Odonata	0.08	0.04	0.00	0.74
Relative abundance of Odonata *	0.09	0.04	0.00	0.74
% Biomass of Odonata - Libellulidae	0.05	0.03	0.00	0.52
% Biomass of Odonata - Libellulidae *	0.07	0.03	0.00	0.67
Relative abundance of Odonata - Libellulidae	0.04	0.02	0.00	0.29
Relative abundance of Odonata - Libellulidae *	0.05	0.03	0.00	0.63

* Indicates metric value calculated without Oligocheata or Chironomidae.

Table 9. Continued.

Ecoregion/ metric *Western Alleghany Plateau Nektonic Sampling(N=43)*	Mean	Std. Error	Minimum	Maximum
% Biomass EPA stressed	0.29	0.05	0.00	1.00
Relative abundance EPA stressed	0.26	0.04	0.00	1.00
% Biomass of Chironomidae	0.02	0.01	0.00	0.27
Relative abundance of Chironomidae	0.13	0.02	0.00	0.61
% Biomass of Corixidae	0.07	0.03	0.00	1.00
% Biomass of Corixidae *	0.07	0.03	0.00	1.00
Relative abundance of Corixidae	0.07	0.03	0.00	1.00
Relative abundance of Corixidae *	0.07	0.03	0.00	1.00
Percent Biomass of Coleoptera	0.10	0.03	0.00	0.98
Percent Biomass of Coleoptera *	0.10	0.03	0.00	1.00
Relative abundance of Coleoptera	0.11	0.03	0.00	0.80
Relative abundance of Coleoptera *	0.13	0.03	0.00	1.00
% Biomass of Coleoptera and Corixidae	0.17	0.04	0.00	1.00
Relative abundance of Coleoptera and Corixidae	0.17	0.04	0.00	1.00
Relative abundance of Coleoptera and Corixidae *	0.18	0.04	0.00	1.00
% Biomass of Dytiscidae	0.20	0.04	0.00	1.00
% Biomass of Dytiscidae *	0.05	0.02	0.00	0.76
Relative abundance of Dytiscidae	0.05	0.02	0.00	0.78
Relative abundance of Dytiscidae *	0.06	0.02	0.00	0.71
% Biomass of collectors	0.07	0.03	0.00	0.89
% Biomass of collectors *	0.48	0.05	0.00	1.00
% Biomass of predators	0.50	0.05	0.00	1.00
% Biomass of predators *	0.33	0.05	0.00	1.00
% Biomass of shredders	0.34	0.05	0.00	1.00
% Biomass of shredders *	0.06	0.02	0.00	0.68
Relative abundance of collectors	0.06	0.02	0.00	0.68
Relative abundance of collectors *	0.40	0.05	0.00	1.00
Relative abundance of predators	0.47	0.05	0.00	1.00
Relative abundance of predators *	0.30	0.04	0.00	1.00
Relative abundance of shredders	0.37	0.05	0.00	1.00
Relative abundance of shredders *	0.05	0.02	0.00	0.50
Family Richness	8.86	0.81	0.00	22.00
Relative abundance of Lestidae	0.00	0.00	0.00	0.01
Relative abundance of Lestidae *	0.00	0.00	0.00	0.01
% Biomass of Libellulidae	0.00	0.00	0.00	0.04
% Biomass of Libellulidae *	0.00	0.00	0.00	0.05
Relative abundance of Libellulidae	0.07	0.03	0.00	0.67
Relative abundance of Libellulidae *	0.07	0.03	0.00	0.68
% Biomass Odonata	0.01	0.01	0.00	0.12
% Biomass Odonata *	0.02	0.01	0.00	0.20
Relative abundance of Odonata	0.16	0.04	0.00	0.98
Relative abundance of Odonata *	0.16	0.04	0.00	1.00
% Biomass of Odonata - Libellulidae	0.08	0.02	0.00	0.50
% Biomass of Odonata - Libellulidae *	0.12	0.03	0.00	1.00
Relative abundance of Odonata - Libellulidae	0.09	0.03	0.00	0.98
Relative abundance of Odonata - Libellulidae *	0.09	0.03	0.00	1.00

* Indicates metric value calculated without Oligocheata or Chironomidae.

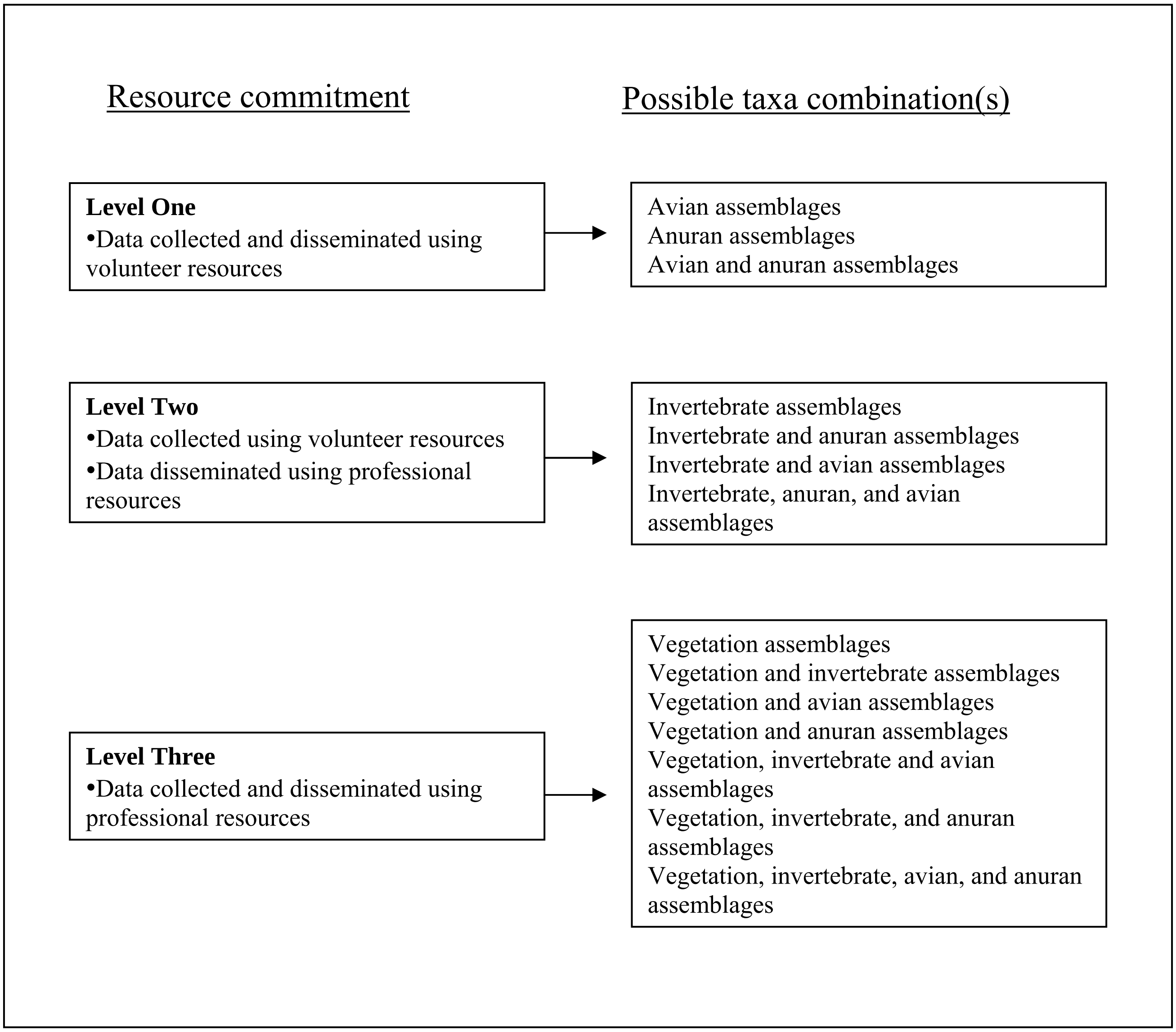

Figure 1. Levels of resource commitment and corresponding taxa groups surveyed necessary for conducting indices of biological integrity (IBIs) for wetlands in West Virginia, USA.

APPENDICES

Appendix A. Response guild designations listed by species occurring in the Mid-Atlantic region for use in developing class-specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA, from 2005-2006 (Croonquist and Brooks 1991; O'Connell and Brooks 1998).

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Cooper's Hawk	*Accipiter cooperii*	0	5	5	4	0	0	0	0
Sharp-Shinned Hawk	*Accipiter striatus*	0	3	4	3	0	0	0	0
Spotted Sandpiper	*Actitis macularia*	5	3	4	5	0	0	0	0
Red-Winged Blackbird	*Agelaius phoeniceus*	3	1	1	3	0	0	1	0
Wood Duck	*Aix sponsa*	5	5	3	4	0	0	0	0
Henslow's Sparrow	*Ammodramus henslowii*	3	3	2	4	0	0	0	0
Grasshopper Sparrow	*Ammodramus savannarum*	1	3	2	4	0	0	0	0
American Widgeon	*Anas americana*	5	3	2	4	0	0	0	0
Mallard	*Anas platyrhynchos*	5	1	1	3	0	0	0	0
Ruby-Throated Hummingbird	*Archilochus colubris*	1	1	3	5	0	0	0	0
Great Egret	*Ardea alba*	5	3	4	4	0	0	0	0
Great Blue Heron	*Ardea herodias*	5	3	4	4	0	0	0	0
Cedar Waxwing	*Bombycilla cedrorum*	0	1	3	3	1	0	0	0
Ruffed Grouse	*Bonasa umbellus*	0	3	1	3	0	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.
Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.
Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
American Bittern	*Botaurus lentiginosus*	5	5	3	4	0	0	0	0
Canada Goose	*Branta canadensis*	5	3	2	4	0	0	0	0
Great Horned Owl	*Bubo virginianus*	0	1	4	3	0	0	0	0
Red-Tailed Hawk	*Buteo jamaicensis*	0	1	4	3	0	0	0	0
Red-Shouldered Hawk	*Buteo lineatus*	3	3	4	3	0	0	0	0
Broad-Winged Hawk	*Buteo platypterus*	0	5	5	5	0	0	0	0
Green Heron	*Butorides virescens*	5	3	4	4	0	0	0	0
Chuck-will's Widow	*Caprimulgus carolinensis*					0	0	0	0
Whip-poor-will	*Caprimulgus vociferus*	0	3	4	5	0	0	0	0
Northern Cardinal	*Cardinalis cardinalis*	0	1	2	3	0	0	1	0
Pine Siskin	*Carduelis pinus*	0	3	1	3	0	0	0	0
American Goldfinch	*Carduelis tristis*	0	1	2	3	1	0	1	0
House Finch	*Carpodacus mexicanus*	0	1	2	3	0	0	0	0
Purple Finch	*Carpodacus purpureus*	0	1	2	3	1	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Turkey Vulture	*Cathartes aura*	0	1	4	3	0	0	0	0
Veery	*Catharus fuscescens*	3	3	1	5	1	1	0	0
Hermit Thrush	*Catharus guttatus*	0	3	1	5	0	1	0	0
Swainson's Thrush	*Catharus ustulatus*	1	3	1	5	0	0	0	0
Brown Creeper	*Certhia americana*	1	5	4	3	1	1	0	0
Belted Kingfisher	*Ceryle alcyon*	5	5	5	3	0	0	0	0
Chimney Swift	*Chaetura pelagica*	0	1	4	5	1	0	0	0
Killdeer	*Charadrius vociferus*	0	1	4	3	0	0	0	0
Common Nighthawk	*Chordeiles minor*					0	0	0	0
Marsh Wren	*Cistothorus palustris*	5				0	0	0	0
Sedge Wren	*Cistothorus platensis*	3	3	4	4	0	0	0	0
Evening Grosbeak	*Coccothraustes vespertinus*	0	3	2	2	0	0	0	0
Yellow-Billed Cuckoo	*Coccyzus americanus*	0	1	1	5	1	0	1	0
Black-billed Cuckoo	*Coccyzus erythropthalmus*	0	1	1	5	1	0	1	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Northern Flicker	*Colaptes auratus*	0	3	1	3	1	0	0	0
Northern Bobwhite	*Colinus virginianus*	0	3	1	3	0	0	0	0
Eastern Wood-Pewee	*Contopus virens*	0	1	4	5	1	0	0	0
American Crow	*Corvus brachyrhynchos*	0	1	1	3	1	0	0	1
Common Raven	*Corvus corax*	1	3	1	3	1	1	0	1
Blue Jay	*Cyanocitta cristata*	0	1	2	3	0	0	0	1
Black-throated Blue Warbler	*Dendroica caerulescens*	1	3	4	5	1	1	1	0
Cerulean Warbler	*Dendroica cerulea*	3	3	4	5	1	1	0	0
Yellow-Rumped Warbler	*Dendroica coronata*	1	3	1	5	0	1	0	0
Prairie Warbler	*Dendroica discolor*	0	1	4	5	1	0	0	0
Yellow-Throated Warbler	*Dendroica dominica*	3	3	4	5	1	1	0	0
Blackburnian Warbler	*Dendroica fusca*	1	5	4	5	0	1	0	0
Magnolia Warbler	*Dendroica magnolia*	0	1	4	5	1	1	1	0
Chestnut-Sided Warbler	*Dendroica pensylvanica*	0	1	4	5	1	0	1	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.
Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.
Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Yellow Warbler	*Dendroica petechia*	1	1	4	5	1	0	1	0
Pine Warbler	*Dendroica pinus*	0	3	4	5	1	1	0	0
Blackpoll Warbler	*Dendroica striata*	1	5	4	5	0	0	0	0
Black-throated Green Warbler	*Dendroica virens*	0	3	4	5	1	1	0	0
Bobolink	*Dolichonyx oryzivorus*	0	3	2	4	1	0	0	0
Pileated Woodpecker	*Dryocopus pileatus*	0	5	4	3	1	1	0	0
Gray Catbird	*Dumetella carolinensis*	1	1	1	3	0	0	1	0
Alder Flycatcher	*Empidonax alnorum*	5	3	4	5	1	0	1	0
Least Flycatcher	*Empidonax minimus*	0	1	4	5	1	0	0	0
Willow Flycatcher	*Empidonax traillii*	5	3	4	5	1	0	1	0
Acadian Flycatcher	*Empidonax virescens*	3	3	4	5	0	1	0	0
Horned Lark	*Eremophila alpestris*	0	1	2	4	0	0	0	0
Semipalmated Sandpiper	*Erolia pusilla*	5	3	4	1	0	0	0	0
Rusty Blackbird	*Euphagus carolinus*	3	3	1	1	0	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
American Kestrel	*Falco sparverius*	0	1	4	0	0	0	0	0
Common Yellowthroat	*Geothlypis trichas*	3	1	4	4	0	0	1	0
Blue Grosbeak	*Guiraca caerulea*	1	3	2	5	0	0	0	0
Worm-Eating Warbler	*Helmitheros vermivorus*	0	3	4	5	1	1	0	0
Cliff Swallow	*Hirundo pyrrhonota*	3	3	4	5	1	0	0	0
Barn Swallow	*Hirundo rustica*	0	1	4	5	0	0	0	0
Wood Thrush	*Hylocichla mustelina*	0	3	1	5	0	0	0	0
Yellow-Breasted Chat	*Icteria virens*	1	3	4	5	0	0	1	0
Baltimore Oriole	*Icterus galbula*	0	1	1	5	1	0	0	0
Orchard Oriole	*Icterus spurius*	3	1	1	5	1	0	0	0
Dark-Eyed Junco	*Junco hyemalis*	0	1	1	3	0	0	0	0
Loggerhead Shrike	*Lanius ludovicianus*					0	0	0	0
Swainson's Warbler	*Limnothlypis swainsonii*	5	5	4	5	0	0	0	0
Hooded Merganser	*Lophodytes cucullatus*	5	5	3	4	0	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Red Crossbill	*Loxia curvirostra*	0	3	3	2	0	0	0	0
Eastern Screech Owl	*Megascops asio*	0	5	4	3	0	0	0	0
Red-Billed Woodpecker	*Melanerpes carolinus*	1	3	1	3	1	0	0	0
Red-Headed Woodpecker	*Melanerpes erythrocephalus*	1	3	1	3	0	0	0	0
Wild Turkey	*Meleagris gallopavo*	0	3	1	3	0	0	0	0
Swamp Sparrow	*Melospiza georgiana*	5	3	1	3	0	0	0	0
Song Sparrow	*Melospiza melodia*	1	1	1	3	0	0	0	0
Northern Mockingbird	*Mimus polyglottos*	0	1	1	3	0	0	1	0
Black-and-White Warbler	*Mniotilta varia*	0	3	4	5	1	1	0	0
Brown-Headed Cowbird	*Molothrus ater*	0	1	1	3	0	0	0	1
Great Crested Flycatcher	*Myiarchus crinitus*	0	3	4	5	1	0	0	0
Northern Waterthrush	*Northern Waterthrush*	5	3	4	5	1	1	0	0
Domestic duck	*not applicable*	3	1	1	3	0	0	0	0
Kentucky Warbler	*Oporornis formosus*	3	3	4	5	1	1	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Mourning Warbler	*Oporornis philadelphia*	0	3	4	5	1	0	0	0
Osprey	*Pandion haliaetus*	5	5	5	3	0	0	0	0
Northern Parula	*Parula americana*	3	3	4	5	1	0	0	0
Tufted Titmouse	*Parus bicolor*	1	3	1	3	1	0	0	0
House Sparrow	*Passer domesticus*	0	1	1	3	0	0	0	0
Savannah Sparrow	*Passerculus sandwichensis*	1	1	2	4	0	0	0	0
Indigo Bunting	*Passerina cyanea*	1	1	1	5	0	0	1	0
Rose-Breasted Grosbeak	*Pheucticus ludovicianus*	0	1	1	5	1	0	0	0
Downy Woodpecker	*Picoides pubescens*	0	1	4	3	1	0	0	0
Hairy Woodpecker	*Picoides villosus*	0	3	4	3	1	1	0	0
Pine Grosbeak	*Pinicola enucleator*	0	3	2	2	0	0	0	0
Eastern Towhee	*Pipilo erythrophthalmus*	0	1	1	4	0	0	0	0
Scarlet Tanager	*Piranga olivacea*	0	1	1	5	1	1	0	0
Summer Tanager	*Piranga rubra*	0	1	1	5	1	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Black-capped Chickadee	*Poecile atricapilla*	0	1	1	3	1	0	0	0
Carolina Chickadee	*Poecile carolinensis*	0	1	1	3	1	0	0	0
Blue-Gray Gnatcatcher	*Polioptila caerulea*	1	3	4	5	1	0	0	0
Vesper Sparrow	*Pooecetes gramineus*	0	3	2	4	0	0	0	0
Purple Martin	*Progne subis*	3	3	4	5	0	0	0	0
Prothonotary Warbler	*Protonotaria citrea*	5	5	4	5	1	0	1	0
Common Grackle	*Quiscalus quiscula*	0	1	1	3	1	0	0	1
Virginia Rail	*Rallus limicola*	5	5	4	4	0	0	0	0
Ruby-Crowned Kinglet	*Regulus calendula*	1	3	1	2	0	0	0	0
Golden-Crowned Kinglet	*Regulus satrapa*	1	3	4	3	0	1	0	0
Bank Swallow	*Riparia riparia*	3	5	4	5	0	0	0	0
Eastern Phoebe	*Sayornis phoebe*	0	1	4	4	0	0	0	0
American Woodcock	*Scolopax minor*	5	3	5	4	0	0	0	0
Ovenbird	*Seiurus aurocapillus*	0	3	4	5	1	1	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Louisiana Waterthrush	*Seiurus motacilla*	5	3	4	5	1	1	0	0
American Redstart	*Setophaga ruticilla*	0	1	4	5	1	1	0	0
Eastern Bluebird	*Sialia sialis*	0	5	1	3	0	0	0	0
Red-Breasted Nuthatch	*Sitta canadensis*	0	5	1	3	1	1	0	0
White-Breasted Nuthatch	*Sitta carolinensis*	0	5	1	3	1	1	0	0
Yellow-Bellied Sapsucker	*Sphyrapicus varius*	0	5	1	5	1	0	0	0
Dickcissel	*Spiza americana*	0	3	2	5	0	0	0	0
American Tree Sparrow	*Spizella arborea*	0	1	2	2	0	0	0	0
Chipping Sparrow	*Spizella passerina*	0	1	1	4	0	0	1	0
Field Sparrow	*Spizella pusilla*	0	1	1	3	0	0	0	0
Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	3	3	4	5	1	0	0	0
Barred Owl	*Strix varia*	0	5	4	3	0	0	0	0
Eastern Meadowlark	*Sturnella magna*	0	1	1	3	0	0	0	0
European Starling	*Sturnus vulgaris*	0	3	1	3	0	0	0	1

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Tree Swallow	*Tachycineta bicolor*	1	5	4	5	1	0	0	0
Bewick's Wren	*Thryomanes bewickii*	0	1	2	3	0	0	0	0
Carolina Wren	*Thryothorus ludovicianus*	0	1	4	3	0	0	0	0
Brown Thrasher	*Toxostoma rufum*	0	1	1	3	0	0	1	0
Solitary Sandpiper	*Tringa solitaria*	5	3	4	1	0	0	0	0
House Wren	*Troglodytes aedon*	0	1	4	4	0	0	0	0
Winter Wren	*Troglodytes troglodytes*	3	3	4	3	1	1	0	0
American Robin	*Turdus migratorius*	0	1	1	3	0	0	0	0
Eastern Kingbird	*Tyrannus tyrannus*	0	3	4	5	1	0	0	0
Golden-Winged Warbler	*Vermivora chrysoptera*	1	3	4	5	1	0	0	0
Tennessee Warbler	*Vermivora peregrina*	0	1	4	1	0	0	0	0
Blue-Winged Warbler	*Vermivora pinus*	1	3	4	5	1	0	0	0
Nashville Warbler	*Vermivora ruficapilla*	1	1	4	5	1	0	0	0
Bell's Vireo	*Vireo bellii*	0	3	4	5	0	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix A. Continued.

Species	Latin name	Wetland Dependency	Habitat Specificity	Trophic Level	Migratory Status	Single-Brood	Forest area Sensitive	Shrub-nesting	Nest predator/ Brood parasite
Yellow-Throated Vireo	*Vireo flavifrons*	1	1	4	5	1	0	0	0
Warbling Vireo	*Vireo gilvus*	0	1	4	5	1	0	0	0
White-Eyed Vireo	*Vireo griseus*	3	3	4	5	1	1	1	0
Red-Eyed Vireo	*Vireo olivaceus*	0	1	4	5	1	0	1	0
Philadelphia Vireo	*Vireo philadelphicus*	0	1	4	1	0	0	0	0
Blue-Headed Vireo	*Vireo solitarius*	0	3	4	5	1	1	0	0
Canada Warbler	*Wilsonia canadensis*	1	1	4	5	1	1	0	0
Hooded Warbler	*Wilsonia citrina*	3	3	4	5	1	1	1	0
Wilson's Warbler	*Wilson's Warbler*	3	3	4	1	0	0	0	0
Mourning Dove	*Zenaida macroura*	0	1	2	3	0	0	0	0
White-Throated Sparrow	*Zonotrichia albicollis*	0	1	1	3	0	0	0	0

Wetland Dependency: 5=dependent, 3=associated, 1=facultative use, wetlands not essential, 0=upland or occasional use.
Habitat Specificity: 5=stenotypic, specialist; 3=landscape dependent; 1=generalists.
Trophic Level status: 5=restricted diet, 4=carnivore, generalists; 3=herbivore specialist; 2=herbivore generalists; 1=omnivore.

Migratory Status: 5=neotropical migrant; 4=short distance migrant; 3=year round resident; 2=nonbreeding season resident ; 1=migratory transient; 0 = occasional.

Single Brood, Forest Area sensitive, shrub-nesting, nest predator/ brood parasite indicated by 1.

Appendix B. Site codes, ecoregion, location, Cowardin class, Hydrogeomorphic (HGM) subclass, origin, disturbance score, and reference/ stressed designations used to develop class-specific wetland indices of biological integrity (IBIs) in West Virginia from 2005-2006.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	Cowardin R/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
CFCROS	69	471974.01	4191083.28	EM		headwater floodplain		natural	23
CFECUR	69	475086.61	4180030.30	SS		riparian depression	R	natural	26.5
CFEINC	69	476377.20	4180819.65	EM	S	headwater impoundment	S	natural	10.5
CFSLCH	69	471978.27	4186916.22	SS		headwater floodplain		natural	27.5
CFSLIN	69	472580.44	4186906.75	EM	R	headwater floodplain		natural	27.5
CGBRID	69	562820.75	4229682.04	SS	R	headwater floodplain	R	natural	39
CGCPAS	69	564291.44	4227601.43	SS	R	headwater floodplain	R	natural	39
CGROAD	69	563203.21	4228790.99	FO	R	slope		natural	35.5
CGTRHE	69	562849.95	4229196.62	FO	R	slope		natural	31
CHNEER	70	425323.03	4263651.17	SS	S	headwater impoundment		natural	21
CHSACH	70	430616.99	4247808.83	SS	S	riparian depression	S	natural	16
CHSAFO	70	430465.63	4247816.18	FO	S	headwater floodplain	S	natural	13
CHSARR	70	430767.87	4248062.35	EM	S	mainstem floodplain	S	natural	6
CHTREE	70	425706.21	4262531.73	FO		riparian depression		natural	23
CHWWBW	70	425517.25	4263436.99	SS	S	headwater impoundment	S	mitigation	18.5
CHWWEM	70	425514.31	4263179.89	EM		riparian depression		natural	23.5

[a] Ecoregion: 67 = Ridge and Valley, 69 = Central Appalachians, 70 = Western Allegheny Plateau.

[b] Cowardin classes: EM= Emergent, SS= Scrub-shrub, FO=Forested.

[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	Cowardin R/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
CHWWFO	70	425400.14	4263773.99	FO	S	headwater impoundment	S	natural	18.5
CVABBW	69	633103.19	4319691.35	EM	R	headwater floodplain		natural	29
CVABCT	69	633226.45	4319366.87	EM	R	headwater floodplain	R	natural	34
CVTIMB	69	636507.69	4322059.22	SS		riparian depression	R	natural	28
DSPICN	67	642625.79	4313855.23	SS	R	slope	R	natural	36.5
DSROAR	67	642463.70	4313302.17	EM	R	headwater floodplain	R	natural	39
DSWILD	67	642973.28	4314272.17	SS	R	slope	R	natural	39
EPCMEM	67	762221.31	4371598.78	EM		riparian depression		natural	19.5
EPCMFO	67	762488.36	4371541.38	FO	S	riparian depression		natural	18
EPDMFO	67	761333.18	4373782.33	FO	S	headwater floodplain		natural	21.5
EPDMPU	67	761577.57	4373610.32	SS	S	headwater floodplain	S	natural	17.5
EPKYVE	67	765034.40	4365206.47	EM		headwater floodplain		natural	22.5
EPRRXC	67	763621.83	4371053.41	FO	S	riparian depression		natural	20
EPSHEM	67	774868.67	4368871.15	EM		riparian depression		natural	23
EPSHSS	67	774668.67	4368706.80	SS	S	riparian depression		natural	17.5
GBBARN	70	391069.62	4271692.43	SS		riparian depression		natural	26

[a] Ecoregion: 67 = Ridge and Valley, 69 = Central Appalachians, 70 = Western Allegheny Plateau.

[b] Cowardinclasses: EM= Emergent, SS= Scrub-shrub, FO=Forested.

[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
GBHOEF	70	390000.91	4271677.51	SS		riparian depression	R	natural	28
GBJENK	70	391336.78	4271734.34	SS		mainstem impoundment	R	natural	28
GBMAPL	70	391085.79	4272250.28	FO		surface water depression	R	natural	29
GBNOFO	70	392949.13	4271460.72	FO		riparian depression	R	natural	30.5
GBNOSS	70	392864.38	4271526.66	SS		riparian depression		natural	23.5
GBPLOT	70	390995.72	4271850.21	EM	R	riparian depression		natural	25.5
HCBEAV	70	539107.79	4489651.55	EM	R	headwater impoundment		natural	25
HCMITI	70	540224.16	4487637.53	EM		riparian depression		mitigation	19
HCPIPE	70	538091.41	4490714.51	EM		riparian depression		natural	19
HCRANG	70	539012.33	4488728.32	EM		riparian depression		natural	17
HIBRID	69	509173.09	4169620.04	FO	S	riparian depression	S	natural	16
HIGATE	69	522508.65	4166557.42	FO		mainstem floodplain		natural	23
HIJHPK	69	520896.31	4167158.68	FO		headwater floodplain		natural	28.5
HIJHTU	69	518493.41	4166288.97	EM	S	riparian depression	S	natural	14.5
HIPENC	69	525233.15	4169097.73	EM	R	headwater impoundment	R	natural	32
HISEWG	69	509915.29	4172726.96	FO		mainstem floodplain		natural	24

[a] Ecoregion: 67 = Ridge and Valley, 69 = Central Appalachians, 70 = Western Allegheny Plateau.

[b]Cowardinclasses: EM= Emergent, SS= Scrub-shrub, FO=Forested.

[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
HITRLR	69	519863.68	4162636.08	EM	S	riparian depression	S	natural	15.5
MCFOUR	70	406635.56	4310843.03	EM	R	riparian depression	R	natural	32.5
MCMEME	70	407114.19	4309269.14	EM	R	mainstem impoundment	R	manmade	30
MCMFOR	70	407137.73	4308870.48	FO		riparian depression	R	manmade	29
MCNPFO	70	406108.70	4310559.18	FO	R	surface water depression	R	natural	31.5
MCPOND	70	407376.85	4307940.29	AB		isolated depression	S	manmade	9.5
MCPOST	70	407360.09	4307509.33	SS		mainstem impoundment		manmade	25
MCTELE	70	406792.34	4308838.63	SS		riparian depression		manmade	21.5
ME5092	69	598571.26	4355049.82	SS	S	riparian depression	S	natural	11.5
MESCOX	69	591596.31	4328816.43	EM		riparian depression		mitigation	18
MESCRO	69	591482.81	4329057.51	EM		headwater impoundment	S	mitigation	17.5
MESCUP	69	591712.71	4329122.08	EM		headwater impoundment	S	mitigation	17
MESIGN	69	594210.99	4330594.33	EM		riparian depression		natural	24
MESILV	69	594132.25	4330927.11	SS		riparian depression		natural	24
METETR	69	597570.89	4329663.27	EM	S	surface water depression	S	manmade	7
MEWOLF	69	593867.97	4331171.92	SS	R	riparian depression	R	natural	33

[a] Ecoregion: 67 = Ridge and Valley, 69 = Central Appalachians, 70 = Western Allegheny Plateau.

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[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
MRBESS	69	524326.40	4188085.26	SS		mainstem impoundment	R	natural	26
MRFARM	69	524385.44	4188482.81	EM	R	slope		natural	27
MRFORE	69	524454.19	4188272.82	FO	R	riparian depression	R	natural	32.5
MRSSSS	69	524641.53	4188638.39	SS	R	riparian depression	R	natural	30.5
MRWEST	69	523960.30	4188265.48	EM	R	riparian depression		natural	25
MU55SS	69	516658.49	4246368.09	SS		riparian depression	R	natural	27.5
MUDBOA	70	407368.48	4222212.05	EM	R	fringing	R	natural	28
MUDEND	70	409136.75	4223182.67	SS		fringing		natural	24
MUDRIC	70	408516.34	4224785.50	SS		fringing	R	natural	28
MUDRIP	70	409223.45	4223347.78	SS		fringing		natural	24
MUDTRA	70	408020.04	4222449.52	SS	S	fringing		manmade	20
MUEPAH	69	516150.16	4246455.17	EM		isolated depression		mitigation	22
MUMINE	69	518089.52	4250923.29	FO		slope		natural	28.5
MUPOWR	69	517473.09	4250134.17	FO	R	headwater floodplain	R	natural	31
MUPULL	69	516820.09	4249186.13	EM	R	headwater floodplain		natural	27.5
MUVBRD	69	517205.10	4248541.57	EM	R	riparian depression	R	natural	31.5

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[b]Cowardinclasses: EM= Emergent, SS= Scrub-shrub, FO=Forested.

[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
MUVCRN	69	516663.13	4248597.40	EM		mainstem impoundment		natural	23.5
OHHSFO	69	486726.19	4204379.08	FO		headwater floodplain		natural	30.5
OHINNS	69	489012.70	4207767.52	EM		headwater floodplain	S	natural	20
OHKMRT	69	489003.17	4207234.86	EM	S	headwater impoundment	S	mitigation	9
PA29TH	70	451974.57	4349022.47	EM	S	surface water depression	S	natural	14.5
PA83CR	70	459390.55	4360390.46	EM		surface water depression	S	natural	16
PAFAMD	70	455150.87	4346356.35	EM	S	mainstem impoundment	S	natural	13.5
PAJCPY	70	451986.58	4350105.90	EM		surface water depression		natural	20.5
PALOUD	70	452937.17	4345749.99	SS	S	riparian depression	S	natural	8
PAPEFO	70	454455.37	4340747.67	FO		headwater floodplain		natural	29
PAPEIM	70	454110.68	4340787.73	EM	S	isolated depression	S	manmade	9.5
PAPESW	70	454429.44	4341097.03	SS		headwater floodplain		natural	26.5
PAWILL	70	461172.76	4361677.52	SS	S	fringing	S	manmade	18.5
PCBLUE	70	581293.37	4343766.39	EM		riparian depression		mitigation	22
PCLPFO	70	584396.09	4346844.44	FO	R	fringing	R	natural	34
PCROAD	70	581759.53	4344161.29	EM	S	headwater floodplain	S	mitigation	12

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[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
PEMIDW	70	575319.40	4393384.71	EM		riparian depression		manmade	21.5
PERDDP	70	576195.70	4393447.11	EM		isolated depression		manmade	17.5
PETHUM	70	575869.39	4393128.30	EM	R	riparian depression	R	natural	26.5
PETOSS	70	575100.98	4393427.83	SS	S	riparian depression		manmade	21
RIASIA	70	493933.77	4325989.71	EM		riparian depression		natural	20
RIBRID	70	483478.17	4325431.95	EM	S	riparian depression	S	natural	8.5
RIEAST	70	505155.40	4331458.27	SS	R	floodplain in-stream	R	natural	31
SJBOAT	70	553817.61	4314292.95	EM		fringing		manmade	19.5
SJBRID	70	551595.30	4308792.29	SS	S	fringing	S	manmade	13.5
SJCHUR	70	553162.97	4312635.85	SS		fringing		natural	22
SJGLAD	70	549304.99	4315181.92	EM		riparian depression		natural	23
SJMUDL	70	546681.89	4307905.42	FO		riparian depression	R	natural	27
SJPLOT	70	553304.39	4312414.21	EM	S	riparian depression	S	natural	13.5
SJTELE	70	548484.71	4307308.08	EM	S	isolated depression	S	natural	14.5
SMDTSS	67	701441.57	4341087.61	SS	R	headwater floodplain	R	natural	36.5
SMFOFL	67	701906.33	4342063.24	FO	R	headwater floodplain	R	natural	36.5

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[c] R = reference, S = stressed.

Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
SMLPEM	67	701813.06	4341692.18	EM	R	headwater floodplain	R	natural	36.5
SMSEFL	67	701657.15	4341357.63	EM	R	headwater impoundment	R	natural	30.5
SMSTEM	67	701178.93	4340693.63	EM	R	headwater floodplain		natural	30.5
TRSPFO	70	535844.63	4487835.71	FO		riparian depression	R	natural	28.5
TRSPRI	70	535011.37	4488866.58	SS	S	fringing	S	natural	18
TVFARM	67	594752.26	4290868.05	EM	S	riparian depression	S	natural	15
TVISLE	67	593490.58	4290989.45	FO		mainstem floodplain		natural	30
TVNEWT	67	596407.82	4294176.49	EM		riparian depression		natural	20.5
TVPOUT	67	594994.36	4293572.02	EM		riparian depression		natural	23.5
TVVBEM	67	591865.70	4291645.36	EM	S	slope	S	natural	9
TVVBIM	67	591950.19	4291462.02	EM		riparian depression		manmade	18
TVVBRV	67	591920.29	4291352.02	FO	R	mainstem floodplain	R	natural	34
TVVBSS	67	592032.24	4291607.52	SS	R	riparian depression	R	manmade	31
UDC001	69	602201.49	4377359.56	SS	R	riparian depression	R	natural	29
UDC002	69	602038.52	4376963.94	EM		headwater impoundment		manmade	20
UDC003	69	602413.85	4376440.18	EM		riparian depression		natural	22.5

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Appendix B. Continued.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
UDC004	69	602188.63	4375849.63	FO		riparian depression		natural	23
UDC005	69	602159.27	4374776.00	EM	S	isolated depression	S	natural	12
UDC007	69	602360.03	4374524.27	SS		riparian depression		natural	23.5
UDC008	69	602414.08	4373761.24	SS		surface water depression	R	manmade	28
UDC012	69	602317.31	4372622.88	EM		headwater impoundment		natural	22
UDC013	69	603563.04	4373327.15	SS		headwater impoundment	R	manmade	27.5
UDC014	69	603502.05	4373177.51	SS	R	headwater floodplain		natural	28.5
UDC015	69	603742.33	4373121.78	SS		headwater impoundment		manmade	23
UDC016	69	602641.92	4375901.37	EM		riparian depression		natural	22.5
UDC017	69	602867.23	4375663.08	EM		headwater impoundment		natural	22.5
UDC018	69	603128.37	4373455.05	EM		headwater floodplain	S	natural	19.5
UDC019	69	603169.43	4373195.39	FO		headwater impoundment		natural	24.5
UDC020	69	603088.50	4375415.43	EM		headwater impoundment		manmade	22.5
VEPCON	69	641127.08	4338137.96	EM		headwater floodplain	S	mitigation	19
VEPCOS	69	641451.23	4338080.36	EM		riparian depression		mitigation	22
WBBARN	67	673918.98	4334374.17	EM	S	headwater floodplain	S	mitigation	15.5

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[b]Cowardinclasses: EM= Emergent, SS= Scrub-shrub, FO=Forested.

[c] R = reference, S = stressed.

Appendix B. Site codes, ecoregion, location, NWI class, Hydrogeomorphic subclass, origin, Disturbance score, and reference/ stressed designations used to develop class-specific wetland indices of biological integrity (IBIs) in West Virginia from 2005-2006.

Site Code	Ecoregion[a]	UTMx	UTMy	Cowardin[b]	CowardinR/ S[c] designation	HGM subclass (Cole et al. 1997)	HGM R/ S[c] designation	Origin	Disturbance Score
WBCORN	67	674210.94	4334514.97	EM		headwater floodplain	S	mitigation	16
WBROAD	67	674507.77	4333367.67	EM	S	slope	S	natural	13.5
WYBEAV	69	437027.12	4163806.72	FO	S	riparian depression	S	natural	15
WYCHWE	69	437146.50	4158673.14	EM	R	fringing	R	natural	28
WYHCEA	69	437557.26	4158505.22	EM		fringing		natural	22
WYINTR	69	440277.95	4160832.91	FO	S	riparian depression		natural	21
WYTHOR	69	437130.74	4164044.53	EM	S	riparian depression	S	natural	13.5

[a] Ecoregion: 67 = Ridge and Valley, 69 = Central Appalachians, 70 = Western Allegheny Plateau.

[b]Cowardinclasses: EM= Emergent, SS= Scrub-shrub, FO=Forested.

[c] R = reference, S = stressed.

Appendix C. Avian species abundance and relative frequency per site used in developing class-specific avian wetland indices of biological integrity (AW-IBI) in West Virginia, USA from 2005-2006.

SiteCode	Species		Latin name	Number observed	Frequency per Site
CFCROS	Site abundance:	31			
	American Goldfinch		*Carduelis tristis*	4	0.1290
	American Robin		*Turdus migratorius*	1	0.0323
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0323
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0323
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0323
	Carolina Chickadee		*Poecile carolinensis*	1	0.0323
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0323
	Common Yellowthroat		*Geothlypis trichas*	1	0.0323
	Indigo Bunting		*Passerina cyanea*	2	0.0645
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0323
	Northern Waterthrush		*Northern Waterthrush*	1	0.0323
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0323
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2581
	Song Sparrow		*Melospiza melodia*	1	0.0323
	Wood Thrush		*Hylocichla mustelina*	1	0.0323
	Yellow Warbler		*Dendroica petechia*	5	0.1613
CFECUR	Site abundance:	16			
	American Goldfinch		*Carduelis tristis*	1	0.0625
	American Redstart		*Setophaga ruticilla*	1	0.0625
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0625
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0625
	Carolina Chickadee		*Poecile carolinensis*	1	0.0625
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0625
	Field Sparrow		*Spizella pusilla*	1	0.0625
	Northern Cardinal		*Cardinalis cardinalis*	2	0.1250
	Ovenbird		*Seiurus aurocapillus*	1	0.0625
	Song Sparrow		*Melospiza melodia*	3	0.1875
	White-Eyed Vireo		*Vireo griseus*	1	0.0625
	Wood Thrush		*Hylocichla mustelina*	1	0.0625
	Yellow Warbler		*Dendroica petechia*	1	0.0625

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
CFEINC	Site abundance:	19			
	Carolina Chickadee		*Poecile carolinensis*	1	0.0526
	European Starling		*Sturnus vulgaris*	2	0.1053
	Gray Catbird		*Dumetella carolinensis*	2	0.1053
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0526
	Mallard		*Anas platyrhynchos*	1	0.0526
	Mourning Dove		*Zenaida macroura*	1	0.0526
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0526
	Northern Parula		*Parula americana*	1	0.0526
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0526
	Red-Winged Blackbird		*Agelaius phoeniceus*	4	0.2105
	Song Sparrow		*Melospiza melodia*	2	0.1053
	Tree Swallow		*Tachycineta bicolor*	2	0.1053
CFSLCH	Site abundance:	29			
	American Crow		*Corvus brachyrhynchos*	2	0.0690
	American Goldfinch		*Carduelis tristis*	1	0.0345
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0345
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0345
	Carolina Chickadee		*Poecile carolinensis*	2	0.0690
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0345
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	1	0.0345
	Gray Catbird		*Dumetella carolinensis*	1	0.0345
	Indigo Bunting		*Passerina cyanea*	1	0.0345
	Indigo Bunting		*Passerina cyanea*	1	0.0345
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0345
	Northern Parula		*Parula americana*	1	0.0345
	Northern Waterthrush		*Northern Waterthrush*	1	0.0345
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0690
	Song Sparrow		*Melospiza melodia*	1	0.0345
	Swamp Sparrow		*Melospiza georgiana*	1	0.0345
	Tree Swallow		*Tachycineta bicolor*	1	0.0345
	Tufted Titmouse		*Parus bicolor*	6	0.2069
	Wood Duck		*Aix sponsa*	1	0.0345
	Wood Thrush		*Hylocichla mustelina*	1	0.0345
	Yellow Warbler		*Dendroica petechia*	1	0.0345

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
CFSLIN	Site abundance:	24			
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0417
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0417
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0417
	Carolina Chickadee		*Poecile carolinensis*	1	0.0417
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0417
	Common Yellowthroat		*Geothlypis trichas*	1	0.0417
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0417
	Gray Catbird		*Dumetella carolinensis*	1	0.0417
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0417
	House Wren		*Troglodytes aedon*	1	0.0417
	Indigo Bunting		*Passerina cyanea*	1	0.0417
	Mourning Dove		*Zenaida macroura*	1	0.0417
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0417
	Northern Parula		*Parula americana*	1	0.0417
	Northern Waterthrush		*Northern Waterthrush*	1	0.0417
	Ovenbird		*Seiurus aurocapillus*	2	0.0833
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0833
	Song Sparrow		*Melospiza melodia*	1	0.0417
	Tree Swallow		*Tachycineta bicolor*	1	0.0417
	Tufted Titmouse		*Parus bicolor*	1	0.0417
	White-Eyed Vireo		*Vireo griseus*	1	0.0417
	Yellow Warbler		*Dendroica petechia*	1	0.0417
CGBRID	Site abundance:	21			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0476
	Alder Flycatcher		*Empidonax alnorum*	2	0.0952
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0476
	Black-throated Green Warbler		*Dendroica virens*	2	0.0952
	Blue Jay		*Cyanocitta cristata*	1	0.0476
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0476
	Common Yellowthroat		*Geothlypis trichas*	2	0.0952
	Golden-Crowned Kinglet		*Regulus satrapa*	2	0.0952
	Northern Waterthrush		*Northern Waterthrush*	2	0.0952
	Red-Breasted Nuthatch		*Sitta canadensis*	2	0.0952
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0476
	Tree Swallow		*Tachycineta bicolor*	3	0.1429
	Yellow Warbler		*Dendroica petechia*	1	0.0476

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
CGCPAS	Site abundance:	18			
	American Redstart		*Setophaga ruticilla*	1	0.0556
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0556
	Black-throated Green Warbler		*Dendroica virens*	1	0.0556
	Blue Jay		*Cyanocitta cristata*	2	0.1111
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0556
	Common Yellowthroat		*Geothlypis trichas*	1	0.0556
	Magnolia Warbler		*Dendroica magnolia*	1	0.0556
	Northern Parula		*Parula americana*	1	0.0556
	Northern Waterthrush		*Northern Waterthrush*	2	0.1111
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0556
	Rose-Breasted Grosbeak		*Pheucticus ludovicianus*	1	0.0556
	Ruby-Crowned Kinglet		*Regulus calendula*	1	0.0556
	Yellow Warbler		*Dendroica petechia*	2	0.1111
	Yellow-Rumped Warbler		*Dendroica coronata*	2	0.1111
CGROAD	Site abundance:	13			
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0769
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0769
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0769
	Golden-Crowned Kinglet		*Regulus satrapa*	2	0.1538
	Magnolia Warbler		*Dendroica magnolia*	2	0.1538
	Purple Finch		*Carpodacus purpureus*	1	0.0769
	Purple Martin		*Progne subis*	1	0.0769
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0769
	Rose-Breasted Grosbeak		*Pheucticus ludovicianus*	1	0.0769
	Tufted Titmouse		*Parus bicolor*	1	0.0769
	Yellow Warbler		*Dendroica petechia*	1	0.0769

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
CGTRHE	Site abundance: 19			
	American Redstart	*Setophaga ruticilla*	1	0.0526
	American Robin	*Turdus migratorius*	1	0.0526
	Black-and-White Warbler	*Mniotilta varia*	1	0.0526
	Black-capped Chickadee	*Poecile atricapilla*	1	0.0526
	Black-throated Blue Warbler	*Dendroica caerulescens*	1	0.0526
	Black-throated Green Warbler	*Dendroica virens*	2	0.1053
	Blue-Headed Vireo	*Vireo solitarius*	1	0.0526
	Eastern Phoebe	*Sayornis phoebe*	1	0.0526
	Golden-Crowned Kinglet	*Regulus satrapa*	2	0.1053
	Hermit Thrush	*Catharus guttatus*	2	0.1053
	Magnolia Warbler	*Dendroica magnolia*	1	0.0526
	Red-Breasted Nuthatch	*Sitta canadensis*	1	0.0526
	Rose-Breasted Grosbeak	*Pheucticus ludovicianus*	1	0.0526
	Veery	*Catharus fuscescens*	1	0.0526
	Wood Thrush	*Hylocichla mustelina*	1	0.0526
	Yellow-Rumped Warbler	*Dendroica coronata*	1	0.0526
CHNEER	Site abundance: 24			
	Blue Jay	*Cyanocitta cristata*	1	0.0417
	Canada Goose	*Branta canadensis*	1	0.0417
	Carolina Wren	*Thryothorus ludovicianus*	1	0.0417
	Cedar Waxwing	*Bombycilla cedrorum*	1	0.0417
	Common Grackle	*Quiscalus quiscula*	1	0.0417
	Common Yellowthroat	*Geothlypis trichas*	1	0.0417
	Gray Catbird	*Dumetella carolinensis*	1	0.0417
	Green Heron	*Butorides virescens*	2	0.0833
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0417
	Red-Winged Blackbird	*Agelaius phoeniceus*	8	0.3333
	Song Sparrow	*Melospiza melodia*	2	0.0833
	Tree Swallow	*Tachycineta bicolor*	3	0.1250
	Yellow Warbler	*Dendroica petechia*	1	0.0417

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
CHSACH	Site abundance:	33			
	American Goldfinch		*Carduelis tristis*	2	0.0606
	American Robin		*Turdus migratorius*	1	0.0303
	Blue Jay		*Cyanocitta cristata*	1	0.0303
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0606
	Common Grackle		*Quiscalus quiscula*	3	0.0909
	Common Yellowthroat		*Geothlypis trichas*	1	0.0303
	European Starling		*Sturnus vulgaris*	2	0.0606
	Field Sparrow		*Spizella pusilla*	1	0.0303
	Green Heron		*Butorides virescens*	1	0.0303
	House Wren		*Troglodytes aedon*	1	0.0303
	Northern Flicker		*Colaptes auratus*	1	0.0303
	Northern Mockingbird		*Mimus polyglottos*	1	0.0303
	Orchard Oriole		*Icterus spurius*	1	0.0303
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.3030
	Song Sparrow		*Melospiza melodia*	3	0.0909
	Willow Flycatcher		*Empidonax traillii*	2	0.0606
CHSAFO	Site abundance:	21			
	American Robin		*Turdus migratorius*	2	0.0952
	Blue Jay		*Cyanocitta cristata*	1	0.0476
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0476
	Carolina Chickadee		*Poecile carolinensis*	5	0.2381
	Gray Catbird		*Dumetella carolinensis*	1	0.0476
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0952
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0476
	Song Sparrow		*Melospiza melodia*	6	0.2857
	Tufted Titmouse		*Parus bicolor*	1	0.0476
	Whip-poor-will		*Caprimulgus vociferus*	1	0.0476

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
CHSARR	Site abundance:	31			
	American Goldfinch		*Carduelis tristis*	1	0.0323
	American Robin		*Turdus migratorius*	1	0.0323
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0323
	Common Grackle		*Quiscalus quiscula*	1	0.0323
	European Starling		*Sturnus vulgaris*	2	0.0645
	Gray Catbird		*Dumetella carolinensis*	2	0.0645
	Green Heron		*Butorides virescens*	2	0.0645
	House Wren		*Troglodytes aedon*	1	0.0323
	Mallard		*Anas platyrhynchos*	12	0.3871
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0645
	Northern Flicker		*Colaptes auratus*	1	0.0323
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0323
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0323
	Song Sparrow		*Melospiza melodia*	2	0.0645
	Spotted Sandpiper		*Actitis macularia*	1	0.0323
CHTREE	Site abundance:	17			
	American Redstart		*Setophaga ruticilla*	2	0.1176
	American Robin		*Turdus migratorius*	2	0.1176
	Carolina Chickadee		*Poecile carolinensis*	1	0.0588
	Common Yellowthroat		*Geothlypis trichas*	1	0.0588
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0588
	Indigo Bunting		*Passerina cyanea*	1	0.0588
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0588
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0588
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0588
	Red-Eyed Vireo		*Vireo olivaceus*	2	0.1176
	Song Sparrow		*Melospiza melodia*	1	0.0588
	Tennessee Warbler		*Vermivora peregrina*	1	0.0588
	Tufted Titmouse		*Parus bicolor*	1	0.0588
	Wood Thrush		*Hylocichla mustelina*	1	0.0588

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
CHWWBW	Site abundance:	49			
	American Goldfinch		*Carduelis tristis*	1	0.0204
	Barn Swallow		*Hirundo rustica*	1	0.0204
	Brown Thrasher		*Toxostoma rufum*	1	0.0204
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0204
	Common Grackle		*Quiscalus quiscula*	5	0.1020
	Common Yellowthroat		*Geothlypis trichas*	2	0.0408
	European Starling		*Sturnus vulgaris*	6	0.1224
	Gray Catbird		*Dumetella carolinensis*	1	0.0204
	Great Blue Heron		*Ardea herodias*	1	0.0204
	Green Heron		*Butorides virescens*	3	0.0612
	House Wren		*Troglodytes aedon*	1	0.0204
	Northern Flicker		*Colaptes auratus*	1	0.0204
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0204
	Red-Winged Blackbird		*Agelaius phoeniceus*	15	0.3061
	Song Sparrow		*Melospiza melodia*	3	0.0612
	Tree Swallow		*Tachycineta bicolor*	1	0.0204
	Warbling Vireo		*Vireo gilvus*	1	0.0204
	Winter Wren		*Troglodytes troglodytes*	1	0.0204
	Wood Duck		*Aix sponsa*	1	0.0204
	Yellow Warbler		*Dendroica petechia*	2	0.0408

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
CHWWEM	Site abundance:	42			
	American Goldfinch		*Carduelis tristis*	2	0.0476
	American Robin		*Turdus migratorius*	4	0.0952
	Carolina Chickadee		*Poecile carolinensis*	2	0.0476
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0238
	Common Grackle		*Quiscalus quiscula*	1	0.0238
	Common Yellowthroat		*Geothlypis trichas*	2	0.0476
	Eastern Bluebird		*Sialia sialis*	1	0.0238
	Eastern Phoebe		*Sayornis phoebe*	1	0.0238
	Hairy Woodpecker		*Picoides villosus*	1	0.0238
	Indigo Bunting		*Passerina cyanea*	1	0.0238
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0238
	Northern Flicker		*Colaptes auratus*	1	0.0238
	Northern Waterthrush		*Northern Waterthrush*	1	0.0238
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.2381
	Savannah Sparrow		*Passerculus sandwichensis*	2	0.0476
	Song Sparrow		*Melospiza melodia*	5	0.1190
	Tree Swallow		*Tachycineta bicolor*	1	0.0238
	Tufted Titmouse		*Parus bicolor*	1	0.0238
	Winter Wren		*Troglodytes troglodytes*	1	0.0238
	Yellow Warbler		*Dendroica petechia*	3	0.0714

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
CHWWFO	Site abundance: 44			
	Black-and-White Warbler	*Mniotilta varia*	1	0.0227
	Blue Jay	*Cyanocitta cristata*	1	0.0227
	Carolina Chickadee	*Poecile carolinensis*	5	0.1136
	Common Grackle	*Quiscalus quiscula*	4	0.0909
	Cooper's Hawk	*Accipiter cooperii*	1	0.0227
	Domestic duck		1	0.0227
	European Starling	*Sturnus vulgaris*	1	0.0227
	Gray Catbird	*Dumetella carolinensis*	1	0.0227
	Great Blue Heron	*Ardea herodias*	4	0.0909
	Great Crested Flycatcher	*Myiarchus crinitus*	1	0.0227
	Green Heron	*Butorides virescens*	2	0.0455
	Mallard	*Anas platyrhynchos*	7	0.1591
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0227
	Northern Flicker	*Colaptes auratus*	2	0.0455
	Pileated Woodpecker	*Dryocopus pileatus*	1	0.0227
	Red-Billed Woodpecker	*Melanerpes carolinus*	1	0.0227
	Ruby-Throated Hummingbird	*Archilochus colubris*	1	0.0227
	Tufted Titmouse	*Parus bicolor*	3	0.0682
	White-Breasted Nuthatch	*Sitta carolinensis*	3	0.0682
	Wood Duck	*Aix sponsa*	3	0.0682
CVABBW	Site abundance: 17			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0588
	Black-and-White Warbler	*Mniotilta varia*	1	0.0588
	Black-capped Chickadee	*Poecile atricapilla*	2	0.1176
	Black-throated Green Warbler	*Dendroica virens*	1	0.0588
	Blue-Headed Vireo	*Vireo solitarius*	1	0.0588
	Common Yellowthroat	*Geothlypis trichas*	2	0.1176
	Eastern Towhee	*Pipilo erythrophthalmus*	1	0.0588
	Marsh Wren	*Cistothorus palustris*	2	0.1176
	Pileated Woodpecker	*Dryocopus pileatus*	1	0.0588
	Red-Breasted Nuthatch	*Sitta canadensis*	1	0.0588
	Ruby-Crowned Kinglet	*Regulus calendula*	1	0.0588
	Swamp Sparrow	*Melospiza georgiana*	2	0.1176
	Wood Thrush	*Hylocichla mustelina*	1	0.0588

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
CVABCT	Site abundance: 21			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0476
	American Crow	*Corvus brachyrhynchos*	1	0.0476
	Black-capped Chickadee	*Poecile atricapilla*	1	0.0476
	Black-throated Green Warbler	*Dendroica virens*	2	0.0952
	Blue Jay	*Cyanocitta cristata*	1	0.0476
	Blue-Headed Vireo	*Vireo solitarius*	1	0.0476
	Brown-Headed Cowbird	*Molothrus ater*	1	0.0476
	Common Yellowthroat	*Geothlypis trichas*	1	0.0476
	Eastern Towhee	*Pipilo erythrophthalmus*	1	0.0476
	Magnolia Warbler	*Dendroica magnolia*	1	0.0476
	Marsh Wren	*Cistothorus palustris*	2	0.0952
	Red-Eyed Vireo	*Vireo olivaceus*	2	0.0952
	Savannah Sparrow	*Passerculus sandwichensis*	1	0.0476
	Song Sparrow	*Melospiza melodia*	2	0.0952
	Swamp Sparrow	*Melospiza georgiana*	1	0.0476
	Wood Thrush	*Hylocichla mustelina*	1	0.0476
	Yellow Warbler	*Dendroica petechia*	1	0.0476
CVTIMB	Site abundance: 17			
	Acadian Flycatcher	*Empidonax virescens*	2	0.1176
	Alder Flycatcher	*Empidonax alnorum*	1	0.0588
	Black-capped Chickadee	*Poecile atricapilla*	2	0.1176
	Blue Jay	*Cyanocitta cristata*	1	0.0588
	Chestnut-Sided Warbler	*Dendroica pensylvanica*	1	0.0588
	Common Yellowthroat	*Geothlypis trichas*	3	0.1765
	Field Sparrow	*Spizella pusilla*	1	0.0588
	Red-Winged Blackbird	*Agelaius phoeniceus*	3	0.1765
	Swamp Sparrow	*Melospiza georgiana*	2	0.1176
	Yellow Warbler	*Dendroica petechia*	1	0.0588

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
DSPICN	Site abundance: 16			
	Black-and-White Warbler	*Mniotilta varia*	1	0.0625
	Black-capped Chickadee	*Poecile atricapilla*	2	0.1250
	Black-throated Green Warbler	*Dendroica virens*	2	0.1250
	Blue Jay	*Cyanocitta cristata*	2	0.1250
	Chestnut-Sided Warbler	*Dendroica pensylvanica*	2	0.1250
	Eastern Towhee	*Pipilo erythrophthalmus*	2	0.1250
	Mourning Warbler	*Oporornis philadelphia*	1	0.0625
	Nashville Warbler	*Vermivora ruficapilla*	1	0.0625
	Ovenbird	*Seiurus aurocapillus*	1	0.0625
	Red-Eyed Vireo	*Vireo olivaceus*	1	0.0625
	Yellow Warbler	*Dendroica petechia*	1	0.0625
DSROAR	Site abundance: 14			
	Blue Jay	*Cyanocitta cristata*	1	0.0714
	Chestnut-Sided Warbler	*Dendroica pensylvanica*	1	0.0714
	Common Yellowthroat	*Geothlypis trichas*	2	0.1429
	Eastern Towhee	*Pipilo erythrophthalmus*	2	0.1429
	Golden-Crowned Kinglet	*Regulus satrapa*	1	0.0714
	Hermit Thrush	*Catharus guttatus*	1	0.0714
	Northern Parula	*Parula americana*	1	0.0714
	Purple Finch	*Carpodacus purpureus*	1	0.0714
	Purple Martin	*Progne subis*	1	0.0714
	Red-Eyed Vireo	*Vireo olivaceus*	1	0.0714
	Veery	*Catharus fuscescens*	1	0.0714
	Yellow Warbler	*Dendroica petechia*	1	0.0714
DSWILD	Site abundance: 14			
	American Robin	*Turdus migratorius*	1	0.0714
	Black-capped Chickadee	*Poecile atricapilla*	2	0.1429
	Black-throated Green Warbler	*Dendroica virens*	1	0.0714
	Blue-Headed Vireo	*Vireo solitarius*	1	0.0714
	Chestnut-Sided Warbler	*Dendroica pensylvanica*	1	0.0714
	Dark-Eyed Junco	*Junco hyemalis*	1	0.0714
	Eastern Towhee	*Pipilo erythrophthalmus*	2	0.1429
	Golden-Crowned Kinglet	*Regulus satrapa*	1	0.0714
	Hermit Thrush	*Catharus guttatus*	1	0.0714
	Mourning Warbler	*Oporornis philadelphia*	1	0.0714
	Pine Warbler	*Dendroica pinus*	1	0.0714
	Yellow Warbler	*Dendroica petechia*	1	0.0714

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
EPCMEM	Site abundance:	38			
	American Robin		*Turdus migratorius*	2	0.0526
	Baltimore Oriole		*Icterus galbula*	1	0.0263
	Blue Jay		*Cyanocitta cristata*	1	0.0263
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0263
	Eastern Phoebe		*Sayornis phoebe*	1	0.0263
	Gray Catbird		*Dumetella carolinensis*	1	0.0263
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0526
	Northern Flicker		*Colaptes auratus*	1	0.0263
	Northern Mockingbird		*Mimus polyglottos*	1	0.0263
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0263
	Red-Tailed Hawk		*Buteo jamaicensis*	1	0.0263
	Red-Winged Blackbird		*Agelaius phoeniceus*	18	0.4737
	Song Sparrow		*Melospiza melodia*	3	0.0789
	Tree Swallow		*Tachycineta bicolor*	2	0.0526
	Yellow Warbler		*Dendroica petechia*	1	0.0263
	Yellow-Breasted Chat		*Icteria virens*	1	0.0263
EPCMFO	Site abundance:	25			
	American Redstart		*Setophaga ruticilla*	1	0.0400
	Brown-Headed Cowbird		*Molothrus ater*	4	0.1600
	Carolina Chickadee		*Poecile carolinensis*	3	0.1200
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0400
	Common Grackle		*Quiscalus quiscula*	1	0.0400
	Eastern Phoebe		*Sayornis phoebe*	1	0.0400
	Gray Catbird		*Dumetella carolinensis*	1	0.0400
	Mallard		*Anas platyrhynchos*	6	0.2400
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0800
	Northern Mockingbird		*Mimus polyglottos*	1	0.0400
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0400
	Tufted Titmouse		*Parus bicolor*	1	0.0400
	Yellow Warbler		*Dendroica petechia*	1	0.0400

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
EPDMFO	Site abundance:	15			
	American Crow		*Corvus brachyrhynchos*	1	0.0667
	American Robin		*Turdus migratorius*	2	0.1333
	Brown Thrasher		*Toxostoma rufum*	1	0.0667
	Carolina Chickadee		*Poecile carolinensis*	2	0.1333
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0667
	Downy Woodpecker		*Picoides pubescens*	1	0.0667
	Eastern Wood-Pewee		*Contopus virens*	1	0.0667
	Northern Cardinal		*Cardinalis cardinalis*	3	0.2000
	Northern Flicker		*Colaptes auratus*	1	0.0667
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0667
	Tufted Titmouse		*Parus bicolor*	1	0.0667
EPDMPU	Site abundance:	11			
	American Crow		*Corvus brachyrhynchos*	1	0.0909
	American Goldfinch		*Carduelis tristis*	2	0.1818
	Carolina Chickadee		*Poecile carolinensis*	4	0.3636
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0909
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0909
	Indigo Bunting		*Passerina cyanea*	1	0.0909
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0909

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
EPKYVE	Site abundance:	42			
	American Goldfinch		*Carduelis tristis*	3	0.0714
	American Robin		*Turdus migratorius*	2	0.0476
	American Robin		*Turdus migratorius*	2	0.0476
	Baltimore Oriole		*Icterus galbula*	1	0.0238
	Belted Kingfisher		*Ceryle alcyon*	1	0.0238
	Blue Jay		*Cyanocitta cristata*	1	0.0238
	Canada Goose		*Branta canadensis*	8	0.1905
	Common Yellowthroat		*Geothlypis trichas*	1	0.0238
	Field Sparrow		*Spizella pusilla*	2	0.0476
	Gray Catbird		*Dumetella carolinensis*	2	0.0476
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0238
	Green Heron		*Butorides virescens*	2	0.0476
	Mourning Dove		*Zenaida macroura*	1	0.0238
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0476
	Northern Mockingbird		*Mimus polyglottos*	1	0.0238
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0238
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.1429
	Tree Swallow		*Tachycineta bicolor*	3	0.0714
	Yellow Warbler		*Dendroica petechia*	1	0.0238
	Yellow-Breasted Chat		*Icteria virens*	1	0.0238
EPRRXC	Site abundance:	14			
	Baltimore Oriole		*Icterus galbula*	1	0.0714
	Brown-Headed Cowbird		*Molothrus ater*	3	0.2143
	Carolina Chickadee		*Poecile carolinensis*	1	0.0714
	Eastern Phoebe		*Sayornis phoebe*	1	0.0714
	Eastern Wood-Pewee		*Contopus virens*	1	0.0714
	Hairy Woodpecker		*Picoides villosus*	1	0.0714
	Hermit Thrush		*Catharus guttatus*	1	0.0714
	Indigo Bunting		*Passerina cyanea*	1	0.0714
	Northern Cardinal		*Cardinalis cardinalis*	2	0.1429
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0714
	Scarlet Tanager		*Piranga olivacea*	1	0.0714

Appendix C.Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
EPSHEM	Site abundance:	26			
	American Goldfinch		*Carduelis tristis*	2	0.0769
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0385
	Carolina Chickadee		*Poecile carolinensis*	3	0.1154
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0385
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0385
	Common Grackle		*Quiscalus quiscula*	2	0.0769
	Common Yellowthroat		*Geothlypis trichas*	2	0.0769
	Gray Catbird		*Dumetella carolinensis*	1	0.0385
	Mallard		*Anas platyrhynchos*	2	0.0769
	Northern Cardinal		*Cardinalis cardinalis*	3	0.1154
	Northern Mockingbird		*Mimus polyglottos*	1	0.0385
	Northern Waterthrush		*Northern Waterthrush*	2	0.0769
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0385
	Song Sparrow		*Melospiza melodia*	3	0.1154
	Wood Thrush		*Hylocichla mustelina*	1	0.0385
EPSHSS	Site abundance:	30			
	American Goldfinch		*Carduelis tristis*	2	0.0667
	American Robin		*Turdus migratorius*	1	0.0333
	Canada Goose		*Branta canadensis*	2	0.0667
	Carolina Chickadee		*Poecile carolinensis*	1	0.0333
	Common Yellowthroat		*Geothlypis trichas*	3	0.1000
	Eastern Wood-Pewee		*Contopus virens*	2	0.0667
	Gray Catbird		*Dumetella carolinensis*	1	0.0333
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0333
	Hermit Thrush		*Catharus guttatus*	1	0.0333
	Indigo Bunting		*Passerina cyanea*	2	0.0667
	Mourning Dove		*Zenaida macroura*	1	0.0333
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0667
	Northern Flicker		*Colaptes auratus*	1	0.0333
	Northern Mockingbird		*Mimus polyglottos*	2	0.0667
	Pileated Woodpecker		*Dryocopus pileatus*	2	0.0667
	Song Sparrow		*Melospiza melodia*	4	0.1333
	White-Eyed Vireo		*Vireo griseus*	1	0.0333
	Willow Flycatcher		*Empidonax traillii*	1	0.0333

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
GBBARN	Site abundance:	24			
	American Goldfinch		*Carduelis tristis*	1	0.0417
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0417
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0417
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0417
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0417
	Common Yellowthroat		*Geothlypis trichas*	2	0.0833
	Eastern Bluebird		*Sialia sialis*	1	0.0417
	Field Sparrow		*Spizella pusilla*	3	0.1250
	Indigo Bunting		*Passerina cyanea*	1	0.0417
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.2083
	Song Sparrow		*Melospiza melodia*	3	0.1250
	Tree Swallow		*Tachycineta bicolor*	2	0.0833
	White-Eyed Vireo		*Vireo griseus*	1	0.0417
	Yellow Warbler		*Dendroica petechia*	1	0.0417
GBHOEF	Site abundance:	44			
	American Goldfinch		*Carduelis tristis*	2	0.0455
	Bank Swallow		*Riparia riparia*	18	0.4091
	Canada Goose		*Branta canadensis*	3	0.0682
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0227
	Common Grackle		*Quiscalus quiscula*	1	0.0227
	Common Yellowthroat		*Geothlypis trichas*	2	0.0455
	Eastern Kingbird		*Tyrannus tyrannus*	2	0.0455
	Eastern Phoebe		*Sayornis phoebe*	1	0.0227
	Field Sparrow		*Spizella pusilla*	1	0.0227
	Indigo Bunting		*Passerina cyanea*	1	0.0227
	Killdeer		*Charadrius vociferus*	1	0.0227
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.1136
	Song Sparrow		*Melospiza melodia*	1	0.0227
	Tree Swallow		*Tachycineta bicolor*	2	0.0455
	Willow Flycatcher		*Empidonax traillii*	3	0.0682

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
GBJENK	Site abundance:	39			
	American Crow		*Corvus brachyrhynchos*	1	0.0256
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0256
	Canada Goose		*Branta canadensis*	16	0.4103
	Common Grackle		*Quiscalus quiscula*	2	0.0513
	Common Yellowthroat		*Geothlypis trichas*	2	0.0513
	Field Sparrow		*Spizella pusilla*	2	0.0513
	Great Blue Heron		*Ardea herodias*	1	0.0256
	Mallard		*Anas platyrhynchos*	2	0.0513
	Orchard Oriole		*Icterus spurius*	1	0.0256
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2051
	Tree Swallow		*Tachycineta bicolor*	2	0.0513
	Yellow Warbler		*Dendroica petechia*	1	0.0256
GBMAPL	Site abundance:	19			
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0526
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0526
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	1	0.0526
	Common Yellowthroat		*Geothlypis trichas*	3	0.1579
	Downy Woodpecker		*Picoides pubescens*	1	0.0526
	Eastern Kingbird		*Tyrannus tyrannus*	1	0.0526
	Field Sparrow		*Spizella pusilla*	1	0.0526
	Gray Catbird		*Dumetella carolinensis*	1	0.0526
	Indigo Bunting		*Passerina cyanea*	1	0.0526
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0526
	Red-Breasted Nuthatch		*Sitta canadensis*	2	0.1053
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0526
	Tufted Titmouse		*Parus bicolor*	3	0.1579
	White-Eyed Vireo		*Vireo griseus*	1	0.0526

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
GBNOFO	Site abundance:	26			
	American Goldfinch		*Carduelis tristis*	1	0.0385
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0385
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0385
	Carolina Wren		*Thryothorus ludovicianus*	2	0.0769
	Common Grackle		*Quiscalus quiscula*	1	0.0385
	Common Yellowthroat		*Geothlypis trichas*	1	0.0385
	Eastern Phoebe		*Sayornis phoebe*	1	0.0385
	Field Sparrow		*Spizella pusilla*	1	0.0385
	Gray Catbird		*Dumetella carolinensis*	1	0.0385
	Northern Mockingbird		*Mimus polyglottos*	1	0.0385
	Prothonotary Warbler		*Protonotaria citrea*	1	0.0385
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0385
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.1923
	Song Sparrow		*Melospiza melodia*	5	0.1923
	White-Eyed Vireo		*Vireo griseus*	1	0.0385
	Willow Flycatcher		*Empidonax traillii*	1	0.0385
	Yellow Warbler		*Dendroica petechia*	1	0.0385
GBNOSS	Site abundance:	26			
	Bank Swallow		*Riparia riparia*	3	0.1154
	Barn Swallow		*Hirundo rustica*	2	0.0769
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0385
	Common Yellowthroat		*Geothlypis trichas*	2	0.0769
	Eastern Bluebird		*Sialia sialis*	1	0.0385
	Field Sparrow		*Spizella pusilla*	1	0.0385
	Gray Catbird		*Dumetella carolinensis*	1	0.0385
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0385
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0385
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.2692
	Song Sparrow		*Melospiza melodia*	3	0.1154
	White-Eyed Vireo		*Vireo griseus*	1	0.0385
	Willow Flycatcher		*Empidonax traillii*	1	0.0385
	Yellow Warbler		*Dendroica petechia*	1	0.0385

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
GBPLOT	Site abundance:	38			
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0263
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0263
	Canada Goose		*Branta canadensis*	13	0.3421
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0263
	Common Yellowthroat		*Geothlypis trichas*	1	0.0263
	Field Sparrow		*Spizella pusilla*	1	0.0263
	Indigo Bunting		*Passerina cyanea*	1	0.0263
	Killdeer		*Charadrius vociferus*	1	0.0263
	Mallard		*Anas platyrhynchos*	1	0.0263
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.1842
	Song Sparrow		*Melospiza melodia*	5	0.1316
	Tree Swallow		*Tachycineta bicolor*	2	0.0526
	Willow Flycatcher		*Empidonax traillii*	2	0.0526
	Yellow Warbler		*Dendroica petechia*	1	0.0263
HCBEAV	Site abundance:	26			
	American Robin		*Turdus migratorius*	2	0.0769
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0385
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0385
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0385
	Carolina Chickadee		*Poecile carolinensis*	1	0.0385
	Common Grackle		*Quiscalus quiscula*	1	0.0385
	Common Yellowthroat		*Geothlypis trichas*	2	0.0769
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0385
	Field Sparrow		*Spizella pusilla*	3	0.1154
	Gray Catbird		*Dumetella carolinensis*	1	0.0385
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0385
	Red-Breasted Nuthatch		*Sitta canadensis*	1	0.0385
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0769
	Scarlet Tanager		*Piranga olivacea*	1	0.0385
	Song Sparrow		*Melospiza melodia*	2	0.0769
	Tree Swallow		*Tachycineta bicolor*	2	0.0769
	Wood Thrush		*Hylocichla mustelina*	1	0.0385
	Yellow Warbler		*Dendroica petechia*	2	0.0769

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
HCMITI	Site abundance:	30			
	American Redstart		*Setophaga ruticilla*	1	0.0333
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0333
	Carolina Chickadee		*Poecile carolinensis*	1	0.0333
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0333
	Common Grackle		*Quiscalus quiscula*	1	0.0333
	Common Yellowthroat		*Geothlypis trichas*	2	0.0667
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0333
	Field Sparrow		*Spizella pusilla*	2	0.0667
	Gray Catbird		*Dumetella carolinensis*	1	0.0333
	Green Heron		*Butorides virescens*	1	0.0333
	Killdeer		*Charadrius vociferus*	1	0.0333
	Marsh Wren		*Cistothorus palustris*	1	0.0333
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0333
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.2000
	Song Sparrow		*Melospiza melodia*	3	0.1000
	Tree Swallow		*Tachycineta bicolor*	3	0.1000
	Willow Flycatcher		*Empidonax traillii*	1	0.0333
	Wood Duck		*Aix sponsa*	1	0.0333
	Yellow Warbler		*Dendroica petechia*	1	0.0333
HCPIPE	Site abundance:	35			
	American Robin		*Turdus migratorius*	2	0.0571
	Blue Jay		*Cyanocitta cristata*	1	0.0286
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0571
	Common Grackle		*Quiscalus quiscula*	1	0.0286
	Common Yellowthroat		*Geothlypis trichas*	2	0.0571
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0571
	Field Sparrow		*Spizella pusilla*	2	0.0571
	Mourning Dove		*Zenaida macroura*	1	0.0286
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0286
	Red-Winged Blackbird		*Agelaius phoeniceus*	12	0.3429
	Song Sparrow		*Melospiza melodia*	2	0.0571
	Tree Swallow		*Tachycineta bicolor*	1	0.0286
	Willow Flycatcher		*Empidonax traillii*	2	0.0571
	Yellow Warbler		*Dendroica petechia*	3	0.0857
	Yellow-Breasted Chat		*Icteria virens*	1	0.0286

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
HCRANG	Site abundance:	28			
	American Goldfinch		*Carduelis tristis*	2	0.0714
	American Robin		*Turdus migratorius*	1	0.0357
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0714
	Common Grackle		*Quiscalus quiscula*	2	0.0714
	Common Yellowthroat		*Geothlypis trichas*	2	0.0714
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0714
	Field Sparrow		*Spizella pusilla*	2	0.0714
	Mourning Dove		*Zenaida macroura*	1	0.0357
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.2500
	Willow Flycatcher		*Empidonax traillii*	1	0.0357
	Willow Flycatcher		*Empidonax traillii*	2	0.0714
	Yellow Warbler		*Dendroica petechia*	3	0.1071
	Yellow-Breasted Chat		*Icteria virens*	1	0.0357
HIBRID	Site abundance:	32			
	American Goldfinch		*Carduelis tristis*	2	0.0625
	American Robin		*Turdus migratorius*	1	0.0313
	Baltimore Oriole		*Icterus galbula*	1	0.0313
	Barn Swallow		*Hirundo rustica*	1	0.0313
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0313
	Common Grackle		*Quiscalus quiscula*	3	0.0938
	Gray Catbird		*Dumetella carolinensis*	1	0.0313
	House Wren		*Troglodytes aedon*	1	0.0313
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0313
	Northern Flicker		*Colaptes auratus*	1	0.0313
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.1875
	Song Sparrow		*Melospiza melodia*	3	0.0938
	Tree Swallow		*Tachycineta bicolor*	5	0.1563
	Warbling Vireo		*Vireo gilvus*	2	0.0625
	Willow Flycatcher		*Empidonax traillii*	1	0.0313
	Yellow Warbler		*Dendroica petechia*	2	0.0625

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
HIGATE	Site abundance:	24			
	American Goldfinch		*Carduelis tristis*	1	0.0417
	American Robin		*Turdus migratorius*	1	0.0417
	American Robin		*Turdus migratorius*	1	0.0417
	Belted Kingfisher		*Ceryle alcyon*	1	0.0417
	Blue Jay		*Cyanocitta cristata*	1	0.0417
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	2	0.0833
	Carolina Chickadee		*Poecile carolinensis*	2	0.0833
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0417
	Common Yellowthroat		*Geothlypis trichas*	2	0.0833
	Eastern Phoebe		*Sayornis phoebe*	1	0.0417
	Gray Catbird		*Dumetella carolinensis*	1	0.0417
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0417
	Indigo Bunting		*Passerina cyanea*	1	0.0417
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0417
	Northern Waterthrush		*Northern Waterthrush*	1	0.0417
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0417
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0417
	Song Sparrow		*Melospiza melodia*	1	0.0417
	Tufted Titmouse		*Parus bicolor*	2	0.0833
	Yellow Warbler		*Dendroica petechia*	1	0.0417

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
HIJHPK	Site abundance:	24			
	American Crow		*Corvus brachyrhynchos*	1	0.0417
	American Robin		*Turdus migratorius*	1	0.0417
	Blue Jay		*Cyanocitta cristata*	1	0.0417
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0417
	Carolina Chickadee		*Poecile carolinensis*	3	0.1250
	Carolina Wren		*Thryothorus ludovicianus*	3	0.1250
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0417
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	1	0.0417
	Common Yellowthroat		*Geothlypis trichas*	0	0.0000
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0833
	Eastern Wood-Pewee		*Contopus virens*	1	0.0417
	Gray Catbird		*Dumetella carolinensis*	1	0.0417
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0417
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0417
	Northern Parula		*Parula americana*	1	0.0417
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0417
	Scarlet Tanager		*Piranga olivacea*	1	0.0417
	Tufted Titmouse		*Parus bicolor*	1	0.0417
	Winter Wren		*Troglodytes troglodytes*	1	0.0417
	Wood Thrush		*Hylocichla mustelina*	1	0.0417
HIJHTU	Site abundance:	21			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0476
	American Goldfinch		*Carduelis tristis*	2	0.0952
	Blue Jay		*Cyanocitta cristata*	1	0.0476
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0476
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0476
	Carolina Chickadee		*Poecile carolinensis*	3	0.1429
	Eastern Phoebe		*Sayornis phoebe*	1	0.0476
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0476
	Gray Catbird		*Dumetella carolinensis*	1	0.0476
	Hooded Warbler		*Wilsonia citrina*	1	0.0476
	Indigo Bunting		*Passerina cyanea*	1	0.0476
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0952
	Orchard Oriole		*Icterus spurius*	1	0.0476
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0476
	Song Sparrow		*Melospiza melodia*	2	0.0952
	Tufted Titmouse		*Parus bicolor*	1	0.0476

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
HIPENC	Site abundance:	32			
	American Robin		*Turdus migratorius*	1	0.0313
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	2	0.0625
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0313
	Blue-Winged Warbler		*Vermivora pinus*	2	0.0625
	Carolina Chickadee		*Poecile carolinensis*	1	0.0313
	Common Yellowthroat		*Geothlypis trichas*	1	0.0313
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0625
	Field Sparrow		*Spizella pusilla*	1	0.0313
	Green Heron		*Butorides virescens*	1	0.0313
	Hermit Thrush		*Catharus guttatus*	1	0.0313
	House Wren		*Troglodytes aedon*	1	0.0313
	Mourning Dove		*Zenaida macroura*	1	0.0313
	Northern Waterthrush		*Northern Waterthrush*	1	0.0313
	Red-Winged Blackbird		*Agelaius phoeniceus*	12	0.3750
	Scarlet Tanager		*Piranga olivacea*	1	0.0313
	Sedge Wren		*Cistothorus platensis*	1	0.0313
	Song Sparrow		*Melospiza melodia*	2	0.0625
HISEWG	Site abundance:	21			
	American Redstart		*Setophaga ruticilla*	2	0.0952
	American Robin		*Turdus migratorius*	1	0.0476
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0476
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0476
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0476
	Carolina Chickadee		*Poecile carolinensis*	1	0.0476
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0476
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0476
	Eastern Wood-Pewee		*Contopus virens*	1	0.0476
	Hermit Thrush		*Catharus guttatus*	1	0.0476
	Mourning Warbler		*Oporornis philadelphia*	1	0.0476
	Northern Flicker		*Colaptes auratus*	2	0.0952
	Northern Waterthrush		*Northern Waterthrush*	1	0.0476
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0476
	Song Sparrow		*Melospiza melodia*	5	0.2381

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
HITRLR	Site abundance:	27			
	American Crow		*Corvus brachyrhynchos*	1	0.0370
	American Robin		*Turdus migratorius*	3	0.1111
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0370
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0370
	Common Yellowthroat		*Geothlypis trichas*	1	0.0370
	Eastern Wood-Pewee		*Contopus virens*	1	0.0370
	Field Sparrow		*Spizella pusilla*	1	0.0370
	Gray Catbird		*Dumetella carolinensis*	1	0.0370
	House Wren		*Troglodytes aedon*	1	0.0370
	Indigo Bunting		*Passerina cyanea*	1	0.0370
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0370
	Northern Mockingbird		*Mimus polyglottos*	1	0.0370
	Orchard Oriole		*Icterus spurius*	1	0.0370
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0370
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2963
	Tree Swallow		*Tachycineta bicolor*	2	0.0741
	Yellow Warbler		*Dendroica petechia*	1	0.0370
MCFOUR	Site abundance:	21			
	American Crow		*Corvus brachyrhynchos*	1	0.0476
	American Goldfinch		*Carduelis tristis*	1	0.0476
	Blue-Winged Warbler		*Vermivora pinus*	3	0.1429
	Brown Thrasher		*Toxostoma rufum*	1	0.0476
	Carolina Chickadee		*Poecile carolinensis*	1	0.0476
	Common Grackle		*Quiscalus quiscula*	1	0.0476
	Common Yellowthroat		*Geothlypis trichas*	2	0.0952
	Eastern Towhee		*Pipilo erythrophthalmus*	3	0.1429
	Field Sparrow		*Spizella pusilla*	2	0.0952
	Gray Catbird		*Dumetella carolinensis*	1	0.0476
	Indigo Bunting		*Passerina cyanea*	2	0.0952
	Kentucky Warbler		*Oporornis formosus*	1	0.0476
	Scarlet Tanager		*Piranga olivacea*	1	0.0476
	Wood Thrush		*Hylocichla mustelina*	1	0.0476

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MCMEME	Site abundance:	47			
	American Crow		*Corvus brachyrhynchos*	1	0.0213
	American Robin		*Turdus migratorius*	1	0.0213
	Canada Goose		*Branta canadensis*	8	0.1702
	Common Grackle		*Quiscalus quiscula*	3	0.0638
	Common Yellowthroat		*Geothlypis trichas*	2	0.0426
	Eastern Kingbird		*Tyrannus tyrannus*	3	0.0638
	Great Blue Heron		*Ardea herodias*	3	0.0638
	Indigo Bunting		*Passerina cyanea*	2	0.0426
	Killdeer		*Charadrius vociferus*	1	0.0213
	Mallard		*Anas platyrhynchos*	1	0.0213
	Osprey		*Pandion haliaetus*	1	0.0213
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.2128
	Song Sparrow		*Melospiza melodia*	3	0.0638
	Tree Swallow		*Tachycineta bicolor*	8	0.1702
MCMFOR	Site abundance:	32			
	American Robin		*Turdus migratorius*	4	0.1250
	Blue Jay		*Cyanocitta cristata*	1	0.0313
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0313
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0313
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0313
	Common Grackle		*Quiscalus quiscula*	1	0.0313
	Eastern Bluebird		*Sialia sialis*	2	0.0625
	Eastern Kingbird		*Tyrannus tyrannus*	1	0.0313
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0313
	Eastern Wood-Pewee		*Contopus virens*	2	0.0625
	Hairy Woodpecker		*Picoides villosus*	1	0.0313
	Mallard		*Anas platyrhynchos*	2	0.0625
	Prothonotary Warbler		*Protonotaria citrea*	1	0.0313
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.0938
	Sedge Wren		*Cistothorus platensis*	2	0.0625
	Song Sparrow		*Melospiza melodia*	1	0.0313
	White-Eyed Vireo		*Vireo griseus*	1	0.0313
	Wood Duck		*Aix sponsa*	3	0.0938
	Wood Thrush		*Hylocichla mustelina*	1	0.0313
	Yellow Warbler		*Dendroica petechia*	2	0.0625

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
MCNPFO	Site abundance:	14			
	American Robin		*Turdus migratorius*	1	0.0714
	Brown Thrasher		*Toxostoma rufum*	1	0.0714
	Carolina Chickadee		*Poecile carolinensis*	1	0.0714
	Common Yellowthroat		*Geothlypis trichas*	1	0.0714
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0714
	Eastern Wood-Pewee		*Contopus virens*	1	0.0714
	Field Sparrow		*Spizella pusilla*	1	0.0714
	Indigo Bunting		*Passerina cyanea*	1	0.0714
	Kentucky Warbler		*Oporornis formosus*	1	0.0714
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0714
	Ovenbird		*Seiurus aurocapillus*	1	0.0714
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0714
	Wood Thrush		*Hylocichla mustelina*	1	0.0714
	Yellow Warbler		*Dendroica petechia*	1	0.0714
MCPOND	Site abundance:	15			
	American Crow		*Corvus brachyrhynchos*	1	0.0667
	American Goldfinch		*Carduelis tristis*	1	0.0667
	Carolina Chickadee		*Poecile carolinensis*	1	0.0667
	Common Yellowthroat		*Geothlypis trichas*	1	0.0667
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0667
	Field Sparrow		*Spizella pusilla*	1	0.0667
	Gray Catbird		*Dumetella carolinensis*	1	0.0667
	Great Blue Heron		*Ardea herodias*	1	0.0667
	Mourning Dove		*Zenaida macroura*	1	0.0667
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0667
	Northern Mockingbird		*Mimus polyglottos*	1	0.0667
	Northern Parula		*Parula americana*	1	0.0667
	Song Sparrow		*Melospiza melodia*	1	0.0667
	White-Eyed Vireo		*Vireo griseus*	1	0.0667
	Wood Thrush		*Hylocichla mustelina*	1	0.0667

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MCPOST	Site abundance:	23			
	American Redstart		*Setophaga ruticilla*	1	0.0435
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0435
	Carolina Chickadee		*Poecile carolinensis*	1	0.0435
	Common Grackle		*Quiscalus quiscula*	3	0.1304
	Common Yellowthroat		*Geothlypis trichas*	2	0.0870
	Eastern Kingbird		*Tyrannus tyrannus*	2	0.0870
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0435
	Eastern Wood-Pewee		*Contopus virens*	1	0.0435
	European Starling		*Sturnus vulgaris*	3	0.1304
	Gray Catbird		*Dumetella carolinensis*	2	0.0870
	Indigo Bunting		*Passerina cyanea*	1	0.0435
	Mallard		*Anas platyrhynchos*	1	0.0435
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0435
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0870
	Song Sparrow		*Melospiza melodia*	1	0.0435
MCTELE	Site abundance:	20			
	American Crow		*Corvus brachyrhynchos*	1	0.0500
	Blue Jay		*Cyanocitta cristata*	1	0.0500
	Brown Thrasher		*Toxostoma rufum*	1	0.0500
	Brown-Headed Cowbird		*Molothrus ater*	2	0.1000
	Carolina Chickadee		*Poecile carolinensis*	2	0.1000
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0500
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0500
	Eastern Wood-Pewee		*Contopus virens*	1	0.0500
	Gray Catbird		*Dumetella carolinensis*	1	0.0500
	Indigo Bunting		*Passerina cyanea*	1	0.0500
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0500
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1500
	Song Sparrow		*Melospiza melodia*	2	0.1000
	White-Eyed Vireo		*Vireo griseus*	1	0.0500
	Yellow-Breasted Chat		*Icteria virens*	1	0.0500

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
ME5092	Site abundance:	21			
	American Goldfinch		*Carduelis tristis*	1	0.0476
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0476
	Common Yellowthroat		*Geothlypis trichas*	2	0.0952
	Field Sparrow		*Spizella pusilla*	1	0.0476
	Gray Catbird		*Dumetella carolinensis*	2	0.0952
	Northern Rough-Winged Swallow		*Stelgidopteryx serripennis*	1	0.0476
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.2381
	Song Sparrow		*Melospiza melodia*	3	0.1429
	Willow Flycatcher		*Empidonax traillii*	2	0.0952
	Yellow Warbler		*Dendroica petechia*	3	0.1429
MESCOX	Site abundance:	26			
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0385
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0385
	Common Yellowthroat		*Geothlypis trichas*	2	0.0769
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0385
	Field Sparrow		*Spizella pusilla*	2	0.0769
	Gray Catbird		*Dumetella carolinensis*	1	0.0385
	House Wren		*Troglodytes aedon*	1	0.0385
	Indigo Bunting		*Passerina cyanea*	1	0.0385
	Mourning Dove		*Zenaida macroura*	1	0.0385
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0385
	Northern Flicker		*Colaptes auratus*	2	0.0769
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0385
	Song Sparrow		*Melospiza melodia*	4	0.1538
	Tree Swallow		*Tachycineta bicolor*	2	0.0769
	Tufted Titmouse		*Parus bicolor*	1	0.0385
	White-Eyed Vireo		*Vireo griseus*	1	0.0385
	Yellow Warbler		*Dendroica petechia*	2	0.0769
	Yellow-Breasted Chat		*Icteria virens*	1	0.0385

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
MESCRO	Site abundance:	31			
	American Goldfinch		*Carduelis tristis*	2	0.0645
	Common Yellowthroat		*Geothlypis trichas*	1	0.0323
	Field Sparrow		*Spizella pusilla*	1	0.0323
	Gray Catbird		*Dumetella carolinensis*	2	0.0645
	House Wren		*Troglodytes aedon*	2	0.0645
	Indigo Bunting		*Passerina cyanea*	2	0.0645
	Northern Parula		*Parula americana*	1	0.0323
	Orchard Oriole		*Icterus spurius*	1	0.0323
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.3226
	Song Sparrow		*Melospiza melodia*	3	0.0968
	Tree Swallow		*Tachycineta bicolor*	2	0.0645
	Willow Flycatcher		*Empidonax traillii*	1	0.0323
	Wood Duck		*Aix sponsa*	1	0.0323
	Yellow Warbler		*Dendroica petechia*	2	0.0645
MESCUP	Site abundance:	22			
	American Goldfinch		*Carduelis tristis*	1	0.0455
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0909
	Common Yellowthroat		*Geothlypis trichas*	1	0.0455
	Eastern Kingbird		*Tyrannus tyrannus*	1	0.0455
	Eastern Phoebe		*Sayornis phoebe*	1	0.0455
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0455
	European Starling		*Sturnus vulgaris*	3	0.1364
	Field Sparrow		*Spizella pusilla*	2	0.0909
	Gray Catbird		*Dumetella carolinensis*	1	0.0455
	Indigo Bunting		*Passerina cyanea*	1	0.0455
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0455
	Song Sparrow		*Melospiza melodia*	3	0.1364
	Tree Swallow		*Tachycineta bicolor*	2	0.0909
	Wood Thrush		*Hylocichla mustelina*	1	0.0455
	Yellow Warbler		*Dendroica petechia*	1	0.0455

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MESIGN	Site abundance:	21			
	American Goldfinch		*Carduelis tristis*	1	0.0476
	American Robin		*Turdus migratorius*	1	0.0476
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0952
	Common Yellowthroat		*Geothlypis trichas*	1	0.0476
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0476
	Gray Catbird		*Dumetella carolinensis*	3	0.1429
	House Wren		*Troglodytes aedon*	2	0.0952
	Indigo Bunting		*Passerina cyanea*	1	0.0476
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0476
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0952
	Song Sparrow		*Melospiza melodia*	3	0.1429
	Tufted Titmouse		*Parus bicolor*	2	0.0952
	Yellow Warbler		*Dendroica petechia*	1	0.0476
MESILV	Site abundance:	29			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0345
	American Goldfinch		*Carduelis tristis*	1	0.0345
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0345
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0345
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0345
	Common Yellowthroat		*Geothlypis trichas*	3	0.1034
	Eastern Phoebe		*Sayornis phoebe*	1	0.0345
	Field Sparrow		*Spizella pusilla*	1	0.0345
	Indigo Bunting		*Passerina cyanea*	1	0.0345
	Northern Mockingbird		*Mimus polyglottos*	1	0.0345
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2759
	Song Sparrow		*Melospiza melodia*	3	0.1034
	Tufted Titmouse		*Parus bicolor*	1	0.0345
	Yellow Warbler		*Dendroica petechia*	3	0.1034
	Yellow-Breasted Chat		*Icteria virens*	2	0.0690

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
METETR	Site abundance:	22			
	Barn Swallow		*Hirundo rustica*	2	0.0909
	Eastern Bluebird		*Sialia sialis*	2	0.0909
	Green Heron		*Butorides virescens*	2	0.0909
	Red-Winged Blackbird		*Agelaius phoeniceus*	9	0.4091
	Ruby-Throated Hummingbird		*Archilochus colubris*	1	0.0455
	Song Sparrow		*Melospiza melodia*	4	0.1818
	Tree Swallow		*Tachycineta bicolor*	1	0.0455
	Yellow Warbler		*Dendroica petechia*	1	0.0455
MEWOLF	Site abundance:	25			
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0400
	Common Yellowthroat		*Geothlypis trichas*	6	0.2400
	Eastern Bluebird		*Sialia sialis*	1	0.0400
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0400
	Gray Catbird		*Dumetella carolinensis*	3	0.1200
	Indigo Bunting		*Passerina cyanea*	1	0.0400
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0400
	Northern Waterthrush		*Northern Waterthrush*	1	0.0400
	Orchard Oriole		*Icterus spurius*	1	0.0400
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0400
	Song Sparrow		*Melospiza melodia*	3	0.1200
	Wood Duck		*Aix sponsa*	1	0.0400
	Yellow Warbler		*Dendroica petechia*	3	0.1200

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MRBESS	Site abundance:	16			
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0625
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0625
	Carolina Chickadee		*Poecile carolinensis*	1	0.0625
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0625
	Common Grackle		*Quiscalus quiscula*	1	0.0625
	Common Yellowthroat		*Geothlypis trichas*	1	0.0625
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0625
	Eastern Wood-Pewee		*Contopus virens*	1	0.0625
	Hooded Warbler		*Wilsonia citrina*	1	0.0625
	Ovenbird		*Seiurus aurocapillus*	1	0.0625
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1875
	White-Breasted Nuthatch		*Sitta carolinensis*	1	0.0625
	Wood Thrush		*Hylocichla mustelina*	1	0.0625
	Yellow-Breasted Chat		*Icteria virens*	1	0.0625
MRFARM	Site abundance:	19			
	American Goldfinch		*Carduelis tristis*	2	0.1053
	Carolina Chickadee		*Poecile carolinensis*	1	0.0526
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0526
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	2	0.1053
	Common Yellowthroat		*Geothlypis trichas*	1	0.0526
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.1053
	Field Sparrow		*Spizella pusilla*	1	0.0526
	Grasshopper Sparrow		*Ammodramus savannarum*	1	0.0526
	Gray Catbird		*Dumetella carolinensis*	1	0.0526
	House Wren		*Troglodytes aedon*	1	0.0526
	Indigo Bunting		*Passerina cyanea*	3	0.1579
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0526
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0526
	Yellow Warbler		*Dendroica petechia*	1	0.0526

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MRFORE	Site abundance:	15			
	American Goldfinch		*Carduelis tristis*	1	0.0667
	Common Grackle		*Quiscalus quiscula*	1	0.0667
	Common Yellowthroat		*Geothlypis trichas*	2	0.1333
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.1333
	Eastern Wood-Pewee		*Contopus virens*	1	0.0667
	Field Sparrow		*Spizella pusilla*	1	0.0667
	Indigo Bunting		*Passerina cyanea*	1	0.0667
	Ovenbird		*Seiurus aurocapillus*	2	0.1333
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0667
	White-Eyed Vireo		*Vireo griseus*	1	0.0667
	Wood Thrush		*Hylocichla mustelina*	1	0.0667
	Yellow Warbler		*Dendroica petechia*	1	0.0667
MRSSSS	Site abundance:	18			
	Blue Jay		*Cyanocitta cristata*	1	0.0556
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0556
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0556
	Carolina Chickadee		*Poecile carolinensis*	2	0.1111
	Common Yellowthroat		*Geothlypis trichas*	1	0.0556
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.1111
	Gray Catbird		*Dumetella carolinensis*	2	0.1111
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0556
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0556
	Scarlet Tanager		*Piranga olivacea*	1	0.0556
	White-Breasted Nuthatch		*Sitta carolinensis*	1	0.0556
	Wood Thrush		*Hylocichla mustelina*	3	0.1667
	Yellow Warbler		*Dendroica petechia*	1	0.0556

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MRWEST	Site abundance:	17			
	American Goldfinch		*Carduelis tristis*	1	0.0588
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0588
	Carolina Chickadee		*Poecile carolinensis*	2	0.1176
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0588
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0588
	Field Sparrow		*Spizella pusilla*	2	0.1176
	Golden-Winged Warbler		*Vermivora chrysoptera*	2	0.1176
	Indigo Bunting		*Passerina cyanea*	1	0.0588
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0588
	Northern Flicker		*Colaptes auratus*	1	0.0588
	Ovenbird		*Seiurus aurocapillus*	1	0.0588
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0588
	Savannah Sparrow		*Passerculus sandwichensis*	1	0.0588
	Wood Thrush		*Hylocichla mustelina*	1	0.0588
MU55SS	Site abundance:	18			
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0556
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0556
	Common Yellowthroat		*Geothlypis trichas*	2	0.1111
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0556
	Field Sparrow		*Spizella pusilla*	1	0.0556
	Gray Catbird		*Dumetella carolinensis*	2	0.1111
	House Wren		*Troglodytes aedon*	2	0.1111
	Indigo Bunting		*Passerina cyanea*	2	0.1111
	Northern Mockingbird		*Mimus polyglottos*	1	0.0556
	Northern Waterthrush		*Northern Waterthrush*	1	0.0556
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.1111
	Song Sparrow		*Melospiza melodia*	1	0.0556
	Yellow Warbler		*Dendroica petechia*	1	0.0556

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
MUDBOA	Site abundance:	14			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0714
	American Redstart		*Setophaga ruticilla*	2	0.1429
	Barred Owl		*Strix varia*	1	0.0714
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0714
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0714
	Cerulean Warbler		*Dendroica cerulea*	1	0.0714
	Dark-Eyed Junco		*Junco hyemalis*	2	0.1429
	Northern Parula		*Parula americana*	1	0.0714
	Northern Waterthrush		*Northern Waterthrush*	1	0.0714
	Ovenbird		*Seiurus aurocapillus*	1	0.0714
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0714
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0714

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
MUDEND	Site abundance: 44			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0227
	Black-and-White Warbler	*Mniotilta varia*	1	0.0227
	Black-capped Chickadee	*Poecile atricapilla*	2	0.0455
	Blue-Gray Gnatcatcher	*Polioptila caerulea*	2	0.0455
	Blue-Headed Vireo	*Vireo solitarius*	1	0.0227
	Brown-Headed Cowbird	*Molothrus ater*	1	0.0227
	Carolina Wren	*Thryothorus ludovicianus*	1	0.0227
	Cerulean Warbler	*Dendroica cerulea*	1	0.0227
	Dark-Eyed Junco	*Junco hyemalis*	2	0.0455
	Eastern Bluebird	*Sialia sialis*	1	0.0227
	Eastern Phoebe	*Sayornis phoebe*	2	0.0455
	European Starling	*Sturnus vulgaris*	1	0.0227
	Indigo Bunting	*Passerina cyanea*	1	0.0227
	Mourning Dove	*Zenaida macroura*	1	0.0227
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0227
	Northern Flicker	*Colaptes auratus*	2	0.0455
	Northern Mockingbird	*Mimus polyglottos*	1	0.0227
	Northern Parula	*Parula americana*	2	0.0455
	Orchard Oriole	*Icterus spurius*	1	0.0227
	Pileated Woodpecker	*Dryocopus pileatus*	1	0.0227
	Red-Billed Woodpecker	*Melanerpes carolinus*	1	0.0227
	Red-Winged Blackbird	*Agelaius phoeniceus*	2	0.0455
	Song Sparrow	*Melospiza melodia*	2	0.0455
	Tree Swallow	*Tachycineta bicolor*	4	0.0909
	White-Breasted Nuthatch	*Sitta carolinensis*	1	0.0227
	Wood Duck	*Aix sponsa*	5	0.1136
	Yellow Warbler	*Dendroica petechia*	2	0.0455
	Yellow-Breasted Chat	*Icteria virens*	1	0.0227

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MUDRIC	Site abundance:	18			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0556
	American Redstart		*Setophaga ruticilla*	2	0.1111
	American Robin		*Turdus migratorius*	1	0.0556
	Black-and-White Warbler		*Mniotilta varia*	1	0.0556
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0556
	Eastern Phoebe		*Sayornis phoebe*	1	0.0556
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0556
	Green Heron		*Butorides virescens*	1	0.0556
	Hermit Thrush		*Catharus guttatus*	1	0.0556
	House Wren		*Troglodytes aedon*	1	0.0556
	Ovenbird		*Seiurus aurocapillus*	1	0.0556
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0556
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0556
	Scarlet Tanager		*Piranga olivacea*	1	0.0556
	White-Breasted Nuthatch		*Sitta carolinensis*	1	0.0556
	White-Eyed Vireo		*Vireo griseus*	1	0.0556
	Wood Thrush		*Hylocichla mustelina*	1	0.0556

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MUDRIP	Site abundance:	39			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0256
	American Goldfinch		*Carduelis tristis*	3	0.0769
	Belted Kingfisher		*Ceryle alcyon*	1	0.0256
	Black-and-White Warbler		*Mniotilta varia*	1	0.0256
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0256
	Carolina Chickadee		*Poecile carolinensis*	1	0.0256
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0256
	Cerulean Warbler		*Dendroica cerulea*	1	0.0256
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	1	0.0256
	Chipping Sparrow		*Spizella passerina*	1	0.0256
	Common Yellowthroat		*Geothlypis trichas*	2	0.0513
	Eastern Phoebe		*Sayornis phoebe*	3	0.0769
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0256
	Eastern Wood-Pewee		*Contopus virens*	1	0.0256
	European Starling		*Sturnus vulgaris*	1	0.0256
	Gray Catbird		*Dumetella carolinensis*	1	0.0256
	Green Heron		*Butorides virescens*	1	0.0256
	Indigo Bunting		*Passerina cyanea*	1	0.0256
	Mourning Dove		*Zenaida macroura*	1	0.0256
	Northern Flicker		*Colaptes auratus*	1	0.0256
	Northern Parula		*Parula americana*	2	0.0513
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0256
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.1282
	Song Sparrow		*Melospiza melodia*	2	0.0513
	Wood Duck		*Aix sponsa*	1	0.0256
	Yellow Warbler		*Dendroica petechia*	2	0.0513
	Yellow-Breasted Chat		*Icteria virens*	1	0.0256

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
MUDTRA	Site abundance: 31			
	American Goldfinch	*Carduelis tristis*	1	0.0323
	Black-and-White Warbler	*Mniotilta varia*	1	0.0323
	Blue-Gray Gnatcatcher	*Polioptila caerulea*	1	0.0323
	Carolina Chickadee	*Poecile carolinensis*	2	0.0645
	Common Yellowthroat	*Geothlypis trichas*	3	0.0968
	Downy Woodpecker	*Picoides pubescens*	2	0.0645
	Eastern Phoebe	*Sayornis phoebe*	1	0.0323
	Eastern Towhee	*Pipilo erythrophthalmus*	1	0.0323
	Gray Catbird	*Dumetella carolinensis*	2	0.0645
	Green Heron	*Butorides virescens*	2	0.0645
	Indigo Bunting	*Passerina cyanea*	3	0.0968
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0323
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0323
	Northern Flicker	*Colaptes auratus*	1	0.0323
	Orchard Oriole	*Icterus spurius*	1	0.0323
	Red-Winged Blackbird	*Agelaius phoeniceus*	2	0.0645
	Song Sparrow	*Melospiza melodia*	2	0.0645
	Tufted Titmouse	*Parus bicolor*	1	0.0323
	White-Eyed Vireo	*Vireo griseus*	1	0.0323
	Yellow Warbler	*Dendroica petechia*	1	0.0323
	Yellow-Breasted Chat	*Icteria virens*	1	0.0323

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
MUEPAH	Site abundance:	22			
	American Goldfinch		*Carduelis tristis*	1	0.0455
	American Goldfinch		*Carduelis tristis*	1	0.0455
	American Robin		*Turdus migratorius*	1	0.0455
	Common Yellowthroat		*Geothlypis trichas*	2	0.0909
	Eastern Phoebe		*Sayornis phoebe*	1	0.0455
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0455
	Field Sparrow		*Spizella pusilla*	1	0.0455
	Green Heron		*Butorides virescens*	1	0.0455
	Indigo Bunting		*Passerina cyanea*	2	0.0909
	Mourning Dove		*Zenaida macroura*	1	0.0455
	Northern Flicker		*Colaptes auratus*	1	0.0455
	Northern Rough-Winged Swallow		*Stelgidopteryx serripennis*	2	0.0909
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1364
	Savannah Sparrow		*Passerculus sandwichensis*	1	0.0455
	Song Sparrow		*Melospiza melodia*	2	0.0909
	Yellow Warbler		*Dendroica petechia*	1	0.0455
MUMINE	Site abundance:	20			
	American Goldfinch		*Carduelis tristis*	1	0.0500
	Blue Jay		*Cyanocitta cristata*	1	0.0500
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0500
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0500
	Blue-Winged Warbler		*Vermivora pinus*	2	0.1000
	Carolina Chickadee		*Poecile carolinensis*	2	0.1000
	Common Yellowthroat		*Geothlypis trichas*	1	0.0500
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0500
	Gray Catbird		*Dumetella carolinensis*	2	0.1000
	Northern Flicker		*Colaptes auratus*	1	0.0500
	Northern Flicker		*Colaptes auratus*	1	0.0500
	Ovenbird		*Seiurus aurocapillus*	1	0.0500
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0500
	Song Sparrow		*Melospiza melodia*	2	0.1000
	Tufted Titmouse		*Parus bicolor*	1	0.0500
	White-Eyed Vireo		*Vireo griseus*	1	0.0500

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MUPOWR	Site abundance:	23			
	Alder Flycatcher		*Empidonax alnorum*	1	0.0435
	American Redstart		*Setophaga ruticilla*	1	0.0435
	Carolina Chickadee		*Poecile carolinensis*	2	0.0870
	Cedar Waxwing		*Bombycilla cedrorum*	3	0.1304
	Common Grackle		*Quiscalus quiscula*	3	0.1304
	Common Yellowthroat		*Geothlypis trichas*	1	0.0435
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0435
	Gray Catbird		*Dumetella carolinensis*	1	0.0435
	Northern Flicker		*Colaptes auratus*	1	0.0435
	Northern Parula		*Parula americana*	1	0.0435
	Ovenbird		*Seiurus aurocapillus*	1	0.0435
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0435
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0870
	Song Sparrow		*Melospiza melodia*	3	0.1304
	Tufted Titmouse		*Parus bicolor*	1	0.0435
MUPULL	Site abundance:	31			
	Alder Flycatcher		*Empidonax alnorum*	1	0.0323
	American Goldfinch		*Carduelis tristis*	2	0.0645
	American Redstart		*Setophaga ruticilla*	1	0.0323
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0323
	Common Yellowthroat		*Geothlypis trichas*	2	0.0645
	European Starling		*Sturnus vulgaris*	1	0.0323
	Gray Catbird		*Dumetella carolinensis*	2	0.0645
	Hairy Woodpecker		*Picoides villosus*	1	0.0323
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0323
	Northern Waterthrush		*Northern Waterthrush*	1	0.0323
	Red-Eyed Vireo		*Vireo olivaceus*	2	0.0645
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.0968
	Sedge Wren		*Cistothorus platensis*	1	0.0323
	Song Sparrow		*Melospiza melodia*	5	0.1613
	Tree Swallow		*Tachycineta bicolor*	1	0.0323
	Tufted Titmouse		*Parus bicolor*	1	0.0323
	White-Eyed Vireo		*Vireo griseus*	1	0.0323
	Willow Flycatcher		*Empidonax traillii*	1	0.0323
	Yellow Warbler		*Dendroica petechia*	3	0.0968

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
MUVBRD	Site abundance:	32			
	American Redstart		*Setophaga ruticilla*	1	0.0313
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0313
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0313
	Common Grackle		*Quiscalus quiscula*	1	0.0313
	Common Yellowthroat		*Geothlypis trichas*	2	0.0625
	Eastern Bluebird		*Sialia sialis*	1	0.0313
	House Wren		*Troglodytes aedon*	1	0.0313
	Indigo Bunting		*Passerina cyanea*	1	0.0313
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0313
	Northern Mockingbird		*Mimus polyglottos*	1	0.0313
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0313
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.2188
	Sedge Wren		*Cistothorus platensis*	1	0.0313
	Sedge Wren		*Cistothorus platensis*	1	0.0313
	Song Sparrow		*Melospiza melodia*	3	0.0938
	Tree Swallow		*Tachycineta bicolor*	5	0.1563
	Tufted Titmouse		*Parus bicolor*	1	0.0313
	Willow Flycatcher		*Empidonax traillii*	1	0.0313
	Yellow Warbler		*Dendroica petechia*	1	0.0313
MUVCRN	Site abundance:	31			
	American Goldfinch		*Carduelis tristis*	1	0.0323
	American Robin		*Turdus migratorius*	1	0.0323
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0323
	Common Yellowthroat		*Geothlypis trichas*	1	0.0323
	Field Sparrow		*Spizella pusilla*	2	0.0645
	Gray Catbird		*Dumetella carolinensis*	1	0.0323
	Mallard		*Anas platyrhynchos*	5	0.1613
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2581
	Song Sparrow		*Melospiza melodia*	3	0.0968
	Tree Swallow		*Tachycineta bicolor*	2	0.0645
	Tufted Titmouse		*Parus bicolor*	1	0.0323
	Willow Flycatcher		*Empidonax traillii*	2	0.0645
	Yellow Warbler		*Dendroica petechia*	3	0.0968

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
OHHSFO	Site abundance: 16			
	American Robin	*Turdus migratorius*	1	0.0625
	Carolina Chickadee	*Poecile carolinensis*	2	0.1250
	Carolina Wren	*Thryothorus ludovicianus*	2	0.1250
	Common Yellowthroat	*Geothlypis trichas*	1	0.0625
	Eastern Towhee	*Pipilo erythrophthalmus*	2	0.1250
	Gray Catbird	*Dumetella carolinensis*	2	0.1250
	Hooded Warbler	*Wilsonia citrina*	1	0.0625
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0625
	Northern Parula	*Parula americana*	1	0.0625
	Red-Billed Woodpecker	*Melanerpes carolinus*	1	0.0625
	White-Breasted Nuthatch	*Sitta carolinensis*	1	0.0625
	Wood Thrush	*Hylocichla mustelina*	1	0.0625
OHINNS	Site abundance: 29			
	American Robin	*Turdus migratorius*	1	0.0345
	Black-and-White Warbler	*Mniotilta varia*	1	0.0345
	Blue-Gray Gnatcatcher	*Polioptila caerulea*	1	0.0345
	Blue-Headed Vireo	*Vireo solitarius*	1	0.0345
	Carolina Chickadee	*Poecile carolinensis*	3	0.1034
	Common Yellowthroat	*Geothlypis trichas*	2	0.0690
	Eastern Bluebird	*Sialia sialis*	2	0.0690
	Eastern Kingbird	*Tyrannus tyrannus*	1	0.0345
	Eastern Towhee	*Pipilo erythrophthalmus*	1	0.0345
	Great Crested Flycatcher	*Myiarchus crinitus*	1	0.0345
	Indigo Bunting	*Passerina cyanea*	1	0.0345
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0345
	Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	2	0.0690
	Northern Waterthrush	*Northern Waterthrush*	1	0.0345
	Red-Winged Blackbird	*Agelaius phoeniceus*	5	0.1724
	Ruby-Throated Hummingbird	*Archilochus colubris*	1	0.0345
	Song Sparrow	*Melospiza melodia*	3	0.1034
	Tufted Titmouse	*Parus bicolor*	1	0.0345

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
OHKMRT	Site abundance:	25			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0400
	American Goldfinch		*Carduelis tristis*	4	0.1600
	American Robin		*Turdus migratorius*	1	0.0400
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0400
	Gray Catbird		*Dumetella carolinensis*	1	0.0400
	Northern Mockingbird		*Mimus polyglottos*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.2400
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.2400
	Tree Swallow		*Tachycineta bicolor*	1	0.0400
	Willow Flycatcher		*Empidonax traillii*	1	0.0400
	Yellow Warbler		*Dendroica petechia*	2	0.0800
PA29TH	Site abundance:	64			
	American Goldfinch		*Carduelis tristis*	2	0.0313
	American Robin		*Turdus migratorius*	2	0.0313
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	3	0.0469
	Carolina Wren		*Thryothorus ludovicianus*	2	0.0313
	Cedar Waxwing		*Bombycilla cedrorum*	19	0.2969
	Common Grackle		*Quiscalus quiscula*	1	0.0156
	Common Yellowthroat		*Geothlypis trichas*	2	0.0313
	European Starling		*Sturnus vulgaris*	1	0.0156
	Gray Catbird		*Dumetella carolinensis*	1	0.0156
	Great Blue Heron		*Ardea herodias*	1	0.0156
	Green Heron		*Butorides virescens*	1	0.0156
	House Wren		*Troglodytes aedon*	2	0.0313
	Mourning Dove		*Zenaida macroura*	1	0.0156
	Northern Cardinal		*Cardinalis cardinalis*	3	0.0469
	Northern Flicker		*Colaptes auratus*	2	0.0313
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0156
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.0938
	Song Sparrow		*Melospiza melodia*	5	0.0781
	Tree Swallow		*Tachycineta bicolor*	2	0.0313
	Tufted Titmouse		*Parus bicolor*	3	0.0469
	Willow Flycatcher		*Empidonax traillii*	3	0.0469
	Yellow Warbler		*Dendroica petechia*	1	0.0156

Appendix C. Continued.

SiteCode	Species	Latin name	Number observed	Frequency per Site
PA83CR	Site abundance: 26			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0385
	American Goldfinch	*Carduelis tristis*	3	0.1154
	American Robin	*Turdus migratorius*	1	0.0385
	Blue Jay	*Cyanocitta cristata*	3	0.1154
	Brown-Headed Cowbird	*Molothrus ater*	1	0.0385
	Carolina Chickadee	*Poecile carolinensis*	3	0.1154
	Cedar Waxwing	*Bombycilla cedrorum*	1	0.0385
	Common Grackle	*Quiscalus quiscula*	3	0.1154
	Eastern Towhee	*Pipilo erythrophthalmus*	1	0.0385
	Gray Catbird	*Dumetella carolinensis*	1	0.0385
	Indigo Bunting	*Passerina cyanea*	1	0.0385
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0385
	Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	1	0.0385
	Red-Billed Woodpecker	*Melanerpes carolinus*	1	0.0385
	Red-Eyed Vireo	*Vireo olivaceus*	1	0.0385
	Scarlet Tanager	*Piranga olivacea*	1	0.0385
	Song Sparrow	*Melospiza melodia*	2	0.0769

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
PAFAMD	Site abundance: 51			
	American Goldfinch	*Carduelis tristis*	1	0.0196
	American Robin	*Turdus migratorius*	1	0.0196
	Belted Kingfisher	*Ceryle alcyon*	1	0.0196
	Blue-Gray Gnatcatcher	*Polioptila caerulea*	1	0.0196
	Carolina Chickadee	*Poecile carolinensis*	3	0.0588
	Cedar Waxwing	*Bombycilla cedrorum*	3	0.0588
	Common Grackle	*Quiscalus quiscula*	1	0.0196
	Eastern Bluebird	*Sialia sialis*	1	0.0196
	Eastern Phoebe	*Sayornis phoebe*	1	0.0196
	Eastern Wood-Pewee	*Contopus virens*	1	0.0196
	Great Blue Heron	*Ardea herodias*	1	0.0196
	Great Crested Flycatcher	*Myiarchus crinitus*	1	0.0196
	Hairy Woodpecker	*Picoides villosus*	2	0.0392
	Indigo Bunting	*Passerina cyanea*	1	0.0196
	Mallard	*Anas platyrhynchos*	4	0.0784
	Mourning Dove	*Zenaida macroura*	4	0.0784
	Northern Cardinal	*Cardinalis cardinalis*	2	0.0392
	Northern Flicker	*Colaptes auratus*	2	0.0392
	Red-Billed Woodpecker	*Melanerpes carolinus*	1	0.0196
	Red-Tailed Hawk	*Buteo jamaicensis*	1	0.0196
	Red-Tailed Hawk	*Buteo jamaicensis*	1	0.0196
	Red-Winged Blackbird	*Agelaius phoeniceus*	5	0.0980
	Song Sparrow	*Melospiza melodia*	3	0.0588
	Tufted Titmouse	*Parus bicolor*	3	0.0588
	Willow Flycatcher	*Empidonax traillii*	1	0.0196
	Wood Duck	*Aix sponsa*	4	0.0784
	Yellow Warbler	*Dendroica petechia*	1	0.0196

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
PAJCPY	Site abundance:	51			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0196
	American Goldfinch		*Carduelis tristis*	3	0.0588
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0196
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0196
	Canada Goose		*Branta canadensis*	5	0.0980
	Carolina Chickadee		*Poecile carolinensis*	3	0.0588
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0392
	Common Yellowthroat		*Geothlypis trichas*	1	0.0196
	Cooper's Hawk		*Accipiter cooperii*	1	0.0196
	Downy Woodpecker		*Picoides pubescens*	2	0.0392
	Gray Catbird		*Dumetella carolinensis*	1	0.0196
	Great Blue Heron		*Ardea herodias*	1	0.0196
	Hairy Woodpecker		*Picoides villosus*	1	0.0196
	House Wren		*Troglodytes aedon*	3	0.0588
	Indigo Bunting		*Passerina cyanea*	1	0.0196
	Mallard		*Anas platyrhynchos*	7	0.1373
	Northern Flicker		*Colaptes auratus*	2	0.0392
	Northern Waterthrush		*Northern Waterthrush*	1	0.0196
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0196
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0196
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0196
	Ruby-Throated Hummingbird		*Archilochus colubris*	1	0.0196
	Tufted Titmouse		*Parus bicolor*	2	0.0392
	Turkey Vulture		*Cathartes aura*	5	0.0980
	Wood Duck		*Aix sponsa*	1	0.0196
	Yellow Warbler		*Dendroica petechia*	2	0.0392

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
PALOUD	Site abundance: 32			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0313
	Blue-Gray Gnatcatcher	*Polioptila caerulea*	1	0.0313
	Brown-Headed Cowbird	*Molothrus ater*	2	0.0625
	Carolina Chickadee	*Poecile carolinensis*	3	0.0938
	Cedar Waxwing	*Bombycilla cedrorum*	2	0.0625
	Common Yellowthroat	*Geothlypis trichas*	1	0.0313
	Eastern Phoebe	*Sayornis phoebe*	1	0.0313
	European Starling	*Sturnus vulgaris*	2	0.0625
	Gray Catbird	*Dumetella carolinensis*	1	0.0313
	Great Crested Flycatcher	*Myiarchus crinitus*	1	0.0313
	Indigo Bunting	*Passerina cyanea*	2	0.0625
	Mallard	*Anas platyrhynchos*	1	0.0313
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0313
	Northern Mockingbird	*Mimus polyglottos*	1	0.0313
	Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	2	0.0625
	Red-Billed Woodpecker	*Melanerpes carolinus*	1	0.0313
	Red-Eyed Vireo	*Vireo olivaceus*	1	0.0313
	Scarlet Tanager	*Piranga olivacea*	1	0.0313
	Song Sparrow	*Melospiza melodia*	3	0.0938
	Tree Swallow	*Tachycineta bicolor*	2	0.0625
	White-Eyed Vireo	*Vireo griseus*	1	0.0313
	Yellow Warbler	*Dendroica petechia*	1	0.0313

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
PAPEFO	Site abundance:	20			
	American Redstart		*Setophaga ruticilla*	1	0.0500
	Blue Jay		*Cyanocitta cristata*	2	0.1000
	Carolina Chickadee		*Poecile carolinensis*	2	0.1000
	Carolina Wren		*Thryothorus ludovicianus*	2	0.1000
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0500
	Common Yellowthroat		*Geothlypis trichas*	1	0.0500
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.1000
	Eastern Wood-Pewee		*Contopus virens*	1	0.0500
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0500
	Northern Mockingbird		*Mimus polyglottos*	1	0.0500
	Northern Waterthrush		*Northern Waterthrush*	2	0.1000
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0500
	Song Sparrow		*Melospiza melodia*	1	0.0500
	Tufted Titmouse		*Parus bicolor*	1	0.0500
	Wood Thrush		*Hylocichla mustelina*	1	0.0500
PAPEIM	Site abundance:	29			
	American Robin		*Turdus migratorius*	6	0.2069
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0345
	Eastern Wood-Pewee		*Contopus virens*	1	0.0345
	Grasshopper Sparrow		*Ammodramus savannarum*	1	0.0345
	Indigo Bunting		*Passerina cyanea*	1	0.0345
	Mourning Dove		*Zenaida macroura*	1	0.0345
	Mourning Dove		*Zenaida macroura*	1	0.0345
	Northern Rough-Winged Swallow		*Stelgidopteryx serripennis*	1	0.0345
	Red-Winged Blackbird		*Agelaius phoeniceus*	14	0.4828
	Savannah Sparrow		*Passerculus sandwichensis*	2	0.0690

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
PAPESW	Site abundance:	40			
	American Robin		*Turdus migratorius*	2	0.0500
	Belted Kingfisher		*Ceryle alcyon*	2	0.0500
	Black-and-White Warbler		*Mniotilta varia*	2	0.0500
	Carolina Chickadee		*Poecile carolinensis*	3	0.0750
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0250
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0500
	Common Yellowthroat		*Geothlypis trichas*	1	0.0250
	Eastern Kingbird		*Tyrannus tyrannus*	2	0.0500
	Eastern Wood-Pewee		*Contopus virens*	1	0.0250
	European Starling		*Sturnus vulgaris*	1	0.0250
	Indigo Bunting		*Passerina cyanea*	1	0.0250
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0250
	Northern Flicker		*Colaptes auratus*	3	0.0750
	Orchard Oriole		*Icterus spurius*	1	0.0250
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0250
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0250
	Red-Tailed Hawk		*Buteo jamaicensis*	1	0.0250
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.1500
	Song Sparrow		*Melospiza melodia*	3	0.0750
	Tree Swallow		*Tachycineta bicolor*	1	0.0250
	Tufted Titmouse		*Parus bicolor*	1	0.0250
	White-Eyed Vireo		*Vireo griseus*	1	0.0250
	Willow Flycatcher		*Empidonax traillii*	1	0.0250
	Wood Duck		*Aix sponsa*	1	0.0250

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
PAWILL	Site abundance:	41			
	American Robin		*Turdus migratorius*	2	0.0488
	Barn Swallow		*Hirundo rustica*	2	0.0488
	Belted Kingfisher		*Ceryle alcyon*	2	0.0488
	Blue Jay		*Cyanocitta cristata*	1	0.0244
	Cedar Waxwing		*Bombycilla cedrorum*	3	0.0732
	Common Grackle		*Quiscalus quiscula*	2	0.0488
	Domestic duck			1	0.0244
	European Starling		*Sturnus vulgaris*	1	0.0244
	Gray Catbird		*Dumetella carolinensis*	1	0.0244
	Green Heron		*Butorides virescens*	1	0.0244
	Mallard		*Anas platyrhynchos*	2	0.0488
	Mourning Dove		*Zenaida macroura*	2	0.0488
	Northern Cardinal		*Cardinalis cardinalis*	3	0.0732
	Northern Flicker		*Colaptes auratus*	1	0.0244
	Red-Winged Blackbird		*Agelaius phoeniceus*	12	0.2927
	Song Sparrow		*Melospiza melodia*	2	0.0488
	Wood Duck		*Aix sponsa*	3	0.0732
PCBLUE	Site abundance:	25			
	American Crow		*Corvus brachyrhynchos*	1	0.0400
	American Goldfinch		*Carduelis tristis*	1	0.0400
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0400
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0400
	Common Grackle		*Quiscalus quiscula*	1	0.0400
	Common Yellowthroat		*Geothlypis trichas*	2	0.0800
	Eastern Kingbird		*Tyrannus tyrannus*	1	0.0400
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0400
	Field Sparrow		*Spizella pusilla*	2	0.0800
	Gray Catbird		*Dumetella carolinensis*	2	0.0800
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0400
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	4	0.1600
	Song Sparrow		*Melospiza melodia*	2	0.0800
	Tree Swallow		*Tachycineta bicolor*	2	0.0800
	Yellow Warbler		*Dendroica petechia*	1	0.0400
	Yellow-Breasted Chat		*Icteria virens*	1	0.0400

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
PCLPFO	Site abundance:	19			
	American Goldfinch		*Carduelis tristis*	1	0.0526
	American Redstart		*Setophaga ruticilla*	4	0.2105
	American Woodcock		*Scolopax minor*	1	0.0526
	Baltimore Oriole		*Icterus galbula*	1	0.0526
	Cedar Waxwing		*Bombycilla cedrorum*	4	0.2105
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0526
	Eastern Wood-Pewee		*Contopus virens*	2	0.1053
	Gray Catbird		*Dumetella carolinensis*	1	0.0526
	Indigo Bunting		*Passerina cyanea*	1	0.0526
	Northern Flicker		*Colaptes auratus*	1	0.0526
	Northern Parula		*Parula americana*	1	0.0526
	Wood Thrush		*Hylocichla mustelina*	1	0.0526
PCROAD	Site abundance:	28			
	American Goldfinch		*Carduelis tristis*	4	0.1429
	Baltimore Oriole		*Icterus galbula*	1	0.0357
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0357
	Common Grackle		*Quiscalus quiscula*	2	0.0714
	Common Yellowthroat		*Geothlypis trichas*	2	0.0714
	Field Sparrow		*Spizella pusilla*	1	0.0357
	Green Heron		*Butorides virescens*	1	0.0357
	Indigo Bunting		*Passerina cyanea*	1	0.0357
	Killdeer		*Charadrius vociferus*	2	0.0714
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0357
	Northern Flicker		*Colaptes auratus*	1	0.0357
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0714
	Song Sparrow		*Melospiza melodia*	3	0.1071
	Tree Swallow		*Tachycineta bicolor*	3	0.1071
	Willow Flycatcher		*Empidonax traillii*	1	0.0357
	Yellow Warbler		*Dendroica petechia*	2	0.0714

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
PEMIDW	Site abundance:	22			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0455
	American Goldfinch		*Carduelis tristis*	1	0.0455
	American Robin		*Turdus migratorius*	1	0.0455
	Baltimore Oriole		*Icterus galbula*	1	0.0455
	Baltimore Oriole		*Icterus galbula*	1	0.0455
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0455
	Common Yellowthroat		*Geothlypis trichas*	1	0.0455
	Eastern Phoebe		*Sayornis phoebe*	1	0.0455
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0909
	Indigo Bunting		*Passerina cyanea*	1	0.0455
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0455
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1364
	Scarlet Tanager		*Piranga olivacea*	2	0.0909
	Song Sparrow		*Melospiza melodia*	1	0.0455
	Tufted Titmouse		*Parus bicolor*	1	0.0455
	Wood Thrush		*Hylocichla mustelina*	1	0.0455
	Yellow Warbler		*Dendroica petechia*	2	0.0909
PERDDP	Site abundance:	28			
	American Goldfinch		*Carduelis tristis*	2	0.0714
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0357
	Common Yellowthroat		*Geothlypis trichas*	1	0.0357
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0357
	Field Sparrow		*Spizella pusilla*	1	0.0357
	Mourning Dove		*Zenaida macroura*	3	0.1071
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.3571
	Song Sparrow		*Melospiza melodia*	4	0.1429
	Tree Swallow		*Tachycineta bicolor*	2	0.0714
	Winter Wren		*Troglodytes troglodytes*	1	0.0357
	Yellow Warbler		*Dendroica petechia*	2	0.0714

Appendix C. Continued.

SiteCode	Species	*Latin name*	Number observed	Frequency per Site
PETHUM	Site abundance: 18			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0556
	Blue-Winged Warbler	*Vermivora pinus*	1	0.0556
	Carolina Wren	*Thryothorus ludovicianus*	2	0.1111
	Common Yellowthroat	*Geothlypis trichas*	1	0.0556
	Eastern Phoebe	*Sayornis phoebe*	1	0.0556
	Eastern Towhee	*Pipilo erythrophthalmus*	1	0.0556
	Gray Catbird	*Dumetella carolinensis*	1	0.0556
	Great Crested Flycatcher	*Myiarchus crinitus*	1	0.0556
	Hairy Woodpecker	*Picoides villosus*	1	0.0556
	Northern Mockingbird	*Mimus polyglottos*	1	0.0556
	Red-Eyed Vireo	*Vireo olivaceus*	1	0.0556
	Red-Winged Blackbird	*Agelaius phoeniceus*	1	0.0556
	Song Sparrow	*Melospiza melodia*	2	0.1111
	Tufted Titmouse	*Parus bicolor*	1	0.0556
	Wood Thrush	*Hylocichla mustelina*	1	0.0556
	Yellow Warbler	*Dendroica petechia*	1	0.0556
PETOSS	Site abundance: 25			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0400
	American Robin	*Turdus migratorius*	1	0.0400
	Baltimore Oriole	*Icterus galbula*	1	0.0400
	Blue-Winged Warbler	*Vermivora pinus*	1	0.0400
	Carolina Chickadee	*Poecile carolinensis*	1	0.0400
	Common Yellowthroat	*Geothlypis trichas*	1	0.0400
	Eastern Phoebe	*Sayornis phoebe*	1	0.0400
	Indigo Bunting	*Passerina cyanea*	1	0.0400
	Mourning Dove	*Zenaida macroura*	1	0.0400
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0400
	Northern Rough-Winged Swallow	*Stelgidopteryx serripennis*	1	0.0400
	Orchard Oriole	*Icterus spurius*	1	0.0400
	Red-Winged Blackbird	*Agelaius phoeniceus*	5	0.2000
	Song Sparrow	*Melospiza melodia*	3	0.1200
	Tufted Titmouse	*Parus bicolor*	2	0.0800
	Wood Thrush	*Hylocichla mustelina*	1	0.0400
	Yellow Warbler	*Dendroica petechia*	2	0.0800

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
RIASIA	Site abundance:	35			
	American Crow		*Corvus brachyrhynchos*	2	0.0571
	American Robin		*Turdus migratorius*	3	0.0857
	Carolina Chickadee		*Poecile carolinensis*	2	0.0571
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0286
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0286
	Common Grackle		*Quiscalus quiscula*	1	0.0286
	Common Yellowthroat		*Geothlypis trichas*	2	0.0571
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0286
	Field Sparrow		*Spizella pusilla*	3	0.0857
	Gray Catbird		*Dumetella carolinensis*	2	0.0571
	Indigo Bunting		*Passerina cyanea*	2	0.0571
	Killdeer		*Charadrius vociferus*	1	0.0286
	Northern Mockingbird		*Mimus polyglottos*	2	0.0571
	Orchard Oriole		*Icterus spurius*	2	0.0571
	Song Sparrow		*Melospiza melodia*	2	0.0571
	Tree Swallow		*Tachycineta bicolor*	2	0.0571
	Tufted Titmouse		*Parus bicolor*	2	0.0571
	Yellow Warbler		*Dendroica petechia*	2	0.0571
	Yellow-Breasted Chat		*Icteria virens*	2	0.0571

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
RIBRID	Site abundance:	31			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0323
	American Redstart		*Setophaga ruticilla*	1	0.0323
	American Robin		*Turdus migratorius*	2	0.0645
	Belted Kingfisher		*Ceryle alcyon*	1	0.0323
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0323
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0323
	Carolina Chickadee		*Poecile carolinensis*	3	0.0968
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0323
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0645
	Cerulean Warbler		*Dendroica cerulea*	1	0.0323
	Chipping Sparrow		*Spizella passerina*	2	0.0645
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0323
	Gray Catbird		*Dumetella carolinensis*	1	0.0323
	Indigo Bunting		*Passerina cyanea*	1	0.0323
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0323
	Ovenbird		*Seiurus aurocapillus*	1	0.0323
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0323
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0323
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0645
	Song Sparrow		*Melospiza melodia*	2	0.0645
	Tufted Titmouse		*Parus bicolor*	1	0.0323
	Wood Thrush		*Hylocichla mustelina*	1	0.0323
	Yellow Warbler		*Dendroica petechia*	2	0.0645

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
RIEAST	Site abundance:	23			
	Acadian Flycatcher		*Empidonax virescens*	2	0.0870
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	2	0.0870
	Carolina Chickadee		*Poecile carolinensis*	2	0.0870
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0435
	Chipping Sparrow		*Spizella passerina*	1	0.0435
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0435
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0435
	Indigo Bunting		*Passerina cyanea*	1	0.0435
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0435
	Northern Parula		*Parula americana*	2	0.0870
	Ovenbird		*Seiurus aurocapillus*	1	0.0435
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0435
	Scarlet Tanager		*Piranga olivacea*	1	0.0435
	Song Sparrow		*Melospiza melodia*	3	0.1304
	Tufted Titmouse		*Parus bicolor*	1	0.0435
	Wood Thrush		*Hylocichla mustelina*	1	0.0435
	Yellow Warbler		*Dendroica petechia*	1	0.0435
SJBOAT	Site abundance:	22			
	American Goldfinch		*Carduelis tristis*	1	0.0455
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0455
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0455
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0909
	Gray Catbird		*Dumetella carolinensis*	1	0.0455
	Indigo Bunting		*Passerina cyanea*	2	0.0909
	Kentucky Warbler		*Oporornis formosus*	2	0.0909
	Mallard		*Anas platyrhynchos*	2	0.0909
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0455
	Ovenbird		*Seiurus aurocapillus*	1	0.0455
	Scarlet Tanager		*Piranga olivacea*	2	0.0909
	Tree Swallow		*Tachycineta bicolor*	4	0.1818
	White-Breasted Nuthatch		*Sitta carolinensis*	1	0.0455
	Yellow Warbler		*Dendroica petechia*	1	0.0455

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
SJBRID	Site abundance:	23			
	American Goldfinch		*Carduelis tristis*	2	0.0870
	Barn Swallow		*Hirundo rustica*	2	0.0870
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0435
	Common Grackle		*Quiscalus quiscula*	1	0.0435
	Common Yellowthroat		*Geothlypis trichas*	1	0.0435
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0435
	Field Sparrow		*Spizella pusilla*	2	0.0870
	Indigo Bunting		*Passerina cyanea*	2	0.0870
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0435
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.2174
	Song Sparrow		*Melospiza melodia*	3	0.1304
	Tree Swallow		*Tachycineta bicolor*	2	0.0870
SJCHUR	Site abundance:	29			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0345
	Alder Flycatcher		*Empidonax alnorum*	1	0.0345
	American Goldfinch		*Carduelis tristis*	1	0.0345
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0345
	Blue-Winged Warbler		*Vermivora pinus*	2	0.0690
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0345
	Common Yellowthroat		*Geothlypis trichas*	1	0.0345
	Eastern Phoebe		*Sayornis phoebe*	1	0.0345
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0345
	Green Heron		*Butorides virescens*	1	0.0345
	Indigo Bunting		*Passerina cyanea*	3	0.1034
	Mallard		*Anas platyrhynchos*	1	0.0345
	Orchard Oriole		*Icterus spurius*	1	0.0345
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0690
	Song Sparrow		*Melospiza melodia*	5	0.1724
	Tree Swallow		*Tachycineta bicolor*	1	0.0345
	White-Breasted Nuthatch		*Sitta carolinensis*	1	0.0345
	Willow Flycatcher		*Empidonax traillii*	2	0.0690
	Yellow Warbler		*Dendroica petechia*	2	0.0690

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
SJGLAD	Site abundance:	22			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0455
	American Goldfinch		*Carduelis tristis*	1	0.0455
	American Redstart		*Setophaga ruticilla*	1	0.0455
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0455
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0455
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0455
	Blue-Winged Warbler		*Vermivora pinus*	2	0.0909
	Common Yellowthroat		*Geothlypis trichas*	1	0.0455
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0455
	Field Sparrow		*Spizella pusilla*	2	0.0909
	Gray Catbird		*Dumetella carolinensis*	1	0.0455
	Indigo Bunting		*Passerina cyanea*	2	0.0909
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0455
	Ovenbird		*Seiurus aurocapillus*	1	0.0455
	Scarlet Tanager		*Piranga olivacea*	1	0.0455
	Song Sparrow		*Melospiza melodia*	2	0.0909
	White-Eyed Vireo		*Vireo griseus*	1	0.0455
	Yellow Warbler		*Dendroica petechia*	1	0.0455

Appendix C. Continued.

SiteCode	Species	Latin name	Number observed	Frequency per Site
SJMUDL	Site abundance: 24			
	Acadian Flycatcher	*Empidonax virescens*	1	0.0417
	Baltimore Oriole	*Icterus galbula*	1	0.0417
	Black-and-White Warbler	*Mniotilta varia*	1	0.0417
	Blue-Gray Gnatcatcher	*Polioptila caerulea*	2	0.0833
	Blue-Winged Warbler	*Vermivora pinus*	1	0.0417
	Carolina Chickadee	*Poecile carolinensis*	1	0.0417
	Carolina Wren	*Thryothorus ludovicianus*	1	0.0417
	Common Grackle	*Quiscalus quiscula*	1	0.0417
	Common Yellowthroat	*Geothlypis trichas*	1	0.0417
	Downy Woodpecker	*Picoides pubescens*	1	0.0417
	Eastern Towhee	*Pipilo erythrophthalmus*	2	0.0833
	Field Sparrow	*Spizella pusilla*	1	0.0417
	Gray Catbird	*Dumetella carolinensis*	1	0.0417
	Indigo Bunting	*Passerina cyanea*	2	0.0833
	Northern Cardinal	*Cardinalis cardinalis*	1	0.0417
	Red-Eyed Vireo	*Vireo olivaceus*	1	0.0417
	Scarlet Tanager	*Piranga olivacea*	1	0.0417
	Song Sparrow	*Melospiza melodia*	1	0.0417
	Wood Thrush	*Hylocichla mustelina*	1	0.0417
	Yellow Warbler	*Dendroica petechia*	1	0.0417
	Yellow-Breasted Chat	*Icteria virens*	1	0.0417

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
SJPLOT	Site abundance:	25			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0400
	American Goldfinch		*Carduelis tristis*	2	0.0800
	Barn Swallow		*Hirundo rustica*	2	0.0800
	Black-and-White Warbler		*Mniotilta varia*	1	0.0400
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0400
	Common Grackle		*Quiscalus quiscula*	1	0.0400
	Common Yellowthroat		*Geothlypis trichas*	2	0.0800
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0800
	Field Sparrow		*Spizella pusilla*	1	0.0400
	Indigo Bunting		*Passerina cyanea*	1	0.0400
	Killdeer		*Charadrius vociferus*	1	0.0400
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0400
	Song Sparrow		*Melospiza melodia*	3	0.1200
	Tree Swallow		*Tachycineta bicolor*	3	0.1200
	Willow Flycatcher		*Empidonax traillii*	1	0.0400
	Yellow Warbler		*Dendroica petechia*	1	0.0400
SJTELE	Site abundance:	19			
	Acadian Flycatcher		*Empidonax virescens*	2	0.1053
	American Redstart		*Setophaga ruticilla*	1	0.0526
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0526
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0526
	Eastern Phoebe		*Sayornis phoebe*	1	0.0526
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0526
	Field Sparrow		*Spizella pusilla*	1	0.0526
	Indigo Bunting		*Passerina cyanea*	3	0.1579
	Mourning Dove		*Zenaida macroura*	1	0.0526
	Northern Parula		*Parula americana*	1	0.0526
	Ovenbird		*Seiurus aurocapillus*	1	0.0526
	Scarlet Tanager		*Piranga olivacea*	1	0.0526
	Song Sparrow		*Melospiza melodia*	2	0.1053
	Yellow Warbler		*Dendroica petechia*	2	0.1053

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
SMDTSS	Site abundance:	24			
	American Goldfinch		*Carduelis tristis*	1	0.0417
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0417
	Blue-Winged Warbler		*Vermivora pinus*	2	0.0833
	Common Yellowthroat		*Geothlypis trichas*	3	0.1250
	Eastern Phoebe		*Sayornis phoebe*	1	0.0417
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0417
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0417
	Mallard		*Anas platyrhynchos*	1	0.0417
	Ovenbird		*Seiurus aurocapillus*	2	0.0833
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0417
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0417
	Red-Tailed Hawk		*Buteo jamaicensis*	1	0.0417
	Red-Winged Blackbird		*Agelaius phoeniceus*	4	0.1667
	Swamp Sparrow		*Melospiza georgiana*	1	0.0417
	Tufted Titmouse		*Parus bicolor*	3	0.1250
SMFOFL	Site abundance:	21			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0476
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	2	0.0952
	Carolina Chickadee		*Poecile carolinensis*	1	0.0476
	Cerulean Warbler		*Dendroica cerulea*	1	0.0476
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	1	0.0476
	Chipping Sparrow		*Spizella passerina*	1	0.0476
	Common Yellowthroat		*Geothlypis trichas*	2	0.0952
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0476
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0476
	Hairy Woodpecker		*Picoides villosus*	1	0.0476
	Northern Parula		*Parula americana*	1	0.0476
	Northern Waterthrush		*Northern Waterthrush*	1	0.0476
	Ovenbird		*Seiurus aurocapillus*	1	0.0476
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0476
	Scarlet Tanager		*Piranga olivacea*	1	0.0476
	Tufted Titmouse		*Parus bicolor*	2	0.0952
	White-Breasted Nuthatch		*Sitta carolinensis*	1	0.0476
	Yellow-Billed Cuckoo		*Coccyzus americanus*	1	0.0476

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
SMLPEM	Site abundance:	33			
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0303
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0303
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0303
	Common Yellowthroat		*Geothlypis trichas*	3	0.0909
	Eastern Phoebe		*Sayornis phoebe*	2	0.0606
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0303
	Gray Catbird		*Dumetella carolinensis*	1	0.0303
	Ovenbird		*Seiurus aurocapillus*	1	0.0303
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0303
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2424
	Savannah Sparrow		*Passerculus sandwichensis*	2	0.0606
	Song Sparrow		*Melospiza melodia*	3	0.0909
	Song Sparrow		*Melospiza melodia*	1	0.0303
	Spotted Sandpiper		*Actitis macularia*	2	0.0606
	Swamp Sparrow		*Melospiza georgiana*	1	0.0303
	Swamp Sparrow		*Melospiza georgiana*	2	0.0606
	Virginia Rail		*Rallus limicola*	1	0.0303
	Yellow-Billed Cuckoo		*Coccyzus americanus*	1	0.0303
SMSEFL	Site abundance:	37			
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0270
	Canada Goose		*Branta canadensis*	6	0.1622
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0270
	Common Grackle		*Quiscalus quiscula*	4	0.1081
	Common Yellowthroat		*Geothlypis trichas*	2	0.0541
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0541
	Gray Catbird		*Dumetella carolinensis*	1	0.0270
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0270
	Northern Waterthrush		*Northern Waterthrush*	1	0.0270
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0270
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0270
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.1622
	Spotted Sandpiper		*Actitis macularia*	3	0.0811
	Swamp Sparrow		*Melospiza georgiana*	2	0.0541
	Tree Swallow		*Tachycineta bicolor*	3	0.0811
	Wood Duck		*Aix sponsa*	2	0.0541

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
SMSTEM	Site abundance:	15			
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0667
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0667
	Common Yellowthroat		*Geothlypis trichas*	2	0.1333
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0667
	Mallard		*Anas platyrhynchos*	2	0.1333
	Northern Waterthrush		*Northern Waterthrush*	1	0.0667
	Ovenbird		*Seiurus aurocapillus*	2	0.1333
	Prothonotary Warbler		*Protonotaria citrea*	1	0.0667
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0667
	Solitary Sandpiper		*Tringa solitaria*	1	0.0667
	Song Sparrow		*Melospiza melodia*	1	0.0667
	Yellow Warbler		*Dendroica petechia*	1	0.0667
TRSPFO	Site abundance:	18			
	Acadian Flycatcher		*Empidonax virescens*	1	0.0556
	American Robin		*Turdus migratorius*	1	0.0556
	Blue Jay		*Cyanocitta cristata*	2	0.1111
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0556
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0556
	Common Yellowthroat		*Geothlypis trichas*	1	0.0556
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.1111
	Eastern Wood-Pewee		*Contopus virens*	1	0.0556
	Field Sparrow		*Spizella pusilla*	1	0.0556
	Gray Catbird		*Dumetella carolinensis*	1	0.0556
	Northern Parula		*Parula americana*	1	0.0556
	Ovenbird		*Seiurus aurocapillus*	1	0.0556
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0556
	Scarlet Tanager		*Piranga olivacea*	1	0.0556
	Wood Thrush		*Hylocichla mustelina*	2	0.1111

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
TRSPRI	Site abundance:	31			
	Baltimore Oriole		*Icterus galbula*	1	0.0323
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0323
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0323
	Carolina Chickadee		*Poecile carolinensis*	1	0.0323
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0323
	Common Yellowthroat		*Geothlypis trichas*	1	0.0323
	Eastern Kingbird		*Tyrannus tyrannus*	2	0.0645
	Eastern Towhee		*Pipilo erythrophthalmus*	1	0.0323
	Field Sparrow		*Spizella pusilla*	1	0.0323
	Gray Catbird		*Dumetella carolinensis*	1	0.0323
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0323
	Northern Flicker		*Colaptes auratus*	1	0.0323
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0323
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0323
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0323
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.1935
	Song Sparrow		*Melospiza melodia*	2	0.0645
	Swamp Sparrow		*Melospiza georgiana*	1	0.0323
	Tree Swallow		*Tachycineta bicolor*	3	0.0968
	Wood Thrush		*Hylocichla mustelina*	1	0.0323
	Yellow Warbler		*Dendroica petechia*	2	0.0645
TVFARM	Site abundance:	20			
	American Robin		*Turdus migratorius*	1	0.0500
	Barn Swallow		*Hirundo rustica*	2	0.1000
	Blue Jay		*Cyanocitta cristata*	1	0.0500
	Common Yellowthroat		*Geothlypis trichas*	1	0.0500
	Eastern Phoebe		*Sayornis phoebe*	1	0.0500
	Northern Cardinal		*Cardinalis cardinalis*	2	0.1000
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0500
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.3500
	Song Sparrow		*Melospiza melodia*	3	0.1500
	Tree Swallow		*Tachycineta bicolor*	1	0.0500

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
TVISLE	Site abundance:	24			
	American Robin		*Turdus migratorius*	1	0.0417
	Belted Kingfisher		*Ceryle alcyon*	1	0.0417
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0417
	Blue Jay		*Cyanocitta cristata*	1	0.0417
	Carolina Chickadee		*Poecile carolinensis*	1	0.0417
	Carolina Wren		*Thryothorus ludovicianus*	3	0.1250
	Common Grackle		*Quiscalus quiscula*	2	0.0833
	Common Yellowthroat		*Geothlypis trichas*	1	0.0417
	Eastern Wood-Pewee		*Contopus virens*	1	0.0417
	European Starling		*Sturnus vulgaris*	2	0.0833
	Gray Catbird		*Dumetella carolinensis*	2	0.0833
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0417
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0417
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0833
	Savannah Sparrow		*Passerculus sandwichensis*	1	0.0417
	Song Sparrow		*Melospiza melodia*	2	0.0833
	Winter Wren		*Troglodytes troglodytes*	1	0.0417

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
TVNEWT	Site abundance:	49			
	American Goldfinch		*Carduelis tristis*	1	0.0204
	American Robin		*Turdus migratorius*	1	0.0204
	Barn Swallow		*Hirundo rustica*	3	0.0612
	Canada Goose		*Branta canadensis*	2	0.0408
	Carolina Wren		*Thryothorus ludovicianus*	2	0.0408
	Common Grackle		*Quiscalus quiscula*	1	0.0204
	Common Yellowthroat		*Geothlypis trichas*	2	0.0408
	Gray Catbird		*Dumetella carolinensis*	1	0.0204
	Green Heron		*Butorides virescens*	1	0.0204
	Hooded Merganser		*Lophodytes cucullatus*	2	0.0408
	Indigo Bunting		*Passerina cyanea*	1	0.0204
	Mallard		*Anas platyrhynchos*	1	0.0204
	Mourning Dove		*Zenaida macroura*	1	0.0204
	Red-Winged Blackbird		*Agelaius phoeniceus*	18	0.3673
	Song Sparrow		*Melospiza melodia*	2	0.0408
	Spotted Sandpiper		*Actitis macularia*	1	0.0204
	Tree Swallow		*Tachycineta bicolor*	2	0.0408
	Willow Flycatcher		*Empidonax traillii*	2	0.0408
	Wood Duck		*Aix sponsa*	2	0.0408
	Yellow Warbler		*Dendroica petechia*	3	0.0612
TVPOUT	Site abundance:	20			
	American Redstart		*Setophaga ruticilla*	2	0.1000
	American Robin		*Turdus migratorius*	3	0.1500
	Blue Jay		*Cyanocitta cristata*	1	0.0500
	Common Yellowthroat		*Geothlypis trichas*	1	0.0500
	Eastern Wood-Pewee		*Contopus virens*	1	0.0500
	Gray Catbird		*Dumetella carolinensis*	3	0.1500
	Indigo Bunting		*Passerina cyanea*	1	0.0500
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0500
	Northern Waterthrush		*Northern Waterthrush*	1	0.0500
	Philadelphia Vireo		*Vireo philadelphicus*	1	0.0500
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0500
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0500
	Ruby-Throated Hummingbird		*Archilochus colubris*	1	0.0500
	Willow Flycatcher		*Empidonax traillii*	1	0.0500
	Yellow Warbler		*Dendroica petechia*	1	0.0500

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
TVVBEM	Site abundance:	15			
	American Goldfinch		*Carduelis tristis*	2	0.1333
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0667
	Common Yellowthroat		*Geothlypis trichas*	1	0.0667
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.6667
	Tree Swallow		*Tachycineta bicolor*	1	0.0667
TVVBIM	Site abundance:	22			
	American Goldfinch		*Carduelis tristis*	1	0.0455
	Brown Thrasher		*Toxostoma rufum*	1	0.0455
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0455
	Common Yellowthroat		*Geothlypis trichas*	3	0.1364
	Eastern Wood-Pewee		*Contopus virens*	1	0.0455
	Gray Catbird		*Dumetella carolinensis*	1	0.0455
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0455
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0455
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.2273
	Savannah Sparrow		*Passerculus sandwichensis*	1	0.0455
	Song Sparrow		*Melospiza melodia*	3	0.1364
	Willow Flycatcher		*Empidonax traillii*	2	0.0909
	Winter Wren		*Troglodytes troglodytes*	1	0.0455
TVVBRV	Site abundance:	25			
	American Goldfinch		*Carduelis tristis*	1	0.0400
	Carolina Wren		*Thryothorus ludovicianus*	2	0.0800
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0400
	Common Grackle		*Quiscalus quiscula*	4	0.1600
	Common Yellowthroat		*Geothlypis trichas*	1	0.0400
	Gray Catbird		*Dumetella carolinensis*	1	0.0400
	Great Crested Flycatcher		*Myiarchus crinitus*	1	0.0400
	Hairy Woodpecker		*Picoides villosus*	2	0.0800
	Killdeer		*Charadrius vociferus*	1	0.0400
	Northern Flicker		*Colaptes auratus*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1200
	Song Sparrow		*Melospiza melodia*	3	0.1200
	Spotted Sandpiper		*Actitis macularia*	1	0.0400
	Tufted Titmouse		*Parus bicolor*	2	0.0800
	Yellow Warbler		*Dendroica petechia*	1	0.0400

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
TVVBSS	Site abundance:	40			
	Baltimore Oriole		*Icterus galbula*	1	0.0250
	Canada Goose		*Branta canadensis*	2	0.0500
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0500
	Common Yellowthroat		*Geothlypis trichas*	3	0.0750
	Downy Woodpecker		*Picoides pubescens*	1	0.0250
	Eastern Bluebird		*Sialia sialis*	1	0.0250
	Eastern Kingbird		*Tyrannus tyrannus*	2	0.0500
	Eastern Phoebe		*Sayornis phoebe*	1	0.0250
	Eastern Wood-Pewee		*Contopus virens*	1	0.0250
	Green Heron		*Butorides virescens*	1	0.0250
	Hooded Merganser		*Lophodytes cucullatus*	3	0.0750
	Indigo Bunting		*Passerina cyanea*	1	0.0250
	Mallard		*Anas platyrhynchos*	1	0.0250
	Red-Winged Blackbird		*Agelaius phoeniceus*	8	0.2000
	Sedge Wren		*Cistothorus platensis*	1	0.0250
	Song Sparrow		*Melospiza melodia*	2	0.0500
	Tree Swallow		*Tachycineta bicolor*	3	0.0750
	Tufted Titmouse		*Parus bicolor*	1	0.0250
	Willow Flycatcher		*Empidonax traillii*	2	0.0500
	Winter Wren		*Troglodytes troglodytes*	1	0.0250
	Yellow Warbler		*Dendroica petechia*	2	0.0500
UDC001	Site abundance:	26			
	American Robin		*Turdus migratorius*	1	0.0385
	Brown Thrasher		*Toxostoma rufum*	1	0.0385
	Chimney Swift		*Chaetura pelagica*	2	0.0769
	Common Grackle		*Quiscalus quiscula*	5	0.1923
	Common Yellowthroat		*Geothlypis trichas*	3	0.1154
	Eastern Wood-Pewee		*Contopus virens*	1	0.0385
	Gray Catbird		*Dumetella carolinensis*	4	0.1538
	Northern Flicker		*Colaptes auratus*	1	0.0385
	Osprey		*Pandion haliaetus*	1	0.0385
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1154
	Song Sparrow		*Melospiza melodia*	4	0.1538

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
UDC002	Site abundance:	28			
	Alder Flycatcher		*Empidonax alnorum*	1	0.0357
	Barn Swallow		*Hirundo rustica*	2	0.0714
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0357
	Chimney Swift		*Chaetura pelagica*	1	0.0357
	Chipping Sparrow		*Spizella passerina*	3	0.1071
	Common Grackle		*Quiscalus quiscula*	3	0.1071
	Common Yellowthroat		*Geothlypis trichas*	2	0.0714
	Gray Catbird		*Dumetella carolinensis*	1	0.0357
	Mallard		*Anas platyrhynchos*	1	0.0357
	Northern Rough-Winged Swallow		*Stelgidopteryx serripennis*	3	0.1071
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1071
	Song Sparrow		*Melospiza melodia*	3	0.1071
	Tree Swallow		*Tachycineta bicolor*	2	0.0714
	Yellow Warbler		*Dendroica petechia*	2	0.0714
UDC003	Site abundance:	21			
	American Goldfinch		*Carduelis tristis*	2	0.0952
	American Robin		*Turdus migratorius*	1	0.0476
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0476
	Chimney Swift		*Chaetura pelagica*	1	0.0476
	Common Yellowthroat		*Geothlypis trichas*	1	0.0476
	Eastern Phoebe		*Sayornis phoebe*	1	0.0476
	Gray Catbird		*Dumetella carolinensis*	2	0.0952
	Mallard		*Anas platyrhynchos*	3	0.1429
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.1429
	Song Sparrow		*Melospiza melodia*	5	0.2381
	Wood Duck		*Aix sponsa*	1	0.0476
UDC004	Site abundance:	15			
	American Robin		*Turdus migratorius*	2	0.1333
	Common Yellowthroat		*Geothlypis trichas*	2	0.1333
	Eastern Wood-Pewee		*Contopus virens*	1	0.0667
	Gray Catbird		*Dumetella carolinensis*	1	0.0667
	Northern Flicker		*Colaptes auratus*	1	0.0667
	Northern Mockingbird		*Mimus polyglottos*	1	0.0667
	Song Sparrow		*Melospiza melodia*	2	0.1333
	Tufted Titmouse		*Parus bicolor*	1	0.0667
	Willow Flycatcher		*Empidonax traillii*	1	0.0667
	Yellow Warbler		*Dendroica petechia*	3	0.2000

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
UDC005	Site abundance:	16			
	Barn Swallow		*Hirundo rustica*	1	0.0625
	Common Grackle		*Quiscalus quiscula*	1	0.0625
	Eastern Meadowlark		*Sturnella magna*	1	0.0625
	Mallard		*Anas platyrhynchos*	4	0.2500
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.4375
	Savannah Sparrow		*Passerculus sandwichensis*	1	0.0625
	Song Sparrow		*Melospiza melodia*	1	0.0625
UDC007	Site abundance:	12			
	American Robin		*Turdus migratorius*	2	0.1667
	Blue Jay		*Cyanocitta cristata*	1	0.0833
	Brown Thrasher		*Toxostoma rufum*	1	0.0833
	Eastern Phoebe		*Sayornis phoebe*	2	0.1667
	Gray Catbird		*Dumetella carolinensis*	1	0.0833
	Indigo Bunting		*Passerina cyanea*	1	0.0833
	Northern Mockingbird		*Mimus polyglottos*	1	0.0833
	Song Sparrow		*Melospiza melodia*	2	0.1667
	Yellow-Rumped Warbler		*Dendroica coronata*	1	0.0833
UDC008	Site abundance:	23			
	American Goldfinch		*Carduelis tristis*	2	0.0870
	American Robin		*Turdus migratorius*	1	0.0435
	Blue Jay		*Cyanocitta cristata*	1	0.0435
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0435
	Common Grackle		*Quiscalus quiscula*	2	0.0870
	Eastern Phoebe		*Sayornis phoebe*	1	0.0435
	Gray Catbird		*Dumetella carolinensis*	3	0.1304
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0435
	Red-Winged Blackbird		*Agelaius phoeniceus*	4	0.1739
	Song Sparrow		*Melospiza melodia*	3	0.1304
	Swamp Sparrow		*Melospiza georgiana*	1	0.0435
	Wood Duck		*Aix sponsa*	1	0.0435
	Yellow Warbler		*Dendroica petechia*	2	0.0870

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
UDC012	Site abundance:	37			
	American Goldfinch		*Carduelis tristis*	6	0.1622
	American Robin		*Turdus migratorius*	1	0.0270
	Blue Jay		*Cyanocitta cristata*	1	0.0270
	Brown Thrasher		*Toxostoma rufum*	2	0.0541
	Canada Goose		*Branta canadensis*	2	0.0541
	Cedar Waxwing		*Bombycilla cedrorum*	2	0.0541
	Common Grackle		*Quiscalus quiscula*	1	0.0270
	Common Yellowthroat		*Geothlypis trichas*	2	0.0541
	Downy Woodpecker		*Picoides pubescens*	1	0.0270
	Eastern Wood-Pewee		*Contopus virens*	1	0.0270
	Gray Catbird		*Dumetella carolinensis*	1	0.0270
	Green Heron		*Butorides virescens*	1	0.0270
	Killdeer		*Charadrius vociferus*	1	0.0270
	Mallard		*Anas platyrhynchos*	2	0.0541
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0270
	Red-Winged Blackbird		*Agelaius phoeniceus*	3	0.0811
	Song Sparrow		*Melospiza melodia*	3	0.0811
	Tree Swallow		*Tachycineta bicolor*	5	0.1351
	Willow Flycatcher		*Empidonax traillii*	1	0.0270
UDC013	Site abundance:	17			
	American Crow		*Corvus brachyrhynchos*	1	0.0588
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0588
	Blue Jay		*Cyanocitta cristata*	1	0.0588
	Common Yellowthroat		*Geothlypis trichas*	2	0.1176
	Eastern Towhee		*Pipilo erythrophthalmus*	3	0.1765
	Gray Catbird		*Dumetella carolinensis*	2	0.1176
	Hermit Thrush		*Catharus guttatus*	1	0.0588
	Magnolia Warbler		*Dendroica magnolia*	1	0.0588
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0588
	Ovenbird		*Seiurus aurocapillus*	1	0.0588
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0588
	Song Sparrow		*Melospiza melodia*	2	0.1176

Appendix C. Continued.

SiteCode	Species		Latin name	Number observed	Frequency per Site
UDC014	Site abundance:	14			
	Alder Flycatcher		*Empidonax alnorum*	1	0.0714
	American Robin		*Turdus migratorius*	1	0.0714
	Black-capped Chickadee		*Poecile atricapilla*	2	0.1429
	Blue Jay		*Cyanocitta cristata*	1	0.0714
	Common Grackle		*Quiscalus quiscula*	1	0.0714
	Common Yellowthroat		*Geothlypis trichas*	3	0.2143
	Hermit Thrush		*Catharus guttatus*	1	0.0714
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0714
	Red-Winged Blackbird		*Agelaius phoeniceus*	1	0.0714
	Song Sparrow		*Melospiza melodia*	1	0.0714
	Yellow Warbler		*Dendroica petechia*	1	0.0714
UDC015	Site abundance:	42			
	American Goldfinch		*Carduelis tristis*	4	0.0952
	American Robin		*Turdus migratorius*	1	0.0238
	Baltimore Oriole		*Icterus galbula*	3	0.0714
	Blue Jay		*Cyanocitta cristata*	1	0.0238
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0238
	Canada Goose		*Branta canadensis*	2	0.0476
	Cedar Waxwing		*Bombycilla cedrorum*	1	0.0238
	Common Grackle		*Quiscalus quiscula*	15	0.3571
	Common Yellowthroat		*Geothlypis trichas*	3	0.0714
	House Wren		*Troglodytes aedon*	1	0.0238
	Indigo Bunting		*Passerina cyanea*	1	0.0238
	Northern Flicker		*Colaptes auratus*	1	0.0238
	Pileated Woodpecker		*Dryocopus pileatus*	1	0.0238
	Red-Winged Blackbird		*Agelaius phoeniceus*	4	0.0952
	Tree Swallow		*Tachycineta bicolor*	2	0.0476
	Turkey Vulture		*Cathartes aura*	1	0.0238

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
UDC016	Site abundance:	24			
	American Robin		*Turdus migratorius*	1	0.0417
	Baltimore Oriole		*Icterus galbula*	1	0.0417
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0417
	Blue Jay		*Cyanocitta cristata*	2	0.0833
	Canada Goose		*Branta canadensis*	2	0.0833
	Common Grackle		*Quiscalus quiscula*	1	0.0417
	Common Yellowthroat		*Geothlypis trichas*	2	0.0833
	Downy Woodpecker		*Picoides pubescens*	1	0.0417
	Gray Catbird		*Dumetella carolinensis*	2	0.0833
	Louisiana Waterthrush		*Seiurus motacilla*	1	0.0417
	Louisiana Waterthrush		*Seiurus motacilla*	1	0.0417
	Mourning Dove		*Zenaida macroura*	3	0.1250
	Northern Cardinal		*Cardinalis cardinalis*	2	0.0833
	Northern Mockingbird		*Mimus polyglottos*	1	0.0417
	Song Sparrow		*Melospiza melodia*	2	0.0833
	Tree Swallow		*Tachycineta bicolor*	1	0.0417
UDC017	Site abundance:	25			
	American Goldfinch		*Carduelis tristis*	1	0.0400
	Baltimore Oriole		*Icterus galbula*	1	0.0400
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0400
	Blue Jay		*Cyanocitta cristata*	1	0.0400
	Chipping Sparrow		*Spizella passerina*	1	0.0400
	Common Grackle		*Quiscalus quiscula*	1	0.0400
	Eastern Towhee		*Pipilo erythrophthalmus*	3	0.1200
	European Starling		*Sturnus vulgaris*	1	0.0400
	Gray Catbird		*Dumetella carolinensis*	4	0.1600
	Great Blue Heron		*Ardea herodias*	1	0.0400
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0400
	Northern Flicker		*Colaptes auratus*	1	0.0400
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.0800
	Ruby-Throated Hummingbird		*Archilochus colubris*	1	0.0400
	Song Sparrow		*Melospiza melodia*	3	0.1200
	Wood Duck		*Aix sponsa*	2	0.0800

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
UDC018	Site abundance:	24			
	American Crow		*Corvus brachyrhynchos*	1	0.0417
	American Robin		*Turdus migratorius*	1	0.0417
	Baltimore Oriole		*Icterus galbula*	2	0.0833
	Barn Swallow		*Hirundo rustica*	2	0.0833
	Chimney Swift		*Chaetura pelagica*	2	0.0833
	Common Yellowthroat		*Geothlypis trichas*	2	0.0833
	Gray Catbird		*Dumetella carolinensis*	2	0.0833
	Mallard		*Anas platyrhynchos*	2	0.0833
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.2500
	Song Sparrow		*Melospiza melodia*	2	0.0833
	Tree Swallow		*Tachycineta bicolor*	1	0.0417
	Wood Duck		*Aix sponsa*	1	0.0417
UDC019	Site abundance:	26			
	Blue Jay		*Cyanocitta cristata*	1	0.0385
	Common Yellowthroat		*Geothlypis trichas*	2	0.0769
	Common Yellowthroat		*Geothlypis trichas*	3	0.1154
	Eastern Bluebird		*Sialia sialis*	1	0.0385
	European Starling		*Sturnus vulgaris*	1	0.0385
	Gray Catbird		*Dumetella carolinensis*	1	0.0385
	Indigo Bunting		*Passerina cyanea*	2	0.0769
	Northern Cardinal		*Cardinalis cardinalis*	3	0.1154
	Northern Mockingbird		*Mimus polyglottos*	1	0.0385
	Red-Winged Blackbird		*Agelaius phoeniceus*	6	0.2308
	Song Sparrow		*Melospiza melodia*	3	0.1154
	Tufted Titmouse		*Parus bicolor*	2	0.0769

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
UDC020	Site abundance:	35			
	American Crow		*Corvus brachyrhynchos*	7	0.2000
	American Robin		*Turdus migratorius*	1	0.0286
	Common Yellowthroat		*Geothlypis trichas*	3	0.0857
	Eastern Wood-Pewee		*Contopus virens*	2	0.0571
	Gray Catbird		*Dumetella carolinensis*	1	0.0286
	Great Blue Heron		*Ardea herodias*	1	0.0286
	Green Heron		*Butorides virescens*	1	0.0286
	Killdeer		*Charadrius vociferus*	1	0.0286
	Mourning Dove		*Zenaida macroura*	3	0.0857
	Red-Winged Blackbird		*Agelaius phoeniceus*	7	0.2000
	Song Sparrow		*Melospiza melodia*	3	0.0857
	Tree Swallow		*Tachycineta bicolor*	3	0.0857
	Virginia Rail		*Rallus limicola*	2	0.0571
VEPCON	Site abundance:	16			
	Alder Flycatcher		*Empidonax alnorum*	1	0.0625
	American Robin		*Turdus migratorius*	1	0.0625
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0625
	Common Yellowthroat		*Geothlypis trichas*	2	0.1250
	Field Sparrow		*Spizella pusilla*	1	0.0625
	Killdeer		*Charadrius vociferus*	1	0.0625
	Mallard		*Anas platyrhynchos*	2	0.1250
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.3125
	Song Sparrow		*Melospiza melodia*	1	0.0625
	Tree Swallow		*Tachycineta bicolor*	1	0.0625
VEPCOS	Site abundance:	11			
	American Crow		*Corvus brachyrhynchos*	1	0.0909
	American Robin		*Turdus migratorius*	1	0.0909
	Brown-Headed Cowbird		*Molothrus ater*	1	0.0909
	Common Yellowthroat		*Geothlypis trichas*	2	0.1818
	Ovenbird		*Seiurus aurocapillus*	1	0.0909
	Red-Winged Blackbird		*Agelaius phoeniceus*	2	0.1818
	Savannah Sparrow		*Passerculus sandwichensis*	2	0.1818
	Song Sparrow		*Melospiza melodia*	1	0.0909

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
WBBARN	Site abundance:	46			
	American Robin		*Turdus migratorius*	1	0.0217
	Barn Swallow		*Hirundo rustica*	2	0.0435
	Common Grackle		*Quiscalus quiscula*	3	0.0652
	Eastern Kingbird		*Tyrannus tyrannus*	1	0.0217
	Eastern Meadowlark		*Sturnella magna*	1	0.0217
	Field Sparrow		*Spizella pusilla*	2	0.0435
	Killdeer		*Charadrius vociferus*	2	0.0435
	Mallard		*Anas platyrhynchos*	1	0.0217
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0217
	Red-Winged Blackbird		*Agelaius phoeniceus*	10	0.2174
	Savannah Sparrow		*Passerculus sandwichensis*	6	0.1304
	Solitary Sandpiper		*Tringa solitaria*	2	0.0435
	Song Sparrow		*Melospiza melodia*	2	0.0435
	Tree Swallow		*Tachycineta bicolor*	3	0.0652
	Turkey Vulture		*Cathartes aura*	1	0.0217
	Virginia Rail		*Rallus limicola*	1	0.0217
	Wood Duck		*Aix sponsa*	5	0.1087
	Yellow Warbler		*Dendroica petechia*	2	0.0435
WBCORN	Site abundance:	31			
	American Goldfinch		*Carduelis tristis*	1	0.0323
	American Kestrel		*Falco sparverius*	1	0.0323
	Barn Swallow		*Hirundo rustica*	3	0.0968
	Eastern Meadowlark		*Sturnella magna*	2	0.0645
	Field Sparrow		*Spizella pusilla*	3	0.0968
	Killdeer		*Charadrius vociferus*	3	0.0968
	Red-Winged Blackbird		*Agelaius phoeniceus*	9	0.2903
	Sedge Wren		*Cistothorus platensis*	2	0.0645
	Song Sparrow		*Melospiza melodia*	3	0.0968
	Wood Duck		*Aix sponsa*	2	0.0645
	Yellow Warbler		*Dendroica petechia*	2	0.0645

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
WBROAD	Site abundance:	27			
	American Goldfinch		*Carduelis tristis*	1	0.0370
	Barn Swallow		*Hirundo rustica*	2	0.0741
	Eastern Bluebird		*Sialia sialis*	3	0.1111
	Eastern Meadowlark		*Sturnella magna*	1	0.0370
	Eastern Phoebe		*Sayornis phoebe*	1	0.0370
	Field Sparrow		*Spizella pusilla*	3	0.1111
	Indigo Bunting		*Passerina cyanea*	1	0.0370
	Red-Winged Blackbird		*Agelaius phoeniceus*	12	0.4444
	Song Sparrow		*Melospiza melodia*	3	0.1111
WYBEAV	Site abundance:	27			
	American Crow		*Corvus brachyrhynchos*	1	0.0370
	American Goldfinch		*Carduelis tristis*	2	0.0741
	Black-and-White Warbler		*Mniotilta varia*	1	0.0370
	Black-capped Chickadee		*Poecile atricapilla*	3	0.1111
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	2	0.0741
	Blue-Headed Vireo		*Vireo solitarius*	1	0.0370
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0370
	Carolina Chickadee		*Poecile carolinensis*	2	0.0741
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0370
	Common Yellowthroat		*Geothlypis trichas*	1	0.0370
	Gray Catbird		*Dumetella carolinensis*	1	0.0370
	Great Blue Heron		*Ardea herodias*	1	0.0370
	Indigo Bunting		*Passerina cyanea*	2	0.0741
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0370
	Northern Parula		*Parula americana*	1	0.0370
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0370
	Red-Eyed Vireo		*Vireo olivaceus*	2	0.0741
	Yellow Warbler		*Dendroica petechia*	2	0.0741
	Yellow-Breasted Chat		*Icteria virens*	1	0.0370

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
WYCHWE	Site abundance:	18			
	Acadian Flycatcher		*Empidonax virescens*	2	0.1111
	American Redstart		*Setophaga ruticilla*	2	0.1111
	Black-throated Green Warbler		*Dendroica virens*	1	0.0556
	Carolina Chickadee		*Poecile carolinensis*	3	0.1667
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0556
	Common Yellowthroat		*Geothlypis trichas*	1	0.0556
	Hooded Warbler		*Wilsonia citrina*	1	0.0556
	Indigo Bunting		*Passerina cyanea*	2	0.1111
	Kentucky Warbler		*Oporornis formosus*	1	0.0556
	Northern Parula		*Parula americana*	2	0.1111
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0556
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0556
WYHCEA	Site abundance:	19			
	American Crow		*Corvus brachyrhynchos*	1	0.0526
	American Goldfinch		*Carduelis tristis*	2	0.1053
	American Redstart		*Setophaga ruticilla*	1	0.0526
	Black-capped Chickadee		*Poecile atricapilla*	1	0.0526
	Black-throated Green Warbler		*Dendroica virens*	1	0.0526
	Chestnut-Sided Warbler		*Dendroica pensylvanica*	1	0.0526
	Common Yellowthroat		*Geothlypis trichas*	2	0.1053
	Gray Catbird		*Dumetella carolinensis*	1	0.0526
	Indigo Bunting		*Passerina cyanea*	2	0.1053
	Kentucky Warbler		*Oporornis formosus*	1	0.0526
	Northern Parula		*Parula americana*	1	0.0526
	Song Sparrow		*Melospiza melodia*	3	0.1579
	White-Eyed Vireo		*Vireo griseus*	1	0.0526
	Yellow Warbler		*Dendroica petechia*	1	0.0526

Appendix C. Continued.

SiteCode	Species		*Latin name*	Number observed	Frequency per Site
WYINTR	Site abundance:	16			
	American Crow		*Corvus brachyrhynchos*	1	0.0625
	American Robin		*Turdus migratorius*	1	0.0625
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0625
	Carolina Chickadee		*Poecile carolinensis*	2	0.1250
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0625
	Common Yellowthroat		*Geothlypis trichas*	1	0.0625
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.1250
	Indigo Bunting		*Passerina cyanea*	2	0.1250
	Northern Cardinal		*Cardinalis cardinalis*	2	0.1250
	Red-Billed Woodpecker		*Melanerpes carolinus*	1	0.0625
	Red-Eyed Vireo		*Vireo olivaceus*	1	0.0625
	Yellow Warbler		*Dendroica petechia*	1	0.0625
WYTHOR	Site abundance:	22			
	Blue Jay		*Cyanocitta cristata*	1	0.0455
	Blue-Gray Gnatcatcher		*Polioptila caerulea*	1	0.0455
	Blue-Winged Warbler		*Vermivora pinus*	1	0.0455
	Carolina Chickadee		*Poecile carolinensis*	1	0.0455
	Carolina Wren		*Thryothorus ludovicianus*	1	0.0455
	Common Yellowthroat		*Geothlypis trichas*	2	0.0909
	Eastern Towhee		*Pipilo erythrophthalmus*	2	0.0909
	European Starling		*Sturnus vulgaris*	1	0.0455
	Field Sparrow		*Spizella pusilla*	1	0.0455
	Gray Catbird		*Dumetella carolinensis*	1	0.0455
	Henslow's Sparrow		*Ammodramus henslowii*	1	0.0455
	Northern Cardinal		*Cardinalis cardinalis*	1	0.0455
	Northern Parula		*Parula americana*	1	0.0455
	Red-Winged Blackbird		*Agelaius phoeniceus*	5	0.2273
	Scarlet Tanager		*Piranga olivacea*	1	0.0455
	Yellow-Breasted Chat		*Icteria virens*	1	0.0455

Appendix D. Part 1. Sites and corresponding metric values used in developing class-specific avian wetland indices of biologicalintegrity (AW-IBI) in West Virginia, USA from 2005-2006. Blanks indicate a metric value of zero.

Site Code	Wetland Dependency	Wetland Associated	Facultative Wetland	neotropical Migrants	Habitat-specific	neotropical Habitat-specific	Edge species	Year-round edge species	Carnivorous Habitat specific	Omnivorous	Insectivorous
CFCROS	0.0323	0.3226	0.6452	0.4194	0.1613	0.1613	0.8387	0.5484	0.1290	0.4516	0.3871
CFECUR		0.0625	0.4375	0.4375	0.3125	0.3125	0.6875	0.5000	0.2500	0.4375	0.3750
CFEINC	0.0526	0.3158	0.6316	0.2632	0.3158	0.2105	0.6842	0.6316	0.2105	0.6316	0.2632
CFSLCH	0.1034	0.2069	0.6207	0.3103	0.4828	0.2069	0.4828	0.3793	0.1724	0.5862	0.2759
CFSLIN	0.0417	0.2500	0.5417	0.4583	0.4167	0.3750	0.5833	0.3750	0.3750	0.3750	0.5417
CGBRID	0.1905	0.3810	0.6667	0.5714	0.7143	0.5238	0.2857	0.1429	0.6190	0.1905	0.7619
CGCPAS	0.1111	0.2222	0.5556	0.6667	0.5000	0.3889	0.5000	0.1667	0.2778	0.3333	0.5556
CGROAD		0.0769	0.3846	0.5385	0.3846	0.1538	0.6154	0.1538	0.3077	0.3077	0.6154
CGTRHE		0.0526	0.2632	0.6842	0.6842	0.5263	0.3158	0.1053	0.3684	0.4737	0.5263
CHNEER	0.1250	0.5000	0.7917	0.1667	0.2500	0.1250	0.7500	0.6667	0.2083	0.5000	0.3333
CHSACH	0.0909	0.4545	0.5455	0.0909	0.1818	0.0606	0.8182	0.7273	0.0909	0.6970	0.1515
CHSAFO			0.3810	0.0476	0.1429	0.0476	0.8571	0.8571	0.0952	0.7619	0.0952
CHSARR	0.4839	0.4839	0.6452	0.0645	0.2258	0.0323	0.7742	0.7097	0.0968	0.7097	0.1935
CHTREE		0.0588	0.2941	0.3529	0.2353	0.0588	0.7647	0.2941	0.0588	0.5294	0.4118
CHWWBW	0.1020	0.4694	0.6327	0.1020	0.3061	0.0204	0.6939	0.5510	0.1224	0.6735	0.2857
CHWWEM	0.0238	0.3333	0.6429	0.1429	0.1667	0.0476	0.8333	0.6190	0.0952	0.6190	0.2619
CHWWFO	0.3636	0.3864	0.5227	0.0682	0.5227	0.0455	0.4773	0.4545	0.2273	0.6364	0.2045
CVABBW	0.2353	0.4118	0.4706	0.2941	0.5882	0.2941	0.2941	0.1176	0.2941	0.4706	0.4118
CVABCT	0.1429	0.2381	0.4286	0.4286	0.2857	0.2381	0.6190	0.2857	0.1905	0.3810	0.4286
CVTIMB	0.1765	0.6471	0.7059	0.2941	0.2941	0.1765	0.7059	0.4118	0.1765	0.4706	0.4706
DSPICN			0.1250	0.6250	0.3125	0.3125	0.6875	0.2500	0.3125	0.2500	0.6250
DSROAR		0.3571	0.5000	0.5000	0.3571	0.2857	0.6429	0.1429	0.2143	0.2857	0.5714
DSWILD			0.1429	0.5000	0.4286	0.3571	0.5714	0.2857	0.3571	0.5000	0.5000
EPCMEM		0.4737	0.7105	0.1842	0.1316	0.1053	0.8684	0.7632	0.1053	0.7105	0.2105
EPCMFO	0.2400	0.2800	0.4000	0.0800	0.0800		0.9200	0.8000	0.0400	0.7200	0.2000
EPDMFO			0.1333	0.0667	0.2000		0.8000	0.7333		0.6000	0.1333

Appendix D. Part 1 continued.

Site Code	Wetland Dependency	Wetland Associated	Facultative Wetland	neotropical Migrants	Habitat-specific	neotropical Habitat-specific	Edge species	Year-round edge species	Carnivorous Habitat specific	Omnivorous	Insectivorous
EPDMPU			0.0909	0.0909			1.0000	0.8182		0.6364	0.0909
EPKYVE	0.2619	0.4286	0.6190	0.1667	0.4048	0.1190	0.5476	0.4762	0.1905	0.3571	0.2143
EPRRXC			0.1429	0.3571	0.2143	0.0714	0.7857	0.4286	0.0714	0.6429	0.2143
EPSHEM	0.1538	0.2692	0.4615	0.1538	0.1538	0.1538	0.8462	0.7692	0.1154	0.5385	0.2308
EPSHSS	0.1000	0.2333	0.4667	0.2667	0.3000	0.1333	0.7000	0.4667	0.1667	0.4333	0.3333
GBBARN		0.3333	0.6667	0.2917	0.2500	0.2083	0.7500	0.5833	0.2083	0.5833	0.3750
GBHOEF	0.1364	0.7045	0.7955	0.5909	0.6364	0.5682	0.3636	0.2727	0.5682	0.2045	0.6818
GBJENK	0.4872	0.7692	0.8462	0.1026	0.4872	0.0513	0.5128	0.4103	0.0769	0.4359	0.1538
GBMAPL		0.2105	0.5263	0.3158	0.4211	0.1579	0.5789	0.2632	0.1579	0.4211	0.5263
GBNOFO	0.0769	0.3462	0.6538	0.2308	0.1538	0.1538	0.8462	0.6923	0.1538	0.5769	0.3846
GBNOSS	0.0385	0.5385	0.7308	0.3462	0.2308	0.1923	0.7692	0.5385	0.1923	0.5000	0.4615
GBPLOT	0.4211	0.6316	0.8684	0.1842	0.4737	0.1316	0.5263	0.4474	0.1316	0.4211	0.2368
HCBEAV		0.1538	0.5000	0.3077	0.2308	0.1923	0.7692	0.5385	0.1538	0.6538	0.3077
HCMITI	0.1333	0.4000	0.7000	0.2333	0.2333	0.1667	0.7333	0.5667	0.2000	0.5000	0.3667
HCPIPE	0.0571	0.4571	0.6571	0.2000	0.1143	0.1143	0.8857	0.6857	0.1143	0.6000	0.2571
HCRANG	0.1071	0.4286	0.5714	0.2500	0.1429	0.1429	0.8571	0.6071	0.1429	0.5000	0.3214
HIBRID	0.0313	0.2188	0.5625	0.3750	0.2188	0.1875	0.7813	0.5625	0.1875	0.5313	0.3750
HIGATE	0.0833	0.1667	0.5417	0.2917	0.3333	0.1667	0.6250	0.3750	0.2083	0.3750	0.4167
HIJHPK		0.0833	0.2083	0.2917	0.2917	0.1667	0.7083	0.5000	0.1667	0.5000	0.3750
HIJHTU		0.1905	0.4762	0.2857	0.2381	0.1905	0.7619	0.5714	0.1905	0.5238	0.2381
HIPENC	0.0625	0.5000	0.6875	0.2500	0.2813	0.2188	0.7188	0.5625	0.2500	0.6563	0.3125
HISEWG	0.0476	0.0476	0.3333	0.4286	0.3333	0.2381	0.6190	0.3810	0.2381	0.5238	0.4286
HITRLR		0.3704	0.6296	0.2593	0.1481	0.1111	0.8519	0.6296	0.1111	0.6667	0.2963
MCFOUR		0.1429	0.4286	0.3810	0.2381	0.2381	0.7619	0.3810	0.1905	0.6667	0.2857
MCMEME	0.2766	0.5319	0.8085	0.2766	0.4894	0.2340	0.5106	0.4255	0.3191	0.4468	0.3617
MCMFOR	0.1875	0.3750	0.4688	0.2500	0.3750	0.1250	0.6250	0.4688	0.1875	0.5000	0.3438

Appendix D. Part 1 continued.

Site Code	Wetland Dependency	Wetland Associated	Facultative Wetland	neotropical Migrants	Habitat-specific	neotropical Habitat-specific	Edge species	Year-round edge species	Carnivorous Habitat specific	Omnivorous	Insectivorous
MCNPFO		0.1429	0.2857	0.5000	0.2143	0.2143	0.7857	0.3571	0.1429	0.5000	0.4286
MCPOND	0.0667	0.2667	0.4000	0.2000	0.2667	0.2000	0.7333	0.6000	0.2000	0.5333	0.2667
MCPOST	0.0435	0.2174	0.4783	0.2609	0.3043	0.1304	0.6957	0.4348	0.1304	0.6957	0.3043
MCTELE		0.2000	0.4500	0.2000	0.1000	0.1000	0.9000	0.7500	0.1000	0.7000	0.2000
ME5092	0.0952	0.4762	0.8571	0.2857	0.1429	0.1429	0.8571	0.6190	0.1429	0.5238	0.3810
MESCOX		0.1154	0.6538	0.3846	0.3462	0.2308	0.6538	0.3462	0.2308	0.4615	0.4615
MESCRO	0.0645	0.4839	0.8387	0.2903	0.1613	0.1290	0.8387	0.5806	0.1290	0.6129	0.2903
MESCUP		0.0909	0.4545	0.2727	0.3182	0.1818	0.6818	0.4545	0.1364	0.5909	0.2727
MESIGN		0.1429	0.6190	0.0952	0.0952		0.9048	0.6190		0.6190	0.1905
MESILV		0.4138	0.7931	0.3103	0.2069	0.1724	0.7931	0.5172	0.1724	0.5172	0.4138
METETR	0.0909	0.5000	0.8182	0.2273	0.2273	0.0455	0.7727	0.5909	0.1364	0.6818	0.2727
MEWOLF	0.0800	0.4000	0.8000	0.2800	0.1200	0.0400	0.8800	0.3600	0.0400	0.4400	0.4400
MRBESS		0.3125	0.4375	0.4375	0.4375	0.3750	0.5625	0.3750	0.3125	0.5000	0.4375
MRFARM		0.1053	0.4211	0.3684	0.0526		0.9474	0.3684		0.4737	0.3158
MRFORE		0.2000	0.3333	0.5333	0.2667	0.2667	0.7333	0.2000	0.2000	0.4000	0.5333
MRSSSS		0.1111	0.3333	0.4444	0.3333	0.2778	0.6667	0.3333	0.1111	0.6667	0.2778
MRWEST			0.2353	0.4118	0.3529	0.2941	0.6471	0.4118	0.2353	0.4706	0.2941
MU55SS	0.0556	0.2778	0.6111	0.2222	0.0556	0.0556	0.9444	0.5000	0.0556	0.5556	0.3889
MUDBOA	0.0714	0.3571	0.4286	0.7143	0.5714	0.5000	0.4286	0.2143	0.5714	0.2143	0.7857
MUDEND	0.1136	0.2727	0.5682	0.3864	0.5682	0.2955	0.4318	0.2955	0.3182	0.4091	0.4318
MUDRIC	0.0556	0.2222	0.2778	0.6111	0.5000	0.3889	0.5000	0.1111	0.3333	0.3889	0.6111
MUDRIP	0.0769	0.3590	0.5641	0.3077	0.3333	0.1795	0.6667	0.3590	0.2564	0.3590	0.4615
MUDTRA	0.0645	0.2903	0.6452	0.2903	0.2581	0.1290	0.7097	0.3871	0.1935	0.4839	0.4194
MUEPAH	0.0455	0.3636	0.6364	0.2273	0.1818	0.0909	0.7727	0.4091	0.1364	0.5000	0.3182
MUMINE		0.1000	0.5000	0.3000	0.4500	0.3000	0.5000	0.4000	0.3500	0.4500	0.4000
MUPOWR	0.0435	0.2174	0.4348	0.2174	0.2174	0.1304	0.7826	0.6087	0.1304	0.6087	0.2609

Appendix D. Part 1 continued.

Site Code	Wetland Dependency	Wetland Associated	Facultative Wetland	neotropical Migrants	Habitat-specific	neotropical Habitat-specific	Edge species	Year-round edge species	Carnivorous Habitat specific	Omnivorous	Insectivorous
MUPULL	0.0968	0.3226	0.7097	0.3548	0.2903	0.1613	0.7097	0.4516	0.2258	0.3871	0.4839
MUVBRD	0.0313	0.3438	0.7500	0.3125	0.3438	0.2188	0.6250	0.4375	0.2813	0.5000	0.4063
MUVCRN	0.2258	0.5161	0.8387	0.2258	0.1613	0.1290	0.8387	0.7097	0.1290	0.6774	0.2581
OHHSFO		0.1875	0.3750	0.1875	0.3125	0.1875	0.6875	0.5000	0.1250	0.6250	0.3125
OHINNS	0.0345	0.3448	0.5862	0.3448	0.3793	0.2759	0.6207	0.4483	0.2759	0.5862	0.3448
OHKMRT	0.0400	0.3200	0.4800	0.2400	0.1600	0.1600	0.6000	0.5200	0.1600	0.3600	0.2400
PA29TH	0.0781	0.2031	0.4531	0.1406	0.2656	0.1250	0.7344	0.6563	0.1563	0.3438	0.2656
PA83CR		0.0769	0.2692	0.1923	0.1154	0.0769	0.8846	0.7308	0.0769	0.5769	0.1154
PAFAMD	0.2157	0.3137	0.5098	0.1176	0.3529	0.0588	0.6275	0.5490	0.1373	0.4902	0.1961
PAJCPY	0.2941	0.3333	0.5098	0.1765	0.3725	0.0784	0.6275	0.4510	0.1569	0.3333	0.4118
PALOUD	0.0313	0.1875	0.5313	0.4063	0.3438	0.2500	0.6563	0.4375	0.2500	0.5313	0.3750
PAPEFO	0.1000	0.1500	0.3000	0.2500	0.2500	0.1500	0.7500	0.5000	0.1000	0.4500	0.3500
PAPEIM		0.5172	0.6552	0.1034	0.0690	0.0345	0.8966	0.7586	0.0345	0.7241	0.0690
PAPESW	0.1000	0.3250	0.5000	0.2500	0.4250	0.1750	0.5750	0.4750	0.2500	0.5500	0.3000
PAWILL	0.1951	0.5122	0.5854	0.0488	0.1951		0.8049	0.7561	0.0732	0.5854	0.0732
PCBLUE		0.2400	0.5600	0.2400	0.1600	0.1600	0.8400	0.6400	0.1600	0.5600	0.3600
PCLPFO	0.0526	0.1053	0.2105	0.5263	0.2105	0.1053	0.7895	0.3158	0.1053	0.3158	0.3684
PCROAD	0.0714	0.2143	0.5357	0.2857	0.2143	0.1429	0.7857	0.5714	0.1786	0.4286	0.3929
PEMIDW		0.2273	0.5000	0.4545	0.1818	0.1364	0.7727	0.2727	0.0909	0.5909	0.3182
PERDDP		0.4286	0.7143	0.1429	0.1071	0.0714	0.8929	0.7500	0.1071	0.5714	0.2143
PETHUM		0.1667	0.5000	0.3333	0.3333	0.2222	0.6667	0.3889	0.2222	0.4444	0.5556
PETOSS		0.3600	0.7200	0.3600	0.2400	0.1600	0.7600	0.4800	0.1200	0.6400	0.2800
RIASIA		0.1143	0.5143	0.2857	0.1714	0.1143	0.8286	0.5714	0.1143	0.6857	0.2857
RIBRID	0.0323	0.1613	0.4839	0.3548	0.2903	0.1935	0.7097	0.4516	0.1935	0.5484	0.3226
RIEAST		0.1739	0.5652	0.5217	0.4783	0.3913	0.5217	0.3043	0.3478	0.5217	0.4348
SJBOAT	0.0909	0.1818	0.6364	0.6364	0.4545	0.4091	0.5455	0.2273	0.4091	0.4545	0.4545

Appendix D. Part 1 continued.

Site Code	Wetland Dependency	Wetland Associated	Facultative Wetland	neotropical Migrants	Habitat-specific	neotropical Habitat-specific	Edge species	Year-round edge species	Carnivorous Habitat specific	Omnivorous	Insectivorous
SJBRID		0.2609	0.5652	0.2609	0.0870	0.0870	0.9130	0.6522	0.0870	0.6522	0.2174
SJCHUR	0.1724	0.3448	0.8276	0.4828	0.3448	0.2759	0.6552	0.3448	0.3103	0.5172	0.4483
SJGLAD		0.1364	0.5455	0.5455	0.3182	0.3182	0.6818	0.3636	0.3182	0.4545	0.4545
SJMUDL		0.0833	0.4583	0.5417	0.2917	0.2917	0.7083	0.3333	0.2500	0.5000	0.4583
SJPLOT	0.0400	0.2000	0.5600	0.4800	0.2800	0.2800	0.7200	0.3600	0.2800	0.3600	0.5600
SJTELE		0.1579	0.5789	0.6316	0.2632	0.2632	0.7368	0.2632	0.2632	0.4737	0.4737
SMDTSS	0.0833	0.3750	0.5833	0.2500	0.4167	0.2083	0.5833	0.3333	0.2500	0.4583	0.5000
SMFOFL	0.0476	0.2857	0.4762	0.5714	0.5714	0.3810	0.4286	0.0476	0.4286	0.3810	0.6190
SMLPEM	0.1818	0.5152	0.7576	0.1515	0.2727	0.1212	0.7273	0.4545	0.1818	0.5758	0.3333
SMSEFL	0.3784	0.5946	0.7297	0.2703	0.5405	0.2432	0.4595	0.3243	0.2703	0.4054	0.3514
SMSTEM	0.3333	0.4667	0.7333	0.5333	0.4667	0.4000	0.5333	0.2000	0.4667	0.2667	0.7333
TRSPFO		0.1667	0.3333	0.5556	0.3889	0.3889	0.6111	0.2778	0.2778	0.4444	0.4444
TRSPRI	0.0323	0.2581	0.5806	0.3871	0.3871	0.2581	0.6129	0.4194	0.2581	0.5484	0.4194
TVFARM		0.4000	0.6500	0.1500	0.1000	0.0500	0.9000	0.7000	0.0500	0.6000	0.2500
TVISLE	0.0417	0.2083	0.4167	0.0833	0.1667		0.8333	0.6667	0.0833	0.5417	0.2917
TVNEWT	0.2245	0.6327	0.8163	0.2449	0.2449	0.1020	0.7551	0.5714	0.1224	0.5102	0.3265
TVPOUT	0.1000	0.2000	0.5000	0.4500	0.1000	0.1000	0.9000	0.4500	0.1000	0.4000	0.4500
TVVBEM		0.7333	0.8000	0.0667	0.0667	0.0667	0.9333	0.8667	0.0667	0.6667	0.1333
TVVBIM	0.0909	0.5000	0.7273	0.1818	0.1818	0.1364	0.8182	0.5909	0.1818	0.4545	0.3636
TVVBRV	0.0400	0.2000	0.4800	0.1200	0.2800	0.0800	0.7200	0.6400	0.1600	0.5600	0.3600
TVVBSS	0.2250	0.5500	0.7750	0.3000	0.4250	0.1750	0.5750	0.3500	0.2500	0.3750	0.4500
UDC001	0.0385	0.2692	0.5769	0.1154	0.0769		0.9231	0.6923	0.0385	0.7308	0.2308
UDC002	0.0714	0.3571	0.6429	0.3929	0.2143	0.2143	0.7857	0.4286	0.2143	0.5000	0.4643
UDC003	0.1905	0.3810	0.7143	0.0476	0.0476		0.9524	0.8095		0.7143	0.1429
UDC004	0.0667	0.2000	0.6667	0.3333	0.2000	0.0667	0.8000	0.4000	0.0667	0.5333	0.4667
UDC005	0.2500	0.6875	0.8125	0.0625			1.0000	0.8750		0.8750	0.0625

Appendix D. Part 1 continued.

Site Code	Wetland Dependency	Wetland Associated	Facultative Wetland	neotropical Migrants	Habitat-specific	neotropical Habitat-specific	Edge species	Year-round edge species	Carnivorous Habitat specific	Omnivorous	Insectivorous
UDC007			0.4167	0.1667	0.0833	0.0833	0.9167	0.6667		0.7500	0.1667
UDC008	0.0870	0.2609	0.6087	0.0870	0.0870		0.9130	0.7826		0.6522	0.1304
UDC012	0.1622	0.2973	0.5405	0.1892	0.2432	0.1622	0.7568	0.6757	0.1892	0.3514	0.3243
UDC013		0.1176	0.3529	0.1765	0.1765	0.1176	0.8235	0.4706	0.1176	0.5882	0.2941
UDC014	0.0714	0.3571	0.5000	0.2143	0.2143	0.1429	0.7857	0.5000	0.1429	0.5000	0.4286
UDC015	0.0476	0.2143	0.2857	0.1429	0.1429	0.0476	0.8571	0.6667	0.0714	0.6190	0.1905
UDC016	0.1250	0.2083	0.4167	0.1250	0.1667	0.0833	0.7917	0.6667	0.1250	0.3750	0.2083
UDC017	0.1200	0.2000	0.5200	0.0800	0.2000		0.8000	0.5600	0.0400	0.7200	0.0400
UDC018	0.1250	0.4583	0.6667	0.2917	0.0833	0.0417	0.9167	0.5833	0.0417	0.6667	0.2917
UDC019		0.4231	0.7308	0.0769	0.1538		0.8462	0.5769		0.6538	0.1923
UDC020	0.1143	0.4000	0.6000	0.1429	0.2000	0.0857	0.8000	0.6571	0.2000	0.5429	0.3714
VEPCON	0.1875	0.6250	0.7500	0.1250	0.1250	0.1250	0.8750	0.7500	0.1250	0.6875	0.3125
VEPCOS		0.3636	0.6364	0.0909	0.0909	0.0909	0.9091	0.5455	0.0909	0.5455	0.2727
WBBARN	0.1957	0.4130	0.7174	0.1739	0.2826	0.0870	0.7174	0.5000	0.1522	0.4565	0.3043
WBCORN	0.0645	0.4194	0.5806	0.1613	0.1290		0.8710	0.6774	0.0645	0.5484	0.3548
WBROAD		0.4444	0.5926	0.1111	0.1111		0.8889	0.7407		0.8519	0.1111
WYBEAV	0.0370	0.1111	0.4815	0.4815	0.3333	0.2593	0.6667	0.4074	0.2963	0.3704	0.5185
WYCHWE		0.3889	0.5556	0.6667	0.4444	0.3889	0.5556	0.2222	0.3889	0.3333	0.6667
WYHCEA		0.2632	0.6316	0.4737	0.2105	0.2105	0.7895	0.4211	0.2105	0.4211	0.4737
WYINTR		0.0625	0.3750	0.3125	0.1250	0.0625	0.8750	0.4375	0.0625	0.5625	0.3125
WYTHOR		0.4091	0.5909	0.2273	0.2727	0.1818	0.7273	0.5000	0.1818	0.5455	0.3182

Appendix D. Part 2. Sites and corresponding metric values used in developing class-specific avian wetland indices of biologicalintegrity (AW-IBI) in West Virginia, USA from 2005-2006.Blanks indicate a metric value of zero.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
CFCROS	5.5588	3.2068	16	31	8	20		0.7097	0.4839	0.1509	0.0645
CFECUR	5.7103	2.1163	13	16	5	7		0.3125	0.5000	0.1908	0.1875
CFEINC	5.4358	2.4844	12	19	6	12	0.1053	0.4211	0.3158	0.1967	
CFSLCH	6.5697	2.4543	21	29	13	19	0.0690	0.2759	0.6207	0.1359	0.0690
CFSLIN	7.0517	2.0260	22	24	12	13	0.0417	0.3333	0.5000	0.1392	0.2083
CGBRID	5.7369	3.5484	13	21	8	14	0.0476	0.2857	0.6667	0.1917	0.4762
CGCPAS	5.9460	2.5427	14	18	7	10	0.1111	0.2222	0.6667	0.1845	0.4444
CGROAD	4.9606	2.3263	11	13	4	5		0.3077	0.6923	0.1959	0.3846
CGTRHE	6.2758	2.3263	16	19	4	5		0.1053	0.5789	0.1703	0.7368
CHNEER	5.1395	3.6715	13	24	8	19	0.0833	0.5000	0.2500	0.1717	
CHSACH	5.5975	2.7411	16	33	6	18	0.1818	0.4848	0.3333	0.1519	
CHSAFO	4.6452	1.0953	10	21	3	8	0.0952	0.1429	0.3333	0.2017	0.0476
CHSARR	5.1773	2.4559	15	31	6	20	0.0968	0.1935	0.1613	0.1499	
CHTREE	5.9604	1.4823	14	17	5	5		0.2941	0.4706	0.1849	0.1765
CHWWBW	5.7290	3.4291	20	49	11	31	0.2245	0.4490	0.2653	0.1244	0.0204
CHWWEM	6.1141	3.8593	20	42	10	27	0.0238	0.4524	0.3333	0.1328	0.0714
CHWWFO	6.3366	3.8744	20	44	9	23	0.1364	0.0455	0.4773	0.1376	0.1136
CVABBW	5.7726	2.7931	13	17	5	8		0.1176	0.4118	0.1928	0.3529

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
CVABCT	6.4023	3.2257	17	21	7	9	0.1429	0.2381	0.4286	0.1636	0.2381
CVTIMB	5.0676	3.1269	10	17	6	12	0.0588	0.5294	0.2941	0.2201	0.1176
DSPICN	5.3866	0.7980	11	16	2	2	0.1250	0.2500	0.7500	0.2127	0.2500
DSROAR	5.1866	2.1043	12	14	6	7	0.0714	0.3571	0.4286	0.1877	0.2143
DSWILD	5.6206	0.7980	12	14	2	2		0.1429	0.5714	0.2034	0.3571
EPCMEM	4.7716	1.9095	16	38	7	27	0.0263	0.6579	0.1842	0.1295	
EPCMFO	5.4796	1.7661	14	25	5	10	0.2000	0.2400	0.3200	0.1700	0.0800
EPDMFO	5.3040	0.7980	11	15	2	2	0.0667	0.2667	0.6000	0.2094	
EPDMPU	4.0704	0.0000	7	11	1	1	0.0909	0.3636	0.6364	0.2525	
EPKYVE	6.2875	3.9622	20	42	10	26	0.0238	0.4048	0.2381	0.1365	
EPRRXC	5.3066	0.7980	11	14	2	2	0.2143	0.2143	0.4286	0.2095	0.2143
EPSHEM	6.0125	3.1269	15	26	7	12	0.0769	0.3846	0.4231	0.1741	0.0769
EPSHSS	6.4082	4.1666	18	30	7	14		0.4667	0.3667	0.1546	0.1333
GBBARN	5.6473	3.5547	14	24	8	16	0.0417	0.4583	0.2917	0.1752	0.0833
GBHOEF	4.9345	2.8995	15	44	8	35	0.0227	0.2955	0.2273	0.1429	
GBJENK	4.4251	3.5047	12	39	8	33	0.1026	0.2821	0.1795	0.1602	
GBMAPL	5.8130	2.7237	14	19	6	10		0.4737	0.5789	0.1803	0.1579
GBNOFO	5.9539	2.8088	17	26	9	17	0.0769	0.5385	0.3077	0.1521	0.0385

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
GBNOSS	5.4664	3.8054	14	26	8	19		0.5769	0.1538	0.1696	0.0385
GBPLOT	4.8744	3.7750	14	38	9	33	0.0263	0.3158	0.1579	0.1512	0.0263
HCBEAV	6.4735	1.7805	18	26	8	13	0.0769	0.3077	0.3846	0.1562	0.0769
HCMITI	6.2877	2.6475	19	30	11	21	0.0333	0.4000	0.3333	0.1437	0.0333
HCPIPE	5.3695	3.1743	15	35	7	23	0.0571	0.6000	0.2571	0.1555	
HCRANG	5.4835	3.5505	13	28	6	16	0.0714	0.6429	0.4286	0.1832	
HIBRID	5.8540	3.6517	16	32	6	18	0.1250	0.4063	0.5313	0.1589	
HIGATE	6.7857	2.2348	20	24	10	13	0.0417	0.3333	0.5000	0.1474	0.0417
HIJHPK	6.5523	1.4823	20	24	6	5	0.0833	0.1250	0.5833	0.1423	0.1250
HIJHTU	6.1929	1.8016	16	21	9	10	0.0476	0.3810	0.4762	0.1681	0.1429
HIPENC	5.4355	1.9103	17	32	8	22		0.4063	0.2500	0.1389	0.1250
HISEWG	5.8239	1.8336	15	21	3	7		0.0476	0.5238	0.1686	0.2381
HITRLR	5.7710	2.1640	17	27	9	17	0.0370	0.5185	0.2963	0.1474	
MCFOUR	5.8315	3.5067	14	21	5	9	0.0952	0.3333	0.4286	0.1809	0.0952
MCMEME	5.3255	4.1767	14	47	9	38	0.0851	0.2979	0.3191	0.1652	
MCMFOR	6.6081	4.5852	20	32	8	15	0.0938	0.2188	0.3125	0.1435	0.0625
MCNPFO	6.0767	1.5960	14	14	4	4		0.4286	0.4286	0.1885	0.1429
MCPOND	6.2355	2.0628	15	15	6	6	0.0667	0.4000	0.3333	0.1805	0.0667

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
MCPOST	6.0047	2.4313	15	23	8	11	0.2609	0.3043	0.4348	0.1739	0.0435
MCTELE	6.0397	2.7371	15	20	6	9	0.2000	0.4500	0.2500	0.1749	0.0500
ME5092	4.9492	3.5631	10	21	7	18		0.7143	0.3810	0.2149	
MESCOX	6.3971	2.7109	18	26	11	17		0.3846	0.4231	0.1543	0.0385
MESCRO	5.3341	2.4513	14	31	11	26		0.6452	0.2903	0.1655	
MESCUP	5.9922	2.6332	15	22	7	10	0.1364	0.2727	0.3182	0.1735	
MESIGN	5.6795	3.0139	13	21	7	13		0.4762	0.2857	0.1897	
MESILV	5.5375	3.1861	15	29	9	23		0.6552	0.2759	0.1603	0.0690
METETR	4.0320	2.4995	8	22	6	18		0.4545	0.0909	0.2189	
MEWOLF	5.5109	2.5216	14	25	9	20		0.6400	0.2800	0.1710	0.0400
MRBESS	5.9098	2.1163	14	16	5	7	0.0625	0.3750	0.5625	0.1833	0.2500
MRFARM	5.8764	2.0439	14	19	6	8		0.6316	0.4211	0.1823	
MRFORE	5.5971	2.3263	12	15	4	5	0.0667	0.4667	0.5333	0.2026	0.2000
MRSSSS	5.7017	2.2184	13	18	5	6	0.0556	0.3333	0.4444	0.1905	0.1667
MRWEST	5.9604	1.5960	14	17	3	4		0.2353	0.5882	0.1849	0.1176
MU55SS	5.7686	2.4313	13	18	7	11		0.5556	0.1667	0.1927	0.0556
MUDBOA	5.6206	2.0628	12	14	6	6		0.1429	0.6429	0.2034	0.5000
MUDEND	7.3492	2.9398	28	44	13	25	0.0455	0.1818	0.4773	0.1140	0.1364

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
MUDRIC	6.4780	2.2235	17	18	5	5		0.1667	0.5000	0.1655	0.5000
MUDRIP	7.2440	2.7498	27	39	14	22	0.0256	0.4359	0.4103	0.1165	0.1026
MUDTRA	6.7996	3.5908	21	31	12	20		0.4839	0.3871	0.1406	0.0645
MUEPAH	6.1921	2.9083	16	22	8	14		0.4091	0.2273	0.1681	
MUMINE	6.2595	1.8016	16	20	7	10	0.0500	0.2500	0.6000	0.1699	0.2000
MUPOWR	5.9523	3.1634	15	23	7	10	0.1304	0.2609	0.6522	0.1723	0.0870
MUPULL	6.4078	4.0010	19	31	12	22	0.0323	0.5806	0.5161	0.1465	0.1290
MUVBRD	6.0841	3.5024	19	32	12	25	0.0313	0.4375	0.4063	0.1391	0.0313
MUVCRN	5.2752	3.6245	13	31	9	26		0.5161	0.3226	0.1762	
OHHSFO	5.5861	2.2184	12	16	5	6		0.3125	0.3750	0.2022	0.1250
OHINNS	6.2610	2.8808	18	29	9	17		0.3103	0.4138	0.1511	0.1034
OHKMRT	4.7930	2.5146	11	25	7	18		0.6000	0.3600	0.1892	0.0800
PA29TH	6.0637	3.9133	22	64	12	29	0.0313	0.2813	0.5781	0.1197	
PA83CR	6.2117	2.1043	17	26	6	7	0.2692	0.2692	0.5385	0.1587	0.0769
PAFAMD	7.1560	2.5439	27	51	12	26	0.0196	0.2157	0.4118	0.1151	0.0392
PAJCPY	6.9524	2.8634	26	51	14	26		0.1765	0.4510	0.1161	0.0980
PALOUD	6.9073	3.0155	22	32	12	17	0.1250	0.2813	0.5000	0.1364	0.0938
PAPEFO	6.0999	2.2184	15	20	5	6	0.1000	0.1500	0.4500	0.1766	0.1500

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
PAPEIM	3.8563	1.7775	10	29	5	19		0.5172	0.1034	0.1675	
PAPESW	6.9069	3.0518	24	40	12	20	0.0250	0.2750	0.5000	0.1250	0.1000
PAWILL	5.7759	3.2649	17	41	8	24	0.0976	0.3902	0.1463	0.1476	
PCBLUE	6.2626	2.5384	17	25	7	14	0.1200	0.5200	0.3200	0.1600	
PCLPFO	5.2678	2.3940	12	19	4	4		0.1579	0.7368	0.1906	0.2105
PCROAD	6.1046	2.8098	16	28	8	15	0.1071	0.4643	0.5000	0.1657	
PEMIDW	6.3372	2.5335	17	22	8	11		0.4091	0.4091	0.1619	0.1364
PERDDP	4.7101	2.4143	11	28	6	20		0.5357	0.2857	0.1860	0.0357
PETHUM	6.3007	1.8939	16	18	8	9		0.3333	0.3333	0.1710	0.1111
PETOSS	6.1116	2.8085	17	25	10	18		0.4000	0.3600	0.1561	0.0400
RIASIA	6.6584	1.1243	19	35	9	18	0.0857	0.3429	0.4000	0.1522	
RIBRID	7.0444	2.4843	23	31	12	15		0.3226	0.4839	0.1330	0.1290
RIEAST	6.3346	2.5596	17	23	8	13		0.1739	0.5217	0.1618	0.1739
SJBOAT	5.8115	3.1785	14	22	8	14		0.2727	0.6364	0.1803	0.2727
SJBRID	5.3902	2.7428	12	23	5	13	0.0870	0.4783	0.2174	0.1951	
SJCHUR	6.4126	3.6961	19	29	14	24	0.0345	0.4138	0.4138	0.1466	0.0690
SJGLAD	6.5370	1.6412	18	22	9	12		0.3636	0.5000	0.1577	0.2727
SJMUDL	6.9187	1.7176	21	24	9	11	0.0417	0.3333	0.4583	0.1431	0.1250

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
SJPLOT	6.2939	2.7023	17	25	9	14	0.0400	0.3600	0.4400	0.1608	0.0800
SJTELE	5.8764	3.2472	14	19	6	11	0.0526	0.2632	0.3684	0.1823	0.2632
SMDTSS	5.8873	3.4185	15	24	6	14		0.3750	0.5000	0.1705	0.1250
SMFOFL	6.5543	2.5427	18	21	7	10		0.2857	0.7619	0.1581	0.3333
SMLPEM	6.0434	3.5347	18	33	11	25		0.3939	0.1818	0.1458	0.0606
SMSEFL	5.8760	4.1135	16	37	10	27	0.1081	0.2703	0.3514	0.1595	0.0541
SMSTEM	5.5971	2.4313	12	15	9	11		0.3333	0.5333	0.2026	0.2000
TRSPFO	6.1233	1.3752	15	18	6	6	0.1111	0.1667	0.3889	0.1773	0.1667
TRSPRI	6.5548	3.2022	21	31	9	18		0.3871	0.4839	0.1356	0.0645
TVFARM	4.6311	2.4553	10	20	5	13	0.0500	0.5000	0.1000	0.2011	
TVISLE	6.3365	3.0729	17	24	7	10	0.2083	0.2917	0.2917	0.1619	0.0417
TVNEWT	5.6855	2.7341	20	49	14	40	0.0204	0.5714	0.1837	0.1235	
TVPOUT	5.9794	2.4222	15	20	8	10	0.0500	0.5000	0.3500	0.1731	0.1500
TVVBEM	2.4881	1.3035	5	15	3	12		0.8667	0.2667	0.2161	
TVVBIM	5.4401	3.6789	13	22	7	16		0.6364	0.3182	0.1817	0.0455
TVVBRV	5.9108	3.7141	15	25	7	12	0.1600	0.2800	0.5200	0.1711	0.0800
TVVBSS	6.4884	3.9456	21	40	14	31		0.4000	0.4000	0.1342	0.0250
UDC001	5.1007	1.9685	11	26	5	15	0.1923	0.4231	0.3462	0.2014	

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
UDC002	5.8615	3.2390	14	28	9	18	0.1071	0.4286	0.4643	0.1818	
UDC003	5.1012	3.7756	11	21	6	15		0.3810	0.1905	0.2014	
UDC004	5.0912	3.3744	10	15	6	10		0.5333	0.4667	0.2211	
UDC005	3.6258	2.0569	7	16	4	13	0.0625	0.4375	0.0625	0.2250	
UDC007	4.9237	1.5851	9	12	4	5	0.0833	0.3333		0.2376	0.0833
UDC008	5.5883	2.6584	13	23	6	14	0.1739	0.5217	0.2609	0.1867	
UDC012	6.3031	3.8587	19	37	9	20	0.0541	0.4324	0.4595	0.1441	
UDC013	5.5140	1.6864	12	17	3	6	0.1176	0.3529	0.2941	0.1996	0.2353
UDC014	5.3066	2.7564	11	14	5	7	0.1429	0.4286	0.4286	0.2095	0.1429
UDC015	5.2579	3.4933	16	42	5	12	0.4048	0.2857	0.6429	0.1427	0.0238
UDC016	6.2035	3.1450	16	24	7	11	0.1250	0.2917	0.2500	0.1684	0.0417
UDC017	6.0385	3.8490	16	25	6	13	0.1200	0.3600	0.2000	0.1639	
UDC018	5.3553	3.4405	12	24	7	16	0.0417	0.4167	0.2500	0.1938	
UDC019	5.3060	3.6285	12	26	7	19	0.0769	0.6923	0.0769	0.1920	
UDC020	5.3445	3.3067	13	35	8	21	0.2000	0.3143	0.3429	0.1785	
VEPCON	4.8270	3.1688	10	16	6	12	0.0625	0.5000	0.1250	0.2096	
VEPCOS	4.6508	2.2884	8	11	4	7	0.1818	0.3636	0.1818	0.2525	0.0909
WBBARN	5.9759	3.9774	18	46	10	33	0.0652	0.2609	0.2174	0.1442	

Appendix D. Part 2 continued.

Site Code	Diversity	Wetland spp. Diversity	Richness	Abundance	Wetland spp. Richness	Wetland spp. abundance	Nest predator, Brood parasite	Shrub nesting	Single Brood	Shannon's Evenness index	Forest area Sensitive
WBCORN	5.0471	3.1721	11	31	5	18		0.3871	0.0968	0.1993	
WBROAD	4.0845	1.6185	9	27	3	16		0.5185	0.0370	0.1971	
WYBEAV	6.5985	2.0260	19	27	10	13	0.0370	0.4444	0.7037	0.1508	0.0741
WYCHWE	5.5244	2.5427	12	18	7	10		0.2778	0.6667	0.1999	0.3889
WYHCEA	5.8764	3.1269	14	19	8	12	0.0526	0.5263	0.5789	0.1823	0.2105
WYINTR	5.5861	2.2184	12	16	5	6	0.0625	0.4375	0.4375	0.2022	
WYTHOR	5.9850	2.4179	16	22	8	13	0.0909	0.4545	0.2273	0.1625	0.0455

Appendix E. Avian community sampling summary statistics of metric scores statewide and by ecoregion used to form avian wetland indices of biological integrity (AW-IBI) for wetlands in West Virginia, USA 2005-2006.

Statewide Avian Sampling (N=151)

	WET ABUNDANCE	PCTCB NEOTROP	PCTCBHAB SPEC	PCTCB NEOHABS	PCTOB FORESTS	PCTCBRES EDGE	BIRD DIVERSITY	CBPCT CARNHAB	PCTOB SINGLE
Minimum	1	0.048	0	0	0	0.048	2.488	0	0
Maximum	40	0.714	0.714	0.568	0.737	0.875	7.349	0.619	0.762
Mean	14.848	0.295	0.269	0.167	0.098	0.491	5.767	0.178	0.389
Std. Error	0.643	0.013	0.012	0.01	0.01	0.015	0.06	0.009	0.013

	PCTCB INSECTI	PCTCB OMNIVOR
Minimum	0.04	0.19
Maximum	0.786	0.875
Mean	0.349	0.522
Std. Error	0.012	0.01

Allegheny Highland Avian Sampling (N=65)

	WET ABUNDANCE	PCTCB NEOTROP	PCTCBHAB SPEC	PCTCB NEOHABS	PCTOB FORESTS	PCTCBRES EDGE	BIRD DIVERSITY	CBPCT CARNHAB	PCTOB SINGLE
Minimum	4	0.048	0	0	0	0.105	3.626	0	0
Maximum	26	0.684	0.714	0.526	0.737	0.875	7.052	0.619	0.704
Mean	13.046	0.301	0.254	0.17	0.107	0.484	5.676	0.17	0.399
Std. Error	0.717	0.019	0.018	0.015	0.018	0.021	0.076	0.014	0.021

	PCTCB INSECTI	PCTCB OMNIVOR
Minimum	0.04	0.19
Maximum	0.762	0.875
Mean	0.353	0.528
Std. Error	0.017	0.016

Appendix E. Continued.

Ridge and Valley Avian Sampling (N=27)

	WET ABUNDANCE	PCTCB NEOTROP	PCTCB HABSPEC	PCTCB NEOHABS	PCTOB FORESTS	PCTCB RESEDGE	BIRD DIVERSITY	CBPCT CARNHAB	PCTOB SINGLE
Minimum	1	0.067	0	0	0	0.048	2.488	0	0.037
Maximum	40	0.625	0.571	0.4	0.357	0.867	6.554	0.467	0.762
Mean	14.926	0.252	0.257	0.137	0.09	0.52	5.476	0.163	0.372
Std. Error	2.001	0.033	0.029	0.023	0.021	0.043	0.171	0.024	0.037

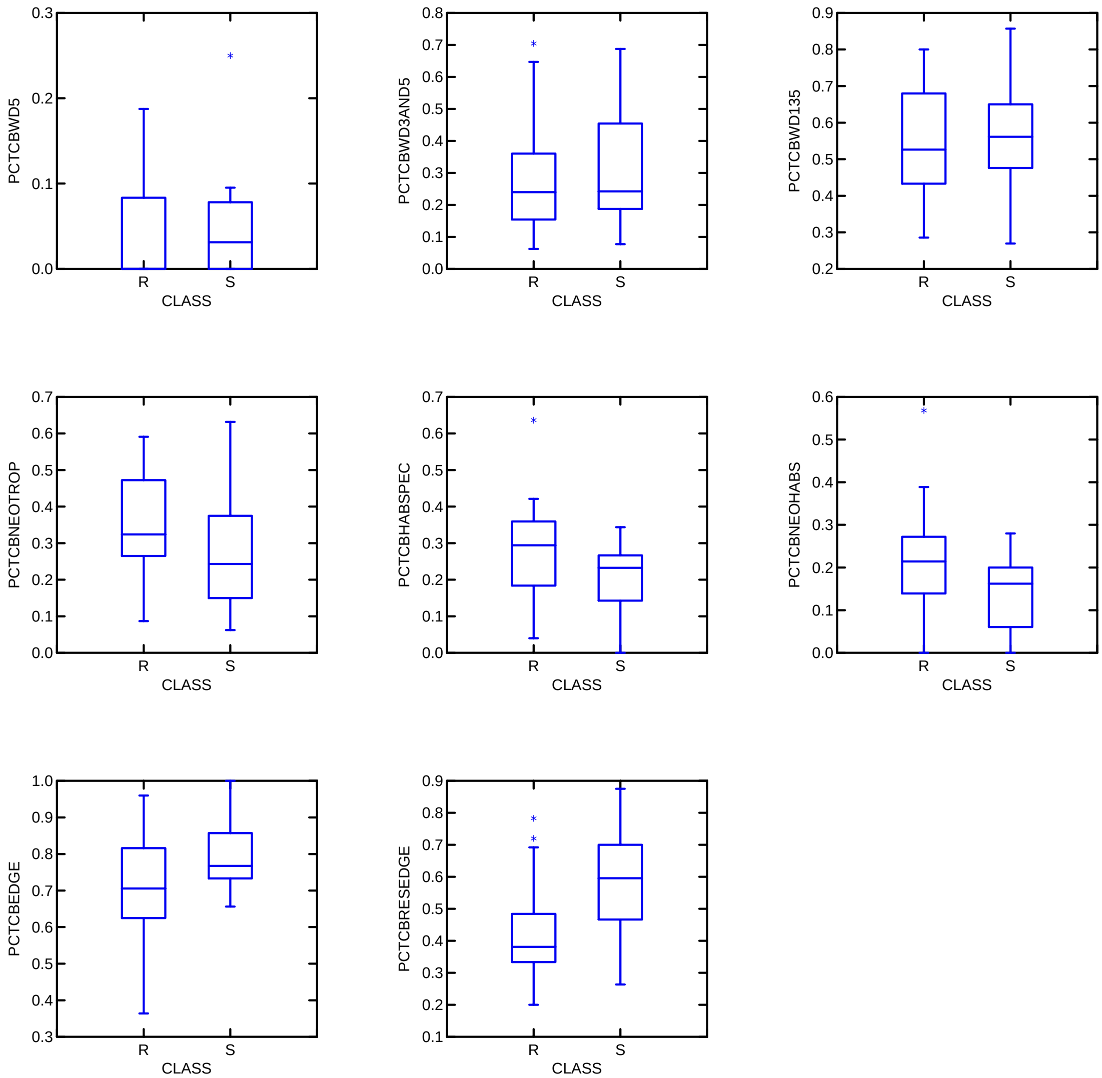
	PCTCB INSECTI	PCTCB OMNIVOR
Minimum	0.091	0.25
Maximum	0.733	0.852
Mean	0.343	0.508
Std. Error	0.032	0.028

Western Allegheny Plateau Avian Sampling (N=59)

	WET ABUNDANCE	PCTCB NEOTROP	PCTCB HABSPEC	PCTCB NEOHABS	PCTOB FORESTS	PCTCB RESEDGE	BIRD DIVERSITY	CBPCT CARNHAB	PCTOB SINGLE
Minimum	4	0.048	0.069	0	0	0.111	3.856	0.034	0.103
Maximum	38	0.714	0.636	0.568	0.5	0.857	7.349	0.571	0.737
Mean	16.797	0.308	0.292	0.177	0.091	0.484	6	0.193	0.386
Std. Error	1.08	0.022	0.017	0.016	0.014	0.022	0.094	0.014	0.017

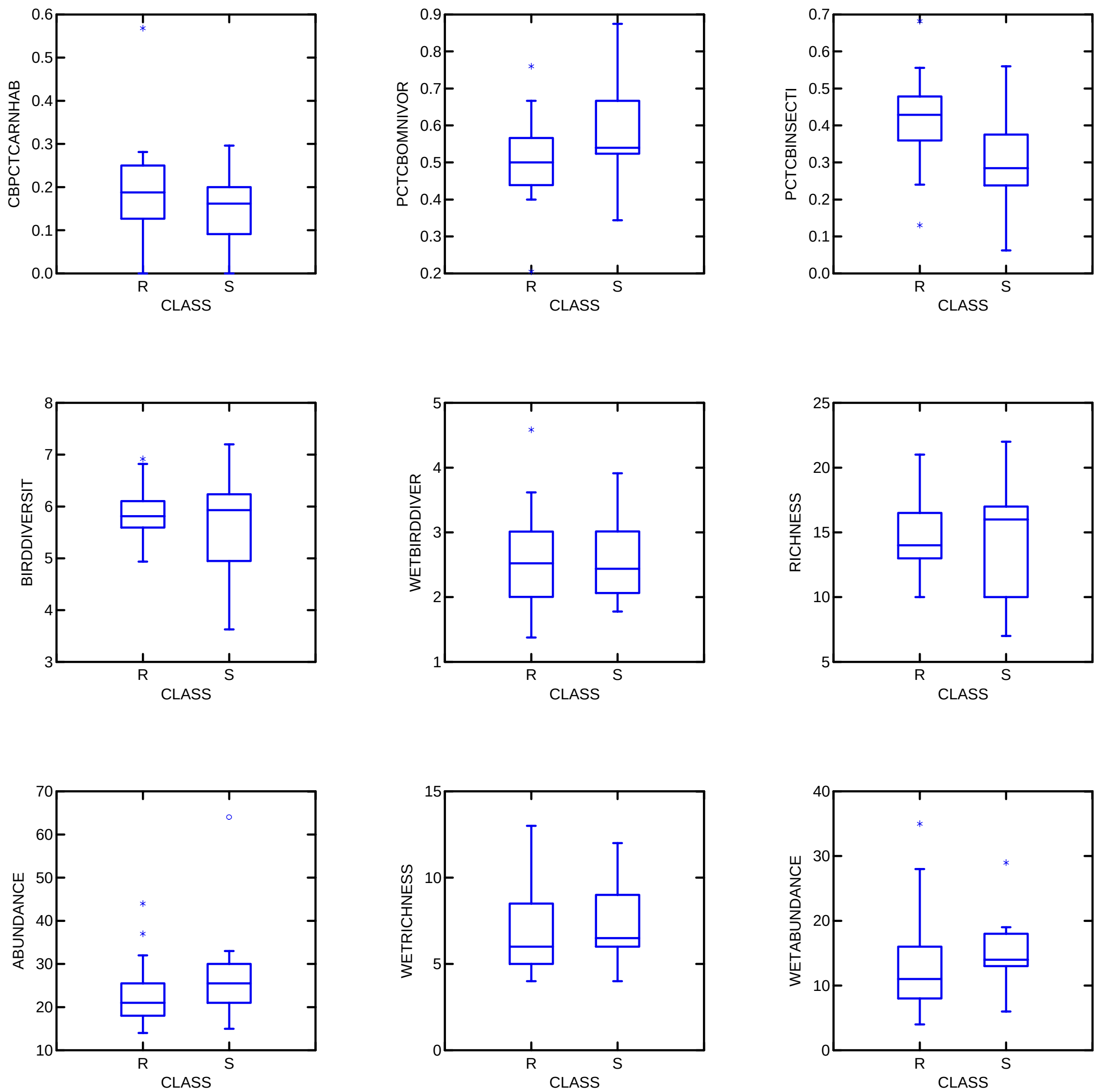
	PCTCB INSECTI	PCTCB OMNIVOR
Minimum	0.069	0.205
Maximum	0.786	0.762
Mean	0.348	0.521
Std. Error	0.019	0.016

Appendix F. Avian community metrics box-and-whisker resultsand narrative descriptions for depressional wetlands (N=37). Classifications are reference (R) and stressed (S).



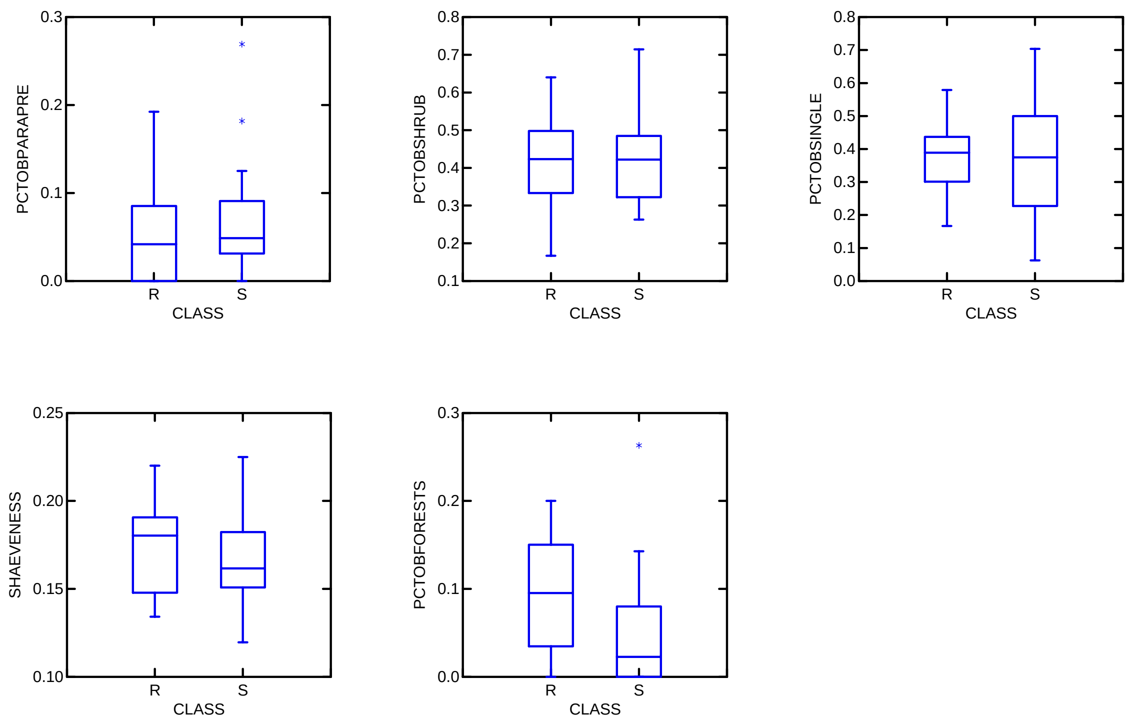
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	poor
PCTWD135	Proportion facultative wetland and above spp.	poor
PCTCBNEOTROP	Proportion neotropical migrants	fair
PCTCBHABSPEC	Proportion habitat specific spp.	fair
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	fair
PCTCBEDGE	Proportion edge spp.	fair
PCTCBRESEDGE	Proportion residential and edge spp.	good

Appendix F. Continued.



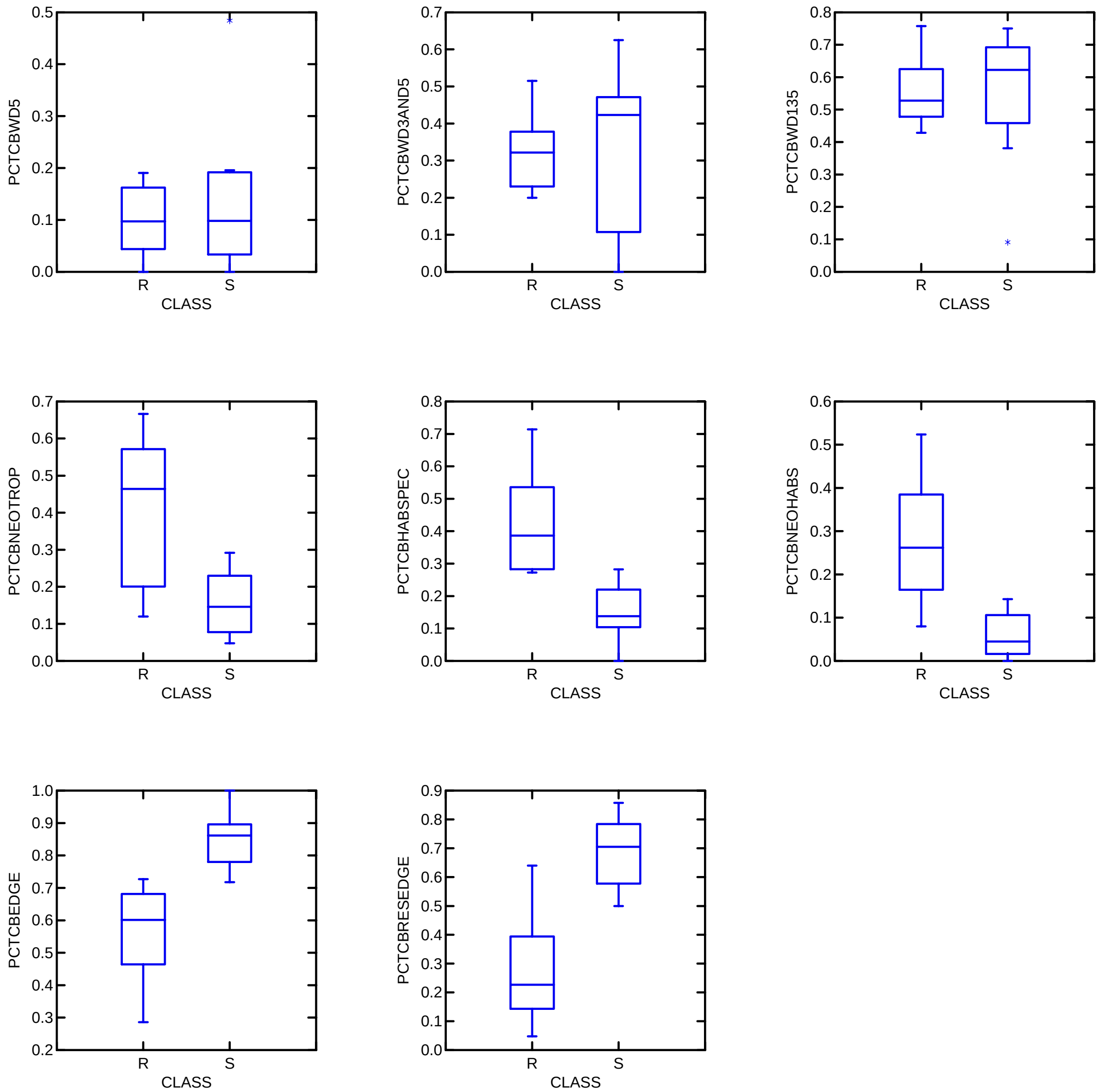
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	poor
PCTOMNIVOR	Proportion omnivorous spp.	fair
PCTINSECTI	Proportion insectivorous spp.	good
BIRDDIVERSIT	Shannon-Weaver diversity index	poor
WETBIRDDIVER	Wetland bird S-W diversity index	poor
RICHNESS	Richness (number of species)	poor
ABUNDANCE	Abundance (count of individuals)	fair
WETRICHNESS	Wetland bird richness	poor
WETABUNDANCE	Wetland bird abundance	fair

Appendix F. Continued.



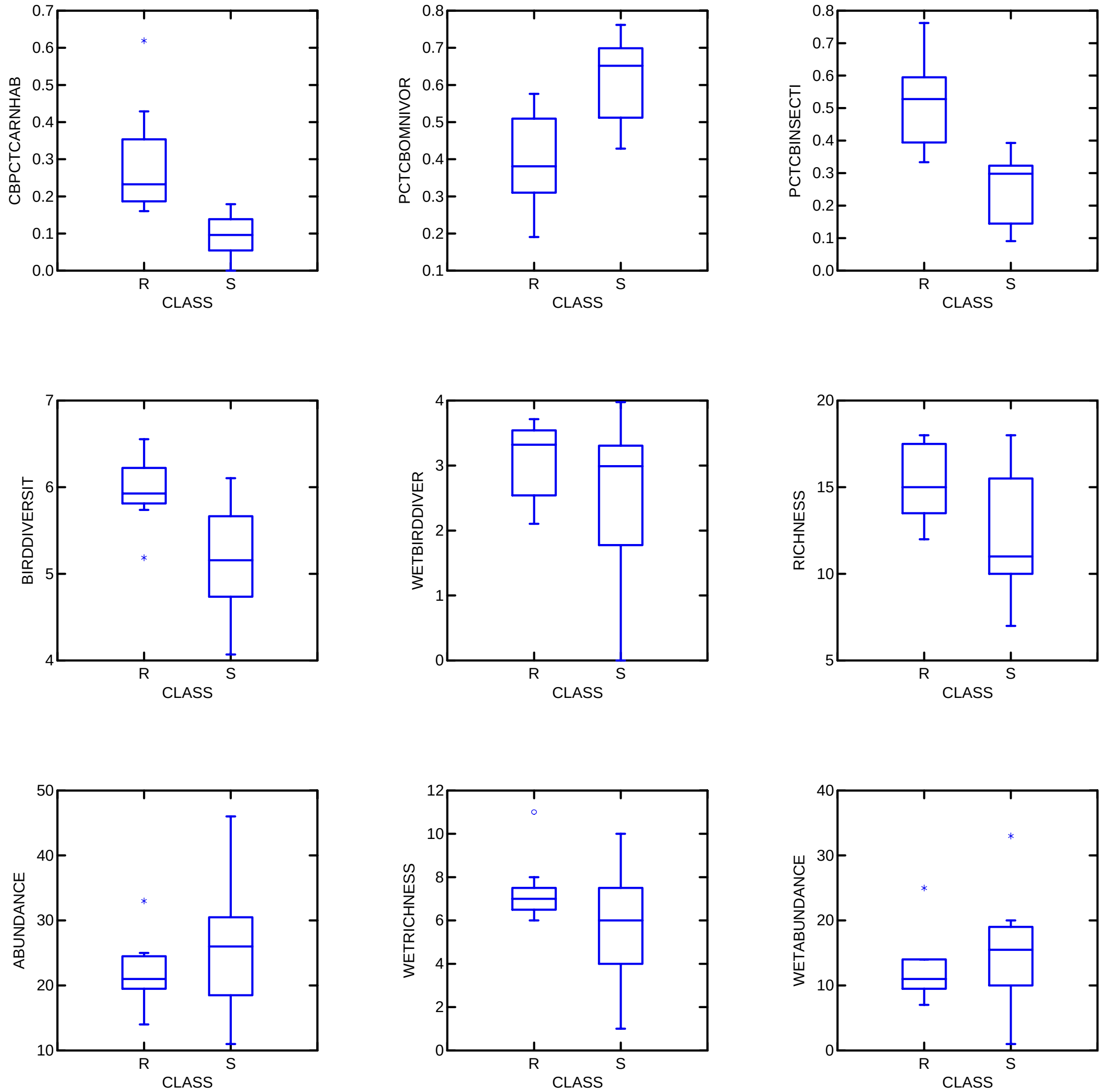
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	poor
PCTOBSINGLE	Proportion single brood spp.	poor
SHAEVENESS	Shannon evenness index	poor
PCTOBFORESTS	Proportion interior forest obligate spp.	fair

Appendix G. Avian community metrics box-and-whisker results and narrative descriptions for floodplain wetlands (N=19). Classifications are reference (R) and stressed (S).



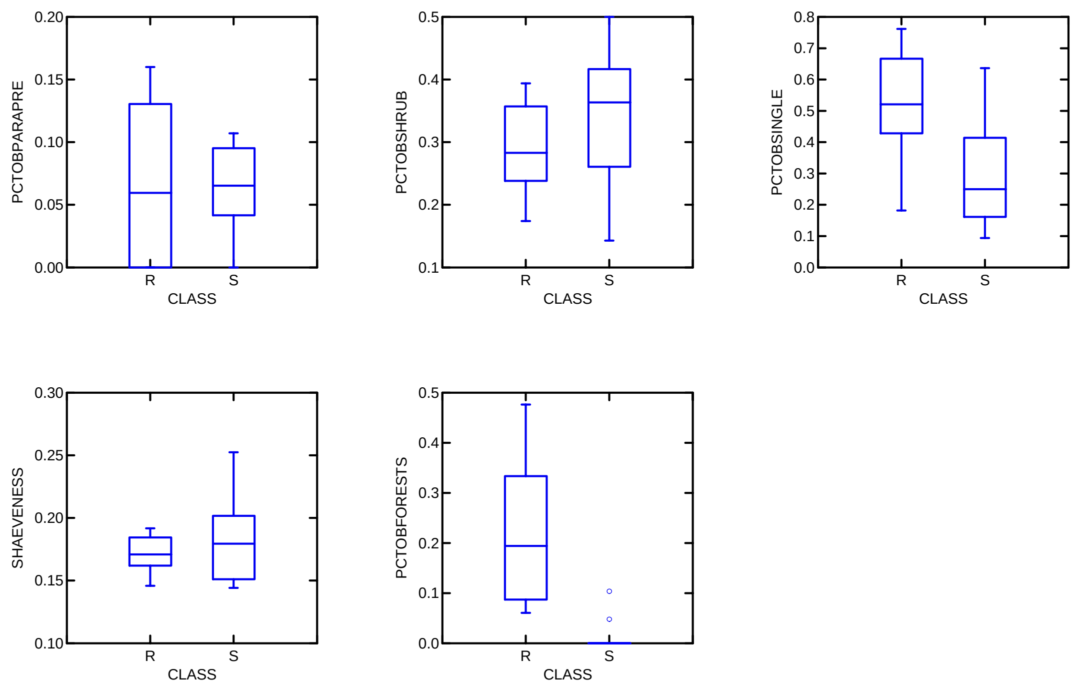
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	fair
PCTWD135	Proportion facultative wetland and above spp.	fair
PCTCBNEOTROP	Proportion neotropical migrants	good
PCTCBHABSPEC	Proportion habitat specific spp.	excellent
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	excellent
PCTCBEDGE	Proportion edge spp.	excellent
PCTCBRESEDGE	Proportion residential and edge spp.	excellent

Appendix G. Continued.



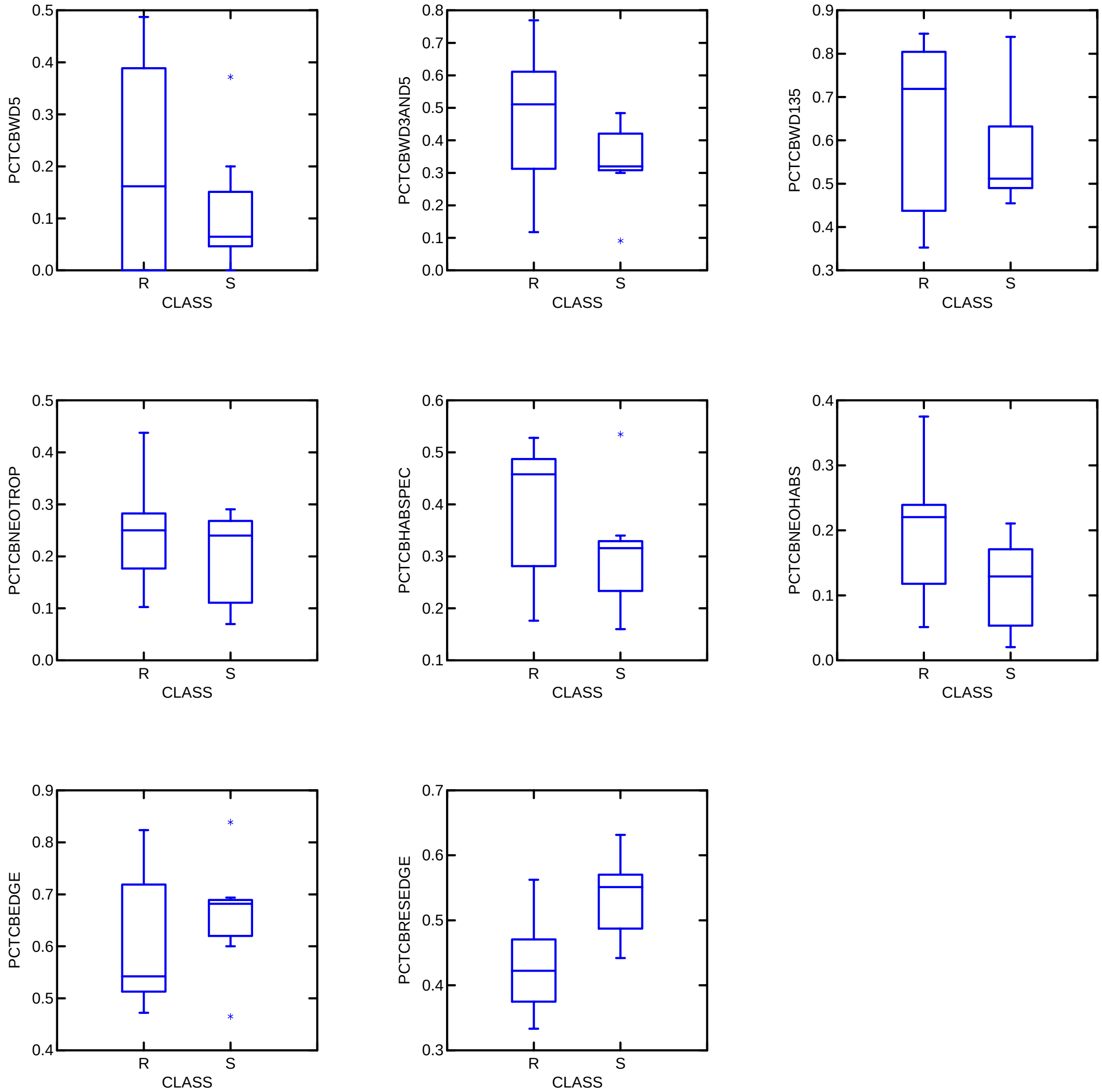
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	excellent
PCTOMNIVOR	Proportion omnivorous spp.	good
PCTINSECTI	Proportion insectivorous spp.	excellent
BIRDDIVERSIT	Shannon-Weaver diversity index	excellent
WETBIRDDIVER	Wetland bird S-W diversity index	fair
RICHNESS	Richness (number of species)	fair
ABUNDANCE	Abundance (count of individuals)	fair
WETRICHNESS	Wetland bird richness	fair
WETABUNDANCE	Wetland bird abundance	fair

Appendix G. Continued.



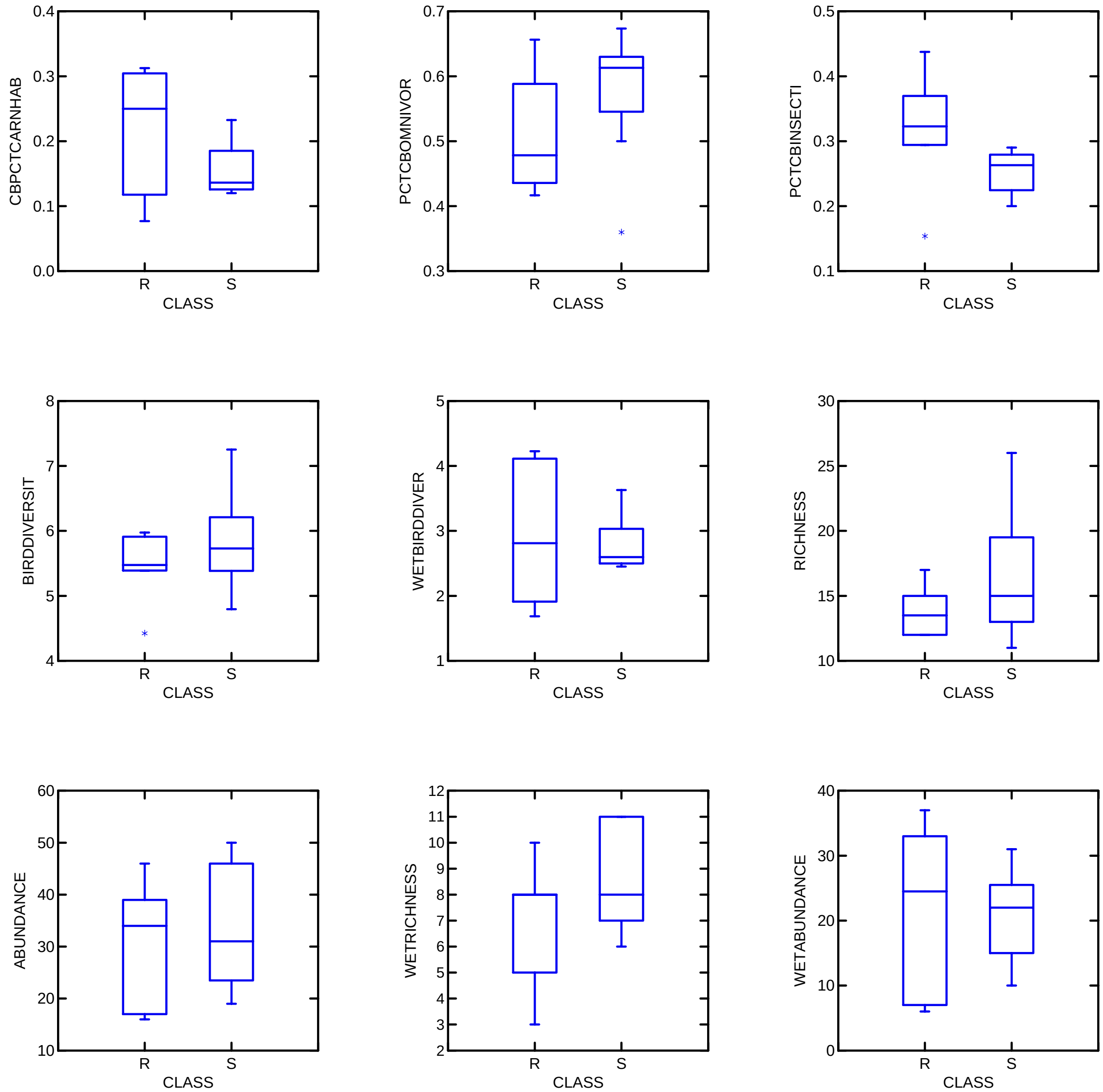
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	fair
PCTOBSINGLE	Proportion single brood spp.	excellent
SHAEVENESS	Shannon evenness index	poor
PCTOBFORESTS	Proportion interior forest obligate spp.	poor

Appendix H. Avian community metricsbox-and-whisker results and narrative for impoundment wetlands (N=13). Classifications are reference (R) and stressed (S).



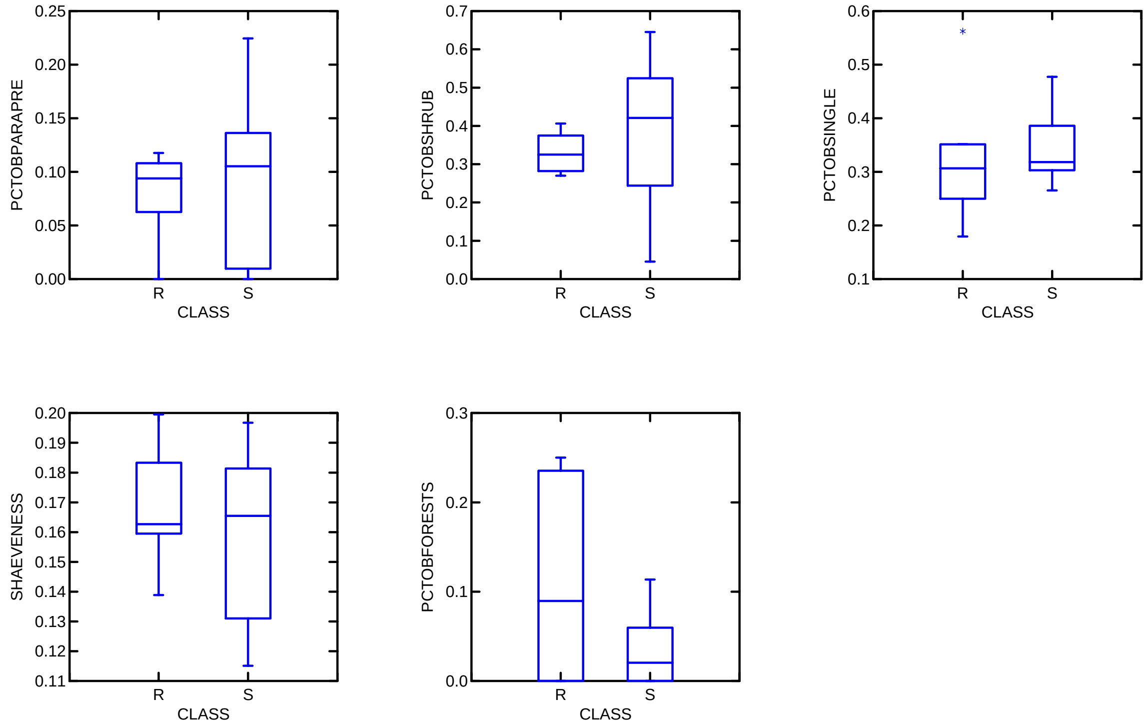
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	fair
PCTWD3AND5	Proportion wetland associated and dependent spp.	fair
PCTWD135	Proportion facultative wetland and above spp.	fair
PCTCBNEOTROP	Proportion neotropical migrants	fair
PCTCBHABSPEC	Proportion habitat specific spp.	fair
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	fair
PCTCBEDGE	Proportion edge spp.	fair
PCTCBRESEDGE	Proportion residential and edge spp.	excellent

Appendix H. Continued.



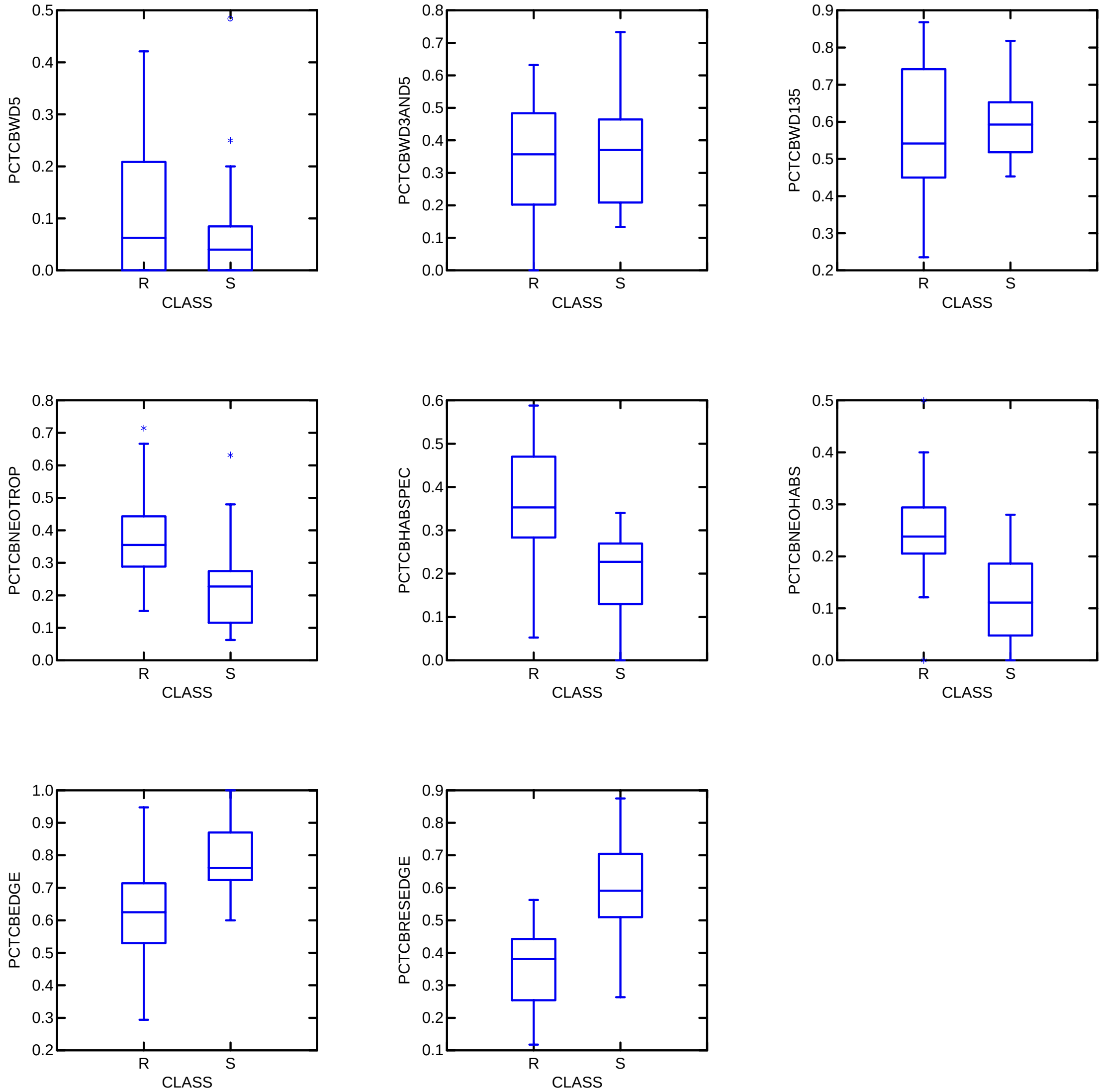
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	fair
PCTOMNIVOR	Proportion omnivorous spp.	good
PCTINSECTI	Proportion insectivorous spp.	exellent
BIRDDIVERSIT	Shannon-Weaver diversity index	poor
WETBIRDDIVER	Wetland bird S-W diversity index	poor
RICHNESS	Richness (number of species)	poor
ABUNDANCE	Abundance (count of individuals)	poor
WETRICHNESS	Wetland bird richness	fair
WETABUNDANCE	Wetland bird abundance	poor

Appendix H. Continued.



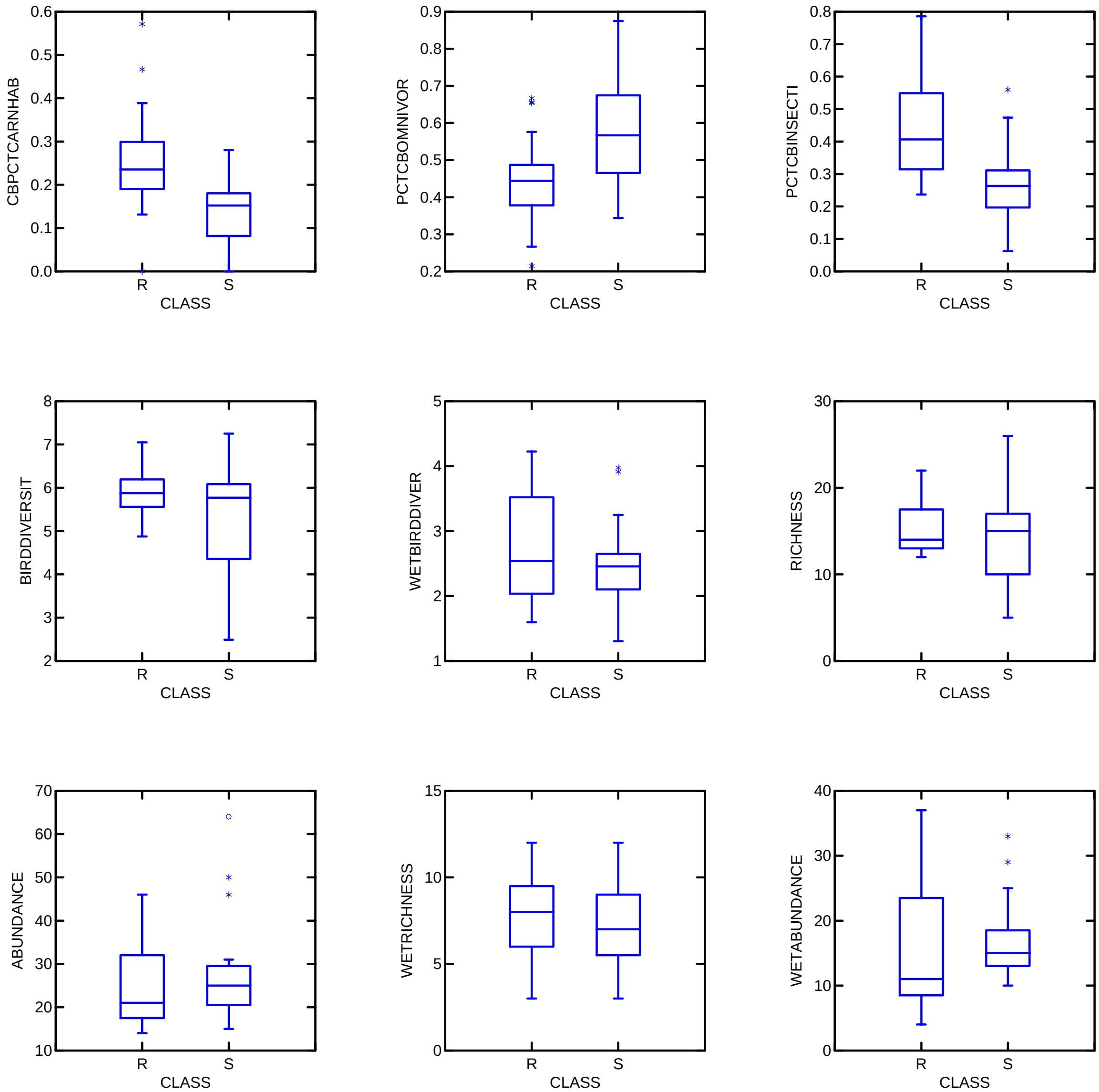
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	fair
PCTOBSINGLE	Proportion single brood spp.	poor
SHAEVENESS	Shannon evenness index	poor
PCTOBFORESTS	Proportion interior forest obligate spp.	poor

Appendix I. Avian community metricsbox-and-whisker results and narrative for emergent wetlands (N=38). Classifications are reference (R) and stressed (S).



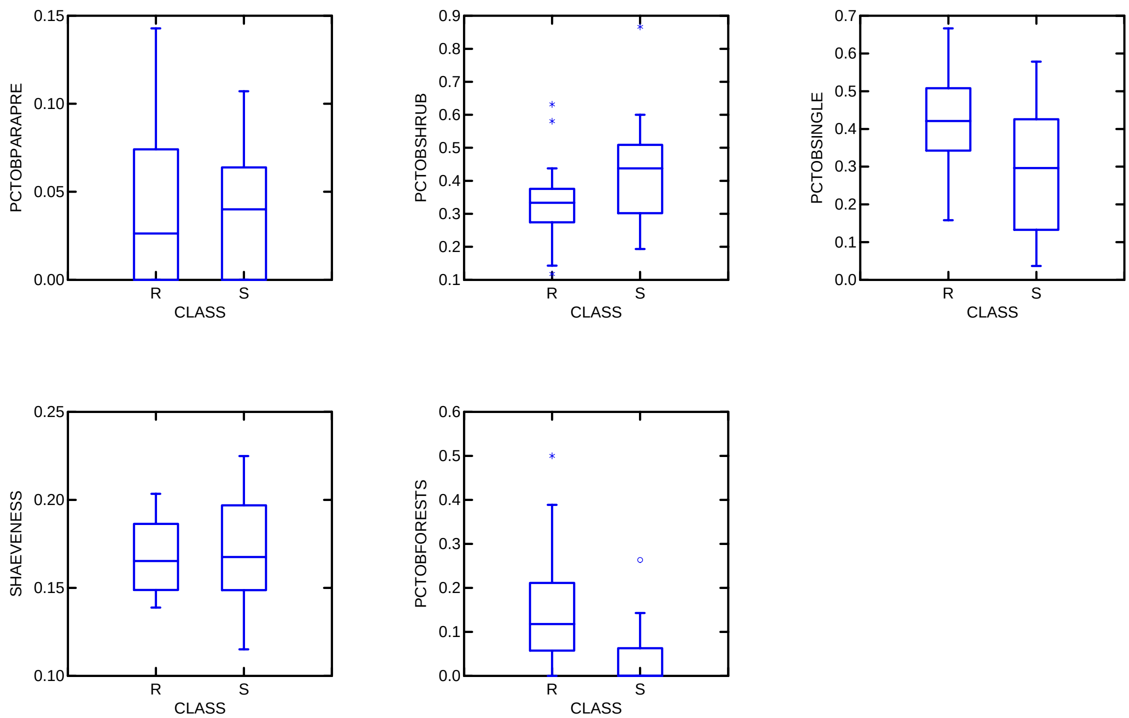
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	poor
PCTWD135	Proportion facultative wetland and above spp.	poor
PCTCBNEOTROP	Proportion neotropical migrants	excellent
PCTCBHABSPEC	Proportion habitat specific spp.	excellent
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	excellent
PCTCBEDGE	Proportion edge spp.	excellent
PCTCBRESEDGE	Proportion residential and edge spp.	excellent

Appendix I. Continued.



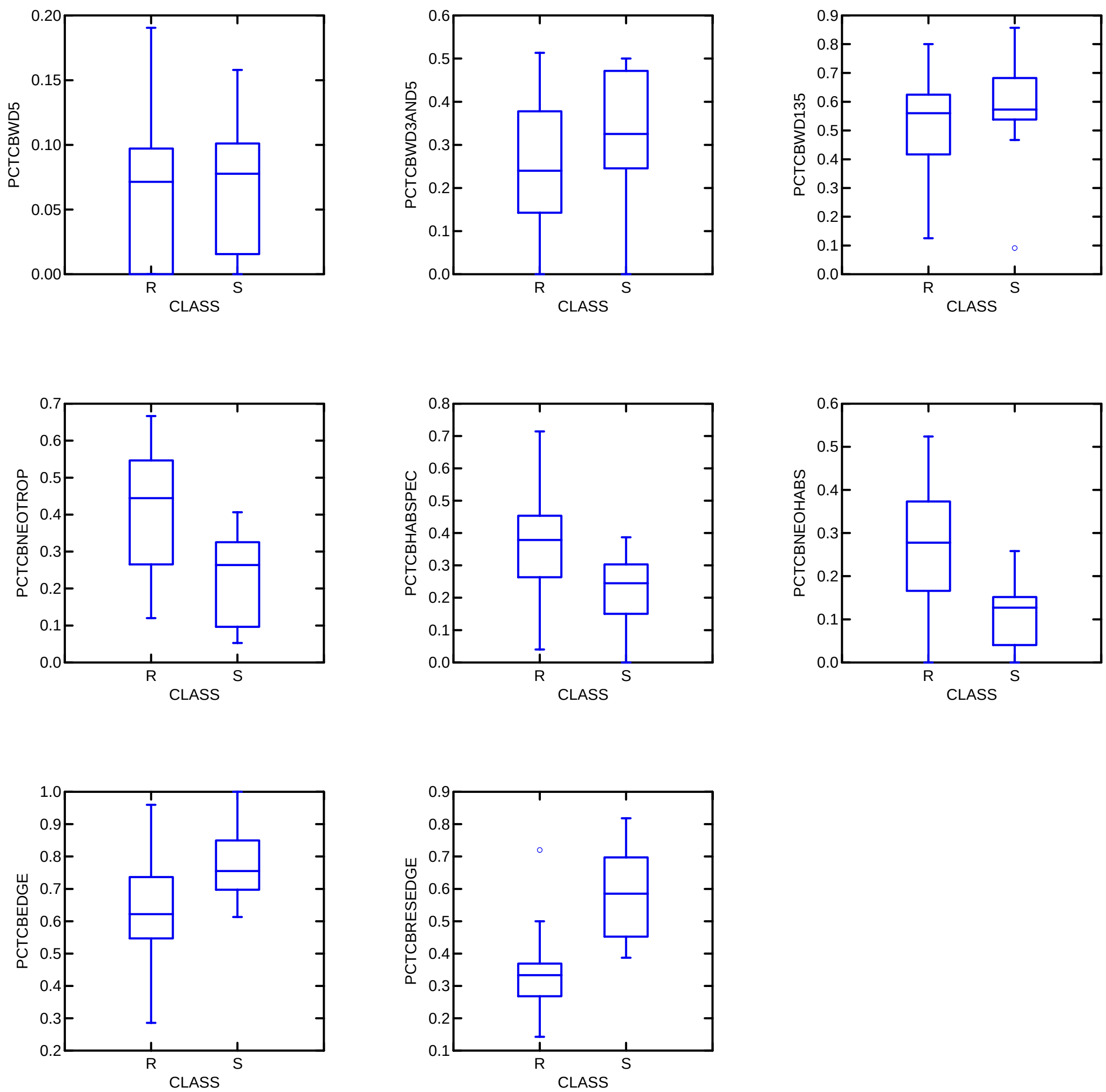
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	excellent
PCTOMNIVOR	Proportion omnivorous spp.	good
PCTINSECTI	Proportion insectivorous spp.	good
BIRDDIVERSIT	Shannon-Weaver diversity index	poor
WETBIRDDIVER	Wetland bird S-W diversity index	poor
RICHNESS	Richness (number of species)	poor
ABUNDANCE	Abundance (count of individuals)	poor
WETRICHNESS	Wetland bird richness	poor
WETABUNDANCE	Wetland bird abundance	fair

Appendix I. Continued.



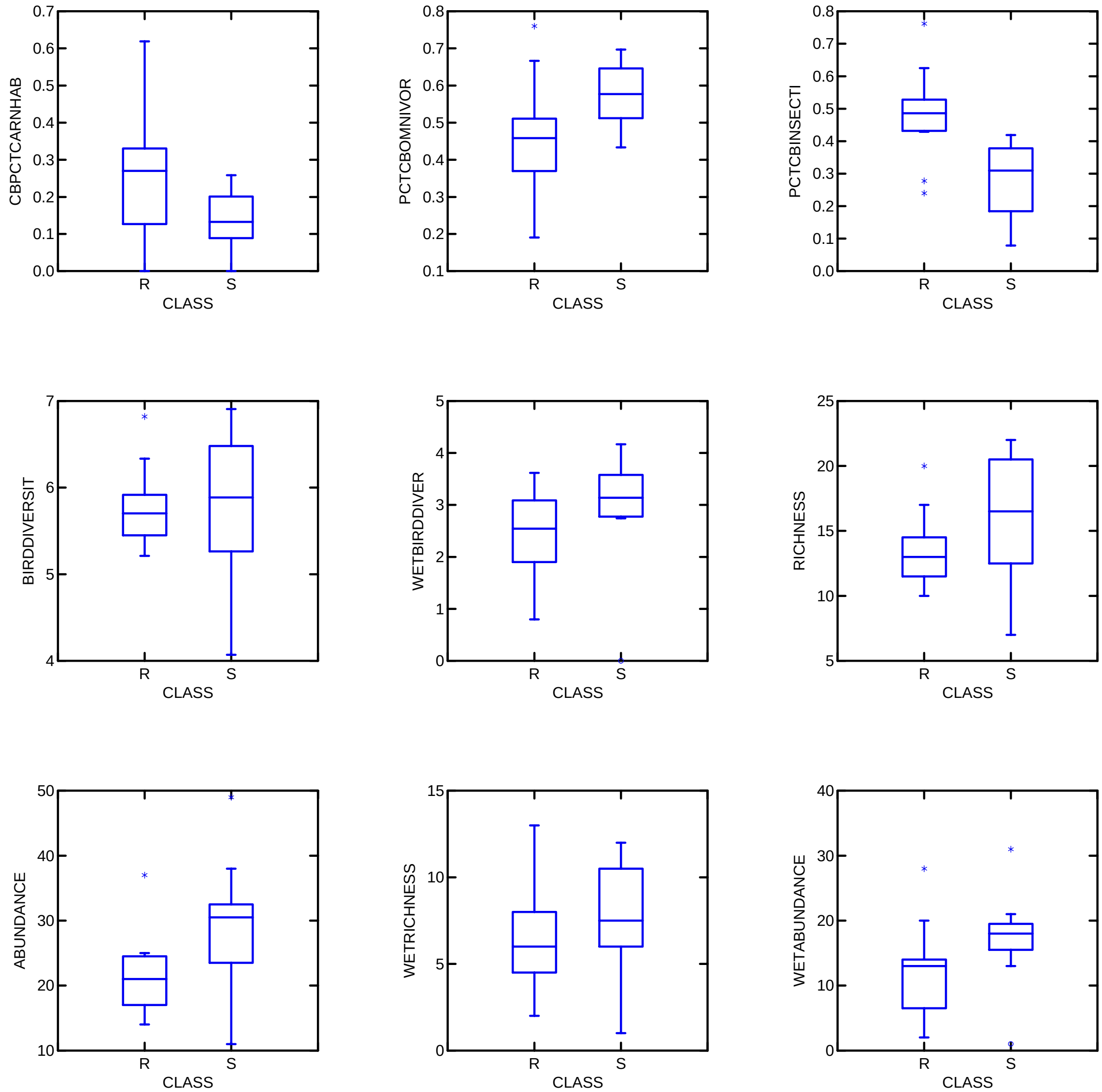
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	fair
PCTOBSINGLE	Proportion single brood spp.	good
SHAEVENESS	Shannon evenness index	poor
PCTOBFORESTS	Proportion interior forest obligate spp.	poor

Appendix J. Avian community metricsbox-and-whisker results and narrative for scrub-shrub wetlands (N=23). Classifications are reference (R) and stressed (S).



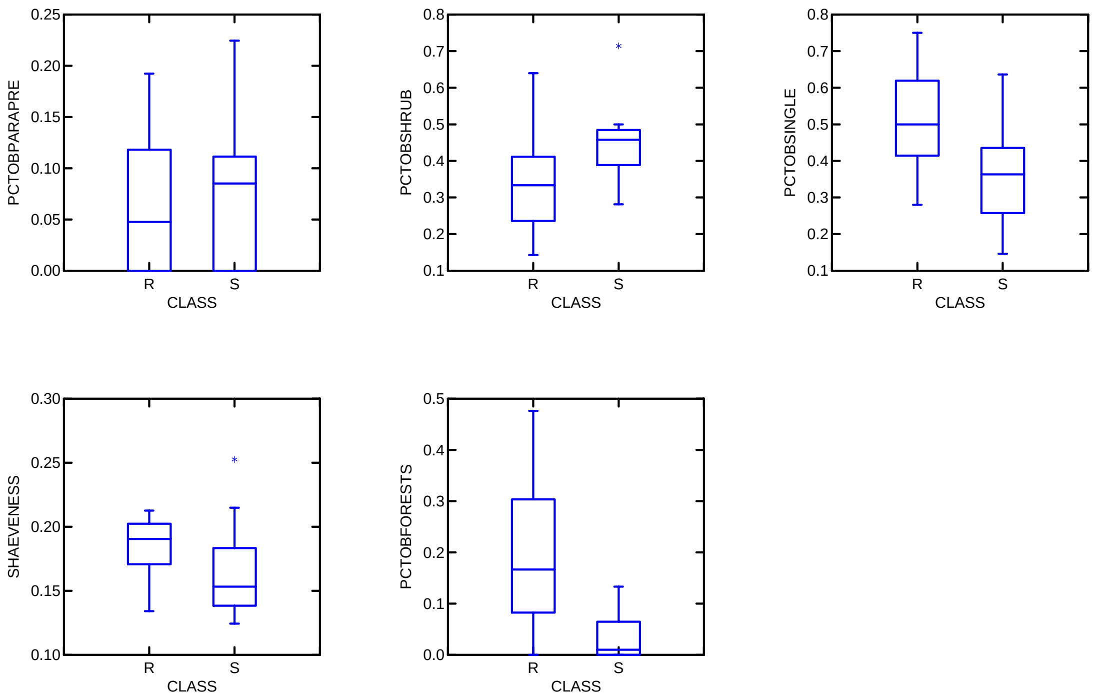
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	fair
PCTWD135	Proportion facultative wetland and above spp.	poor
PCTCBNEOTROP	Proportion neotropical migrants	fair
PCTCBHABSPEC	Proportion habitat specific spp.	good
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	good
PCTCBEDGE	Proportion edge spp.	good
PCTCBRESEDGE	Proportion residential and edge spp.	excellent

Appendix J. Continued.



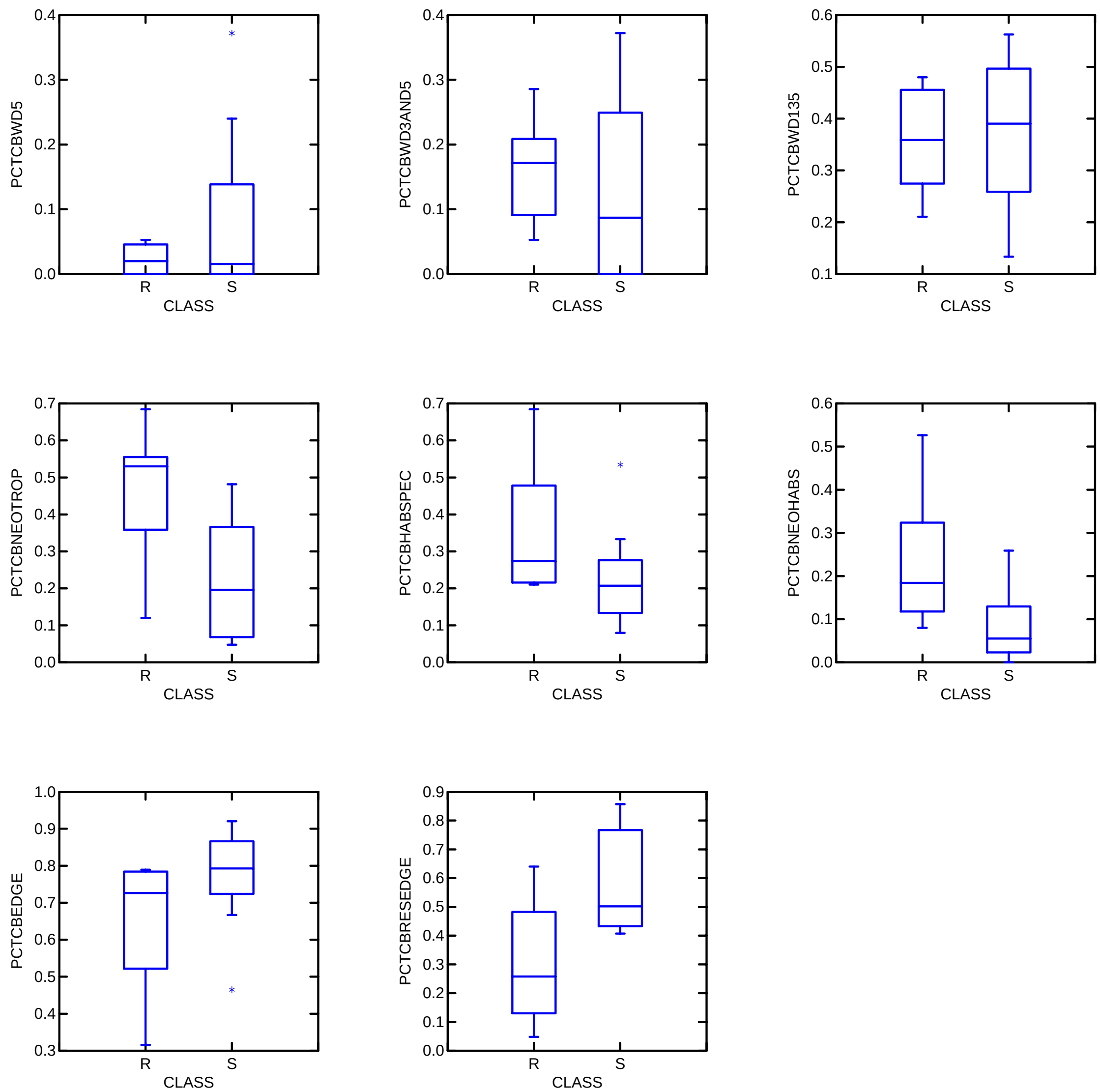
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	fair
PCTOMNIVOR	Proportion omnivorous spp.	good
PCTINSECTI	Proportion insectivorous spp.	excellent
BIRDDIVERSIT	Shannon-Weaver diversity index	poor
WETBIRDDIVER	Wetland bird S-W diversity index	fair
RICHNESS	Richness (number of species)	fair
ABUNDANCE	Abundance (count of individuals)	good
WETRICHNESS	Wetland bird richness	poor
WETABUNDANCE	Wetland bird abundance	excellent

Appendix J. Continued.



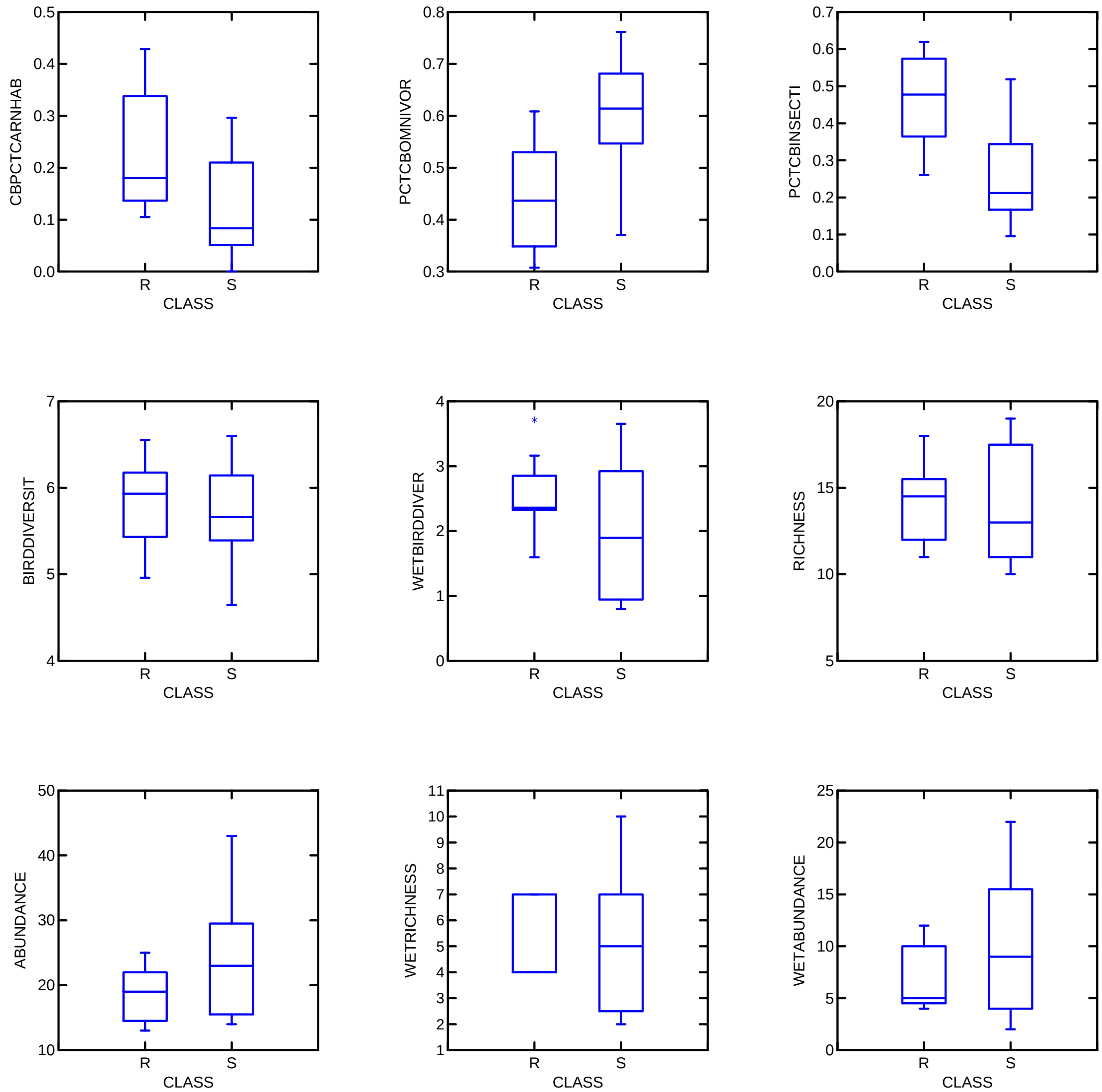
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	good
PCTOBSINGLE	Proportion single brood spp.	good
SHAEVENESS	Shannon evenness index	good
PCTOBFORESTS	Proportion interior forest obligate spp.	fair

Appendix K. Avian community metricsbox-and-whisker results and narrative for forested wetlands (N=16). Classifications are reference (R) and stressed (S).



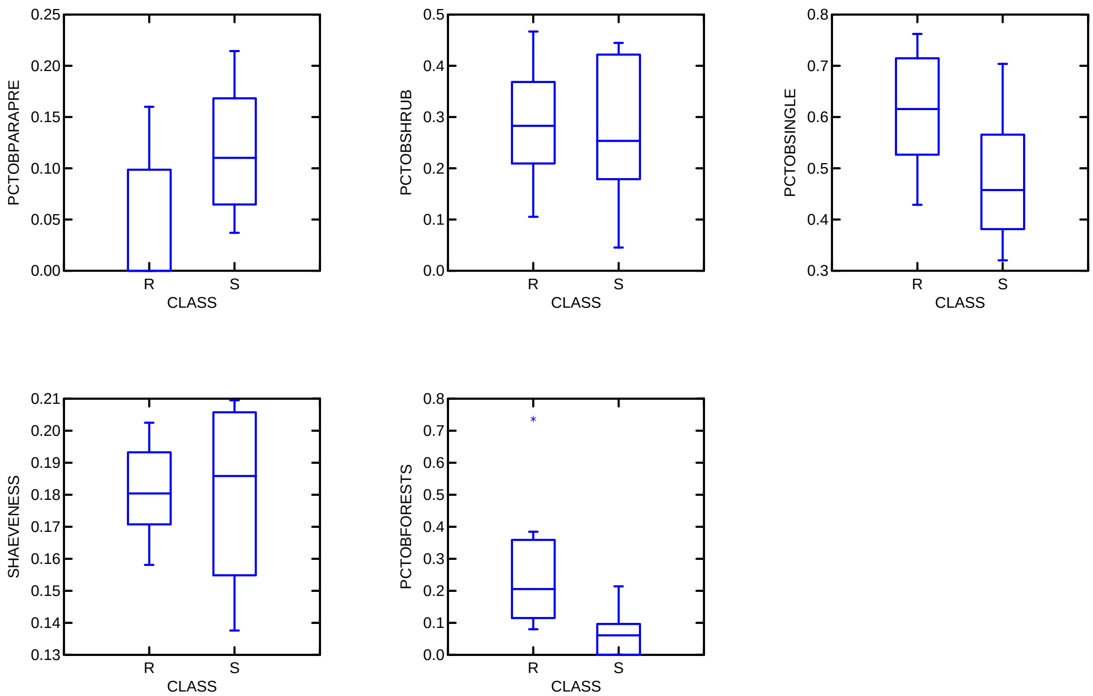
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	fair
PCTWD135	Proportion facultative wetland and above spp.	poor
PCTCBNEOTROP	Proportion neotropical migrants	good
PCTCBHABSPEC	Proportion habitat specific spp.	good
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	good
PCTCBEDGE	Proportion edge spp.	fair
PCTCBRESEDGE	Proportion residential and edge spp.	good

Appendix K. Continued.



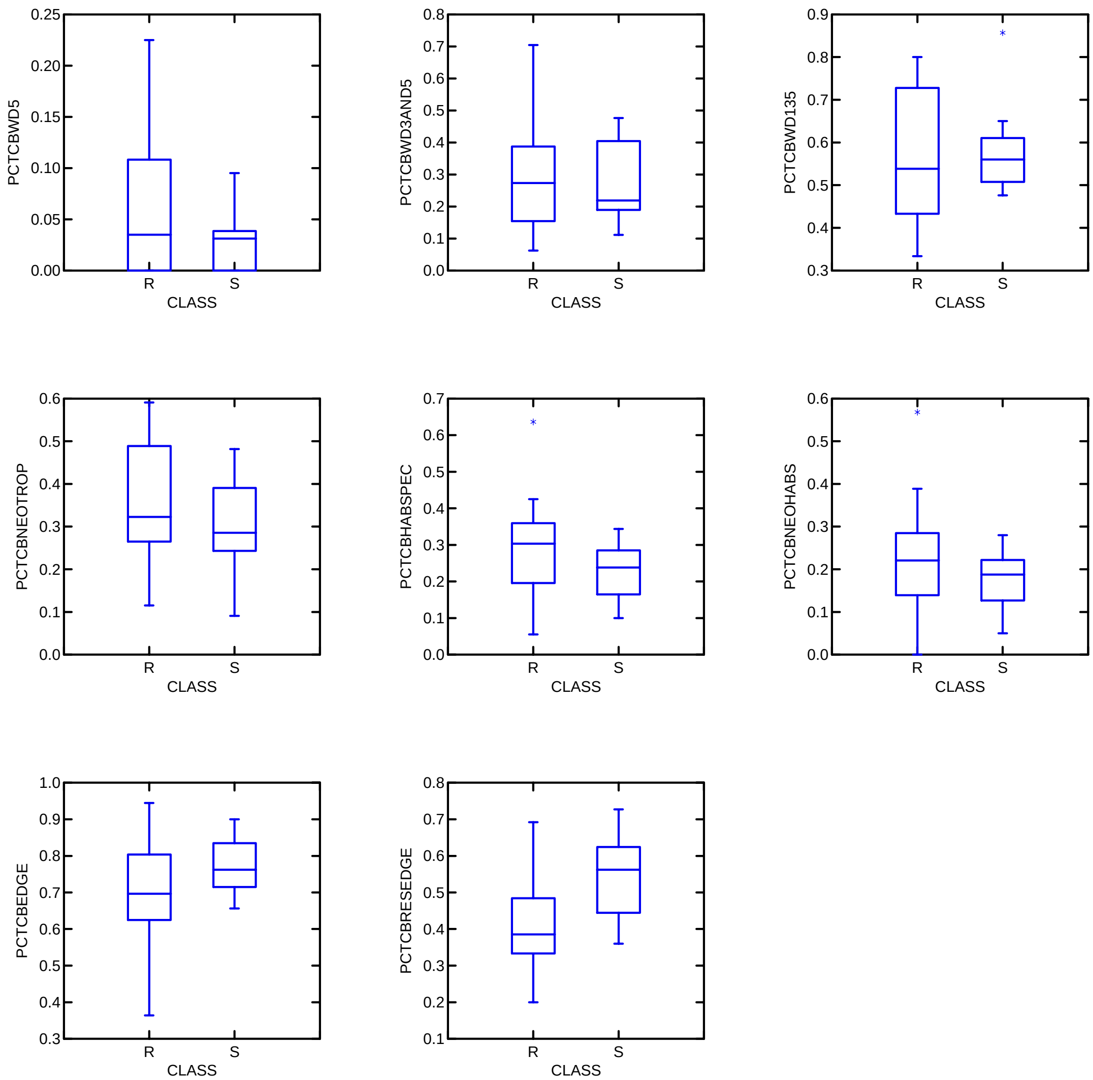
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	fair
PCTOMNIVOR	Proportion omnivorous spp.	excellent
PCTINSECTI	Proportion insectivorous spp.	excellent
BIRDDIVERSIT	Shannon-Weaver diversity index	poor
WETBIRDDIVER	Wetland bird S-W diversity index	fair
RICHNESS	Richness (number of species)	poor
ABUNDANCE	Abundance (count of individuals)	fair
WETRICHNESS	Wetland bird richness	fair
WETABUNDANCE	Wetland bird abundance	poor

Appendix K. Continued.



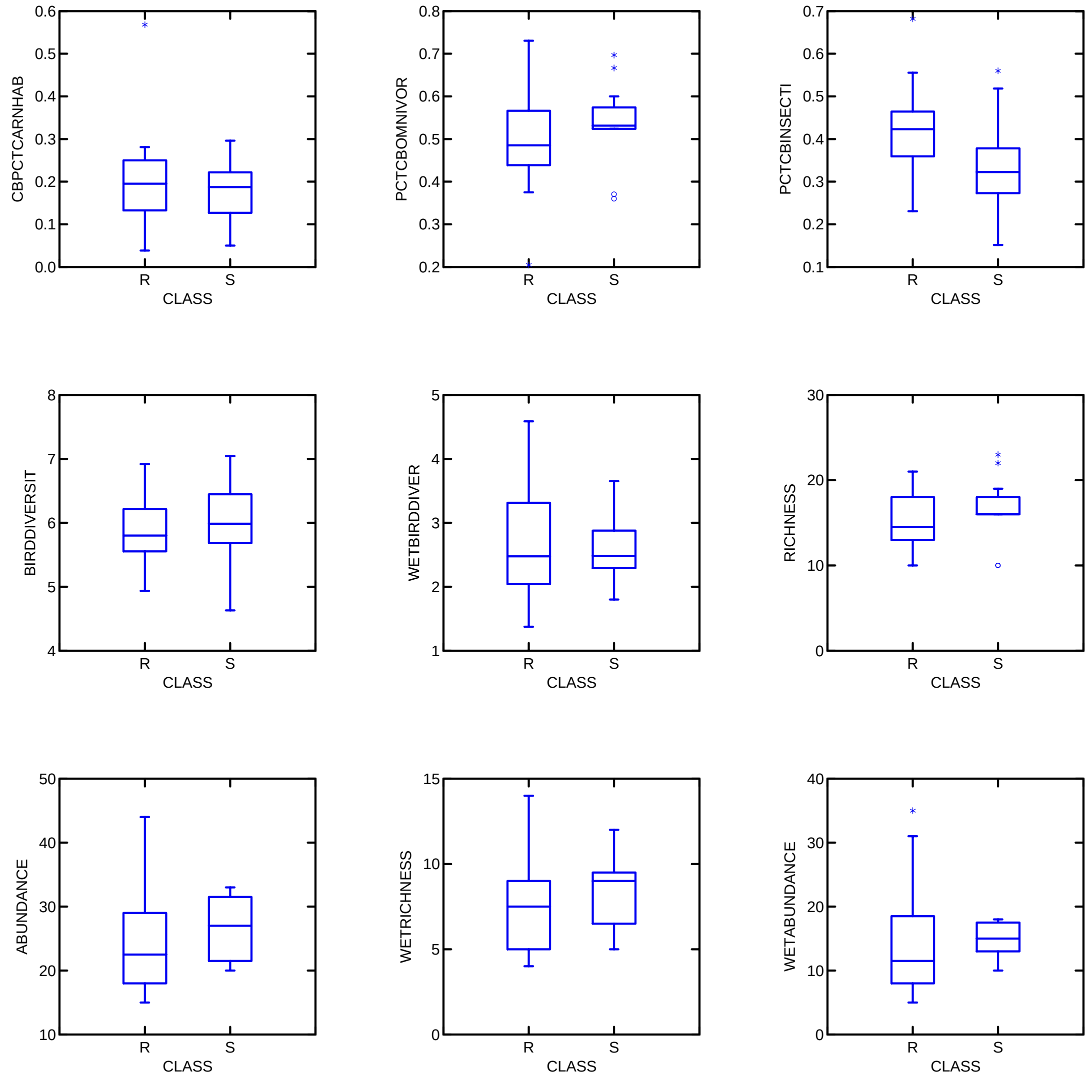
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	fair
PCTOBSHRUB	Proportion shrub nesting spp.	poor
PCTOBSINGLE	Proportion single brood spp.	good
SHAEVENESS	Shannon evenness index	fair
PCTOBFORESTS	Proportion interior forest obligate spp.	good

Appendix L. Avian community metrics box-and-whisker results and narrative descriptions for riparian depression wetlands (N=27). Classifications are reference (R) and stressed (S).



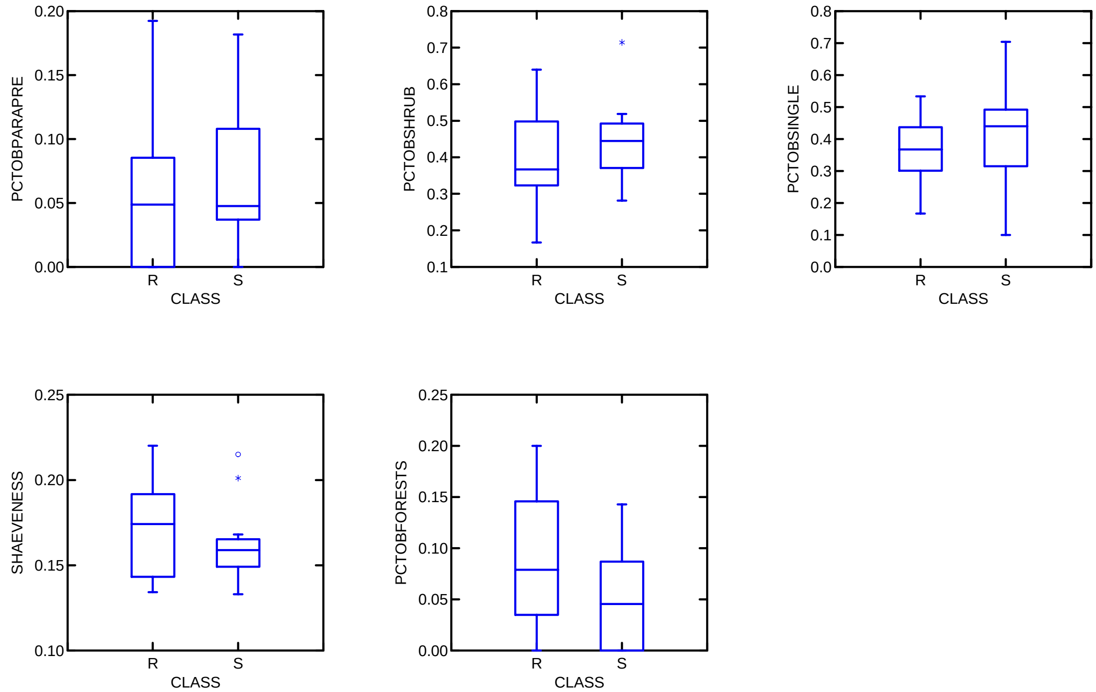
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	poor
PCTWD135	Proportion facultative wetland and above spp.	poor
PCTCBNEOTROP	Proportion neotropical migrants	poor
PCTCBHABSPEC	Proportion habitat specific spp.	fair
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	fair
PCTCBEDGE	Proportion edge spp.	fair
PCTCBRESEDGE	Proportion residential and edge spp.	good

Appendix L. Continued.



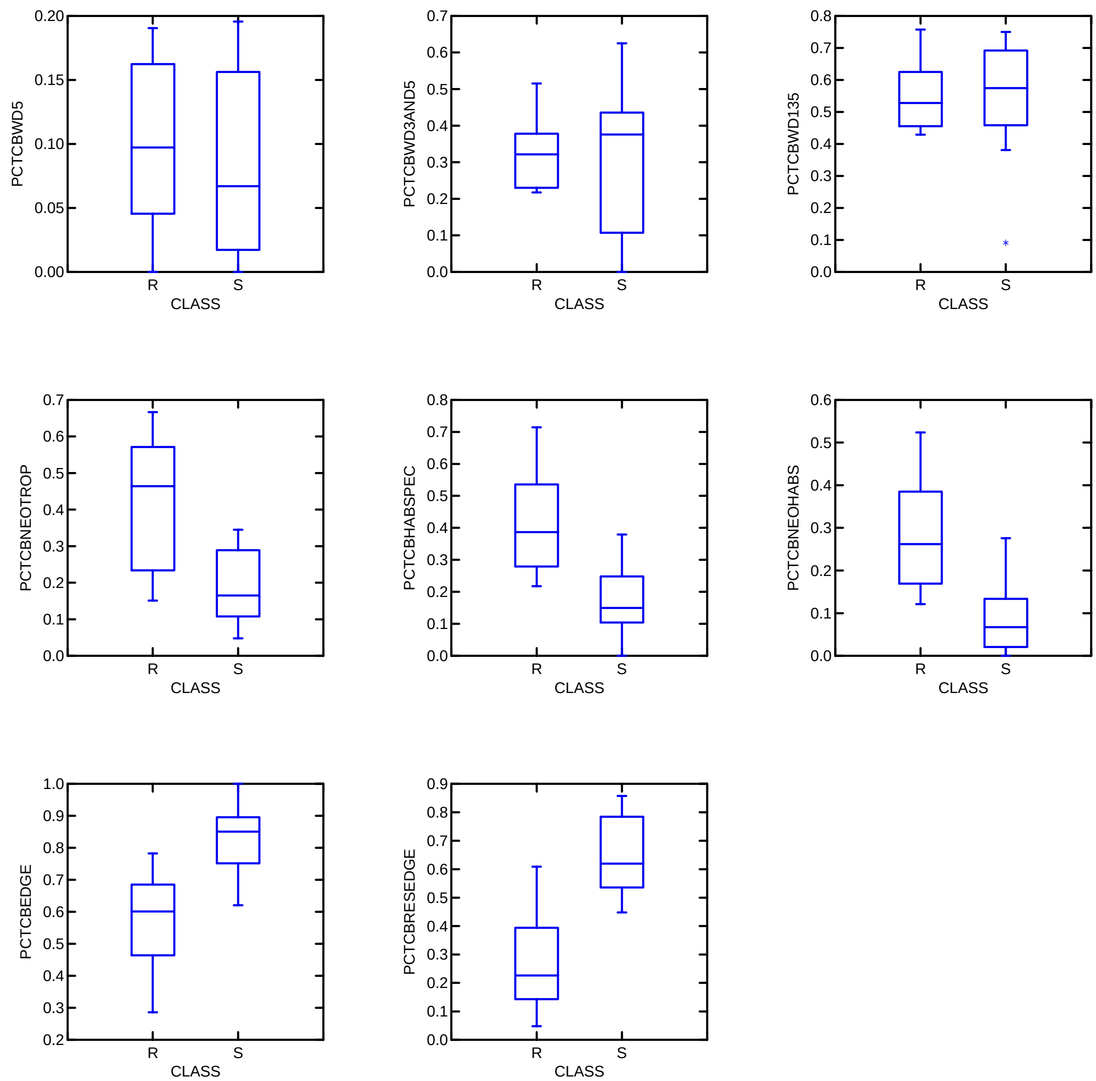
Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	poor
PCTOMNIVOR	Proportion omnivorous spp.	fair
PCTINSECTI	Proportion insectivorous spp.	good
BIRDDIVERSIT	Shannon-Weaver diversity index	poor
WETBIRDDIVER	Wetland bird S-W diversity index	poor
RICHNESS	Richness (number of species)	poor
ABUNDANCE	Abundance (count of individuals)	poor
WETRICHNESS	Wetland bird richness	poor
WETABUNDANCE	Wetland bird abundance	fair

Appendix L. Continued.



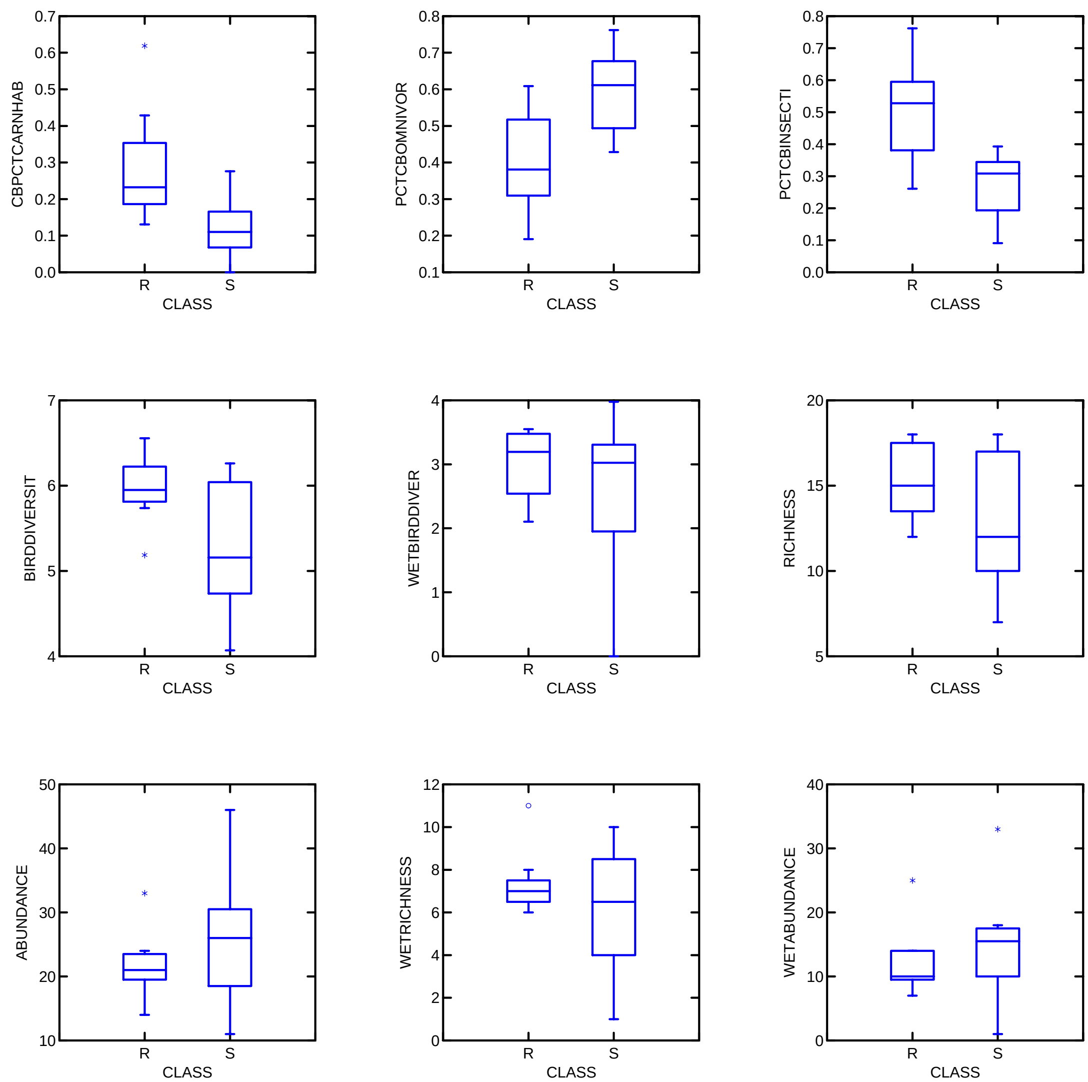
Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	fair
PCTOBSINGLE	Proportion single brood spp.	fair
SHAEVENESS	Shannon evenness index	fair
PCTOBFORESTS	Proportion interior forest obligate spp.	poor

Appendix M. Avian community metrics box-and-whisker results and narrative descriptions for headwater floodplain wetlands (N=16). Classifications are reference (R) and stressed (S).



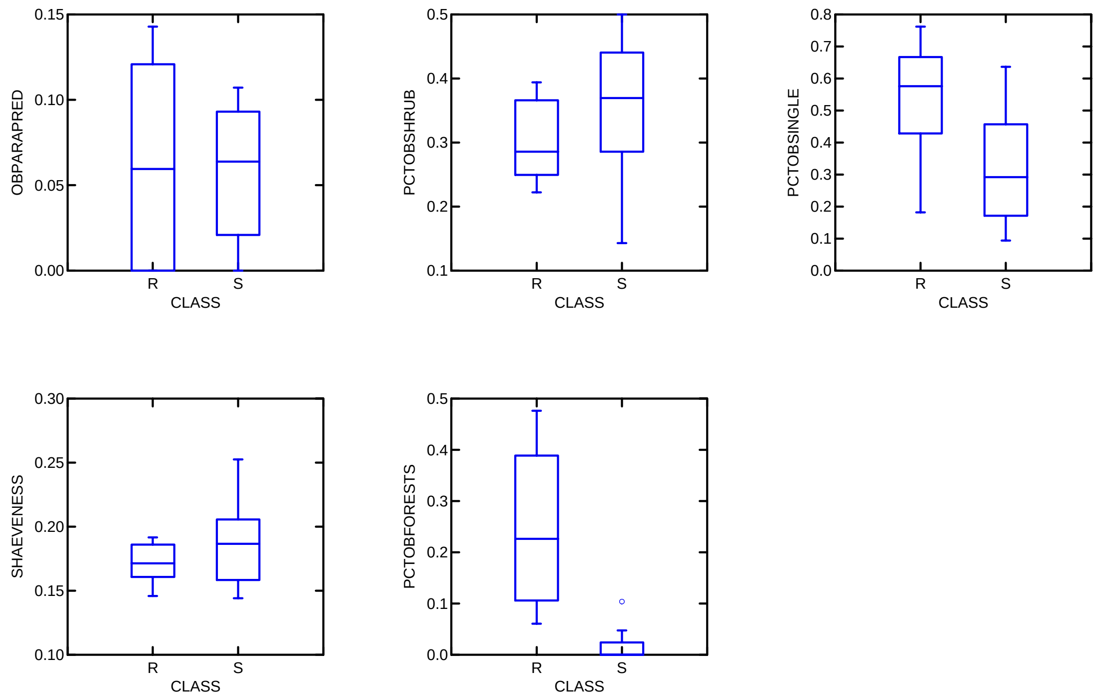
Metric code	Metric Description	Rating
PCTWD5	Proportion wetland dependent spp.	poor
PCTWD3AND5	Proportion wetland associated and dependent spp.	fair
PCTWD135	Proportion facultative wetland and above spp.	poor
PCTCBNEOTROP	Proportion neotropical migrants	good
PCTCBHABSPEC	Proportion habitat specific spp.	excellent
PCTNEOHABSPEC	Proportion neotropical migrants and habitat specific spp.	excellent
PCTCBEDGE	Proportion edge spp.	excellent
PCTCBRESEDGE	Proportion residential and edge spp.	excellent

Appendix M. Continued.



Metric code	Metric Description	Rating
PCTCBCARNHAB	Proportion carnivorous and habitat specific spp.	excellent
PCTOMNIVOR	Proportion omnivorous spp.	good
PCTINSECTI	Proportion insectivorous spp.	excellent
BIRDDIVERSIT	Shannon-Weaver diversity index	fair
WETBIRDDIVER	Wetland bird S-W diversity index	poor
RICHNESS	Richness (number of species)	fair
ABUNDANCE	Abundance (count of individuals)	fair
WETRICHNESS	Wetland bird richness	fair
WETABUNDANCE	Wetland bird abundance	fair

Appendix M. Continued.



Metric code	Metric Description	Rating
PCTOBPARAPRED	Proportion brood parasite / nest predator spp.	poor
PCTOBSHRUB	Proportion shrub nesting spp.	fair
PCTOBSINGLE	Proportion single brood spp.	good
SHAEVENESS	Shannon evenness index	fair
PCTOBFORESTS	Proportion interior forest obligate spp.	fair

Appendix N. Anuran richness, maximum Wisconsin Index (WI) call chorus, and max estimate for anuran species bysite used to form anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.

Site Code	Species	Latin name	Max Chorus	Max Estimate
CFCROS	Richness	4		
	Gray treefrog	*Hyla versicolor*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Mountain chorus frog	*Pseudacris brachyphona*	1	3
	Wood frog	*Rana sylvatica*	2	20
CFECUR	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Mountain chorus frog	*Pseudacris brachyphona*	1	2
CFEINC	Richness	4		
	Northern pickerel frog	*Rana palustris*	1	1
	Northern green frog	*Rana clamitans*	1	8
	Northern spring peeper	*Pseudacris crucifer*	2	30
	Eastern American toad	*Bufo americanus*	1	1
CFSLCH	Richness	7		
	American bullfrog	*Rana catesbeiana*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Mountain chorus frog	*Pseudacris brachyphona*	1	3
	Northern pickerel frog	*Rana palustris*	1	1
	Northern green frog	*Rana clamitans*	1	7
	Wood frog	*Rana sylvatica*	2	15
	Upland chorus frog	*Pseudacris triseriata*	1	4
CFSLIN	Richness	6		
	Wood frog	*Rana sylvatica*	2	25
	Gray treefrog	*Hyla versicolor*	1	1
	Northern green frog	*Rana clamitans*	1	5
	Upland chorus frog	*Pseudacris triseriata*	1	4
	Northern pickerel frog	*Rana palustris*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	40
CGBRID	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	2
CGCPAS	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
CGROAD	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	1

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
CGTRHE	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	2	8
CHNEER	Richness	6		
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	1
	Upland chorus frog	*Pseudacris triseriata*	1	4
	American bullfrog	*Rana catesbeiana*	2	24
	Gray treefrog	*Hyla versicolor*	1	2
	Northern green frog	*Rana clamitans*	2	15
	Northern spring peeper	*Pseudacris crucifer*	2	45
CHSACH	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	3
CHSAFO	Richness	1		
	Gray treefrog	*Hyla versicolor*	1	2
CHSARR	Richness	3		
	Gray treefrog	*Hyla versicolor*	1	3
	Northern spring peeper	*Pseudacris crucifer*	1	3
	Northern green frog	*Rana clamitans*	1	5
CHTREE	Richness	2		
	Gray treefrog	*Hyla versicolor*	1	1
	Northern spring peeper	*Pseudacris crucifer*	1	3
CHWWBW	Richness	5		
	Northern spring peeper	*Pseudacris crucifer*	2	35
	Northern pickerel frog	*Rana palustris*	1	3
	Gray treefrog	*Hyla versicolor*	2	5
	American bullfrog	*Rana catesbeiana*	2	21
	Northern green frog	*Rana clamitans*	1	7
CHWWEM	Richness	7		
	Upland chorus frog	*Pseudacris triseriata*	2	16
	American bullfrog	*Rana catesbeiana*	1	2
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	2	21
	Northern pickerel frog	*Rana palustris*	1	2
	Gray treefrog	*Hyla versicolor*	1	1
	Wood frog	*Rana sylvatica*	2	15

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
CHWWFO	Richness	8		
	Eastern American toad	*Bufo americanus*	1	2
	Northern pickerel frog	*Rana palustris*	1	5
	Gray treefrog	*Hyla versicolor*	3	50
	Cope's Gray treefrog	*Hyla chrysoscelis*	2	5
	Northern green frog	*Rana clamitans*	1	7
	American bullfrog	*Rana catesbeiana*	1	10
	Upland chorus frog	*Pseudacris triseriata*	1	2
	Northern spring peeper	*Pseudacris crucifer*	2	30
CVABBW	Richness	2		
	Upland chorus frog	*Pseudacris triseriata*	1	1
	Northern spring peeper	*Pseudacris crucifer*	1	5
CVABCT	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	3
CVTIMB	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	2	10
DSPICN	Richness	2		
	Wood frog	*Rana sylvatica*	1	3
	Northern spring peeper	*Pseudacris crucifer*	2	20
DSROAR	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	1
EPCMEM	Richness	5		
	Northern green frog	*Rana clamitans*	1	3
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern pickerel frog	*Rana palustris*	1	3
	Wood frog	*Rana sylvatica*	1	1
	Eastern American toad	*Bufo americanus*	2	4
EPKYVE	Richness	5		
	Northern green frog	*Rana clamitans*	1	5
	Wood frog	*Rana sylvatica*	2	15
	Eastern American toad	*Bufo americanus*	1	3
	Northern spring peeper	*Pseudacris crucifer*	2	35
	Northern pickerel frog	*Rana palustris*	1	2

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
EPRRXC	Richness	1		
	Northern green frog	*Rana clamitans*	1	1
EPSHEM	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	1	4
	Northern green frog	*Rana clamitans*	1	2
EPSHSS	Richness	4		
	Wood frog	*Rana sylvatica*	1	2
	Northern green frog	*Rana clamitans*	1	2
	Eastern American toad	*Bufo americanus*	2	5
	Northern spring peeper	*Pseudacris crucifer*	2	10
GBBARN	Richness	7		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Wood frog	*Rana sylvatica*	2	12
	Eastern American toad	*Bufo americanus*	2	15
	American bullfrog	*Rana catesbeiana*	1	1
	Leopard frog	*Rana pipiens*	1	4
	Northern green frog	*Rana clamitans*	1	3
	Northern pickerel frog	*Rana palustris*	1	8
GBHOEF	Richness	4		
	Northern spring peeper	*Pseudacris crucifer*	2	40
	Wood frog	*Rana sylvatica*	2	5
	Northern pickerel frog	*Rana palustris*	2	5
	Northern green frog	*Rana clamitans*	1	12
GBJENK	Richness	6		
	Eastern American toad	*Bufo americanus*	2	5
	American bullfrog	*Rana catesbeiana*	2	20
	Northern green frog	*Rana clamitans*	1	8
	Leopard frog	*Rana pipiens*	1	1
	Northern pickerel frog	*Rana palustris*	1	5
	Northern spring peeper	*Pseudacris crucifer*	3	50
GBMAPL	Richness	5		
	Wood frog	*Rana sylvatica*	3	50
	Eastern American toad	*Bufo americanus*	1	1
	Northern pickerel frog	*Rana palustris*	1	4
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Leopard frog	*Rana pipiens*	1	1

Appendix N. Continued..

Site Code	Species	Latin name	Max Chorus	Max Estimate
GBNOFO	Richness	4		
	Northern pickerel frog	*Rana palustris*	1	2
	Northern spring peeper	*Pseudacris crucifer*	2	20
	Northern green frog	*Rana clamitans*	1	3
	Eastern American toad	*Bufo americanus*	1	1
GBNOSS	Richness	5		
	Northern green frog	*Rana clamitans*	1	2
	Leopard frog	*Rana pipiens*	1	1
	Eastern American toad	*Bufo americanus*	2	6
	American bullfrog	*Rana catesbeiana*	1	3
	Northern spring peeper	*Pseudacris crucifer*	3	50
GBPLOT	Richness	7		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Eastern American toad	*Bufo americanus*	1	4
	Northern green frog	*Rana clamitans*	2	7
	Northern pickerel frog	*Rana palustris*	2	20
	Leopard frog	*Rana pipiens*	1	3
	Wood frog	*Rana sylvatica*	3	50
	American bullfrog	*Rana catesbeiana*	2	8
HCBEAV	Richness	4		
	Northern pickerel frog	*Rana palustris*	1	2
	Wood frog	*Rana sylvatica*	2	20
	Northern green frog	*Rana clamitans*	1	3
	Northern spring peeper	*Pseudacris crucifer*	3	50
HCMITI	Richness	6		
	Northern green frog	*Rana clamitans*	1	1
	Wood frog	*Rana sylvatica*	2	10
	Northern pickerel frog	*Rana palustris*	1	5
	Gray treefrog	*Hyla versicolor*	2	7
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Mountain chorus frog	*Pseudacris brachyphona*	1	2

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
HCPIPE	Richness	3		
	Northern green frog	*Rana clamitans*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Eastern American toad	*Bufo americanus*	1	2
HCRANG	Richness	3		
	Wood frog	*Rana sylvatica*	1	2
	Gray treefrog	*Hyla versicolor*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
HIBRID	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	1
HIGATE	Richness	2		
	American bullfrog	*Rana catesbeiana*	1	3
	Northern spring peeper	*Pseudacris crucifer*	2	25
HIJHPK	Richness	3		
	Wood frog	*Rana sylvatica*	1	7
	Eastern American toad	*Bufo americanus*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	24
HIJHTU	Richness	6		
	Northern green frog	*Rana clamitans*	1	4
	Wood frog	*Rana sylvatica*	2	20
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	1	2
	Eastern American toad	*Bufo americanus*	1	2
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	2
HIPENC	Richness	6		
	Northern pickerel frog	*Rana palustris*	1	12
	American bullfrog	*Rana catesbeiana*	1	3
	Wood frog	*Rana sylvatica*	3	50
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	2	13
	Gray treefrog	*Hyla versicolor*	1	5

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
HISEWG	Richness	2		
	Gray treefrog	*Hyla versicolor*	1	3
	Eastern American toad	*Bufo americanus*	1	1
HITRLR	Richness	5		
	Wood frog	*Rana sylvatica*	2	20
	Gray treefrog	*Hyla versicolor*	1	4
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	1
	Eastern American toad	*Bufo americanus*	1	1
MCFOUR	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	2	18
	Northern pickerel frog	*Rana palustris*	1	1
MCMEME	Richness	6		
	Northern pickerel frog	*Rana palustris*	1	3
	Gray treefrog	*Hyla versicolor*	2	8
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	9
	American bullfrog	*Rana catesbeiana*	2	8
	Wood frog	*Rana sylvatica*	1	1
MCMFOR	Richness	5		
	Northern pickerel frog	*Rana palustris*	1	3
	Northern green frog	*Rana clamitans*	1	4
	Gray treefrog	*Hyla versicolor*	2	10
	Mountain chorus frog	*Pseudacris brachyphona*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
MCNPFO	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	4
MCPOND	Richness	2		
	American bullfrog	*Rana catesbeiana*	1	2
	Northern green frog	*Rana clamitans*	1	3
MCPOST	Richness	5		
	Gray treefrog	*Hyla versicolor*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	15
	American bullfrog	*Rana catesbeiana*	2	5
	Northern green frog	*Rana clamitans*	1	8
	Northern pickerel frog	*Rana palustris*	2	6

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
MCTELE	Richness	4		
	American bullfrog	*Rana catesbeiana*	2	8
	Northern spring peeper	*Pseudacris crucifer*	2	8
	Northern green frog	*Rana clamitans*	1	4
	Gray treefrog	*Hyla versicolor*	2	8
ME5092	Richness	4		
	American bullfrog	*Rana catesbeiana*	1	2
	Northern green frog	*Rana clamitans*	1	8
	Northern spring peeper	*Pseudacris crucifer*	2	30
	Gray treefrog	*Hyla versicolor*	1	3
MESCOX	Richness	4		
	Northern spring peeper	*Pseudacris crucifer*	2	15
	Northern pickerel frog	*Rana palustris*	1	1
	Northern green frog	*Rana clamitans*	1	1
	Wood frog	*Rana sylvatica*	1	3
MESCRO	Richness	4		
	Wood frog	*Rana sylvatica*	2	11
	Northern green frog	*Rana clamitans*	1	2
	Northern pickerel frog	*Rana palustris*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	15
MESCUP	Richness	4		
	Wood frog	*Rana sylvatica*	1	4
	Northern pickerel frog	*Rana palustris*	2	7
	Northern spring peeper	*Pseudacris crucifer*	2	21
	Northern green frog	*Rana clamitans*	2	20
MESIGN	Richness	4		
	Northern green frog	*Rana clamitans*	1	4
	Upland chorus frog	*Pseudacris triseriata*	1	1
	Wood frog	*Rana sylvatica*	1	4
	Northern spring peeper	*Pseudacris crucifer*	2	25

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
MESILV	Richness	4		
	Northern green frog	*Rana clamitans*	1	3
	Wood frog	*Rana sylvatica*	1	5
	Northern spring peeper	*Pseudacris crucifer*	2	23
	Gray treefrog	*Hyla versicolor*	1	3
METETR	Richness	3		
	Upland chorus frog	*Pseudacris triseriata*	1	5
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Northern green frog	*Rana clamitans*	1	1
MEWOLF	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	2
	Wood frog	*Rana sylvatica*	1	12
MRBESS	Richness	3		
	Wood frog	*Rana sylvatica*	1	3
	Northern spring peeper	*Pseudacris crucifer*	2	12
	Northern green frog	*Rana clamitans*	1	3
MRFARM	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	2	40
	Upland chorus frog	*Pseudacris triseriata*	1	1
MRFORE	Richness	2		
	Eastern American toad	*Bufo americanus*	1	2
	Northern spring peeper	*Pseudacris crucifer*	2	10
MRSSSS	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Upland chorus frog	*Pseudacris triseriata*	1	2
MRWEST	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	2	12
MU55SS	Richness	4		
	Gray treefrog	*Hyla versicolor*	1	2
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	4
	Wood frog	*Rana sylvatica*	2	15

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
MUDBOA	Richness	4		
	Gray treefrog	*Hyla versicolor*	1	1
	Northern spring peeper	*Pseudacris crucifer*	1	11
	American bullfrog	*Rana catesbeiana*	1	1
	Northern green frog	*Rana clamitans*	1	1
MUDEND	Richness	6		
	Gray treefrog	*Hyla versicolor*	1	1
	Wood frog	*Rana sylvatica*	1	6
	American bullfrog	*Rana catesbeiana*	2	21
	Northern spring peeper	*Pseudacris crucifer*	2	37
	Northern green frog	*Rana clamitans*	1	7
	Northern pickerel frog	*Rana palustris*	1	7
MUDRIC	Richness	6		
	Gray treefrog	*Hyla versicolor*	2	9
	Northern green frog	*Rana clamitans*	2	11
	American bullfrog	*Rana catesbeiana*	2	6
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Wood frog	*Rana sylvatica*	2	12
	Northern pickerel frog	*Rana palustris*	1	2
MUDRIP	Richness	6		
	Northern pickerel frog	*Rana palustris*	1	7
	Northern green frog	*Rana clamitans*	1	8
	American bullfrog	*Rana catesbeiana*	1	4
	Northern spring peeper	*Pseudacris crucifer*	2	35
	Gray treefrog	*Hyla versicolor*	2	7
	Wood frog	*Rana sylvatica*	2	10
MUDTRA	Richness	7		
	Wood frog	*Rana sylvatica*	1	10
	Northern spring peeper	*Pseudacris crucifer*	2	40
	Northern pickerel frog	*Rana palustris*	1	5
	American bullfrog	*Rana catesbeiana*	1	1
	Mountain chorus frog	*Pseudacris brachyphona*	1	6
	Northern green frog	*Rana clamitans*	1	3
	Gray treefrog	*Hyla versicolor*	2	6

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
MUEPAH	Richness	4		
	Northern green frog	*Rana clamitans*	1	5
	Northern spring peeper	*Pseudacris crucifer*	2	40
	Wood frog	*Rana sylvatica*	2	15
	Gray treefrog	*Hyla versicolor*	1	4
MUMINE	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	6
MUPOWR	Richness	2		
	Gray treefrog	*Hyla versicolor*	1	4
	Northern spring peeper	*Pseudacris crucifer*	1	5
MUPULL	Richness	4		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Wood frog	*Rana sylvatica*	1	12
	Northern pickerel frog	*Rana palustris*	1	3
	Gray treefrog	*Hyla versicolor*	1	1
MUVBRD	Richness	4		
	Wood frog	*Rana sylvatica*	2	12
	Northern green frog	*Rana clamitans*	1	6
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	1	4
MUVCRN	Richness	3		
	Northern green frog	*Rana clamitans*	1	6
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	2	8
OHHSFO	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	1	15
	Eastern American toad	*Bufo americanus*	1	1
OHINNS	Richness	5		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	2	4
	Wood frog	*Rana sylvatica*	2	12
	Northern green frog	*Rana clamitans*	1	1
	Northern pickerel frog	*Rana palustris*	1	2

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
OHKMRT	Richness	3		
	Gray treefrog	*Hyla versicolor*	1	3
	Northern green frog	*Rana clamitans*	1	6
	Northern spring peeper	*Pseudacris crucifer*	2	21
PA29TH	Richness	4		
	Gray treefrog	*Hyla versicolor*	1	1
	Northern green frog	*Rana clamitans*	1	3
	Wood frog	*Rana sylvatica*	2	10
	Northern spring peeper	*Pseudacris crucifer*	2	30
PA83CR	Richness	4		
	Northern spring peeper	*Pseudacris crucifer*	2	35
	Northern green frog	*Rana clamitans*	1	2
	Gray treefrog	*Hyla versicolor*	2	12
	Wood frog	*Rana sylvatica*	1	4
PAFAMD	Richness	5		
	Gray treefrog	*Hyla versicolor*	2	10
	American bullfrog	*Rana catesbeiana*	3	50
	Northern spring peeper	*Pseudacris crucifer*	2	10
	Northern green frog	*Rana clamitans*	2	12
	Northern pickerel frog	*Rana palustris*	2	12
PAJCPY	Richness	4		
	Northern green frog	*Rana clamitans*	1	5
	Eastern American toad	*Bufo americanus*	1	2
	Gray treefrog	*Hyla versicolor*	3	50
	Northern spring peeper	*Pseudacris crucifer*	1	8
PALOUD	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	1	10
	Northern pickerel frog	*Rana palustris*	2	10
	Gray treefrog	*Hyla versicolor*	2	25
PAPEFO	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	1	1

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
PAPEIM	Richness	3		
	Eastern American toad	*Bufo americanus*	2	12
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Northern green frog	*Rana clamitans*	1	6
PAPESW	Richness	3		
	Wood frog	*Rana sylvatica*	2	35
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	7
PAWILL	Richness	6		
	Leopard frog	*Rana pipiens*	1	1
	Northern spring peeper	*Pseudacris crucifer*	1	16
	Gray treefrog	*Hyla versicolor*	1	1
	American bullfrog	*Rana catesbeiana*	2	8
	Eastern American toad	*Bufo americanus*	1	1
	Northern green frog	*Rana clamitans*	1	4
PCBLUE	Richness	5		
	Northern pickerel frog	*Rana palustris*	1	3
	American bullfrog	*Rana catesbeiana*	3	50
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Cope's Gray treefrog	*Hyla chrysoscelis*	2	10
	Northern green frog	*Rana clamitans*	1	10
PCLPFO	Richness	6		
	Northern pickerel frog	*Rana palustris*	1	2
	Cope's Gray treefrog	*Hyla chrysoscelis*	2	25
	Wood frog	*Rana sylvatica*	3	50
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Eastern American toad	*Bufo americanus*	1	2
	Fowlers Toad	*Bufo woodhousii fowleri*	1	5
PCROAD	Richness	5		
	Northern pickerel frog	*Rana palustris*	1	3
	Wood frog	*Rana sylvatica*	2	10
	Northern spring peeper	*Pseudacris crucifer*	3	50
	American bullfrog	*Rana catesbeiana*	1	5
	Northern green frog	*Rana clamitans*	1	5

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
PEMIDW	Richness	6		
	Gray treefrog	*Hyla versicolor*	2	6
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	1
	Eastern American toad	*Bufo americanus*	1	6
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	2
	Wood frog	*Rana sylvatica*	2	20
PERDDP	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Wood frog	*Rana sylvatica*	2	15
	Gray treefrog	*Hyla versicolor*	1	3
PETHUM	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Wood frog	*Rana sylvatica*	2	23
PETOSS	Richness	1		
	Gray treefrog	*Hyla versicolor*	1	3
RIASIA	Richness	6		
	American bullfrog	*Rana catesbeiana*	1	6
	Northern green frog	*Rana clamitans*	1	1
	Mountain chorus frog	*Pseudacris brachyphona*	1	2
	Northern spring peeper	*Pseudacris crucifer*	2	20
	Northern pickerel frog	*Rana palustris*	1	2
	Gray treefrog	*Hyla versicolor*	1	4
RIBRID	Richness	5		
	Mountain chorus frog	*Pseudacris brachyphona*	2	7
	Northern spring peeper	*Pseudacris crucifer*	1	7
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	1
	Northern green frog	*Rana clamitans*	1	1
	American bullfrog	*Rana catesbeiana*	1	2
RIEAST	Richness	2		
	Leopard frog	*Rana pipiens*	1	1
	Northern spring peeper	*Pseudacris crucifer*	1	1

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
SJBOAT	Richness	4		
	Northern pickerel frog	*Rana palustris*	1	5
	Northern green frog	*Rana clamitans*	1	4
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	4
SJBRID	Richness	6		
	Northern pickerel frog	*Rana palustris*	1	1
	American bullfrog	*Rana catesbeiana*	1	1
	Eastern American toad	*Bufo americanus*	2	2
	Mountain chorus frog	*Pseudacris brachyphona*	1	1
	Northern green frog	*Rana clamitans*	1	2
	Northern spring peeper	*Pseudacris crucifer*	2	25
SJCHUR	Richness	4		
	Eastern American toad	*Bufo americanus*	1	1
	Northern pickerel frog	*Rana palustris*	2	5
	Northern green frog	*Rana clamitans*	2	15
	Northern spring peeper	*Pseudacris crucifer*	3	50
SJGLAD	Richness	4		
	Northern green frog	*Rana clamitans*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Mountain chorus frog	*Pseudacris brachyphona*	1	2
	Wood frog	*Rana sylvatica*	1	1
SJMUDL	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	2	12
	Northern green frog	*Rana clamitans*	1	1
	Mountain chorus frog	*Pseudacris brachyphona*	1	3
SJPLOT	Richness	7		
	Northern pickerel frog	*Rana palustris*	2	7
	Eastern American toad	*Bufo americanus*	2	2
	Northern green frog	*Rana clamitans*	1	4
	Wood frog	*Rana sylvatica*	1	2
	Mountain chorus frog	*Pseudacris brachyphona*	1	2
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	3
	Northern spring peeper	*Pseudacris crucifer*	2	25

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
SMDTSS	Richness	2		
	Northern pickerel frog	*Rana palustris*	1	4
	Northern spring peeper	*Pseudacris crucifer*	2	25
SMFOFL	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
SMLPEM	Richness	3		
	Upland chorus frog	*Pseudacris triseriata*	1	3
	Northern green frog	*Rana clamitans*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
SMSEFL	Richness	4		
	Northern green frog	*Rana clamitans*	1	5
	Northern pickerel frog	*Rana palustris*	2	7
	American bullfrog	*Rana catesbeiana*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
SMSTEM	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	2	25
	Northern pickerel frog	*Rana palustris*	1	2
TRSPFO	Richness	1		
	Northern green frog	*Rana clamitans*	1	1
TRSPRI	Richness	5		
	American bullfrog	*Rana catesbeiana*	1	2
	Wood frog	*Rana sylvatica*	2	15
	Northern green frog	*Rana clamitans*	1	2
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	2	9
TVFARM	Richness	3		
	Gray treefrog	*Hyla versicolor*	1	2
	Wood frog	*Rana sylvatica*	2	25
	Northern spring peeper	*Pseudacris crucifer*	3	50

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
TVISLE	Richness	3		
	Northern green frog	*Rana clamitans*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	12
	Gray treefrog	*Hyla versicolor*	1	3
TVNEWT	Richness	6		
	Wood frog	*Rana sylvatica*	3	50
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	2
	Gray treefrog	*Hyla versicolor*	1	5
	Northern green frog	*Rana clamitans*	2	16
	Eastern American toad	*Bufo americanus*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
TVPOUT	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	3
	Wood frog	*Rana sylvatica*	2	13
TVVBEM	Richness	3		
	Northern green frog	*Rana clamitans*	1	3
	Wood frog	*Rana sylvatica*	1	6
	Northern spring peeper	*Pseudacris crucifer*	2	15
TVVBIM	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	2	40
	Wood frog	*Rana sylvatica*	2	12
	Northern green frog	*Rana clamitans*	1	1
TVVBRV	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	1	4
	Eastern American toad	*Bufo americanus*	1	1
	Gray treefrog	*Hyla versicolor*	1	2
TVVBSS	Richness	4		
	Northern green frog	*Rana clamitans*	3	50
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Wood frog	*Rana sylvatica*	2	25
	Northern pickerel frog	*Rana palustris*	1	1

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
UDC001	Richness	5		
	Northern green frog	*Rana clamitans*	2	9
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	2	6
	Wood frog	*Rana sylvatica*	2	10
	Eastern American toad	*Bufo americanus*	3	50
UDC002	Richness	4		
	Eastern American toad	*Bufo americanus*	3	50
	Gray treefrog	*Hyla versicolor*	1	2
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC003	Richness	4		
	American bullfrog	*Rana catesbeiana*	1	1
	Eastern American toad	*Bufo americanus*	3	50
	Northern green frog	*Rana clamitans*	1	4
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC004	Richness	5		
	American bullfrog	*Rana catesbeiana*	1	3
	Gray treefrog	*Hyla versicolor*	1	2
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	1	5
	Eastern American toad	*Bufo americanus*	1	1
UDC005	Richness	2		
	Eastern American toad	*Bufo americanus*	1	2
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC007	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC008	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC012	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	American bullfrog	*Rana catesbeiana*	2	13
UDC013	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	1	4

Appendix N. Continued..

Site Code	Species	Latin name	Max Chorus	Max Estimate
UDC014	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Gray treefrog	*Hyla versicolor*	1	4
UDC015	Richness	3		
	American bullfrog	*Rana catesbeiana*	1	3
	Northern green frog	*Rana clamitans*	1	5
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC016	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC017	Richness	3		
	American bullfrog	*Rana catesbeiana*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	60
	Northern green frog	*Rana clamitans*	2	5
UDC018	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC019	Richness	1		
	Northern spring peeper	*Pseudacris crucifer*	3	50
UDC020	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	3	50
	Northern green frog	*Rana clamitans*	2	9
	American bullfrog	*Rana catesbeiana*	1	6
VEPCON	Richness	3		
	Mountain chorus frog	*Pseudacris brachyphona*	1	5
	Eastern American toad	*Bufo americanus*	1	1
	Northern spring peeper	*Pseudacris crucifer*	3	50
VEPCOS	Richness	3		
	Eastern American toad	*Bufo americanus*	2	3
	Mountain chorus frog	*Pseudacris brachyphona*	1	6
	Northern spring peeper	*Pseudacris crucifer*	3	50
WBBARN	Richness	4		
	Wood frog	*Rana sylvatica*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	30
	Eastern American toad	*Bufo americanus*	2	5
	Northern pickerel frog	*Rana palustris*	1	2

Appendix N. Continued.

Site Code	Species	Latin name	Max Chorus	Max Estimate
WBCORN	Richness	4		
	Eastern American toad	*Bufo americanus*	2	5
	Northern green frog	*Rana clamitans*	1	1
	Northern spring peeper	*Pseudacris crucifer*	2	20
	Northern pickerel frog	*Rana palustris*	2	7
WBROAD	Richness	2		
	Northern spring peeper	*Pseudacris crucifer*	2	10
	Eastern American toad	*Bufo americanus*	1	1
WYBEAV	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	2	20
	Cope's Gray treefrog	*Hyla chrysoscelis*	2	8
	Northern green frog	*Rana clamitans*	1	3
WYCHWE	Richness	6		
	Northern spring peeper	*Pseudacris crucifer*	2	10
	American bullfrog	*Rana catesbeiana*	2	5
	Mountain chorus frog	*Pseudacris brachyphona*	2	3
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	1
	Northern pickerel frog	*Rana palustris*	1	4
	Northern green frog	*Rana clamitans*	1	2
WYHCEA	Richness	8		
	Cope's Gray treefrog	*Hyla chrysoscelis*	1	1
	Northern pickerel frog	*Rana palustris*	2	4
	American bullfrog	*Rana catesbeiana*	2	2
	Mountain chorus frog	*Pseudacris brachyphona*	2	10
	Northern spring peeper	*Pseudacris crucifer*	2	30
	Wood frog	*Rana sylvatica*	2	10
	Eastern American toad	*Bufo americanus*	1	2
	Northern green frog	*Rana clamitans*	1	3
WYINTR	Richness	3		
	Northern spring peeper	*Pseudacris crucifer*	2	15
	Eastern American toad	*Bufo americanus*	2	8
	Mountain chorus frog	*Pseudacris brachyphona*	2	10
WYTHOR	Richness	5		
	Eastern American toad	*Bufo americanus*	1	4
	Northern green frog	*Rana clamitans*	1	2
	Cope's Gray treefrog	*Hyla chrysoscelis*	2	3
	Northern spring peeper	*Pseudacris crucifer*	2	12
	Mountain chorus frog	*Pseudacris brachyphona*	1	4

Appendix O. Metrics values by site used to form anuran acoustically-based indices of biological integrity (AA-IBI) in West Virginia, USA from 2005-2006.Blanks indicate a metric value of zero.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
CFCROS	2.94	0.29		0.57	0.29	4.00	7.00	0.32	4.00	4.25	0.43	0.43	
CFECUR	1.47			1.00		2.00	3.00	0.32	2.33	2.50	0.33	0.67	
CFEINC	3.07	0.20		0.80		4.00	5.00	0.33	2.80	3.00		0.60	0.20
CFSLCH	4.35	0.33	0.11	0.67	0.22	7.00	9.00	0.27	3.89	3.71	0.33	0.22	0.22
CFSLIN	3.99	0.38	0.13	0.50	0.25	6.00	8.00	0.29	4.38	4.33	0.25	0.25	0.13
CGBRID	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
CGCPAS	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
CGROAD	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
CGTRHE	0.00			1.00		1.00	2.00	0.00	2.00	2.00		1.00	
CHNEER	4.00		0.11	0.78		6.00	9.00	0.29	2.78	3.17		0.22	0.44
CHSACH	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
CHSAFO	0.00					1.00	1.00	0.00	5.00	5.00			
CHSARR	2.53			0.67		3.00	3.00	0.37	3.00	3.00		0.33	0.33
CHTREE	1.60			0.50		2.00	2.00	0.35	3.50	3.50		0.50	
CHWWBW	3.59	0.13		0.63		5.00	8.00	0.31	3.38	3.60		0.25	0.38
CHWWEM	4.29	0.25	0.17	0.67	0.17	7.00	12.00	0.27	3.67	4.00	0.17	0.25	0.25
CHWWFO	4.56	0.08	0.08	0.50		8.00	12.00	0.25	3.67	3.38		0.25	0.17
CVABBW	1.60		0.50	1.00		2.00	2.00	0.35	2.50	2.50		0.50	
CVABCT	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
CVTIMB	0.00			1.00		1.00	2.00	0.00	2.00	2.00		1.00	
DSPICN	1.47	0.33		0.67	0.33	2.00	3.00	0.32	3.67	4.50	0.33	0.67	

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
DSROAR	0.00	1.00	1.00	1.00	0.00	2.00	2.00	1.00					
DSWILD						0.00	0.00						
EPCMEM	3.44	0.25		0.75	0.13	5.00	8.00	0.30	3.00	3.80	0.13	0.63	0.13
EPCMFO						0.00	0.00						
EPDMFO						0.00	0.00						
EPDMPU						0.00	0.00						
EPKYVE	3.57	0.43		0.57	0.29	5.00	7.00	0.31	4.00	3.80	0.29	0.43	0.14
EPRRXC	0.00			1.00		1.00	1.00	0.00	2.00	2.00			1.00
EPSHEM	1.60			1.00		2.00	2.00	0.35	2.00	2.00		0.50	0.50
EPSHSS	3.06	0.17		0.83	0.17	4.00	6.00	0.33	2.50	3.00	0.17	0.67	0.17
GBBARN	4.25	0.27	0.09	0.73	0.18	7.00	11.00	0.26	3.18	3.29	0.18	0.45	0.18
GBHOEF	3.11	0.57		0.43	0.29	4.00	7.00	0.34	4.86	4.50	0.29	0.29	0.14
GBJENK	3.90	0.10	0.10	0.90		6.00	10.00	0.28	2.30	2.67		0.50	0.30
GBMAPL	3.37	0.44	0.11	0.56	0.33	5.00	9.00	0.29	4.11	3.80	0.33	0.44	
GBNOFO	3.07	0.20		0.80		4.00	5.00	0.33	2.80	3.00		0.60	0.20
GBNOSS	3.44		0.13	1.00		5.00	8.00	0.30	1.75	1.80		0.63	0.25
GBPLOT	4.31	0.36	0.07	0.64	0.21	7.00	14.00	0.27	3.71	3.29	0.21	0.29	0.29
HCBEAV	2.94	0.43		0.57	0.29	4.00	7.00	0.32	4.14	4.50	0.29	0.43	0.14
HCMITI	3.90	0.30		0.50	0.20	6.00	10.00	0.28	4.20	4.33	0.30	0.30	0.10
HCPIPE	2.19			1.00		3.00	5.00	0.32	1.80	1.67		0.80	0.20
HCRANG	2.19	0.20		0.60	0.20	3.00	5.00	0.32	3.60	4.67	0.20	0.60	

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
HIBRID	0.00	1.00	1.00	1.00	0.00	2.00	2.00	1.00					
HIGATE	1.47			1.00		2.00	3.00	0.32	2.00	2.00		0.67	0.33
HIJHPK	2.39	0.25		0.75	0.25	3.00	4.00	0.35	3.00	3.33	0.25	0.75	
HIJHTU	3.86	0.22		0.56	0.22	6.00	9.00	0.28	3.67	3.67	0.22	0.44	0.11
HIPENC	3.85	0.36		0.55	0.27	6.00	11.00	0.28	4.09	4.17	0.27	0.27	0.27
HISEWG	1.60			0.50		2.00	2.00	0.35	3.00	3.00		0.50	
HITRLR	3.44	0.25		0.63	0.25	5.00	8.00	0.30	3.50	3.40	0.25	0.50	0.13
MCFOUR	1.47	0.33		0.67		2.00	3.00	0.32	3.67	4.50		0.67	
MCMEME	3.90	0.20		0.60	0.10	6.00	10.00	0.28	3.60	4.17	0.10	0.30	0.30
MCMFOR	3.44	0.13		0.63		5.00	8.00	0.30	3.50	3.80	0.13	0.38	0.13
MCNPFO	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
MCPOND	1.60			1.00		2.00	2.00	0.35	2.00	2.00			1.00
MCPOST	3.59	0.25		0.63		5.00	8.00	0.31	3.63	3.60		0.25	0.38
MCTELE	3.11			0.71		4.00	7.00	0.34	2.86	2.75		0.29	0.43
ME5092	3.07			0.80		4.00	5.00	0.33	2.60	2.75		0.40	0.40
MESCOX	3.07	0.40		0.60	0.20	4.00	5.00	0.33	4.00	4.50	0.20	0.40	0.20
MESCRO	3.06	0.50		0.50	0.33	4.00	6.00	0.33	4.50	4.50	0.33	0.33	0.17
MESCUP	3.11	0.43		0.57	0.14	4.00	7.00	0.34	4.14	4.50	0.14	0.29	0.29
MESIGN	3.07	0.20	0.20	0.80	0.20	4.00	5.00	0.33	3.20	3.50	0.20	0.40	0.20
MESILV	3.07	0.20		0.60	0.20	4.00	5.00	0.33	3.60	4.00	0.20	0.40	0.20
METETR	2.39		0.25	1.00		3.00	4.00	0.35	2.25	2.33		0.50	0.25

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
MEWOLF	2.19	0.20	0.80	0.20	3.00	5.00	0.32	3.00	3.67	0.20	0.60	0.20	
MRBESS	2.39	0.25		0.75	0.25	3.00	4.00	0.35	3.25	3.67	0.25	0.50	0.25
MRFARM	1.47		0.33	1.00		2.00	3.00	0.32	2.33	2.50		0.67	
MRFORE	1.47			1.00		2.00	3.00	0.32	1.67	1.50		1.00	
MRSSSS	1.47		0.33	1.00		2.00	3.00	0.32	2.33	2.50		0.67	
MRWEST	0.00			1.00		1.00	2.00	0.00	2.00	2.00		1.00	
MU55SS	2.94	0.29		0.57	0.29	4.00	7.00	0.32	3.86	4.00	0.29	0.43	0.14
MUDBOA	3.19			0.75		4.00	4.00	0.35	2.75	2.75		0.25	0.50
MUDEND	3.99	0.25		0.63	0.13	6.00	8.00	0.29	3.63	4.17	0.13	0.25	0.38
MUDRIC	4.03	0.25		0.58	0.17	6.00	12.00	0.29	3.75	4.17	0.17	0.25	0.33
MUDRIP	4.00	0.33		0.44	0.22	6.00	9.00	0.29	4.33	4.17	0.22	0.22	0.22
MUDTRA	4.35	0.22		0.56	0.11	7.00	9.00	0.27	3.89	4.00	0.22	0.22	0.22
MUEPAH	3.06	0.33		0.50	0.33	4.00	6.00	0.33	4.17	4.00	0.33	0.33	0.17
MUMINE	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
MUPOWR	1.60			0.50		2.00	2.00	0.35	3.50	3.50		0.50	
MUPULL	2.86	0.33		0.50	0.17	4.00	6.00	0.31	4.17	5.25	0.17	0.50	
MUVBRD	2.94	0.29		0.57	0.29	4.00	7.00	0.32	3.86	4.00	0.29	0.43	0.14
MUVCRN	2.33			0.67		3.00	6.00	0.34	3.00	3.00		0.50	0.17
OHHSFO	1.60			1.00		2.00	2.00	0.35	1.50	1.50		1.00	
OHINNS	3.51	0.33		0.44	0.22	5.00	9.00	0.30	4.33	4.60	0.22	0.33	0.11
OHKMRT	2.39			0.75		3.00	4.00	0.35	2.75	3.00		0.50	0.25

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
PA29TH	3.06	0.33		0.50	0.33	4.00	6.00	0.33	4.17	4.00	0.33	0.33	0.17
PA83CR	3.06	0.17		0.50	0.17	4.00	6.00	0.33	3.83	4.00	0.17	0.33	0.17
PAFAMD	3.67	0.18		0.64		5.00	11.00	0.32	3.45	3.60		0.18	0.45
PAJCPY	2.86			0.50		4.00	6.00	0.31	3.33	2.50		0.33	0.17
PALOUD	2.43	0.40		0.20		3.00	5.00	0.35	5.20	4.67		0.20	
PAPEFO	0.00			1.00		1.00	1.00	0.00	2.00	2.00		1.00	
PAPEIM	2.43			1.00		3.00	5.00	0.35	1.60	1.67		0.80	0.20
PAPESW	2.33	0.33		0.67	0.33	3.00	6.00	0.34	3.67	3.67	0.33	0.50	0.17
PAWILL	4.02		0.14	0.86		6.00	7.00	0.29	2.29	2.33		0.29	0.43
PCBLUE	3.46	0.10		0.70		5.00	10.00	0.30	3.10	3.60		0.30	0.40
PCLPFO	3.85	0.36		0.45	0.27	6.00	11.00	0.28	4.18	3.83	0.27	0.36	
PCROAD	3.44	0.38		0.63	0.25	5.00	8.00	0.30	3.88	4.00	0.25	0.38	0.25
PEMIDW	3.90	0.20		0.50	0.20	6.00	10.00	0.28	3.80	3.67	0.20	0.40	0.10
PERDDP	2.33	0.33		0.50	0.33	3.00	6.00	0.34	4.17	4.67	0.33	0.50	
PETHUM	1.55	0.40		0.60	0.40	2.00	5.00	0.34	4.00	4.50	0.40	0.60	
PETOSS	0.00					1.00	1.00	0.00	5.00	5.00			
RIASIA	4.02	0.14		0.71		6.00	7.00	0.29	3.29	3.50	0.14	0.29	0.29
RIBRID	3.59			0.83		5.00	6.00	0.31	2.83	2.80	0.33	0.17	0.33
RIEAST	1.60		0.50	1.00		2.00	2.00	0.35	2.00	2.00		0.50	
SJBOAT	2.86	0.17		0.67		4.00	6.00	0.31	3.33	4.00		0.50	0.17
SJBRID	3.99	0.13		0.88		6.00	8.00	0.29	2.50	2.83	0.13	0.50	0.25

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
SJCHUR	3.04	0.25	0.75	4.00	8.00	0.33	3.13	3.00	0.50	0.25			
SJGLAD	3.07	0.20		0.80	0.20	4.00	5.00	0.33	3.20	3.50	0.40	0.40	0.20
SJMUDL	2.39			1.00		3.00	4.00	0.35	2.25	2.33	0.25	0.50	0.25
SJPLOT	4.34	0.30		0.60	0.10	7.00	10.00	0.27	3.70	3.86	0.20	0.40	0.10
SJTELE	2.53			1.00		3.00	3.00	0.37	2.00	2.00	0.33	0.33	0.33
SMDTSS	1.47	0.33		0.67		2.00	3.00	0.32	3.67	4.50		0.67	
SMFOFL	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
SMLPEM	2.19		0.20	1.00		3.00	5.00	0.32	2.20	2.33		0.60	0.20
SMSEFL	2.94	0.29		0.71		4.00	7.00	0.32	3.43	3.25		0.43	0.29
SMSTEM	1.47	0.33		0.67		2.00	3.00	0.32	3.67	4.50		0.67	
TRSPFO	0.00			1.00		1.00	1.00	0.00	2.00	2.00			1.00
TRSPRI	3.51	0.22		0.56	0.22	5.00	9.00	0.30	3.78	3.60	0.22	0.33	0.22
TVFARM	2.33	0.33		0.50	0.33	3.00	6.00	0.34	4.17	4.67	0.33	0.50	
TVISLE	2.39			0.75		3.00	4.00	0.35	2.75	3.00		0.50	0.25
TVNEWT	3.85	0.27		0.55	0.27	6.00	11.00	0.28	3.82	3.67	0.27	0.36	0.18
TVPOUT	2.33	0.33		0.67	0.33	3.00	6.00	0.34	3.67	3.67	0.33	0.50	0.17
TVVBEM	2.39	0.25		0.75	0.25	3.00	4.00	0.35	3.25	3.67	0.25	0.50	0.25
TVVBIM	2.43	0.40		0.60	0.40	3.00	5.00	0.35	4.00	3.67	0.40	0.40	0.20
TVVBRV	2.53			0.67		3.00	3.00	0.37	2.67	2.67		0.67	
TVVBSS	3.02	0.33		0.67	0.22	4.00	9.00	0.33	3.67	4.50	0.22	0.33	0.33
UDC001	3.66	0.17		0.67	0.17	5.00	12.00	0.32	3.08	3.40	0.17	0.50	0.17

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
UDC002	2.89			0.88		4.00	8.00	0.31	1.88	2.25		0.88	
UDC003	2.89			1.00		4.00	8.00	0.31	1.63	1.75		0.75	0.25
UDC004	3.40			0.86		5.00	7.00	0.30	2.29	2.40		0.57	0.29
UDC005	1.29			1.00		2.00	4.00	0.28	1.75	1.50		1.00	
UDC007	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
UDC008	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
UDC012	1.55			1.00		2.00	5.00	0.34	2.00	2.00		0.60	0.40
UDC013	1.29			0.75		2.00	4.00	0.28	2.75	3.50		0.75	
UDC014	1.29			0.75		2.00	4.00	0.28	2.75	3.50		0.75	
UDC015	2.19			1.00		3.00	5.00	0.32	2.00	2.00		0.60	0.40
UDC016	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
UDC017	2.33			1.00		3.00	6.00	0.34	2.00	2.00		0.50	0.50
UDC018	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
UDC019	0.00			1.00		1.00	3.00	0.00	2.00	2.00		1.00	
UDC020	2.33			1.00		3.00	6.00	0.34	2.00	2.00		0.50	0.50
VEPCON	2.19			1.00		3.00	5.00	0.32	2.00	2.00	0.20	0.80	
VEPCOS	2.33			1.00		3.00	6.00	0.34	1.83	2.00	0.17	0.83	
WBBARN	3.06	0.33		0.67	0.17	4.00	6.00	0.33	3.33	4.25	0.17	0.67	
WBCORN	3.11	0.29		0.71		4.00	7.00	0.34	3.14	3.00		0.57	0.14
WBROAD	1.47			1.00		2.00	3.00	0.32	1.67	1.50		1.00	
WYBEAV	2.43			0.60		3.00	5.00	0.35	3.20	3.00		0.40	0.20

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix O. Continued.

Site Code	Diversity	Sensitive	SOC	Tolerant	WOFRchorus	Richness	Abundance	Evenness	AQAI[a]	CoC[b]	UPLSens[c]	UPLTol[d]	Fish[e]
WYCHWE	4.00	0.11	0.78	6.00	9.00	0.29	3.11	3.50	0.22	0.22	0.33		
WYHCEA	4.68	0.31		0.62	0.15	8.00	13.00	0.25	3.85	3.63	0.31	0.23	0.23
WYINTR	2.53			1.00		3.00	6.00	0.37	2.00	2.00	0.33	0.67	
WYTHOR	3.57			0.71		5.00	7.00	0.31	2.86	2.60	0.14	0.43	0.14

[a] Amphibian Quality Assessment Index (Miccahion 2002).

[b] Average coefficient of conservatism.

[c] Proportion of upland sensitive species.

[d] Proportion of upland tolerant species.

[e] Proportion of fish tolerant species.

Appendix P. Anuran community sampling summary statistics of metric scores statewide and by ecoregion used to form acoustically-based anuran indices of biological integrity (AA-IBI) for wetlands in West Virginia, USA 2005-2006.

Statewide Anuran Sampling (N=133)

	ANURAN RELDIV	PCTANUSE NS	PCTANSO C	PCTAN TOL	PCTWOFR CHORU	ANURAN RICHNE	TOTAL ANUR ANR	SHAEVE NESS	AQAI
Minimum	0	0	0	0.2	0	1	2	0	1.5
Maximum	4.678	0.571	0.5	1	0.4	8	14	0.366	5.2
Mean	2.671	0.159	0.027	0.738	0.099	3.812	6.128	0.296	3.076
Std. Error	0.097	0.014	0.007	0.017	0.011	0.145	0.243	0.007	0.074

	ANURAN COC	ANPCTUPL SENS	ANPCTUPL TOL	ANPCT FISH
Minimum	1.5	0	0	0
Maximum	5.25	0.429	1	1
Mean	3.217	0.126	0.51	0.173
Std. Error	0.081	0.012	0.02	0.014

Allegheny Highland Anuran Sampling (N=59)

	ANURAN RELDIV	PCTANUSE NS	PCTANSO C	PCTAN TOL	PCTWOFR CHORU	ANURAN RICHNE	TOTAL ANUR ANR	SHAEVE NESS	AQAI
Minimum	0	0	0	0.444	0	1	2	0	1.5
Maximum	4.678	0.5	0.5	1	0.333	8	13	0.366	4.5
Mean	2.269	0.112	0.031	0.797	0.083	3.271	5.373	0.276	2.816
Std. Error	0.159	0.02	0.013	0.026	0.015	0.211	0.332	0.015	0.113

	ANURAN COC	ANPCTUPL SENS	ANPCTUPL TOL	ANPCT FISH
Minimum	1.5	0	0.222	0
Maximum	5.25	0.429	1	0.5
Mean	2.943	0.114	0.601	0.134
Std. Error	0.125	0.017	0.032	0.019

Appendix P. Continued.

Ridge and Valley Anuran Sampling (N=21)

	ANURAN RELDIV	PCTANUSE NS	PCTANSO C	PCTAN TOL	PCTWOFR CHORU	ANURAN RICHNE	TOTAL ANUR ANR	SHAEVE NESS	AQAI
Minimum	0	0	0	0.5	0	1	2	0	1.667
Maximum	3.851	0.429	0.2	1	0.4	6	11	0.366	4.167
Mean	2.386	0.223	0.01	0.733	0.138	3.238	5.286	0.312	3.155
Std. Error	0.199	0.034	0.01	0.033	0.032	0.266	0.512	0.016	0.162

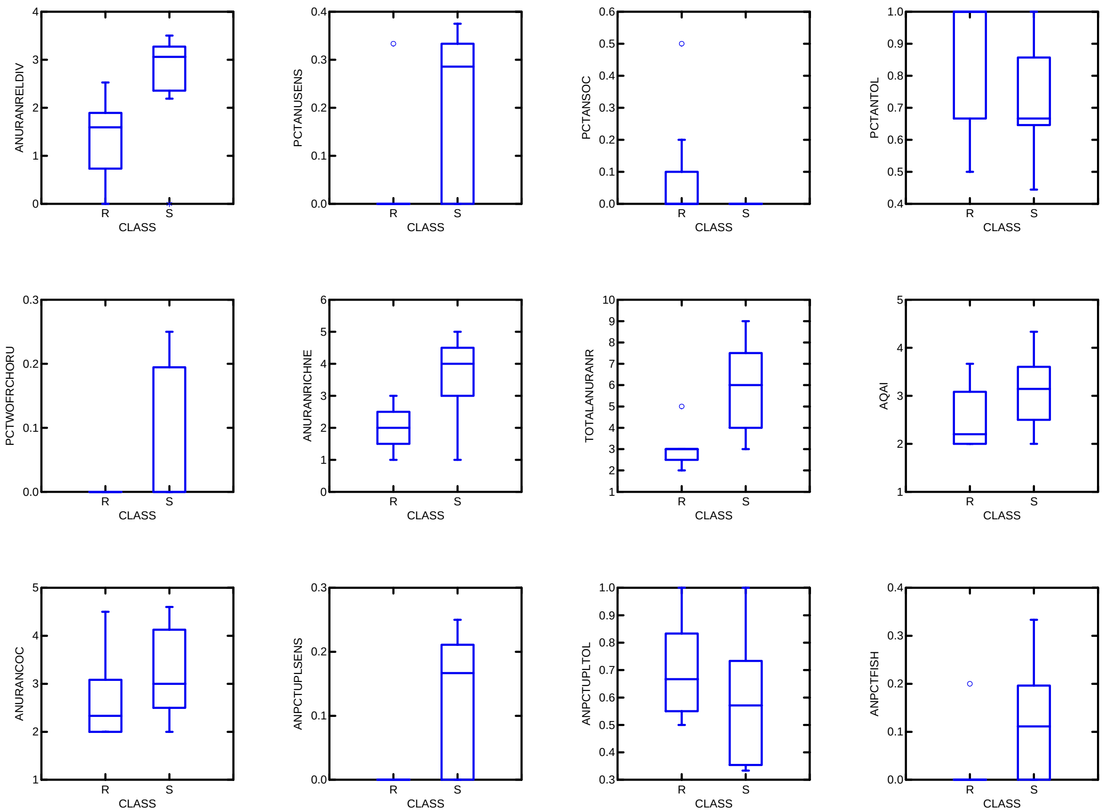
	ANURAN COC	ANPCTUPL SENS	ANPCTUPL TOL	ANPCT FISH
Minimum	1.5	0	0.333	0
Maximum	4.667	0.4	1	0.5
Mean	3.425	0.138	0.583	0.14
Std. Error	0.204	0.032	0.038	0.03

Western Allegheny Plateau Anuran Sampling (N=53)

	ANURAN RELDIV	PCTANUSE NS	PCTANSO C	PCTAN TOL	PCTWOFR CHORU	ANURAN RICHNE	TOTAL ANUR ANR	SHAEVE NESS	AQAI
Minimum	1.466	0	0	0.2	0	2	2	0.247	1.6
Maximum	4.557	0.571	0.5	1	0.4	8	14	0.366	5.2
Mean	3.231	0.187	0.028	0.673	0.102	4.642	7.302	0.311	3.334
Std. Error	0.114	0.021	0.011	0.025	0.017	0.214	0.393	0.004	0.109

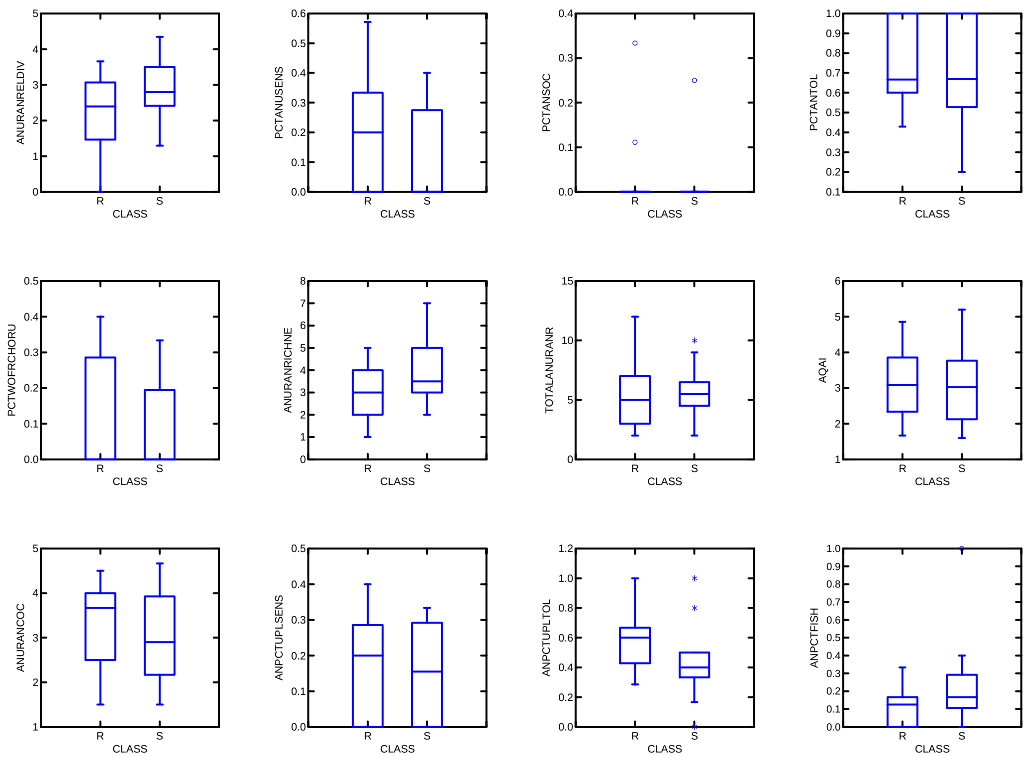
	ANURAN COC	ANPCTUPL SENS	ANPCTUPL TOL	ANPCT FISH
Minimum	1.667	0	0	0
Maximum	4.667	0.4	0.8	1
Mean	3.44	0.136	0.38	0.229
Std. Error	0.115	0.019	0.022	0.024

Appendix Q. Anuran community metrics box-and-whisker results and narrative descriptions for floodplain wetlands (N= 14). Classifications are reference (R) and stressed (S).



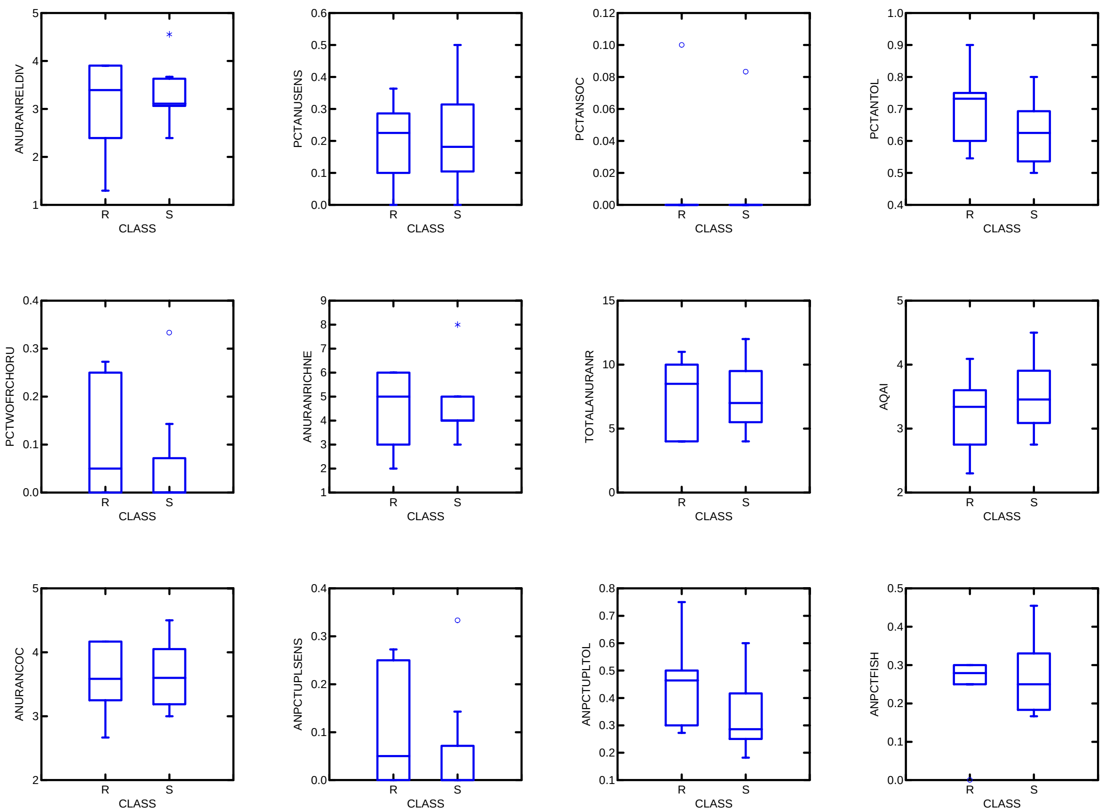
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	good
PCTANUSENS	Proportionsensitive anurans	poor
PCTANSOC	Proportionspecies of concern anurans	poor
PCTANTOL	Proportiontolerant anurans	fair
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	good
TOTALANURANRE	Total anuran relative abundance	good
AQAI	Amphibian Quality Assessment Index score	fair
ANURANCOC	Average coefficient of conservatism	fair
ANPCTUPLSENS	Proportionanuran upland sensitive	poor
ANPCTUPLTOL	Proportionanuran upland tolerant	poor
ANPCTFISH	Proportionanuran fish tolerant	poor

Appendix R. Anuran community metrics box-and-whisker results and narrative descriptions for depressionalwetlands (N= 33). Classifications are reference (R) and stressed (S).



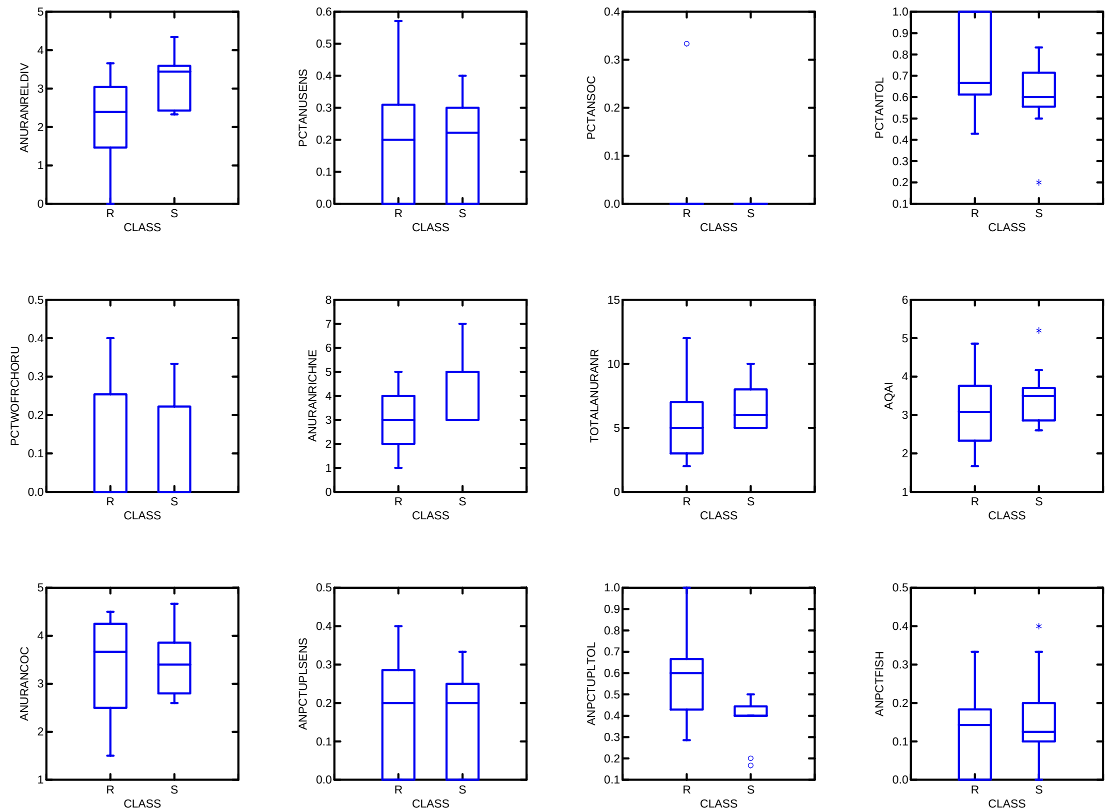
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	fair
PCTANUSENS	Proportion sensitive anurans	poor
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	poor
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	fair
TOTALANURANRE	Total anuran relative abundance	poor
AQAI	Amphibian Quality Assessment Index score	poor
ANURANCOC	Average coefficient of conservatism	poor
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	good
ANPCTFISH	Proportion anuran fish tolerant	fair

Appendix S. Anuran community metrics box-and-whisker results and narrative descriptions for impoundment wetlands (N= 13). Classifications are reference (R) and stressed (S).



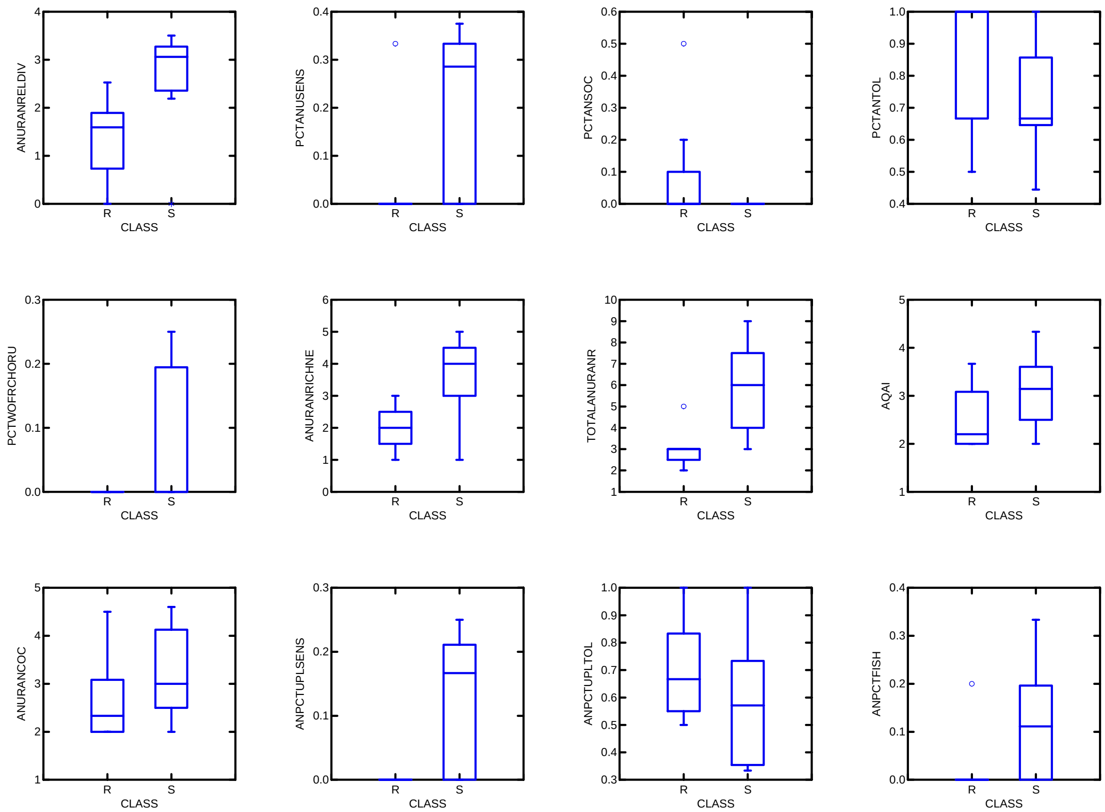
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	poor
PCTANUSENS	Proportion sensitive anurans	poor
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	fair
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	poor
TOTALANURANRE	Total anuran relative abundance	poor
AQAI	Amphibian Quality Assessment Index score	poor
ANURANCOC	Average coefficient of conservatism	poor
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	poor
ANPCTFISH	Proportion anuran fish tolerant	poor

Appendix T. Anuran community metrics box-and-whisker results and narrative descriptions for riparian depression wetlands (N= 24). Classifications are reference (R) and stressed (S).



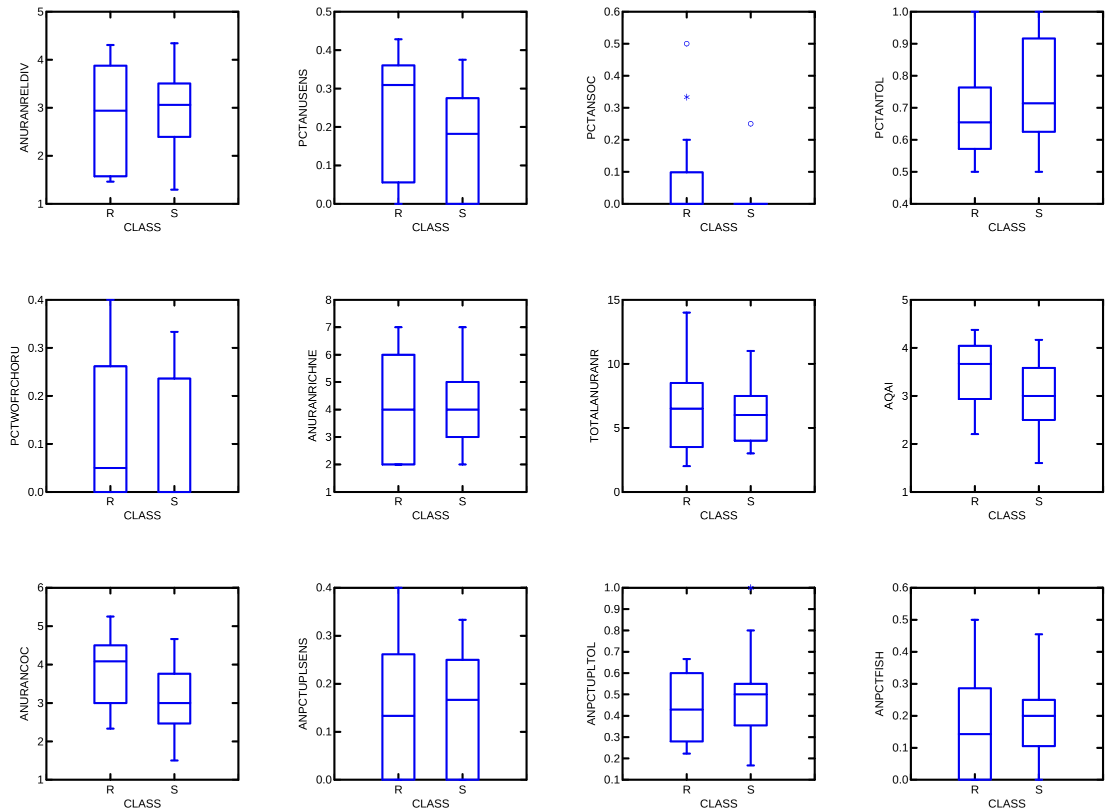
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	good
PCTANUSENS	Proportion sensitive anurans	poor
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	poor
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	fair
TOTALANURANRE	Total anuran relative abundance	poor
AQAI	Amphibian Quality Assessment Index score	poor
ANURANCOC	Average coefficient of conservatism	poor
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	poor
ANPCTFISH	Proportion anuran fish tolerant	poor

Appendix U. Anuran community metrics box-and-whisker results and narrative descriptions for headwater floodplain wetlands (N= 12). Classifications are reference (R) and stressed (S).



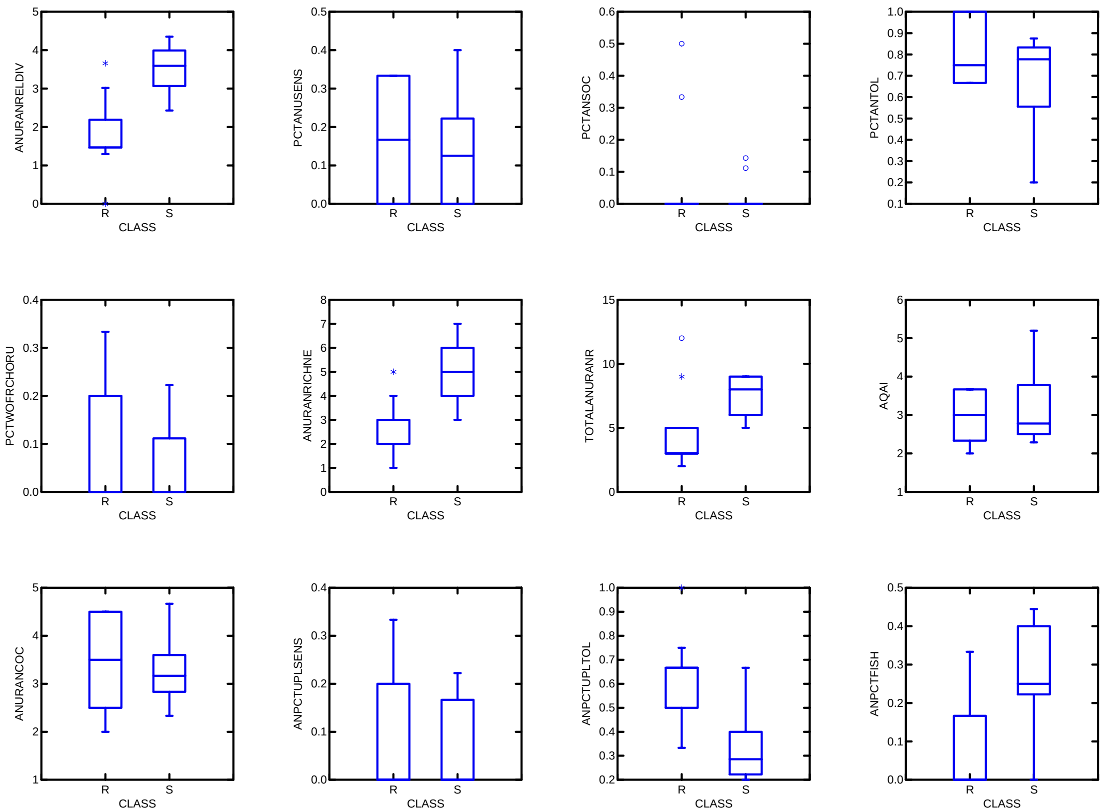
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	good
PCTANUSENS	Proportion sensitive anurans	poor
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	poor
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	good
TOTALANURANRE	Total anuran relative abundance	good
AQAI	Amphibian Quality Assessment Index score	poor
ANURANCOC	Average coefficient of conservatism	poor
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	poor
ANPCTFISH	Proportion anuran fish tolerant	poor

Appendix V. Anuran community metrics box-and-whisker results and narrative descriptions for emergent wetlands (N= 35). Classifications are reference (R) and stressed (S).



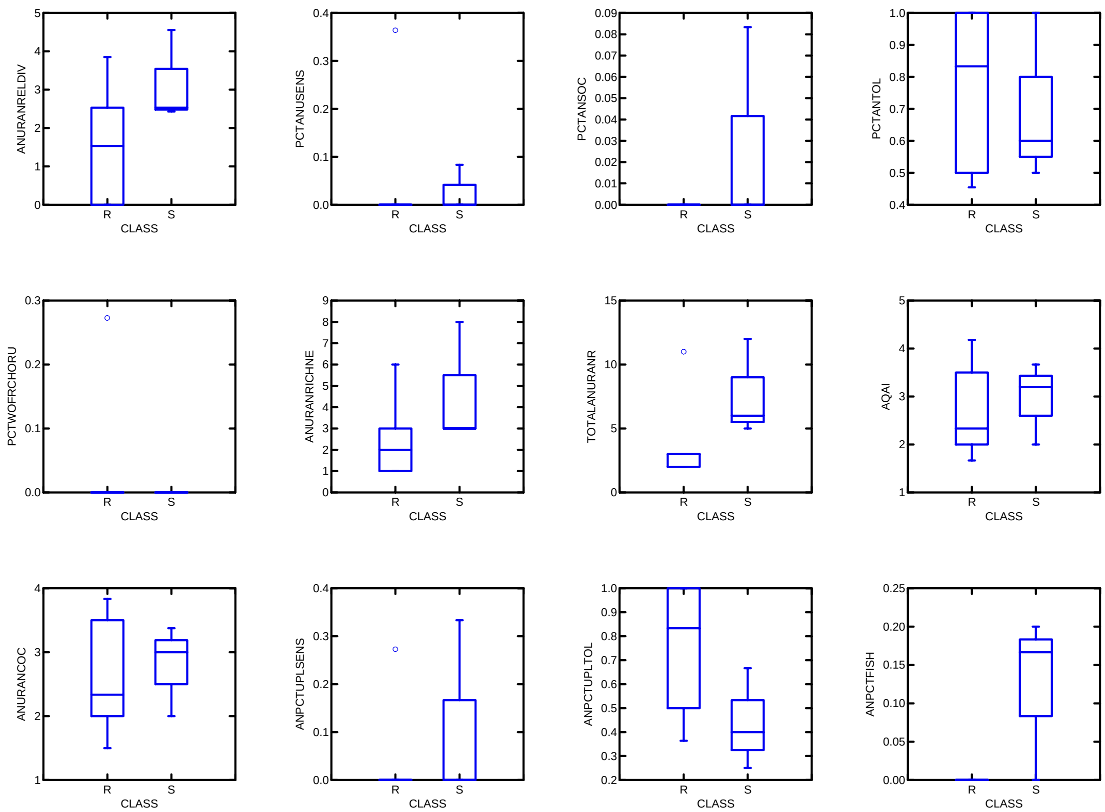
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	poor
PCTANUSENS	Proportion sensitive anurans	fair
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	poor
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	poor
TOTALANURANRE	Total anuran relative abundance	poor
AQAI	Amphibian Quality Assessment Index score	fair
ANURANCOC	Average coefficient of conservatism	fair
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	poor
ANPCTFISH	Proportion anuran fish tolerant	poor

Appendix W. Anuran community metrics box-and-whisker results and narrative descriptions for scrub-shrub wetlands (N= 18). Classifications are reference (R) and stressed (S).



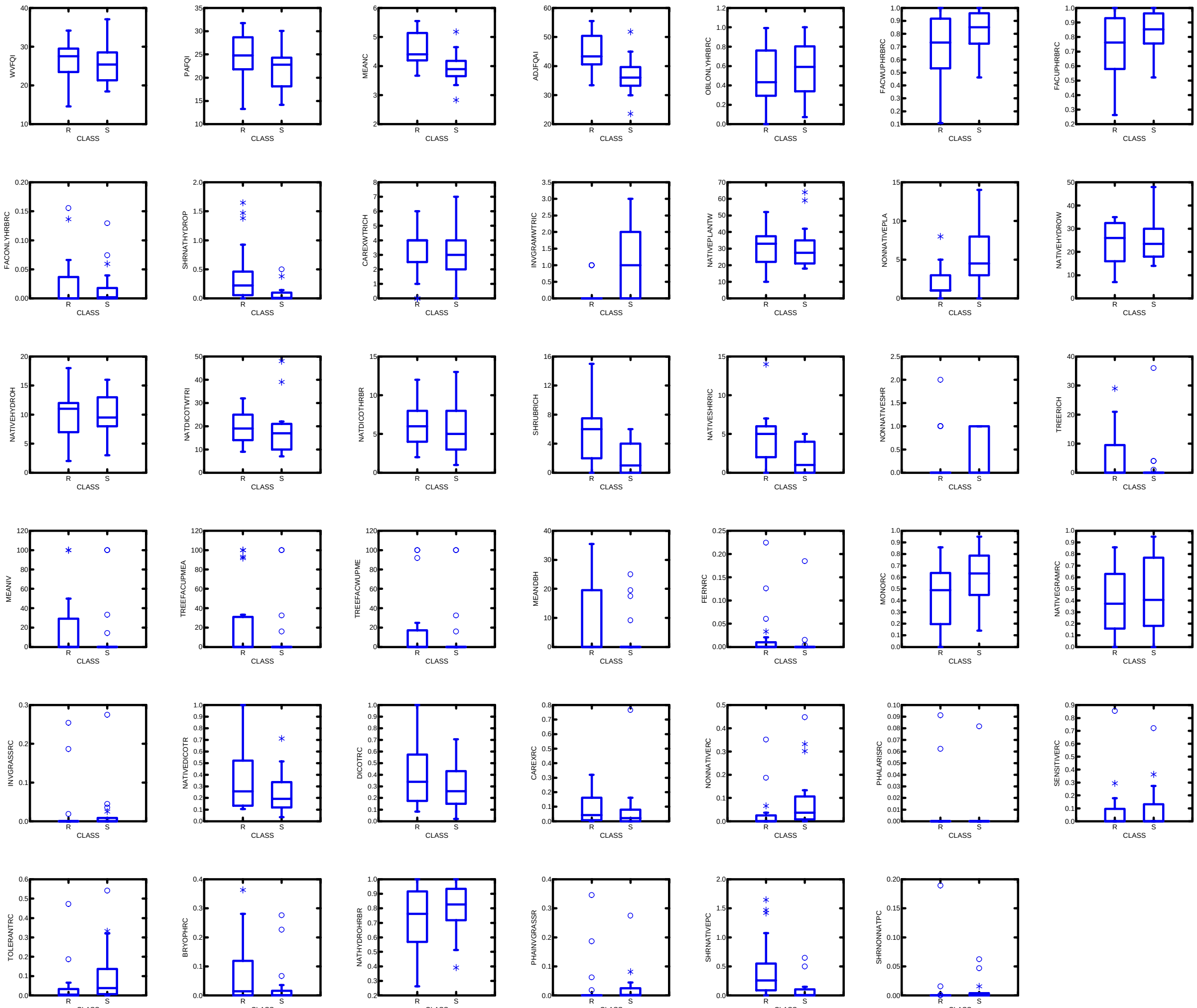
Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	good
PCTANUSENS	Proportion sensitive anurans	poor
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	poor
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	good
TOTALANURANRE	Total anuran relative abundance	good
AQAI	Amphibian Quality Assessment Index score	poor
ANURANCOC	Average coefficient of conservatism	poor
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	poor
ANPCTFISH	Proportion anuran fish tolerant	good

Appendix X. Anuran community metrics box-and-whisker results and narrative descriptions for forested wetlands (N=9). Classifications are reference (R) and stressed (S).



Metric Code	Metrics	Rating
ANURANRELDIV	Anuran relative diversity	good
PCTANUSENS	Proportion sensitive anurans	poor
PCTANSOC	Proportion species of concern anurans	poor
PCTANTOL	Proportion tolerant anurans	fair
PCTWOFRCHORU	Proportion of wood frog abundance	poor
ANURANRICHNE	Anuran richness	good
TOTALANURANRE	Total anuran relative abundance	good
AQAI	Amphibian Quality Assessment Index score	fair
ANURANCOC	Average coefficient of conservatism	fair
ANPCTUPLSENS	Proportion anuran upland sensitive	poor
ANPCTUPLTOL	Proportion anuran upland tolerant	poor
ANPCTFISH	Proportion anuran fish tolerant	excellent

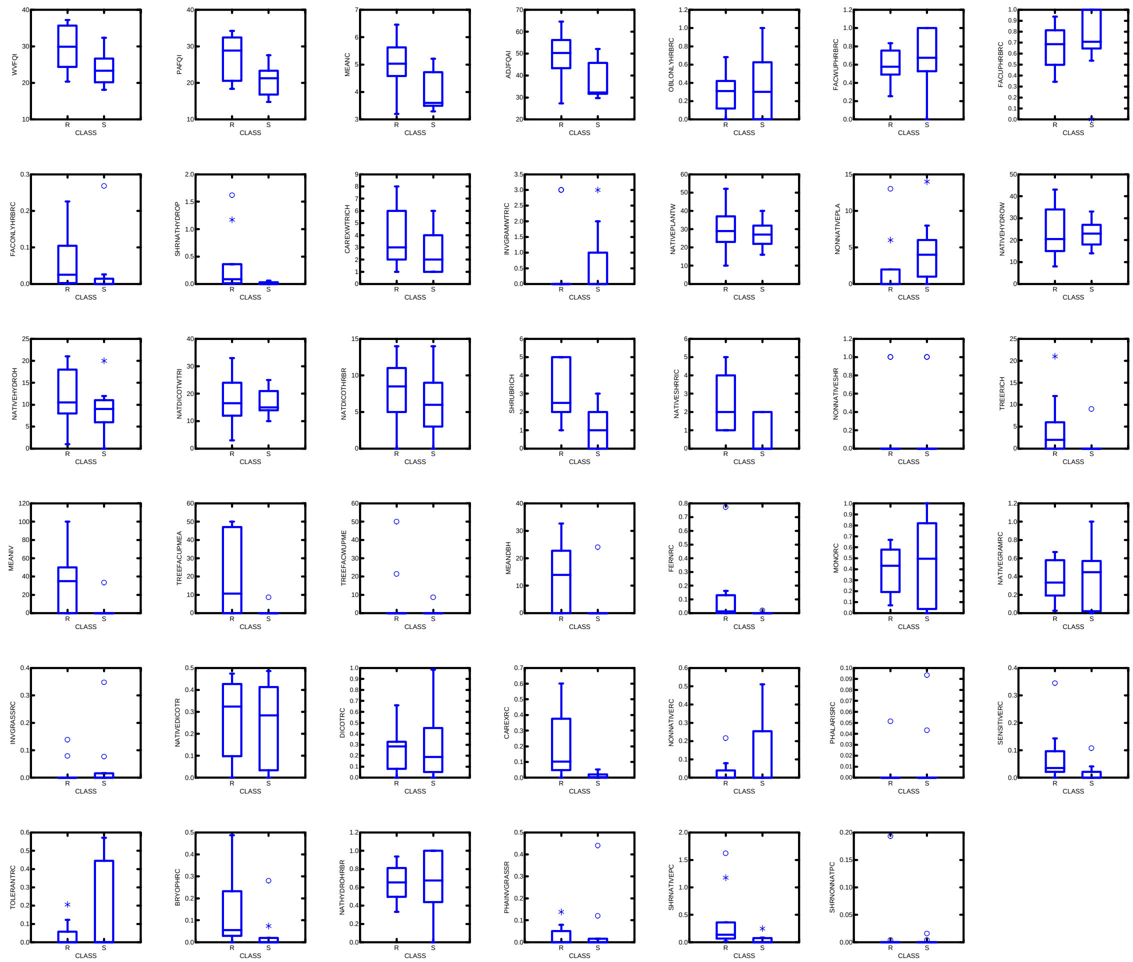
Appendix Y. Vegetation community metrics box-and-whisker results and narrative descriptions for depressional wetlands (N=37). Classifications are reference (R) and stressed (S).



Appendix Y. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	poor
PAFQI	Pennsylvania Floristic Quality Index	fair
MEANC	Mean Coefficient of Conservatism	good
ADJFQAI	Adjusted Floristic Quality Index	good
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	poor
CAREXWTRICH	Carex walk-through richness	poor
INVGRAMWTRC	Invasive graminoid walk-through richness	poor
NATIVEPLANTW	Native plant walk-through richness	poor
NONNNATIVEPLANT	Non-native plant walk-through richness	good
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	poor
NATDICOTWTRI	Native dicot walk-through richness	poor
NATDICOTHRB	Native dicot herbaceous richness	poor
SHRUBRICH	Shrub richness	good
NATIVESHRRIC	Native shrub richness	good
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	NA
MEANIV	Mean Importance Value	poor
TREEFACUPMEA	Tree facultative and wetter mean IV	poor
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	poor
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	fair
NATIVEGRAMRC	Native graminoid relative cover	poor
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	poor
DICOTRC	Dicot relative cover	poor
CAREXRC	Carex relative cover	poor
NONNATIVERC	Non-native relative cover	poor
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	poor
TOLERANTRC	Tolerant species relative cover	good
BRYOPHRC	Bryophyte relative cover	poor
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	poor
SHRNATIVEPC	Native shrub percent cover	good
SHRNONNATPC	Non-native shrub percent cover	poor

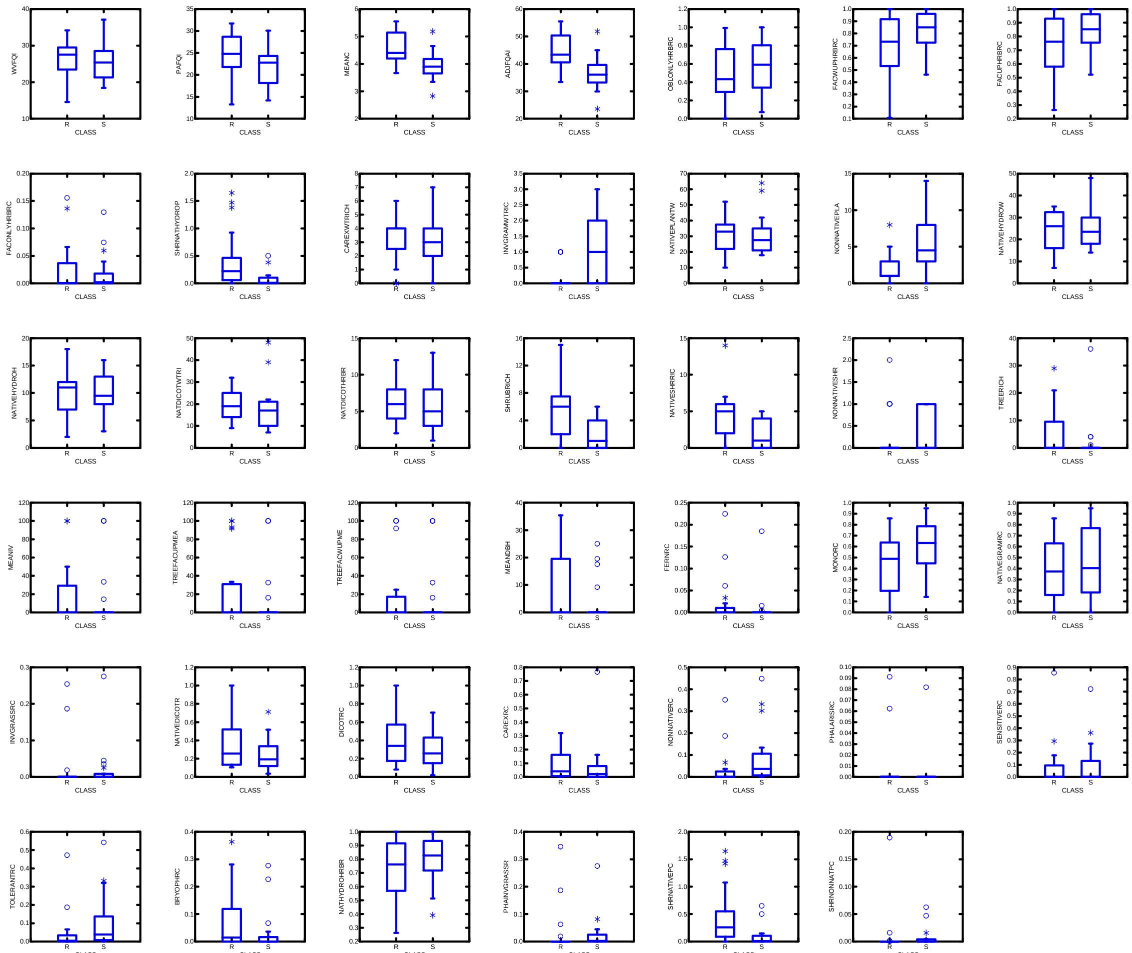
Appendix Z. Vegetation community metrics box-and-whisker results s and narrative descriptions for floodplain wetlands (N=19). Classifications are reference (R) and stressed (S).



Appendix Z. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	good
PAFQI	Pennsylvania Floristic Quality Index	fair
MEANC	Mean Coefficient of Conservatism	good
ADJFQAI	Adjusted Floristic Quality Index	good
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	poor
CAREXWTRICH	Carex walk-through richness	fair
INVGRAMWTRC	Invasive graminoid walk-through richness	poor
NATIVEPLANTW	Native plant walk-through richness	poor
NONNNATIVEPLANT	Non-native plant walk-through richness	good
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	poor
NATDICOTWTRI	Native dicot walk-through richness	poor
NATDICOTHRB	Native dicot herbaceous richness	poor
SHRUBRICH	Shrub richness	good
NATIVESHRRIC	Native shrub richness	good
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	NA
MEANIV	Mean Importance Value	good
TREEFACUPMEA	Tree facultative and wetter mean IV	good
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	good
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	poor
NATIVEGRAMRC	Native graminoid relative cover	poor
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	poor
DICOTRC	Dicot relative cover	poor
CAREXRC	Carex relative cover	good
NONNATIVERC	Non-native relative cover	good
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	good
TOLERANTRC	Tolerant species relative cover	good
BRYOPHRC	Bryophyte relative cover	good
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	poor
SHRNATIVEPC	Native shrub percent cover	good
SHRNONNATPC	Non-native shrub percent cover	poor

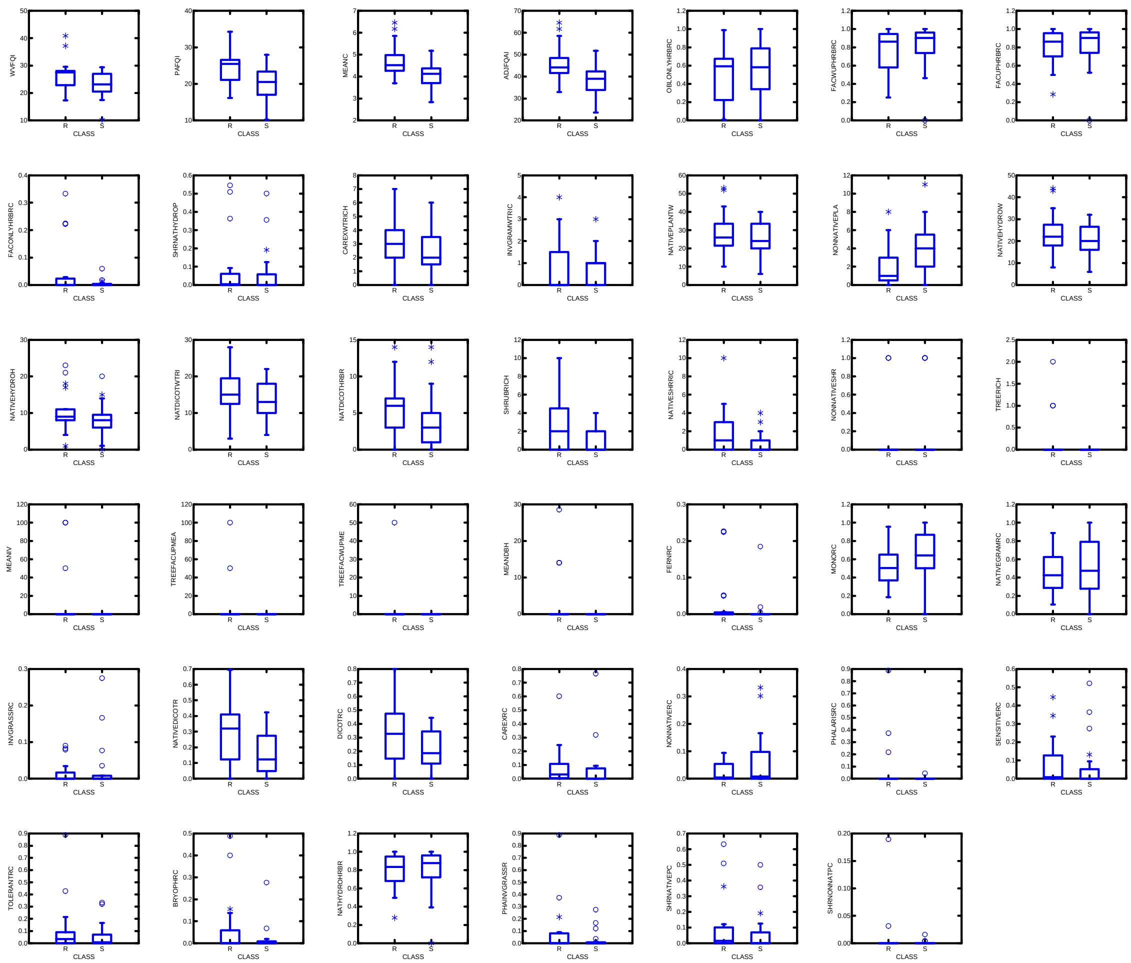
Appendix AA. Vegetation community metrics box-and-whisker results and narrative descriptions for impoundment wetlands (N=13). Classifications are reference (R) and stressed (S).



Appendix AA. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	good
PAFQI	Pennsylvania Floristic Quality Index	good
MEANC	Mean Coefficient of Conservatism	good
ADJFQAI	Adjusted Floristic Quality Index	good
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	poor
CAREXWTRICH	Carex walk-through richness	poor
INVGRAMWTRC	Invasive graminoid walk-through richness	poor
NATIVEPLANTW	Native plant walk-through richness	poor
NONNNATIVEPLANT	Non-native plant walk-through richness	poor
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	good
NATDICOTWTRI	Native dicot walk-through richness	poor
NATDICOTHRB	Native dicot herbaceous richness	good
SHRUBRICH	Shrub richness	poor
NATIVESHRRIC	Native shrub richness	poor
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	NA
MEANIV	Mean Importance Value	poor
TREEFACUPMEA	Tree facultative and wetter mean IV	poor
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	poor
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	good
NATIVEGRAMRC	Native graminoid relative cover	poor
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	poor
DICOTRC	Dicot relative cover	good
CAREXRC	Carex relative cover	good
NONNATIVERC	Non-native relative cover	poor
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	poor
TOLERANTRC	Tolerant species relative cover	poor
BRYOPHRC	Bryophyte relative cover	poor
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	poor
SHRNATIVEPC	Native shrub percent cover	poor
SHRNONNATPC	Non-native shrub percent cover	poor

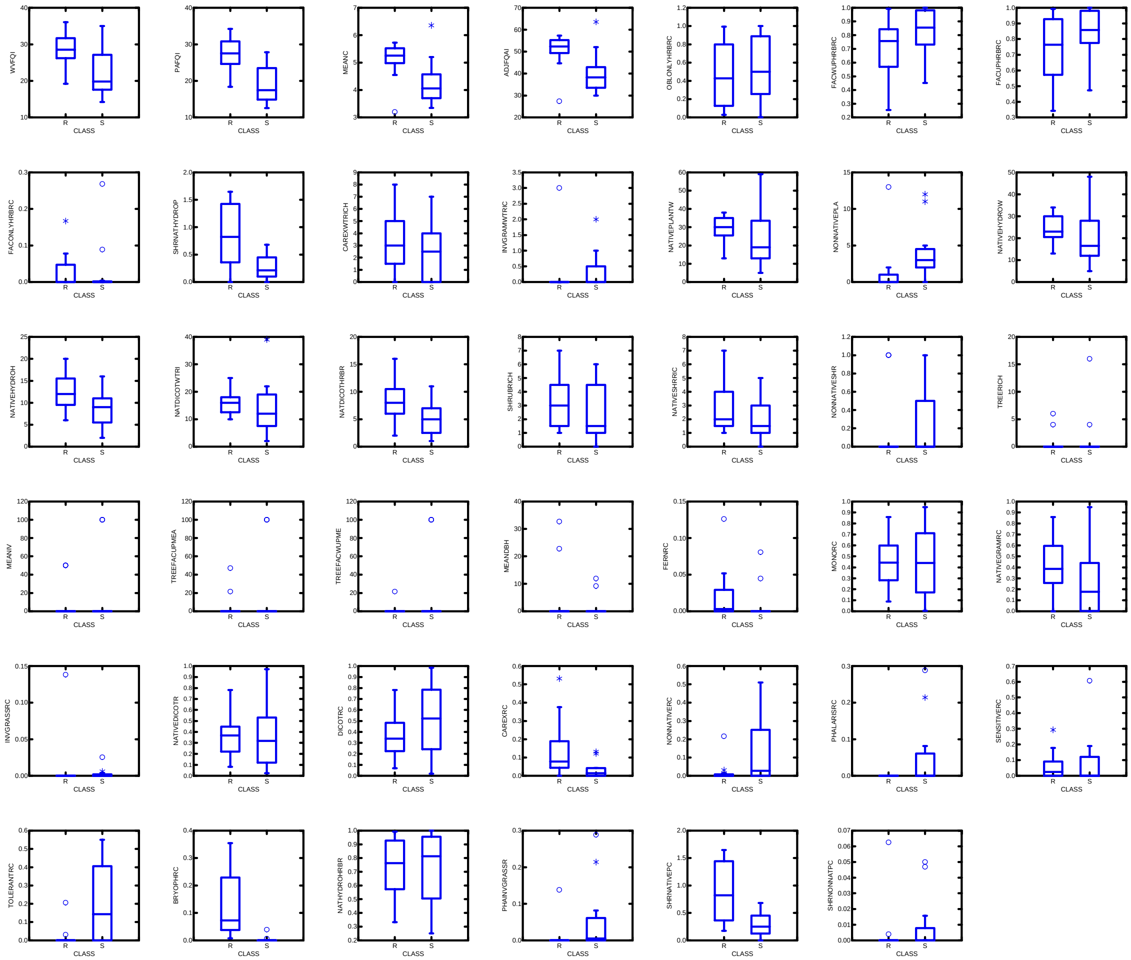
Appendix AB. Vegetation community metrics box-and-whisker results and narrative descriptions for emergent wetlands (N=38). Classifications are reference (R) and stressed (S).



Appendix AB. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	good
PAFQI	Pennsylvania Floristic Quality Index	good
MEANC	Mean Coefficient of Conservatism	good
ADJFQAI	Adjusted Floristic Quality Index	good
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	poor
CAREXWTRICH	Carex walk-through richness	fair
INVGRAMWTRC	Invasive graminoid walk-through richness	poor
NATIVEPLANTW	Native plant walk-through richness	poor
NONNNATIVEPLANT	Non-native plant walk-through richness	good
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	poor
NATDICOTWTRI	Native dicot walk-through richness	fair
NATDICOTHRB	Native dicot herbaceous richness	good
SHRUBRICH	Shrub richness	poor
NATIVESHRRIC	Native shrub richness	poor
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	NA
MEANIV	Mean Importance Value	poor
TREEFACUPMEA	Tree facultative and wetter mean IV	poor
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	poor
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	fair
NATIVEGRAMRC	Native graminoid relative cover	poor
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	good
DICOTRC	Dicot relative cover	poor
CAREXRC	Carex relative cover	poor
NONNATIVERC	Non-native relative cover	poor
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	poor
TOLERANTRC	Tolerant species relative cover	poor
BRYOPHRC	Bryophyte relative cover	poor
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	poor
SHRNATIVEPC	Native shrub percent cover	poor
SHRNONNATPC	Non-native shrub percent cover	poor

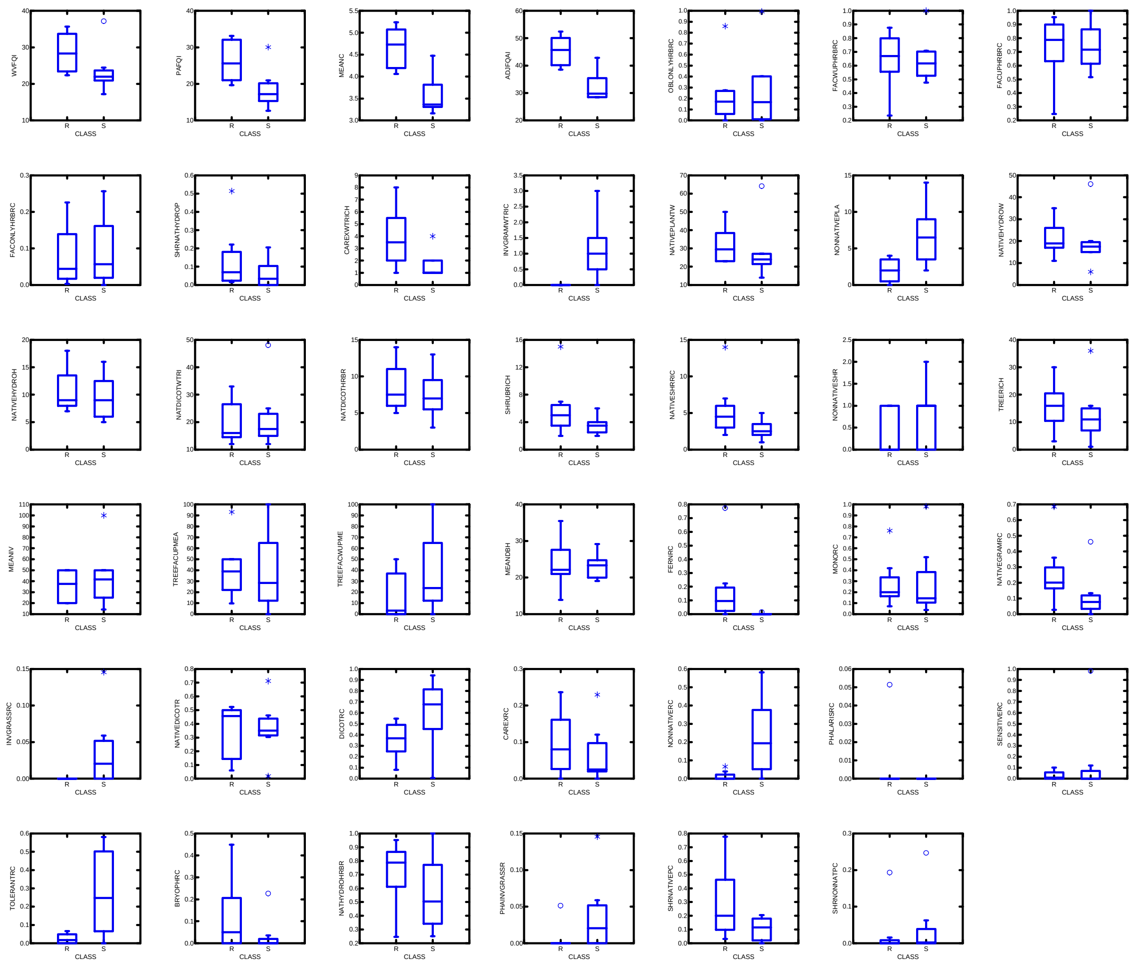
Appendix AC. Vegetation community metrics box-and-whisker results and narrative descriptions for scrub-shrub wetlands (N=23). Classifications are reference (R) and stressed (S).



Appendix AC. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	good
PAFQI	Pennsylvania Floristic Quality Index	good
MEANC	Mean Coefficient of Conservatism	good
ADJFQAI	Adjusted Floristic Quality Index	good
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	good
CAREXWTRICH	Carex walk-through richness	poor
INVGRAMWTRC	Invasive graminoid walk-through richness	poor
NATIVEPLANTW	Native plant walk-through richness	fair
NONNNATIVEPLANT	Non-native plant walk-through richness	good
NATIVEHYDROW	Native hydrophyte walk-through richness	fair
NATIVEHYDROH	Native hydrophyte herbaceous richness	good
NATDICOTWTRI	Native dicot walk-through richness	fair
NATDICOTHRB	Native dicot herbaceous richness	poor
SHRUBRICH	Shrub richness	poor
NATIVESHRRIC	Native shrub richness	poor
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	NA
MEANIV	Mean Importance Value	poor
TREEFACUPMEA	Tree facultative and wetter mean IV	poor
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	poor
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	poor
NATIVEGRAMRC	Native graminoid relative cover	fair
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	poor
DICOTRC	Dicot relative cover	fair
CAREXRC	Carex relative cover	good
NONNATIVERC	Non-native relative cover	poor
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	poor
TOLERANTRC	Tolerant species relative cover	good
BRYOPHRC	Bryophyte relative cover	good
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	poor
SHRNATIVEPC	Native shrub percent cover	good
SHRNONNATPC	Non-native shrub percent cover	poor

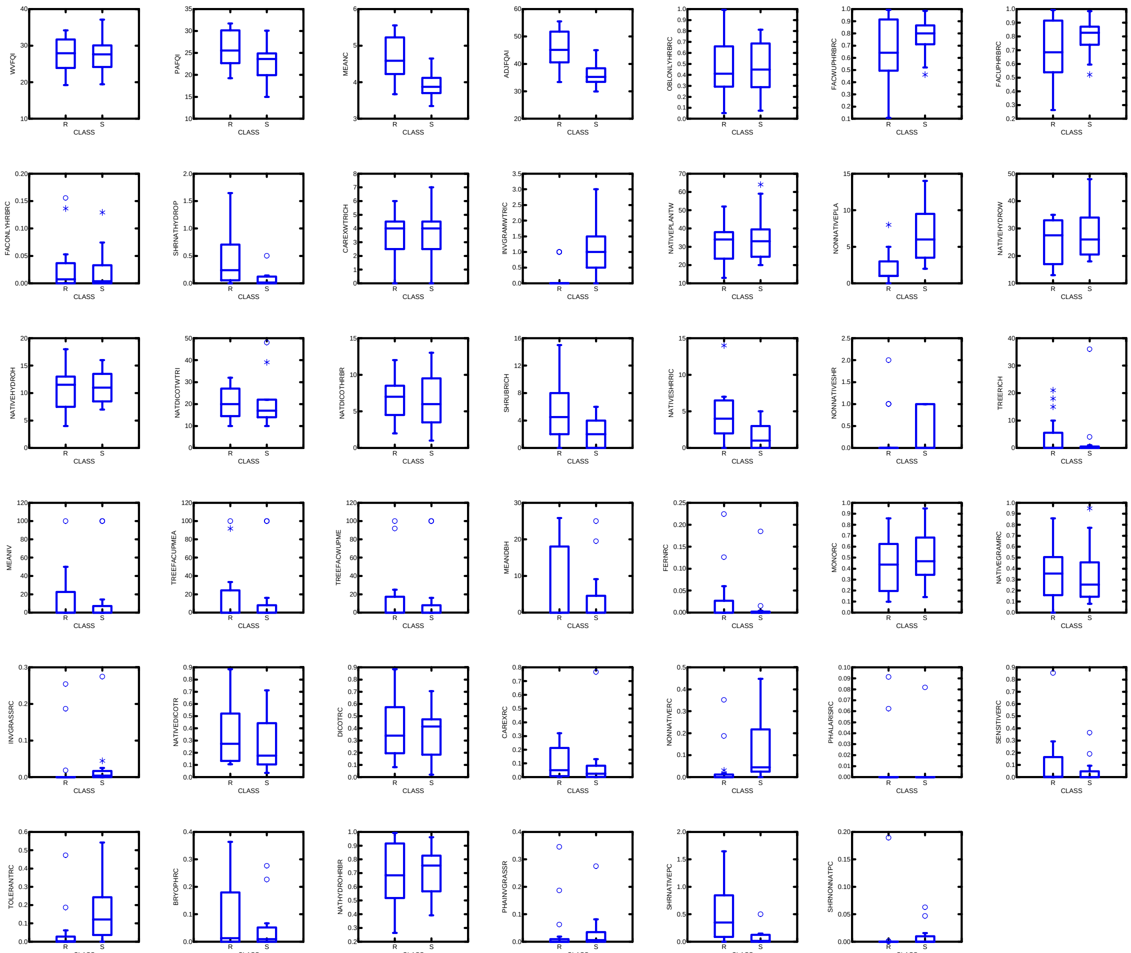
Appendix AD. Vegetation community metrics box-and-whisker results and narrative descriptions for forested wetlands (N=16). Classifications are reference (R) and stressed (S).



Appendix AD. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	good
PAFQI	Pennsylvania Floristic Quality Index	good
MEANC	Mean Coefficient of Conservatism	good
ADJFQAI	Adjusted Floristic Quality Index	good
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	poor
CAREXWTRICH	Carex walk-through richness	good
INVGRAMWTRC	Invasive graminoid walk-through richness	good
NATIVEPLANTW	Native plant walk-through richness	good
NONNNATIVEPLANT	Non-native plant walk-through richness	good
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	poor
NATDICOTWTRI	Native dicot walk-through richness	poor
NATDICOTHRB	Native dicot herbaceous richness	poor
SHRUBRICH	Shrub richness	fair
NATIVESHRRIC	Native shrub richness	good
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	NA
MEANIV	Mean Importance Value	poor
TREEFACUPMEA	Tree facultative and wetter mean IV	poor
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	poor
FERNRC	Fern relative cover	good
MONORC	Monocot relative cover	fair
NATIVEGRAMRC	Native graminoid relative cover	good
INVGRASSRC	Invasive grass relative cover	good
NATIVEDICOTR	Native dicot relative cover	fair
DICOTRC	Dicot relative cover	good
CAREXRC	Carex relative cover	fair
NONNATIVERC	Non-native relative cover	good
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	poor
TOLERANTRC	Tolerant species relative cover	good
BRYOPHRC	Bryophyte relative cover	good
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	good
PHAINVGRASSR	Phalaris and invasive grasses relative cover	good
SHRNATIVEPC	Native shrub percent cover	fair
SHRNONNATPC	Non-native shrub percent cover	poor

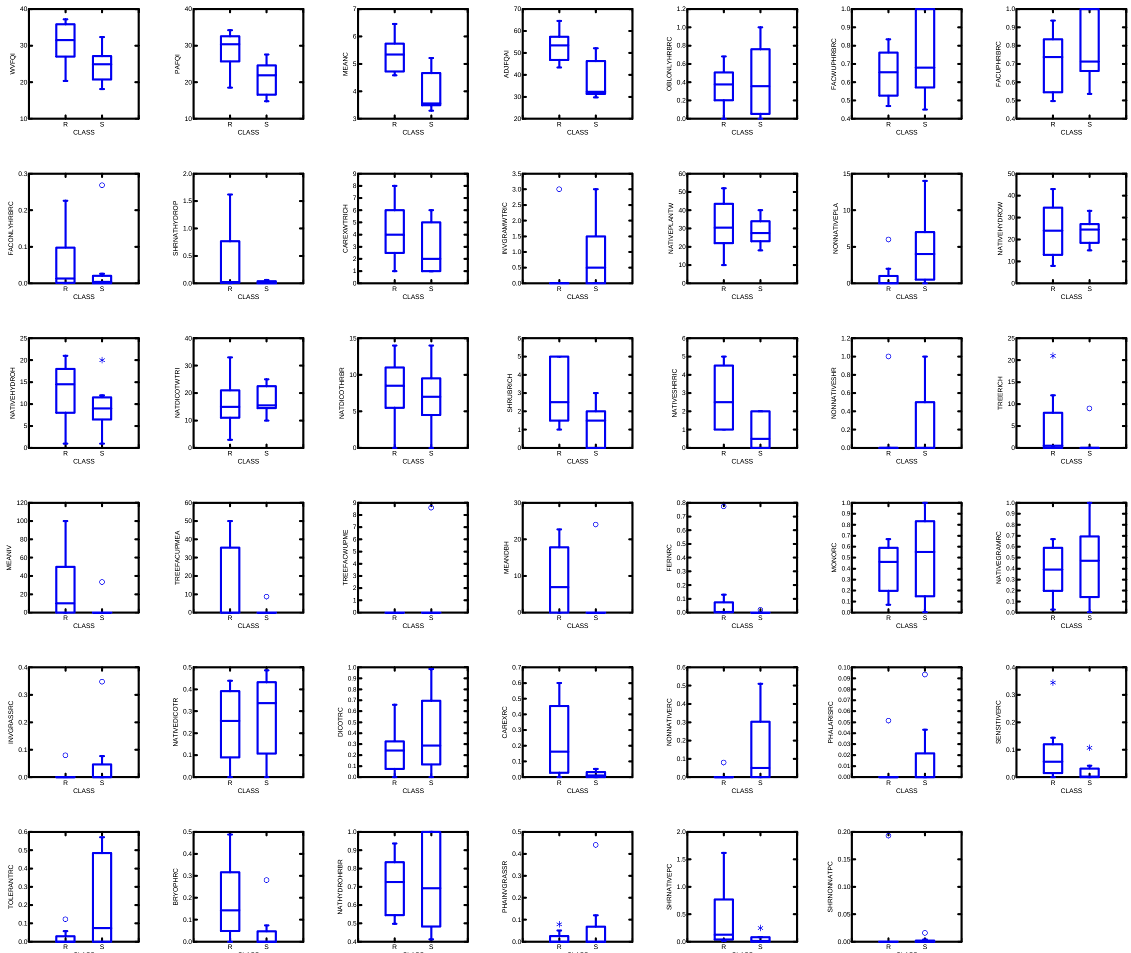
Appendix AE. Vegetation community metrics box-and-whisker results and narrative descriptions for riparian depression wetlands (N=27). Classifications are reference (R) and stressed (S).



Appendix AE. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	poor
PAFQI	Pennsylvania Floristic Quality Index	poor
MEANC	Mean Coefficient of Conservatism	excellent
ADJFQAI	Adjusted Floristic Quality Index	excellent
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	fair
FACUPHRBRC	Facultative and wetter herbaceous relative cover	fair
FACONLYHRBRC	Facultative only herbaceous relative cover	poor
SHRNATHYDROP	Native shrub hydrophyte percent cover	fair
CAREXWTRICH	Carex walk-through richness	poor
INVGRAMWTRC	Invasive graminoid walk-through richness	fair
NATIVEPLANTW	Native plant walk-through richness	fair
NONNNATIVEPLANT	Non-native plant walk-through richness	excellent
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	poor
NATDICOTWTRI	Native dicot walk-through richness	poor
NATDICOTHRB	Native dicot herbaceous richness	poor
SHRUBRICH	Shrub richness	fair
NATIVESHRRIC	Native shrub richness	good
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	poor
MEANIV	Mean Importance Value	poor
TREEFACUPMEA	Tree facultative and wetter mean IV	poor
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	poor
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	poor
NATIVEGRAMRC	Native graminoid relative cover	poor
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	poor
DICOTRC	Dicot relative cover	poor
CAREXRC	Carex relative cover	poor
NONNATIVERC	Non-native relative cover	fair
PHALARISRC	Phalaris relative cover	poor
SENSITIVERC	Sensitive species relative cover	poor
TOLERANTRC	Tolerant species relative cover	good
BRYOPHRC	Bryophyte relative cover	poor
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	poor
SHRNATIVEPC	Native shrub percent cover	good
SHRNONNATPC	Non-native shrub percent cover	poor

Appendix AF. Vegetation community metrics box-and-whisker results and narrative descriptions for headwater floodplain wetlands (N=16). Classifications are reference (R) and stressed (S).



Appendix AF. Continued.

Metric Code	Metric Description	Rating
WVFQI	West Virginia Floristic Quality Index	excellent
PAFQI	Pennsylvannia Floristic Quality Index	excellent
MEANC	Mean Coefficient of Conservatism	excellent
ADJFQAI	Adjusted Floristic Quality Index	excellent
OBLONLYHRBRC	Obligate only Herbaceous relative cover	poor
FACWUPHRBRC	Facultative wet and wetter herbaceous relative cover	poor
FACUPHRBRC	Facultative and wetter herbaceous relative cover	poor
FACONLYHRBRC	Facultative only herbaceous relative cover	fair
SHRNATHYDROP	Native shrub hydrophyte percent cover	fair
CAREXWTRICH	Carex walk-through richness	fair
INVGRAMWTRC	Invasive graminoid walk-through richness	fair
NATIVEPLANTW	Native plant walk-through richness	poor
NONNNATIVEPLANT	Non-native plant walk-through richness	fair
NATIVEHYDROW	Native hydrophyte walk-through richness	poor
NATIVEHYDROH	Native hydrophyte herbaceous richness	fair
NATDICOTWTRI	Native dicot walk-through richness	poor
NATDICOTHRB	Native dicot herbaceous richness	poor
SHRUBRICH	Shrub richness	fair
NATIVESHRRIC	Native shrub richness	good
NONNATIVESHR	Non-native shrub richness	poor
TREERICH	Tree richness	poor
MEANIV	Mean Importance Value	good
TREEFACUPMEA	Tree facultative and wetter mean IV	good
TREEFACWUPME	Tree facultative wet and wetter meanIV	poor
MEANDBH	Mean DBH	good
FERNRC	Fern relative cover	poor
MONORC	Monocot relative cover	poor
NATIVEGRAMRC	Native graminoid relative cover	poor
INVGRASSRC	Invasive grass relative cover	poor
NATIVEDICOTR	Native dicot relative cover	poor
DICOTRC	Dicot relative cover	fair
CAREXRC	Carex relative cover	good
NONNATIVERC	Non-native relative cover	fair
PHALARISRC	Phalaris relative cover	fair
SENSITIVERC	Sensitive species relative cover	fair
TOLERANTRC	Tolerant species relative cover	fair
BRYOPHRC	Bryophyte relative cover	fair
NATHYDROHRBRC	Native hydrophyte herbaceous relative cover	poor
PHAINVGRASSR	Phalaris and invasive grasses relative cover	fair
SHRNATIVEPC	Native shrub percent cover	good
SHRNONNATPC	Non-native shrub percent cover	fair

Appendix AG. Part 1. Relative and percent cover metric values for use in developing class-specific vegetation-based indices of biological integrity (Veg-IBI) in West Virginia, USA, from 2005-2006. Blanks indicate a metric value of zero.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
CFCROS		0.18	0.18		0.77	0.76	0.05	0.01	0.96	0.00	0.34
CFECUR	0.02	0.65	0.65		0.29	0.25	0.02		0.26	0.00	0.61
CFEINC		0.94	0.79				0.32		1.00	0.00	0.19
CFSLCH	0.09	0.89	0.89		0.02	0.02		0.28	0.91	0.28	0.17
CFSLIN		0.95	0.86		0.05	0.05	0.08	0.22	1.00	0.22	0.51
CGBRID	0.02	0.58	0.58		0.31	0.29	0.53		0.94	0.00	1.62
CGCPAS	0.00	0.09	0.09		0.43	0.66	0.05		0.50	0.00	1.18
CGROAD	0.05	0.16	0.16		0.49	0.55	0.11		0.61	0.00	0.63
CGTRHE		0.17	0.17		0.06	0.33	0.01	0.00	0.25	0.00	0.03
CHNEER		0.03			0.97	0.97			1.00	0.00	0.40
CHSACH		0.47	0.47		0.07	0.53	0.13	0.54	0.54	0.08	0.10
CHSAFO		0.04	0.02	0.02	0.41	0.94	0.02	0.57	0.41	0.02	0.08
CHSARR										0.00	
CHTREE		0.31	0.28	0.03	0.34	0.67	0.13	0.33	0.55	0.03	0.34
CHWWBW		0.80			0.20	0.20			1.00	0.00	0.60
CHWWEM		0.42	0.37		0.55	0.55	0.03		1.00	0.00	0.05
CHWWFO		0.98			0.02	0.01			1.00	0.00	0.21
CVABBW	0.05	0.46	0.37	0.09	0.43	0.34	0.24	0.09	0.67	0.09	0.06
CVABCT	0.00	0.50	0.42	0.08	0.36	0.33	0.20	0.12	0.70	0.08	0.02
CVTIMB		0.10	0.10	0.02	0.64	0.58	0.08	0.02	0.63	0.02	0.49
DSPICN		0.45	0.45		0.47	0.47	0.10		0.76	0.00	0.68
DSROAR		0.31	0.31		0.21	0.19	0.00		0.50	0.00	0.12
DSWILD		0.21	0.21		0.43	0.43	0.00		0.40	0.00	0.36
EPCMEM		0.80	0.54		0.16	0.20		0.29	0.97	0.25	
EPCMFO		0.25	0.05	0.15	0.30	0.66	0.03	0.36	0.27	0.15	0.02

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 1. Continued.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
EPDMFO		0.13	0.13		0.36	0.70	0.12	0.43	0.25	0.00	0.19
EPDMPU		0.00	0.00		0.49	0.98	0.00	0.52	0.44	0.00	0.25
EPKYVE		0.78	0.78		0.22	0.21	0.02	0.72	0.93	0.72	
EPRRXC		0.08	0.08		0.34	0.92	0.02	0.58	0.41	0.00	0.03
EPSHEM		0.80	0.80		0.04	0.20		0.73	0.82	0.57	0.09
EPSHSS	0.04	0.20	0.08		0.17	0.71	0.12	0.55	0.25	0.04	0.50
GBBARN		0.96	0.93		0.03	0.03		0.93	1.00	0.93	0.14
GBHOEF		0.12	0.11		0.88	0.88		0.06	0.45	0.06	0.02
GBJENK		0.45			0.55	0.55			0.93	0.00	1.70
GBMAPL					1.00	1.00			1.00	0.00	
GBNOFO		0.63	0.37	0.25	0.10	0.31	0.26	0.47	0.51	0.35	1.07
GBNOSS		0.78	0.67		0.20	0.18	0.01		0.99	0.00	1.23
GBPLOT		0.96	0.89		0.04	0.04		0.89	1.00	0.89	0.02
HCBEAV	0.05	0.43	0.39		0.32	0.51	0.00	0.43	0.71	0.37	0.02
HCMITI		0.78	0.74		0.06	0.20	0.06	0.01	0.81	0.01	0.00
HCPIPE		0.83	0.83		0.01	0.15		0.84	0.85	0.83	0.17
HCRANG		0.68	0.13		0.15	0.27	0.04		0.78	0.00	0.04
HIBRID		0.14	0.08	0.03	0.71	0.70	0.02	0.14	0.76	0.03	0.15
HIGATE	0.16	0.06	0.06		0.51	0.63		0.14	0.74	0.00	0.45
HIJHPK		0.79	0.79		0.21	0.21			1.00	0.00	0.86
HIJHTU	0.00	0.74	0.22		0.12	0.24		0.03	0.72	0.00	0.09
HIPENC		0.60	0.53		0.40	0.40	0.02	0.00	1.00	0.00	0.02
HISEWG	0.05	0.27	0.03	0.23	0.40	0.44		0.35	0.40	0.23	0.36
HITRLR		0.30	0.30		0.09	0.42	0.00	0.33	0.39	0.00	0.50
MCFOUR		0.18	0.16		0.16	0.80	0.13	0.01	0.28	0.00	0.11

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 1. Continued.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
MCMEME		0.74	0.27		0.12	0.19		0.08	0.83	0.00	0.09
MCMFOR		0.38	0.20		0.26	0.22	0.01		0.61	0.00	0.05
MCNPFO		0.76	0.69		0.19	0.17	0.04	0.07	0.88	0.00	0.29
MCPOND		0.72			0.28	0.28			1.00	0.00	
MCPOST		0.46			0.54	0.54			1.00	0.00	0.18
MCTELE		0.98			0.02	0.02			1.00	0.00	0.01
ME5092		0.39	0.18	0.01	0.52	0.52	0.02	0.12	0.80	0.01	0.14
MESCOX		0.34	0.34		0.66	0.66			1.00	0.00	0.02
MESCRO		0.85	0.85		0.15	0.14		0.04	1.00	0.00	0.00
MESCUP		0.60	0.60		0.39	0.39	0.03		1.00	0.00	
MESIGN		0.68	0.68		0.32	0.24			1.00	0.00	
MESILV		0.38	0.38		0.48	0.37	0.18		0.90	0.00	0.40
METETR		0.81	0.81		0.12	0.19			0.93	0.00	
MEWOLF		0.86	0.86		0.14	0.14	0.07		0.99	0.00	1.65
MRBESS		0.87	0.87		0.08	0.04	0.07		0.98	0.00	0.48
MRFARM		0.22	0.14	0.03	0.68	0.69	0.03	0.03	0.83	0.03	0.63
MRFORE	0.06	0.21	0.21		0.52	0.41	0.19		0.76	0.00	0.26
MRSSSS	0.13	0.39	0.39		0.11	0.18	0.23	0.03	0.65	0.00	1.42
MRWEST		0.50	0.45	0.03	0.34	0.32	0.16	0.03	0.57	0.03	0.36
MU55SS		0.38	0.38		0.52	0.57	0.32	0.00	0.90	0.00	0.44
MUDBOA		0.29	0.23		0.66	0.70		0.05	0.95	0.00	
MUDEND		0.52	0.46		0.46	0.43		0.02	0.98	0.00	0.50
MUDRIC		0.42	0.21	0.21	0.27	0.47		0.23	0.48	0.21	0.27
MUDRIP		0.87	0.82	0.06	0.07	0.05	0.02	0.06	0.93	0.06	0.17
MUDTRA		0.41	0.41		0.55	0.57	0.04	0.24	0.95	0.21	0.10

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 1. Continued.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
MUEPAH		0.54	0.54		0.20	0.18	0.22	0.03	0.70	0.00	0.70
MUMINE	0.04	0.50	0.40	0.10	0.36	0.39	0.02	0.27	0.74	0.27	1.06
MUPOWR	0.13	0.42	0.36		0.44	0.32	0.13	0.06	0.81	0.05	0.13
MUPULL	0.23	0.64	0.64		0.12	0.12	0.00		0.89	0.00	
MUVBRD	0.22	0.66	0.66		0.11	0.08	0.03		0.95	0.00	
MUVCRN		0.06	0.04		0.91	0.91			1.00	0.00	
OHHSFO		0.26	0.26		0.66	0.54	0.01		0.86	0.00	0.29
OHINNS		0.82	0.82		0.18	0.18	0.04		1.00	0.00	0.03
OHKMRT		1.00	1.00						1.00	0.00	0.13
PA29TH		0.87	0.87		0.12	0.12			0.96	0.00	0.02
PA83CR		0.77	0.36		0.21	0.15	0.16	0.02	0.98	0.00	0.65
PAFAMD		0.63			0.37	0.37			1.00	0.00	0.36
PAJCPY					0.97	0.98		0.03	0.97	0.00	
PALOUD		0.95	0.95	0.00	0.04	0.02		0.17	0.83	0.00	
PAPEFO	0.00	0.17	0.17		0.18	0.82	0.14	0.58	0.36	0.00	0.08
PAPEIM		0.64	0.48		0.25	0.32		0.04	0.86	0.00	
PAPESW		0.59	0.54		0.41	0.41			1.00	0.00	0.72
PAWILL		0.14			0.86	0.86			0.96	0.00	0.17
PCBLUE		0.81	0.81		0.04	0.16	0.17	0.17	0.86	0.17	0.00
PCLPFO	0.22	0.25	0.24		0.51	0.49	0.24	0.03	0.95	0.00	0.78
PCROAD	0.02	0.50	0.45	0.08	0.28	0.19	0.05	0.15	0.71	0.12	
PEMIDW		0.60	0.60	0.01	0.06	0.35	0.17	0.44	0.66	0.01	0.24
PERDDP		0.92	0.80		0.07	0.07			0.98	0.00	
PETHUM		0.49	0.34		0.42	0.44		0.01	0.91	0.00	0.07
PETOSS		0.49	0.62	0.03	0.33	0.29	0.03	0.03	0.79	0.03	0.30

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 1. Continued.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
RIASIA	0.02	0.82	0.75		0.09	0.08		0.01	0.95	0.00	0.17
RIBRID	0.18	0.49	0.25	0.27	0.18	0.15	0.07	0.32	0.51	0.27	0.02
RIEAST	0.04	0.44	0.31	0.14	0.34	0.27	0.08	0.21	0.33	0.14	0.36
SJBOAT		0.55	0.54	0.01	0.21	0.30	0.15	0.15	0.74	0.01	0.33
SJBRID		0.64	0.17		0.31	0.34	0.04		0.47	0.00	0.25
SJCHUR		0.34	0.27		0.55	0.52	0.08		0.81	0.00	1.00
SJGLAD	0.01	0.65	0.19	0.03	0.28	0.29	0.10	0.03	0.67	0.03	0.10
SJMUDL		0.63	0.40	0.19	0.19	0.34	0.28	0.19	0.53	0.19	0.21
SJPLOT		0.79	0.77		0.13	0.17	0.77	0.04	0.89	0.00	
SJTELE		0.86	0.77	0.01	0.11	0.11	0.08	0.01	0.88	0.01	0.05
SMDTSS	0.00	0.67	0.67		0.08	0.07	0.38		0.75	0.00	0.36
SMFOFL	0.77	0.07	0.03		0.10	0.08			0.86	0.00	0.07
SMLPEM		0.60	0.60				0.60		0.59	0.00	0.02
SMSEFL		0.69	0.69		0.17	0.17	0.09		0.86	0.00	
SMSTEM		0.64	0.61		0.35	0.35	0.05		0.96	0.00	
TRSPFO	0.03	0.59	0.16		0.13	0.10			0.72	0.00	0.48
TRSPRI	0.08	0.78	0.29		0.02	0.13		0.29	0.89	0.29	0.68
TVFARM		0.62	0.10		0.34	0.19			0.96	0.00	
TVISLE	0.30				0.61	0.61			0.60	0.00	0.04
TVNEWT		0.30	0.05		0.70	0.70	0.01		1.00	0.00	0.03
TVPOUT		0.58	0.50		0.42	0.42			1.00	0.00	0.24
TVVBEM		0.89	0.79		0.01	0.11	0.01		0.90	0.00	
TVVBIM		0.24	0.24		0.76	0.76			1.00	0.00	
TVVBRV	0.16	0.19	0.19		0.47	0.49	0.05	0.04	0.61	0.00	0.14
TVVBSS		0.14			0.78	0.78			0.92	0.00	0.17

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 1. Continued.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
UDC001		0.62	0.61		0.37	0.34	0.04		0.99	0.00	1.47
UDC002		0.39	0.39		0.07	0.07			0.46	0.00	
UDC003		0.99	0.99		0.01	0.01		0.99	1.00	0.99	
UDC004		0.08	0.01		0.82	0.82		0.01	0.70	0.00	0.51
UDC005		0.51	0.47	0.04	0.26	0.44	0.08	0.10	0.72	0.04	
UDC007	0.02	0.13	0.11	0.02	0.80	0.81	0.00	0.13	0.35	0.12	0.06
UDC008		0.81	0.72		0.11	0.14	0.07	0.04	0.92	0.00	0.24
UDC012	0.06	0.11	0.10		0.69	0.69	0.04	0.05	0.80	0.00	0.09
UDC013		0.59	0.59		0.35	0.35	0.11		0.92	0.00	
UDC014	0.05	0.35	0.30		0.47	0.49	0.15		0.82	0.00	0.82
UDC015		0.93	0.93		0.02	0.02	0.12		1.00	0.00	0.04
UDC016	0.01	0.90	0.90		0.08	0.08		0.90	0.99	0.90	0.06
UDC017		0.72	0.72		0.27	0.27		0.72	0.99	0.72	0.35
UDC018		0.61	0.57		0.39	0.39			1.00	0.00	
UDC019	0.03	0.82	0.82		0.14	0.12	0.52		0.99	0.00	
UDC020		0.51	0.45		0.49	0.49			1.00	0.00	
VEPCON		0.26	0.26		0.45	0.45			0.68	0.00	0.08
VEPCOS	0.00	0.18	0.18		0.26	0.15	0.02	0.01	0.38	0.00	0.03
WBBARN		1.00	1.00						1.00	0.00	
WBCORN		0.85	0.50	0.35	0.03	0.05	0.02	0.44	0.53	0.44	
WBROAD		0.61	0.44	0.17	0.35	0.38		0.17	0.80	0.17	
WYBEAV	0.01	0.15	0.10	0.04	0.46	0.43	0.07	0.06	0.60	0.04	0.00
WYCHWE	0.01	0.19	0.10	0.08	0.69	0.74	0.08	0.09	0.81	0.08	
WYHCEA		0.21	0.19	0.01	0.17	0.75	0.04	0.01	0.36	0.01	
WYINTR		0.52	0.46	0.06	0.33	0.47	0.23	0.07	0.79	0.06	0.17

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 1. Continued.

Site Code	FernRC[a]	MonoRC[b]	Native GramRC[c]	InvGrassRC[d]	DicotRC[e]	DicotRC[f]	CarexRC[g]	TolerantRC[h]	NatHydro HrbRC[i]	PhalarisInv GrassRC[j]	ShrNativePC[k]
WYTHOR		0.45	0.45	0.01	0.42	0.41	0.09	0.02	0.83	0.01	

[a] Relative cover of ferns and fern allies; [b] Relative cover of monocot species; [c] Relative cover of native graminoids; [d] Relative cover of invasive grasses; [e] Relative cover of native dicots;

[f] Relative cover of dicot species; [g] Relative cover of *Carex spp.*; [h] Relative cover of tolerant species; [i] Relative cover of native, hydrophytic herbaceous vegetation;

[j] Relative cover of *Phalaris spp.*and invasive species; [k] Percent cover of native shrub vegetation.

Appendix AG. Part 2. Relative and percent cover metric values for use in developing class-specific vegetation-based indices of biological integrity (Veg-IBI) in West Virginia, USA, from 2005-2006. Blanks indicate a metric value of zero.

Site Code	NonNativeRC[a]	PhalarisRC[b]	SensitiveRC[c]	BryophRC[d]	ShrNonNatPC[e]
CFCROS	0.01			0.02	
CFECUR				0.02	
CFEINC					
CFSLCH		0.28			
CFSLIN		0.22			
CGBRID			0.14	0.05	
CGCPAS			0.03	0.23	
CGROAD			0.10	0.22	
CGTRHE	0.00		0.01	0.45	
CHNEER			0.03		
CHSACH	0.45	0.08			
CHSAFO	0.25		0.02		0.02
CHSARR					
CHTREE	0.33				
CHWWBW			0.61		
CHWWEM			0.07		
CHWWFO			0.98		
CVABBW	0.09		0.21	0.04	
CVABCT	0.08		0.10	0.06	
CVTIMB	0.02		0.01	0.20	
DSPICN				0.07	
DSROAR			0.34	0.49	
DSWILD			0.02	0.35	
EPCMEM	0.03	0.25	0.27		
EPCMFO	0.36			0.00	0.25
EPDMFO	0.39		0.12		
EPDMPU	0.51				
EPKYVE		0.72	0.05		
EPRRXC	0.58				0.00
EPSHEM	0.16	0.57	0.03		
EPSHSS	0.51	0.04		0.04	0.05
GBBARN		0.93	0.01		

[a] Non-native species relative cover; [b]*Phalaris spp.* Relative cover; [c] Sensitive species relative cover; [d] Bryophyte raltive cover;
[e] Non-native shrub species percent cover.

Appendix AG. Part 2. Continued.

Site Code	NonNativeRC[a]	PhalarisRC[b]	SensitiveRC[c]	BryophRC[d]	ShrNonNatPC[e]
GBHOEF		0.06	0.85		
GBJENK			0.19		
GBMAPL					
GBNOFO	0.35	0.09			
GBNOSS					
GBPLOT		0.89	0.02		
HCBEAV	0.05	0.37			0.19
HCMITI		0.01			
HCPIPE	0.03	0.83			
HCRANG				0.00	
HIBRID	0.13			0.04	0.00
HIGATE	0.14		0.02	0.12	
HIJHPK					
HIJHTU	0.03		0.36	0.02	0.02
HIPENC	0.00		0.01		
HISEWG	0.32			0.19	
HITRLR	0.33			0.28	
MCFOUR	0.01				
MCMEME	0.08		0.45	0.06	
MCMFOR			0.18	0.36	
MCNPFO	0.07			0.05	0.02
MCPOND			0.72		
MCPOST			0.46		
MCTELE			1.00		
ME5092	0.05				0.05
MESCOX					
MESCRO					
MESCUP					
MESIGN					
MESILV				0.04	
METETR			0.13		
MEWOLF				0.01	

[a] Non-native species relative cover; [b]*Phalaris spp.* Relative cover; [c] Sensitive species relative cover; [d] Bryophyte raltive cover;
[e] Non-native shrub species percent cover.

Appendix AG. Part 2. Continued.

Site Code	NonNativeRC[a]	PhalarisRC[b]	SensitiveRC[c]	BryophRC[d]	ShrNonNatPC[e]
MRBESS			0.03	0.01	
MRFARM	0.03				
MRFORE			0.01	0.19	0.00
MRSSSS	0.03		0.29	0.28	
MRWEST	0.03			0.16	0.03
MU55SS	0.00		0.04	0.01	
MUDBOA	0.05				
MUDEND	0.02				
MUDRIC	0.23				
MUDRIP	0.06				
MUDTRA	0.03	0.21			
MUEPAH	0.03			0.15	0.01
MUMINE	0.10	0.17	0.00	0.04	0.14
MUPOWR		0.05	0.08		0.19
MUPULL			0.10		
MUVBRD					
MUVCRN			0.03		
OHHSFO			0.21	0.09	0.10
OHINNS			0.04		
OHKMRT					
PA29TH			0.27	0.00	
PA83CR	0.02				
PAFAMD			0.52		
PAJCPY	0.03				
PALOUD	0.01		0.19		
PAPEFO	0.60		0.00	0.00	
PAPEIM	0.11				
PAPESW					
PAWILL			0.11		
PCBLUE		0.17			0.02
PCLPFO					
PCROAD	0.10	0.04		0.02	0.00

[a] Non-native species relative cover; [b]*Phalaris spp.* Relative cover; [c] Sensitive species relative cover; [d] Bryophyte raltive cover;
[e] Non-native shrub species percent cover.

Appendix AG. Part 2. Continued.

Site Code	NonNativeRC[a]	PhalarisRC[b]	SensitiveRC[c]	BryophRC[d]	ShrNonNatPC[e]
PEMIDW	0.32			0.01	
PERDDP			0.11		
PETHUM			0.15	0.01	
PETOSS	0.03		0.14		
RIASIA	0.01				
RIBRID	0.30			0.01	0.00
RIEAST	0.22		0.04	0.03	0.00
SJBOAT	0.18		0.02		0.00
SJBRID				0.01	0.02
SJCHUR					
SJGLAD	0.03				0.19
SJMUDL	0.19				0.19
SJPLOT	0.04		0.09		
SJTELE	0.01			0.01	
SMDTSS			0.02	0.23	
SMFOFL				0.05	
SMLPEM			0.01	0.40	
SMSEFL			0.23	0.14	
SMSTEM			0.00		
TRSPFO				0.17	0.00
TRSPRI	0.02	0.29			
TVFARM					
TVISLE					0.00
TVNEWT					
TVPOUT			0.11		
TVVBEM					
TVVBIM			0.15		
TVVBRV	0.04		0.03		
TVVBSS			0.18	0.07	
UDC001				0.01	
UDC002				0.54	
UDC003		0.99			

[a] Non-native species relative cover; [b]*Phalaris spp.* Relative cover; [c] Sensitive species relative cover; [d] Bryophyte raltive cover;
[e] Non-native shrub species percent cover.

Appendix AG. Part 2. Continued.

Site Code	NonNativeRC[a]	PhalarisRC[b]	SensitiveRC[c]	BryophRC[d]	ShrNonNatPC[e]
UDC004	0.01			0.03	
UDC005	0.09				
UDC007	0.03	0.11		0.02	
UDC008	0.04			0.04	
UDC012	0.05	0.00	0.19	0.04	
UDC013			0.06	0.00	
UDC014	0.02			0.05	0.06
UDC015					
UDC016		0.90		0.01	
UDC017		0.72		0.01	
UDC018					
UDC019	0.01				
UDC020			0.40		
VEPCON			0.00	0.28	
VEPCOS			0.04	0.49	
WBBARN					
WBCORN	0.35	0.09	0.11	0.07	
WBROAD	0.17		0.01	0.00	
WYBEAV	0.04			0.23	0.06
WYCHWE	0.08			0.01	
WYHCEA	0.01				
WYINTR	0.06				
WYTHOR	0.02			0.07	

[a] Non-native species relative cover; [b]*Phalaris spp.* Relative cover; [c] Sensitive species relative cover; [d] Bryophyte raltive cover;
[e] Non-native shrub species percent cover.

Appendix AH. Relative and percent cover metric values of facultative wetland rating and wetter metrics for use in developing class-specific vegetation-based indices of biological integrity (Veg-IBI) in West Virginia, USA, from 2005-2006. Blanks indicate a metric value of zero.

Site Code	FAConlyHrbRC[a]	ShrNatHydroPC[b]	OblHerbRC[c]	FACWupHrbRC[d]	FACupHrbRC[f]
CFCROS		0.34	0.31	0.96	0.96
CFECUR	0.16	0.49	0.05	0.11	0.26
CFEINC		0.19	0.54	1.00	1.00
CFSLCH		0.17		0.91	0.91
CFSLIN		0.51	0.69	1.00	1.00
CGBRID	0.17	1.62	0.42	0.77	0.94
CGCPAS	0.00	1.17	0.14	0.49	0.50
CGROAD	0.00	0.02	0.16	0.61	0.61
CGTRHE	0.01	0.03	0.19	0.23	0.25
CHNEER		0.40	1.00	1.00	1.00
CHSACH		0.10	0.81	0.98	0.98
CHSAFO	0.03	0.06		0.61	0.65
CHSARR					
CHTREE	0.22	0.24	0.50	0.63	0.85
CHWWBW		0.60	1.00	1.00	1.00
CHWWEM		0.05	1.00	1.00	1.00
CHWWFO		0.21	0.99	1.00	1.00
CVABBW	0.00	0.05	0.35	0.68	0.69
CVABCT	0.00		0.36	0.72	0.72
CVTIMB	0.05	0.35	0.31	0.58	0.63
DSPICN		0.68	0.48	0.76	0.76
DSROAR	0.03	0.00	0.39	0.47	0.50
DSWILD	0.03		0.09	0.37	0.40
EPCMEM			0.55	0.97	0.97
EPCMFO	0.04	0.00	0.24	0.48	0.52
EPDMFO	0.01	0.00		0.62	0.63
EPDMPU	0.27	0.05	0.00	0.45	0.72
EPKYVE			0.06	0.93	0.93
EPRRXC	0.19		0.02	0.71	0.90
EPSHEM		0.06	0.23	0.82	0.82
EPSHSS		0.50	0.09	0.76	0.76
GBBARN			0.07	1.00	1.00

[a] Facultative-only herbaceous species relative cover; [b] Native hydrophytic shrubs percent cover; [c] Obligate-only herbaceous species relative cover; [d] Facultative-wet and wetter herbaceous species relative cover; [e] Facultative and wetter herbaceous species relative cover.

Appendix AH. Continued.

Site Code	FAConlyHrbRC[a]	ShrNatHydroPC[b]	OblHerbRC[c]	FACWupHrbRC[d]	FACupHrbRC[f]
GBHOEF		0.02	0.34	0.45	0.45
GBJENK		1.70	0.93	0.93	0.93
GBMAPL				1.00	1.00
GBNOFO		0.93	0.36	0.55	0.55
GBNOSS		1.23	0.50	0.99	0.99
GBPLOT			0.11	1.00	1.00
HCBEAV	0.22	0.01	0.04	0.49	0.71
HCMITI		0.00	0.73	0.81	0.81
HCPIPE		0.17	0.01	0.85	0.85
HCRANG	0.01	0.04	0.66	0.77	0.78
HIBRID	0.13	0.14	0.09	0.70	0.83
HIGATE	0.06	0.16	0.45	0.82	0.87
HIJHPK		0.80	1.00	1.00	1.00
HIJHTU	0.00	0.08	0.60	0.75	0.76
HIPENC		0.02	0.80	1.00	1.00
HISEWG	0.00	0.36	0.05	0.49	0.49
HITRLR		0.50	0.58	0.72	0.72
MCFOUR	0.03	0.00	0.12	0.25	0.28
MCMEME		0.09	0.61	0.91	0.91
MCMFOR	0.14	0.05	0.43	0.47	0.61
MCNPFO	0.07	0.11	0.86	0.88	0.94
MCPOND			1.00	1.00	1.00
MCPOST		0.18	1.00	1.00	1.00
MCTELE		0.01	1.00	1.00	1.00
ME5092		0.14	0.34	0.80	0.80
MESCOX		0.02	1.00	1.00	1.00
MESCRO		0.00	0.43	1.00	1.00
MESCUP			0.86	1.00	1.00
MESIGN	0.00		0.75	1.00	1.00
MESILV	0.04	0.40	0.67	0.86	0.90
METETR			0.54	0.93	0.93
MEWOLF		1.65	0.99	0.99	0.99

[a] Facultative-only herbaceous species relative cover; [b] Native hydrophytic shrubs percent cover; [c] Obligate-only herbaceous species relative cover; [d] Facultative-wet and wetter herbaceous species relative cover; [e] Facultative and wetter herbaceous species relative cover.

Appendix AH. Continued.

Site Code	FAConlyHrbRC[a]	ShrNatHydroPC[b]	OblHerbRC[c]	FACWupHrbRC[d]	FACupHrbRC[f]
MRBESS	0.01	0.45	0.90	0.97	0.98
MRFARM	0.33	0.54	0.01	0.50	0.83
MRFORE	0.02	0.22	0.27	0.73	0.76
MRSSSS		1.38	0.11	0.65	0.65
MRWEST	0.01	0.36	0.09	0.57	0.58
MU55SS	0.02	0.44	0.56	0.86	0.90
MUDBOA			0.99	1.00	1.00
MUDEND		0.49	0.94	1.00	1.00
MUDRIC		0.27	0.29	0.48	0.48
MUDRIP		0.16	0.74	0.93	0.93
MUDTRA		0.10	0.48	0.98	0.98
MUEPAH	0.03	0.10	0.53	0.70	0.73
MUMINE	0.11	0.07	0.24	0.63	0.74
MUPOWR	0.23	0.02	0.26	0.56	0.81
MUPULL			0.60	0.89	0.89
MUVBRD			0.66	0.95	0.95
MUVCRN			1.00	1.00	1.00
OHHSFO	0.08	0.03	0.01	0.73	0.86
OHINNS		0.03	0.89	1.00	1.00
OHKMRT		0.13	1.00	1.00	1.00
PA29TH		0.02	0.90	0.96	0.96
PA83CR	0.04	0.38	0.80	0.96	1.00
PAFAMD		0.36	1.00	1.00	1.00
PAJCPY	0.01		0.94	0.99	1.00
PALOUD	0.00		0.80	0.82	0.83
PAPEFO	0.05	0.01	0.61	0.89	0.94
PAPEIM	0.02		0.80	0.95	0.96
PAPESW		0.72	0.99	1.00	1.00
PAWILL		0.17	0.96	0.96	0.96
PCBLUE	0.03	0.00	0.47	0.83	0.86
PCLPFO	0.17	0.51		0.76	0.95
PCROAD	0.01		0.11	0.68	0.71

[a] Facultative-only herbaceous species relative cover; [b] Native hydrophytic shrubs percent cover; [c] Obligate-only herbaceous species relative cover; [d] Facultative-wet and wetter herbaceous species relative cover; [e] Facultative and wetter herbaceous species relative cover.

Appendix AH. Continued.

Site Code	FAConlyHrbRC[a]	ShrNatHydroPC[b]	OblHerbRC[c]	FACWupHrbRC[d]	FACupHrbRC[f]
PEMIDW		0.24	0.42	0.66	0.66
PERDDP			0.54	0.98	0.98
PETHUM		0.07	0.66	0.91	0.91
PETOSS	0.09	0.30	0.38	0.70	0.79
RIASIA		0.17	0.89	0.96	0.96
RIBRID	0.06	0.02	0.24	0.46	0.52
RIEAST	0.08	0.36	0.03	0.25	0.34
SJBOAT	0.01	0.33	0.76	0.86	0.87
SJBRID		0.25	0.17	0.47	0.47
SJCHUR	0.06	0.09	0.48	0.75	0.81
SJGLAD	0.08	0.09	0.52	0.59	0.67
SJMUDL	0.01	0.20	0.39	0.51	0.53
SJPLOT	0.01		0.07	0.91	0.91
SJTELE		0.04	0.63	0.88	0.88
SMDTSS		0.36	0.68	0.75	0.75
SMFOFL	0.02	0.03		0.83	0.86
SMLPEM		0.02	0.59	0.59	0.59
SMSEFL			0.78	0.86	0.86
SMSTEM	0.02		0.89	0.94	0.96
TRSPFO	0.05	0.25	0.51	0.64	0.72
TRSPRI		0.68	0.52	0.89	0.89
TVFARM			0.77	0.96	0.96
TVISLE	0.31			0.30	0.60
TVNEWT		0.03	1.00	1.00	1.00
TVPOUT		0.24	1.00	1.00	1.00
TVVBEM			0.72	0.90	0.90
TVVBIM			1.00	1.00	1.00
TVVBRV	0.10	0.14	0.12	0.55	0.65
TVVBSS		0.17	0.92	0.92	0.92
UDC001		1.47	0.96	0.99	0.99
UDC002			0.46	0.46	0.46
UDC003				1.00	1.00

[a] Facultative-only herbaceous species relative cover; [b] Native hydrophytic shrubs percent cover; [c] Obligate-only herbaceous species relative cover; [d] Facultative-wet and wetter herbaceous species relative cover; [e] Facultative and wetter herbaceous species relative cover.

Appendix AH. Continued.

Site Code	FAConlyHrbRC[a]	ShrNatHydroPC[b]	OblHerbRC[c]	FACWupHrbRC[d]	FACupHrbRC[f]
UDC004	0.04	0.51		0.63	0.70
UDC005			0.11	0.72	0.72
UDC007		0.06	0.01	0.37	0.37
UDC008		0.23	0.91	0.92	0.92
UDC012	0.21	0.09	0.47	0.59	0.81
UDC013			0.61	0.92	0.92
UDC014	0.06	0.82	0.43	0.76	0.82
UDC015		0.04	0.99	1.00	1.00
UDC016		0.06	0.03	0.99	0.99
UDC017		0.35	0.08	0.99	0.99
UDC018			0.63	1.00	1.00
UDC019	0.05		0.51	0.94	0.99
UDC020			1.00	1.00	1.00
VEPCON			0.30	0.68	0.68
VEPCOS	0.02	0.00	0.22	0.37	0.38
WBBARN			1.00	1.00	1.00
WBCORN	0.01		0.41	0.53	0.54
WBROAD	0.00		0.50	0.80	0.80
WYBEAV	0.07		0.40	0.52	0.60
WYCHWE	0.22		0.32	0.59	0.81
WYHCEA			0.33	0.36	0.36
WYINTR	0.26	0.06	0.40	0.53	0.79
WYTHOR	0.00		0.45	0.82	0.83

[a] Facultative-only herbaceous species relative cover; [b] Native hydrophytic shrubs percent cover; [c] Obligate-only herbaceous species relative cover; [d] Facultative-wet and wetter herbaceous species relative cover; [e] Facultative and wetter herbaceous species relative cover

Appendix AI. Part 1. Richness metrics used in developing vegetation based indices of biological integrity (Veg-IBI) in West Virginia, USA from 2005-2006. Blanks indicate a metric value of zero.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
CFCROS	1	3	1	1		40
CFECUR		3	8	6		48
CFEINC		1	3	3		40
CFSLCH			3	3		28
CFSLIN			3	3		26
CGBRID			1	1		36
CGCPAS			2	2	2	37
CGROAD			5	4	4	39
CGTRHE		4	2	2	6	32
CHNEER			1	1		12
CHSACH		11	5	5	1	42
CHSAFO	1	6	3	2	3	27
CHSARR		1				16
CHTREE	1	3	7	7	5	38
CHWWBW			1	1		5
CHWWEM		1	1	1		26
CHWWFO	1	2	4	4	4	23
CVABBW	4	8	5	4	1	53
CVABCT	3	6	2	1	1	52
CVTIMB	1	1	2	2		21
DSPICN			1	1		38
DSROAR			5	5		21

[a] Invasive graminoid walk-through richness; [b] Non-native plant walk-though richness; [c] Shrub richness; [d] Native Shrub Richness; [e] Tree species richness; [f] Native Plant Richness

Appendix AI. Part 1. Continued.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
DSWILD			3	3		20
EPCMEM		1				10
EPCMFO	1	10	4	2	4	27
EPDMFO		4	2	2	2	14
EPDMPU		4	2	2		18
EPKYVE		5				25
EPRRXC		7	4	3	2	24
EPSHEM		2	3	3		13
EPSHSS		4	4	3		33
GBBARN			1	1		13
GBHOEF		1	2	2		18
GBJENK		1	1	1		17
GBMAPL					1	10
GBNOFO	1	4	8	7	2	21
GBNOSS		3	2	2		28
GBPLOT	1	2	1	1		14
HCBEAV	2	6	5	3		24
HCMITI		4	1	1		27
HCPIPE	1	10	1	1		15
HCRANG	1	3	1	1		29
HIBRID	3	14	6	5	7	64
HIGATE		3	6	6	4	31

[a] Invasive graminoid walk-through richness; [b] Non-native plant walk-though richness; [c] Shrub richness; [d] Native Shrub Richness; [e] Tree species richness; [f] Native Plant Richness

Appendix AI. Part 1. Continued.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
HIJHPK	1	4	3	3	3	22
HIJHTU	1	6	3	2		33
HIPENC		1	1	1	2	22
HISEWG	1	6	4	4	2	54
HITRLR	1	4	1	1		34
MCFOUR		3	7	5		30
MCMEME		2	2	2		27
MCMFOR		2	3	2	3	37
MCNPFO		4	6	5	2	23
MCPOND		1				18
MCPOST		1	2	2		35
MCTELE	1	7	3	3		34
ME5092	2	12	6	4		59
MESCOX		2	2	2		24
MESCRO			1	1		20
MESCUP						25
MESIGN		3				41
MESILV	1	3	5	5	2	47
METETR	1	5				35
MEWOLF		1	6	5		27
MRBESS			9	9		35
MRFARM	1	1	10	10		31

[a] Invasive graminoid walk-through richness; [b] Non-native plant walk-though richness; [c] Shrub richness; [d] Native Shrub Richness; [e] Tree species richness; [f] Native Plant Richness

Appendix AI. Part 1. Continued.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
MRFORE		1	15	14	4	38
MRSSSS		1	7	7		26
MRWEST	2	3	4	3		20
MU55SS		5	3	3		34
MUDBOA		2				29
MUDEND		2	4	4		36
MUDRIC	1	3	2	2		39
MUDRIP	2	7	5	5		39
MUDTRA		3	1	1	1	27
MUEPAH	1	7	5	4	1	39
MUMINE	2	4	7	5	5	58
MUPOWR		2	5	4	2	50
MUPULL		1				26
MUVBRD		1				36
MUVCRN						14
OHHSFO		4	9	6	6	32
OHINNS			2	2		24
OHKMRT			2	2		6
PA29TH			1	1		21
PA83CR		3	4	4	3	34
PAFAMD		4	1	1		27
PAJCPY		1				21

[a] Invasive graminoid walk-through richness; [b] Non-native plant walk-though richness; [c] Shrub richness; [d] Native Shrub Richness; [e] Tree species richness; [f] Native Plant Richness

Appendix AI. Part 1. Continued.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
PALOUD	1	5				20
PAPEFO		3	4	4	3	31
PAPEIM		4				18
PAPESW		4	3	3	1	38
PAWILL		2	1	1		14
PCBLUE		2	2	1		29
PCLPFO		3	7	7	2	27
PCROAD	2	8	2			36
PEMIDW	1	8	1	1		29
PERDDP						16
PETHUM		1	2	2		40
PETOSS	1	3	1	1		34
RIASIA		5	1	1	1	36
RIBRID	2	8	2	1		37
RIEAST	3	13	3	2	2	33
SJBOAT	1	12	5	3		45
SJBRID		2	5	3		16
SJCHUR		2	7	6	1	26
SJGLAD	2	4	6	4	1	28
SJMUDL	1	8	8	6	1	38
SJPLOT		6				21
SJTELE	2	4	4	4		22

[a] Invasive graminoid walk-through richness; [b] Non-native plant walk-though richness; [c] Shrub richness; [d] Native Shrub Richness; [e] Tree species richness; [f] Native Plant Richness

Appendix AI. Part 1. Continued.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
SMDTSS			3	3		25
SMFOFL			5	5	5	23
SMLPEM			1	1		10
SMSEFL						17
SMSTEM						23
TRSPFO		2	9	7	4	52
TRSPRI		2	2	2		10
TVFARM		2				30
TVISLE		2	3	2	6	29
TVNEWT	1	5	1	1		25
TVPOUT		2	2	2		38
TVVBEM	1	2				13
TVVBIM		1				12
TVVBRV		2	2	2	2	23
TVVBSS			2	2		13
UDC001			1	1		34
UDC002						16
UDC003	1	5				22
UDC004		2	4	3	2	37
UDC005	3	11				24
UDC007	1	2	1	1	1	19
UDC008		1	6	6		33

[a] Invasive graminoid walk-through richness; [b] Non-native plant walk-though richness; [c] Shrub richness; [d] Native Shrub Richness; [e] Tree species richness; [f] Native Plant Richness

Appendix AI. Part 1. Continued.

Site Code	InvGramWTRich[a]	NonNativePlantWTRich[b]	ShrubRich[c]	NativeShrRich[d]	TreeRich[e]	NativePlantRich[f]
UDC012		4	2	2	3	46
UDC013						41
UDC014		2	6	5		30
UDC015			4	4		19
UDC016			1	1		21
UDC017			2	2		22
UDC018		1				32
UDC019		2				28
UDC020						22
VEPCON			1	1		28
VEPCOS			2	2		36
WBBARN	1	4				22
WBCORN	3	14				40
WBROAD	1	2				19
WYBEAV	1	3	2	1	1	24
WYCHWE	2	6				43
WYHCEA	1	1				19
WYINTR	2	8	3	3	2	20
WYTHOR	1	2				25

a Invasive graminoid walk-through richness; b Non-native plant walk-though richness; c Shrub richness; d Native Shrub Richness; e Tree species richness; f Native Plant Richness

Appendix AI. Part 2. Richness metrics used in developing vegetation based indices of biological integrity (Veg-IBI) in West Virginia, USA from 2005-2006. Blanks indicate a metric value of zero.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
CFCROS	31	23	6	4	10	
CFECUR	35	32	11	2	11	
CFEINC	32	20		3	6	
CFSLCH	26	18	1	2	4	
CFSLIN	26	15	3	3	8	
CGBRID	34	17	10	8	18	
CGCPAS	29	18	11	6	17	
CGROAD	19	25	10	2	11	
CGTRHE	19	16	8	8	9	
CHNEER	11	7	1		2	
CHSACH	37	22	3	7	11	
CHSAFO	19	25	10	1	9	1
CHSARR	14	10		2		
CHTREE	27	26	9	7	12	
CHWWBW	5	2	1		4	
CHWWEM	24	12	2	3	9	
CHWWFO	15	17	3	1	5	
CVABBW	44	27	14	7	23	
CVABCT	43	24	11	6	21	
CVTIMB	16	10	7	4	12	
DSPICN	31	16	7	5	12	
DSROAR	15	13	6	3	9	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d] *Carex spp.* Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AI. Part 2. Continued.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
DSWILD	13	10	8	1	10	
EPCMEM	10	3	1		4	
EPCMFO	20	21	9	1	13	2
EPDMFO	6	12	7	1	5	
EPDMPU	15	15	8	2	7	
EPKYVE	16	15	5	1	5	
EPRRXC	15	18	6	1	7	1
EPSHEM	12	11	3		4	
EPSHSS	30	20	5	3	9	1
GBBARN	12	8	2		6	
GBHOEF	14	12	4		6	
GBJENK	15	14	2		3	
GBMAPL	7	9	2	1	2	
GBNOFO	16	14	5	4	12	
GBNOSS	23	16	6	3	12	
GBPLOT	12	8	4		8	
HCBEAV	19	13	6	5	9	1
HCMITI	22	14	3	6	8	
HCPIPE	14	11	2		3	
HCRANG	24	13	7	6	13	
HIBRID	46	48	13	4	16	1
HIGATE	24	25	6	1	10	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d] *Carex spp.*Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AI. Part 2. Continued.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
HIJHPK	20	16	1	2	2	
HIJHTU	26	17	1	2	8	1
HIPENC	22	12	3	1	11	
HISEWG	32	47	15		13	
HITRLR	31	19	2	4	8	
MCFOUR	18	18	5	4	4	
MCMEME	22	17	6	1	11	
MCMFOR	32	26	6	3	7	
MCNPFO	15	14	6	3	8	1
MCPOND	14	10	1		3	
MCPOST	28	23	3	4	5	
MCTELE	21	23	1	2	3	
ME5092	48	39	11	4	13	1
MESCOX	22	12	1	2	2	
MESCRO	18	11	4		11	
MESCUP	24	13	4	3	10	
MESIGN	36	30	10	4	13	
MESILV	44	32	14	5	21	
METETR	30	21	3	1	10	
MEWOLF	23	16	2	3	6	
MRBESS	34	20	9	7	19	
MRFARM	26	18	7	3	10	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d] *Carex spp.*Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AI. Part 2. Continued.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
MRFORE	31	28	12	6	16	1
MRSSSS	23	15	4	4	11	
MRWEST	18	15	7	2	10	1
MU55SS	34	22	8	4	12	
MUDBOA	26	15	6	4	9	
MUDEND	31	18	8	4	15	
MUDRIC	28	24	12	2	16	
MUDRIP	33	23	7	3	13	
MUDTRA	23	14	5	4	11	
MUEPAH	32	21	9	6	13	1
MUMINE	44	34	10	5	15	1
MUPOWR	35	33	14	5	18	1
MUPULL	22	15	2	3	7	
MUVBRD	29	21	4	6	10	
MUVCRN	12	8	2		5	
OHHSFO	18	23	9	4	10	3
OHINNS	23	14	6	2	12	
OHKMRT	6	4			1	
PA29TH	17	10	3		8	
PA83CR	27	21	6	5	14	
PAFAMD	25	16	2	3	4	
PAJCPY	19	21	6		6	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d] *Carex spp.* Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AI. Part 2. Continued.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
PALOUD	18	10	6		9	
PAPEFO	26	23	8	4	14	
PAPEIM	15	7	4	2	6	
PAPESW	33	21	5	6	8	
PAWILL	13	8	2		3	
PCBLUE	25	15	3	6	15	1
PCLPFO	21	15	6	4	9	
PCROAD	27	21	14	6	20	1
PEMIDW	26	14	4	4	13	
PERDDP	15	4	1	2	6	
PETHUM	35	28	12	1	18	
PETOSS	26	18	9	4	16	
RIASIA	25	19	6	5	12	
RIBRID	25	22	12	3	14	1
RIEAST	22	25	12	1	9	1
SJBOAT	37	23	10	6	16	1
SJBRID	14	10	6	3	10	1
SJCHUR	19	18	9	2	12	
SJGLAD	23	15	8	6	16	1
SJMUDL	33	24	8	6	18	1
SJPLOT	18	10	5	5	7	
SJTELE	20	13	5	3	10	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d] *Carex spp.* Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AI. Part 2. Continued.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
SMDTSS	19	10	5	3	12	
SMFOFL	11	12	7	1	7	
SMLPEM	8	3		2	1	
SMSEFL	15	9	2	2	7	
SMSTEM	20	9	3	2	8	
TRSPFO	26	30	9	4	12	2
TRSPRI	9	5	3	1	7	
TVFARM	28	16	4	5	9	
TVISLE	17	24	5	1	4	1
TVNEWT	24	10	2	3	7	
TVPOUT	35	25	6	3	10	
TVVBEM	13	6	1	1	6	
TVVBIM	12	5	2		3	
TVVBRV	19	16	5	2	8	
TVVBSS	13	10	7		8	
UDC001	33	19	8	5	14	
UDC002	15	10	1		4	
UDC003	19	11	1	3	2	
UDC004	25	24	13	2	10	
UDC005	15	17	9	2	9	
UDC007	13	13	7	1	7	
UDC008	29	22	4	4	7	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d] *Carex spp.*Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AI. Part 2. Continued.

Site Code	NativeHydroWTRich[a]	NatDicotWTRich[b]	NatDicotRich[c]	CarexRichness[d]	NatHydroHrbRich[e]	NonNativeShrRich[f]
UDC012	37	26	13	6	18	
UDC013	36	22	8	5	14	
UDC014	25	18	16	2	20	1
UDC015	17	9	1	3	6	
UDC016	19	16	3	2	5	
UDC017	22	13	5	4	6	
UDC018	26	24	3	1	6	
UDC019	24	17	5	3	13	
UDC020	20	8	3	3	7	
VEPCON	27	16	9	4	11	
VEPCOS	31	18	12	5	19	
WBBARN	18	10		1	1	
WBCORN	33	15	6	6	9	
WBROAD	17	10	5	2	9	
WYBEAV	19	17	7	2	12	1
WYCHWE	35	26	11	4	17	
WYHCEA	19	8	8	3	12	
WYINTR	16	13	5	2	9	
WYTHOR	22	12	8	4	15	

[a] Native hydrophyte walk-through richness; [b] Native dicot walk-through richness; [c] Native dicot herbaceous-layer richness; [d]*Carex spp.*Richness;
[e] Native hydrophyte herbaceous-layer richness; [f] Non-native shrub richness.

Appendix AJ. Importance values (IV) and mean DBH of tree strata metrics used to develop vegetation-based indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA from 2005-2006. Blanks indicate a metric value of zero.

Site Code	MeanIV[a]	TreeFACupMeanIV[b]	TreeFACWupMeanIV[c]	MeanDBH[d]
CFCROS				
CFECUR				
CFEINC				
CFSLCH				
CFSLIN				
CGBRID				
CGCPAS	50.00	47.13		22.75
CGROAD	25.00	27.96	6.42	22.55
CGTRHE	20.00	9.79		25.20
CHNEER				
CHSACH	100.00	100.00	100.00	9.15
CHSAFO	33.33	8.60	8.60	24.02
CHSARR				
CHTREE	20.00	23.97	28.23	22.57
CHWWBW				
CHWWEM				
CHWWFO	25.00	30.25	21.05	29.16
CVABBW	100.00	100.00		14.00
CVABCT	100.00			14.00
CVTIMB				
DSPICN				
DSROAR				
DSWILD				
EPCMEM				
EPCMFO	25.00	39.80	39.80	19.05
EPDMFO	50.00	26.66	26.66	22.64
EPDMPU				
EPKYVE				
EPRRXC	50.00			20.48
EPSHEM				
EPSHSS				
GBBARN				
GBHOEF				
GBJENK				
GBMAPL	100.00	100.00	100.00	21.26
GBNOFO	50.00	91.80	91.80	20.28
GBNOSS				
GBPLOT				

[a] Mean IV; [b] Mean IV of tress facultative or wetter; [c] Mean IV of trees facultative-wet or wetter; [d] Mean diameter-breast-height.

Appendix AJ. Continued.

Site Code	MeanIV[a]	TreeFACupMeanIV[b]	TreeFACWupMeanIV[c]	MeanDBH[d]
HCBEAV				
HCMITI				
HCPIPE				
HCRANG				
HIBRID	14.29	17.68	17.68	19.50
HIGATE	25.00	13.99	15.82	20.24
HIJHPK	33.33	45.80	45.80	39.69
HIJHTU				
HIPENC	50.00	50.00	50.00	28.50
HISEWG	50.00	50.00	50.00	40.15
HITRLR				
MCFOUR				
MCMEME				
MCMFOR	33.33	33.33	10.24	25.86
MCNPFO	50.00	93.14		35.44
MCPOND				
MCPOST				
MCTELE	100.00	100.00	100.00	13.00
ME5092				
MESCOX				
MESCRO				
MESCUP				
MESIGN				
MESILV	100.00	100.00	100.00	30.40
METETR				
MEWOLF				
MRBESS				
MRFARM				
MRFORE	20.00	20.00	24.21	20.93
MRSSSS				
MRWEST				
MU55SS				
MUDBOA				
MUDEND				
MUDRIC				
MUDRIP				
MUDTRA	100.00	100.00	100.00	11.91
MUEPAH	100.00	100.00	100.00	8.68

[a] Mean IV; [b] Mean IV of tress facultative or wetter; [c] Mean IV of trees facultative-wet or wetter; [d] Mean diameter-breast-height.

Appendix AJ. Continued.

Site Code	MeanIV[a]	TreeFACupMeanIV[b]	TreeFACWupMeanIV[c]	MeanDBH[d]
MUMINE	20.00	29.40	12.39	18.78
MUPOWR	50.00	50.00		13.88
MUPULL				
MUVBRD				
MUVCRN				
OHHSFO	16.67	14.86		12.39
OHINNS				
OHKMRT				
PA29TH				
PA83CR	33.33	32.48	32.48	17.50
PAFAMD				
PAJCPY				
PALOUD				
PAPEFO	33.33	24.55	24.55	17.47
PAPEIM				
PAPESW	100.00			25.45
PAWILL				
PCBLUE				
PCLPFO	50.00	50.00	50.00	21.00
PCROAD				
PEMIDW				
PERDDP				
PETHUM				
PETOSS				
RIASIA	100.00	100.00	100.00	28.20
RIBRID				
RIEAST	50.00	21.41	21.41	32.67
SJBOAT				
SJBRID				
SJCHUR	100.00			17.00
SJGLAD	100.00	100.00	100.00	14.00
SJMUDL	100.00	100.00	100.00	17.30
SJPLOT				
SJTELE				
SMDTSS				
SMFOFL	20.00	23.91		21.63
SMLPEM				
SMSEFL				

[a] Mean IV; [b] Mean IV of tress facultative or wetter; [c] Mean IV of trees facultative-wet or wetter; [d]Mean diameter-breast-height.

Appendix AJ. Continued.

Site Code	MeanIV[a]	TreeFACupMeanIV[b]	TreeFACWupMeanIV[c]	MeanDBH[d]
SMSTEM				
TRSPFO	25.00	28.75	24.88	18.80
TRSPRI				
TVFARM				
TVISLE	14.29	26.66	26.66	34.73
TVNEWT				
TVPOUT				
TVVBEM				
TVVBIM				
TVVBRV	50.00	50.00	50.00	30.03
TVVBSS				
UDC001				
UDC002				
UDC003				
UDC004	50.00	33.87		17.92
UDC005				
UDC007	100.00			12.20
UDC008				
UDC012	50.00	50.00	80.15	30.30
UDC013				
UDC014				
UDC015				
UDC016				
UDC017				
UDC018				
UDC019				
UDC020				
VEPCON				
VEPCOS				
WBBARN				
WBCORN				
WBROAD				
WYBEAV	100.00	100.00	100.00	25.00
WYCHWE				
WYHCEA				
WYINTR	50.00	89.83	89.83	24.50
WYTHOR				

[a] Mean IV; [b] Mean IV of tress facultative or wetter; [c] Mean IV of trees facultative-wet or wetter; [d]Mean diameter-breast-height.

Appendix AK. Vegetation summary statistics of metric scores statewide and by ecoregion used to form vegetation-based indices of biological integrity (Veg-IBI) for wetlands in West Virginia, USA 2005-2006.

Statewide Vegetation Sampling (N=151)

	WVFQI	PAFQI	MEANC	ADJFQAI	OBLONLY HRBRC	FACWUP HRBRC	FACUPHR BRC	FACONLY HRBRC	SHRNATHY DROP
Minimum	10.174	10.174	2.831	23.593	0	0	0	0	0
Maximum	40.851	34.262	6.459	64.586	1	1	1	0.333	1.696
Mean	25.47	22.71	4.386	42.172	0.497	0.778	0.812	0.033	0.208
Std. Error	0.44	0.426	0.054	0.627	0.028	0.018	0.017	0.005	0.028

	CAREXW TRICH	INVGRA MWTRIC	NATIVE PLANT W	NONNAT IVEPLA	NATIVEHY DROW	NATIVE HYDROH	NATDICOT WTRI	NATDICOT HRBR	SHRUBRICH
Minimum	0	0	5	0	5	0	2	0	0
Maximum	8	4	64	14	48	23	48	16	15
Mean	2.927	0.497	28.364	3.026	23.02	9.675	16.96	5.907	2.662
Std. Error	0.165	0.067	0.905	0.256	0.715	0.39	0.633	0.305	0.214

	NATIVES HRRIC	NONNAT IVESHR	TREERI CH	MEANIV	TREEFACU PMEA	TREEFA CWUPM E	MEANDBH	FERNRC	MONORC
Minimum	0	0	0	0	0	0	0	0	0
Maximum	14	3	36	100	100	100	40.15	0.773	1
Mean	2.325	0.205	3.344	17.463	14.927	12.232	6.836	0.022	0.509
Std. Error	0.189	0.039	0.573	2.576	2.432	2.31	0.897	0.006	0.023

	NATIVEG RAMRC	INVGRA SSRC	NATIVE DICOTR	DICOTRC	CAREXRC	NONNAT IVERC	PHALARIS RC	SENSITIVE RC	TOLERANTR C
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.347	1	1	0.766	0.601	0.993	1	0.993
Mean	0.405	0.019	0.318	0.37	0.068	0.061	0.06	0.077	0.127
Std. Error	0.024	0.004	0.02	0.022	0.01	0.01	0.016	0.014	0.018

	BRYOPH RC	NATHYD ROHRBR	PHAINV GRASSR	SHRNATI VEPC	SHRNONN ATPC
Minimum	0	0	0	0	0
Maximum	0.541	1	0.993	1.696	0.247
Mean	0.049	0.78	0.079	0.255	0.011
Std. Error	0.009	0.019	0.016	0.03	0.003

Appendix AK. Continued.

Allegheny Highlands Vegetation Sampling (N=65)

	WVFQI	PAFQI	MEANC	ADJFQAI	OBLONLY HRBRC	FACWUP HRBRC	FACUPHR BRC	FACONLY HRBRC	SHRNATHY DROP
Minimum	10.174	10.174	2.831	23.593	0	0.108	0.247	0	0
Maximum	40.851	34.262	5.624	56.243	1	1	1	0.333	1.647
Mean	27.369	24.976	4.479	43.501	0.453	0.769	0.809	0.037	0.256
Std. Error	0.706	0.653	0.068	0.802	0.04	0.028	0.025	0.009	0.05

	CAREXW TRICH	INVGRA MWTRIC	NATIVEP LANTW	NONNAT IVEPLA	NATIVEHY DROW	NATIVE HYDROH	NATDICOT WTRI	NATDICOT HRBR	SHRUBRICH
Minimum	0	0	6	0	6	1	4	0	0
Maximum	8	4	64	14	48	23	48	16	15
Mean	3.354	0.585	32.308	2.615	26.631	11.015	19.585	6.846	2.985
Std. Error	0.243	0.116	1.463	0.383	1.112	0.629	1.071	0.536	0.377

	NATIVES HRRIC	NONNAT IVESHR	TREERIC H	MEANIV	TREEFACU PMEA	TREEFA CWUPM E	MEANDBH	FERNRC	MONORC
Minimum	0	0	0	0	0	0	0	0	0.056
Maximum	14	3	36	100	100	100	40.15	0.226	1
Mean	2.646	0.2	3.708	17.297	14.594	10.625	7.101	0.022	0.492
Std. Error	0.338	0.063	0.992	3.864	3.553	3.309	1.414	0.006	0.035

	NATIVEG RAMRC	INVGRA SSRC	NATIVE DICOTR	DICOTR C	CAREXRC	NONNAT IVERC	PHALARIS RC	SENSITIVE RC	TOLERANTR C
Minimum	0.005	0	0	0	0	0	0	0	0
Maximum	1	0.226	0.906	0.906	0.532	0.332	0.993	0.403	0.993
Mean	0.454	0.013	0.345	0.365	0.08	0.029	0.053	0.041	0.086
Std. Error	0.036	0.004	0.029	0.029	0.014	0.008	0.024	0.011	0.024

	BRYOPH RC	NATHYD ROHRBR	PHAINV GRASSR	SHRNAT IVEPC	SHRNONN ATPC
Minimum	0	0.247	0	0	0
Maximum	0.541	1	0.993	1.647	0.193
Mean	0.073	0.797	0.066	0.312	0.01
Std. Error	0.015	0.027	0.024	0.052	0.004

Appendix AK. Continued.

Ridge and Valley Vegetation Sampling (N=27)

	WVFQI	PAFQI	MEANC	ADJFQAI	OBLONLY HRBRC	FACWUP HRBRC	FACUPHR BRC	FACONLY HRBRC	SHRNATHY DROP
Minimum	15.405	12.658	3.161	28.469	0	0.295	0.405	0	0
Maximum	33.656	32.815	6.459	64.586	1	1	1	0.307	0.675
Mean	23.972	21.107	4.558	43.788	0.464	0.751	0.789	0.039	0.085
Std. Error	1.014	1.049	0.18	2.072	0.071	0.042	0.035	0.016	0.033

	CAREXW TRICH	INVGRA MWTRIC	NATIVEP LANTW	NONNAT IVEPLA	NATIVEHY DROW	NATIVE HYDROH	NATDICOT WTRI	NATDICOT HRBR	SHRUBRICH
Minimum	0	0	10	0	6	1	3	0	0
Maximum	6	3	40	14	35	13	25	9	5
Mean	1.926	0.296	22.407	2.704	17.963	7.185	12.741	4.63	1.741
Std. Error	0.302	0.129	1.634	0.645	1.471	0.597	1.097	0.49	0.327

	NATIVES HRRIC	NONNAT IVESHR	TREERIC H	MEANIV	TREEFACU PMEA	TREEFA CWUPM E	MEANDBH	FERNRC	MONORC
Minimum	0	0	0	0	0	0	0	0	0
Maximum	5	2	21	50	50	50	34.729	0.773	1
Mean	1.556	0.185	3	7.751	6.186	5.301	5.503	0.048	0.448
Std. Error	0.294	0.093	1.208	3.182	2.68	2.6	2.086	0.031	0.059

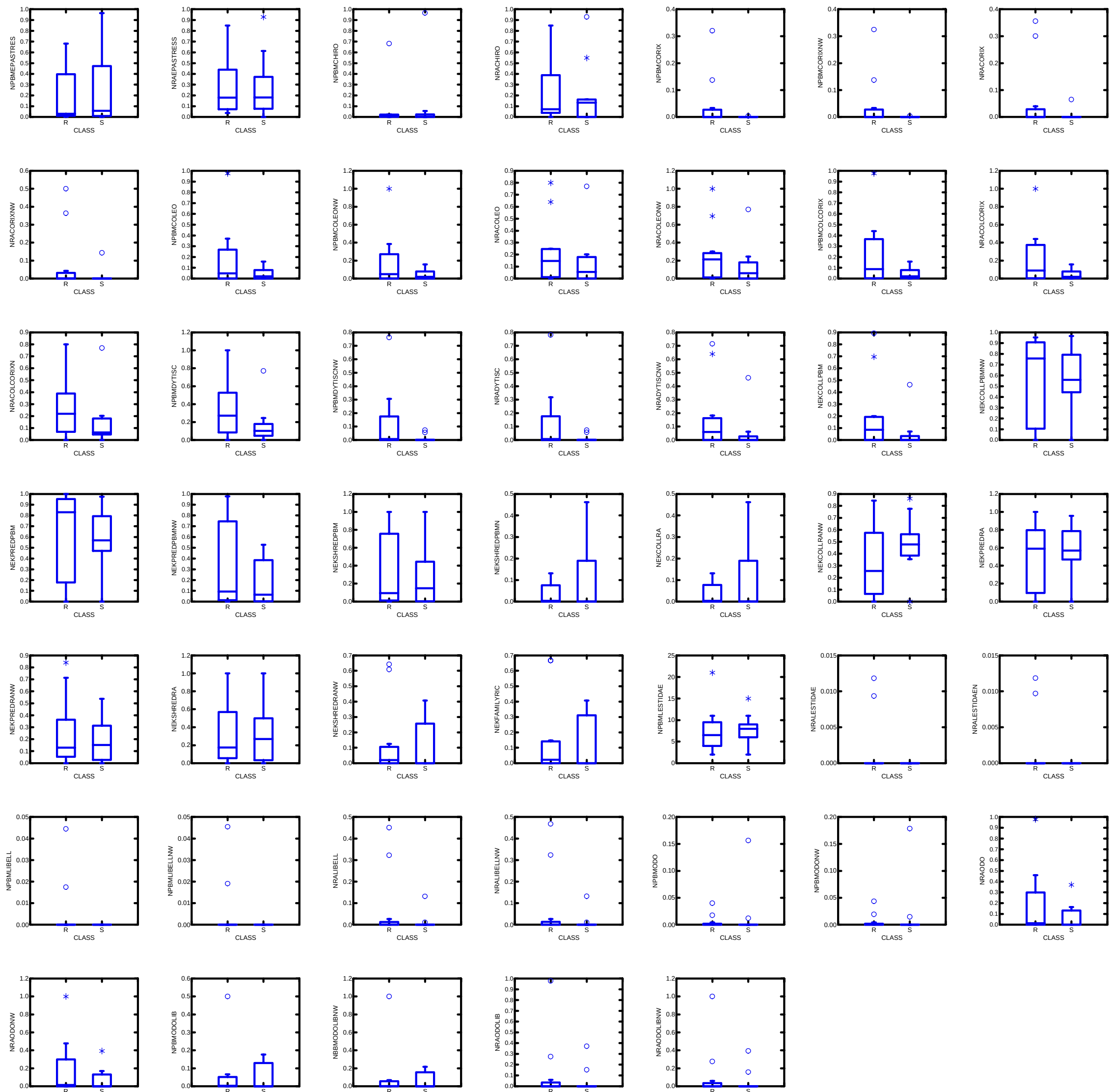
	NATIVEG RAMRC	INVGRA SSRC	NATIVE DICOTR	DICOTR C	CAREXRC	NONNAT IVERC	PHALARIS RC	SENSITIVE RC	TOLERANTR C
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.347	0.782	0.984	0.601	0.581	0.723	0.344	0.73
Mean	0.364	0.024	0.31	0.401	0.06	0.115	0.062	0.063	0.179
Std. Error	0.059	0.015	0.045	0.057	0.026	0.037	0.034	0.018	0.05

	BRYOPH RC	NATHYD ROHRBR	PHAINV GRASSR	SHRNAT IVEPC	SHRNONN ATPC
Minimum	0	0.251	0	0	0
Maximum	0.488	1	0.723	0.675	0.247
Mean	0.071	0.717	0.087	0.122	0.011
Std. Error	0.026	0.049	0.037	0.034	0.009

Appendix AK. Continued.

Western Allegheny Plateau (N=59)									
	WVFQI	PAFQI	MEANC	ADJFQAI	OBLONLY HRBRC	FACWUP HRBRC	FACUPHR BRC	FACONLY HRBRC	SHRNATHY DROP
Minimum	14.215	12.552	3.199	26.942	0	0	0	0	0
Maximum	34.17	31.172	6.357	63.571	1	1	1	0.224	1.696
Mean	24.064	20.947	4.204	39.969	0.561	0.8	0.827	0.025	0.211
Std. Error	0.584	0.534	0.076	0.895	0.045	0.03	0.028	0.007	0.041
	CAREXW TRICH	INVGRA MWTRIC	NATIVEP LANTW	NONNAT IVEPLA	NATIVEHY DROW	NATIVE HYDROH	NATDICOT WTRI	NATDICOT HRBR	SHRUBRICH
Minimum	0	0	5	0	5	0	2	0	0
Maximum	7	3	52	13	37	20	30	14	9
Mean	2.915	0.492	26.746	3.627	21.356	9.339	16	5.458	2.729
Std. Error	0.282	0.098	1.286	0.399	0.969	0.608	0.849	0.431	0.317
	NATIVES HRRIC	NONNAT IVESHR	TREERIC H	MEANIV	TREEFACU PMEA	TREEFA CWUPM E	MEANDBH	FERNRC	MONORC
Minimum	0	0	0	0	0	0	0	0	0
Maximum	7	2	29	100	100	100	35.444	0.224	0.981
Mean	2.322	0.22	3.102	22.09	19.293	17.173	7.153	0.011	0.556
Std. Error	0.27	0.06	0.822	4.753	4.627	4.447	1.41	0.005	0.036
	NATIVEG RAMRC	INVGRA SSRC	NATIVE DICOTR	DICOTR C	CAREXRC	NONNAT IVERC	PHALARIS RC	SENSITIVE RC	TOLERANTR C
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.949	0.275	1	1	0.766	0.601	0.929	1	0.929
Mean	0.369	0.022	0.291	0.361	0.06	0.071	0.067	0.122	0.148
Std. Error	0.039	0.008	0.034	0.036	0.015	0.017	0.026	0.033	0.031
	BRYOPH RC	NATHYD ROHRBR	PHAINV GRASSR	SHRNAT IVEPC	SHRNONN ATPC				
Minimum	0	0	0	0	0				
Maximum	0.364	1	0.929	1.696	0.189				
Mean	0.012	0.789	0.09	0.254	0.011				
Std. Error	0.007	0.03	0.027	0.045	0.005				

Appendix AL. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for depressional wetlands (N=22). Classifications are reference (R) and stressed (S).

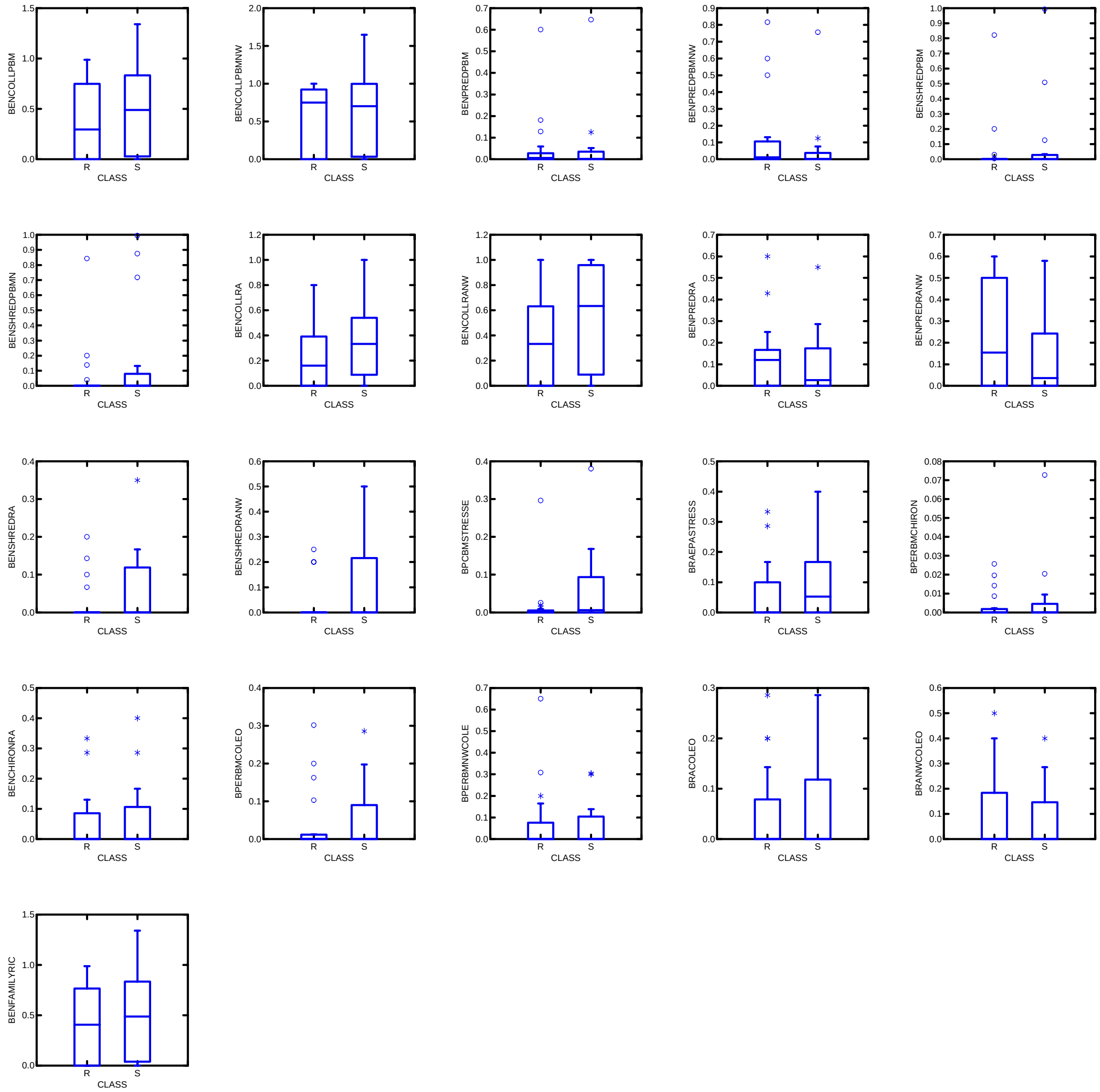


Appendix AL. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	poor
nRAepaStress	Relative abundance EPA stressed	poor
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	poor
npBMCorix	% Biomass Corixidae	poor
npBMCorixNW	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorixNW	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeoNW	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeoNW	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	fair
npBMColCorixNW	% Biomass Coleoptera + Corixidae NW	fair
nRAColCorix	Relative abundance Coleoptera + Corixidae	fair
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	good
npBMDytisc	% Biomass Dytiscidae	good
npBMDytiscNW	% Biomass Dytiscidae NW	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytiscNW	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBMNW	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	fair
nekPredpBMNW	% Biomass predator[a]	poor
nekShredpBM	% Biomass shredder	poor
nekShredpBMNW	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRANW	Relative abundance collector[a]	fair
nekPredRA	Relative abundance predator	poor
nekPredRANW	Relative abundance predator[a]	poor
nekShredRA	Relative abundance shredder	poor
nekShredRANW	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	poor
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibellNW	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibellNW	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdoNW	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdoNW	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLibNW	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLibNW	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AM. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for depressional wetlands (N=35). Classifications are reference (R) and stressed (S).

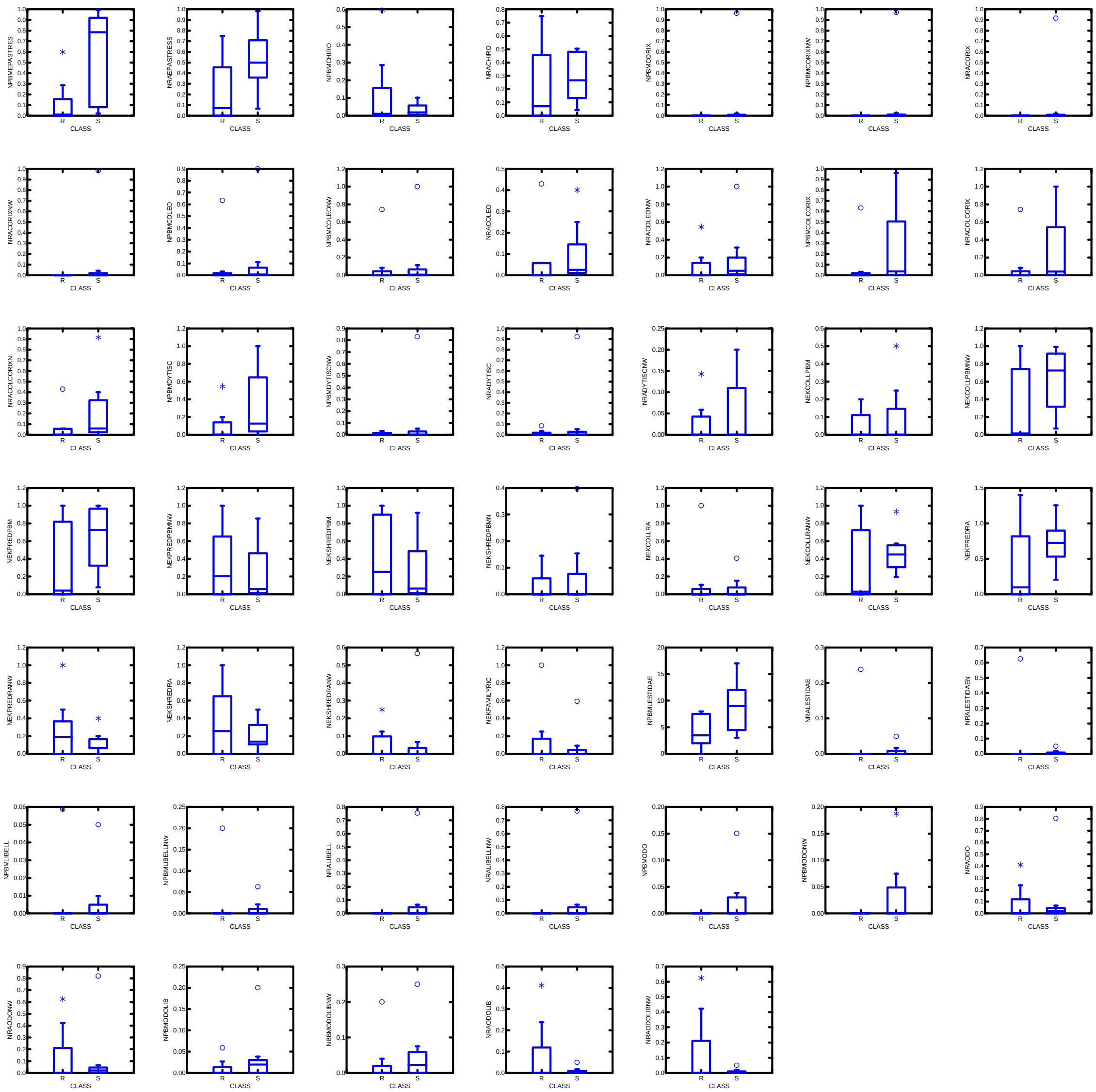


Appendix AM. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	poor
benCollpBM*	% Biomass collector[a]	fair
benPredpBM	% Biomass predator	fair
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	good
benCollRA*	Relative abundance collector[a]	good
benPredRA	Relative abundance predator	good
benPredRA*	Relative abundance predator[a]	good
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	good
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AN. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for floodplain wetlands (N=15). Classifications are reference (R) and stressed (S).

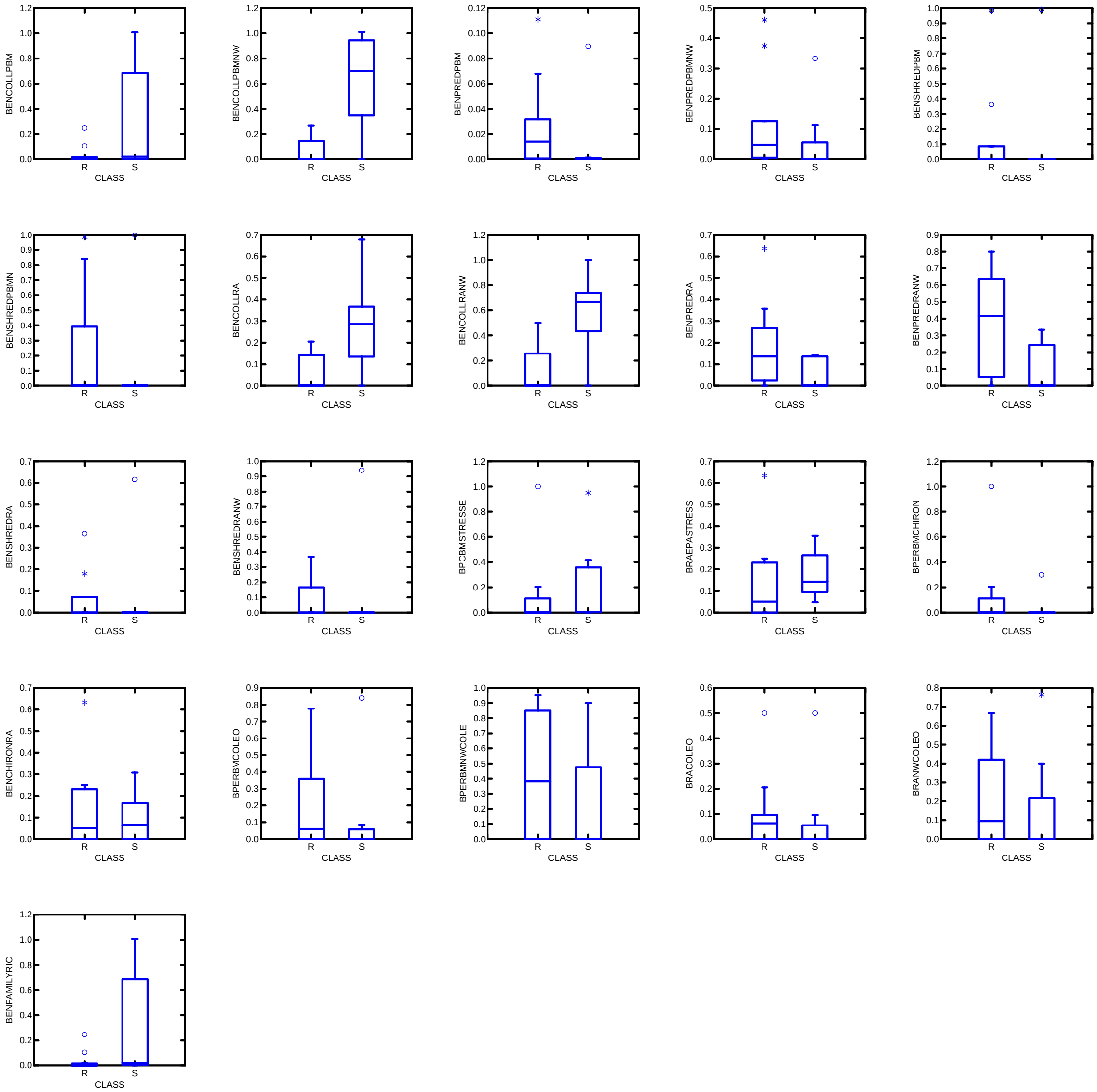


Appendix AN. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	good
nRAepaStress	Relative abundance EPA stressed	good
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	fair
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeo*	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	poor
npBMColCorix*	% Biomass Coleoptera + Corixidae *	poor
nRAColCorix	Relative abundance Coleoptera + Corixidae	poor
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	poor
npBMDytisc	% Biomass Dytiscidae	poor
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	fair
nekPredpBM*	% Biomass predator[a]	poor
nekShredpBM	% Biomass shredder	poor
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	poor
nekPredRA	Relative abundance predator	fair
nekPredRA*	Relative abundance predator[a]	fair
nekShredRA	Relative abundance shredder	fair
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	good
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibell*	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdo*	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AO. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for floodplain wetlands (N=17). Classifications are reference (R) and stressed (S).

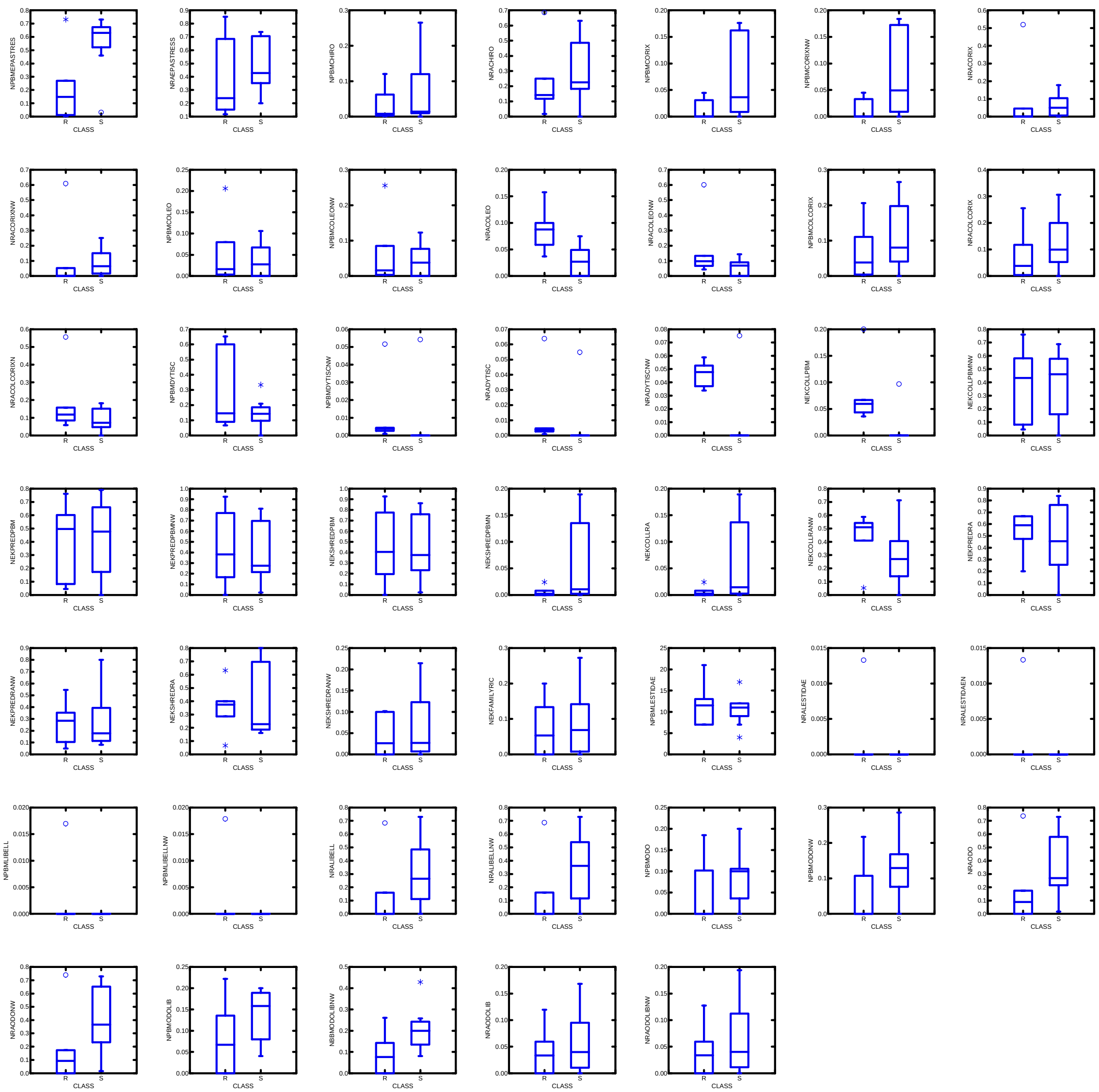


Appendix AO. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	fair
benCollpBM*	% Biomass collector[a]	good
benPredpBM	% Biomass predator	fair
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	good
benCollRA*	Relative abundance collector[a]	good
benPredRA	Relative abundance predator	good
benPredRA*	Relative abundance predator[a]	good
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	fair
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AP. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for impoundment wetlands (N=13). Classifications are reference (R) and stressed (S).

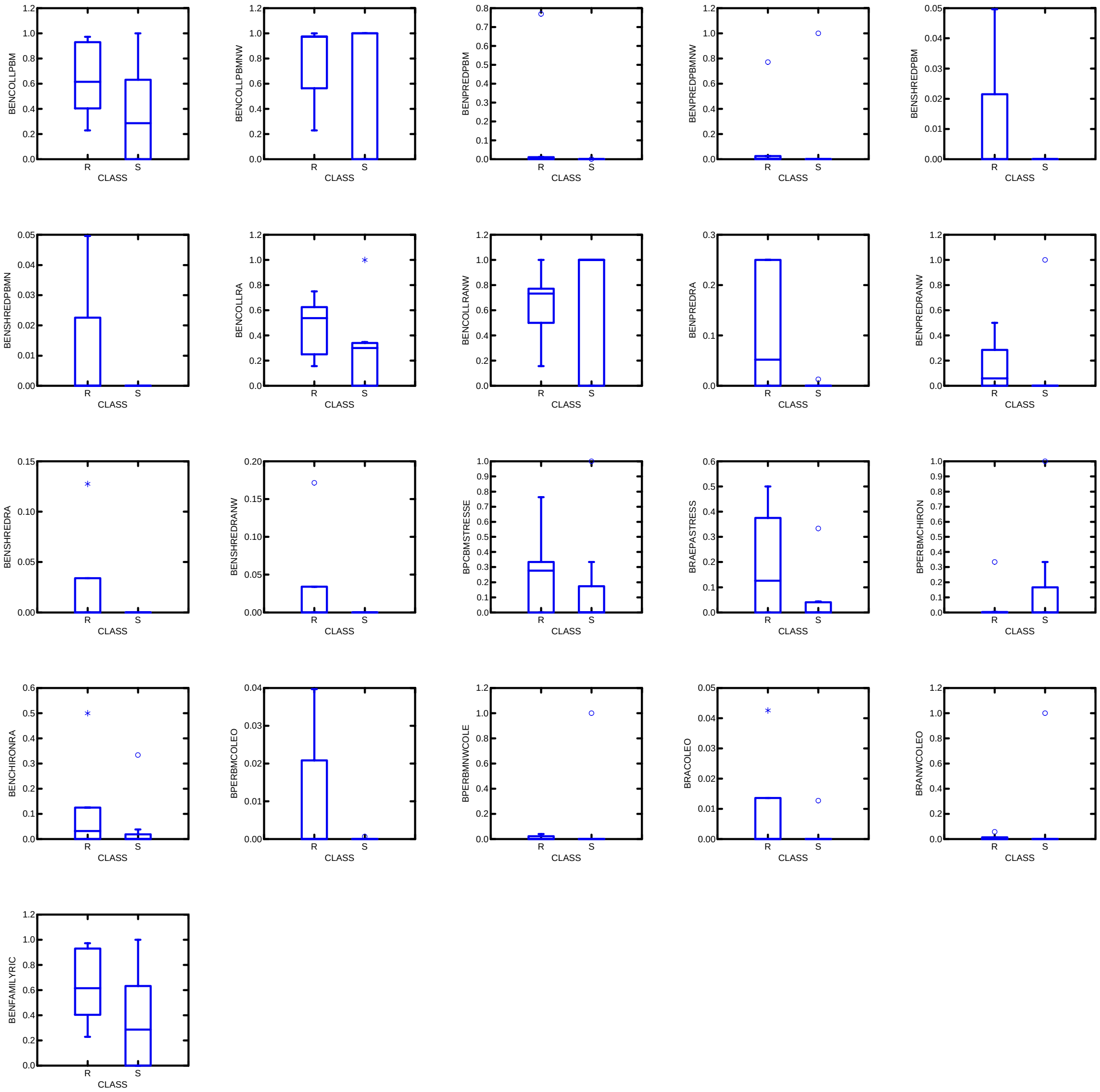


Appendix AP. Contunued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	good
nRAepaStress	Relative abundance EPA stressed	fair
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	poor
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	good
nRAColeo*	Relative abundance Coleoptera[a]	fair
npBMColCorix	% Biomass Coleoptera + Corixidae	fair
npBMColCorix*	% Biomass Coleoptera + Corixidae *	fair
nRAColCorix	Relative abundance Coleoptera + Corixidae	fair
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	fair
npBMDytisc	% Biomass Dytiscidae	poor
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	poor
nekPredpBM*	% Biomass predator[a]	poor
nekShredpBM	% Biomass shredder	poor
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	good
nekPredRA	Relative abundance predator	fair
nekPredRA*	Relative abundance predator[a]	poor
nekShredRA	Relative abundance shredder	fair
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	poor
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	good
npBMLibell*	% Biomass Libellulidae[a]	good
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	fair
nRAOdo	Relative abundance Odonata	good
nRAOdo*	Relative abundance Odonata[a]	good
npBMOdoLib	% Biomass Odonata - Libellulidae	good
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	good
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AQ. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for impoundment wetlands (N=13). Classifications are reference (R) and stressed (S).

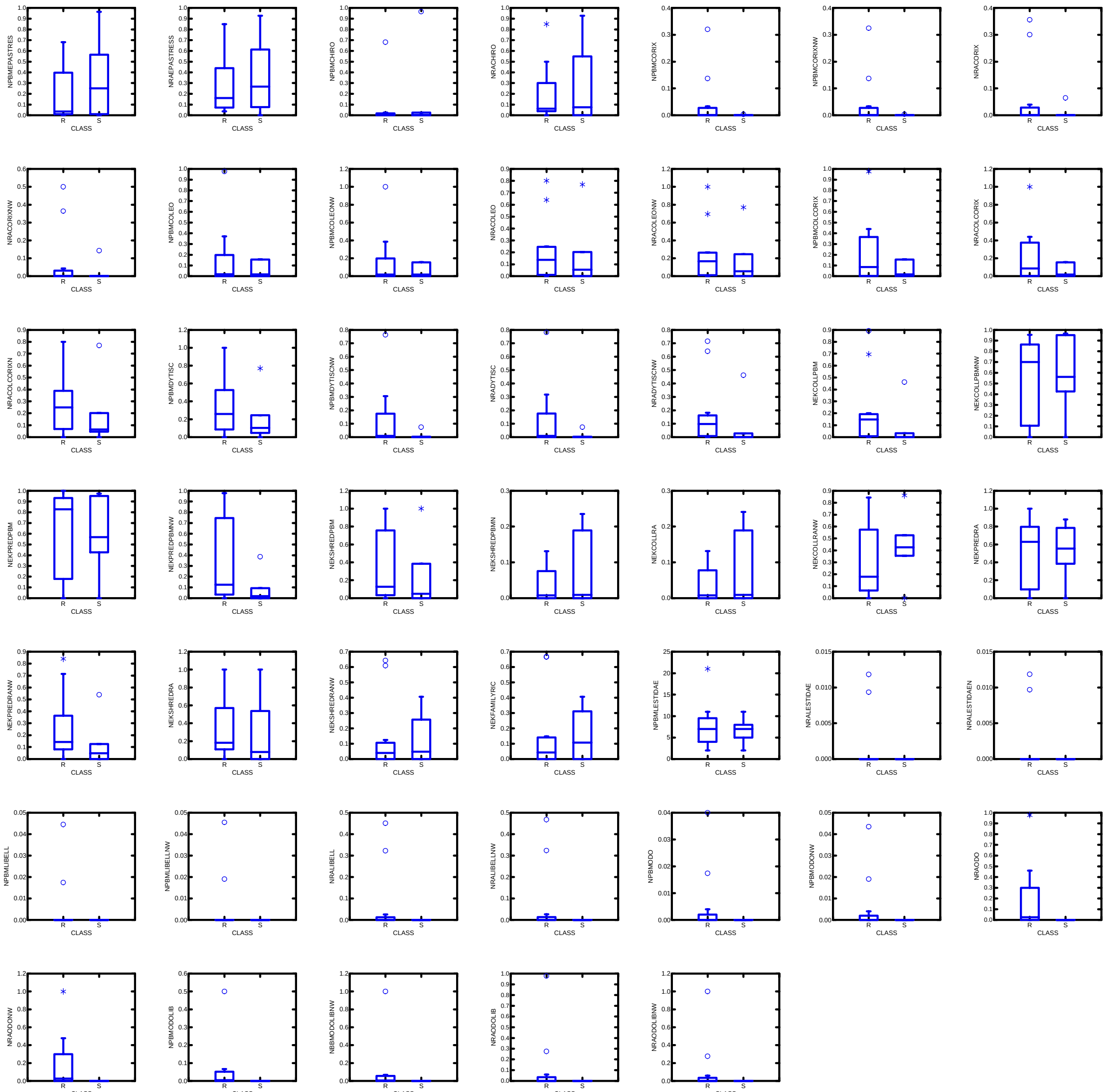


Appendix AQ. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	good
benCollpBM*	% Biomass collector[a]	fair
benPredpBM	% Biomass predator	poor
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	fair
benCollRA*	Relative abundance collector[a]	poor
benPredRA	Relative abundance predator	poor
benPredRA*	Relative abundance predator[a]	poor
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	poor
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	good

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AR. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for riparian depression wetlands (N=17). Classifications are reference (R) and stressed (S).

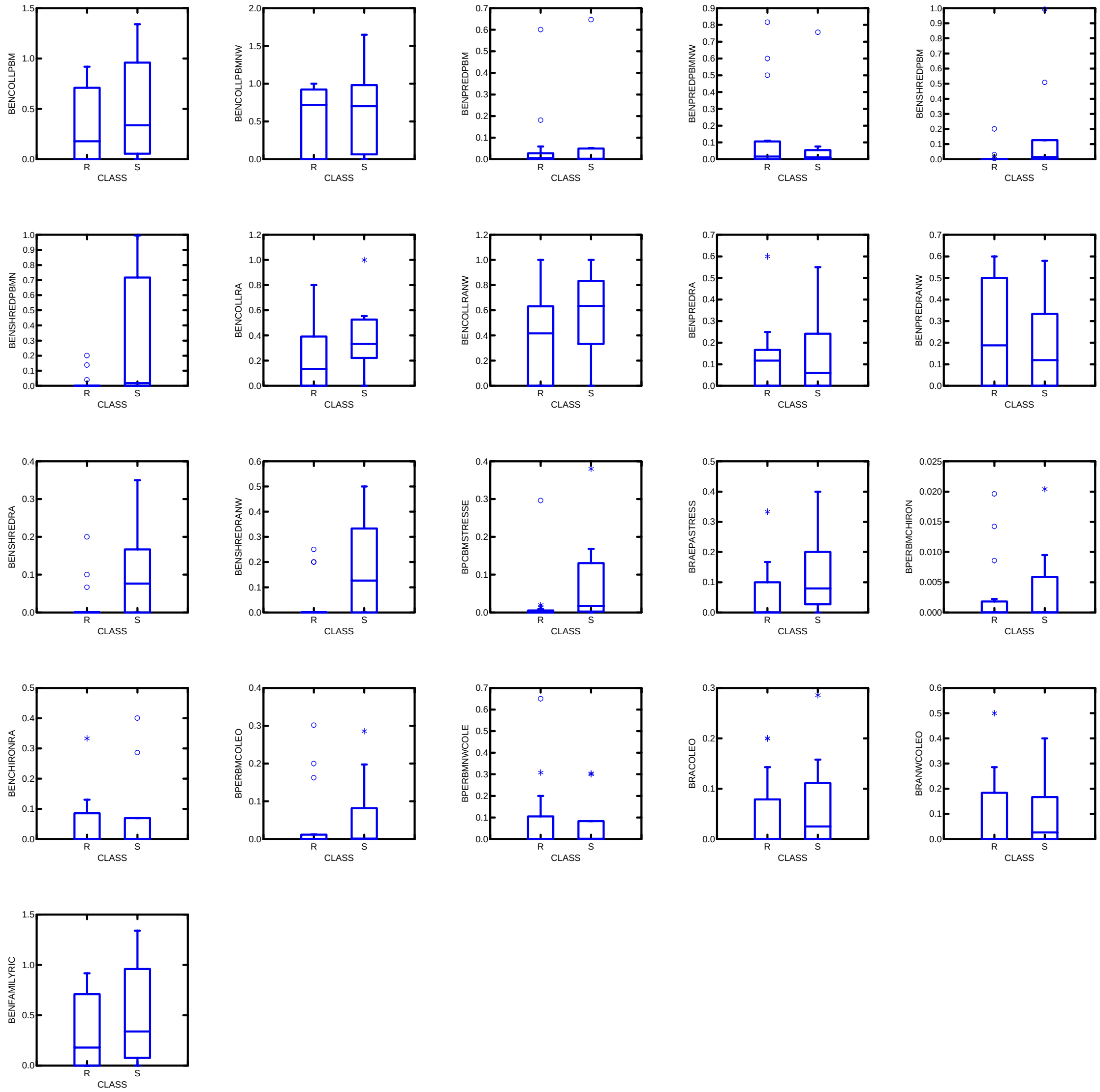


Appendix AR. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	poor
nRAepaStress	Relative abundance EPA stressed	poor
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	poor
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeo*	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	poor
npBMColCorix*	% Biomass Coleoptera + Corixidae *	poor
nRAColCorix	Relative abundance Coleoptera + Corixidae	poor
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	good
npBMDytisc	% Biomass Dytiscidae	good
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	poor
nekPredpBM*	% Biomass predator[a]	poor
nekShredpBM	% Biomass shredder	poor
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	fair
nekPredRA	Relative abundance predator	poor
nekPredRA*	Relative abundance predator[a]	poor
nekShredRA	Relative abundance shredder	fair
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	poor
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibell*	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdo*	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AS. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for riparian depression wetlands (N=26). Classifications are reference (R) and stressed (S).

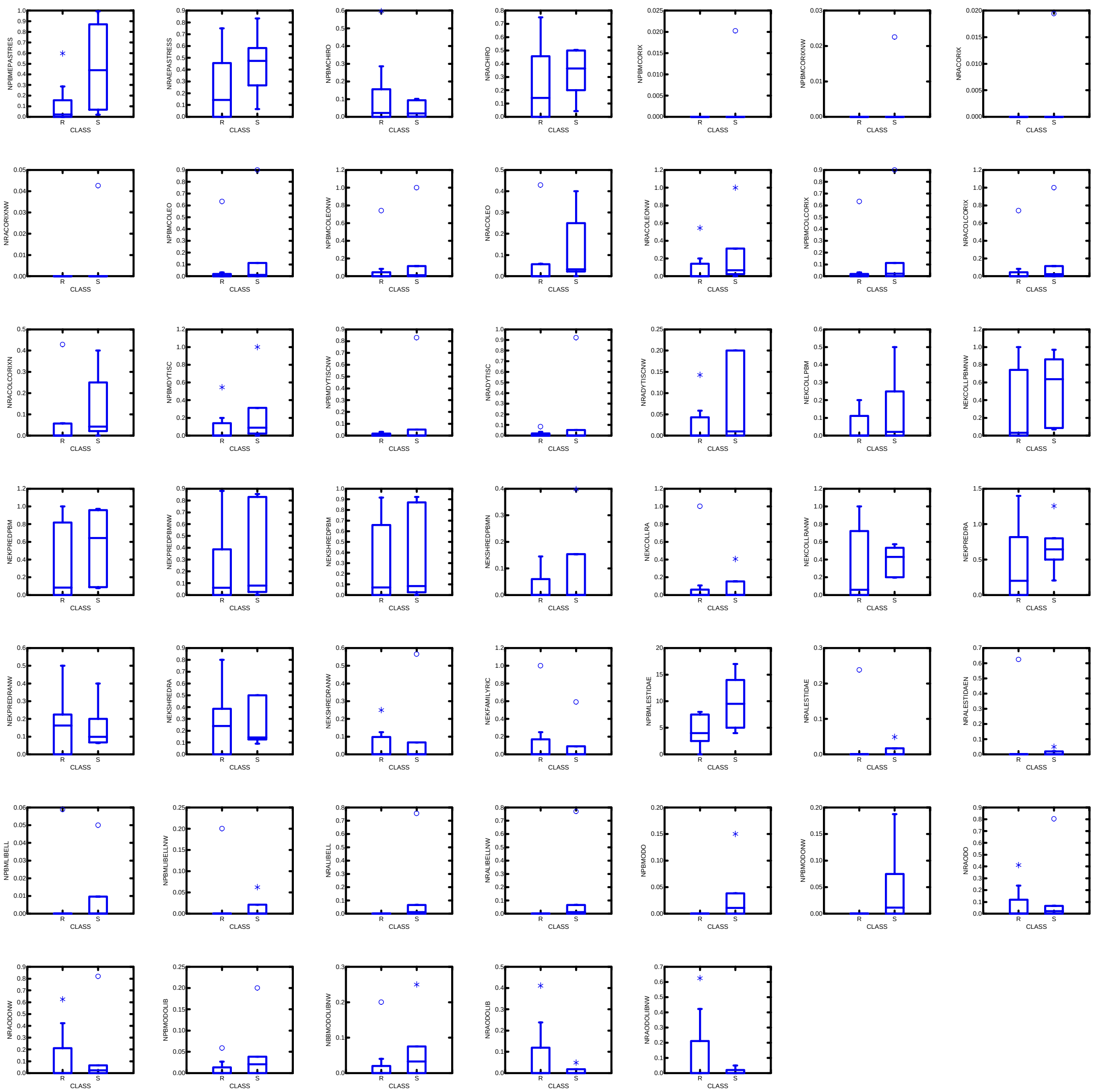


Appendix AS. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	poor
benCollpBM*	% Biomass collector[a]	poor
benPredpBM	% Biomass predator	poor
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	fair
benCollRA*	Relative abundance collector[a]	fair
benPredRA	Relative abundance predator	poor
benPredRA*	Relative abundance predator[a]	poor
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	poor
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	fair

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AT. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for headwater floodplain wetlands (N=13). Classifications are reference (R) and stressed (S).

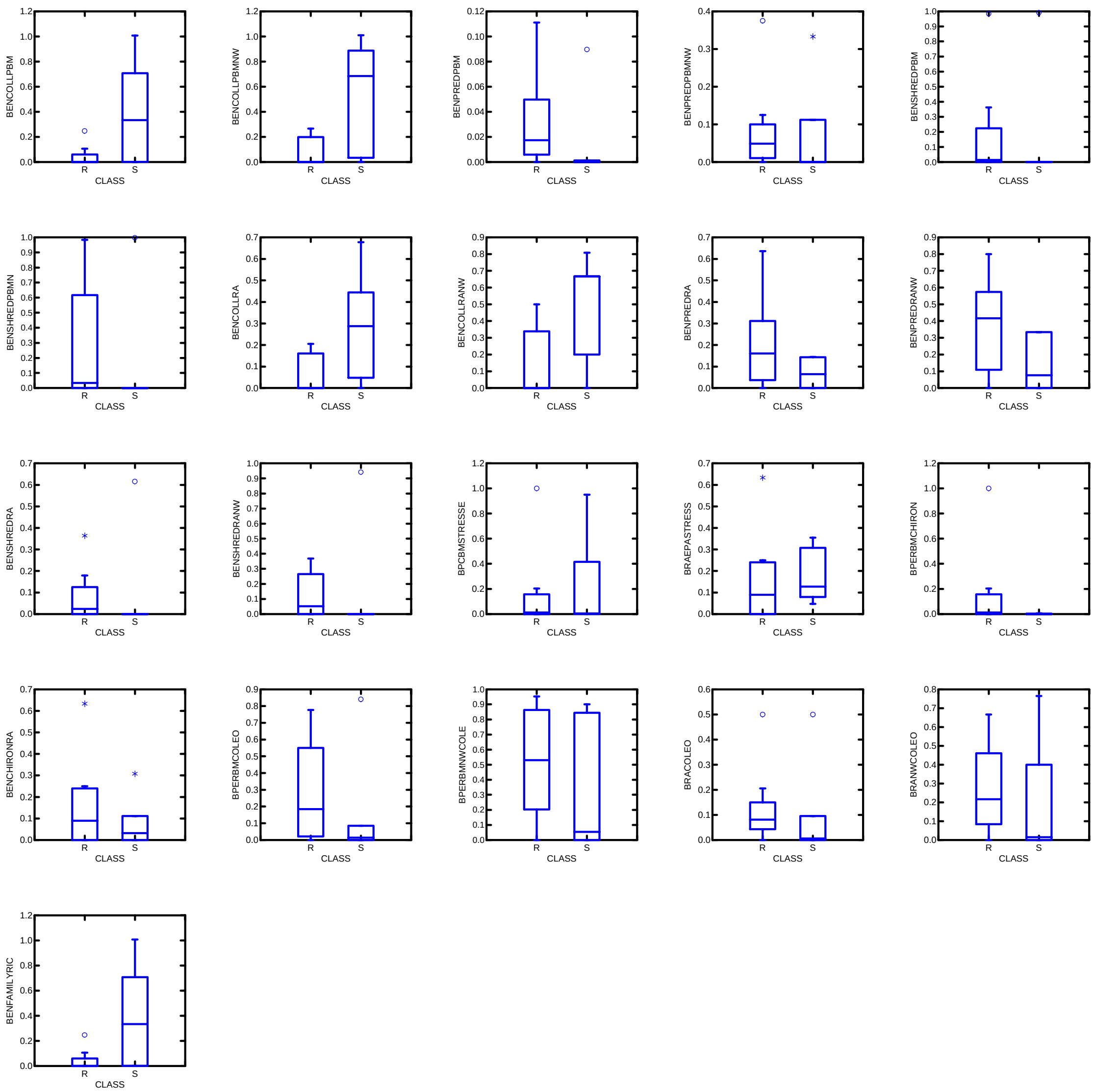


Appendix AT. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	good
nRAepaStress	Relative abundance EPA stressed	good
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	fair
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeo*	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	poor
npBMColCorix*	% Biomass Coleoptera + Corixidae *	poor
nRAColCorix	Relative abundance Coleoptera + Corixidae	poor
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	poor
npBMDytisc	% Biomass Dytiscidae	poor
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	fair
nekPredpBM*	% Biomass predator[a]	poor
nekShredpBM	% Biomass shredder	poor
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	fair
nekPredRA	Relative abundance predator	fair
nekPredRA*	Relative abundance predator[a]	fair
nekShredRA	Relative abundance shredder	fair
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	good
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibell*	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdo*	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AU. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for headwater floodplain wetlands (N=14). Classifications are reference (R) and stressed (S).

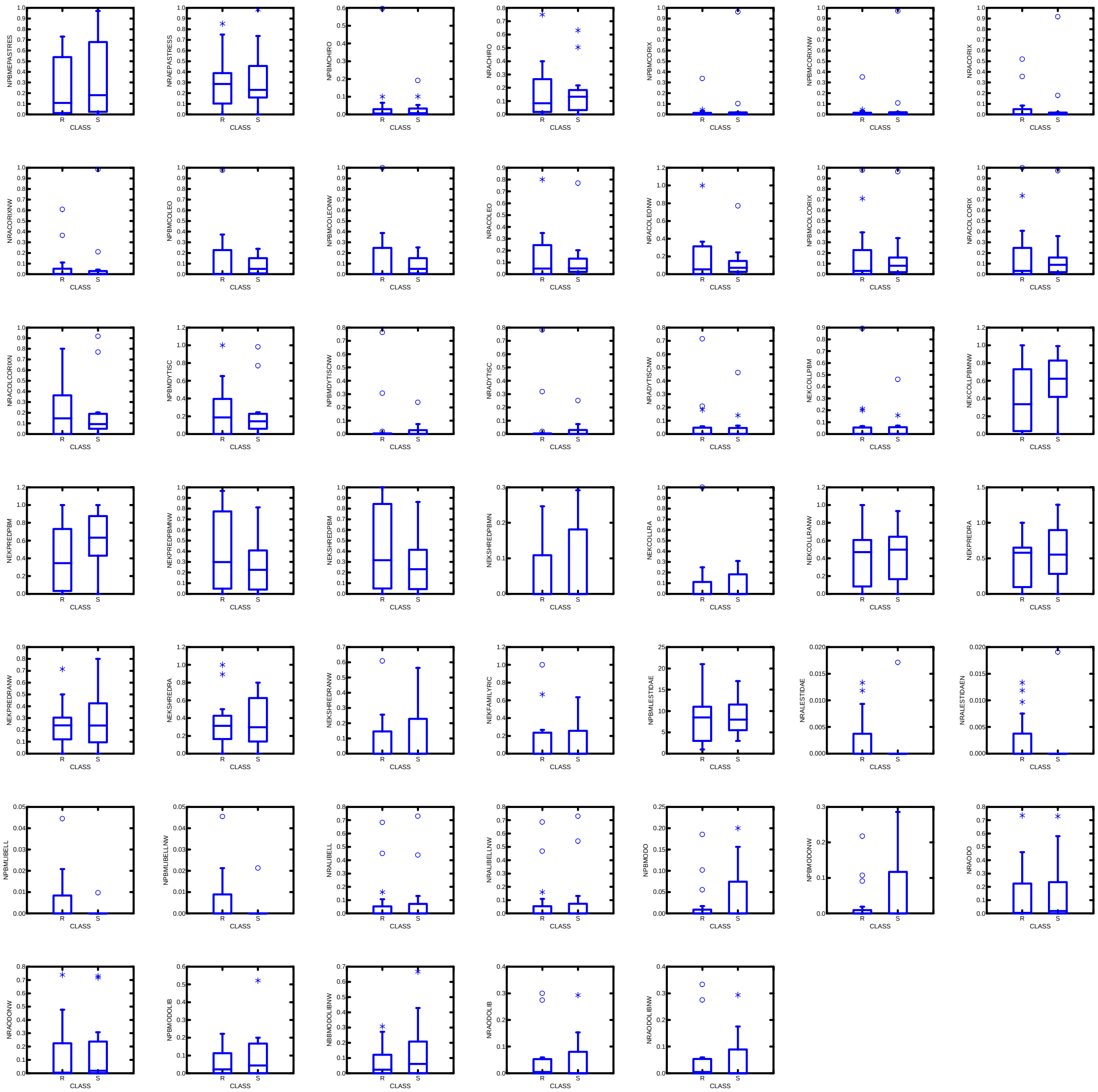


Appendix AU. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	good
benCollpBM*	% Biomass collector[a]	good
benPredpBM	% Biomass predator	fair
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	good
benCollRA*	Relative abundance collector[a]	fair
benPredRA	Relative abundance predator	fair
benPredRA*	Relative abundance predator[a]	good
benShredRA	Relative abundance shredder	fair
benShredRA*	Relative abundance shredder[a]	fair
bPcBMstressed	% Biomass EPA stressed	fair
bRAEPAstressed	Relative abundance EPA stressed	poor
bPerBMChiron	% Biomass Chironomidae	fair
BenChironRA	Relative abundance chironomidae	fair
bPerBMColeo	% Biomass Coleoptera	fair
bPerBM*Coleo	% Biomass Coleoptera[a]	fair
bRAColeo	Relative abundance Coleoptera	fair
bRA*Coleo	Relative abundance Coleoptera[a]	fair
BenFamilyRic	Familial Richness	fair

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AV. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for emergent wetlands (N=28). Classifications are reference (R) and stressed (S).

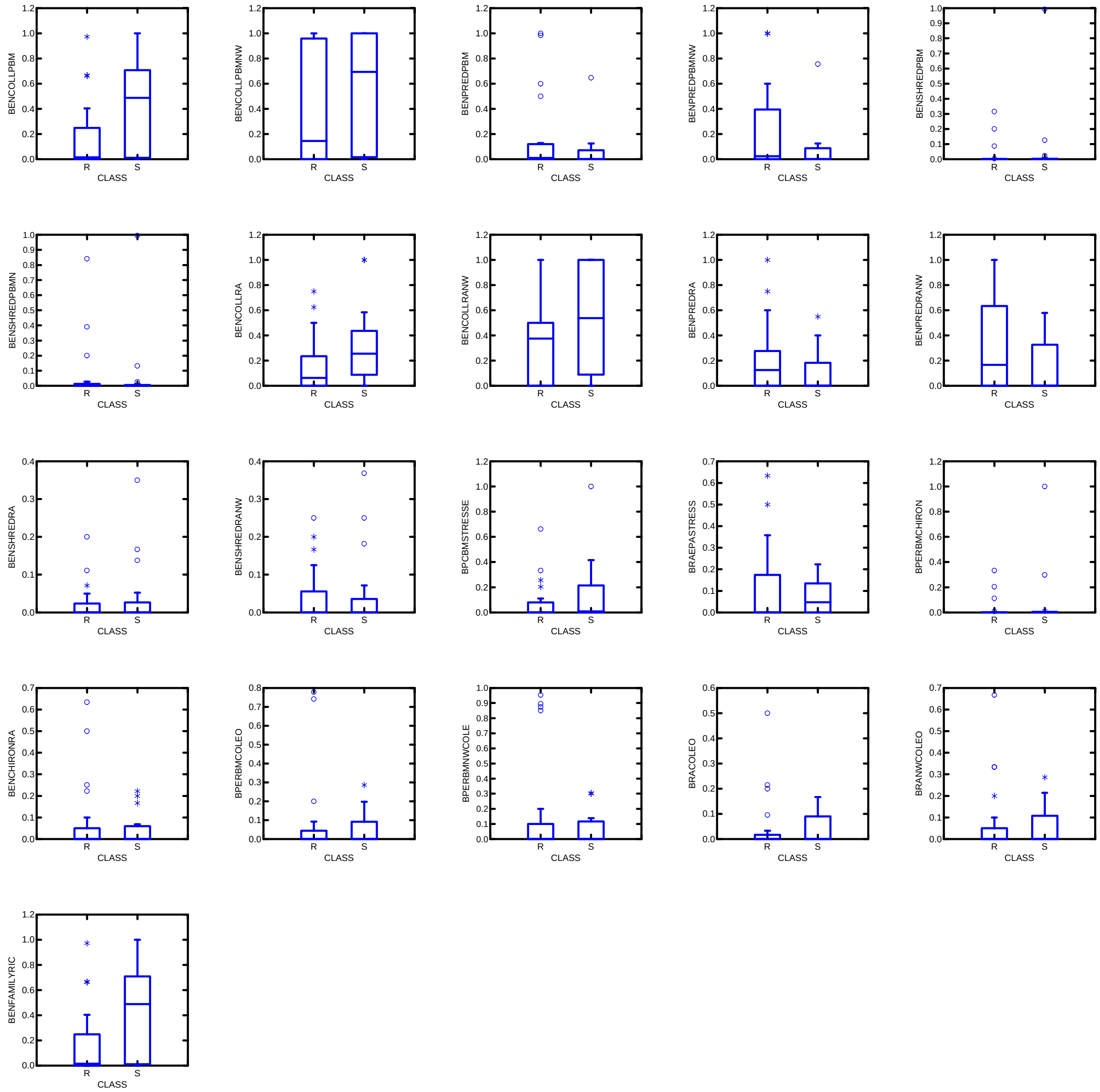


Appendix AV. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	poor
nRAepaStress	Relative abundance EPA stressed	poor
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	poor
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeo*	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	poor
npBMColCorix*	% Biomass Coleoptera + Corixidae *	poor
nRAColCorix	Relative abundance Coleoptera + Corixidae	poor
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	poor
npBMDytisc	% Biomass Dytiscidae	poor
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	fair
nekPredpBM	% Biomass predator	fair
nekPredpBM*	% Biomass predator[a]	poor
nekShredpBM	% Biomass shredder	poor
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	poor
nekPredRA	Relative abundance predator	poor
nekPredRA*	Relative abundance predator[a]	poor
nekShredRA	Relative abundance shredder	poor
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	poor
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibell*	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdo*	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AW. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for emergent wetlands (N=35). Classifications are reference (R) and stressed (S).

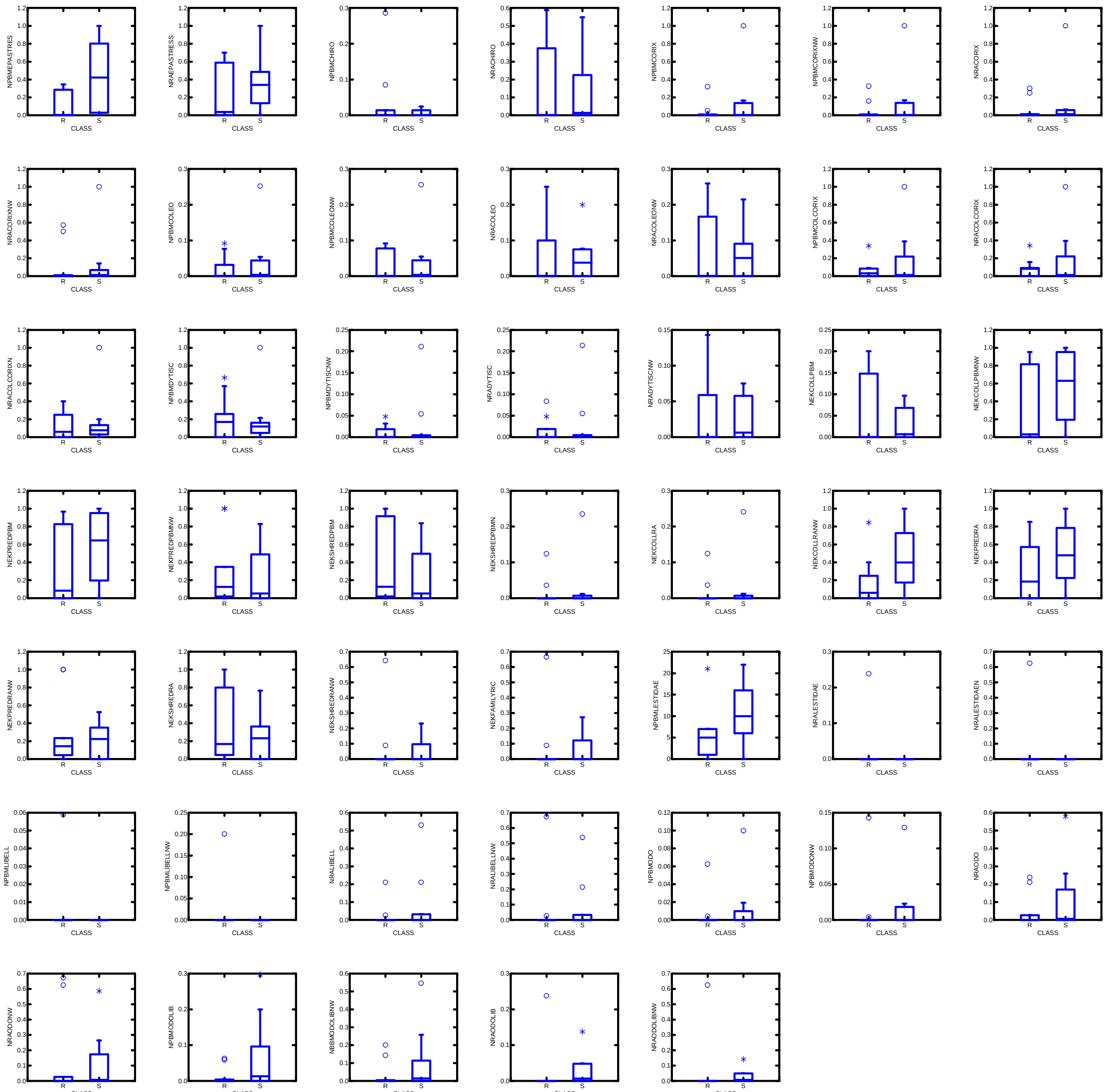


Appendix AW. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	fair
benCollpBM*	% Biomass collector[a]	poor
benPredpBM	% Biomass predator	poor
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	good
benCollRA*	Relative abundance collector[a]	fair
benPredRA	Relative abundance predator	fair
benPredRA*	Relative abundance predator[a]	fair
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	poor
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AX. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for scrub-shrub wetlands (N=19). Classifications are reference (R) and stressed (S).

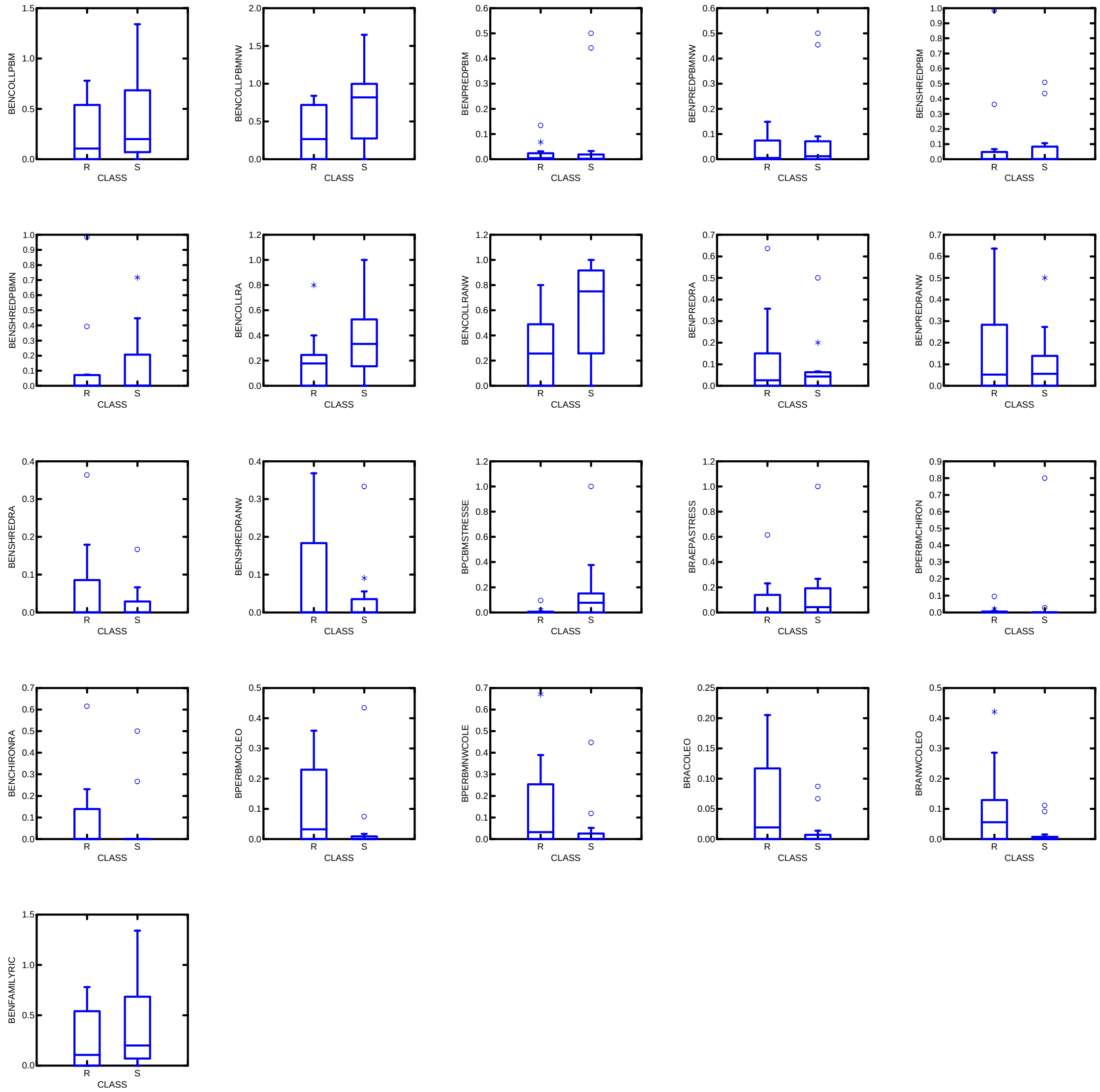


Appendix AX. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	poor
nRAepaStress	Relative abundance EPA stressed	poor
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	poor
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeo*	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	poor
npBMColCorix*	% Biomass Coleoptera + Corixidae *	poor
nRAColCorix	Relative abundance Coleoptera + Corixidae	poor
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	poor
npBMDytisc	% Biomass Dytiscidae	poor
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	faair
nekPredpBM*	% Biomass predator[a]	fair
nekShredpBM	% Biomass shredder	poor
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	good
nekPredRA	Relative abundance predator	fair
nekPredRA*	Relative abundance predator[a]	poor
nekShredRA	Relative abundance shredder	poor
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	good
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibell*	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdo*	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AY. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for scrub-shrub wetlands (N=22). Classifications are reference (R) and stressed (S).

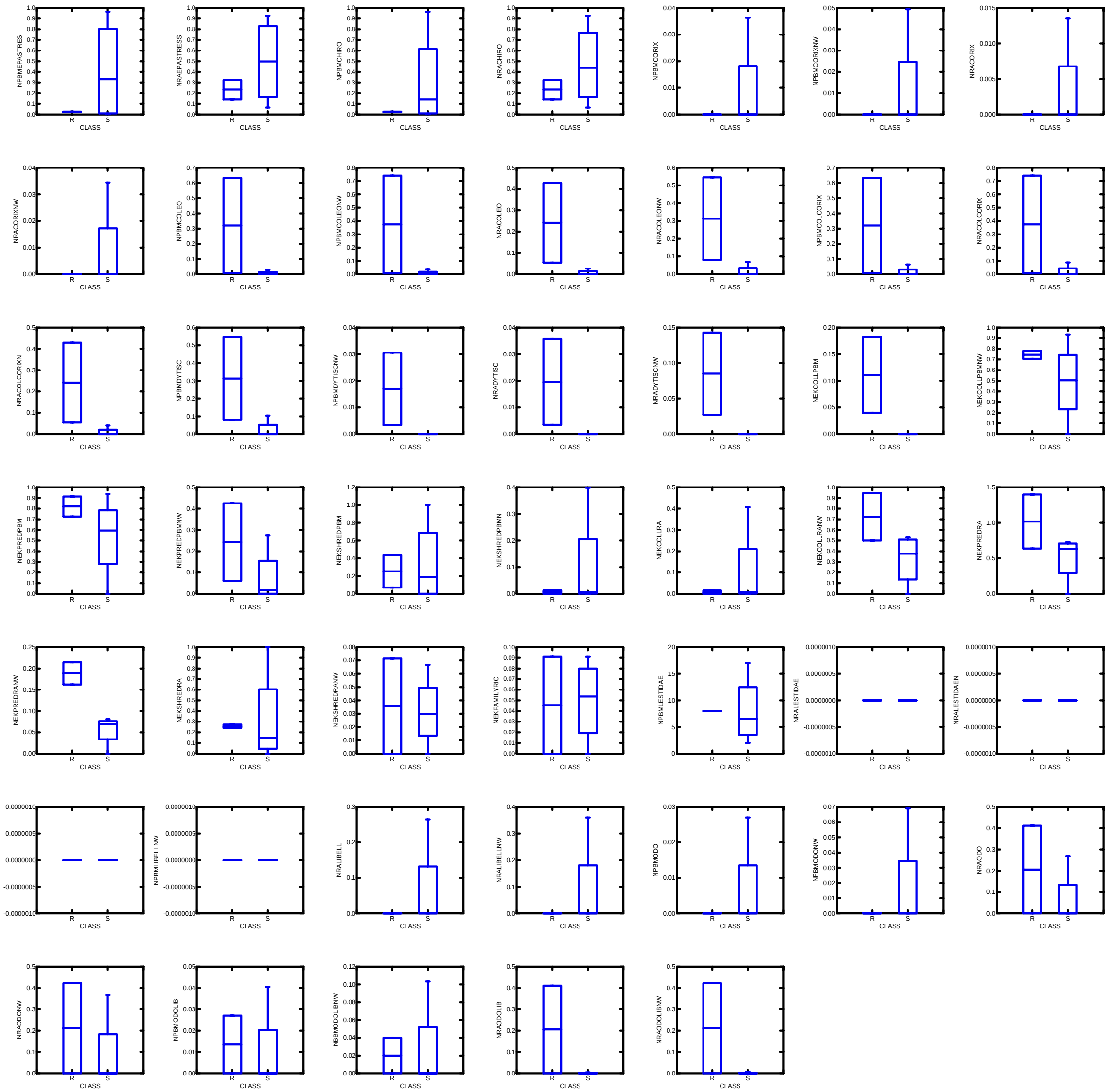


Appendix AY. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	poor
benCollpBM*	% Biomass collector[a]	good
benPredpBM	% Biomass predator	poor
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	fair
benCollRA*	Relative abundance collector[a]	good
benPredRA	Relative abundance predator	poor
benPredRA*	Relative abundance predator[a]	poor
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	poor
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix AZ. Nektonic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for forested wetlands (N=6). Classifications are reference (R) and stressed (S).

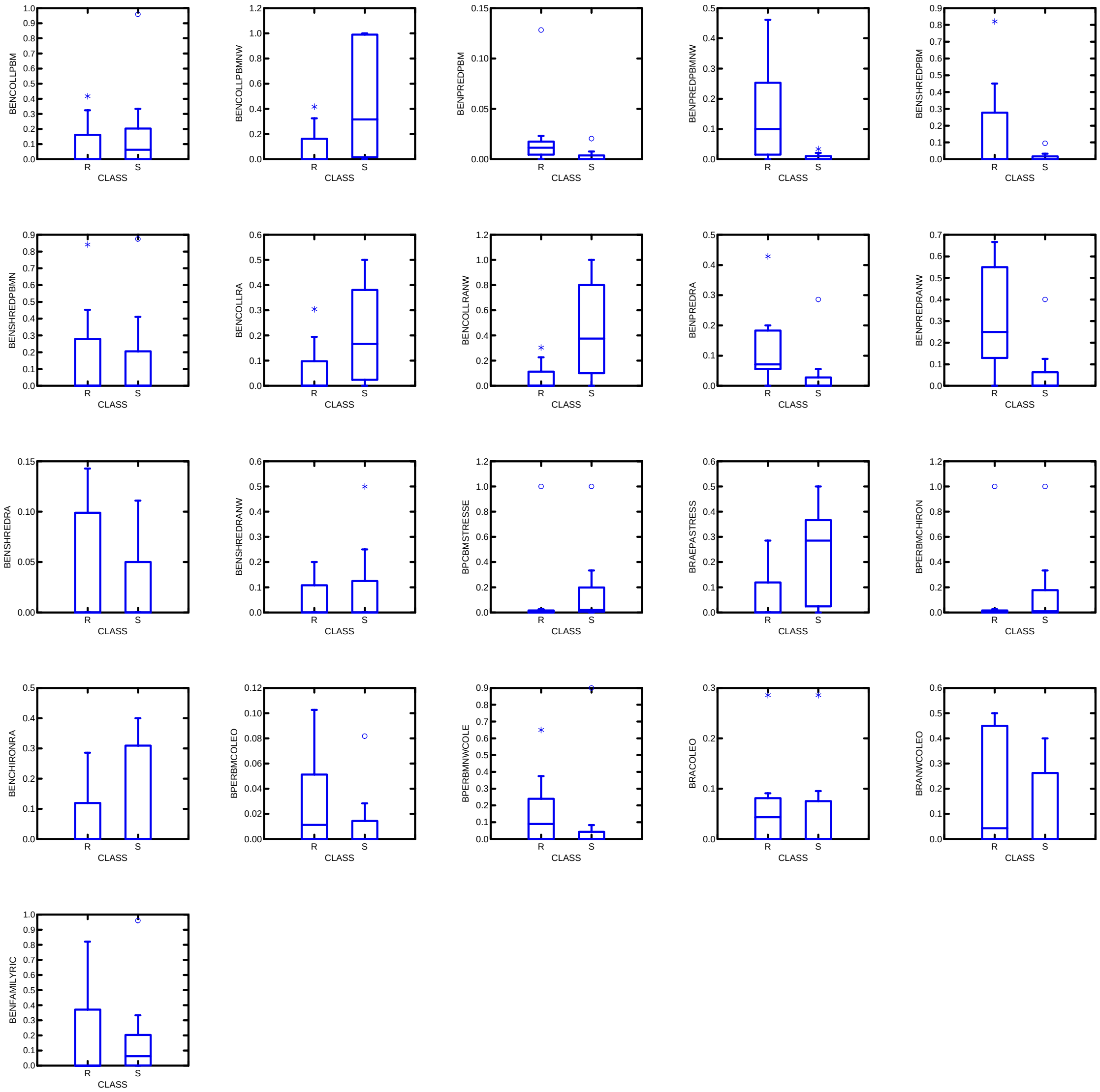


Appendix AZ. Continued.

Metric Code	Metric Description	Rating
npBMepaStres	% Biomass EPA stressed	fair
nRAepaStress	Relative abundance EPA stressed	poor
npBMChiro	% Biomass Chironomidae	poor
nRAChiro	Relative abundance Chironomidae	fair
npBMCorix	% Biomass Corixidae	poor
npBMCorix*	% Biomass Corixidae[a]	poor
nRACorix	Relative abundance Corixidae	poor
nRACorix*	Relative abundance Corixidae[a]	poor
npBMColeo	% Biomass Coleoptera	poor
npBMColeo*	% Biomass Coleoptera[a]	poor
nRAColeo	Relative abundance Coleoptera	poor
nRAColeo*	Relative abundance Coleoptera[a]	poor
npBMColCorix	% Biomass Coleoptera + Corixidae	poor
npBMColCorix*	% Biomass Coleoptera + Corixidae *	poor
nRAColCorix	Relative abundance Coleoptera + Corixidae	poor
nRAColCorixN	Relative abundance Coleoptera + Corixidae[a]	poor
npBMDytisc	% Biomass Dytiscidae	poor
npBMDytisc*	% Biomass Dytiscidae *	poor
nRADytisc	Relative abundance Dytiscidae	poor
nRADytisc*	Relative abundance Dytiscidae[a]	poor
nekCollpBM	% Biomass collector	poor
nekCollpBM*	% Biomass collector[a]	poor
nekPredpBM	% Biomass predator	poor
nekPredpBM*	% Biomass predator[a]	good
nekShredpBM	% Biomass shredder	good
nekShredpBM*	% Biomass shredder[a]	poor
nekCollRA	Relative abundance collector	poor
nekCollRA*	Relative abundance collector[a]	poor
nekPredRA	Relative abundance predator	poor
nekPredRA*	Relative abundance predator[a]	poor
nekShredRA	Relative abundance shredder	poor
nekShredRA*	Relative abundance shredder[a]	poor
NekFamilyRich	Familial richness	poor
npBMLestidae	% Biomass Lestidae	poor
npBMLestidaeN	% Biomass Lestidae[a]	poor
nRALestidae	Relative abundance Lestidae	poor
nRALestidaeN	Relative abundance Lestidae[a]	poor
npBMLibell	% Biomass Libellulidae	poor
npBMLibell*	% Biomass Libellulidae[a]	poor
nRALibell	Relative abundance Libellulidae	poor
nRALibell*	Relative abundance Libellulidae[a]	poor
npBMOdo	% Biomass Odonata	poor
npBMOdo*	% Biomass Odonata[a]	poor
nRAOdo	Relative abundance Odonata	poor
nRAOdo*	Relative abundance Odonata[a]	poor
npBMOdoLib	% Biomass Odonata - Libellulidae	poor
nbBMOdoLib*	% Biomass Odonata - Libellulidae[a]	poor
nRAOdoLib	Relative abundance Odonata - Libellulidae	poor
nRAOdoLib*	Relative abundance Odonata - Libellulidae	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix BA. Benthic macroinvertebrate community metrics box-and-whisker results and narrative descriptions for forested wetlands (N=14). Classifications are reference (R) and stressed (S).



Appendix BA. Continued.

Metric code	Metric description	Rating
benCollpBM	% Biomass collector	poor
benCollpBM*	% Biomass collector[a]	fair
benPredpBM	% Biomass predator	fair
benPredpBM*	% Biomass predator[a]	poor
benShredpBM	% Biomass shredder	poor
benShredpBMN	% Biomass shredder[a]	poor
benCollRA	Relative abundance collector	good
benCollRA*	Relative abundance collector[a]	good
benPredRA	Relative abundance predator	good
benPredRA*	Relative abundance predator[a]	good
benShredRA	Relative abundance shredder	poor
benShredRA*	Relative abundance shredder[a]	poor
bPcBMstressed	% Biomass EPA stressed	poor
bRAEPAstressed	Relative abundance EPA stressed	good
bPerBMChiron	% Biomass Chironomidae	poor
BenChironRA	Relative abundance chironomidae	poor
bPerBMColeo	% Biomass Coleoptera	poor
bPerBM*Coleo	% Biomass Coleoptera[a]	poor
bRAColeo	Relative abundance Coleoptera	poor
bRA*Coleo	Relative abundance Coleoptera[a]	poor
BenFamilyRic	Familial Richness	poor

* Indicates metric calculated without including Chironomidae or Oligochaeta.

Appendix BB. Nektonic macroinvertebrate richness, count and weight by family used to form macroinvertebrate indices of biological integrity for wetlands in West Virginia, USA 2005-2006.

SiteCode	Order	Family	Count	Weight
CFCROS	Nektonic Family Richness	4		
	Diptera	Chironomidae	3	0.0002
	Ephemeroptera	Caenidae	1	0.0002
	Megaloptera	Corydalidae	1	0.0014
	Coleoptera	Elmidae	1	0.0005
CFECUR	Nektonic Family Richness	3		
	Diptera	Chironomidae	17	0.0062
	Ephemeroptera	Caenidae	1	0.0004
	Oligochaeta	NA	2	0.0025
CFEINC	Nektonic Family Richness	7		
	Odonata	Libellulidae	2	0.0071
	Odonata	Coenagrionidae	1	0.0023
	Diptera	Chironomidae	12	0.0031
	Gastropoda	Physidae	1	0.0013
	Hemiptera	Gerridae	1	0.0006
	Ephemeroptera	Caenidae	1	0.0005
	Coleoptera	Staphylinidae	1	0.0013
CFSLCH	Nektonic Family Richness	8		
	Diptera	Chironomidae	18	0.0052
	Isopoda	Asellidae	5	0.0016
	Ephemeroptera	Baetidae	10	0.0065
	Coleoptera	Dytiscidae	2	0.0009
	Gastropoda	Physidae	2	0.033
	Hydracarina	NA	1	0.0001
	Diptera	Culicidae	3	0.0008
	Cladocera	NA	24	0.0018
CFSLIN	Nektonic Family Richness	10		
	Diptera	Culicidae	1	0.0001
	Megaloptera	Sialidae	1	0.0001
	Ephemeroptera	Baetidae	1	0.001
	Hymenoptera	Formicidae	1	0.0002
	Hemiptera	Belostomatidae	1	0.0914
	Odonata	Libellulidae	1	0.0121
	Odonata	Coenagrionidae	2	0.006
	Cladocera	NA	3	0.0001
	Diptera	Chironomidae	5	0.0012
	Oligochaeta	NA	2	0.0012

Appendix BB. Continued.

SiteCode		Order	Family	Count	Weight
CHNEER	Nektonic Family Richness		18		
		Bivalvia	Sphaeriidae	1	0.0004
		Coleoptera	Dytiscidae	3	0.0271
		Diptera	Chaoboridae	3	0.0006
		Diptera	Chironomidae	8	0.0018
		Diptera	Culicidae	2	0.0001
		Gastropoda	Planorbidae	4	0.0016
		Hemiptera	Corixidae	3	0.0176
		Hemiptera	Belostomotidae	2	0.0363
		Hemiptera	Notonectidae	1	0.0018
		Hemiptera	Veliidae	3	0.0001
		Hemiptera	Hydrometridae	1	0.0008
		Podocopa	NA	1	0.0001
		Coleoptera	Hydrophilidae	1	0.0053
		Isopoda	Asellidae	12	0.0015
		Cladocera	NA	2	0.0001
		Odonata	Coenagrionidae	3	0.0038
		Odonata	Libellulidae	1	0.0271
		Odonata	Aeshnidae	1	0.0025
CHSAFO	Nektonic Family Richness		5		
		Decapoda	Cambaridae	1	0.0304
		Gastropoda	Physidae	8	0.0419
		Diptera	Chironomidae	4	0.0016
		Diptera	Stratiomyidae	1	0.0024
		Hemiptera	Veliidae	1	0.0001
CHSARR	Nektonic Family Richness		3		
		Diptera	Chironomidae	4	0.0006
		Bivalvia	Sphaeriidae	1	0.0019
		Hemiptera	Corixidae	55	0.0628
CHWWBW	Nektonic Family Richness		12		
		Ephemeroptera	Baetidae	2	0.0014
		Hemiptera	Pleidae	4	0.0001
		Odonata	Libellulidae	4	0.0363
		Hemiptera	Veliidae	2	0.0001
		Coleoptera	Dytiscidae	3	0.0037
		Hemiptera	Naucoridae	5	0.0036
		Hemiptera	Notonectididae	1	0.0069
		Hemiptera	Corixidae	2	0.0113
		Diptera	Culicidae	1	0.0001
		Diptera	Chaoboridae	3	0.0007
		Diptera	Chironomidae	9	0.0009
		Odonata	Coenagrionidae	4	0.0033

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
CHWWEM	Nektonic Family Richness	15		
	Gastropoda	Physidae	2	0.0098
	Diptera	Chironomidae	17	0.0031
	Ephemeroptera	Baetidae	5	0.0027
	Coleoptera	Haliplidae	1	0.0029
	Coleoptera	Dytiscidae	8	0.0172
	Coleoptera	Hydrophilidae	6	0.0137
	Odonata	Coenagrionidae	1	0.0018
	Odonata	Libellulidae	2	0.0114
	Odonata	Aeshnidae	1	0.0222
	Isopoda	Asellidae	11	0.0012
	Hemiptera	Mesoveliidae	1	0.0001
	Diptera	Ceratopogonidae	2	0.0001
	Hemiptera	Corixidae	1	0.0009
	Diptera	Culicidae	2	0.0001
	Hemiptera	Pleidae	1	0.0006
CHWWFO	Nektonic Family Richness	17		
	Isopoda	Asellidae	2	0.0005
	Coleoptera	Haliplidae	1	0.0012
	Coleoptera	Hydrophilidae	1	0.0001
	Hemiptera	Veliidae	1	0.0001
	Hemiptera	Corixidae	1	0.0017
	Ephemeroptera	Baetidae	1	0.0019
	Cladocera	NA	2	0.0001
	Odonata	Libellulidae	2	0.0124
	Odonata	Coenagrionidae	1	0.0002
	Gastropoda	Physidae	1	0.0054
	Bivalvia	Sphaeriidae	3	0.0074
	Gastropoda	Planorbidae	5	0.0022
	Diptera	Chaoboridae	1	0.0001
	Diptera	Ceratopogonidae	1	0.0001
	Diptera	Culicidae	5	0.0009
	Diptera	Chironomidae	45	0.0124
	Calanoida	NA	1	0.0001
CVABBW	Nektonic Family Richness	1		
	Amphipoda	Gammaridae	53	0.0148
CVABCT	Nektonic Family Richness	2		
	Ephemeroptera	Ephemeridae	3	0.0052
	Amphipoda	Gammaridae	18	0.0226
DSPICN	Nektonic Family Richness	1		
	Megaloptera	Sialidae	3	0.0074
DSROAR	Nektonic Family Richness	4		
	Megaloptera	Sialidae	1	0.0046
	Plecoptera	Leuctridae	1	0.0009
	Diptera	unknown pupae	1	0.0001
	Aranae	NA	1	0.0028

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
EPCMEM	Nektonic Family Richness	6		
	Amphipoda	Gammaridae	12	0.0021
	Diptera	Culicidae	1	0.0001
	Diptera	Stratiomyidae	5	0.0141
	Isopoda	Asellidae	4	0.0017
	Gastropoda	Physidae	14	0.0793
	Oligochaeta	NA	5	0.0039
EPCMFO	Nektonic Family Richness	8		
	Oligochaeta	NA	3	0.0001
	Podacopa	NA	10	0.0033
	Amphipoda	Gammaridae	5	0.0056
	Gastropoda	Lynaeidae	1	0.0009
	Gastropoda	Physidae	4	0.03
	Bivalvia	Sphaeriidae	5	0.0152
	Isopoda	Asellidae	1	0.0001
	Diptera	Chironomidae	2	0.0001
EPKYVE	Nektonic Family Richness	10		
	Diptera	Ceratopogonidae	1	0.0002
	Oligochaeta	NA	2	0.0117
	Diptera	Chironomidae	24	0.0046
	Gastropoda	Physidae	25	0.1681
	Hemiptera	Corixidae	1	0.0002
	Coleoptera	Chrysomelidae	1	0.0089
	Isopoda	Asellidae	12	0.0058
	Amphipoda	Gammaridae	2	0.005
	Bivalvia	Sphaeriidae	1	0.0075
	Gastropoda	Lymnaeidae	2	0.012
EPSHEM	Nektonic Family Richness	4		
	Coleoptera	Curculionidae	1	0.0078
	Diptera	Culicidae	9	0.0016
	Gastropoda	Lymnaeidae	2	0.0142
	Aranae	Pisauridae	2	0.0044

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
EPSHSS	Nektonic Family Richness	12		
	Aranae	Pisauridae	1	0.0361
	Oligochaeta	NA	1	0.0005
	Hydracarina	NA	1	0.0001
	Gastropoda	Lymnaeidae	2	0.0041
	Collembola	Isotomidae	1	0.0001
	Thysanoptera	NA	2	0.0001
	Coleoptera	Dytiscidae	1	0.0002
	Aranae	Lycosidae	1	0.001
	Cyclopoida	NA	1	0.0001
	Coleoptera	Scirtidae	2	0.0019
	Hemiptera	Gerridae	1	0.0023
	Bivalvia	Sphaeriidae	1	0.0013
GBBARN	Nektonic Family Richness	8		
	Odonata	Libellulidae	2	0.0238
	Ephemeroptera	Baetidae	2	0.0002
	Diptera	Chironomidae	7	0.0009
	Odonata	Coenagrionidae	2	0.0089
	Megaloptera	Corydalidae	1	0.0081
	Diptera	Culicidae	1	0.0001
	Isopoda	Asellidae	1	0.0014
	Hemiptera	Pleidae	1	0.0004
GBHOEF	Nektonic Family Richness	7		
	Hemiptera	Belostomatidae	2	0.0015
	Hemiptera	Naucoridae	2	0.0023
	Hemiptera	Corixidae	1	0.005
	Odonata	Libellulidae	1	0.0118
	Diptera	Chironomidae	2	0.0001
	Coleoptera	Dytiscidae	16	0.0111
	Lepidoptera	Pyralidae	1	0.0048
GBJENK	Nektonic Family Richness	12		
	Hemiptera	Naucoridae	6	0.0096
	Hemiptera	Hebridae	1	0.0001
	Hemiptera	Mesoveliidae	1	0.0001
	Coleoptera	Dytiscidae	1	0.0001
	Coleoptera	Noteridae	1	0.0017
	Diptera	Culicidae	1	0.0001
	Odonata	Aeshnidae	1	0.0027
	Diptera	Chaoboridae	2	0.0002
	Gastropoda	Planorbidae	1	0.004
	Ephemeroptera	Baetidae	3	0.0019
	Diptera	Chironomidae	3	0.0014
	Hemiptera	Corixidae	1	0.0007

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
GBPLOT	Nektonic Family Richness	9		
	Hemiptera	Mesoveliidae	1	0.0001
	Diptera	Chironomidae	3	0.0003
	Isopoda	Asellidae	2	0.0018
	Diptera	Ceratopogonidae	1	0.0001
	Coleoptera	Hydrophilidae	1	0.001
	Hemiptera	Corixidae	1	0.0028
	Hemiptera	Aphididae	1	0.0001
	Coleoptera	Staphylinidae	1	0.0001
	Coleoptera	Haliplidae	1	0.002
HCBEAV	Nektonic Family Richness	8		
	Copapoda	NA	1	0.0001
	Diptera	Chironomidae	6	0.0003
	Coleoptera	Elmidae	3	0.0007
	Odonata	Coenagrionidae	4	0.0009
	Cladocera	NA	2	0.0001
	Coleoptera	Hydrophilidae	1	0.0003
	Amphipoda	Gammaridae	1	0.0005
	Ephemeroptera	Caenidae	1	0.0001
HIGATE	Nektonic Family Richness	8		
	Gastropoda	Physidae	2	0.013
	Cladocera	NA	2	0.0001
	Diptera	Chironomidae	5	0.0024
	Diptera	Chaoboridae	1	0.0001
	Cyclopoida	NA	1	0.0001
	Hemiptera	Gerridae	1	0.0001
	Oligochaeta	NA	1	0.0003
	Isopoda	Asellidae	10	0.0085
HIJHPK	Nektonic Family Richness	7		
	Bivalvia	Sphaeriidae	1	0.0114
	Oligochaeta	NA	3	0.005
	Hemiptera	Corixidae	1	0.0002
	Gastropoda	Lymnaeidae	1	0.0014
	Hemiptera	Gerridae	2	0.0035
	Hemiptera	Veliidae	2	0.0002
	Diptera	Chironomidae	16	0.0102
HIJHTU	Nektonic Family Richness	11		
	Bivalvia	Sphaeriidae	1	0.0021
	Coleoptera	Haliplidae	1	0.0019
	Cyclopoida	NA	2	0.0001
	Amphipoda	Gammaridae	12	0.0027
	Isopoda	Asellidae	19	0.0074
	Gastropoda	Physidae	11	0.3933
	Oligochaeta	NA	2	0.0018
	Coleoptera	Dytiscidae	2	0.0014
	Coleoptera	Scirtidae	12	0.0051
	Diptera	Dixidae	1	0.0001
	Diptera	Chironomidae	11	0.0022

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
HIPENC	Nektonic Family Richness	21		
	Cyclopoida	NA	3	0.0001
	Decapoda	Cambaridae	1	0.0035
	Odonata	Coenagrionidae	1	0.0002
	Isopoda	Asellidae	5	0.0005
	Hemiptera	Hebridae	1	0.0001
	Gastropoda	Physidae	12	0.1196
	Diptera	Culicidae	2	0.0008
	Odonata	Libellulidae	6	0.0264
	Oligochaeta	NA	2	0.0002
	Coleoptera	Staphylinidae	1	0.0011
	Coleoptera	Haliplidae	2	0.0029
	Odonata	Lestidae	1	0.0022
	Cladocera	NA	5	0.0001
	Gastropoda	Physidae	2	0.003
	Diptera	Dixidae	1	0.0001
	Diptera	Ceratopogonidae	1	0.0001
	Diptera	Chironomidae	1	0.0001
	Coleoptera	Dytiscidae	2	0.0007
	Hemiptera	Veliidae	2	0.0001
	Hemiptera	Gerridae	1	0.0016
	Amphipoda	Gammaridae	7	0.002
HISEWG	Nektonic Family Richness	4		
	Isopoda	Asellidae	1	0.0009
	Oligochaeta	NA	1	0.0015
	Coleoptera	Haliplidae	1	0.0022
	Diptera	Chironomidae	2	0.0002
MCFOUR	Nektonic Family Richness	3		
	Coleoptera	Hydrophilidae	3	0.0159
	Coleoptera	Dytiscidae	25	0.0567
	Diptera	Chironomidae	7	0.0018
MCMEME	Nektonic Family Richness	11		
	Odonata	Coenagrionidae	3	0.0045
	Cladocera	NA	1	0.0001
	Coleoptera	Dytiscidae	2	0.0002
	Hemiptera	Notonectidae	2	0.0185
	Gastropoda	Physidae	1	0.0007
	Diptera	Chironomidae	4	0.0002
	Ephemeroptera	Baetidae	3	0.001
	Hemiptera	Pleidae	1	0.0003
	Hemiptera	Belostomatidae	4	0.0468
	Diptera	Chaoboridae	1	0.0001
	Ephemeroptera	Caenidae	12	0.0034

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
MCMFOR	Nektonic Family Richness	9		
	Isopoda	Asellidae	4	0.004
	Coleoptera	Dytiscidae	5	0.0026
	Hemiptera	Mesoveliidae	1	0.0007
	Coleoptera	Scirtidae	2	0.0003
	Bivalvia	Sphaeriidae	1	0.0214
	Gastropoda	Planorbidae	1	0.0004
	Diptera	Chironomidae	2	0.0001
	Oligochaeta	NA	22	0.0193
	Gastropoda	Physidae	13	0.4772
MCPOND	Nektonic Family Richness	9		
	Hemiptera	Pleidae	1	0.0008
	Hemiptera	Hebridae	6	0.0008
	Hemiptera	Veliidae	1	0.0007
	Diptera	Ceratopogonidae	1	0.0001
	Odonata	Coenagrionidae	4	0.004
	Ephemeroptera	Baetidae	1	0.0011
	Ephemeroptera	Caenidae	11	0.0026
	Diptera	Chironomidae	5	0.0006
	Hemiptera	Mesoveliidae	1	0.0001
MCPOST	Nektonic Family Richness	7		
	Odonata	Libellulidae	1	0.0142
	Ephemeroptera	Caenidae	1	0.0001
	Hemiptera	Hebridae	3	0.0001
	Hemiptera	Naucoridae	1	0.0005
	Cladocera	NA	1	0.0001
	Diptera	Chironomidae	1	0.0001
	Odonata	Coenagrionidae	4	0.006
MCTELE	Nektonic Family Richness	8		
	Coleoptera	Hydrophilidae	1	0.0066
	Isopoda	Asellidae	1	0.0001
	Coleoptera	Noteridae	2	0.0049
	Gastropoda	Physidae	8	0.039
	Nematoda	NA	19	0.0192
	Bivalvia	Sphaeriidae	3	0.02
	Gastropoda	Planorbidae	3	0.0038
	Gastropoda	Viviparidae	1	0.0074

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
ME5092	Nektonic Family Richness	8		
	Hemiptera	Corixidae	2	0.0004
	Ephemeroptera	Baetidae	1	0.0012
	Gastropoda	Physidae	3	0.0437
	Bivalvia	Sphaeriidae	2	0.0131
	Diptera	Ephydridae	2	0
	Diptera	Chironomidae	17	0.003
	Decapoda	Cambaridae	3	0.0289
	Odonota	Cordulegastridae	1	0.0327
MESCOX	Nektonic Family Richness	14		
	Hemiptera	Belastomatidae	1	0.0222
	Coleoptera	Elmidae	1	0.0009
	Coleoptera	Curculionidae	4	0.0054
	Ephemeroptera	Baetidae	1	0.0006
	Gastropoda	Lymnaeidae	1	0.0044
	Odonata	Ashnidae	1	0.005
	Odonata	Libellulidae	6	0.0156
	Odonata	Coenagrionidae	1	0.0006
	Diptera	Chironomidae	4	0.0002
	Diptera	Chaoboridae	1	0.0001
	Gastropoda	Physidae	1	0.0078
	Gastropoda	Planorbidae	1	0.001
	Coleoptera	Dytiscidae	1	0.0008
	Colembella	Poduridae	2	0.0001
MESCRO	Nektonic Family Richness	11		
	Gastropoda	Lymnaeidae	1	0.0012
	Ephemeroptera	Baetidae	1	0.0011
	Gastropoda	Planorbidae	2	0.006
	Isopoda	Asellidae	1	0.0001
	Odonata	Libellulidae	1	0.0013
	Odonata	Aeshnidae	1	0.0038
	Hemiptera	Corixidae	3	0.0036
	Coleoptera	Hydrophilidae	1	0.0024
	Oligochaeta	NA	2	0.0019
	Diptera	Chironomidae	8	0.0011
	Diptera	Dixidae	1	0.0001

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
MESCUP	Nektonic Family Richness	11		
	Odonata	Coenagrionidae	1	0.0001
	Isopoda	Asellidae	6	0.0017
	Hemipetra	Corixidae	2	0.0031
	Oligocheata	NA	1	0.0001
	Bivalvia	Sphaeriidae	2	0.0036
	Gastropoda	Valvatidae	4	0.0028
	Odonata	Aeshnidae	1	0.0006
	Gastropoda	Physidae	1	0.0006
	Gastropoda	Lymnaeidae	1	0.002
	Diptera	Chironomidae	6	0.0001
	Odonata	Libellulidae	3	0.0029
MESIGN	Nektonic Family Richness	3		
	Coleptera	Hydrophilidae	1	0.0008
	Diptera	Stratiomyidae	1	0.0013
	Gastropoda	Lymnaeidae	1	0.0058
MESILV	Nektonic Family Richness	8		
	Coleoptera	Staphylinidae	1	0.0006
	Isopoda	Asellidae	16	0.0028
	Diptera	Dixidae	3	0.0001
	Diptera	Chironomidae	3	0.0001
	Gastropoda	Lymnaeidae	2	0.0207
	Gastropoda	Physidae	6	0.0502
	Decapoda	Cambaridae	1	0.0029
	Coleoptera	Dytiscidae	8	0.0086
METETR	Nektonic Family Richness	6		
	Coleoptera	Dytiscidae	2	0.0038
	Coleoptera	Hydrophilidae	2	0.0015
	Odonata	Libellulidae	5	0.0088
	Hemiptera	Mesoveliidae	3	0.0012
	Diptera	Chironomidae	4	0.0001
	Gastropoda	Physidae	16	0.0516
MEWOLF	Nektonic Family Richness	7		
	Decapoda	Cambaridae	2	0.0082
	Gastropoda	Physidae	1	0.1469
	Coleoptera	Hydrophilidae	3	0.0082
	Coleoptera	Dytiscidae	4	0.009
	Bivalvia	Sphaeriidae	1	0.0002
	Isopoda	Asellidae	16	0.0151
	Diptera	Chironomidae	1	0.0001

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
MRBESS	Nektonic Family Richness	13		
	Cladocera	NA	1	0.0001
	Copepoda	NA	1	0.0001
	Diptera	Culicidae	1	0.0001
	Amphipoda	Talitridae	1	0.0001
	Coleoptera	Dytiscidae	1	0.0001
	Ephemeroptera	Baetidae	1	0.0009
	Diptera	Dixidae	1	0.0001
	Bivalvia	Sphaeriidae	1	0.0104
	Decapoda	NA	2	0.0416
	Gastropoda	Physidae	2	0.0466
	Diptera	Chironomidae	5	0.0012
	Coleoptera	Hydrophilidae	1	0.0003
	Isopoda	Asellidae	2	0.0008
MU55SS	Nektonic Family Richness	5		
	Odonata	Gomphidae	1	0.007
	Decapoda	Cambaridae	1	0.0046
	Diptera	Chironomidae	1	0.0001
	Bivalvia	Sphaeriidae	12	0.105
	Isopoda	Asellidae	1	0.0001
MUDBOA	Nektonic Family Richness	15		
	Coleoptera	Hydrophilidae	4	0.0021
	Coleoptera	Scirtidae	1	0.0001
	Aranae	Pisaurdiae	1	0.0066
	Diptera	Tipulidae	1	0.0001
	Ephemeroptera	Baetidae	1	0.0006
	Hemiptera	Mesoveliidae	2	0.0001
	Coleoptera	Curculionidae	9	0.0103
	Coleoptera	Haliplidae	1	0.001
	Gastropoda	Lymnaeidae	8	0.0239
	Gastropoda	Physidae	1	0.012
	Bivalvia	Sphaeriidae	8	0.0358
	Decapoda	Cambaridae	1	0.0168
	Diptera	Chironomidae	2	0.0006
	Odonata	Coenagrionidae	1	0.0001
	Hemiptera	Veliidae	2	0.0001
MUDEND	Nektonic Family Richness	9		
	Hemiptera	Mesoveliidae	3	0.0003
	Collembola	Isotomidae	1	0.0001
	Odonata	Libellulidae	1	0.0002
	Odonata	Coenagrionidae	6	0.0025
	Hemiptera	Veliidae	3	0.0001
	Gastropoda	Planorbidae	1	0.0168
	Cladocera	NA	2	0.0001
	Diptera	Chironomidae	7	0.0007
	Hemiptera	Belostomatidae	2	0.004

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
MUDRIC	Nektonic Family Richness	10		
	Coleopotera	Haliplidae	1	0.0022
	Diptera	Ceratopogonidae	3	0.0001
	Coleoptera	Dytiscidae	1	0.0002
	Hemiptera	Veliidae	1	0.0001
	Odonata	Coenagrionidae	2	0.0027
	Odonata	Libellulidae	3	0.0319
	Gastropoda	Physidae	1	0.0075
	Gastropoda	Planorbidae	4	0.085
	Diptera	Chironomidae	7	0.0006
	Bivalvia	Sphaeriidaer	6	0.0123
MUDRIP	Nektonic Family Richness	14		
	Hemiptera	Belostomatidae	1	0.0016
	Coleoptera	Staphylinidae	1	0.0006
	Gastropoda	Planorbidae	1	0.0042
	Gastropoda	Lymnaeidae	2	0.0024
	Diptera	Dixidae	1	0.0001
	Podocopa	NA	1	0.0001
	Hemiptera	veliidae	3	0.0001
	Hemiptera	Hydrometridae	1	0.0002
	Bivalvia	Sphaeriidae	1	0.0019
	Diptera	Culicidae	1	0.0004
	Diptera	Chironomidae	5	0.0002
	Odonata	Coenagrionidae	2	0.0046
	Hemiptera	Mesoveliidae	1	0.0001
	Oligochaeta	NA	4	0.0031
MUDTRA	Nektonic Family Richness	16		
	Ephemeroptera	Baetidae	1	0.0001
	Hemiptera	Mesoveliidae	4	0.0001
	Coleoptera	Dytiscidae	3	0.0008
	Cladocera	NA	1	0.0001
	Cyclopoida	NA	1	0.0001
	Odonata	Libellulidae	1	0.0057
	Gastropoda	Hydrobiidae	1	0.0044
	Aranae	Pisauridae	1	0.0009
	Homoptera	Aphididae	7	0.0007
	Odonata	Corduliidae	1	0.0154
	Odonata	Coenagrionidae	28	0.0089
	Aranae	hydracarina	1	0.0001
	Diptera	Tabanidae	1	0.0032
	Diptera	Chaoboridae	2	0.0001
	Diptera	Chironomidae	46	0.0035
	Gastropoda	Planorbidae	2	0.1325

Appendix BB.Continued.

SiteCode		Order	Family	Count	Weight
MUEPAH	Nektonic Family Richness		12		
		Hemiptera	Corixidae	3	0.0059
		Hemiptera	Veliidae	22	0.001
		Hemiptera	Gerridae	1	0.0001
		Diptera	Culicidae	3	0.0008
		Diptera	Chironomidae	5	0.0005
		Diptera	Dixidae	1	0.0008
		Diptera	Tabanidae	1	0.0012
		Odonata	Libellulidae	1	0.0008
		Coleoptera	Chrysomelidae	1	0.0034
		Aranae	Pisauridae	1	0.0036
		Hemiptera	Mesoveliidae	1	0.0001
		Coleoptera	Dytiscidae	4	0.0008
MUPOWR	Nektonic Family Richness		8		
		Bivalvia	Sphaeriidae	2	0.0116
		Megaloptera	Corydalidae	1	0.0002
		Ephemeroptera	Baetidae	16	0.0047
		Coleoptera	Dytiscidae	1	0.0001
		Odonata	Calopterygidae	1	0.0123
		Diptera	Ceratopogonidae	3	0.0001
		Diptera	Chironomidae	12	0.0008
		Coleoptera	Elmidae	1	0.0001
MUPULL	Nektonic Family Richness		14		
		Hemiptera	Belostomatidae	3	0.0018
		Diptera	Chironomidae	1	0.0011
		Cladocera	NA	2	0.0001
		Ephemeroptera	Caenidae	4	0.002
		Odonata	Lestidae	1	0.0016
		Hemiptera	Corixidae	4	0.0019
		Coleoptera	Haliplidae	1	0.0024
		Coleoptera	Hydrophilidae	4	0.0014
		Coleoptera	Dytiscidae	10	0.0041
		Bivalvia	Sphaeriidae	4	0.0416
		Gastropoda	Planorbidae	7	0.1148
		Aranae	Pisauridae	1	0.0194
		Decapoda	Cambaridae	1	0.0073
		Gastropoda	Lymnaeidae	5	0.014
MUVBRD	Nektonic Family Richness		10		
		Odonata	Lestidae	2	0.0012
		Diptera	Chironomidae	6	0.0012
		Isopoda	Asellidae	70	0.0142
		Coleoptera	Dytiscidae	21	0.0393
		Hemiptera	Corixidae	2	0.0027
		Coleoptera	Staphylinidae	1	0.0015
		Odonata	Libellulidae	2	0.0579
		Diptera	Culicidae	1	0.0001
		Coleoptera	Hydrophilidae	6	0.0069
		Oligochaeta	NA	4	0.0035

Appendix BB. Continued.

SiteCode	Order	Family	Count	Weight
MUVCRN	Nektonic Family Richness	12		
	Ephemeroptera	Baetridae	1	0.0002
	Diptera	Chironomidae	20	0.0028
	Cyclopoida	NA	1	0.0001
	Gastropoda	Lymnaeidae	1	0.0009
	Cladocera	NA	9	0.0001
	Hemiptera	Veliidae	1	0.0001
	Coleoptera	Dytiscidae	3	0.0033
	Coleoptera	Haliplidae	2	0.0024
	Odonata	Libellulidae	2	0.0057
	Decapoda	Cambaridae	1	0.0084
	Gastropoda	Planorbidae	1	0.0031
	Odonata	Coenagrionidae	1	0.0038
OHHSFO	Nektonic Family Richness	2		
	Bivalvia	Sphaeriidae	4	0.0088
	Isopoda	Asellidae	11	0.0028
OHINNS	Nektonic Family Richness	9		
	Odonata	Lestidae	1	0.0021
	Ephemeroptera	Baetidae	2	0.0009
	Coleoptera	Dytiscidae	4	0.0022
	Coleoptera	Haliplidae	1	0.0026
	Gastropoda	Lymnaeidae	1	0.0016
	Diptera	Culicidae	2	0.0002
	Cladocera	NA	2	0.0001
	Odonata	Libellulidae	3	0.0323
	Diptera	Chironomidae	4	0.0008
OHKMRT	Nektonic Family Richness	4		
	Isopoda	Asellidae	1	0.0007
	Hemiptera	Veliidae	2	0.0001
	Hemiptera	Hebridae	1	0.0002
	Odonata	Libellulidae	1	0.0027
PA83CR	Nektonic Family Richness	9		
	Diptera	Culicidae	9	0.0038
	Hemiptera	Mesoveliidae	2	0.002
	Hemiptera	Veliidae	3	0.0001
	Coleoptera	Dytiscidae	1	0.0004
	Coleoptera	Hydrophilidae	5	0.0036
	Isopoda	Asellidae	8	0.0017
	Bivalvia	Sphaeriidae	5	0.0471
	Decapoda	Cambaridae	5	0.0473
	Coleoptera	Gyrinidae	1	0.0002

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
PAFAMD	Nektonic Family Richness	12		
	Hemiptera	Gerridae	1	0.0018
	Hemiptera	Veliidae	2	0.0001
	Ephemeroptera	Baetidae	3	0.0013
	Ephemeroptera	Caenidae	6	0.0025
	Aranae	Hydracarina	2	0.0001
	Diptera	Chironomidae	11	0.0042
	Gastropoda	Physidae	21	0.1032
	Decapoda	Cambaridae	1	0.0525
	Bivalvia	Spaheriidae	6	0.0283
	Mysidacea	Mysidae	2	0.0976
	Odonata	Coenagrionidae	5	0.005
	Hemiptera	Corixidae	13	0.0053
PAJCPY	Nektonic Family Richness	6		
	Aranae	Lycosidae	1	0.0023
	Coleoptera	Carabidae	1	0.0034
	Aranae	Hydracarina	1	0.0001
	Diptera	Culicidae	5	0.0001
	Aranae	Pisauridae	2	0.0002
	Gastropoda	Physidae	2	0.002
PALOUD	Nektonic Family Richness	8		
	Hirudinea	Haemopidae	3	0.0058
	Diptera	Culicidae	1	0.0001
	Gastropoda	Lymnaeidae	14	0.0801
	Amphipoda	Gammaridae	1	0.0001
	Coleoptera	Haliplidae	2	0.0027
	Oligochaeta	NA	1	0.0001
	Gastropoda	Physidae	17	0.0751
	Bivalvia	Sphaeriidae	4	0.0111
PAPEIM	Nektonic Family Richness	15		
	Coleoptera	Hydrophilidae	4	0.0022
	Diptera	Ceratopogonidae	1	0.0001
	Ephemeroptera	Baetidae	23	0.0082
	Hemiptera	Nepidae	1	0.0197
	Odonata	Libellulidae	1	0.0013
	Odonata	Coenagrionidae	13	0.0128
	Odonata	Aeshnidae	1	0.0061
	Hemiptera	Belostomatidae	4	0.0099
	Oligochaeta	NA	4	0.0019
	Bivalvia	Sphaeriidae	2	0.0122
	Hemiptera	Notonectidae	4	0.0032
	Diptera	Chironomidae	12	0.0017
	Gastropoda	Lymnaeidae	4	0.0042
	Gastropoda	Physidae	10	0.0399
	Hemiptera	Mesoveliidae	1	0.0001

Appendix BB.Continued.

SiteCode		Order	Family	Count	Weight
PAPESW	Nektonic Family Richness		13		
		Coleoptera	Hydrophilidae	2	0.001
		Bivalvia	Sphaeriidae	14	0.0711
		Hemiptera	Hydrometridae	1	0.0007
		Hirudinea	Glossiphoniidae	30	0.0109
		Odonata	Coenagrionidae	6	0.0059
		Coleoptera	Dytiscidae	1	0.0045
		Gastropoda	Physidae	46	0.2016
		Coleoptera	Haliplidae	1	0.0023
		Nematoda	NA	1	0.0001
		Amphipoda	Gammaridae	7	0.0038
		Gastropoda	Planorbidae	6	0.0962
		Diptera	Chironomidae	2	0.0001
		Odonata	Libellulidae	1	0.0168
PAWILL	Nektonic Family Richness		22		
		Coleoptera	Staphylinidae	1	0.0001
		Oligochaeta	NA	1	0.0002
		Diptera	Chironomidae	2	0.0005
		Diptera	Chaoboridae	8	0.0006
		Diptera	Tipulidae	1	0.0005
		Coleoptera	Dytiscidae	1	0.0001
		Coleoptera	Chrysomelidae	1	0.0037
		Aranae	Pisauridae	1	0.0006
		Isopoda	Asellidae	7	0.0023
		Hemiptera	Hydrometridae	1	0.0003
		Coleoptera	Hydrophilidae	2	0.001
		Hemiptera	Corixidae	2	0.017
		Odonata	Aeshnidae	1	0.0246
		Odonata	Coenagrionidae	1	0.0004
		Gastropoda	Lymaeidae	12	0.1088
		Hemiptera	Naucoridae	1	0.002
		Hemiptera	Belostomatidae	5	0.105
		Hemiptera	Pleidae	3	0.0008
		Hemiptera	Mesoveliidae	8	0.0013
		Gastropoda	Planorbidae	13	1.6112
		Cladocera	NA	2	0.0001
		Gastropoda	Physidae	3	0.0546

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
PEMIDW	Nektonic Family Richness	11		
	Diptera	Culicidae	4	0.0002
	Gastropoda	Lynaeidae	2	0.0024
	Collembola	Isotomidae	1	0.0001
	Ephemeroptera	Baetidae	2	0.002
	Coleoptera	Dytiscidae	4	0.0014
	Hemiptera	Veliidae	1	0.0001
	Gastropoda	Physidae	1	0.0013
	Diptera	Chironomidae	5	0.0009
	Hemiptera	Gerridae	1	0.0024
	Hemiptera	Corixidae	4	0.0036
	Bivalvia	Sphaeriidae	4	0.0144
PERDDP	Nektonic Family Richness	13		
	Ephemeroptera	Baetidae	10	0.0079
	Coleoptera	Hydrophilidae	1	0.0005
	Coleoptera	Dytiscidae	5	0.0053
	Hemiptera	Notonectidae	2	0.0018
	Hemiptera	Gerridae	1	0.0023
	Diptera	Stratiomyidae	1	0.0018
	Diptera	Culicidae	1	0.0006
	Diptera	Chaoboridae	4	0.0001
	Diptera	Chironomidae	3	0.0002
	Gastropoda	Lymnaeidae	1	0.0023
	Gastropoda	Physidae	50	0.3774
	Hemiptera	Corixidae	1	0.0016
	Cladocera	NA	3	0.0002
PETHUM	Nektonic Family Richness	11		
	Diptera	Chironomidae	1	0.0008
	Cladocaera	NA	1	0.0001
	Coleoptera	Dytiscidae	1	0.0006
	Diptera	Culicidae	4	0.0006
	Bivalvia	Sphaeriidae	13	0.3311
	Odonata	Aeshnidae	1	0.1311
	Hemiptera	Corixidae	16	0.0167
	Odonata	Lestidae	2	0.0059
	Hemiptera	Notonectidae	3	0.011
	Diptera	Ceratopogonidae	1	0.0001
	Gastropoda	Physidae	2	0.0012
PETOSS	Nektonic Family Richness	6		
	Ephemeroptera	Heptageniidae	5	0.0078
	Plecoptera	Nemouridae	1	0.0001
	Hemiptera	Veliidae	1	0.0003
	Ephemeroptera	Leptophlebiidae	1	0.0006
	Odonata	Cordulegastridae	1	0.0002
	Ephemeroptera	Siphlonuridae	2	0.0058

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
RIASIA	Nektonic Family Richness	11		
	Coleoptera	Staphylinidae	1	0.0004
	Gastropoda	Planorbidae	1	0.0036
	Isopoda	Asellidae	1	0.0001
	Collembola	Poduridae	1	0.0001
	Cladocera	NA	1	0.0001
	Diptera	Chironomidae	2	0.0001
	Bivalvia	Sphaeriidae	5	0.0248
	Diptera	Culicidae	4	0.0001
	Decapoda	Cambaridae	2	0.0104
	Gastropoda	Lymnaeidae	6	0.0212
	Odonata	Coenagrionidae	1	0.0001
RIBRID	Nektonic Family Richness	6		
	Coleoptera	Dytiscidae	6	0.0008
	Hemiptera	Cicadellidae	1	0.0029
	Collembola	Isotomidae	1	0.0001
	Coleoptera	Staphylinidae	1	0.0002
	Coleoptera	Hydrophilidae	3	0.0007
	Gastropoda	Lymnaeidae	1	0.0061
RIEAST	Nektonic Family Richness	2		
	Hemiptera	Gerridae	2	0.0009
	Coleptera	Staphylinidae	1	0.0002
SJBOAT	Nektonic Family Richness	7		
	Oligochaeta	NA	2	0.0001
	Hemiptera	Veliidae	1	0.0001
	Decapoda	Cambaridae	4	0.0504
	Lepidoptera	Pyralidae	1	0.0001
	Coleoptera	Dytiscidae	0	0.0228
	Diptera	Ceratopogonidae	1	0.0001
	Bivalvia	Sphaeriidae	1	0.0003
SJGLAD	Nektonic Family Richness	1		
	Hemiptera	Veliidae	1	0.0005
SJMUDL	Nektonic Family Richness	2		
	Odonata	Gomphidae	1	0.0045
	Diptera	Chironomidae	1	0.0001
SMDTSS	Nektonic Family Richness	7		
	Diptera	Chironomidae	10	0.0018
	Diptera	Culicidae	1	0.0002
	Hemiptera	Veliidae	1	0.0001
	Aranae	Pisauridae	1	0.0004
	Odonata	Lestidae	1	0.0015
	Oligochaeta	NA	2	0.0021
	Coleoptera	Dytiscidae	1	0.0002

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
SMFOFL	Nektonic Family Richness	8		
	Plecoptera	Leuctridae	1	0.0003
	Ephemeroptera	Leptophlebiidae	2	0.0039
	Hemiptera	Veliidae	1	0.0007
	Diptera	Culicidae	1	0.0002
	Coleoptera	Hydrophilidae	4	0.0138
	Oligochaeta	NA	1	0.0028
	Diptera	Chironomidae	2	0.0005
	Coleoptera	Dytiscidae	2	0.0007
SMLPEM	Nektonic Family Richness	3		
	Oligochaeta	NA	2	0.0016
	Diptera	Chironomidae	12	0.0037
	Plecoptera	Leuctridae	2	0.0009
SMSEFL	Nektonic Family Richness	7		
	Odonata	Coenagrionidae	1	0.0046
	Trichoptera	Phyrganeidae	1	0.0157
	Hemiptera	Notonectidae	1	0.0028
	Odonata	Libellulidae	5	0.0596
	Hemiptera	Corixidae	14	0.0039
	Diptera	Chironomidae	4	0.0004
	Coleoptera	Dytiscidae	1	0.0003
SMSTEM	Nektonic Family Richness	3		
	Aranae	Pisauridae	1	0.0049
	Diptera	Chironomidae	4	0.0007
	Oligochaeta	NA	5	0.0051
TRSPRI	Nektonic Family Richness	1		
	Hemiptera	Corixidae	2	0.0003
TVFARM	Nektonic Family Richness	5		
	Isopoda	Asellidae	13	0.0028
	Aranae	Pisauridae	1	0.0036
	Coleoptera	Hydrophilidae	2	0.0023
	Diptera	Culicidae	13	0.004
	Hemiptera	Gerridae	3	0.0021
TVNEWT	Nektonic Family Richness	9		
	Hemiptera	Corixidae	2	0.0051
	Coleoptera	Dytiscidae	5	0.0047
	Coleoptera	Staphylinidae	1	0.0002
	Isopoda	Asellidae	22	0.0043
	Bivalvia	Sphaeriidae	3	0.0978
	Gastropoda	Planorbidae	1	0.001
	Gastropoda	Physidae	10	0.0101
	Oligochaeta	NA	1	0.0007
	Hirudinea	Erpobdellidae	1	0.0173

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
TVPOUT	Nektonic Family Richness		23	
	Ephemeroptera	Baetidae	4	0.0035
	Hemiptera	Gerridae	1	0.0001
	Cyclopoida	NA	3	0.0001
	Hemiptera	Veliidae	1	0.0001
	Coleoptera	Dytiscidae	10	0.0076
	Coleoptera	Hydrophilidae	3	0.0007
	Coleoptera	Curculionidae	1	0.001
	Hemiptera	Belostomatidae	1	0.0012
	Coleoptera	Chrysomelidae	1	0.002
	Hirudinea	Erpobdellidae	7	0.0253
	Coleoptera	Haliplidae	1	0.0033
	Odonata	Lestidae	4	0.0156
	Diptera	Chironomidae	11	0.0011
	Homoptera	Cicadellidae	1	0.0012
	Odonata	Aeshnidae	4	0.0037
	Hemiptera	Corixidae	6	0.0094
	Gastropoda	Physidae	1	0.0022
	Gastropoda	Lymnaeidae	3	0.009
	Bivalvia	Sphaeriidae	3	0.0372
	Isopoda	Asellidae	2	0.0009
	Oligochaeta	NA	1	0.0001
	Hemiptera	Notonectidae	1	0.0047
	Odonata	Libellulidae	3	0.0196
TVVBEM	Nektonic Family Richness	9		
	Hemiptera	Corixidae	1	0.0034
	Hemiptera	Veliidae	5	0.0002
	Coleoptera	Dytiscidae	10	0.008
	Cladocera	NA	1	0.0001
	Isopoda	Asellidae	40	0.0098
	Diptera	Chironomidae	8	0.0018
	Gastropoda	Planorbidae	2	0.0025
	Bivalvia	Sphaeriidae	2	0.0077
	Cyclopoida	NA	2	0.0001

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
TVVBIM	Nektonic Family Richness	16		
	Hemiptera	Veliidae	1	0.0001
	Coleoptera	Curculionidae	1	0.0013
	Hirudinea	Erpobdellidae	1	0.0004
	Coleoptera	Dytiscidae	18	0.0251
	Homoptera	Cicadellidae	1	0.0001
	Hemiptera	Notonectidae	1	0.0031
	Hemiptera	Corixidae	3	0.0038
	Isopoda	Asellidae	30	0.0068
	Diptera	Chironomidae	2	0.0007
	Bivalvia	Sphaeriidae	2	0.031
	Gastropoda	Physidae	5	0.0076
	Odonata	Lestidae	1	0.0059
	Gastropoda	Planorbidae	4	0.0366
	Amphipoda	Gammaridae	1	0.0008
	Aranae	Pisauridae	2	0.0251
	Coleoptera	Hydrophilidae	5	0.0419
TVVBSS	Nektonic Family Richness	21		
	Coleoptera	Hydrophilidae	2	0.0079
	Coleoptera	Scirtidae	24	0.0144
	Aranae	Pisauridae	3	0.0356
	Amphipoda	Gammaridae	140	0.0791
	Gastropoda	Physidae	17	0.0864
	Bivalvia	Sphaeriidae	9	0.2175
	Gastropoda	Planorbidae	14	0.0862
	Coleoptera	Curculionidae	5	0.0029
	Coleoptera	Dytiscidae	4	0.0054
	Gastropoda	Lymnaeidae	1	0.0027
	Oligochaeta	NA	3	0.0118
	Hirudinea	Erpobdellidae	1	0.0005
	Ephemeroptera	Caenidae	1	0.0005
	Coleoptera	Haliplidae	1	0.0026
	Odonata	Libellulidae	1	0.016
	Hemiptera	Belostomatidae	2	0.0073
	Hemiptera	Notonectidae	1	0.0124
	Hemiptera	Corixidae	3	0.0053
	Isopoda	Asellidae	14	0.0054
	Coleoptera	Chrysomelidae	3	0.0135
	Homoptera	Aphididae	1	0.0001
UDC001	Nektonic Family Richness	5		
	Diptera	Chironomidae	4	0.0006
	Hemiptera	Pleidae	1	0.0006
	Gastropoda	Physidae	1	0.0271
	Hemiptera	Corixidae	3	0.0137
	Coleoptera	Dytiscidae	1	0.0008

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
UDC002	Nektonic Family Richness	8		
	Coleoptera	Dytiscidae	1	0.0099
	Diptera	Chironomidae	50	0.0079
	Copepoda	NA	1	0.0001
	Odonata	Aeshnidae	1	0.0036
	Nematoda	NA	3	0.0001
	Hemiptera	Notonectidae	3	0.0228
	Hemiptera	Corixidae	2	0.0055
	Aranae	NA	1	0.0001
UDC004	Nektonic Family Richness	3		
	Diptera	Chironomidae	3	0.0007
	Hemiptera	Veliidae	1	0.0001
	Diptera	Chaoboridae	1	0.0001
UDC008	Nektonic Family Richness	6		
	Cladocera	NA	4	0.0001
	Copepoda	NA	1	0.0001
	Coleoptera	Elmidae	6	0.0155
	Diptera	Chironomidae	12	0.0014
	Nematoda	NA	8	0.004
	Gastropoda	Viviparidae	1	0.0452
UDC012	Nektonic Family Richness	12		
	Coleoptera	Carabidae	1	0.0121
	Ephemeroptera	Caenidae	1	0.0001
	Diptera	Ceratopogonidae	2	0.0008
	Amphipoda	Talitridae	2	0.0001
	Odonata	Coenagrionidae	4	0.0121
	Bivalvia	Sphaeriidae	5	0.0149
	Ephemeroptera	Baetidae	1	0.001
	Gastropoda	Physidae	29	0.2065
	Diptera	Chironomidae	20	0.0116
	Hemiptera	Corixidae	11	0.0072
	Coleoptera	Dytiscidae	1	0.0013
	Cladocera	NA	6	0.0001
UDC013	Nektonic Family Richness	7		
	Bivalvia	Sphaeriidae	1	0.0113
	Coleoptera	Coccinellidae	1	0.0035
	Oligochaeta	NA	1	0.0017
	Coleoptera	Chrysomelidae	1	0.0001
	Diptera	Tabanidae	1	0.0027
	Diptera	Chironomidae	13	0.0028
	Coleoptera	Dytiscidae	1	0.0012

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
UDC014	Nektonic Family Richness	5		
	Diptera	Chironomidae	6	0.0029
	Hemiptera	Corixidae	4	0.0017
	Megaloptera	Sialidae	2	0.0018
	Odonata	Libellulidae	1	0.0072
	Oligochaeta	NA	3	0.0206
UDC015	Nektonic Family Richness	4		
	Odonata	Aeshnidae	1	0.0018
	Diptera	Chironomidae	2	0.0002
	Hemiptera	Corixidae	1	0.0003
	Megaloptera	Sialidae	1	0.0013
UDC017	Nektonic Family Richness	7		
	Diptera	Chironomidae	1	0.0001
	Diptera	Empididae	1	0.0015
	Gastropoda	Planorbidae	2	0.0313
	Diptera	Tabanidae	1	0.0056
	Hemiptera	Notonectidae	1	0.0032
	Bivalvia	Sphaeriidae	2	0.0011
	Hemiptera	Corixidae	4	0.0031
UDC018	Nektonic Family Richness	14		
	Gastropoda	Hydrobiidae	1	0.0172
	Diptera	Chironomidae	2	0.0001
	Homoptera	Cicadellidae	1	0.0002
	Aranae	Hydracarina	1	0.0004
	Aranae	NA	1	0.0001
	Isopoda	Asellidae	26	0.0182
	Coleoptera	Phalacridae	1	0.0008
	Nematoda	NA	1	0.0013
	Hemiptera	Veliidae	1	0.0035
	Odonata	Libellulidae	1	0.0078
	Gastropoda	Valvatidae	1	0.0047
	Bivalvia	Sphaeriidae	1	0.0026
	Gastropoda	Physidae	6	0.0611
	Diptera	Dolichopodidae	2	0.0001
UDC019	Nektonic Family Richness	7		
	Nematoda	NA	2	0.0001
	Hemiptera	Hebridae	1	0.0001
	Megaloptera	Sialidae	2	0.0015
	Diptera	Chironomidae	3	0.0003
	Megaloptera	Corydalidae	1	0.0077
	Coleoptera	Elateridae	1	0.0004
	Hemiptera	Corixidae	2	0.0014

Appendix BB.Continued.

SiteCode	Order	Family	Count	Weight
UDC020	Nektonic Family Richness	6		
	Hirudinea	Glossiphoniidae	9	0.0059
	Oligochaeta	NA	3	0.0005
	Hemiptera	Corixidae	11	0.0062
	Odonata	Libellulidae	1	0.009
	Diptera	Chironomidae	5	0.0015
	Bivalvia	Sphaeriidae	1	0.0004
VEPCON	Nektonic Family Richness	4		
	Coleoptera	Hydrophilidae	2	0.0012
	Oligochaeta	NA	1	0.0001
	Coleoptera	Dytiscidae	2	0.0141
	Diptera	Chironomidae	5	0.0016
VEPCOS	Nektonic Family Richness	5		
	Diptera	Culicidae	1	0.0001
	Odonata	Coenagrionidae	2	0.0015
	Diptera	Chironomidae	1	0.0001
	Coleoptera	Scirtidae	1	0.0003
	Odonata	Libellulidae	1	0.0035
WBBARN	Nektonic Family Richness	17		
	Gastropoda	Physidae	3	0.0095
	Coleoptera	Haliplidae	2	0.0042
	Coleoptera	Dytiscidae	2	0.001
	Amphipoda	Gammaridae	1	0.0002
	Odonata	Lestidae	1	0.0055
	Odonata	Coenagrionidae	1	0.0004
	Nematoda	NA	1	0.0001
	Gastropoda	Planorbidae	2	0.2044
	Hemiptera	Corixidae	2	0.0065
	Bivalvia	Sphaeriidae	3	0.0285
	Diptera	Tabanidae	2	0.0111
	Diptera	Culicudae	1	0.0001
	Oligochaeta	NA	4	0.0003
	Diptera	Ceratopogonidae	1	0.0009
	Diptera	Chironomidae	52	0.0325
	Ephemeroptera	Baetidae	23	0.0116
	Gastropoda	Lymnaeidae	2	0.0046
WBCORN	Nektonic Family Richness	10		
	Hemiptera	Hebridae	1	0.001
	Coleoptera	Haliplidae	2	0.0054
	Ephemeroptera	Caenidae	1	0.0002
	Oligochaeta	NA	2	0.0001
	Gastropoda	Physidae	7	0.018
	Diptera	Chironomidae	36	0.0036
	Diptera	Ceratopogonidae	1	0.0001
	Podacopa	NA	1	0.0001
	Gastropoda	Planorbidae	24	3.2556
	Odonata	Libellulidae	3	0.0873

Appendix BB.Continued.

SiteCode		Order	Family	Count	Weight
WBROAD	Nektonic Family Richness		9		
		Odonata	Libellulidae	1	0.0029
		Coleoptera	Elmidae	1	0.0318
		Hemiptera	Veliidae	1	0.0001
		Ephemeroptera	Baetidae	1	0.0003
		Odonata	Calopterygidae	1	0.0159
		Odonata	Cordulegastridae	10	0.0476
		Diptera	Stratiomyidae	1	0.0071
		Diptera	Chironomidae	5	0.0006
		Gastropoda	Physidae	2	0.1105
WYBEAV	Nektonic Family Richness		2		
		Diptera	Chironomidae	13	0.0028
		Diptera	Chaoboridae	1	0.0001
WYHCEA	Nektonic Family Richness		1		
		Diptera	Chironomidae	4	0.0015

Appendix BC. Benthic macroinvertebrate richness, count and weight by family used to form macroinvertebrate indices of biological integrity for wetlands in West Virginia, USA 2005-2006.

SiteCode	Order		Family	Count	Weight
CFCROS	Benthic Family Richness	2			
	Oligochaeta		NA	1	0.0031
	Nematoda		NA	2	0.0001
CFECUR	Benthic Family Richness	3			
	Oligochaeta		NA	4	0.0015
	Nematoda		NA	1	0.0001
	Diptera		Dolichopodidae	1	0.0001
CFEINC	Benthic Family Richness	1			
	Diptera		Chironomidae	1	0.0001
CFSLCH	Benthic Family Richness	4			
	Nematoda		NA	1	0.0001
	Diptera		Ceratopogonidae	1	0.0001
	Diptera		Chironomidae	1	0.0001
	Diptera		Stratiomyidae	1	0.0022
CFSLIN	Benthic Family Richness	2			
	Diptera		Ceratopogonidae	1	0.0001
	Oligochaeta		NA	1	0.0001
CGBRID	Benthic Family Richness	10			
	Collembola		Onychiuridae	1	0.0001
	Coleoptera		Staphylinidae	1	0.0011
	Coleoptera		Elateridae	2	0.0084
	Diptera		Psychodidae	1	0.0001
	Coleoptera		Hydrophilidae	5	0.0003
	Bivalvia		Sphaeriidae	1	0.0032
	Diptera		Tipulidae	7	0.001
	Diptera		Chironomidae	9	0.0001
	Oligochaeta		NA	11	0.0202
	Diplura		Japygidae	1	0.0004

Appendix BC. Continued.

SiteCode	Order	Family	Count	Weight
CGCPAS	Benthic Family Richness 13			
	Oligochaeta	NA	7	0.0037
	Coleoptera	Meloidae	1	0.0005
	Hirudinea	Glossiphoniidae	1	0.0152
	Bivalvia	Sphaeriidae	7	0.0154
	Diptera	Ceratopogonidae	18	0.0011
	Hydrocarina	NA	1	0.0001
	Diptera	Chironomidae	10	0.0013
	Nematoda	NA	1	0.0001
	Megaloptera	Sialidae	2	0.0033
	Coleoptera	Chrysomelidae	2	0.0228
	Diptera	Ephydridae	3	0.0006
	Amphipod	Gammaridae	1	0.0001
	Diptera	Tipulidae	2	0.0007
CGROAD	Benthic Family Richness 9			
	Diptera	Psychodidae	1	0.0007
	Diptera	Cecidomyidae	1	0.0007
	Nematoda	NA	7	0.001
	Trichoptera	Polycentropodidae	5	0.0016
	Diptera	Tipulidae	4	0.0078
	Bivalvia	Sphaeriidae	6	0.0049
	Diptera	Chironomidae	5	0.0001
	Diptera	Ceratopogonidae	6	0.0004
	Hydracarina	NA	1	0.0001
CGTRHE	Benthic Family Richness 11			
	Coleoptera	Hydrophilidae	1	0.0005
	Diptera	Cecidomyidae	1	0.0001
	Geophilomorpha	NA	3	0.0028
	Coleoptera	Chrysomelidae	1	0.002
	Nematoda	NA	19	0.0077
	Diptera	Ceratopogonidae	2	0.0001
	Bivalvia	Sphaeriidae	13	0.0111
	Nematoda	NA	1	0.0024
	Diplura	Japygidae	1	0.0001
	Diptera	Tipulidae	3	0.0009
	Diptera	Dolichopodidae	1	0.0001

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
CHNEER	Benthic Family Richness	2			
	Gastropoda		Planorbidae	1	0.0002
	Diptera		Chironomidae	1	0.0008
CHSACH	Benthic Family Richness	5			
	Bivalvia		Sphaeriidae	3	0.0037
	Diptera		Ceratopogonidae	1	0.0001
	Gastropoda		Physidae	1	0.0013
	Oligochaeta		NA	9	0.0478
	Collembola		Isotomidae	1	0.0001
CHSAFO	Benthic Family Richness	4			
	Coleoptera		Tenebrionidae	2	0.0054
	Diplopoda		NA	2	0.0004
	Gastropoda		Planorbidae	1	0.0002
	Oligochaeta		NA	16	0.1848
CHSARR	Benthic Family Richness	4			
	Diptera		Chironomidae	2	0.0045
	Bivalvia		Sphaeriidae	1	0.0001
	Oligochaeta		NA	5	0.0103
	Gastropoda		Physidae	1	0.0002
CHTREE	Benthic Family Richness	4			
	Bivalvia		Sphaeriidae	8	0.0083
	Gastropoda		Lymnaeidae	2	0.0236
	Diptera		Tabanidae	2	0.0011
	Nematoda		NA	5	0.0001
CHWWBW	Benthic Family Richness	1			
	Gastropoda		Physidae	1	0.0081
CHWWEM	Benthic Family Richness	4			
	Diptera		Ceratopogonidae	1	0.0001
	Oligochaeta		NA	2	0.0004
	Gastropoda		Physidae	1	0.002
	Coleoptera		Circulionoidea	1	0.0006
CHWWFO	Benthic Family Richness	3			
	Diptera		Chironomidae	1	0.0001
	Cyclopoida		NA	1	0.0001
	Oligochaeta		NA	1	0.0001

Appendix BC. Continued.

SiteCode		Order	Family	Count	Weight
CVABBW	Benthic Family Richness 10				
		Aranae	NA	1	0.0009
		Diptera	Ceratopogonidae	1	0.0001
		Diptera	Ephydridae	1	0.0001
		Bivalvia	Sphaeriidae	1	0.004
		Oligochaeta	NA	10	0.0023
		Diptera	Ceratopogonidae	1	0.0003
		Diptera	Tipulidae	1	0.0039
		Diptera	Chironomidae	2	0.0001
		Bivalvia	Sphaeriidae	1	0.0004
		Diptera	Dolichopodidae	1	0.0003
CVABCT	Benthic Family Richness 5				
		Coleoptera	Chrysomelidae	1	0.0174
		Diptera	Ceratopogonidae	1	0.0001
		Oligochaeta	NA	15	0.18
		Bivalvia	Sphaeriidae	3	0.003
		Coleoptera	Ptilodactylidae	1	0.0002
CVTIMB	Benthic Family Richness 6				
		Oligochaeta	NA	6	0.0376
		Coleoptera	Ptilodactylidae	1	0.0005
		Diptera	Tipulidae	1	0.0015
		Aranae	NA	1	0.0068
		Diptera	Chironomidae	5	0.0007
		Diptera	Dolichopodidae	1	0.0021
DSPICN	Benthic Family Richness 9				
		Diptera	Ptychopteridae	1	0.002
		Diptera	Chironomidae	32	0.0017
		Megaloptera	Sialidae	1	0.0019
		Coleoptera	Ptilodactylidae	1	0.0032
		Lepidoptera	unknown	1	0.0009
		Oligochaeta	NA	2	0.0001
		Diptera	Ceratopogonidae	2	0.0005
		Diptera	Tipulidae	2	0.0003
		Bivalvia	Sphaeriidae	10	0.0073

Appendix BC.Continued.

SiteCode	Order		Family	Count	Weight
DSROAR	Benthic Family Richness	5			
	Diptera		Chironomidae	19	0.0011
	Diptera		Ceratopogonidae	8	0.0001
	Oligochaeta		NA	1	0.0001
	Trichoptera		Polycentropodidae	1	0.0001
	Coleoptera		Chyrosomelidae	1	0.004
DSWILD	Benthic Family Richness	1			
	Nematoda		NA	1	0.0006
EPCMEM	Benthic Family Richness	7			
	Bivalvia		Sphaeriidae	7	0.0068
	Gastropoda		Physidae	2	0.0186
	Diptera		Dolichopodidae	1	0.0001
	Diptera		Stratiomyidae	2	0.0045
	Gastropoda		Planorbidae	7	0.0685
	Oligochaeta		NA	10	0.003
	Gastropoda		Lymnaeidae	2	0.0149
EPCMFO	Benthic Family Richness	1			
	Diptera		Chironomidae	1	0.0001
EPKYVE	Benthic Family Richness	6			
	Diptera		Ephydridae	1	0.0001
	Oligochaeta		NA	8	0.0272
	Bivalvia		Sphaeriidae	3	0.0062
	Gastropoda		Lymnaeidae	1	0.0146
	Gastropoda		Physidae	7	0.1379
	Gastropoda		Hydrophilidae	4	0.0033
EPRRXC	Benthic Family Richness	2			
	Oligochaeta		NA	1	0.009
	Gastropoda		Planorbidae	1	0.0006
EPSHEM	Benthic Family Richness	4			
	Bivalvia		Sphaeriidae	7	0.0186
	Oligochaeta		NA	1	0.0044
	Gastropoda		Sphaeriidae	4	0.0488
	Gastropoda		Physidae	1	0.0001

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
EPSHSS	Benthic Family Richness	9			
	Gastropoda		Planorbidae	1	0.0045
	Diptera		Tabanidae	1	0.0031
	Gastropoda		Lymnaeidae	4	0.0316
	Coleoptera		Hydrophilidae	1	0.0012
	Bivalvia		Sphaeriidae	7	0.0025
	Coleoptera		Chrysomelidae	1	0.0059
	Diptera		Ephydridae	1	0.0001
	Oligochaeta		NA	5	0.0356
	Diptera		Stratiomyidae	2	0.0112
GBBARN	Benthic Family Richness	3			
	Bivalvia		Sphaeriidae	1	0.0034
	Gastropoda		Planorbidae	1	0.0054
	Oligochaeta		NA	14	0.0584
GBHOEF	Benthic Family Richness	4			
	Bivalvia		Sphaeriidae	9	0.0034
	Diptera		Chironomidae	1	0.0001
	Diptera		Ceratopogonidae	2	0.0001
	Diptera		Stratiomyidae	2	0.0015
GBJENK	Benthic Family Richness	5			
	Odonata		Libellulidae	1	0.0263
	Diptera		Chironomidae	1	0.0001
	Gastropoda		Physidae	4	0.0077
	Gastropoda		Planorbidae	1	0.0003
	Hemiptera		Naucoridae	1	0.0006
GBMAPL	Benthic Family Richness	2			
	Nematoda		NA	1	0.0001
	Bivalvia		Sphaeriidae	4	0.0076
GBNOFO	Benthic Family Richness	3			
	Oligochaeta		NA	2	0.0029
	Bivalvia		Sphaeriidae	1	0.0089
	Diptera		Ceratopogonidae	1	0.0001

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
GBNOSS	Benthic Family Richness	10			
	Diptera		Muscidae	3	0.0002
	Gastropoda		Physidae	2	0.0464
	Homoptera		Cercopidae	1	0.0001
	Nematoda		NA	10	0.0023
	Diptera		Tabanidae	1	0.0042
	Diptera		Chironomidae	2	0.0002
	Diptera		Tipulidae	2	0.0003
	Bivalvia		Sphaeriidae	75	0.1666
	Coleoptera		NA	1	0.0001
	Oligochaeta		NA	1	0.0006
GBPLOT	Benthic Family Richness	3			
	Oligochaeta		NA	4	0.035
	Nematoda		NA	5	0.0013
	Gastropoda		Planorbidae	5	0.071
HCBEAV	Benthic Family Richness	4			
	Oligochaeta		NA	8	0.0701
	Nematoda		NA	5	0.0019
	Bivalvia		Sphaeriidae	2	0.0073
	Gastropoda		Planorbidae	1	0.004
HCMITI	Benthic Family Richness	6			
	Bivalvia		Sphaeriidae	1	0.0001
	Gastropoda		Planorbidae	2	0.0097
	Coleoptera		Hydrophilidae	1	0.0029
	Oligochaeta		NA	9	0.2089
	Nematoda		NA	19	0.0026
	Diptera		Tabanidae	1	0.0018
HCPIPE	Benthic Family Richness	7			
	Oligochaeta		NA	12	0.0724
	Nematoda		NA	26	0.0035
	Hydrocarina		NA	1	0.0001
	Diptera		Dolichopodidae	1	0.0006
	Homoptera		Cicadellidae	1	0.0001
	Coletoptera		Elateridae	1	0.0029
	Diplopoda		NA	1	0.0001

Appendix BC.Continued.

SiteCode	Order		Family	Count	Weight
HCRANG	Benthic Family Richness	11			
	Bivalvia		Sphaeriidae	2	0.0011
	Diptera		Cecidomyidae	1	0.0001
	Diptera		unknown	1	0.0001
	Diptera		Ceratopogonidae	1	0.0001
	Diptera		Tabanidae	1	0.0001
	Coleoptera		Staphylinidae	2	0.0001
	Coleoptera		Carabidae	5	0.0057
	Diptera		Chironomidae	1	0.0001
	Nematoda		NA	9	0.0006
	Diptera		Dolichopodidae	1	0.0017
	Oligochaeta		NA	12	0.0512
HIBRID	Benthic Family Richness	4			
	Oligochaeta		NA	4	0.0201
	Nematoda		NA	1	0.0001
	Diptera		Chironomidae	4	0.0002
	Diptera		Tipulidae	1	0.0007
HIGATE	Benthic Family Richness	6			
	Oligochaeta		NA	5	0.0012
	Coleoptera		Elmidae	1	0.0003
	Acanae		Lycosidae	1	0.0054
	Diptera		Dolichopodidae	2	0.0002
	Diptera		Ceratopogonidae	1	0.0001
	Diptera		Chironomidae	6	0.0019
HIJHPK	Benthic Family Richness	1			
	Nematoda		NA	4	0.0001

Appendix BC. Continued.

SiteCode	Order	Family	Count	Weight
HIJHTU	Benthic Family Richness 14			
	Coleoptera	Helodidae	2	0.0013
	Diptera	Stratiomyidae	2	0.0179
	Diptera	Tabanidae	1	0.0769
	Diptera	Ceratopogonidae	3	0.0001
	Isopoda	NA	1	0.0023
	Isopoda	Asellidae	3	0.0007
	Megaloptera	Corydalidae	1	0.002
	Aranae	Pisauridae	1	0.0002
	Gastropoda	Planorbidae	1	0.0011
	Bivalvia	Sphaeriidae	3	0.0014
	Gastropoda	Physidae	3	0.0036
	Oligochaeta	NA	5	0.0189
	Diptera	Chironomidae	2	0.0008
	Hemiptera	Hebridae	1	0.0086
HIPENC	Benthic Family Richness 4			
	Oligochaeta	NA	4	0.0055
	Gastropoda	Planorbidae	1	0.0024
	Diptera	Ceratopogonidae	2	0.0001
	Bivalvia	Sphaeriidae	1	0.0014
HISEWG	Benthic Family Richness 3			
	Gastropoda	Physidae	1	0.0091
	Oligochaeta	NA	10	0.0966
	Nematoda	NA	2	0.004
HITRLR	Benthic Family Richness 7			
	Oligochaeta	NA	6	0.005
	Nematoda	NA	1	0.0001
	Gastropoda	Planorbidae	1	0.0054
	Diptera	Ceratopogonidae	4	0.0007
	Diptera	Ephydridae	1	0.0001
	Isopoda	Asellidae	3	0.0001
	Coleoptera	Elmidae	2	0.0028

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
MCFOUR	Benthic Family Richness	4			
	Diptera		Muscidae	2	0.0002
	Nematoda		NA	1	0.0001
	Coleoptera		Staphylinidae	1	0.0001
	Diptera		Tipulidae	1	0.0001
MCMEME	Benthic Family Richness	3			
	Bivalvia		Sphaeriidae	1	0.0004
	Nematoda		NA	1	0.0001
	Gastropoda		Physidae	2	0.0031
MCMFOR	Benthic Family Richness	8			
	Bivalvia		Sphaeriidae	10	0.0041
	Oligochaeta		NA	2	0.0054
	Diptera		Chironomidae	3	0.0001
	Nematoda		NA	2	0.0001
	Diptera		Ceratopogonidae	1	0.0001
	Diptera		Dolichopodidae	1	0.0001
	Coleoptera		Hydrophilidae	1	0.0001
	Gastropoda		Physidae	3	0.0609
MCNPFO	Benthic Family Richness	5			
	Hymenoptera		Formicidae	1	0.0001
	Coleoptera		Carabidae	2	0.0004
	Isopoda		Asellidae	1	0.0032
	Diptera		Muscidae	1	0.0001
	Diptera		Chironomidae	2	0.0001
MCPOND	Benthic Family Richness	2			
	Oligochaeta		NA	2	0.0051
	Diptera		Chironomidae	3	0.0004
MCPOST	Benthic Family Richness	2			
	Hemiptera		Mesoveliidae	1	0.0001
	Diptera		Chironomidae	5	0.0001
MCTELE	Benthic Family Richness	5			
	Gastropoda		Physidae	1	0.0018
	Bivalvia		Sphaeriidae	2	0.0005
	Diptera		Chironomidae	1	0.0001
	Gastropoda		Planorbidae	8	0.003
	Nematoda		NA	1	0.0002

Appendix BC.Continued.

SiteCode	Order		Family	Count	Weight
ME5092	Benthic Family Richness	4			
	Diptera		Tipulidae	1	0.0127
	Oligochaeta		NA	3	0.0073
	Gastropoda		Planorbidae	1	0.0042
	Bivalvia		Sphaeriidae	1	0.0008
MESCOX	Benthic Family Richness	6			
	Gastropoda		Planorbidae	2	0.0033
	Bivalvia		Sphaeriidae	1	0.0052
	Gastropoda		Physidae	1	0.0008
	Diptera		Tabanidae	1	0.006
	Coleoptera		Staphylinidae	1	0.0001
	Oligochaeta		NA	4	0.0016
MESCRO	Benthic Family Richness	3			
	Diptera		Chironomidae	3	0.0001
	Oligochaeta		NA	75	0.1532
	Coleoptera		Staphylinidae	1	0.0001
MESCUP	Benthic Family Richness	2			
	Oligochaeta		NA	7	0.0192
	Bivalvia		Sphaeriidae	3	0.0077
MESIGN	Benthic Family Richness	4			
	Coleoptera		Chyrosomelidae	1	0.0086
	Oligochaeta		NA	7	0.0026
	Diptera		Tipulidae	1	0.0012
	Bivalvia		Sphaeriidae	3	0.0151
MESILV	Benthic Family Richness	4			
	Oligochaeta		NA	4	0.0011
	Gastropoda		Physidae	2	0.0411
	Diptera		Chironomidae	1	0.0001
	Gastropoda		Planorbidae	1	0.0075
METETR	Benthic Family Richness	5			
	Coleoptera		Elmidae	1	0.0015
	Oligochaeta		NA	3	0.0091
	Gastropoda		Physidae	5	0.0193
	Diptera		Chironomidae	2	0.0001
	Coleoptera		Hydrophilidae	1	0.0016

Appendix BC. Continued.

SiteCode	Order	Family	Count	Weight
MEWOLF	Benthic Family Richness	6		
	Coleoptera	Chysomelidae	1	0.0122
	Oligochaeta	NA	2	0.0009
	Coleoptera	unknown	1	0.0012
	Diptera	Chironomidae	1	0.0001
	Diptera	Dolichopodidae	1	0.0002
	Bivalvia	Sphaeriidae	4	0.0299
MRBESS	Benthic Family Richness 10			
	Oligochaeta	NA	9	0.0064
	Gastropoda	Bithyniidae	2	0.0021
	Diptera	Tabanidae	1	0.0003
	Coleoptera	Chrysomelidae	2	0.003
	Diptera	Ceratopogonidae	1	0.0001
	Diptera	Chironomidae	3	0.0001
	Gastropoda	Physidae	3	0.0356
	Gastropoda	Planorbidae	3	0.0428
	Bivalvia	Sphaeriidae	19	0.0534
	Diptera	Tipulidae	4	0.0001
MRFARM	Benthic Family Richness 3			
	Bivalvia	Sphaeriidae	10	0.0081
	Oligochaeta	NA	4	0.0811
	Diptera	Muscidae	2	0.0019
MRFORE	Benthic Family Richness 5			
	Coleoptera	Tenebrionidae	1	0.0033
	Coleoptera	Carabidae	1	0.0006
	Geophilomorpha	NA	1	0.0009
	Oligochaeta	NA	18	0.3016
	Diptera	Syrphidae	1	0.0012

Appendix BC. Continued.

SiteCode	Order	Family		Count	Weight
MRSSSS	Benthic Family Richness		7		
		Diptera	Ceratopogonidae	1	0.0001
		Hydracarina	NA	1	0.0001
		Isopoda	Asellidae	1	0.0001
		Diptera	Chironomidae	1	0.0003
		Diptera	Muscidae	1	0.0001
		Oligochaeta	NA	4	0.0322
		Bivalvia	Sphaeriidae	1	0.0021
MRWEST	Benthic Family Richness		5		
		Oligochaeta	NA	3	0.0937
		Diptera	Chironomidae	2	0.0001
		Diptera	Tipulidae	1	0.0001
		Bivalvia	Sphaeriidae	2	0.0034
		Chilopoda	NA	1	0.0001
MU55SS	Benthic Family Richness		3		
		Gastropoda	Planorbidae	1	0.0016
		Oligochaeta	NA	4	0.0036
		Diptera	Dolichopodidae	1	0.0002
MUDBOA	Benthic Family Richness		4		
		Diptera	Dolichopodidae	1	0.0001
		Oligochaeta	NA	4	0.0031
		Nematoda	NA	1	0.0001
		Diptera	Tabanidae	1	0.1839
MUDEND	Benthic Family Richness		4		
		Nematoda	NA	1	0.0001
		Oligochaeta	NA	1	0.0015
		Gastropoda	Lymnaeidae	1	0.0058
		Bivalvia	Sphaeriidae	4	0.0033
MUDRIC	Benthic Family Richness		3		
		Oligochaeta	NA	8	0.027
		Diptera	Ceratopogonidae	1	0.0001
		Gastropoda	Planorbidae	1	0.0612
MUDRIP	Benthic Family Richness		2		
		Diptera	Sciomyzidae	1	0.0001
		Coleoptera	Elateridae	1	0.0003

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
MUDTRA	Benthic Family Richness	4			
	Diptera		Ceratopogonidae	1	0.0001
	Oligochaeta		NA	8	0.0167
	Nematoda		NA	5	0.0001
	Bivalvia		Sphaeriidae	3	0.0009
MUEPAH	Benthic Family Richness	3			
	Diptera		Chironomidae	2	0.0001
	Colcoptera		Chrysomelidae	3	0.0084
	Oligochaeta		NA	4	0.0001
MUMINE	Benthic Family Richness	4			
	Oligochaeta		NA	7	0.0002
	Diptera		Chironomidae	1	0.0001
	Diptera		Ceratopogonidae	3	0.0001
	Diptera		Tabanidae	2	0.0004
MUPOWR	Benthic Family Richness	3			
	Coleoptera		Staphylinidae	1	0.0003
	Nematoda		NA	1	0.0005
	Oligochaeta		NA	12	0.0258
MUPULL	Benthic Family Richness	2			
	Diptera		Ceratopogonidae	1	0.0001
	Diptera		Tabanidae	2	0.0043
MUVBRD	Benthic Family Richness	2			
	Bivalvia		Sphaeriidae	1	0.0001
	Oligochaeta		NA	15	0.0059
MUVCRN	Benthic Family Richness	1			
	Isopoda		Asellidae	1	0.0001
OHHSFO	Benthic Family Richness	3			
	Diptera		Chironomidae	1	0.0001
	Oligochaeta		NA	1	0.0036
	Diptera		Dolichopodidae	1	0.0001
OHINNS	Benthic Family Richness	4			
	Gastropoda		Planorbidae	1	0.0001
	Bivalvia		Sphaeriidae	1	0.0001
	Oligochaeta		NA	4	0.0789
	Diptera		Ceratopogonidae	1	0.0001
OHKMRT	Benthic Family Richness	1			
	Nothing		NA	0	0

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
PA29TH	Benthic Family Richness	3			
	Gastropoda		Physidae	1	0.0004
	Coleoptera		Staphylinidae	1	0.0001
	Bivavlia		Sphaeriidae	6	0.0003
PA83CR	Benthic Family Richness	3			
	Diptera		Chironomidae	2	0.0001
	Diptera		Ceratopogonidae	1	0.0001
	Bivalvia		Sphaeriidae	11	0.0648
PAFAMD	Benthic Family Richness	4			
	Bivalvia		Sphaeriidae	1	0.0012
	Oligochaeta		NA	15	0.0043
	Gastropoda		Physidae	6	0.0554
	Gastropoda		Planorbidae	1	0.0009
PAJCPY	Benthic Family Richness	4			
	Oligochaeta		NA	20	0.2384
	Gastropoda		Physidae	1	0.0184
	Gastropoda		Lymnaeidae	2	0.0247
	Bivalvia		Sphaeriidae	2	0.0086
PALOUD	Benthic Family Richness	8			
	Oligochaeta		NA	25	0.1692
	Oligochaeta		NA	8	0.018
	Gastropoda		Physidae	22	0.2739
	Bivalvia		Sphaeriidae	8	0.019
	Gastropoda		Physidae	6	0.0544
	Gastropoda		Lymnaeidae	2	0.0324
	Bivalvia		Sphaeriidae	2	0.0007
	Amphipoda		Gammaridae	1	0.0001
PAPEFO	Benthic Family Richness	4			
	Diptera		Chironomidae	5	0.0001
	Lepidoptera		NA	1	0.0019
	Oligochaeta		NA	2	0.0002
	Bivalvia		Sphaeriidae	4	0.0106
PAPEIM	Benthic Family Richness	3			
	Oligochaeta		NA	12	0.0364
	Gastropoda		Physidae	3	0.017
	Bivalvia		Sphaeriidae	3	0.0237

Appendix BC. Continued.

SiteCode	Order	Family	Count	Weight
PAPESW	Benthic Family Richness	5		
	Oligochaeta	NA	1	0.0001
	Bivalvia	Sphaeriidae	3	0.0067
	Gastropoda	Lymnaeidae	2	0.0122
	Gastropoda	Physidae	4	0.0608
	Gastropoda	Planorbidae	1	0.118
PAWILL	Benthic Family Richness	4		
	Gastropoda	Physidae	2	0.022
	Gastropoda	Planorbidae	1	0.0036
	Oligochaeta	NA	6	0.0012
	Nematoda	NA	1	0.0001
PEMIDW	Benthic Family Richness	6		
	Isopoda	Porcellionidae	1	0.0071
	Gastropoda	Physidae	1	0.018
	Gastropoda	Lymnaeidae	2	0.0234
	Nematoda	NA	1	0.0006
	Oligochaeta	NA	2	0.0264
	Bivalvia	Sphaeriidae	2	0.0019
PERDDP	Benthic Family Richness	5		
	Coleoptera	Dytiscidae	2	0.0048
	Oligochaeta	NA	3	0.0001
	Diptera	Chironomidae	1	0.0001
	Diptera	Stratiomyidae	1	0.0144
	Gastropoda	Physidae	8	0.0586
PETHUM	Benthic Family Richness	1		
	oligochaeta	NA	1	0.0001
PETOSS	Benthic Family Richness	7		
	Diptera	Ceratopogonidae	2	0.0001
	Collembola	Isotomidae	1	0.0001
	Diptera	Ephydridae	1	0.0002
	Coleoptera	Chrysomelidae	1	0.0063
	Nematoda	NA	5	0.0011
	Diptera	Tabanidae	1	0.0063
	Diptera	Chironomidae	4	0.0004

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
RIASIA	Benthic Family Richness	3			
	Oligochaeta		NA	4	0.0001
	Nematoda		NA	3	0.0001
	Bivalvia		Sphaeriidae	2	0.0024
RIBRID	Benthic Family Richness	3			
	Gastropoda		Lymnaeidae	2	0.0068
	Bivalvia		Sphaeriidae	7	0.0404
	Gastropoda		Physidae	1	0.0049
RIEAST	Benthic Family Richness	1			
	Oligochaeta		NA	8	0.0022
SJBOAT	Benthic Family Richness	1			
	Nematoda		NA	6	0.0058
SJBRID	Benthic Family Richness	2			
	Diptera		Dolichopodidae	1	0.0001
	Nematoda		NA	1	0.0001
SJMUDL	Benthic Family Richness	2			
	Nematoda		NA	16	0.0007
	Oligochaeta		NA	2	0.0097
SJTELE	Benthic Family Richness	1			
	Oligochaeta		NA	2	0.0114
SMDTSS	Benthic Family Richness	4			
	Diptera		Tipulidae	3	0.0235
	Diptera		Tabanidae	1	0.0002
	Diptera		Ceratopogonidae	6	0.0002
	Coleoptera		Chrysomelidae	1	0.0008
SMFOFL	Benthic Family Richness	1			
	Diptera		Chironomidae	2	0.0002
SMLPEM	Benthic Family Richness	3			
	Coleoptera		Chyrosomelidae	2	0.0007
	Diptera		Chironomidae	1	0.0001
	Diptera		Ceratopogonidae	1	0.0001
SMSEFL	Benthic Family Richness	2			
	Diptera		Chironomidae	1	0.0003
	Bivalvia		Sphaeriidae	1	0.0006

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
SMSTEM	Benthic Family Richness	3			
	Diptera		Tabanidae	2	0.0002
	Oligochaeta		NA	1	0.0116
	Diptera		Dolichopodidae	1	0.0001
TRSPFO	Benthic Family Richness	5			
	Homoptera		Cicadidae	2	0.0001
	Diptera		Dolichopodidae	1	0.0002
	Bivalvia		Sphaeriidae	5	0.0121
	Oligochaeta		NA	4	0.0172
	Diptera		Dolichopodidae	1	0.0002
TRSPRI	Benthic Family Richness	11			
	Bivalvia		Sphaeriidae	3	0.0009
	Coleoptera		Elateridae	1	0.0013
	Homoptera		Cicadellidae	1	0.0002
	Aranae		NA	1	0.0001
	Homoptera		Aphididae	1	0.0001
	Diptera		Dolichopodidae	3	0.0002
	Gastropoda		Planorbidae	3	0.0058
	Nematoda		NA	32	0.0061
	Oligochaeta		NA	6	0.0495
	Hymenoptera		Formicidae	20	0.0025
	Diptera		Tipulidae	1	0.0079
TVFARM	Benthic Family Richness	8			
	Bivalvia		Sphaeriidae	3	0.0084
	Coleoptera		Scarabaeidae	1	0.0022
	Diptera		Ephydridae	6	0.0011
	Diptera		Tabanidae	1	0.0012
	Coleoptera		Hydrophilidae	1	0.0015
	Oligochaeta		NA	5	0.0011
	Coleoptera		Chrysomelidae	1	0.0029
	Diptera		Stratiomyidae	1	0.0047
TVISLE	Benthic Family Richness	1			
	Oligochaeta		NA	3	0.0023

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
TVNEWT	Benthic Family Richness	1			
	Oligochaeta		NA	1	0.0008
TVPOUT	Benthic Family Richness	4			
	Oligochaeta		NA	5	0.0011
	Bivalvia		Sphaeriidae	4	0.003
	Diptera		Dolichopodidae	1	0.0002
	Gastropoda		Lymnaeidae	2	0.0144
TVVBEM	Benthic Family Richness	1			
	Bivalvia		Sphaeriidae	2	0.0013
TVVBIM	Benthic Family Richness	3			
	Bivalvia		Sphaeriidae	6	0.0165
	Diptera		Chironomidae	3	0.0001
	Hirudinea		Erpobdellidae	1	0.0034
TVVBRV	Benthic Family Richness	4			
	Oligochaeta		NA	6	0.0491
	Diptera		Dolichopodidae	2	0.0006
	Diptera		Chironomidae	1	0.0001
	Nematoda		NA	1	0.0007
TVVBSS	Benthic Family Richness	2			
	Mysidacca		Mysidae	1	0.0005
	Bivalvia		Sphaeriidae	4	0.0015
UDC001	Benthic Family Richness	4			
	Oligochaeta		NA	1	0.0003
	Nematoda		NA	3	0.0008
	Coleoptera		unknown	1	0.0031
	Bivalvia		Sphaeriidae	2	0.0149
UDC002	Benthic Family Richness	2			
	Nematoda		NA	3	0.0001
	Diptera		Chironomidae	1	0.0001

Appendix BC.Continued.

SiteCode	Order		Family	Count	Weight
UDC003	Benthic Family Richness	9			
	Diptera		Psychodidae	1	0.0004
	Diptera		unknown	1	0.001
	Diptera		Ephydridae	1	0.0001
	Diplura		Japygidae	1	0.0001
	Coleoptera		Scarabaeidae	1	0.0022
	Gastropoda		Viviparidae	1	0.0203
	Bivalvia		Sphaeriidae	2	0.0092
	Nematoda		NA	175	0.0206
	Gastropoda		Physidae	5	0.1004
UDC004	Benthic Family Richness	1			
	Bivalvia		Sphaeriidae	1	0.005
UDC008	Benthic Family Richness	6			
	Nematoda		NA	18	0.0028
	Diptera		Ceratopogonidae	2	0.0001
	Diptera		Dolichopodidae	1	0.0001
	Bivalvia		Sphaeriidae	1	0.0024
	Gastropoda		Viviparidae	2	0.0043
	Gastropoda		Hydrobiidae	1	0.0093
UDC012	Benthic Family Richness	3			
	Gastropoda		Planorbidae	1	0.0048
	Oligochaeta		NA	16	0.0039
	Bivalvia		Sphaeriidae	1	0.0016
UDC013	Benthic Family Richness	6			
	Nematoda		NA	109	0.0177
	Diptera		Ceratopogonidae	9	0.0002
	Coleoptera		Chrysomelidae	2	0.002
	Bivalvia		Sphaeriidae	23	0.0284
	Gastropda		Physidae	1	0.0016
	Diptera		Tipulidae	3	0.0005
UDC014	Benthic Family Richness	1			
	Psocoptera		Liposcelidae	1	0.0001
UDC015	Benthic Family Richness	0			
	Nothing		NA	0	0
UDC017	Benthic Family Richness	0			
	Nothing		NA	0	0

Appendix BC. Continued.

SiteCode	Order		Family	Count	Weight
UDC018	Benthic Family Richness	5			
	Bivalvia		Sphaeriidae	2	0.0055
	Diptera		Chironomidae	1	0.0001
	Gastropoda		Physidae	2	0.0072
	Diptera		Stratiomyidae	2	0.0054
	Oligochaeta		NA	2	0.0009
UDC019	Benthic Family Richness	3			
	Bivalvia		Sphaeriidae	1	0.0003
	Oligochaeta		NA	3	0.0005
	Diptera		Tabanidae	1	0.0001
UDC020	Benthic Family Richness	3			
	Diptera		unknown	1	0.0007
	Diptera		unknown	1	0.0001
	Diptera		Chironomidae	2	0.0001
VEPCON	Benthic Family Richness	5			
	Oligochaeta		NA	1	0.0001
	Coleoptera		Chrysomelidae	13	0.0294
	Diptera		Chironomidae	8	0.0001
	Diptera		Tipulidae	3	0.0053
	Nematoda		NA	1	0.0001
VEPCOS	Benthic Family Richness	6			
	Diptera		Tipulidae	1	0.0004
	Nematoda		NA	1	0.0005
	Coleoptera		Hydrophilidae	1	0.0078
	Coleoptera		Chrysomelidae	2	0.0011
	Diptera		Chironomidae	18	0.0011
	Oligochaeta		NA	3	0.0004
WBBARN	Benthic Family Richness	7			
	Bivalvia		Sphaeriidae	5	0.0152
	Coleoptera		Belostomatidae	1	0.0248
	Gastropoda		Physidae	11	0.0695
	Oligochaeta		NA	43	0.0591
	Diptera		Ceratopogonidae	9	0.0011
	Diptera		Dolichopodidae	1	0.0001
	Gastropoda		Planorbidae	6	0.1206

Appendix BC.Continued.

SiteCode	Order		Family	Count	Weight
WBCORN	Benthic Family Richness	8			
	Hemiptera		Cicadellidae	1	0.0001
	Gastropoda		Hydrophilidae	2	0.0089
	Gastropoda		Planorbidae	9	0.8169
	Nematoda		NA	2	0.0001
	Oligochaeta		NA	3	0.0019
	Diptera		Chironomidae	2	0.0001
	Diptera		Ceratopogonidae	4	0.0001
	Gastropoda		Physidae	8	0.0313
WBROAD	Benthic Family Richness	5			
	Diptera		Ephydridae	1	0.0002
	Diptera		Ceratopogonidae	1	0.0001
	Diptera		Chironomidae	1	0.0001
	Diptera		Tabanidae	1	0.0006
	Diptera		Stratiomyidae	1	0.0062
WYBEAV	Benthic Family Richness	4			
	Coleoptera		Hydrophilidae	2	0.0004
	Diptera		Chironomidae	2	0.0001
	Bivalvia		Sphaeriidae	1	0.0043
	Diptera		Muscidae	2	0.0001
WYCHWE	Benthic Family Richness	6			
	Diptera		Tipulidae	1	0.0001
	Coleoptera		Elateridae	2	0.0001
	Coleoptera		NA	1	0.0033
	Nematoda		NA	1	0.0001
	Homoptera		Aphididae	4	0.0002
	Oligochaeta		NA	5	0.033
WYHCEA	Benthic Family Richness	3			
	Collembola		Poduridae	1	0.0001
	Diptera		Chironomidae	1	0.0001
	Diptera		Ceratopogonidae	1	0.0001

Appendix BC.Continued.

SiteCode	Order		Family	Count	Weight
WYINTR	Benthic Family Richness	7			
	Gastropoda		Hydrobiidae	1	0.01
	Bivalvia		Sphaeriidae	2	0.0041
	Chilopda		NA	1	0.0105
	Coleoptera		NA	1	0.0001
	Diptera		Muscidae	1	0.0015
	Oligochaeta		NA	10	0.1498
	Diptera		Tipulidae	2	0.0183
WYTHOR	Benthic Family Richness	4			
	Coleoptera		Hydrophilidae	1	0.0001
	Diptera		Ceratopogonidae	11	0.0001
	Diptera		Tipulidae	7	0.0385
	Diptera		Chironomidae	1	0.0001

Appendix BD. Combined and stratified benthic and nektomic data summary statistics of metrics scores statewide and by ecoregion used to used to form macroinvertebrate indices of biological integrity for wetlands in West Virginia, USA 2005-2006.

Benthic and Nektonic Sampling Statewide (N=106)

	% Biomass EPA Stressed	% Biomass Collectors	% Biomass Collectors *	% Biomass Predators	% Biomass Predators *	% Biomass Shredders	% Biomass Shredders *	% Biomass Chironomidae	% Biomass Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.985	0.976	0.978	0.981	1	0.784	0.897	0.889	0.969
Mean	0.249	0.332	0.396	0.241	0.307	0.066	0.082	0.049	0.101
Std. Error	0.025	0.03	0.031	0.026	0.031	0.013	0.015	0.012	0.018

	% Biomass Coleoptera *	% Biomass Dytiscidae	% Biomass Corixidae	% Biomass Corixidae *	% Biomass Coleoptera and Corixidae	% Biomass Libellulidae	% Biomass Libellulidae *	% Biomass Odonata - Libellulidae	% Biomass Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.993	0.757	0.776	0.781	0.966	0.969	0.993	0.73	0.764
Mean	0.114	0.033	0.034	0.027	0.033	0.128	0.148	0.069	0.085
Std. Error	0.019	0.009	0.01	0.009	0.01	0.02	0.022	0.015	0.018

	% Biomass Odonata	% Biomass Odonata *	Relative Abundance EPA Stressed	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.5	0.865	0.948	0.957	0.884	0.812	0.966	0.8	1
Mean	0.042	0.056	0.111	0.141	0.294	0.239	0.336	0.186	0.289
Std. Error	0.008	0.012	0.018	0.022	0.021	0.019	0.024	0.016	0.023

	Relative Abundance Chironomidae	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Relative Abundance Dytiscidae	Relative Abundance Dytiscidae *	Relative Abundance Coleoptera and Corixidae	Relative Abundance Corixidae	Relative Abundance Corixidae *	Relative Abundance Libellulidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.611	0.762	0.773	0.7	0.848	0.625	0.758	0.797	0.948
Mean	0.084	0.114	0.193	0.084	0.115	0.038	0.047	0.123	0.17
Std. Error	0.014	0.017	0.019	0.011	0.015	0.008	0.01	0.014	0.018

Appendix BD. Continued.

	Relative Abundance Libellulidae *	Relative Abundance Libellulidae	Relative Abundance Libellulidae *	Relative Abundance Odonata	Relative Abundance Odonata *
Minimum	0	0	0	0	0
Maximum	0.797	0.948	0.2	0.286	0.5
Mean	0.04	0.056	0.018	0.028	0.042
Std. Error	0.011	0.014	0.004	0.005	0.008

Appendix BD. Continued.

Allegheny Highlands Benthic and Nektonic Sampling (N=46)

	% Biomass EPA Stressed	% Biomass Collectors	% Biomass Collectors *	% Biomass Predators	% Biomass Predators *	% Biomass Shredders	% Biomass Shredders *	% Biomass Chironomidae	% Biomass Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.889	0.881	0.902	0.966	0.987	0.667	0.693	0.889	0.86
Mean	0.234	0.298	0.369	0.231	0.306	0.072	0.085	0.077	0.098
Std. Error	0.035	0.045	0.046	0.039	0.046	0.019	0.021	0.024	0.029

	% Biomass Coleoptera *	% Biomass Dytiscidae	% Biomass Corixidae	% Biomass Corixidae *	% Biomass Coleoptera and Corixidae	% Biomass Libellulidae	% Biomass Libellulidae *	% Biomass Odonata - Libellulidae	% Biomass Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.892	0.292	0.317	0.254	0.278	0.86	0.892	0.73	0.764
Mean	0.12	0.025	0.028	0.028	0.036	0.126	0.156	0.077	0.105
Std. Error	0.031	0.01	0.01	0.009	0.011	0.03	0.032	0.023	0.031

	% Biomass Odonata	% Biomass Odonata *	Relative Abundance EPA Stressed	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.5	0.529	0.73	0.813	0.803	0.74	0.885	0.8	0.8
Mean	0.036	0.048	0.113	0.153	0.336	0.194	0.308	0.163	0.271
Std. Error	0.013	0.016	0.026	0.034	0.034	0.025	0.033	0.023	0.032

	Relative Abundance Chironomidae	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Relative Abundance Dytiscidae	Relative Abundance Dytiscidae *	Relative Abundance Coleoptera and Corixidae	Relative Abundance Corixidae	Relative Abundance Corixidae *	Relative Abundance Libellulidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.611	0.762	0.773	0.472	0.81	0.196	0.211	0.472	0.81
Mean	0.103	0.144	0.245	0.073	0.116	0.027	0.036	0.114	0.183
Std. Error	0.024	0.031	0.033	0.014	0.022	0.007	0.009	0.017	0.025

Appendix BD. Continued.

	Relative Abundance Libellulidae *	Relative Abundance Libellulidae	Relative Abundance Libellulidae *	Relative Abundance Odonata	Relative Abundance Odonata *
Minimum	0	0	0	0	0
Maximum	0.333	0.5	0.2	0.286	0.5
Mean	0.04	0.067	0.025	0.039	0.036
Std. Error	0.012	0.019	0.007	0.01	0.013

Appendix BD. Continued.

Ridge and Valley Benthic and Nektonic Sampling (N=21)

	% Biomass EPA Stressed	% Biomass Collectors	% Biomass Collectors *	% Biomass Predators	% Biomass Predators *	% Biomass Shredders	% Biomass Shredders *	% Biomass Chironomidae
Minimum	0	0	0	0	0	0	0	0
Maximum	0.985	0.976	0.978	0.763	1	0.784	0.897	0.535
Mean	0.239	0.377	0.404	0.188	0.24	0.082	0.109	0.045
Std. Error	0.059	0.074	0.08	0.04	0.056	0.038	0.048	0.025

	% Biomass Coleoptera	% Biomass Coleoptera *	% Biomass Dytiscidae	% Biomass Corixidae	% Biomass Corixidae *	% Biomass Coleoptera and Corixidae	% Biomass Libellulidae	% Biomass Libellulidae *	% Biomass Odonata - Libellulidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.628	0.74	0.229	0.242	0.097	0.103	0.628	0.74	0.676
Mean	0.1	0.109	0.023	0.024	0.013	0.013	0.113	0.122	0.041
Std. Error	0.032	0.037	0.012	0.012	0.006	0.006	0.034	0.038	0.032

	% Biomass Odonata - Libellulidae *	% Biomass Odonata	% Biomass Odonata *	Relative Abundance EPA Stressed	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator	Relative Abundance Predator *	Relative Abundance Shredder
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.681	0.283	0.284	0.728	0.734	0.828	0.788	0.798	0.536
Mean	0.041	0.026	0.026	0.066	0.067	0.303	0.293	0.379	0.169
Std. Error	0.033	0.014	0.014	0.037	0.038	0.051	0.049	0.061	0.03

	Relative Abundance Shredder *	Relative Abundance Chironomidae	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Relative Abundance Dytiscidae	Relative Abundance Dytiscidae *	Relative Abundance Coleoptera and Corixidae	Relative Abundance Corixidae	Relative Abundance Corixidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.548	0.615	0.65	0.375	0.545	0.205	0.217	0.517
Mean	0.281	0.116	0.154	0.207	0.085	0.108	0.039	0.047	0.117
Std. Error	0.058	0.035	0.04	0.044	0.022	0.028	0.013	0.015	0.031

Appendix BD. Continued.

	Relative Abundance Libellulidae	Relative Abundance Libellulidae *	Relative Abundance Libellulidae	Relative Abundance Libellulidae *	Relative Abundance Odonata	Relative Abundance Odonata *
Minimum	0	0	0	0	0	0
Maximum	0.625	0.483	0.583	0.172	0.208	0.283
Mean	0.147	0.032	0.039	0.013	0.017	0.026
Std. Error	0.038	0.023	0.028	0.008	0.01	0.014

Appendix BD. Continued.

Western Allegheny Plateau Benthic and Nektonic Sampling (N=39)

	% Biomass EPA Stressed	% Biomass Collectors	% Biomass Collectors *	% Biomass Predators	% Biomass Predators *	% Biomass Shredders	% Biomass Shredders *	% Biomass Chironomidae	% Biomass Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.845	0.969	0.97	0.981	1	0.634	0.634	0.265	0.969
Mean	0.273	0.349	0.425	0.282	0.344	0.052	0.065	0.017	0.104
Std. Error	0.046	0.047	0.052	0.048	0.055	0.019	0.022	0.007	0.032

	% Biomass Coleoptera *	% Biomass Dytiscidae	% Biomass Corixidae	% Biomass Corixidae *	% Biomass Coleoptera and Corixidae	% Biomass Libellulidae	% Biomass Libellulidae *	% Biomass Odonata - Libellulidae	% Biomass Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.993	0.757	0.776	0.781	0.966	0.969	0.993	0.667	0.673
Mean	0.11	0.047	0.048	0.035	0.041	0.139	0.151	0.074	0.085
Std. Error	0.033	0.022	0.023	0.02	0.025	0.038	0.041	0.025	0.028

	% Biomass Odonata	% Biomass Odonata *	Relative Abundance EPA Stressed	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.3	0.865	0.948	0.957	0.884	0.812	0.966	0.7	1
Mean	0.057	0.082	0.132	0.166	0.239	0.262	0.345	0.223	0.315
Std. Error	0.015	0.026	0.032	0.04	0.029	0.032	0.039	0.028	0.041

	Relative Abundance Chironomidae	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Relative Abundance Dytiscidae	Relative Abundance Dytiscidae *	Relative Abundance Coleoptera and Corixidae	Relative Abundance Corixidae	Relative Abundance Corixidae *	Relative Abundance Libellulidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.312	0.357	0.597	0.7	0.848	0.625	0.758	0.797	0.948
Mean	0.045	0.057	0.124	0.096	0.117	0.051	0.061	0.139	0.168
Std. Error	0.013	0.015	0.02	0.023	0.027	0.02	0.023	0.03	0.034

Appendix BD. Continued.

	Relative Abundance Libellulidae *	Relative Abundance Libellulidae	Relative Abundance Libellulidae *	Relative Abundance Odonata	Relative Abundance Odonata *
Minimum	0	0	0	0	0
Maximum	0.797	0.948	0.098	0.167	0.3
Mean	0.043	0.051	0.012	0.02	0.057
Std. Error	0.022	0.026	0.004	0.006	0.015

Appendix BD. Continued.

Benthic Sampling Statewide (N=140)

	% Biomass Collector	% Biomass Collector *	% Biomass Predator	% Biomass Predator *	% Biomass Shredder	% Biomass Shredder *	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1.34	1.647	1	1	1	1	1	1	1
Mean	0.35	0.506	0.067	0.129	0.066	0.087	0.258	0.42	0.105
Std. Error	0.033	0.038	0.015	0.023	0.018	0.02	0.024	0.033	0.014

	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *	% Biomass EPA Stressed	Relative Abundance EPA Stressed	% Biomass Chironomidae	Relative Abundance of Chironomidae	% Biomass Coleoptera	% Biomass Coleoptera *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	1	1	1	1	1	0.833	0.84	1
Mean	0.19	0.039	0.065	0.134	0.13	0.053	0.087	0.057	0.103
Std. Error	0.023	0.01	0.014	0.021	0.016	0.015	0.014	0.013	0.02

	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Family Richness
Minimum	0	0	1
Maximum	0.5	1	14
Mean	0.04	0.078	4.307
Std. Error	0.008	0.014	0.227

Appendix BD. Continued.

Allegheny Highlands Benthic Sampling (N=62)

	% Biomass Collector	% Biomass Collector *	% Biomass Predator	% Biomass Predator *	% Biomass Shredder	% Biomass Shredder *	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	1	1	1	1	1	1	1	1
Mean	0.253	0.402	0.07	0.162	0.101	0.142	0.165	0.313	0.117
Std. Error	0.041	0.051	0.023	0.039	0.033	0.038	0.025	0.043	0.022

	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *	% Biomass EPA Stressed	Relative Abundance EPA Stressed	% Biomass Chironomidae	Relative Abundance of Chironomidae	% Biomass Coleoptera	% Biomass Coleoptera *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	1	1	1	0.692	1	0.692	0.84	1
Mean	0.235	0.068	0.123	0.077	0.116	0.041	0.098	0.062	0.132
Std. Error	0.039	0.02	0.03	0.022	0.019	0.019	0.019	0.021	0.035

	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Family Richness
Minimum	0	0	1
Maximum	0.5	1	14
Mean	0.046	0.114	4.597
Std. Error	0.011	0.026	0.377

Appendix BD. Continued.

Ridge and Valley Benthic Sampling (N=25)

	% Biomass Collector	% Biomass Collector *	% Biomass Predator	% Biomass Predator *	% Biomass Shredder	% Biomass Shredder *	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1.008	1.02	0.134	1	0.984	0.984	1	1.25	0.75
Mean	0.401	0.484	0.024	0.084	0.05	0.052	0.349	0.496	0.122
Std. Error	0.083	0.092	0.008	0.043	0.039	0.039	0.069	0.09	0.04

	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *	% Biomass EPA Stressed	Relative Abundance EPA Stressed	% Biomass Chironomidae	Relative Abundance of Chironomidae	% Biomass Coleoptera	% Biomass Coleoptera *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.364	0.364	1	0.633	1	0.633	0.778	0.952
Mean	0.196	0.021	0.026	0.245	0.17	0.111	0.107	0.087	0.103
Std. Error	0.059	0.015	0.016	0.071	0.042	0.056	0.04	0.043	0.051

	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Family Richness
Minimum	0	0	1
Maximum	0.5	0.667	9
Mean	0.036	0.051	4.04
Std. Error	0.021	0.028	0.54

Appendix BD. Continued.

Western Allegheny Plateau Benthic Sampling (N=53)

	% Biomass Collector	% Biomass Collector *	% Biomass Predator	% Biomass Predator *	% Biomass Shredder	% Biomass Shredder *	Relative Abundance Collector	Relative Abundance Collector *	Relative Abundance Predator
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1.34	1.647	0.983	1	0.821	0.842	1	1	0.6
Mean	0.439	0.638	0.083	0.112	0.034	0.04	0.324	0.509	0.082
Std. Error	0.058	0.063	0.029	0.035	0.018	0.019	0.042	0.054	0.019

	Relative Abundance Predator *	Relative Abundance Shredder	Relative Abundance Shredder *	% Biomass EPA Stressed	Relative Abundance EPA Stressed	% Biomass Chironomidae	Relative Abundance of Chironomidae	% Biomass Coleoptera	% Biomass Coleoptera *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.2	0.2	1	1	0.8	0.833	0.75	0.9
Mean	0.135	0.012	0.016	0.149	0.129	0.04	0.066	0.038	0.069
Std. Error	0.031	0.005	0.007	0.036	0.029	0.019	0.021	0.017	0.026

	Relative Abundance Coleoptera	Relative Abundance Coleoptera *	Family Richness
Minimum	0	0	1
Maximum	0.5	0.5	11
Mean	0.036	0.05	4.094
Std. Error	0.013	0.016	0.32

Appendix BD. Continued.

Nektonic Sampling Statewide (N=111)

	% Biomass EPA stressed	Relative Abundance EPA Stressed	% Biomass of Chironomidae	Relative Abundance of Chironomidae	% Biomass of Corixidae	% Biomass of Corixidae *	Relative abundance of Corixidae	Relative abundance of Corixidae *	Percent Biomass of Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	1	0.966	0.929	1	1	1	1	0.976
Mean	0.289	0.319	0.056	0.204	0.045	0.048	0.053	0.069	0.092
Std. Error	0.029	0.025	0.014	0.021	0.014	0.014	0.014	0.017	0.016

	Percent Biomass of Coleoptera *	Relative Abundance of Coleoptera	Relative Abundance of Coleoptera *	% Biomass of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae *	% Biomass of Dytiscidae	% Biomass of Dytiscidae *	Relative Abundance of Dytiscidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.8	1	1	1	1	1	0.829	0.922
Mean	0.1	0.095	0.128	0.137	0.147	0.148	0.197	0.04	0.042
Std. Error	0.018	0.014	0.018	0.021	0.022	0.019	0.023	0.012	0.012

	Relative Abundance of Dytiscidae *	% Biomass of Collectors	% Biomass of Collectors *	% Biomass of Predators	% Biomass of Predators *	% Biomass of Shredders	% Biomass of Shredders *	Relative Abundance of Collectors	Relative Abundance of Collectors *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.714	0.893	1	1.087	1	1	0.683	1	1
Mean	0.048	0.062	0.472	0.5	0.305	0.348	0.056	0.066	0.366
Std. Error	0.01	0.013	0.034	0.035	0.031	0.034	0.011	0.014	0.027

	Relative Abundance of Predators	Relative Abundance of Predators *	Relative Abundance of Shredders	Relative Abundance of Shredders *	Family Richness	Relative Abundance of Lestidae	Relative Abundance of Lestidae *	% Biomass of Libellulidae
Minimum	0	0	0	0	0	0	0	0
Maximum	1.4	1	1	0.733	23	0.238	0.625	0.059
Mean	0.472	0.233	0.327	0.092	8.207	0.004	0.008	0.003
Std. Error	0.031	0.022	0.028	0.016	0.478	0.002	0.006	0.001

Appendix BD. Continued.

	% Biomass of Libellulidae *	Relative Abundance of Libellulidae	Relative Abundance of Libellulidae *	% Biomass Odonata	% Biomass Odonata *	Relative Abundance of Odonata	Relative Abundance of Odonata *	% Biomass of Odonata - Libellulidae	% Biomass of Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.2	0.755	0.769	0.231	0.286	0.978	1	0.522	1
Mean	0.004	0.078	0.085	0.022	0.03	0.136	0.15	0.065	0.092
Std. Error	0.002	0.017	0.018	0.005	0.006	0.022	0.024	0.011	0.016

	Relative Abundance of Odonata - Libellulidae	Relative Abundance of Odonata - Libellulidae *
Minimum	0	0
Maximum	0.978	1
Mean	0.058	0.065
Std. Error	0.013	0.014

Appendix BD. Continued.

Allegheny Highlands Nektonic Sampling(N=46)

	% Biomass EPA stressed	Relative Abundance EPA Stressed	% Biomass of Chironomidae	Relative Abundance of Chironomidae	% Biomass of Corixidae	% Biomass of Corixidae *	Relative abundance of Corixidae	Relative abundance of Corixidae *	Percent Biomass of Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.966	0.929	0.966	0.929	0.32	0.325	0.367	0.571	0.9
Mean	0.312	0.398	0.093	0.282	0.038	0.042	0.049	0.079	0.086
Std. Error	0.043	0.038	0.03	0.037	0.012	0.013	0.014	0.022	0.024

	Percent Biomass of Coleoptera *	Relative Abundance of Coleoptera	Relative Abundance of Coleoptera *	% Biomass of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae *	% Biomass of Dytiscidae	% Biomass of Dytiscidae *	Relative Abundance of Dytiscidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.4	1	0.9	1	0.4	1	0.829	0.922
Mean	0.098	0.086	0.138	0.124	0.14	0.135	0.217	0.041	0.044
Std. Error	0.028	0.015	0.029	0.026	0.03	0.018	0.032	0.019	0.021

	Relative Abundance of Dytiscidae *	% Biomass of Collectors	% Biomass of Collectors *	% Biomass of Predators	% Biomass of Predators *	% Biomass of Shredders	% Biomass of Shredders *	Relative Abundance of Collectors	Relative Abundance of Collectors *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.208	0.5	1	1.087	0.966	1	0.346	0.388	1
Mean	0.038	0.056	0.467	0.513	0.288	0.358	0.053	0.057	0.349
Std. Error	0.01	0.015	0.054	0.055	0.047	0.055	0.013	0.015	0.04

	Relative Abundance of Predators	Relative Abundance of Predators *	Relative Abundance of Shredders	Relative Abundance of Shredders *	Family Richness	Relative Abundance of Lestidae	Relative Abundance of Lestidae *	% Biomass of Libellulidae
Minimum	0	0	0	0	0	0	0	0
Maximum	1.4	0.8	1	0.733	21	0.049	0.05	0.05
Mean	0.495	0.181	0.298	0.111	7.348	0.002	0.002	0.002
Std. Error	0.048	0.027	0.041	0.029	0.62	0.001	0.001	0.001

Appendix BD. Continued.

	% Biomass of Libellulidae *	Relative Abundance of Libellulidae	Relative Abundance of Libellulidae *	% Biomass Odonata	% Biomass Odonata *	Relative Abundance of Odonata	Relative Abundance of Odonata *	% Biomass of Odonata - Libellulidae	% Biomass of Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.062	0.755	0.769	0.231	0.286	0.909	0.926	0.5	0.6
Mean	0.003	0.103	0.118	0.033	0.045	0.148	0.166	0.059	0.084
Std. Error	0.002	0.029	0.033	0.009	0.012	0.035	0.038	0.015	0.02

	Relative Abundance of Odonata - Libellulidae	Relative Abundance of Odonata - Libellulidae *
Minimum	0	0
Maximum	0.5	0.529
Mean	0.045	0.048
Std. Error	0.015	0.016

Appendix BD. Continued.

Ridge and Valley Nektonic Sampling (N= 22)

	% Biomass EPA stresseda	Relative Abundance EPA Stressed	% Biomass of Chironomidae	Relative Abundance of Chironomidae	% Biomass of Corixidae	% Biomass of Corixidae *	Relative abundance of Corixidae	Relative abundance of Corixidae *	Percent Biomass of Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.994	0.852	0.597	0.75	0.101	0.107	0.519	0.609	0.633
Mean	0.233	0.267	0.053	0.177	0.013	0.014	0.034	0.04	0.098
Std. Error	0.064	0.06	0.029	0.049	0.006	0.006	0.023	0.028	0.034

	Percent Biomass of Coleoptera *	Relative Abundance of Coleoptera	Relative Abundance of Coleoptera *	% Biomass of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae *	% Biomass of Dytiscidae	% Biomass of Dytiscidae *	Relative Abundance of Dytiscidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.74	0.429	0.545	0.633	0.74	0.556	0.652	0.238	0.252
Mean	0.106	0.088	0.108	0.111	0.12	0.122	0.148	0.024	0.028
Std. Error	0.037	0.024	0.029	0.035	0.038	0.034	0.039	0.012	0.013

	Relative Abundance of Dytiscidae *	% Biomass of Collectors	% Biomass of Collectors *	% Biomass of Predators	% Biomass of Predators *	% Biomass of Shredders	% Biomass of Shredders *	Relative Abundance of Collectors	Relative Abundance of Collectors *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.231	0.237	0.971	0.972	1	1	0.292	1	0.844
Mean	0.044	0.056	0.464	0.484	0.289	0.341	0.057	0.097	0.341
Std. Error	0.014	0.017	0.079	0.082	0.068	0.08	0.019	0.047	0.056

	Relative Abundance of Predators	Relative Abundance of Predators *	Relative Abundance of Shredders	Relative Abundance of Shredders *	Family Richness	Relative Abundance of Lestidae	Relative Abundance of Lestidae *	% Biomass of Libellulidae
Minimum	0	0	0	0	0	0	0	0
Maximum	1.255	1	1	0.563	23	0.238	0.625	0.059
Mean	0.436	0.21	0.301	0.128	8.727	0.018	0.035	0.006
Std. Error	0.074	0.051	0.068	0.038	1.286	0.012	0.029	0.004

Appendix BD. Continued.

	% Biomass of Libellulidae *	Relative Abundance of Libellulidae	Relative Abundance of Libellulidae *	% Biomass Odonata	% Biomass Odonata *	Relative Abundance of Odonata	Relative Abundance of Odonata *	% Biomass of Odonata - Libellulidae	% Biomass of Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.2	0.683	0.686	0.185	0.217	0.735	0.739	0.522	0.667
Mean	0.014	0.04	0.04	0.014	0.018	0.075	0.093	0.047	0.066
Std. Error	0.009	0.031	0.031	0.009	0.011	0.037	0.044	0.026	0.033

	Relative Abundance of Odonata - Libellulidae	Relative Abundance of Odonata - Libellulidae *
Minimum	0	0
Maximum	0.293	0.625
Mean	0.035	0.052
Std. Error	0.017	0.031

Appendix BD. Continued.

Western Alleghany Plateau Nektonic Sampling(N=43)

	% Biomass EPA stresseda	Relative Abundance EPA Stressed	% Biomass of Chironomidae	Relative Abundance of Chironomidae	% Biomass of Corixidae	% Biomass of Corixidae *	Relative abundance of Corixidae	Relative abundance of Corixidae *	Percent Biomass of Coleoptera
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	1	0.265	0.608	1	1	1	1	0.976
Mean	0.292	0.262	0.019	0.134	0.07	0.071	0.068	0.073	0.096
Std. Error	0.049	0.037	0.007	0.023	0.033	0.033	0.032	0.033	0.028

	Percent Biomass of Coleoptera *	Relative Abundance of Coleoptera	Relative Abundance of Coleoptera *	% Biomass of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae	Relative Abundance of Coleoptera and Corixidae *	% Biomass of Dytiscidae	% Biomass of Dytiscidae *	Relative Abundance of Dytiscidae
Minimum	0	0	0	0	0	0	0	0	0
Maximum	1	0.8	1	1	1	1	1	0.762	0.781
Mean	0.098	0.108	0.128	0.166	0.169	0.176	0.202	0.047	0.047
Std. Error	0.029	0.029	0.034	0.042	0.043	0.04	0.044	0.021	0.021

	Relative Abundance of Dytiscidae *	% Biomass of Collectors	% Biomass of Collectors *	% Biomass of Predators	% Biomass of Predators *	% Biomass of Shredders	% Biomass of Shredders *	Relative Abundance of Collectors	Relative Abundance of Collectors *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.714	0.893	1	1	1	1	0.683	0.684	1
Mean	0.061	0.072	0.482	0.496	0.331	0.34	0.06	0.06	0.397
Std. Error	0.024	0.028	0.054	0.054	0.054	0.054	0.022	0.022	0.045

	Relative Abundance of Predators	Relative Abundance of Predators *	Relative Abundance of Shredders	Relative Abundance of Shredders *	Family Richness	Relative Abundance of Lestidae	Relative Abundance of Lestidae *	% Biomass of Libellulidae
Minimum	0	0	0	0	0	0	0	0
Maximum	1	1	1	0.5	22	0.012	0.012	0.044
Mean	0.466	0.302	0.373	0.054	8.86	0	0	0.001
Std. Error	0.048	0.041	0.048	0.016	0.805	0	0	0.001

Appendix BD. Continued.

	% Biomass of Libellulidae *	Relative Abundance of Libellulidae	Relative Abundance of Libellulidae *	% Biomass Odonata	% Biomass Odonata *	Relative Abundance of Odonata	Relative Abundance of Odonata *	% Biomass of Odonata - Libellulidae	% Biomass of Odonata - Libellulidae *
Minimum	0	0	0	0	0	0	0	0	0
Maximum	0.045	0.673	0.676	0.118	0.2	0.978	1	0.5	1
Mean	0.001	0.07	0.073	0.014	0.019	0.155	0.162	0.08	0.115
Std. Error	0.001	0.025	0.026	0.005	0.007	0.038	0.039	0.018	0.03

	Relative Abundance of Odonata - Libellulidae	Relative Abundance of Odonata - Libellulidae *
Minimum	0	0
Maximum	0.978	1
Mean	0.085	0.089
Std. Error	0.027	0.027