

METHODS DEVELOPMENT AND USE OF MACROINVERTEBRATES AS INDICATORS OF ECOLOGICAL CONDITIONS FOR STREAMS IN THE MID-ATLANTIC HIGHLANDS REGION

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Abstract. The Mid-Atlantic Highlands Assessment (MAHA) included the sampling of macroinvertebrates from 424 Wadeable stream sites to determine status and trends, biological conditions, and water quality in first through third order streams in the Mid-Atlantic Highlands Region (MAHR) of the United States in 1993–1995. We identified reference and impaired sites using water chemistry and habitat criteria and evaluated a set of candidate macroinvertebrate metrics using a stepwise process. This process examined several metric characteristics, including ability of metrics to discriminate reference and impaired sites, relative scope of impairment, correlations with chemical and habitat indicators of stream disturbance, redundancy with other metrics, and within-year variability. Metrics that performed well were compared with metrics currently being used by three states in the region: Pennsylvania, Virginia, and West Virginia. Some of the metrics used by these states did not perform well when evaluated using regional data, while other metrics used by all three states in some form, specifically number of taxa, number of EPT taxa, and Hilsenhoff Biotic Index, performed well overall. Reasons for discrepancies between state and regional evaluations of metrics are explored. We also provide a set of metrics that, when used in combination, may provide a useful assessment of stream conditions in the MAHR.

Keywords: benthic macroinvertebrates, bioassessment, biological monitoring, EMAP, methods development, metrics, Mid-Atlantic Highlands Region, multimetrics, PCA, stream condition

1. Introduction

Using benthic macroinvertebrate community metrics and/or a multimetric method for evaluating biological impairment in streams has become a familiar research practice (Resh and Jackson, 1993; Lenat, 1993; Barbour *et al.*, 1995, 1996b; Gerritsen, 1995; Fore *et al.*, 1996; Wallace *et al.*, 1996; Carlisle and Clements, 1999). A multimetric method was first used to assess biotic integrity of fish communities in Illinois streams (Karr, 1981; Karr *et al.*, 1986), and later for fish and macroinvertebrate communities by the Ohio Environmental Protection Agency (Ohio EPA)



(Ohio EPA, 1988a–c; DeShon, 1995; Yoder and Rankin, 1995), and by the USEPA (Plafkin *et al.*, 1989). The strength of using metrics or a multimetric approach is the ability to integrate data on community structure, to evaluate biological conditions, and to make scientific conclusions with reference to biogeography and water quality (Karr *et al.*, 1986; Plafkin *et al.*, 1989; Karr, 1991; Karr and Kerans, 1992). Ideally, macroinvertebrate metrics should be used that assess biological condition based on measures of taxa richness, composition, pollution tolerance, and trophic structure (Karr and Kerans, 1992; Resh and Jackson, 1993; Carlisle and Clements, 1999; Karr and Chu, 1999). Individual metrics should respond to specific in-stream stressors and to general, cumulative perturbations (Karr, 1993; Karr and Chu, 1999), but they also should not be too variable to be useful. Suter (1993) and Polls (1994) cautioned against the loss of biological information when using metrics in a multimetric method without first statistically evaluating, calibrating, and rigorously testing them.

Some U.S. states use multimetric methods for bioassessment, but other states have not been able to evaluate or standardize their sampling and processing methods because of lack of monetary and/or personnel resources or breadth of taxonomic expertise. Other problems include the difficulty in characterizing the reference conditions against which the impaired sites are compared (Hughes, 1995; Reynoldson *et al.*, 1997). Finally, identification of organisms to the lowest possible taxon can be a critical issue, even though genus and/or species level data can provide more ecological information (e.g., more precise pollution tolerance values (Appendix) and functional feeding groups) and taxonomic resolution. This more precise data can help to distinguish more subtle differences in biological conditions and can add strength to biocriteria development (Resh and Unzicker, 1975; Resh and McElravy, 1993; Davis and Simon, 1995; Karr and Chu, 1999; Waite *et al.*, 2000).

Many studies have shown that benthic macroinvertebrates are important biological indicators of water quality. They inhabit the sediment or live on the bottom substrates of lakes, streams, and rivers and reflect the biological integrity of the aquatic ecosystem (Klemm *et al.*, 1990; Rosenberg and Resh, 1993; Davies and Simon, 1995). Many macroinvertebrates have relatively long life cycles of a year or more, are especially important biological indicators of site conditions over time, and respond rapidly and predictably to changes in water quality and habitat changes. Additionally, some groups are tolerant and are found in polluted environments, while other groups are intolerant and respond to either specific stressors or a wide array of stressor and anthropogenic disturbances (Klemm *et al.*, 1990; Rosenberg and Resh, 1993; Davis and Simon, 1995; Meyer, 1997; Karr and Chu, 1999). In addition, standardized sampling and processing methods for macroinvertebrates are well-developed and taxonomic keys are available to identify most specimens to genus and/or species.

In this article, we statistically evaluated 45 macroinvertebrate metrics that measure a variety of ecosystem characteristics, many of which have been traditionally

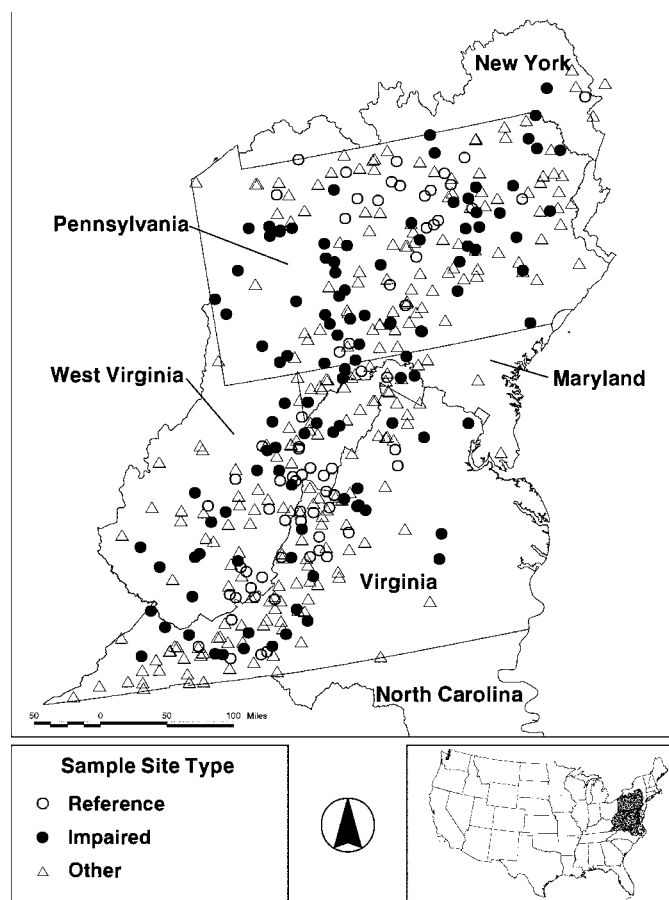


Figure 1. Sites sampled for the Mid-Atlantic Highlands Assessment (MAHA). Site designations of 'Reference' and 'Impaired' indicate that sites met the reference and impairment criteria, respectively (Table I). A designation of 'Other' indicates that the site met neither the reference nor the impairment criteria.

studied at the state or watershed scale (Plafkin *et al.*, 1989; Green, 1990; Barbour *et al.*, 1992, 1996a, b; DeShon, 1995). The metrics were evaluated for use in region-scale assessment of wadeable streams as part of the U.S. Environmental Protection Agency, Environmental Monitoring and Assessment Program-Surface Waters (EMAP-SW). Evaluation of metrics was based on the ability of individual metrics to discriminate condition and respond to stressors, as well as the consistency of metrics over multiple visits. The metrics that performed well at the regional scale were then compared to metrics currently used in the region at the state level. An additional objective of the assessment and evaluation was to determine which metrics, individually or as a group, explain the greatest amount of variability among sites in the region.

TABLE I

Criteria developed to identify reference and impaired sites within the MAHR using water chemistry and habitat information (Waite *et al.*, 2000)

Variable	Reference criteria	Impairment criteria
Acid neutralizing capacity ($\mu\text{eq L}^{-1}$)	>50	* ^a
Chloride ($\mu\text{ eq L}^{-1}$)	<100	>1000
Sulfate ($\mu\text{eq L}^{-1}$)	<400	>1000
Total phosphorus ($\mu\text{g L}^{-1}$)	<20	>100
Total nitrogen ($\mu\text{g L}^{-1}$)	<750	>5000
Mean RBP habitat score	>15 (optimal)	<10 (marginal)
pH	* ^a	<5
Total number of individuals counted	>99	* ^a

^a * Indicates that no criteria were established for that parameter.

2. Methods

2.1. STUDY AREA AND SURVEY DESIGN

The Mid-Atlantic Highlands Region of the United States extends northeast from northern North Carolina to the Catskill Mountains of New York and west from the Fall Line to the Western Allegheny Plateau of eastern Ohio (Figure 1). The data in this article were compiled from the EMAP-SW, Mid-Atlantic Highlands Assessment (MAHA) stream surveys conducted in 1993–1995. Stream sampling sites were selected using a randomized systematic design with a spatial component (Overton *et al.*, 1991; Herlihy *et al.*, 2000). Using the stream network on the digitized version of the 1:100 000 scale United States Geological Survey (USGS) topographic maps as the sample frame, sites were randomly chosen, but restricted to wadeable streams defined as first, second, and third order (Strahler, 1957) according to a 1:100 000 scale map (USEPA, 1998a; Herlihy *et al.*, 2000). Sample probabilities were set so that roughly equal numbers of first, second, and third order streams would appear in the sample. These probability sites were supplemented with hand-picked sites chosen by USEPA Region 3 state biologists. Data from 424 wadeable stream sites were analyzed in the present study (Figure 1).

2.2. REFERENCE AND IMPAIRED SITES

We identified reference stream sites using chemical, habitat, and minimum organism count criteria developed for wadeable streams in the Mid-Atlantic Highlands Region (Waite *et al.*, 2000) (Table I). The chemical criteria were used to identify and exclude from the reference group those sites affected by acidification, mine drainage, nutrient enrichment, and/or general human disturbance (Herlihy *et al.*,

1991, 1998), and a habitat criterion identified sites with optimal Rapid Bioassessment Protocols (RBPs) habitat scores (Plafkin *et al.*, 1989; Hughes, 1995; Barbour *et al.*, 1999). Minimum organism count criterion was used to identify and exclude from the reference group those sites which might have some unmeasured impairment. Impaired sites were identified by applying chemical and RBP habitat score criteria to identify sites with the most highly impaired conditions in the study area. A site was classified as reference only if all of the reference criteria were met, but if any impairment criterion was met, a site was classified as impaired. Seventy reference sites and 105 impaired sites were identified from the probability and hand-picked sites using the criteria. All sites that did not meet the reference or impaired site criteria were designated as 'Other' sites (Figure 1).

2.3. SAMPLE COLLECTION AND PROCESSING

Samples were collected during the spring base-flow period, April to June 1993–1995. Sample sites consisted of a length of stream equal to 40 times the mean wetted width (minimum of 150 m and maximum of 500 m) delineated around a randomly selected midpoint. Eleven evenly-spaced transects were laid out within this reach. Benthic macroinvertebrates were collected from the inner nine transects and water chemistry samples were collected from the midpoint using EMAP-SW protocols (USEPA, 1998a). The habitat data used for this study were collected using RBPs (Barbour and Stribling, 1991). Macroinvertebrate samples were collected from riffle/run and pool/glide habitats, composited by habitat, and processed separately. If a sample was collected from three or fewer transects, from the same habitat type, the entire sample was retained for processing. However, if the sample was composited from four or more transects only a third of the sample was retained. Only riffle/run data were used in our analyses because samples were collected from riffles/runs for over 90% of sites and from pools/glides at less than 40% of sites. Pool/glide and riffle/run data were not directly comparable due to potentially very different taxonomic composition between the two habitat types, even within the same site. In addition, the range of conditions was much more limited among sites with pool/glide data, and sampling procedures are more standardized and more widely used for riffle/run habitats than for pool/glide habitats (Klemm *et al.*, 1990; Plafkin *et al.*, 1989; Barbour *et al.*, 1999).

Macroinvertebrate samples were processed using standard EMAP benthic macroinvertebrate laboratory protocols (USEPA, 1994, 2001). A sample was placed in a sorting pan with 40 numbered squares, and the organisms were sorted from the squares, based on a random number generator. Squares were chosen and sorted in this way until at least 270 organisms (within 10% of the 300 organism target) or the entire sample (composites of three or fewer transects) or the 1/3 subsample (composites of four or more transects) were sorted. All organisms were identified to the lowest possible level of taxonomy (Appendix) based on available keys and specimen condition and stage. Quality assurance and quality control (QA/QC) pro-

TABLE II

Metrics used by states (Jim Green, USEPA, Region III, pers. comm.) with sampling sites in the MAHA study

Metrics	Pennsylvania	Virginia	West Virginia
Taxa richness	X	X	X
EPT richness		X	X
Modified EPT richness (PTV \leq 4)	X		
% EPT individuals ratio			X
Modified % Ephemeroptera (PTV \leq 4)	X		
% Chironomidae individuals			X
EPT/Chironomidae individuals ratio		X	
% Dominant taxon	X	X	
% 2 Dominant taxa			X
Hilsenhoff Biotic Index (HBI)	X	X	X
Scraper/Collector-filterer individuals		X	
% Shredder individuals		X	
Community Similarity Index		X	

cedures for processing (sorting, counting, and identification) of macroinvertebrate samples included recounting and re-identification of 10% of the macroinvertebrate samples, use of a reference collection, and verification of difficult organisms by outside experts (Klemm *et al.*, 1990; USEPA, 1994, 2001; Barbour *et al.*, 1999). Water chemistry samples were analyzed and QA/QC procedures were followed, according to USEPA and EMAP protocols (USEPA, 1987, 1994).

2.4. DATA USED FOR METRIC EVALUATION

Riffle/run data obtained from the first visit to a site were used in the metric evaluation process. Data on 35 revisits to sites were excluded except for the evaluation of metric repeatability.

We evaluated 45 metrics based on taxa richness, composition, pollution tolerance and functional feeding groups (Table III). Pollution tolerance values (Appendix) for each taxon were obtained from literature when possible (Green, 1990; Klemm *et al.*, 1990; Lewis and Klemm, 1990; Lenat, 1993; Barbour *et al.*, 1999; Maxted *et al.*, 2000). Otherwise, they were assigned based on literature and professional judgement. Functional feeding groups were determined for each taxon based on literature (Green, 1990; Merritt and Cummins, 1996; Barbour *et al.*, 1999).

A majority of sites sampled for MAHA were in Pennsylvania, Virginia, and West Virginia, and we included metrics currently being used or tested by these states when possible (Table II, Jim Green, USEPA Region 3, pers. comm.). The

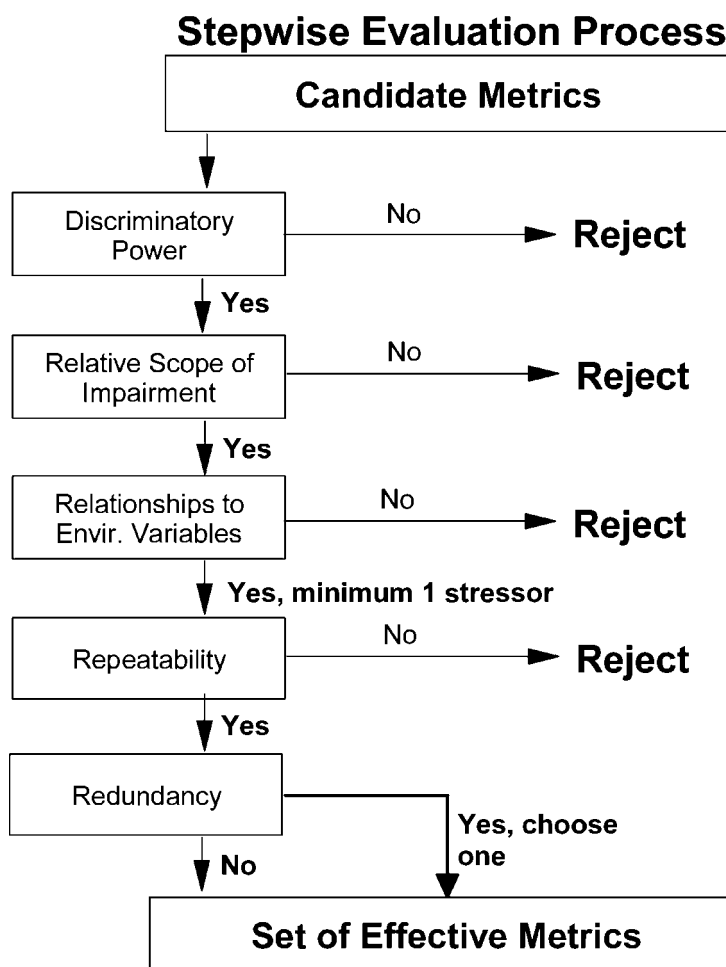


Figure 2. Flowchart describing the stepwise process used to evaluate candidate metrics.

data were not conducive to calculating the Community Similarity Index (CSI), used by Virginia. Thus, the CSI was not included in the evaluation.

2.5. METRIC EVALUATION

Using a stepwise process (Figure 2), we evaluated four metric characteristics: (1) discriminatory power, (2) relative scope of impairment, (3) relationship to stressors, and (4) repeatability. Discriminatory power is the ability of a metric to distinguish between reference and impaired conditions. Relative scope of impairment is a measure of metric variability and indicates the ease with which deviation from unimpaired conditions can be detected (USEPA, 1998b). Responsiveness or relationship of a metric to environmental variables is a measure of that metric's ability to detect detrimental levels of specific measured stressors. Finally, repeat-

ability of a metric between visits to a site is the level of variability to be expected through time, given no changes in site condition.

2.5.1. *Discriminatory Power*

Discriminatory power was assessed for each of 45 initial candidate metrics (Table III). Box-and-whisker plots were plotted separately for reference and impaired sites to evaluate the ability of each macroinvertebrate metric to discriminate between the reference and impaired sites. The degree of overlap of medians and interquartile ranges (IQRs) between reference and impaired sites was considered a signal of the discriminatory capability of the metric. Using the system developed by Barbour *et al.* (1996b), the medians and IQRs of the impaired and reference sites were compared, and metrics were scored as follows: a score of 0 (lowest discriminatory power) if there was complete overlap of each group's IQRs with the median of the other group, a score of 1 if only one median was overlapping with the IQR of the other group, a score of 2 if neither median overlapped with the IQR of the other group but the IQRs overlapped, and a score of 3 (highest discriminatory power) if the IQRs did not overlap. Scores of 2 and 3 demonstrated an ability to distinguish between reference and impaired sites, and we retained only those metrics with a score of 2 or 3 for further evaluation.

2.5.2. *Relative Scope of Impairment*

We evaluated the relative scope of impairment using the interquartile coefficient (USEPA, 1998b). We calculated this value by comparing the ratio of the IQR for reference sites to the range of impairment. Range of impairment is measured as the difference between the lowest quartile among reference sites and the minimum value overall for metrics that decrease with increasing stress or the difference between the highest quartile among reference sites and the maximum value overall for metrics that increase with increasing stress (Barbour *et al.*, 1996a, b; Stribling *et al.*, 1998). We retained only those metrics with an interquartile coefficient of approximately one or lower for further analysis because an interquartile coefficient much greater than one shows excessive variability among reference sites (IQ range) as compared to the range for impairment (USEPA, 1998b).

2.5.3. *Relationship to Environmental Variables*

We evaluated the remaining metrics to determine which were correlated with particular environmental variables. The set of environmental variables included in the analysis was reduced by retaining only one variable from each group of highly correlated (>0.50) measures. Variables included measures of water chemistry (variables used for reference/impairment criteria, DOC, conductivity, total dissolved aluminum, turbidity, total suspended solids), habitat (RBP individual metric scores), and land use (estimated number of and density in watershed of population, road, and housing units). We used Spearman rank correlations and scatter plots of candidate metrics and stressor variables to identify potential stressor-metric relation-

TABLE III

Definitions and expected responses to stresses of 45 candidate metrics evaluated. When available, expected responses to stress were compiled from DeShon (1995), Barbour *et al.* (1996a), Fore *et al.* (1996), and Hilsenhoff (1987)

Metric	Definition	Response to stress	Discrim. power
Total no. of taxa	No. of taxa in sample	Decrease	2
Simpsons Diversity Index	Probability that 2 randomly chosen individuals will belong to the same taxon	Increase	2
Shannon Diversity Index	Incorporates diversity and evenness	Decrease	2
No. EPT taxa	No. of Ephemeroptera, Plecoptera, and Trichoptera taxa	Decrease	3
Modified number EPT taxa	No. EPT taxa, excluding taxa with PTV > 4	Decrease	3
No. Ephemeroptera taxa	No. Ephemeroptera taxa	Decrease	3
No. Plecoptera taxa	No. Plecoptera taxa	Decrease	3
No. Trichoptera taxa	No. Trichoptera taxa	Decrease	2
No. Megaloptera taxa	No. Megaloptera taxa	Increase	0
No. Chironomid taxa	Number Chironomidae (midge) taxa	Increase	0
No. intolerant taxa	No. of taxa with PTV < 4	Decrease	3
HBI	$\sum_i p_i t_i$, where p_i is the proportion of individuals in taxon i and t_i is the PTV for taxon i , PTVs for general pollution	Increase	2
% Intolerant taxa	Percentage of taxa with PTV < 4	Decrease	3
% Tolerant taxa	Percentage of taxa with PTV > 6	Increase	3
% Facultative taxa	Percentage of taxa with PTV ≥ 4 and ≤ 6	Increase	2
% Indiv. in dominant taxon	Percentage of individuals in the single dominant taxon	Increase	2
% Indiv. 2 dominant taxa	Percentage of individuals in 2 dominant taxa	Increase	2
% Indiv. 5 dominant taxa	Percentage of individuals in 5 dominant taxa	Increase	2
No. individuals per taxon	(Total no. of individuals)/(Total no. of taxa)	Increase	0
% Non-insects	Percentage of individuals not insects	Increase	2
% Oligochaetes and Leeches	Percentage of individuals in Oligochaeta and Hirudinea	Increase	1
% EPT taxa	Percentage of taxa which are EPT taxa	Decrease	3
% Ephemeroptera taxa	Percentage of taxa which are in Ephemeroptera	Decrease	3
% Plecoptera taxa	Percentage of taxa which are in Plecoptera	Decrease	2
% Trichoptera taxa	Percentage of taxa which are in Trichoptera	Decrease	2
% Ephemeroptera individuals	Percentage of total individuals in Ephemeroptera	Decrease	2
% EPT individuals	Percentage of total individuals in EPT taxa	Decrease	3
Modified % Ephemeroptera individuals	Percentage of total individuals in Ephemeroptera, excluding taxa with PTV > 4	Decrease	3
% Plecoptera individuals	Percentage of total individuals in Plecoptera	Decrease	2
% Trichoptera individuals	Percentage of total individuals in Trichoptera	Decrease	1
% Chironomid taxa	Percentage of taxa which are in Chironomidae	Increase	2
% Chironomid individuals	Percentage of total individuals in Chironomidae	Increase	1
% Megaloptera taxa	Percentage of taxa which are in Megaloptera	Increase	0
% Megaloptera individuals	Percentage of total individuals in Megaloptera	Increase	0

TABLE III
(continued)

Metric	Definition	Response to stress	Discrim. power
EPT/Chironomidae ratio	Ratio of EPT individuals to Chironomidae individuals	Decrease	2
% Collector-filterer indiv.	Percentage of individuals in collector-filterer taxa	Decrease	0
% Collector-gatherer indiv.	Percentage of individuals in collector-gatherer taxa	Decrease	1
% Mixed function indiv.	Percentage of individuals in mixed function taxa	Decrease	0
% Omnivore indiv.	Percentage of individuals in omnivorous taxa	Increase	0
% Parasitic indiv.	Percentage of individuals in parasitic taxa	Variable	0
% Herbivorous piercer indiv.	Percentage of individuals in herbivorous piercer taxa	Variable	0
% Predator indiv.	Percentage of individuals in predaceous taxa	Variable	0
% Shredder indiv.	Percentage of individuals in shredder taxa	Decrease	0
% Scraper indiv.	Percentage of individuals in scraper taxa	Decrease	1
Scrapers/Coll.-filterers	Ratio of individuals in scraper and collector-filterer taxa	Decrease	1

ships. Due to the large number of correlations run, an individual correlation was considered significant only if the p-value was ≤ 0.0001 . We retained only metrics with at least one significant correlation for further evaluation. It was also at this stage that we eliminated metrics with conflicting responses in the correlations with stressors and the box plots.

2.5.4. Repeatability

Repeatability of individual metrics within a year was determined from those sites with two visits within a given year between 1993 and 1995. There were 35 pairs of within-year visits. As these plots represented less than 10% of sites, we used this step only as a coarse screen for metrics. For each remaining metric, we plotted the mean value for a site in a particular year against individual visit values. A plot with a strong linear trend around the diagonal (45-degree line) indicates that within-year visits show similar metric values and the mean metric value for a site is unrelated to the amount of within-year variability (i.e., larger mean values do not show higher variability). We examined the plots and excluded those with cone-shaped relationships or a high degree of variability around the diagonal (45-degree line) because those metrics had an undesirable relationship between mean and variability or excessively high within-year variability, respectively.

2.6. OTHER CONSIDERATIONS

2.6.1. *Redundancy of Metrics*

The redundancy among metrics used for biological assessment is an important characteristic to evaluate. Using two or more metrics which have a strong linear relationship to one another as indicators results in no new information being contributed to an assessment (USEPA, 1998b). We used Pearson pairwise correlations and bivariate scatter plots to identify redundant pairs or groups among the remaining metrics. Among pairs with high correlations ($r > 0.70$), we examined scatter plots to determine the nature of the relationship. If the relationship between metrics was curved, cone-shaped, or had a wide spread in some ranges, we concluded that the metrics were not redundant (USEPA, 1998b). Only tight relationships where both metrics fell close to a straight line were considered redundant. For the purposes of later analysis of metrics, a single metric was selected from each group based on correlations with environmental variables, discriminatory power, and correlations with other metrics.

2.6.2. *Relationships to Watershed Size*

Some macroinvertebrate metrics are expected to vary naturally with stream size in the watershed according to the river continuum concept (Vannote *et al.*, 1980). Thus, we plotted reference sites for each selected metric against the natural logarithm of the watershed drainage area to identify metrics related to watershed area. We looked for general trends with watershed area, as well as trends along the maximum or minimum of the metric distribution.

2.7. MULTIVARIATE ANALYSES

A Principal Components Analysis (PCA) of the metric data allowed us to determine which metrics contributed the most to explaining variability in the macroinvertebrate community data. In addition, PCA indicates how well the candidate metrics, in combination, can distinguish a stressor gradient (reference vs. impaired sites). PCA is based on the assumption of multivariate normality among the distributions (Johnson and Wichern, 1992). Therefore, we tested each candidate metric for univariate normality and used a series of Box-Cox power transformations to identify an optimal transformation for metrics which were not normally distributed (Box and Cox, 1964; Neter *et al.*, 1996).

We ran two PCAs, one based on the full set of candidate metrics and one based on the subset of those metrics remaining following the entire evaluation process. For the second PCA, we included only a single metric from each group of redundant metrics in the analysis. Data from all three types of sites (reference, impaired, and other) were used in this analysis. We also ran a linear discriminant analysis (Johnson and Wichern, 1992) to determine how well the PCA axes were able to classify reference and impaired sites.

3. Results

3.1. METRIC EVALUATION

3.1.1. *Discriminatory Power*

Twenty-seven of the initial 45 metrics showed clear discriminatory power between reference and impaired sites, scoring a 2 or a 3 in box plots of reference versus impaired sites (Table III). Only these metrics were retained for further evaluation.

3.1.2. *Relative Scope of Impairment*

Of the 27 remaining metrics, only percent Plecoptera individuals and EPT/Chironomidae ratio had little relative scope of impairment and were excluded from subsequent analyses (Table IV). Percent Plecoptera taxa had a marginal interquartile coefficient (1.06), but it was retained for further analysis because it was very close to the desired range. The coefficients for most other metrics were well below 1.

3.1.3. *Relationship to Environmental Variables*

All of the 25 remaining candidate metrics were correlated with one or more environmental variables (Table IV).

3.1.4. *Repeatability*

Most of the remaining metrics had reasonably good repeatability between site visits. Plots for percent tolerant taxa, Simpson's diversity index, percent Ephemeroptera individuals, modified percent Ephemeroptera individuals, and percent Ephemeroptera taxa all showed cone-shaped trends or high variability around the 45-degree line, so these metrics were eliminated (Table IV, Figure 3).

3.2. OTHER CONSIDERATIONS

3.2.1. *Redundancy of Metrics*

Among the remaining 20 metrics, many were correlated with one another, but most did not indicate redundancy in plots. Percent intolerant taxa and percent EPT taxa were highly correlated and redundant ($r = 0.91$). Based on both correlations and scatter plots, percent intolerant taxa was also redundant with percent facultative taxa ($r = 0.82$). Numbers of EPT taxa, modified EPT taxa, intolerant taxa, and Ephemeroptera taxa were also redundant ($r = 0.84$ to 0.98). Number of Trichoptera taxa was redundant with percent Trichoptera taxa ($r = 0.81$). Shannon diversity was redundant with percent dominant 5 taxa, percent dominant 2 taxa, and percent dominant taxon ($r = -0.95$, -0.95 , and -0.91 , respectively). Finally, HBI was redundant with percent EPT individuals ($r = -0.857$). For all other pairs of correlated metrics, scatter plots indicated either a non-linear relationship or wide variation along a linear trend, such that each metric could be considered separately.

TABLE IV
Results of evaluation based on metrics passing test of discriminatory power (Table III)

Metric	Rel. scope of impairment	Relationship to environmental variables, top 3 significant correlations (r, n)			Repeatability trend
Total no. of taxa	0.36	Sulfate (-0.292, 422)	- ^a	-	Linear
Simpson's Diversity Index	0.04	Sulfate (0.243, 422)	-	-	Cone-shaped
Shannon Diversity Index	0.18	Sulfate (-0.283, 422)	-	-	Linear
No. of EPT taxa	0.35	RBP embeddedness (0.410, 382)	Conductivity (-0.404, 422)	Population density (-0.384, 424)	Linear
Modified no. EPT taxa	0.44	Conductivity (-0.454, 422)	RBP embed. (0.417, 382)	Population density (-0.410, 424)	Linear
No. Ephemeroptera taxa	0.75	RBP embed. (0.313, 382)	Sulfate (-0.289, 422)	Total dissolved Al (-0.282, 422)	Linear
No. Plecoptera taxa	1.00	Conductivity (-0.575, 422)	Chloride (-0.495, 422)	Population density (0.471, 424)	Linear
No. Trichoptera taxa	0.75	RBP mean habitat (0.362, 413)	RBP epifaunal substrate (0.334, 413)	RBP embed. (0.326, 382)	Linear
No. intolerant taxa	0.47	Conductivity (-0.396, 422)	RBP embed. (0.394, 382)	Sulfate (-0.370, 422)	Linear
HBI	0.17	Population density (0.475, 424)	Conductivity (0.470, 422)	Chloride (0.459, 422)	Linear
% Intolerant taxa	0.29	Population density (-0.453, 424)	Conductivity (-0.442, 422)	Chloride (-0.434, 422)	Linear
% Tolerant taxa	0.04	Conductivity (0.452, 422)	Chloride (0.446, 422)	Population density (0.432, 424)	Cone-shaped
% Facultative taxa	0.23	RBP epifaunal subst. (-0.322, 413)	DOC (0.305, 422)	Population density (0.282, 424)	Linear
% Indiv. in dominant taxon	0.12	RBP embed. (-0.203, 382)	Sulfate (0.193, 422)	-	Linear
% in 2 dominant taxa	0.18	Sulfate (0.213, 422)	-	-	Linear
% in 5 dominant taxa	0.40	Sulfate (0.260, 422)	-	-	Linear
% Non-insects	0.02	TSS (0.348, 422)	Conductivity (0.330, 422)	Population density (0.325, 424)	Linear
% EPT taxa	0.24	Population density (-0.470, 424)	Conductivity (-0.461, 422)	Chloride (-0.449, 422)	Linear
% Ephemeroptera taxa	0.33	RBP embed. (0.318, 382)	Population density (-0.298, 424)	Total nitrogen (-0.270, 422)	Cone-shaped
% Plecoptera taxa	1.09	ANC (-0.541, 422)	Conductivity (-0.538, 422)	Chloride (-0.521, 422)	Linear
% Trichoptera taxa	0.63	RBP mean habitat (0.390, 413)	RBP bank condition (0.349, 413)	RBP embed. (0.344, 382)	Linear
% EPT individuals	0.60	Conductivity (-0.457, 422)	Population density (-0.457, 424)	Housing density (-0.446, 383)	Linear
% Ephemeroptera individuals	0.65	Conductivity (-0.310, 422)	Chloride (-0.309, 422)	Total nitrogen (-0.294, 422)	Highly variable
Modified % Ephem. indiv.	0.79	Conductivity (-0.311, 422)	Chloride (-0.305, 422)	Total nitrogen (-0.291, 422)	Cone-shaped
% Plecoptera individuals	2.31	-	-	-	-
% Chironomid taxa	0.17	Population density (0.368, 424)	Chloride (0.360, 422)	Housing unit density (0.359, 383)	Linear
EPT/Chironomid ratio	2.47	-	-	-	-

^a - Indicates metric not evaluated at this step because already eliminated or no additional significant correlations were observed.

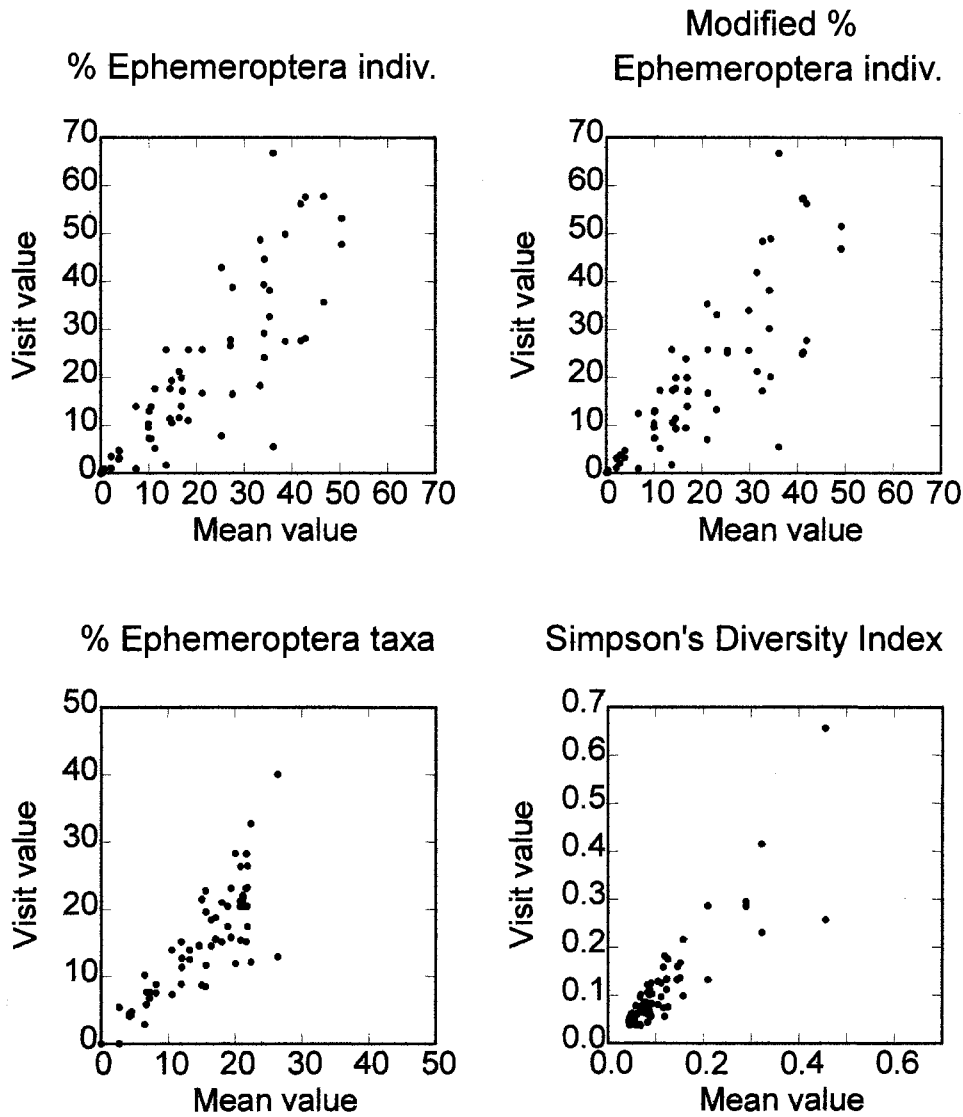


Figure 3. Metrics showing poor within-year repeatability.

3.2.2. Relationships to Watershed Size

When plotted against the natural log of drainage area, several of the remaining metrics exhibited an apparent relationship with watershed size among reference sites. The maximum values for number of taxa, number of Ephemeroptera taxa, and number of Trichoptera taxa and the minimum value for percent facultative taxa increased with increasing watershed size. The maximum value for percent Plecoptera taxa and the minimum values for percent individuals in the dominant

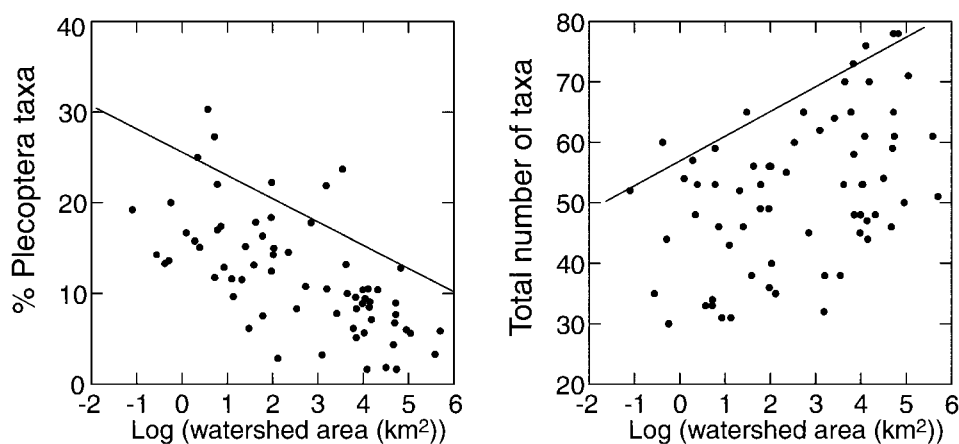


Figure 4. Examples of relationships between log(watershed area) and maximum values for total number of taxa and percent Plecoptera taxa.

2 taxa and percent individuals in the dominant 5 taxa decreased with increasing watershed size. Examples of relationships observed are shown in Figure 4.

3.3. MULTIVARIATE ANALYSES

The Box-Cox procedure preceding PCA indicated that most metrics required transformation to optimize univariate normality. The preferred transformations consisted of exponentiations of the raw data. First axes of the two PCAs were highly correlated ($r = 0.95$), and the second axes of the two PCAs were just as highly correlated with one another ($r = 0.95$). The first principal components axis, based the full set of metrics, represented about 34% of the variability in the data, and loadings for this axis were relatively large (>0.20) for about half of the set of metrics remaining after evaluation. These included numbers of EPT, modified EPT, intolerant, Ephemeroptera, and Plecoptera taxa, percentages of EPT and intolerant taxa, percentages of Ephemeroptera, modified Ephemeroptera, and EPT individuals, and the EPT/Chironomidae ratio. The second axis (17% of variability) had high loadings (>0.20) for number of taxa, Simpson diversity index, Shannon diversity, number of chironomid taxa, percentage chironomid individuals, and percentages in the dominant 1, 2, and 5 taxa. The first axis of the PCA based on the subset of metrics represented 50% of the variability in the data, and loadings were large (>0.25) for all but the number of taxa and percent dominant taxon, which had the highest loadings (0.64 and 0.55, respectively) on the second axis (20% of variability). A linear discriminant function using the PCA axes based on the nine selected metrics showed that the axes were effective at distinguishing reference from impaired sites (Figure 5). Approximately 91% of reference sites and 78% of impaired sites were correctly classified using the linear discriminant function.

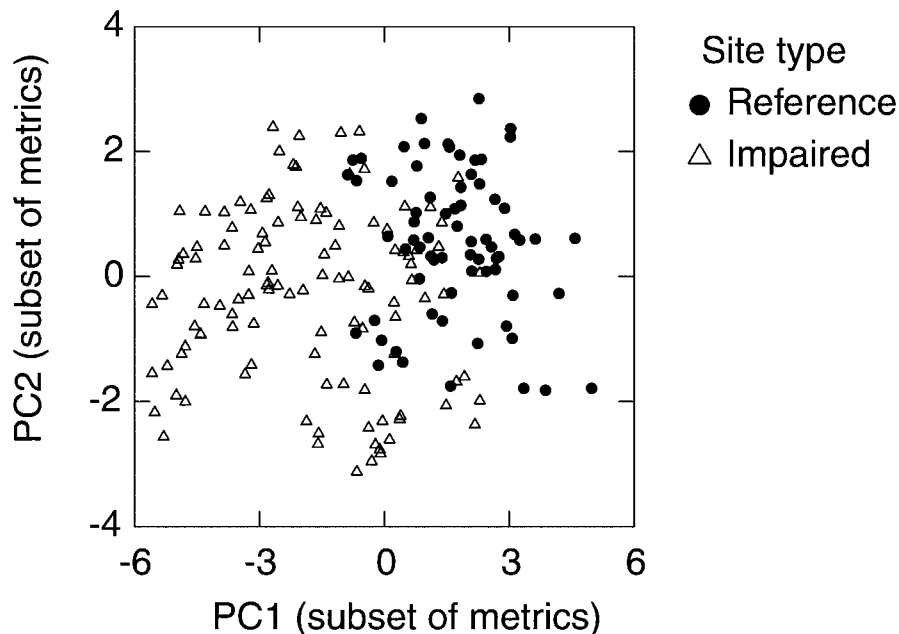


Figure 5. Separation of reference and impaired sites along first and second principal component axes based on 9 selected metrics.

4. Discussion

Several of the region-scale candidate metrics were effective in detecting general impairment in the MAHR. However, when metrics currently being used by the three states in which the majority of MAHA samples were collected were applied at the regional scale, there was great variation in their performance. Those that are used in some form by all three of the states (Table II) that performed well included number of taxa, EPT richness, and HBI. These same metrics performed well for mid-Atlantic coastal plain streams and were selected as part of the Coastal Plain Macroinvertebrate Index (CPMI) (Maxted *et al.*, 2000). Numbers of total taxa and EPT taxa were also among the most responsive metrics in a Swedish study of acidification and eutrophication in streams (Sandin and Johnson, 2000). These metrics, along with percent dominant taxon, were also the best indicators of metals contamination in the Clark Fork River in Montana (Poulton *et al.*, 1995). Other metrics that performed well that were used by at least one of the three states were percent EPT individuals and percent dominant 2 taxa.

Several state metrics did not perform well at the region level. State metrics unable to distinguish reference from impaired sites at the region level included percent shredder individuals, the ratio of scrapers to collector-filterers, and percent chironomid individuals. The ratio of EPT to Chironomidae individuals distinguished reference and impaired sites, but this metric was too variable among

regional reference sites to be effective at detecting impairment. Based on revisits to sites, the modified % Ephemeroptera metric was highly variable within a year. Finally, at the regional scale, the HBI was redundant with percent EPT individuals.

Among the other candidate metrics, none of the functional feeding group metrics performed well at the regional scale. Our results support the conclusions of Karr and Chu (1997) that trophic metrics are not generally as reliable as metrics based on taxonomic groupings. In a study in southwest Germany, several functional feeding group metrics differed significantly between reference and impaired sites in highlands streams (Rawer *et al.*, 2000). However, in southeastern Kentucky, functional feeding groups showed little difference between a reference headwater stream and one with past mining and logging disturbance (Pond, 2000). Carlisle and Clements (1999) also found that most functional feeding group metrics had low statistical power and were insensitive to metal pollution in the Arkansas River. In addition, classification of macroinvertebrates into functional feeding groups can be problematic because the feeding mode of a given taxon may be unknown (Merritt and Cummins, 1996) or change with life stage (Allan, 1995).

This study evaluated the performance of macroinvertebrate metrics at the regional scale, and most of the sites sampled were chosen using a probability-based design. Thus, factors affecting the range and performance of individual metrics reflect regional characteristics. It is not surprising, therefore, that some of the metrics used by individual states did not perform well at the regional scale. This analysis does not necessarily invalidate those metrics. By the regional and probabilistic nature of its design, this study did not include all areas of any given state, and metric evaluation incorporated conditions and potential stressors which may vary from state to state in the region. Thus, metrics useful at the regional scale should be evaluated and applied at the appropriate scale.

An additional limitation to comparing these results to those obtained by individual states in the region is that all metrics for this study were based on identification of specimens to the lowest possible taxon, and the pollution tolerance values were determined at that taxonomic level. Identification of specimens to a higher taxonomic level (i.e., class or family) or to varying levels depending on the macroinvertebrate group by states would likely have generated different results and data interpretation. In such a situation, a direct comparison of our region-scale results with state-specific results might be confounded by differences in taxonomic resolution.

Several metrics remaining after regional-scale evaluation appeared to be related to watershed area. Ohio EPA also observed relationships with watershed size for number of taxa, number of Ephemeroptera taxa, and number of Trichoptera taxa, although the direction of trends of our data do not necessarily correspond with those found by Ohio EPA (DeShon, 1995). As recognized by DeShon (1995), if a metric that is related to drainage area (watershed size) is included in a multi-metric index, the expectations need to be adjusted when scoring the metric. For metrics that decrease with increasing stress, the maximum value as watershed size

increases is of greatest interest because higher values indicate higher quality sites. However, for metrics that increase with increasing stress, the minimum value is more important because the lower the values for these metrics, the higher quality the sites.

All metrics used by states that were evaluated and had discriminatory power were important in separating sites along the first or second axis of the PCAs. The smaller subset of metrics, which excluded any redundant metrics, effectively summarized the information in the larger set of metrics. In addition, this combination of metrics along the two PCA gradients (axes) was also effective in distinguishing reference from impaired sites. Based on this analysis, measures of composition and richness of specific macroinvertebrate groups may be more important in distinguishing reference and impaired sites than total richness, diversity, evenness, or functional feeding group measures.

Acknowledgements

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Appendix

Mid-Atlantic Highlands Region (MAHR) macroinvertebrate taxa list with pollution tolerance values (PTV^a)

Taxa name	PTV
Haplotaxida	
<i>Aeolosoma</i> sp.	8.0
Arhynchobdellida	
<i>Erpobdella punctata punctata</i>	8.0
Rhynchobdellida	
<i>Helobdella stagnalis</i>	8.0
<i>Placobdella hollensis</i>	6.0
<i>Placobdella</i> sp.	6.0
<i>Piscicola milneri</i>	6.5
<i>Piscicola</i> sp.	6.5
Branchiobdellida	7.0
<i>Xironogiton</i> sp.	6.7
Haplotaxida	
<i>Haplotaxis cf. gordioides</i>	5.5
Lumbriculida	
<i>Eclipidrilus</i> sp.	7.5
<i>Lumbriculus inconstans</i>	7.8
<i>Lumbriculus variegatus</i>	8.0
<i>Stylodrilus heringianus</i>	8.3
<i>Lumbricidae</i>	7.7
Tubificida	
<i>Enchytraeidae</i>	7.0
<i>Arcteonais lomondi</i>	6.7
<i>Bratislava/Pristinella</i>	9.0
<i>Chaetogaster diaphanus</i>	6.0
<i>Chaetogaster</i> sp.	6.0
<i>Dero obtusa</i>	8.0
<i>Dero</i> sp.	8.0
<i>Nais barbata</i>	8.0
<i>Nais behningi</i>	6.0
<i>Nais bretscheri</i>	7.0
<i>Nais communis</i>	8.3
<i>Nais elinguis</i>	10.0
<i>Nais pardalis</i>	8.3
<i>Nais pseudobtusa</i>	8.3

^a Pollution Tolerance Values (PTV) range from 0 (most intolerant) to 10 (most tolerant) and were obtained by determining the tolerance values of organisms to various types of stressors and calculating an average value.

Appendix
(continued)

Taxa name	PTV
Tubificida (continued)	
<i>Nais simplex</i>	6.5
<i>Nais variabilis</i>	10.0
<i>Ophidonais serpentina</i>	6.5
<i>Piguetiella michiganensis</i>	6.0
<i>Piguetiella/Uncinais</i>	8.0
<i>Pristinella jenkiniae</i>	8.9
<i>Pristinella osborni</i>	8.9
<i>Pristinella</i> sp.	8.9
<i>Slavina appendiculata</i>	6.3
<i>Specaria josinae</i>	5.0
<i>Stylaria lacustris</i>	6.0
<i>Aulodrilus americanus</i>	6.7
<i>Aulodrilus limnobius</i>	6.7
<i>Aulodrilus pluriseta</i>	6.7
<i>Bothrioneurum vej dovskyanum</i>	5.3
<i>Branchiura sowerbyi</i>	8.0
<i>Ilyodrilus templetoni</i>	7.0
<i>Isochaetides curvisetosus</i>	6.0
<i>Isochaetides freyi</i>	8.0
<i>Limnodrilus cervix</i>	8.8
<i>Limnodrilus claparedianus</i>	8.0
<i>Limnodrilus hoffmeisteri</i>	9.3
<i>Limnodrilus tortilipenis</i>	8.3
<i>Limnodrilus udekemianus</i>	10.0
<i>Potamothrix hammoniensis</i>	6.0
<i>Potamothrix moldaviensis</i>	6.0
<i>Potamothrix vej dovskyi</i>	6.0
<i>Quistadrilus multisetosus</i>	8.0
<i>Rhyacodrilus falciformis</i>	5.0
<i>Rhyacodrilus</i> sp.	5.0
<i>Spirosperma carolinensis</i>	7.8
<i>Spirosperma ferox</i>	6.0
<i>Spirosperma nikolskyi</i>	7.2
<i>Tasserkidrilus kessleri</i>	8.0
<i>Tubifex tubifex</i>	9.5
<i>Tubificidae w/capilliform chaetae</i>	8.0
<i>Tubificidae w/o capilliform chaetae</i>	8.0

Appendix
(continued)

Taxa name	PTV
Acariformes	
<i>Hygrobates</i> sp.	6.0
<i>Lebertia</i> sp.	6.0
<i>Limnesia</i> sp.	6.0
<i>Limnochares</i> sp.	6.0
<i>Sperchon</i> sp.	6.0
Amphipoda	
<i>Crangonyx</i> sp.	8.1
<i>Stygonectes</i> sp.	5.0
<i>Synurella chamberlaini</i>	4.0
<i>Gammarus minus</i>	5.3
<i>Gammarus</i> sp.	5.3
<i>Stygobromus</i> sp.	6.0
<i>Hyaella azteca</i>	6.0
Decapoda	
<i>Cambarus bartonii</i>	6.0
<i>Cambarus bartonii/sciotensis</i>	6.0
<i>Cambarus cornutus</i>	6.0
<i>Cambarus/Fallicambarus</i>	6.0
<i>Orconectes limosus</i>	5.5
<i>Orconectes rusticus</i>	6.5
<i>Orconectes sanborni</i>	5.7
<i>Orconectes</i> sp.	6.0
Isopoda	
<i>Caecidotea kenki</i>	6.7
<i>Caecidotea</i> sp.	6.7
<i>Lirceus brachyurus</i>	7.3
<i>Lirceus</i> sp.	7.3
Coleoptera	
<i>Helichus basalis</i>	6.0
<i>Helichus fastigiatus</i>	6.0
<i>Agabus</i> sp.	4.7
<i>Deronectes/Oreodytes</i>	5.6
<i>Hydaticus</i> sp.	6.0
<i>Hydroporus</i> sp.	5.0
<i>Ilybius</i> sp.	5.7
<i>Laccophilus</i> sp.	5.3
<i>Liodessus</i> sp.	6.0
<i>Lioporeus</i> sp.	6.0

Appendix
(continued)

Taxa name	PTV
Coleoptera (continued)	
<i>Oreodytes</i> sp.	5.6
<i>Uvarus</i> sp.	5.3
<i>Ancyronyx variegata</i>	4.6
<i>Dubiraphia bivittata</i>	6.3
<i>Dubiraphia quadrinotata</i>	7.7
<i>Dubiraphia vittata</i>	6.7
<i>Macronychus glabratus</i>	5.7
<i>Microcylloepus</i> sp.	3.7
<i>Optioservus ampliatus</i>	3.3
<i>Optioservus fastiditus</i>	3.7
<i>Optioservus immunis</i>	3.5
<i>Optioservus ovalis</i>	3.5
<i>Optioservus trivittatus</i>	3.7
<i>Oulimnius latiusculus</i>	3.2
<i>Promoresia elegans</i>	4.0
<i>Promoresia tardella</i>	3.2
<i>Stenelmis concinna</i>	5.7
<i>Stenelmis crenata</i>	5.7
<i>Stenelmis gammoni</i>	5.7
<i>Stenelmis mera</i>	5.7
<i>Stenelmis morsei</i>	5.7
<i>Dineutus</i> sp.	6.0
<i>Gyrinus</i> sp.	5.7
<i>Peltodytes</i> sp.	6.3
<i>Helophorus</i> sp.	5.3
<i>Hydraenidae</i>	5.3
<i>Hydrochus</i> sp.	5.0
<i>Anacaena</i> sp.	5.7
<i>Berosus</i> sp.	6.3
<i>Cymbiodyta</i> sp.	4.7
<i>Enochrus</i> sp.	5.0
<i>Helocombus</i> sp.	5.3
<i>Hydrobius</i> sp.	3.7
<i>Laccobius</i> sp.	5.3
<i>Paracymus</i> sp.	5.3
<i>Sperchopsis</i> sp.	5.0
<i>Sperchopsis tessellata</i>	5.0

Appendix
(continued)

Taxa name	PTV
Coleoptera (continued)	
<i>Tropisternus</i> sp.	5.7
<i>Ectopria nervosa</i>	3.3
<i>Ectopria</i> sp.	3.3
<i>Psephenus herricki</i>	4.7
<i>Anchytarsus bicolor</i>	4.7
<i>Cyphon</i> sp.	6.0
Diptera	
<i>Atherix</i> sp.	3.7
<i>Atherix variegata</i>	3.7
<i>Blepharicera</i> sp.	4.0
<i>Blepharicera tenuipes</i>	3.5
<i>Alluaudomyia</i> sp.	6.2
<i>Atrichopogon</i> sp.	5.3
<i>Bezzia</i> gr.	6.3
<i>Ceratopogon</i> sp.	6.3
<i>Culicoides</i> sp.	7.0
<i>Dasyhelea</i> sp.	6.3
<i>Palpomyia</i> sp.	6.3
<i>Probezzia</i> sp.	6.3
<i>Stilobezzia</i> sp.	6.7
<i>Ablabesmyia janta</i>	5.7
<i>Ablabesmyia mallochi</i>	4.7
<i>Ablabesmyia monilis</i>	5.5
<i>Ablabesmyia rhamphe</i> gr.	5.7
<i>Ablabesmyia simpsoni</i>	6.0
<i>Ablabesmyia</i> sp.	5.3
<i>Antillocladius</i> sp.	5.7
<i>Apsectrotanypus johnsoni</i>	1.3
<i>Arctopelopia</i> sp.	4.0
<i>Brillia flavifrons</i>	3.3
<i>Brillia parva</i>	2.5
<i>Brillia sera</i>	2.7
<i>Brundiniella eumorpha</i>	3.7
<i>Bryophaenocladus</i> sp.	4.7
<i>Cardiocladius</i> sp.	5.6
<i>Chaetocladius piger</i> gr.	5.2
<i>Chaetocladius</i> sp.	5.2

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Chironomus</i> sp.	8.3
<i>Cladopelma laccophila</i> gr.	5.0
<i>Cladopelma</i> sp.	5.0
<i>Cladotanytarsus mancus</i> gr.	5.3
<i>Cladotanytarsus</i> sp.	5.5
<i>Cladotanytarsus vanderwulpi</i> gr.	5.5
<i>Clinotanypus pinguis</i>	5.0
<i>Conchapelopia</i> sp.	5.8
<i>Constempellina</i> sp.	4.8
<i>Corynoneura</i> sp.	6.7
<i>Cricotopus annectens</i>	6.3
<i>Cricotopus annulator</i> gr.	6.7
<i>Cricotopus bicinctus</i>	7.0
<i>Cricotopus curtus</i> gr.	6.7
<i>Cricotopus flavocinctus</i>	6.7
<i>Cricotopus fuscus</i> gr.	6.7
<i>Cricotopus intersectus</i> gr.	6.5
<i>Cricotopus laetus</i>	6.7
<i>Cricotopus</i> sp.	6.3
<i>Cricotopus sylvestris</i> gr.	5.0
<i>Cricotopus tremulus</i> gr.	6.0
<i>Cricotopus triannulatus</i> gr.	6.5
<i>Cricotopus tricinctus</i>	6.7
<i>Cricotopus trifascia</i>	6.0
<i>Cricotopus tristis</i>	6.7
<i>Cricotopus vierriensis</i>	4.8
<i>Cryptochironomus fulvus</i> gr.	6.3
<i>Cryptochironomus</i> sp.	6.0
<i>Cryptotendipes</i> sp.	5.2
<i>Demicryptochironomus</i> sp.	4.3
<i>Diamesa nivoriunda</i>	4.2
<i>Diamesa</i> sp.	3.7
<i>Diamesa spinacies</i>	4.2
<i>Dicrotendipes fumidus</i>	5.3
<i>Dicrotendipes incurvus</i>	6.7
<i>Dicrotendipes modestus</i>	4.7
<i>Dicrotendipes neomodestus</i>	7.0

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Dicrotendipes nervosus</i>	5.2
<i>Diplocladius cultriger</i>	3.7
<i>Djalmabatista pulchra</i>	5.6
<i>Djalmabatista</i> sp.	6.0
<i>Doithrix</i> sp.	3.5
<i>Doithrix villosa</i>	3.5
<i>Einfeldia natchitocheae</i>	6.7
<i>Einfeldia</i> sp.	6.7
<i>Endochironomus nigricans</i>	6.0
<i>Endochironomus subtendens</i>	6.0
<i>Epoicocladius flavens</i>	1.7
<i>Epoicocladius</i> sp.	2.7
<i>Eukiefferiella brehmi</i> gr.	4.7
<i>Eukiefferiella brevicealcar</i> gr.	5.0
<i>Eukiefferiella claripennis</i> gr.	5.0
<i>Eukiefferiella coerulescens</i> gr.	5.0
<i>Eukiefferiella cyanea</i> gr.	5.0
<i>Eukiefferiella devonica</i> gr.	5.0
<i>Eukiefferiella gracei</i> gr.	4.5
<i>Eukiefferiella pseudomontana</i> gr.	5.7
<i>Eukiefferiella rectangularis</i> gr.	4.5
<i>Euryhopsis</i> sp.	5.0
<i>Glyptotendipes</i> sp.	6.7
<i>Glyptotendipes</i> sp. A	6.7
<i>Guttipelopia guttipennis</i>	3.0
<i>Harnischia</i> sp.	6.0
<i>Hayesomyia senata</i>	4.7
<i>Heleniella</i> sp.	5.3
<i>Helopelopia</i> sp.	5.7
<i>Heterotrissocladius hirtapex</i>	4.0
<i>Heterotrissocladius marcidus</i> gr.	4.0
<i>Heterotrissocladius</i> sp.	3.7
<i>Heterotrissocladius subpilosus</i>	4.0
<i>Hydrobaenus</i> sp.	4.7
<i>Kiefferulus</i> sp.	5.3
<i>Krenopelopia</i> sp.	4.3
<i>Krenosmittia</i> sp.	5.3

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Labrundinia pilosella</i>	6.0
<i>Labrundinia</i> sp.	6.0
<i>Larsia</i> sp.	6.0
<i>Lauterborniella agrayloides</i>	4.3
<i>Limnophyes</i> sp.	5.0
<i>Lopescladius</i> sp.	5.7
<i>Macropelopia decedens</i>	5.2
<i>Meropelopia americanus</i>	5.3
<i>Meropelopia flavifrons</i>	5.7
<i>Mesocricotopus</i> sp.	4.5
<i>Mesocricotopus thienemanni</i>	4.5
<i>Mesosmittia</i> sp.	6.0
<i>Metriocnemus fuscipes</i> gr.	5.0
<i>Metriocnemus</i> sp.	5.0
<i>Microchironomus</i> sp.	5.3
<i>Micropsectra</i> sp.	5.0
<i>Micropsectra</i> sp. 1	5.0
<i>Micropsectra</i> sp. 2	5.0
<i>Microtendipes pedellus</i> gr.	5.3
<i>Microtendipes rydalensis</i> gr.	5.3
<i>Nanocladius (Plecopteracoluthus)</i>	3.5
<i>Nanocladius balticus</i> gr.	3.3
<i>Nanocladius crassicornus</i> gr.	3.8
<i>Nanocladius distinctus</i>	3.3
<i>Nanocladius downesi</i>	3.7
<i>Nanocladius parvulus</i>	3.7
<i>Nanocladius parvulus</i> gr.	3.7
<i>Nanocladius rectinervis</i>	3.3
<i>Natarsia baltimorea</i>	5.7
<i>Natarsia</i> sp. A	5.7
<i>Neozavrelia</i> sp.	5.3
<i>Nilotanypus fimbriatus</i>	5.0
<i>Nilotanypus</i> sp.	5.7
<i>Nilothauma</i> sp.	4.2
<i>Odontomesa fulva</i>	4.5
<i>Oliveridia</i> sp.	4.7
<i>Omisis</i> sp.	4.6

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Orthoclaadiinae</i> genus F	5.0
<i>Orthocladius</i> (<i>Eudactylocladius</i>) sp.	5.0
<i>Orthocladius</i> (<i>Euorthocladius</i>) sp.	5.0
<i>Orthocladius carlatus</i>	4.7
<i>Orthocladius clarkei</i>	4.3
<i>Orthocladius curtisetia</i> gr.	4.3
<i>Orthocladius dentifer</i>	4.0
<i>Orthocladius dorenius</i>	4.7
<i>Orthocladius lapponicus</i>	4.7
<i>Orthocladius</i> (<i>Symposiocladius</i>) <i>lignicola</i>	5.0
<i>Orthocladius mallochi</i>	5.0
<i>Orthocladius nigritus</i> gr.	4.0
<i>Orthocladius obumbratus</i>	5.0
<i>Orthocladius oliveri</i>	5.0
<i>Orthocladius robacki</i>	4.7
<i>Pagastia</i> sp.	1.8
<i>Pagastia</i> sp. A	1.8
<i>Pagastiella</i> sp.	4.0
<i>Paraboreochlus</i> sp.	5.3
<i>Parachaetocladius</i> sp.	4.3
<i>Parachironomus pectinatellae</i>	5.8
<i>Parachironomus</i> sp.	6.0
<i>Paracladius</i> sp.	4.3
<i>Paracladopelma camptolabis</i> gr.	5.0
<i>Paracladopelma doris</i>	5.0
<i>Paracladopelma nais</i>	5.3
<i>Paracladopelma nereis</i> gr.	6.0
<i>Paracladopelma undine</i>	5.3
<i>Paracricotopus</i> sp.	5.3
<i>Parakiefferiella</i> sp.	4.7
<i>Paralauterborniella nigrohalteralis</i>	5.3
<i>Paralimmophyes</i> sp.	8.5
<i>Paramerina anomala</i>	4.5
<i>Paramerina</i> sp.	5.0
<i>Parametriocnemus lundbecki</i>	3.3
<i>Parametriocnemus</i> sp.	3.7

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Parametriocnemus</i> sp. F	3.7
<i>Paraphaenocladus</i> sp.	4.0
<i>Parasmittia</i> sp.	4.0
<i>Paratanytarsus</i> sp.	5.0
<i>Paratendipes albimanus</i>	4.0
<i>Paratendipes</i> sp.	4.4
<i>Paratendipes subaequalis</i> gr.	4.8
<i>Paratrachocladus</i> sp.	6.0
<i>Pentaneura</i> sp.	6.0
<i>Phaenopsectra dyari</i>	5.0
<i>Phaenopsectra obediens</i> gr.	4.7
<i>Phaenopsectra punctipes</i> gr.	5.0
<i>Polypedilum angulum</i>	5.8
<i>Polypedilum aviceps</i>	5.3
<i>Polypedilum convictum</i> gr.	6.2
<i>Polypedilum fallax</i>	6.3
<i>Polypedilum halterale</i> gr.	5.3
<i>Polypedilum illinoense</i> gr.	6.3
<i>Polypedilum laetum</i>	4.3
<i>Polypedilum obtusum</i>	6.0
<i>Polypedilum ophioides</i>	5.7
<i>Polypedilum scalaenum</i> gr.	5.7
<i>Polypedilum simulans</i> gr.	5.7
<i>Polypedilum</i> sp. A	5.8
<i>Polypedilum</i> sp. C	5.8
<i>Polypedilum trigonus</i>	6.0
<i>Polypedilum tritum</i>	5.7
<i>Potthastia gaedii</i> gr.	4.7
<i>Potthastia longimana</i> gr.	4.7
<i>Procladius (Psilotanypus) bellus</i>	6.7
<i>Procladius</i> sp.	6.3
<i>Prodiamesa olivacea</i>	4.3
<i>Propsilocerus</i> sp.	4.7
<i>Psectrocladius (Mesopsectrocladius)</i>	5.7
<i>Psectrocladius limbatellus</i>	5.7
<i>Psectrocladius psilopterus</i> gr.	4.8
<i>Psectrocladius</i> sp.	5.7

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Psectrotanypus discolor</i>	6.0
<i>Psectrotanypus dyari</i>	6.3
<i>Pseudochironomus articaudus</i>	4.5
<i>Pseudochironomus fulviventris</i>	3.7
<i>Pseudochironomus</i> sp.	4.3
<i>Pseudodiamesa</i> sp.	3.3
<i>Pseudorthocladus</i> sp.	5.7
<i>Pseudosmittia</i> sp.	3.0
<i>Psilometriocnemus</i> sp.	5.3
<i>Rheocricotopus cf. atripes</i>	5.0
<i>Rheocricotopus eminellobus</i>	6.0
<i>Rheocricotopus fuscipes</i> gr.	5.5
<i>Rheocricotopus glabricollis</i>	5.0
<i>Rheocricotopus pauciseta</i>	5.0
<i>Rheocricotopus robacki</i>	4.7
<i>Rheocricotopus tuberculatus</i>	5.3
<i>Rheopelopia</i> sp.	5.3
<i>Rheosmittia</i> sp.	5.3
<i>Rheotanytarsus distinctissimus</i> gr.	4.7
<i>Rheotanytarsus exiguus</i> gr.	4.5
<i>Rheotanytarsus</i> sp.	4.0
<i>Robackia demeijerei</i>	4.7
<i>Robackia</i> sp.	4.3
<i>Saetheria</i> sp.	4.0
<i>Saetheria tylus</i> gr.	4.3
<i>Smittia</i> sp.	5.6
<i>Stempellina bausei</i> gr.	3.3
<i>Stempellina johannseni</i> gr.	3.7
<i>Stempellina</i> sp.	3.3
<i>Stempellinella</i> sp.	4.7
<i>Stenochironomus</i> sp.	4.0
<i>Stictochironomus annulicris</i>	4.3
<i>Stictochironomus devinctus</i>	4.3
<i>Stictochironomus flavicingula</i>	4.3
<i>Stictochironomus marmoreus</i>	5.3
<i>Stictochironomus</i> sp.	4.7
<i>Stilocladius clinopecten</i>	5.0

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Sublettea coffmani</i>	2.0
<i>Sympotthastia</i> sp.	4.7
<i>Syndiamesa</i> sp.	5.3
<i>Synorthocladus</i> sp.	5.3
<i>Tanypus carinatus</i>	4.3
<i>Tanypus punctipennis</i>	4.7
<i>Tanypus</i> sp.	5.0
<i>Tanytarsus curticornis</i> gr.	5.7
<i>Tanytarsus glabrescens</i>	6.7
<i>Tanytarsus guerlus</i> gr.	6.3
<i>Tanytarsus</i> sp. 1	6.0
<i>Tanytarsus</i> sp. 2	6.0
<i>Tanytarsus</i> sp. 3	6.0
<i>Tanytarsus</i> sp. 4	6.0
<i>Tanytarsus</i> sp. 5	6.0
<i>Tanytarsus</i> sp. 6	6.0
<i>Tanytarsus</i> sp. 7	6.0
<i>Tanytarsus</i> sp. 8	6.0
<i>Tanytarsus</i> sp. 9	6.0
<i>Tanytarsus</i> sp. 10	6.0
<i>Tanytarsus</i> sp. 11	6.0
<i>Tanytarsus</i> sp. 12	6.0
<i>Tanytarsus</i> sp. 13	6.0
<i>Telopelopia</i> sp.	5.2
<i>Thienemannia</i> sp.	5.7
<i>Thienemanniella</i> sp.	5.3
<i>Thienemanniella xena</i>	5.5
<i>Thienemannimyia</i> gr.	5.2
<i>Thienemannimyia</i> sp.	5.2
<i>Tribelos fuscicorne</i>	5.2
<i>Tribelos jucundum</i>	4.3
<i>Tribelos</i> sp.	4.8
<i>Trissopelopia ogemawi</i>	3.7
<i>Tvetenia bavarica</i> gr.	5.8
<i>Tvetenia discoloripes</i> gr.	5.7
<i>Unniella multivirga</i>	1.2
<i>Xenochironomus</i> sp.	4.0

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Xylotopus par</i>	6.0
<i>Zavrelia</i> sp.	5.0
<i>Zavrelimyia</i> sp.	5.0
<i>Aedes</i> sp.	6.7
<i>Anopheles</i> sp.	6.7
<i>Dixa</i> sp.	6.0
<i>Dixella</i> sp.	6.0
<i>Dolichopodidae</i>	5.3
<i>Chelifera</i> sp.	6.3
<i>Clinocera</i> sp.	6.0
<i>Hemerodromia</i> sp.	6.3
<i>Oreogeton</i> sp.	6.5
<i>Ephydridae</i>	5.6
<i>Limnophora</i> sp.	5.0
<i>Pericoma</i> sp.	6.7
<i>Psychoda</i> sp.	8.7
<i>Bittacomorpha</i> sp.	5.3
<i>Ptychoptera</i> sp.	5.0
<i>Scathophagidae</i>	6.0
<i>Cnephia</i> sp.	3.3
<i>Prosimulium rhizophorum</i>	5.0
<i>Prosimulium</i> sp.	5.3
<i>Simulium decorum</i>	5.6
<i>Simulium quebecense</i>	5.0
<i>Simulium</i> sp.	5.6
<i>Simulium tuberosum complex</i>	4.7
<i>Simulium venustum/verecundum complex</i>	4.5
<i>Simulium vittatum</i>	6.0
<i>Stegopterna mutata</i>	3.3
<i>Stegopterna</i> sp.	3.3
<i>Twinnia tibblesi</i>	3.5
<i>Caloparyphus</i> sp.	6.2
<i>Euparyphus</i> sp.	6.7
<i>Myxosargus</i> sp.	6.2
<i>Nemotelus</i> sp.	6.2
<i>Odontomyia</i> sp.	6.0
<i>Chrysops</i> sp.	6.0

Appendix
(continued)

Taxa name	PTV
Diptera (continued)	
<i>Hybomitra</i> sp.	6.7
<i>Tabanus</i> sp.	6.7
<i>Protoplasa fitchii</i>	4.3
<i>Antocha</i> sp.	3.7
<i>Cryptolabis</i> sp.	4.0
<i>Dactylolabis</i> sp.	4.0
<i>Dicranota</i> sp.	4.8
<i>Erioptera</i> sp.	3.3
<i>Gonomyia</i> sp.	5.6
<i>Helius</i> sp.	4.7
<i>Hexatoma</i> sp.	5.3
<i>Limnophila</i> sp.	4.3
<i>Limonia</i> sp.	4.7
<i>Lipsothrix</i> sp.	4.3
<i>Molophilus</i> sp.	5.3
<i>Ormosia</i> sp.	5.3
<i>Paradelphomyia</i> sp.	4.3
<i>Pedicia</i> sp.	4.3
<i>Pilaria</i> sp.	4.3
<i>Polymera</i> sp.	5.8
<i>Prionocera</i> sp.	5.7
<i>Pseudolimnophila</i> sp.	3.3
<i>Rhabdomastix</i> sp.	3.3
<i>Tipula</i> sp.	5.7
Ephemeroptera	
<i>Ameletus</i> sp.	3.7
<i>Acentrella ampla</i>	3.3
<i>Acentrella insignificans</i>	2.7
<i>Acentrella</i> sp.	3.3
<i>Acerpenna macdunnoughi</i>	3.5
<i>Baetis brunneicolor</i>	2.7
<i>Baetis flavistriga</i>	2.7
<i>Baetis intercalaris</i>	2.7
<i>Baetis tricaudatus</i> gr.	2.7
<i>Callibaetis</i> sp.	4.0
<i>Centroptilum</i> sp.	2.5
<i>Cloeon</i> sp.	2.8
<i>Baetisca carolina</i>	3.4

Appendix
(continued)

Taxa name	PTV
Ephemeroptera (continued)	
<i>Baetisca gibbera</i>	2.2
<i>Baetisca</i> sp.	3.8
<i>Brachycercus</i> sp.	4.3
<i>Caenis anceps</i>	2.2
<i>Caenis diminuta</i>	3.8
<i>Caenis latipennis</i>	2.7
<i>Caenis tardata</i>	3.3
<i>Attenella</i> sp.	3.0
<i>Drunella cornuta</i>	3.0
<i>Drunella cornutella</i>	3.0
<i>Drunella lata</i>	2.7
<i>Drunella tuberculata</i>	2.7
<i>Drunella walkeri</i>	2.7
<i>Ephemerella aurivillii</i>	2.7
<i>Ephemerella catawba</i>	3.3
<i>Ephemerella coxalis</i>	2.7
<i>Ephemerella dorothea</i>	3.0
<i>Ephemerella excrucians</i>	3.0
<i>Ephemerella inconstans</i>	3.0
<i>Ephemerella invaria</i>	3.0
<i>Ephemerella needhami</i>	2.7
<i>Ephemerella rossi</i>	2.0
<i>Ephemerella rotunda</i>	2.7
<i>Ephemerella septentrional</i>	3.0
<i>Ephemerella simila</i>	2.7
<i>Ephemerella subvaria</i>	2.7
<i>Eurylophella aestiva</i>	3.3
<i>Eurylophella bicolor</i>	3.2
<i>Eurylophella bicoloroides</i>	3.2
<i>Eurylophella doris</i>	3.3
<i>Eurylophella funeralis</i>	3.3
<i>Eurylophella macdunnoughi</i>	3.3
<i>Eurylophella minimella</i>	3.7
<i>Eurylophella temporalis</i>	3.7
<i>Eurylophella verisimilis</i>	3.3
<i>Serratella deficiens</i>	3.0
<i>Serratella serrata</i>	3.7

Appendix
(continued)

Taxa name	PTV
Ephemeroptera (continued)	
<i>Timpanoga lita</i>	3.3
<i>Timpanoga simplex</i>	3.3
<i>Ephemera blanda</i>	2.0
<i>Ephemera guttulata</i>	2.3
<i>Ephemera simulans</i>	1.7
<i>Ephemera varia</i>	1.8
<i>Hexagenia atrocaudata</i>	3.8
<i>Hexagenia limbata</i>	4.5
<i>Hexagenia</i> sp.	5.7
<i>Litobrancha recurvata</i>	4.7
<i>Cinygmula</i> sp.	2.2
<i>Epeorus</i> sp.	3.7
<i>Heptagenia</i> sp.	4.3
<i>Leucrocuta</i> sp.	3.0
<i>Rhithrogena</i> sp.	3.7
<i>Stenacron interpunctatum</i>	5.0
<i>Stenacron pallidum</i>	4.3
<i>Stenonema carlsoni</i>	4.0
<i>Stenonema femoratum</i>	5.0
<i>Stenonema integrum</i>	5.0
<i>Stenonema ithaca</i>	3.3
<i>Stenonema luteum</i>	3.3
<i>Stenonema mediopunctatum</i>	4.2
<i>Stenonema meririvulanum</i>	2.7
<i>Stenonema modestum</i>	3.8
<i>Stenonema pudicum</i>	3.7
<i>Stenonema pulchellum</i>	4.3
<i>Stenonema rubromaculatum</i>	3.3
<i>Stenonema rubrum</i>	4.3
<i>Stenonema sinclairi</i>	3.5
<i>Stenonema terminatum</i>	4.7
<i>Stenonema tripunctatum</i>	5.3
<i>Stenonema vicarium</i>	4.0
<i>Isonychia</i> sp.	2.2
<i>Choroterpes</i> sp.	2.7
<i>Habrophlebia vibrans</i>	2.0
<i>Habrophlebiodes</i> sp.	4.0

Appendix
(continued)

Taxa name	PTV
Ephemeroptera (continued)	
<i>Leptophlebia</i> sp.	3.7
<i>Paraleptophlebia</i> sp.	2.7
<i>Ephoron leukon</i>	2.3
<i>Anthopotamus myops</i>	3.2
<i>Anthopotamus</i> sp.	4.0
<i>Siphonurus</i> sp.	3.7
<i>Leptohyphes</i> sp.	2.7
<i>Tricorythodes</i> sp.	2.8
Hemiptera	
<i>Corisella</i> sp.	6.3
<i>Dasycorixa</i> sp.	7.0
<i>Hesperocorixa</i> sp.	9.0
<i>Palmacorixa</i> sp.	6.7
<i>Sigara</i> sp.	6.7
<i>Gerris</i> sp.	8.0
<i>Limnopus</i> sp.	7.7
<i>Trepobates</i> sp.	6.7
<i>Notonectidae</i>	7.0
<i>Saldidae</i>	8.3
<i>Microvelia</i> sp.	7.3
<i>Rhagovelia</i> sp.	7.3
Lepidoptera	
<i>Parapoynx</i> sp.	3.7
<i>Petrophila</i> sp.	3.7
Megaloptera	
<i>Corydalus cornutus</i>	5.8
<i>Nigronia fasciatus</i>	3.0
<i>Nigronia serricornis</i>	3.7
<i>Sialis</i> sp.	7.0
Odonata	
<i>Aeshna</i> sp.	5.7
<i>Boyeria grafiana</i>	6.0
<i>Boyeria vinosa</i>	6.0
<i>Calopteryx maculata</i>	4.8
<i>Calopteryx</i> sp.	4.7
<i>Argia</i> sp.	5.0
<i>Enallagma</i> sp.	7.9

Appendix
(continued)

Taxa name	PTV
Odonata (continued)	
<i>Cordulegaster diastops</i>	4.0
<i>Cordulegaster erroneus</i>	5.0
<i>Cordulegaster maculata</i>	4.7
<i>Cordulegaster obliqua</i>	4.0
<i>Didymops transversa</i>	4.7
<i>Helocordulia</i> sp.	6.0
<i>Neurocordulia</i> sp.	5.0
<i>Somatochlora</i> sp.	4.3
<i>Arigomphus lentulus/pallidus</i>	5.0
<i>Arigomphus</i> sp.	5.0
<i>Dromogomphus</i> sp.	4.3
<i>Dromogomphus spinosus</i>	4.3
<i>Erpetogomphus</i> sp.	4.7
<i>Gomphus descriptus</i>	5.3
<i>Gomphus exilis</i>	5.3
<i>Hagenius brevistylus</i>	4.0
<i>Lanthus parvulus</i>	5.2
<i>Lanthus</i> sp.	3.3
<i>Ophiogomphus mainensis</i>	4.0
<i>Ophiogomphus</i> sp.	3.7
<i>Progomphus</i> sp.	4.3
<i>Stylogomphus albistylus</i>	3.3
<i>Stylurus</i> sp.	4.7
<i>Erythemis</i> sp.	6.3
<i>Pachydiplax longipennis</i>	6.0
<i>Perithemis</i> sp.	5.7
<i>Macromia</i> sp.	5.0
Plecoptera	
<i>Allocapnia</i> sp.	1.3
<i>Capnia</i> sp.	1.7
<i>Nemocapnia</i> sp.	1.7
<i>Alloperla</i> sp.	1.0
<i>Alloperla/Paraperla</i>	1.3
<i>Haploperla brevis</i>	1.7
<i>Haploperla</i> sp.	1.7
<i>Rasvena</i> sp.	0.7
<i>Suwallia marginata</i>	1.0

Appendix
(continued)

Taxa name	PTV
Plecoptera (continued)	
<i>Sweltsa</i> sp.	2.0
<i>Utaperla</i> sp.	2.0
<i>Leuctra</i> sp.	2.3
<i>Paraleuctra</i> sp.	3.3
<i>Zealeuctra</i> sp.	3.3
<i>Amphinemura delosa</i>	4.7
<i>Amphinemura</i> sp.	4.7
<i>Nemoura</i> sp.	3.7
<i>Ostrocerca</i> sp.	3.3
<i>Paranemoura</i> sp.	3.3
<i>Soyedina</i> sp.	3.0
<i>Zapada</i> sp.	3.3
<i>Peltoperla</i> sp.	2.8
<i>Tallaperla</i> sp.	1.0
<i>Viehoplerlaada</i>	2.7
<i>Acroneuria abnormis</i>	3.5
<i>Acroneuria carolinensis</i>	2.3
<i>Acroneuria</i> sp.	2.7
<i>Aagnetina</i> sp.	1.7
<i>Attaneuria</i> sp.	2.7
<i>Eccoptura xanthenes</i>	3.3
<i>Hansonoperla appalachia</i>	2.5
<i>Hesperoperla</i> sp.	3.0
<i>Neoperla</i> sp.	3.3
<i>Paragnetina</i> sp.	2.7
<i>Perlesta</i> sp.	3.7
<i>Perlinella</i> sp.	3.0
<i>Clioperla clio</i>	2.0
<i>Cultus decisis</i>	2.8
<i>Diploperla</i> sp.	2.3
<i>Diura</i> sp.	0.5
<i>Isoperla bilineata</i>	2.8
<i>Isoperla lata</i>	3.0
<i>Isoperla nana</i>	3.0
<i>Malirekus hastatus</i>	2.7
<i>Malirekus iroquois</i>	2.7

Appendix
(continued)

Taxa name	PTV
Plecoptera (continued)	
<i>Remenus bilobatus</i>	2.3
<i>Yugus bulbosus</i>	3.0
<i>Yugus</i> sp.	3.0
<i>Pteronarcys</i> sp.	4.3
<i>Bolotoperla</i> sp.	3.0
<i>Taeniopteryx</i> sp.	3.0
Trichoptera	
<i>Brachycentrus appalachia</i>	4.5
<i>Brachycentrus</i> sp.	4.5
<i>Micrasema</i> sp.	3.7
<i>Anisocentropus pyraloides</i>	2.0
<i>Phylocentropus</i> sp.	3.4
<i>Agapetus</i> sp.	3.0
<i>Culoptila</i> sp.	3.7
<i>Glossosoma</i> sp.	3.3
<i>Matrioptila jeanae</i>	2.3
<i>Goera</i> sp.	1.0
<i>Goerita</i> sp.	2.7
<i>Helicopsyche borealis</i>	3.0
<i>Cheumatopsyche</i> sp.	5.5
<i>Diplectrona modesta</i>	3.7
<i>Diplectrona</i> sp.	3.7
<i>Hydropsyche betteni</i> gr.	5.7
<i>Hydropsyche carolina</i>	4.3
<i>Hydropsyche depravata</i>	4.3
<i>Hydropsyche dicantha/scalaris</i>	3.7
<i>Hydropsyche scalaris</i> gr.	4.3
<i>Parapsyche apicalis</i>	3.3
<i>Parapsyche flavida</i>	3.3
<i>Parapsyche</i> sp.	3.3
<i>Symphitopsyche alhedra</i>	1.7
<i>Symphitopsyche bronta</i> gr.	6.0
<i>Symphitopsyche cheilonis</i>	4.3
<i>Symphitopsyche etnieri</i>	3.0
<i>Symphitopsyche morosa</i>	4.3
<i>Symphitopsyche slossonae</i>	3.7
<i>Symphitopsyche sparna</i>	4.7

Appendix
(continued)

Taxa name	PTV
Trichoptera (continued)	
<i>Symphitopsyche ventura</i>	3.7
<i>Symphitopsyche walkeri</i>	3.8
<i>Dibusa</i> sp.	4.7
<i>Hydroptila</i> sp.	4.7
<i>Leucotrichia</i> sp.	3.3
<i>Neotrichia</i> sp.	5.3
<i>Ochrotrichia</i> sp.	5.0
<i>Palaeagapetus celsus</i>	2.7
<i>Stactobiella</i> sp.	2.8
<i>Lepidostoma</i> sp.	3.0
<i>Ceraclea</i> sp.	4.0
<i>Mystacides</i> sp.	4.0
<i>Nectopsyche</i> sp.	4.4
<i>Oecetis</i> sp.	4.3
<i>Setodes</i> sp.	3.7
<i>Triaenodes</i> sp.	4.5
<i>Anabolia</i> sp.	3.7
<i>Apatania</i> sp.	2.3
<i>Frenesia</i> sp.	3.3
<i>Hesperophylax</i> sp.	3.7
<i>Hydatophylax argus</i>	3.7
<i>Ironoquia</i> sp.	4.3
<i>Limnephilus</i> sp.	3.7
<i>Onocosmoecus</i> sp.	3.3
<i>Pseudostenophylax</i> sp.	2.0
<i>Pycnopsyche</i> sp.	4.7
<i>Molanna blenda</i>	3.0
<i>Molanna</i> sp.	3.0
<i>Molanna tryphena</i>	3.0
<i>Psilotreta labida</i>	1.0
<i>Psilotreta</i> sp.	1.0
<i>Chimarra</i> sp.	4.0
<i>Dolophilodes</i> sp.	3.3
<i>Wormaldia</i> sp.	1.3
<i>Oligostomis</i> sp.	4.0
<i>Cernotina</i> sp.	4.3
<i>Cyrnellus fraternus</i>	4.0

Appendix
(continued)

Taxa name	PTV
Trichoptera (continued)	
<i>Neureclipsis crepuscularis</i>	5.3
<i>Neureclipsis</i> sp.	5.3
<i>Nyctiophylax</i> sp.	3.7
<i>Polycentropus</i> sp.	4.7
<i>Lype diversa</i>	3.3
<i>Psychomyia flavida</i>	2.3
<i>Psychomyia</i> sp.	2.3
<i>Rhyacophila carolina</i> gr.	4.3
<i>Rhyacophila fuscata</i> gr.	3.3
<i>Agarodes</i> sp.	2.7
<i>Fattigia</i> sp.	3.0
<i>Neophylax</i> sp.	3.3
Gastropoda	
<i>Ferrissia rivularis</i>	5.0
<i>Rhodacmea hinkleyi</i>	4.0
<i>Fossaria</i> sp.	4.5
<i>Physa</i> sp.	7.3
<i>Physella</i> sp.	7.3
<i>Gyraulus circumstriatus</i>	7.5
<i>Gyraulus parvus</i>	7.0
<i>Helisoma</i> sp.	4.7
<i>Micromenetus dilatatus</i>	4.7
<i>Planorbula</i> sp.	6.8
<i>Promenetus umbilicatellus</i>	7.5
<i>Somatogyrus</i> sp.	5.0
<i>Elimia</i> sp.	3.3
<i>Leptoxis carinata</i>	2.8
<i>Leptoxis praerosa</i>	2.8
<i>Leptoxis</i> sp.	2.8
<i>Lithasia</i> sp.	6.0
<i>Mudalia</i> sp.	3.0
<i>Pleurocera</i> sp.	5.0
<i>Pomatiopsis</i> sp.	6.0
<i>Valvata</i> sp.	4.5
<i>Campeloma decisum</i>	5.7

Appendix*(continued)*

Taxa name	PTV
Pelecypoda	
<i>Lampsilis radiata</i>	5.0
<i>Corbicula fluminea</i>	6.3
<i>Musculium partumeium</i>	8.0
<i>Musculium</i> sp.	7.5
<i>Pisidium</i> sp.	8.0
<i>Sphaerium rhomboideum</i>	7.0
<i>Sphaerium simile</i>	8.0
<i>Sphaerium</i> sp.	8.0
<i>Sphaerium striatinum</i>	7.6
<i>Sphaerium transversum</i>	8.0
Nematoda	6.0
Hoplonemertea	
<i>Prostoma graecense</i>	6.3
Turbellaria	6.0
Tricladia	
<i>Phagocata morgani</i>	5.0

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