FINAL REPORT

Studies of Benthic Macroinvertebrates and Fish in Streams Within EPA Region 3 for Development of Biological Indicators of Ecological Condition

Part I
Benthic Macroinvertebrates

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INTRODUCTION

This report is submitted in accordance with the terms of Cooperative Agreement CF821462010, as modified August 1994. The major objectives of the modified cooperative agreement were to:

1) develop and evaluate individual metrics and multimetric indices for biological condition in the Mid-Appalachian Highlands;

2) develop a computer database of applicable historical data;

3) analyze how well the ecoregions and subregions proposed by biogeography group at EPA Corvallis Laboratory predict the community structure of benthic macroinvertebrates and fish in the study area within EPA Region 3.

The three objectives are strongly interrelated. Objectives 2 and 3 were necessary steps for the successful completion of Objective 1. Hence, the objectives will not be addressed individually. This report is framed around Objective 1, and it will be readily apparent where Objectives 2 and 3 fit into this framework. This document is Part I of the overall final report for the project and covers the benthic macroinvertebrate portion. Part II on fish will be submitted as a separate document.

BACKGROUND

A major goal of water quality legislation has been the maintenance of biological integrity in water ecosystems (Water Pollution Control Act, 1972 amendments, PL 92-500). Ecosystems that display biological integrity are capable of withstanding and recovering from most natural disturbances (Cairns 1975) and many types of human interference. Biological communities differ among ecosystems and regions, so the human influences that might adversely affect the maintenance of biological integrity are likely to vary regionally.

Biological monitoring (usually abbreviated as "biomonitoring") consists of taking field measurements of natural communities to determine if their success is being impaired by pollution or other human activities. Biomonitoring can be used in combination with water quality and habitat analyses to determine the cause of impairment and to follow recovery after corrective action has been taken. The advantages of monitoring biological communities are: they reflect overall ecological integrity (i.e., physical, chemical and biological), they provide a holistic measure of environmental condition by integrating stresses over time, and the public better understands them as measures of a "healthy" environment (Plafkin et al. 1989). Benthic macroinvertebrates and fish are the two communities used most often for biomonitoring, and both have unique characteristics that make them useful for this purpose. A dependable, comprehensive biomonitoring program will include both components.

The U. S. Environmental Protection Agency (EPA) has provided guidelines for biomonitoring with benthic macroinvertebrates and fish (Plafkin et al. 1989). The EPA protocols for using benthic macroinvertebrates are commonly referred to as "rapid bioassessment," and the protocols for similar biomonitoring with fish are usually called "IBI," which is an abbreviation for Index of Biotic Integrity. Although the macroinvertebrate and fish protocols have different names, they share a common purpose; both were developed to provide cost-effective approaches for determining the biological condition of flowing waters by a combination of water quality, habitat, and biological measures.

The Index of Biotic Integrity (IBI) was initially developed for streams in Illinois, where it was shown to be sensitive to water quality and habitat degradation (Karr 1981, Karr et al. 1986). Research in numerous regions of North America, including West Virginia (Leonard and Orth 1986), has demonstrated the broad applicability of the IBI as a biomonitoring tool (Fausch et al. 1984, Hughes and Gammon 1987, Miller et al. 1988, Steedman 1988). Success of the IBI approach stems, in part, from the integration of information from individual, population, and community levels of biological organization. Many states use the IBI regularly in biomonitoring programs because it synthesizes complex biological information into a simple numerical form that can be easily communicated to policy makers and the public. Analogous approaches to biological assessment are being developed for estuaries of Chesapeake Bay and for reservoir waters.

Rapid bioassessment with benthic macroinvertebrates has also been documented to be successful for determining biological condition (see recent reviews by Resh and Jackson 1992, Lenat and Barbour 1994, Barbour et al. 1995). In Ohio, the state EPA developed the Invertebrate Condition Index (ICI) based upon an extensive survey of surface waters in the state, and this multimetric index is now used routinely to enforce environmental regulations (Ohio EPA 1987, DeShon 1995, Yoder and Rankin 1995). The status of using biological criteria based on multimetric indices in the U.S. has been reviewed by Southerland and Stribling (1995). More recently, Barbour et al. (1996) used their research in Florida as a basis for proposing a general framework for developing macroinvertebrate multimetric indices to be used as biological criteria.

An essential component of IBI and rapid bioassessment approaches is knowledge of regional distribution patterns. Geographic patterns of similarity among ecosystems can be grouped into ecoregions (Omernik 1987, 1995). Natural biotic assemblages are expected to differ among ecoregions but to be relatively similar within a given ecoregion. Therefore, regulatory agencies can use relatively few regional reference sites to characterize the attainable biological condition for an entire region (Hughes 1995, Hughes et al. 1986,). Because ecoregions and their linked biological conditions transcend state jurisdictional boundaries, assistance in developing the data base for reference stream conditions and proposed measures of biological integrity will obviate potential duplication of effort among states.

In EPA Region 3, ecoregions and subregions have been mapped for the Mid-Appalachian Highlands area, but macroinvertebrates and fish have not been studied throughout the ecoregions to know the range of expected values for IBI and rapid bioassessment types of metrics and

indices. The Mid-Appalachian Highlands area is of special interest because of evidence of stream acidification from atmospheric deposition.

DEVELOPMENT OF INDIVIDUAL METRICS AND MULTIMETRIC INDICES

We generally followed the stepwise framework suggested by Barbour et al. (1995) and Barbour et al. (1996). The procedures that we used and the results we obtained are presented according to six sequential steps that we performed. We used some different procedures from the previous work within Steps 3-6 to analyze the data and develop a multimetric index with criteria for biological condition.

Step 1: Stream Classification

This step involves determining the regional extent over which a particular biological attribute is applicable. Omernik (1987) proposed ecoregions and subregions for this purpose, and those are what we used for our initial stream classification. Other arrangements of ecoregions and subregions were considered as part of Step 3 (see below). For our analyses, we used the most recent revisions of ecoregion maps for the Mid-Atlantic Highlands, which were kindly provided by J. M. Omernik from USEPA - Corvallis. The ecoregions and subregions considered in our studies are listed in Table 1.

Table 1 - Ecoregions and subregions

Step 2: Data Acquisition

This step usually involves conducting biological surveys of minimally impaired (reference) sites. It is best to supplement the data with habitat and water quality data. Sampling a gradient of conditions permits metric calibration and discrimination. It is essential that methods be standardized.

When this project was modified in 1994, it was decided that we would not wait for data from the ongoing biological surveys being conducted as part of the EMAP program. Instead we were to proceed with developing a comprehensive historical database on benthic macroinvertebrates in wadeable streams within the Mid-Atlantic Highlands. We requested data from personnel in the water quality agencies in Maryland, Pennsylvania, Virginia and West Virginia and received excellent cooperation. Because of our involvement in developing a biomonitoring program for the George Washington and Thomas Jefferson National Forests, we were also given access to considerable data for streams in western Virginia from the U. S. Forest

Service. Lastly, we had original data from many streams in western Virginia that were obtained by Shane Evans for his doctoral dissertation. These sources are summarized Table 2.

Several agencies provided us with ecoregion/subregion designation for each site. Other agencies supplied map coordinates for each site, which we used to determine ecoregion and subregion from maps. With the help of persons in the various agencies, we were also able to assign a biological condition to each site (reference, impacted, or unknown). This information is summarized for ecoregions and subregions in Table 3.

Tables 2 and 3 - Data sources and number of samples by ecoregions, subregions

Because the data were obtained from different sources, we had to resolve important differences in seasons, habitats, sampling methods, subsampling, and taxonomic level. To reduce the seasonal variation inherent in benthic macroinvertebrate samples, we only included samples collected between June and early October. Some of the sites were sampled in more than one year, and we included those data as separate samples. Thus, a sample is defined as a collection at one site on one date. We restricted all data to those obtained from riffle areas of wadeable streams. Sampling methods were restricted to open net devices, such as a D-frame dip net or a kick screen, used on natural substratum. There were differences in subsampling, but we did not exclude any data for that reason because we did not plan to consider any metrics based on absolute abundance. All data from the U.S. Forest Service and our original data from Virginia were derived from 200-organism subsamples. Data from state agencies, except West Virginia, were derived from 100-organism subsamples. Samples from West Virginia were not subsampled, but sample sizes were standardized to desired levels by sampling approximately 1 square meter for 60 seconds. For much of the data, organisms were identified only to the family level. Therefore, when organisms had been identified to genus or species levels, we compressed the data to the family level to make the database consistent.

All data were initially entered into the Excel spreadsheet program. Samples were coded according to source, ecoregion, subecoregion, and biological condition. The biological condition categories were reference (minimally disturbed), impacted, and unknown. These designations were provided by the state regional biologists who provided the data. They were asked to base their categorization on their knowledge of physical and chemical perturbations at the sites, not on the benthic macroinvertebrate data. A list of all sampling sites is included as Appendix A.

The original benthic macroinvertebrate data in each sample included taxonomic names and counts of each organism. Taxonomic names were coded with a hierarchical phylogenetic system developed in the Aquatic Entomology Program at Virginia Tech. Three types of ecological information was entered for each taxon: functional feeding group, habit, and pollution tolerance. Merritt and Cummins (1996) was used primarily as the reference for classifying taxa according to functional feeding group and habit, with some modifications based on our research experience in the Mid-Atlantic Highlands. In the case of habit, we created one new category, crawlers, to be

able to explain adequately the ecological relationships between behavior and habitat requirements. We defined crawlers as those organisms that move about regularly, but slowly, on or within spaces in solid substrata that is relatively clean. Most stoneflies and some mayflies, such as Ephemerellidae, are good examples of organisms with this habit. In Merritt and Cummins (1996) these types of organisms are variously categorized as either clingers or sprawlers, neither of which accurately depicts their movements or habitat preferences. The numerical pollution tolerance values ranging from 0 (most intolerant) to 10 (most tolerant) were based on the work of Hilsenhoff in Wisconsin, with modifications for this area based on our research and that of state regional biologists in Virginia.

Step 3: Part A, Data Evaluation and Part B, Metric Calibration

Data evaluation and metric calibration are distinctly different activities, and could be considered as different steps; however, we adhered to the framework described by Barbour et al. (1995) and Barbour et al. (1996). We distinguished these activities as Parts A and B, respectively. Part A, data evaluation, involves evaluating possible metrics and choosing a subset of the best ones. "Best" metrics are those that have low variability within reference conditions, but exhibit distinguishable, predictable changes when a stream is impaired. Part B, metric calibration, involves determining if individual metrics for reference conditions are distinctly different among stream classes. If they are not different, stream classes are not necessary or some classes can be combined.

Part A, Data Evaluation

We worked through a selection process that began with 69 metrics from various published sources, potential transformation of metrics, and our professional expertise and eventually wound up with a set of 10 candidate metrics. A complete list of all metrics that we considered is given in Table 4. There were several types of analyses including univariate and multivariate methods, and criteria that were considered together. Descriptions of the multivariate methods are given following the Literature Cited section. The first step was to summarize and graph the full set of data in several ways (Appendix B). The graphical displays include boxplots of both the impact and reference sites on the same display and two types of probability plots. The empirical probability plot is a display of the cumulative distribution of the data. This is the plot of $p_i = (i-0.5)/n$ versus the ith ordered observation. This plot allows comparison of the medians of impact versus reference (comparing the values for $p=0.5$) as well as the general separation between the sites. The other plot is a normal probability plot, which is a plot of the ranked data versus normal quantiles. This plot is useful for evaluating if a metric is normally distributed in reference or impact sites. Straight lines indicate normality. Graphs for all metrics are presented in the Appendix B.

Table 4 - Metric list and explanations

Summary statistics are presented in Tables 5 and 6. Summary statistics include the common mean, median, standard deviation, and coefficient of variation, as well as measures of separation and robust measures. A robust measure of variation is the pseudo-standard deviation which is 1.35*(IQR) where IQR is the interquartile range. The robust coefficient of variation is the pseudo-standard deviation divided by the median. The separation statistic is the difference between the reference and impact means divided by the pooled standard deviation. A value of 1 indicates that the reference mean is 1 standard deviation from the impact mean. The robust separation statistic uses the median and robust measure of pooled standard deviation. The Tables 5 and 6 contain the same information, sorted in different manner. We emphasized those metrics for which the robust coefficient of variation among reference sites was less than 50% and the separation statistic between reference and impacted sites had separation values greater than +1 or less than -1.

Tables 5 and 6 - Summary statistics, sorted by robust CV and mean separation

Another analytical approach was based on the use of stepwise discriminant analysis to eliminate redundancy among metrics. Stepwise discriminant analysis is similar to stepwise regression analysis. The goal is to select a subset of metrics which provide the best separation. The process is sequential; variables are added if the separation between impact and reference is significant on that metric, given the contribution of the other metrics in the set. Variables are removed if they do not have significant separation given the others in the model. At each step the metric with the greatest (significant) separation is added to the set and the variable with the lowest (non-significant) separation is removed, if possible. The stepwise discriminant analysis indicates which metrics detected the greatest difference between reference and impacted sites and those which detected the lowest percentages of difference. Metrics with low percentages were deemed to be providing redundant information, and those were not emphasized in the selection process.

Table 7 lists the top variables that were selected in the stepwise separation process, with the process carried out separately for each ecoregion with sufficient data. Note that for all four ecoregions with sufficient data, different metrics were selected from a relatively long list of metrics involved in different ecoregions. However, there is not as much difference in the results as suggested by the tables. First, note that the F-statistics are quite large for the first metric selected then drop considerably after the first metric is accounted for. Additional metrics increase separation but not by a considerable amount. Thus, most of the information about separation is contained in EPT Index, Number of Intolerant Taxa, and Number of Mayfly Taxa. Second, there is some similarity in these metrics. For example, in Ecoregion 67, the F-statistics for separating impact and reference at step 1 are 30.9 for EPT Index, 30.7 for Number of Intolerant Taxa, and 47.9 for Number of Mayfly Taxa. Number of Mayfly Taxa is entered into the model and at step 2, the partial F (adjusted for Number of Mayfly Taxa) drops to 7.5 for EPT Index and 6.1 for Number of Intolerant Taxa. Thus, while selecting different metrics to

include, there is a degree of similarity and different subsets of metrics can be found which give roughly equivalent separation.

Table 7 - Stepwise discriminant analysis to separate impact and reference in each ecoregion.

Lastly, we maintained balanced representation of metrics among six categories that reflect diverse aspects of benthic macroinvertebrate communities and ecological conditions. This will make the final multimetric index sensitive to a wide array of different types of impact (e.g., toxic substances versus nutrient loading versus sedimentation). The six categories of metrics were: richness, composition, balance, tolerance, trophic relations, and habits. The first five categories of metrics have been used in recent studies of multimetric indices (e.g., Lenat and Barbour 1993, Barbour et al. 1995, Barbour et al. 1996), however, the use of these terms has not been consistent. We defined the first five metric categories as follows.

Richness includes the metrics that count the number of taxa, in this case families, without regard to the abundance of individuals belonging to the taxa. Composition metrics are those that calculate the proportion of individuals in one or more taxa in relation to the number of individuals in the total community. The balance category is similar to composition, with both calculating the proportion of individuals in one or more taxa in relation to the number of individuals in a larger unit of individuals. Some balance metrics deal with the single most abundant taxon or several of the most abundant taxa. Other balance metrics calculate the ratio of the abundance of individuals in one or more taxa with particular significance in pollution studies to the abundance of individuals in some larger unit, other than the total community. Diversity indices are also included in the balance category of metrics. Tolerance metrics include a numerical scoring system that ranks organisms according to their sensitivity to pollution or environmental stress. Scores range from 0 (most sensitive) to 10 (most tolerant). Tolerance values were originally developed for use in Wisconsin by Hilsenhoff (1982, 1987, 1988). They have modified for use in the Mid-Atlantic Highlands by the best professional judgment of persons in the Aquatic Entomology program at Virginia Tech and the Virginia Department of Environmental Quality. Trophic metrics are based on the concept of functional feeding groups, which categorizes organisms according to how they obtain their food (Merritt and Cummins 1996).

The sixth metric category is an original one that we developed as part of this project. Habits refers to how organisms move or maintain their position, which is dependent on characteristics of the substratum where they reside. There are two categories of habits. Haptobenthos are the organisms that cling to or crawl slowly on substratum that must be clean, coarse, and firm. Herpobenthos are the organisms that burrow in or sprawl on substratum that is fine and soft or coarse, firm substratum that is covered with thick, slippery films of algae, bacteria, or fungi. Organisms occurring the database were categorized by the best professional judgment of persons in the Aquatic Entomology program at Virginia Tech and information in Merritt and Cummins (1996). In order to use the information from Merritt and Cummins (1996) on habits (also called mode of existence), we found it necessary to establish a new category. The

reason for a new category was that those authors define sprawlers as organisms adapted for inhabiting the surface of fine sediments, but they designate many organisms that crawl around in rocks or coarse detritus in this category (especially some mayflies and stoneflies). We agree with the definition of sprawlers, but we restrict the use of the category to only those organisms that reside on top of fine, soft sediments. Therefore, we established a new category for organisms that move around slowly in clean, firm substratum such as loose rocks, leaves, and branches, and called the category "crawlers." After categorizing all taxa in the database according to our definitions of habits, we calculated haptobenthos as the sum of all clingers and sprawlers and herpobenthos as the sum of all sprawlers and burrowers.

The various analyses described above suggested 10 metrics that we considered to be "best" and worthy of further consideration. These are listed in Table 8. This list is a compromise among the different approaches. The list will not be unique in the sense that metrics are often correlated with other metrics, and, hence, substitution of other metrics is possible. We have not distinguished between transformed and untransformed metrics, although some transformed metrics were used in the data analysis. The reason for ignoring transformation in the list of metrics for further consideration is that all metrics are later assigned unitless, standardized scores for the development of the multimetric index, and this process is invariant to the type of transformation (monotone) that we used for all but one multimetric.

Table 8 - Ten best metrics selected for further investigation.

To evaluate the stream classifications, discriminant analysis was used. The method involved determining the error rate for sites being designated in the appropriate reference or impacted condition. Evaluation was based on two types of error rates: resubstitution and cross validation. Resubstitution uses all observations in developing a classification rule and designating a site. Crossvalidation removes the site before developing the rule and designating the site. The resubstitution rule will generally produce optimistic error rates because the evaluation data is the same as the data used to generate the rule. With increasing numbers of metrics the resubstitution error rate decreases, but the crossvalidation increases. Thus multimetrics with a smaller number of metrics is favored by the crossvalidation method. The crossvalidation method produces more realistic rates, especially when the sample sizes are large relative to the number of metrics. When the sample sizes are small, individual observations have great influence on the summary statistics and the error rates are often great.

Classification rates for separate sets of metrics are presented in Table 9. The first part of the table uses a different set of metrics and different rules for classification for each ecoregion. These represent the best that might be done, given the data. As part of our investigation involved the development of a single multimetric, we also considered the use of a common set of metrics with different rules for the ecoregions. The results using the ten best metrics is presented at the bottom of the table.

The classification for the ecoregions using separate sets of metrics is quite good. The total error rate across all ecoregions was only 7%. The crossvalidation method indicates this is optimistic, especially for ecoregion 69. However, the total error rate is still quite small (13%). For the ten best metrics, the estimated classification rates increase slightly using the resubstitution method but are considerably greater when using the crossvalidation method. These error rates are still reasonably small and evenly balanced across the impact and reference sites.

Part B, Metric Calibration

The ecoregion analysis is based on the premise that the ecoregions provide suitable groupings for the benthic macroinvertebrate data. The purpose of the calibration component of the analysis is to assess if the data suggest a better stream classification structure. This procedure involved reanalyzing the original classification of streams by ecoregions and subregions. We considered several other groupings of subregions as well as no classification.

There were two lines of analysis. First, using metric data, stepwise discriminant analysis was used on the group of reference sites from subregions to choose important metrics that separated the subregions. The important metrics were used in a canonical variate analysis. Scores on the first two canonical variates were graphed to investigate which groups separated or clustered together. These were then used to form new stream classifications that can be referred to as "bioregions" (Barbour et al. 1996).

Second, using nonmetric data (taxonomic composition of community), taxa abundance was used to compute a similarity matrix using the cosine measure of site similarity, i.e.

$$\cos(site_i, site_j) = \frac{\sum_{taxa} x_{ik} x_{jk}}{\sqrt{\sum_{taxa} x_{ik}^2 \sum_{taxa} x_{jk}^2}}$$

where x is the abundance of the taxa, the subscripts i and j refer to sites and k to taxa.

This matrix was then analyzed using metric scaling. The scores from the metric scaling were graphed and again used to form new bioregions. These new bioregions were then evaluated to assess if they provided better designations of impact and reference sites.

The different subregion classifications were evaluated using classification analysis to evaluate if the classification into reference or impact groups would be enhanced.

Table 9. Classification rates for predicting site status using separate analyses for ecoregions with different and the same set of 10 metrics.

Figure 1. Plot of canonical scores which provide maximal separation of subregion reference sites

Figure 2. Plot of mean canonical scores showing separation of subregion reference sites

A canonical variate analysis indicated that the subregions were significantly different (p-value < 0.0001), although the F statistic for separation is not large (F=3.77, using Wilk's Lambda statistic). Note that the separation between ecoregions (reference sites only) is also significant (F=2.47, p<0.0001) but not as significant. Thus there is more separation amongst the subregions than the ecoregions but not a great deal. Figure 1 displays the scores resulting from the canonical analysis. If there are strong differences between the reference sites in the ecoregions, then the graph should show different clusters of observations. As indicated in the graph, there is considerable overlap between the groups. A graph of the mean scores on the first two canonical variates is given in Figure 2. This figure does not indicate strong separation of groups or distinct clusters of subregions. Based on the figures and geographical information, the subregions were clustered as follows: {66A, 67D, 67C, 66B, 67B}, {62X, 66C, 69B, 69A, 60X}, {67A} and {70X}. Another approach not discussed used {66A, 66B, 66C, 67B, 67C, 67D, 62X}, {69A, 69B, 60X}, {67A}, {70X}. This set of subregions was also selected from the canonical variate analysis. Results from using these clusters were not very different. The groupings are quite similar to the ecoregions with the North Central Appalachians (66) grouping with the Central Appalachians Ridge and Valleys (67) and separating from the Central Appalachian ecoregion (69). The groupings indicate that subregion 67A (limestone and dolomite valleys) is different from the other subregions in the Central Appalachian Ridges and Valleys.

The clusters were used in classification analysis to predict if sites were impact or reference. The analysis used 15 metrics selected from stepwise discriminant analysis and ecological reasoning. This list was further reduced using a classification approach. A forward selection procedure with classification rates to select a subset of metrics. For example, in the first step, the metric with the lowest misclassification rate was selected. In the second step, this metric was combined with others and the two metrics with the best classification were selected. This continued until classification could not be improved. In addition, several other candidate sets of metrics were analyzed. Table 11 gives the classification rates for the four regions.

Table 10. Stepwise selection (first 10 metrics) for separating ecoregions.

A similar view is given in Figure 3, which describes the metric analysis of the cosine measure. Note that this analysis takes a quite different approach in that all the taxa information is used to estimate distance between the subregions. Figure 3 suggests again that there is considerable overlap in the subregions and not distinct clusters of subregions. Further indication of the lack of distinct clusters of subregions is given by the relative size of the eigenvalues from the analysis. The first two eigenvalues summarize only 58% of the information provided by the distance matrix. If there were strong differences between the subregions, the distance matrix would have a pattern that would result in a large eigenvalue associated with the pattern, and the plot would reflect this pattern. The mean scores for the analysis are displayed in Figure 4.

Based on this figure and geographical information, the following sets of clusters were obtained: {66A, 67D, 67C, 66B, 67B, 66C, 62X}, {69B, 69A, 60X}, {67A} and {70X}

Figure 3. Plot of scores from metric scaling of cosine similarity measure

Figure 4. Plot of mean scores from metric scaling of cosine similarity measure

Table 11 Classification of impact and reference sites in new regions created from subregions using various sets of metrics for a. canonical analysis groupings and b. metric scaling groups

The clusters formed from metric scaling analyzed in the same fashion as the clusters from canonical variate analysis. The groups were used in classification analysis to predict if sites were impact or reference. The analysis used the top 15 metrics selected from stepwise discriminant analysis. Table 11 gives the classification rates for the four regions for several sets of metrics that produced good classifications (relative to other sets). In comparing Table 11 with Table 9, note that classification rates are not considerably different between the two analyses. Using ecoregions as groups resulted in lower error rates with the resubstitution method but slightly higher error rates with crossvalidation. The higher error rates were due in part to the larger number of metrics selected based on ecological rather than statistical criteria.

We concluded that the reclassification of streams into new bioregions based on rearrangement of subregions did not improve results. Similarly, combining all streams without any classification did not improve results. The best results were obtained by classifying streams into the original ecoregions, but without further classification into subregions. A possible consideration is the separation of subregion 67A from the Central Appalachian Ridge and Valley ecoregion. We chose not to exclude the subregion due to sample size considerations.

Step 4: Metric Transformation

The various metrics that might be selected for a multimetric index have different ranges of values and even different directions of responses. Metrics cannot be combined until they have been transformed so that all have the same range of values and directions of responses. This step facilitates combining unlike measurements into a multimetric index by standardizing the individual metrics as unitless scores (e.g., 0,1,2). The highest score is assigned to indicate a close approximation of reference condition, then consecutively lower scores are assigned to progressively lower metric values indicating impacted conditions. We investigated six methods for assigning scores, including one similar to that used by Barbour et al. (1996) and five that we devised. Five of the methods for assigning scores are based on the quantiles of standard boxplots, which are illustrated in Figure 5 below.

Figure 5 - boxplot display

The six methods for assigning unitless scores that we investigated are summarized in Table 12. In Methods 1-3, metric values were assigned one of three unitless scores. Method 4 used a standardization approach. In Methods 5 and 6, metric values were assigned one of four unitless scores. We quickly found that there was too much variation and overlap within the data to characterize metric values with four scores, so those results are not presented. In all methods, we chose to use sequential scores beginning with zero (0,1,2 or 0,1,2,3). Most multimetric indices for macroinvertebrates and fish use even or odd numbers for individual metric scores, and in some cases they do not begin with zero. The effect of using even or odd numbers for individual metric scores is to increase the highest possible total score for the multimetric index, thereby implying greater sensitivity for detecting differences. However, the impression of greater sensitivity is completely false, because half of the total score values cannot possibly be achieved by summing individual scores with either even or odd values. In addition, we believe that total scores for multimetric indices give a more accurate impression of biological condition if the lowest possible score for all individual metrics is zero. This way it is theoretically possible for a stream in really bad condition to receive a total score of zero for the multimetric index.

Method 1 is based on Barbour et al. (1996). It is calculated entirely on data from reference sites. The highest score is assigned to metric values greater than the lower quartile. The low and middle score was based on whether or not the value fell below or above the lower quartile divided by two. Values below were assigned a score of 0 and above 0.5*Q1 but less than Q1 were given a value of 1. Values above Q1 were given values of 2. Two metrics (% 5 most dominant and HI) increase with decreasing quality. For the % 5 most dominant, the value was first adjusted by subtracting from 100 and the same method used. For HBI, an approach based on using the negative of HBI produced a cutoff that was too extreme so we used the lower fence of -HBI as the cutoff for assigning a score of 0 or 1.

It is our opinion that standardized unitless scores can be assigned more accurately if data from reference and impacted sites are integrated, so we devised and analyzed five methods for doing this (Methods 2-6). Results of our analyses of Methods 2-4 are presented here as the last methods were not useful for classification. In Method 2, the highest score is assigned to metric values greater than the upper quartile of the impact sites, and the lowest score is assigned to metric values less than or equal to the fence for the reference sites. The intermediate score is assigned to metric values greater than the fence for the reference sites up to and including the value of the upper quartile of the impact sites.

We developed Method 3 to broaden the designation for the intermediate score, which would simultaneously reserve the highest and lowest scores for streams that tend to be especially good or especially bad, respectively. However, in order to do this we had to deal with a problem that we sometimes encountered involving overlaps between the upper quartile of sites designated as "impact" and the lower quartile of sites designated as "reference." The likely explanation for this overlap lies in using historical databases from a wide geographic area and with many different biologists collecting the data. In this case, we did have sufficient quantity of data to subdivide

the impact sites according to type of pollution or environmental stress. In addition, the designation of "impact" site was based on the best professional judgment of different state biologists within the region. In Method 3, the criterion for assigning the highest score for a metric value is the highest of either greater than lower quartile of reference sites or upper quartile of impact sites. The lowest score is assigned to metric values less than or equal to the first quartile of impact sites. The intermediate score is assigned to metric values that are greater than the first quartile of impact sites up to and including the criterion that was selected for the highest score.

Method 4 is not based on quantiles but rather scales a metric based on the range then sums across the metrics for form a measure. To compute the index, the metric has the minimum value subtracted and then is divided by the range (reference maximum minus impact minimum). This results in a value between zero and one (inclusive). It is possible the a standardized value could be negative and in this case, would be set to zero. The scaled values are then summed to create the index. The rationale for this method is that the other methods make the metric discrete and hence omit some information. By standardizing the metrics to the same scale, no information is lost and the metrics can be combined. The drawback to the method is that to scale the metrics, the minimum and maximum must be given or estimated. In general, these quantities have high uncertainty (relative to other quantities such as the mean). Further, the distribution of the metric becomes important and metrics which have skewed distributions may not be useful. The other approaches are not as influenced by the shape of the distribution of the metric.

Pertinent boxplot values used in the various standardization methods are presented in Table 13 for the ten best metrics. Metric values for assigning the standardized unitless scores in each method are summarized in Table 14. Note that the two metrics for which high values indicate poor biological condition (% 5 Dominant Taxa, HBI) have been adjusted to be consistent with the other eight metrics for which high values indicate good biological condition.

Based on this selection process, we proceeded into Step 5 with four methods for assigning scores.

Step 5: Multimetric Index Development

After transforming individual metrics into standardized unitless scores, selected groups of metrics were aggregated into several multimetric indices by summing the scores of the individual metrics. The range of the derived multimetric will be from 0 to the number of metrics. Only integer values are possible.

For the final metric selection, we conducted further analyses of error rates on the transformed metrics for sites being designated in the appropriate reference or impacted condition. The approach was a metric selection approach in which the first step selects the metric with lowest classification rate, then we consider if additional metrics improve classification. Based on this approach, five multimetrics resulted. Multimetric 1 (MM1) was based on the EPT Index, %

Scrapers, # Intolerant Taxa, % Mayflies (transformed) and % Haptobenthos. The second multimetric (MM5) used # Stonflies rather than % Haptobenthos. MM8 used the EPT Index, % Scrapers, Simpson's Diversity Index, # Intolerant Taxa, % Mayflies and % Haptobenthos. MM10 used the ten best metrics from Table 8. The last multimetric was the same as MM10 except that % EPT was not included. Classification rates for these multimetrics are presented in Table 15.

To evaluate metrics graphically, boxplots were drawn for each mutlimetric and method. Figures 6-9 give boxplots for four multimetrics using method 3. These illustrate the separation (or overlap) between impact and reference sites for the different ecoregions. Boxplots for reference sites tend to be less variable than those for impact sites. Again they display that a separate cutoff would be required for each of the ecoregion as the medians for the difference reference regions appear different. Also, in the boxplot for region 69, several extreme sites are displayed as outliers. These values are possible incorrectly classified sites and will not be correctly classified using any of the approaches we applied. Finally, note that the boxplots indicate that the classification is likely to be good for ecoregions 67, 69 and 70 but not as good for ecoregion 66. Boxplots were similar for the other methods and not included in this report.

There is no specific criterion for what is an acceptable misclassification rate. Considering that the assignment of reference versus impacted status was determined by best professional judgment of different state biologists rather than empirical data, we considered misclassification rates ≤10% to be excellent, 11-20% very good, and 21-30% acceptable. We lack confidence in any multimetric index or standardization method that misclassifies either reference or impact sites >30% of the time. Crossvalidation produced almost identical results and does not need to be discussed separately. Classification rates for ecoregion 70 are probably not meaningful because there were so few replicates of both reference and impacted sites. As a result of low replication and good separation, all multimetric indices and all standardization methods appear to do a good job of distinguishing reference and impacted conditions in ecoregion 70. Misclassification rates were consistently higher for all multimetric indices and all standardization methods in ecoregion 66, especially for impacted sites. There were disproportionately low numbers of impacted sites compared to reference sites in ecoregion 66. Examination of the database (Appendix A) revealed that the impacted designation was always attributed to acidification from atmospheric deposition in ecoregion 66. Acidification from atmospheric deposition is a long-term process, and during the early stages the macroinvertebrate communities are not drastically changed. We believe that the results from ecoregion 66 are not reliable because there was only one type of pollution or environmental stress reflected in the database, and some of the designations of sites as impacted may have been flawed. Therefore, we have emphasized results from ecoregions 67 and 69 in our analyses and interpretations.

Based on our previous analyses of redundancy among individual metrics, we suspected that multimetric indices with fewer individual metrics would have lower misclassification rates. This did not prove to be the case. For example, if you look at ecoregion 67 (most replicates) and

follow any standardization method for multimetric indices with 5, 6, 9, and 10 individual metrics, there is very little difference in the misclassification rates for either reference or impacted sites. Although not shown in Table 15, we also examined multimetric indices with 7 and 8 individual metrics and found the same results. Since our selection of individual metrics involved distributing them evenly among six categories, we believe it is desirable to have greater numbers of metrics, as long as there is no increase in misclassification. Having more individual metrics should make the multimetric index respond to a wider variety of potential impacts, especially some that might not have been included in this particular database. According to this line of reasoning, we suggest that Multimetric Index 10, which has 10 individual metrics, is the most promising, but Multimetric Index 8 (6 metrics) and Multimetric Index 11 (9 metrics) should also be considered further.

The four standardization methods were also evaluated by classification rates (Table 15). In general, the four methods performed about the same for classifying reference and impact sites. All four methods misclassified reference sites < 10% in ecoregion 67 for all multimetric indices and error rates of between 20 and 30% for impact sites. As expected, error rates were high in region 66 as there was considerable overlap in the boxplot displays. Error rates for region 69 tended to be roughly equal for impact and reference sites. Method 4 tended to have slightly higher misclassification rates. Some of the differences between the ecoregion classification rates may be due to sample sizes. The sample size in region 67 favored the reference sites while the sample sizes in region 69 were more balanced. Also, the possible outliers increased the error rates for region 69. The error rates displayed in Table 15 are comparable to those using the similar approach in Table 9 with ten metrics and discriminant analysis of the metrics.

Based solely on classification rates, it is difficult to recommend a single multimetric. Based on classification and biological considerations, our recommendation would be to use, Multimetric Index 10 and Multimetric Index 11 calculated by standardization method 2. The method incorporates sufficient biological information to be sensitive to a number of types of environmental alterations and has good classification rates. The same multimetric indices calculated by the other standardization methods could also be considered further. The differences between these multimetrics was deemed to be minor.

Finally note that in the classification analysis, all methods used the linear rule for classification. Improvements can be made, sometimes significant, using a quadratic rule. Our preference was to use the linear rule however as this was simpler, consistent approach to developing a cutoff and categorization scheme.

Step 6: Biocriteria Development

In this step, criteria for assessing biological condition were formulated from the multimetric indices and calibrated by stream classes (ecoregions). The essential element is a threshold to discriminate impaired versus unimpaired biological conditions. Also, it is important to distinguish different categories of impairment and exceptional conditions. However, these

criteria have very important legal, economic, and aesthetic ramifications, so our recommendations are very general and will require careful validations by appropriate persons in the regulatory arena. There is no best approach to select the criteria for boundaries. The approach that was used in our analysis is given in Table 16. For the threshold to discriminate impaired versus unimpaired biological conditions we suggest using the average of the multimetric index mean for impacted sites and the multimetric index mean for reference sites. This is based on the classification cutoff from linear discriminant analysis and will give classification similar to the discriminant analysis classification in Table 15. We recommend that multimetric index values greater than this threshold value be considered acceptable biological condition and values less than this threshold value be considered unacceptable biological condition. We further recommend that two categories be established on both sides of the threshold by using the third and first quartile values. Multimetric index values greater than or equal to the third quartile (of reference sites) are categorized as "very good." The very good category might be useful for distinguishing exceptional streams that are worthy of special conservation measures. Multimetric index values less than or equal to the first quartile (of impact sites) are categorized as "poor." The poor category might be useful for distinguishing streams that are severely impaired and in immediate need of regulatory actions.

Tables 17-20 give classification results for three multimetric indices (MM8 - 8 metrics, MM10 - 10 metrics, MM11 - 9 metrics) using four different standardization methods (1, 2, 3, 4). If a multimetric index worked perfectly at classifying streams according to impairment, you would expect to have no impact sites designated as very good or good. Also, it would be reasonable to expect that more impact sites would be designated as fair than poor. For reference sites, perfect results from a multimetric index would be no sites designated as fair or poor, and more sites designated as good than very good. Obviously multimetric indices are not going to work perfectly, especially ones developed from a historical database such as this. However, some of the results presented in Tables 17-20 are very encouraging. For the same reasons explained in Step 5, we have emphasized ecoregions 67 and 69 in our interpretations.

Based on the classifications, it is difficult to distinguish between the three multimetrics. Misclassification rates tend to be higher for impact sites than for reference sites for all three multimetrics. Improvement in the classification of reference sites was offset by poorer classification of the reference sites. For example, for multimetrics 11, the misclassification for ecoregion 69, multimetric 3 was 21% for impact and 16% for reference. The classification was better for metric 2 for impact (17% misclassified) but worse for reference (24%).

If a choice has to be made based on this information, we would recommend multimetric 11 using method 2. The classification using this metric is as good as the other multimetrics. The metric is based on information from the impact as well as the reference sites and include metrics of both ecological and statistical significance. In addition, the error rates for this metric are good (an average of 15% for reference and 19% for impact) and are balanced across the impact and reference sites. The other methods have smaller rates for the reference sites at the expense of larger error rates for impact. Method 1 has an average error rate for reference of about 12% but

the average error rate is about 24% for impact. Method 3 has an error rate of around 10% for reference but averages about 25% for impact. As already noted, the discriminant analysis results in higher error rates for impact sites over reference sites, especially in ecoregions with a greater number of reference sites (e.g. 67). However, balance in the rates is important as both error rates should be small. The imbalance can be adjusted for by adjusting the cutoffs with the possibility of an increase in the total error rate. Table 21 illustrates the effect of altering the cutoff for the Good classification using method 2 with multimetrics 10 and 11. Compare the rates for ecoregion 67 from Table 18 with those in Table 21 for multimetric 11. Note that the slight shift in the classification of Good causes a dramatic shift in the proportion classified as Good or Very Good for impact sites. In Table 18, 21% were classified as Good or better. The rate is 11% in Table 21. This improvement is achieved as the expense of an increase in the number of reference sites which are misclassified. The reason for the change is that there are a number of impact sites with value 12 but only a few reference sites with that value. When the cutoff shifts these values are not classified correctly for impact but incorrectly for reference. Rates for region 69 are not as affected by changes since the sample sizes are more balanced. This example also illustrates the need for further refinement of the cutoffs, especially those that are nearly integer valued and we caution against the application of cutoffs (in general) without validation with an additional data set.

CONCLUSIONS AND RECOMMENDATIONS

1) Statistical analyses of family-level macroinvertebrate data in this historical database could not discern significant differences among ecoregions or subregions within the Mid-Atlantic Highlands. Rearrangement of subregions into various new groupings called bioregions also did not produce any predictable spatial distribution patterns for benthic macroinvertebrate communities. Analysis of ecoregions and subregions and other patterns of spatial distribution would be more informative with species-level data. The EMAP data may work for this. The same statistical procedures used in this project could be applied to the EMAP database.

2) Even though ecoregions and subregions did not explain benthic macroinvertebrate community structure, individual metrics and multimetric indices classified streams according to ecological condition (level of impairment) better within ecoregions than by considering all streams within the Mid-Atlantic Highlands together.

3) Even though there was some redundancy among individual metrics, multimetric indices with more individual metrics (as many as 10) classified streams according to ecological condition slightly better than multimetric indices with fewer individual metrics (as few as 5). The potential advantage of incorporating more individual metrics is to increase the likelihood of response to more types of pollution or environmental stress. There were only slight differences in effectiveness among four different standardization methods for scoring individual metrics. We recommend that Multimetric Indices 8, 10, and 11 (composed of 6, 10, and 9 individual metrics, respectively) calculated by Standardization Methods 1, 2, 3, and 4 are worthy of further investigation.

4) The results of this project need to be validated with different data. For validation purposes, the designations of reference versus impacted sites should be based exclusively on empirical data for water quality and habitat. Designations of reference versus impacted sites must not be based on macroinvertebrate data. Validation should be done with family-level data in order to provide a practical biomonitoring tool for state and federal regulatory agencies. Other multimetric indices could also be developed from species-level data generated by EMAP by following the same procedures used in this project.

5) Although our analysis is based on all regions, our conclusions emphasize results from ecoregions 67 and 69. There were insufficient reference and impacted site replicates in ecoregion 70. In ecoregion 66, there were insufficient numbers of impacted site replicates and the only type of impact represented in the database was acid deposition, which may cause atypical changes in macroinvertebrate communities. We recommend that more site replicates and sites representing a variety of impacts be acquired for ecoregions 66 and 70. In the meantime, the results of ecoregions 67 and 69 might be used with caution as a preliminary multimetric index for the ecoregions 66 and 70.

6) If EPA Region III desires to recommend a single multimetric index at the present time for state regulatory agencies to try in streams within the Mid-Atlantic Highlands, we recommend Multimetric Index 11 (composed of 9 metrics) calculated by Standardization Method 2.

7) We plan to publish the results of this project in a peer reviewed journal. The multimetric index will be called the Macroinvertebrate Aggregated Index for Streams and will have the acronym MAIS.

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STATISTICAL METHODOLOGIES

Canonical variate analysis: the purpose of this method is to provide a graphical display of the separation between groups based on data collected on a number of variables (metrics). The method uses linear combinations of the variables to obtain summaries of the separation. Typically two combinations are used.

Discriminant analysis (classification analysis): The purpose of this method is to predict the group a site belongs to based on a number of variables (metrics). The linear classification rule is based on a linear combination of variables and is similiar to using a regression analysis to obtain a classification rule for prediction. The classification analysis is summarized by a table summarizing the number (or proportion) of correctly and incorrectly classified observations.

Stepwise discriminant analysis: The purpose of this method is to obtain a set of variables which is useful for separation of groups and is not redundant with other variables. The method is based on stepwise selection in which variables are added or removed based on their ability to improve (or not) separation.

Metric scaling: The purpose of this method is to obtain a set of variables given a distance or similarity matrix. The interest is in a set of variables which when plotted give a visual display of the distances and and is of low dimension (two or three derived variables are desired). The approach often starts with a large number of variables (species or taxa), converts this to a distance or similarity matrix, then this matrix is reduced.

Table 1. Ecoregions and subregions included in the Mid-Atlantic Highlands.

Ecoregion	Subregions	Number/Letter Code
Northern Appalachian Plateau and Uplands	None	60
North Central Appalachians	None	62
Blue Ridge Mountains		66
	Non-Calcareous	66A
	Shale-Dominated Ridges	66B
	Interior Plateau	66C
Central Appalachian Ridges and Valleys		67
	Limestone and Dolomite Valleys	67A
	Shale and Slate Valleys	67B
	Sandstone Ridges	67C
	Shale Ridges	67D
Central Appalachians		69
	Forested Hills and Mountains	69A
	Uplands and Valleys of Mixed Land Use	69B
Western Alleghany Plateau	None	70

Table 2. Sources of benthic macroinvertebrate data for historical database from wadeable streams in the Mid-Atlantic Highlands.

State	Agency/Unit	# Samples	Person(s)
Maryland	Dept. of Environment, Water Quality Monitoring	51	Niles Primrose
Pennsylvania	Dept. of Environmental Resources, Bureau of Water Quality	53	Rick Shertzer, Tony Shaw
Virginia	U.S. Forest Service, George Washington and Thomas Jefferson National Forests	101	Mark Hudy
Virginia	Dept. of Environmental Quality	25	Lou Seivard
Virginia	Virginia Tech, Dept. of Entomology	25	Shane Evans
West Virginia	Dept. of Natural Resources	200	Janice Smithson

N= 455

Table 3. Numbers of samples according to ecoegion/subregion and biological condition category.

Ecoregions/Subregions (Numerical Designation)	#Reference	#Impacted	#Unknown Status	Total Samples
Ecoregion: Northern Appalachian Plateau and Uplands (60)	6	0	0	6
Ecoregion: North Central Appalachians (62)	20	0	0	20
Ecoregion: Blue Ridge Mountains (66)	35	11	13	59
Subregion: Non-calcareous (66A)	17	0	6	
Subregion: Shale-dominated ridges (66B)	10	8	3	
Subregion: Interior Plateau (66C)	4	3	4	
Subregion: Mixed subregions (66M)	4	0	0	
Ecoregion: Central Appalachian Ridges and Valleys (67)	60	28	55	143
Subregion: Limestone and Dolomite Valleys (67A)	5	10	4	
Subregion: Shale and Slate Valleys (67B)	I	0	10	
Subregion: Sandstone Ridges (67C)	23	12	19	
Subregion: Shale Ridges (67D)	22	5	8	
Subregion: Mixed subregions (67M)	9	1	14	
Ecoregion: Central Appalachians (69)	25	23	129	177
Subregion: Forested Hills and Mountains (69A)	11	14	107	
Subregion: Uplands and Valleys of Mixed Land Use (69B)	14	9	22	
Ecoregion: Western Alleghany Plateau (70)	7	6	32	45
Total	153	68	229	450

Table 4. List of candidate metrics with explanations and expected responses to perturbation in streams of Mid-Atlantic Highlands.

Category	Metric	Explanation	Expected Response To Perturbation
Richness measures	Taxa Richness	Number of macroinvertebrate families	–
	EPT Index	Number of mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) families	–
	# Mayfly Taxa	Number of mayfly families	–
	# Stonefly Taxa	Number of stonefly families	–
	# Caddisfly Taxa	Number of caddisfly families	–
	# Beetle Taxa	Number of beetle (Coleoptera) families	–
	# True Fly Taxa	Number of true fly (Diptera) families	–
	# Non-Insect Taxa	Number of non-insect families	–
Composition measures	% EPT	Percent abundance of mayfly nymphs (Ephemeroptera), stonefly nymphs (Plecoptera) and caddisfly larvae and pupae (Trichoptera)	–
	% EPT (Modified)	Percent abundance of mayfly nymphs (Ephemeroptera), stonefly nymphs (Plecoptera) and caddisfly larvae and pupae (Trichoptera) minus the abundance of mayflies in the family Baetidae and caddisflies in the family Hydropsychidae	–
	% Mayflies	Percent abundance of mayfly nymphs	–
	% Stoneflies	Percent abundance of stonefly nymphs	–
	% Caddisflies	Percent abundance of caddisfly larvae and pupae	–
	% Beetles	Percent abundance of beetle larvae and adults	+ or –
	% True Flies	Percent abundance of true fly larvae and pupae	+
	% Non-Insects	Percent abundance of individuals classified as non-insects	+
Balance measures	% Dominant Taxon	Percent abundance of the single most abundant taxon	+
	% 5 Dominant Taxa	Percent abundance of the 5 most abundant taxa combined	+
	EPT/[EPT + Chironomidae]	Number of mayfly nymphs (Ephemeroptera), stonefly nymphs (Plecoptera) and caddisfly larvae and pupae (Trichoptera) divided by number of EPT plus the number of larvae and pupae in the true fly family Chironomidae	–

	Modified EPT/(EPT + Chironomidae)	Percent abundance of mayfly nymphs (Ephemeroptera), stonefly nymphs (Plecoptera) and caddisfly larvae and pupae (Trichoptera) minus the abundance of mayflies in the family Baetidae and caddisflies in the family Hydropsychidae divided by the abundance of mayfly nymphs (Ephemeroptera), stonefly nymphs (Plecoptera) and caddisfly larvae and pupae (Trichoptera) plus the abundance of larvae and pupae in the true fly family Chironomidae	–
	Hydropsychidae/ Trichoptera	Number of larvae and pupae in the caddisfly family Hydropsychidae divided by the total number of caddisfly larvae and pupae	+
	% Hydropsychidae	Percent abundance of larvae and pupae in the caddisfly family Hydropsychidae	+
	% Baetidae	Percent abundance of nymphs in the mayfly family Baetidae	+
	Baetidae/Ephemeroptera	Number of nymphs in the mayfly family Baetidae divided by the total number of mayfly nymphs	+
	% Chironomidae	Percent abundance of larvae and pupae in the true fly family Chironomidae	+
	Shannon-Wiener Diversity Index [log 2]	Integrates richness and evenness into a measure of general diversity [1]	–
	Simpson Diversity Index	Integrates richness and evenness into a measure of general diversity [2]	–
Tolerance measures	HBI (Hilsenhoff Biotic Index)	Weighted sum of total taxa by pollution tolerance [3]	+
	HBI-Hydropsychidae	Weighted sum of total taxa minus hydropsychid caddisfly larvae and pupae by pollution tolerance	+
	HBI-Chironomidae	Weighted sum of total taxa minus Chironomidae larvae and pupae by pollution tolerance	+
	HBI - Hydropsychidae + Chironomidae	Weighted sum of total taxa minus larvae and pupae in the caddisfly family Hydropsychidae and the true fly family Chironomidae	+
	# Intolerant Taxa	Number of macroinvertebrate families with tolerance values of 5 or less	–
	# Tolerant Taxa	Number of macroinvertebrate families with tolerance values of 6 or more	+
	% Intolerant	Percent abundance of macroinvertebrates with tolerance values of 5 or less	–
	% Tolerant	Percent abundance of macroinvertebrates with tolerance values of 6 or more	+

Trophic measures	Scrapers/[Scrapers + Collector-Filterers]	Number of macroinvertebrates scraping and feeding upon periphyton divided by number of macroinvertebrates scraping and feeding upon periphyton and number of macroinvertebrates filtering and feeding upon organic material suspended in water	–
	% Predators	Percent abundance of macroinvertebrates feeding upon other animals	+ or -
	% Collector-Gatherers	Percent abundance of macroinvertebrates gathering and feeding upon detritus in sediment	+ or -
	% Collector-Filterers	Percent abundance of macroinvertebrates filtering and feeding upon organic material suspended in water	+
	% Shredders	Percent abundance of macroinvertebrates feeding on coarse particulate organic matter	–
	% Scrapers	Percent abundance of macroinvertebrates scraping and feeding upon periphyton	–
	Scrapers/[Scrapers + Collector-Gatherers]	Number of macroinvertebrates scraping and feeding upon periphyton divided by number of macroinvertebrates scraping and feeding upon periphyton and number of macroinvertebrates gathering and feeding upon detritus in sediment	–
	Scrapers/[Scrapers + Collector-Gatherers + Collector-Filterers]	Number of macroinvertebrates scraping and feeding upon periphyton divided by number of macroinvertebrates scraping and feeding upon periphyton and number of macroinvertebrates gathering and feeding upon detritus in sediment and the number of macroinvertebrates filtering and feeding upon organic material suspended in water	–
	% Macrophyte-Piercers	Percent abundance of macroinvertebrates feeding by piercing aquatic plants	+ or -
Habit measures	% Haptobenthos	Percent abundance of macroinvertebrates requiring clean, coarse, firm substrates	–
	% Herpobenthos	Percent abundance of macroinvertebrates adapted to living in or on fine, soft substrate or substrate covered with thick, slippery films of algae, bacteria, or fungi	+
	Haptobenthos/[Haptobenthos + Herpobenthos]	Number of macroinvertebrates requiring clean, coarse, firm substrates divided by the number of macroinvertebrates requiring clean, coarse substrates and the number of macroinvertebrates adapted to living in or on fine, soft substrate or substrate covered with thick, slippery films of algae, bacteria, or fungi	–

	Haptobenthos-Hydropsychidae/ [(Haptobenthos-Hydropsychidae) + Herpobenthos]	Number of macroinvertebrates requiring clean, coarse, firm substrates (minus the number of hydropsychid caddisfly larvae and pupae) divided by the number of macroinvertebrates requiring clean, coarse, firm substrates (minus the number of hydropsychid caddisfly larvae and pupae) and the number of macroinvertebrates adapted to living in or on fine, soft substrate or substrate covered with thick, slippery films of algae, bacteria, or fungi	–

1. Shannon-Wiener Index $$H = -\sum_{k=1}^{S} p_k \log p_k$$

   Where

   S = number of taxa
   p_k = proportion of individuals in taxa k

2. Simpson's index of diversity $$\lambda = 1 - \sum_{k=1}^{S} P_k^2$$

   Where

   S = number of taxa
   p_k = proportion of individuals in taxa k

3. Hilsenhoff's Biotic Index (HBI) $$HBI = \sum \frac{x_i t_i}{n}$$

   Where

   x_i = number of individuals within a taxon
   t_i = tolerance value of a taxon
   n = total number of organisms in the sample

Table 5. Metrics sorted by robust coefficient of variation for reference sites. Note that the first two metrics have missing values.

Rank	Metric	CV Impact	CV Reference	Robust CV Reference	Robust CV Impact	Separation Statistic	Robust Separation
1	% Macrophyte-Piercers (Trans.)	369.715	487.353	.	.	-0.41701	.
2	% Macrophyte-Piercers	428.823	534.955	.	.	-0.40646	.
3	Simpson Diversity Index	30.378	11.456	7.857	17.58	0.86901	0.88239
4	% 5 Most Dom. Taxa (Trans.)	18.587	11.694	11.527	16.08	-0.90177	-1.06863
5	HBI	25.451	16.720	12.050	21.94	-0.87059	-1.30368
6	Haptobenthos/Haptobenthos+Herpobenthos	53.846	17.425	13.260	59.04	1.08285	0.68002
7	% Haptobenthos	55.619	17.692	13.512	66.34	1.09042	0.70500
8	% 5 Most Dom. Taxa	17.113	12.882	13.524	13.85	-0.82449	-1.06767
9	Shannon H (log 2)	35.991	16.564	16.122	35.00	1.22536	1.16254
10	EPT/EPT+Chironomidae (Trans.)	53.513	18.698	16.310	53.47	0.98630	0.65076
11	EPT/EPT+Chironomidae	59.670	19.469	16.558	69.65	1.03219	0.63354
12	HAP(H)/HAP(H)+HERP	61.884	19.863	16.977	82.81	1.16687	0.85967
13	% EPT (Transformed)	57.025	21.522	17.412	58.78	0.92408	0.57416
14	% Dominant Taxon (Trans.)	33.152	22.540	20.403	22.75	-0.78347	-0.82222
15	HBI-Chironomidae	43.291	25.781	21.084	36.99	-0.21518	-0.08376
16	%Haptobenthos-Hydropsychidae	69.135	25.871	24.083	95.80	1.00895	0.78214
17	% EPT	68.198	28.158	24.371	84.59	0.88846	0.62322
18	Taxa Richness	39.694	25.486	26.144	40.40	1.38460	1.35000
19	Modified EPT/(EPT+Chironomidae Abundanc	83.234	30.429	26.855	109.24	1.04839	0.71278
20	% Intolerant Taxa	62.772	27.965	27.447	72.35	0.99656	0.87709
21	% Collector-Gatherers (Trans.)	43.440	34.010	27.826	51.59	-0.48840	-0.08207
22	% Mayflies (Transformed)	103.063	33.915	29.603	171.66	1.27699	1.60628
23	EPT Index	69.842	31.817	29.630	74.07	1.55417	1.55805
24	Hydropyschidae/Trichoptera (Trans.)	71.859	39.001	33.908	110.83	0.19779	0.36959
25	No. Intolerant Taxa	54.268	29.817	34.188	56.98	1.67179	1.53651
26	Scrapers/Scrapers+Coll. Filt. (Trans.)	88.620	38.685	36.685	125.69	0.97425	0.87333
27	% Dominant Taxon	46.643	38.954	36.691	38.48	-0.78778	-0.82315
28	Number of Mayfly Taxa	98.009	32.744	37.037	222.22	1.66544	1.72092
29	No. Tolerant Taxa	53.648	40.596	37.037	37.04	-0.09622	0.00000
30	Number of Beetle Taxa	81.517	52.151	37.037	74.07	0.68380	1.35000
31	% Collector-Filterers (Trans.)	57.293	33.571	37.098	58.64	0.24421	0.13896
32	HBI-Hydropsychidae+Chironomidae	59.846	37.490	38.079	53.13	-0.24964	-0.12782
33	% EPT(modified)	88.525	38.008	39.410	104.36	0.88461	0.70424
34	% Predators (Trans.)	76.685	40.542	39.575	77.05	0.41834	0.50602
35	% Scrapers (Trans.)	92.034	44.877	40.244	133.05	1.22743	1.25997
36	% Caddisflies (Transformed)	69.912	39.967	42.723	87.05	0.34030	0.33855
37	Total Abundance	173.796	101.039	43.519	76.83	-0.04649	0.71080
38	% Total Diptera (Transformed)	51.946	39.107	44.505	50.19	-0.58540	-0.55222

39	Hydropyschidae/Trichoptera	77.084	45.038	44.893	140.18	0.27039	0.44558
40	% Tolerant Taxa	45.679	47.090	47.735	55.86	-0.99656	-0.87709
41	% Collector-Gatherers	60.291	53.188	47.742	90.21	-0.49744	-0.08229
42	Number of Diptera Taxa	46.685	36.343	49.383	24.69	0.50934	0.00000
43	Number of Caddisfly Taxa	73.206	43.825	49.383	74.07	1.04278	0.67500
44	% Chironomidae (Transformed)	63.359	48.639	50.185	58.91	-0.51484	-0.45063
45	% Mayflies	140.824	54.794	52.934	377.15	0.97662	1.68709
46	Scrapers/Scrapers+Coll. Filt.	113.182	55.757	60.779	190.48	0.84466	1.01406
47	Scrapers/Scrapers+Collector-Gatherers	115.606	60.589	61.102	214.49	1.06618	1.22823
48	Scrapers/Scrapers+Coll.Gath+Coll.Filter	133.441	70.981	65.146	212.15	0.99613	1.35024
49	% Beetles (Transformed)	98.808	67.959	65.378	126.28	0.64729	0.76152
50	% Collector-Filterers	78.870	53.925	65.969	103.24	0.11827	0.14227
51	% Non-insects (Transformed)	123.753	116.114	69.153	184.82	-0.57116	-0.28221
52	Baetidae/Ephemeroptera (Trans.)	115.598	66.244	72.315	830.71	0.09134	0.73352
53	Number of Stonefly Taxa	113.178	67.617	74.074	148.15	0.69488	0.98844
54	Number of Non-insect Taxa	116.598	89.594	74.074	148.15	-0.19832	0.00000
55	% Scrapers	145.096	75.656	74.978	232.77	0.96387	1.21100
56	% Stoneflies (Transformed)	118.219	66.996	76.623	303.95	0.25638	0.68192
57	% Caddisflies	92.339	64.659	76.726	163.39	0.16126	0.34879
58	% Herpobenthos	76.470	76.292	77.799	88.01	-0.90786	-0.71434
59	% Predators	130.624	74.343	79.112	151.54	0.17814	0.49683
60	% Shredders (Trans.)	110.466	68.148	80.530	174.35	0.11542	0.38164
61	% Total Diptera	71.629	65.637	81.523	86.96	-0.67138	-0.56470
62	% Hydropsychidae	120.230	82.905	94.328	237.81	0.07357	0.43838
63	% Chironomidae	94.139	82.746	98.743	113.10	-0.60041	-0.44014
64	% Beetles	170.650	116.421	126.161	212.81	0.50324	0.67572
65	Baetidae/Ephemeroptera	119.955	88.360	132.970	3018.52	-0.04479	0.50996
66	% Stoneflies	163.525	104.603	150.923	1178.39	0.01619	0.53523
67	% Baetidae	173.146	122.123	151.056	2918.91	0.20488	0.68039
68	% Non-insects	171.236	258.648	151.088	440.36	-0.59849	-0.20705
69	% Shredders	163.180	113.411	161.656	397.68	-0.10215	0.35028

Table 6. Metrics sorted by mean separation between reference and impact.

Rank	Metric	CV Impact	CV Reference	Robust CV Reference	Robust CV Impact	Separation Statistic	Robust Separation
1	% Tolerant Taxa	45.679	47.090	47.735	55.86	-0.99656	-0.87709
2	% Herpobenthos	76.470	76.292	77.799	88.01	-0.90786	-0.71434
3	% 5 Most Dom. Taxa (Trans.)	18.587	11.694	11.527	16.08	-0.90177	-1.06863
4	HBI	25.451	16.720	12.050	21.94	-0.87059	-1.30368
5	% 5 Most Dom. Taxa	17.113	12.882	13.524	13.85	-0.82449	-1.06767
6	% Dominant Taxon	46.643	38.954	36.691	38.48	-0.78778	-0.82315
7	% Dominant Taxon (Trans.)	33.152	22.540	20.403	22.75	-0.78347	-0.82222
8	% Total Diptera	71.629	65.637	81.523	86.96	-0.67138	-0.56470
9	% Chironomidae	94.139	82.746	98.743	113.10	-0.60041	-0.44014
10	% Non-insects	171.236	258.648	151.088	440.36	-0.59849	-0.20705
11	% Total Diptera (Transformed)	51.946	39.107	44.505	50.19	-0.58540	-0.55222
12	% Non-insects (Transformed)	123.753	116.114	69.153	184.82	-0.57116	-0.28221
13	% Chironomidae (Transformed)	63.359	48.639	50.185	58.91	-0.51484	-0.45063
14	% Collector-Gatherers	60.291	53.188	47.742	90.21	-0.49744	-0.08229
15	% Collector-Gatherers (Trans.)	43.440	34.010	27.826	51.59	-0.48840	-0.08207
16	% Macrophyte-Piercers (Trans.)	369.715	487.353	.	.	-0.41701	.
17	% Macrophyte-Piercers	428.823	534.955	.	.	-0.40646	.
18	HBI-Hydropsychidae+Chironomidae	59.846	37.490	38.079	53.13	-0.24964	-0.12782
19	HBI-Chironomidae	43.291	25.781	21.084	36.99	-0.21518	-0.08376
20	Number of Non-insect Taxa	116.598	89.594	74.074	148.15	-0.19832	0.00000
21	% Shredders	163.180	113.411	161.656	397.68	-0.10215	0.35028
22	No. Tolerant Taxa	53.648	40.596	37.037	37.04	-0.09622	0.00000
23	Total Abundance	173.796	101.039	43.519	76.83	-0.04649	0.71080
24	Baetidae/Ephemeroptera	119.955	88.360	132.970	3018.52	-0.04479	0.50996
25	% Stoneflies	163.525	104.603	150.923	1178.39	0.01619	0.53523
26	% Hydropsychidae	120.230	82.905	94.328	237.81	0.07357	0.43838
27	Baetidae/Ephemeroptera (Trans.)	115.598	66.244	72.315	830.71	0.09134	0.73352
28	% Shredders (Trans.)	110.466	68.148	80.530	174.35	0.11542	0.38164
29	% Collector-Filterers	78.870	53.925	65.969	103.24	0.11827	0.14227
30	% Caddisflies	92.339	64.659	76.726	163.39	0.16126	0.34879
31	% Predators	130.624	74.343	79.112	151.54	0.17814	0.49683
32	Hydropyschidae/Trichoptera (Trans.)	71.859	39.001	33.908	110.83	0.19779	0.36959
33	% Baetidae	173.146	122.123	151.056	2918.91	0.20488	0.68039
34	% Collector-Filterers (Trans.)	57.293	33.571	37.098	58.64	0.24421	0.13896
35	% Stoneflies (Transformed)	118.219	66.996	76.623	303.95	0.25638	0.68192
36	Hydropyschidae/Trichoptera	77.084	45.038	44.893	140.18	0.27039	0.44558
37	% Caddisflies (Transformed)	69.912	39.967	42.723	87.05	0.34030	0.33855
38	% Predators (Trans.)	76.685	40.542	39.575	77.05	0.41834	0.50602

39	% Beetles	170.650	116.421	126.161	212.81	0.50324	0.67572
40	Number of Diptera Taxa	46.685	36.343	49.383	24.69	0.50934	0.00000
41	% Beetles (Transformed)	98.808	67.959	65.378	126.28	0.64729	0.76152
42	Number of Beetle Taxa	81.517	52.151	37.037	74.07	0.68380	1.35000
43	Number of Stonefly Taxa	113.178	67.617	74.074	148.15	0.69488	0.98844
44	Scrapers/Scrapers+Coll. Filt.	113.182	55.757	60.779	190.48	0.84466	1.01406
45	Simpson Diversity Index	30.378	11.456	7.857	17.58	0.86901	0.88239
46	% EPT(modified)	88.525	38.008	39.410	104.36	0.88461	0.70424
47	% EPT	68.198	28.158	24.371	84.59	0.88846	0.62322
48	% EPT (Transformed)	57.025	21.522	17.412	58.78	0.92408	0.57416
49	% Scrapers	145.096	75.656	74.978	232.77	0.96387	1.21100
50	Scrapers/Scrapers+Coll. Filt. (Trans.)	88.620	38.685	36.685	125.69	0.97425	0.87333
51	% Mayflies	140.824	54.794	52.934	377.15	0.97662	1.68709
52	EPT/EPT+Chironomidae (Trans.)	53.513	18.698	16.310	53.47	0.98630	0.65076
53	Scrapers/Scrapers+Coll.Gath+Coll.Filter	133.441	70.981	65.146	212.15	0.99613	1.35024
54	% Intolerant Taxa	62.772	27.965	27.447	72.35	0.99656	0.87709
55	%Haptobenthos-Hydropsychidae	69.135	25.871	24.083	95.80	1.00895	0.78214
56	EPT/EPT+Chironomidae	59.670	19.469	16.558	69.65	1.03219	0.63354
57	Number of Caddisfly Taxa	73.206	43.825	49.383	74.07	1.04278	0.67500
58	Modified EPT/(EPT+Chironomidae Abundanc	83.234	30.429	26.855	109.24	1.04839	0.71278
59	Scrapers/Scrapers+Collector-Gatherers	115.606	60.589	61.102	214.49	1.06618	1.22823
60	Haptobenthos/Haptobenthos+Herpobenthos	53.846	17.425	13.260	59.04	1.08285	0.68002
61	% Haptobenthos	55.619	17.692	13.512	66.34	1.09042	0.70500
62	HAP(H)/HAP(H)+HERP	61.884	19.863	16.977	82.81	1.16687	0.85967
63	Shannon H (log 2)	35.991	16.564	16.122	35.00	1.22536	1.16254
64	% Scrapers (Trans.)	92.034	44.877	40.244	133.05	1.22743	1.25997
65	% Mayflies (Transformed)	103.063	33.915	29.603	171.66	1.27699	1.60628
66	Taxa Richness	39.694	25.486	26.144	40.40	1.38460	1.35000
67	EPT Index	69.842	31.817	29.630	74.07	1.55417	1.55805
68	Number of Mayfly Taxa	98.009	32.744	37.037	222.22	1.66544	1.72092
69	No. Intolerant Taxa	54.268	29.817	34.188	56.98	1.67179	1.53651

Table 7. Metrics selected in each ecoregion using stepwise discriminant analysis to separate impact and reference sites.

Ecoregion=66, 11 impact and 35 reference sites

Step	Metric	Number entered	R square for metric	F statistic	p-value
1	Number of Intolerant Taxa	1	0.3251	21.197	0.0001
2	% Scraper transformed	2	0.1736	9.032	0.0044
3	Modified EPT	3	0.1172	5.574	0.0229
4	Baetidae/Ephemeroptera	4	0.0783	3.484	0.0691
5	Total Abundance	5	0.1034	4.615	0.0378
6	% Noninsect	6	0.0634	2.640	0.1122
7	# Stonefly Taxa	7	0.1581	7.139	0.0110
8	% Noninsect transformed	8	0.1114	4.639	0.0378
9 (removed)	Modified EPT	7	0.0228	0.863	0.3590
10	Scrapers/(Scrapers+Gathers+ Collecters)	8	0.1032	4.260	0.0461
11	HBI-Hydroosychidae-Chironomidae	9	0.0879	3.470	0.0707
12	# Caddisfly Taxa	10	0.0710	2.676	0.1108

Ecoregion=67, 28 impact sites, 60 reference sites

Step	Metric	Number entered	R square for metric	F statistic	p-value
1	# Mayfly Taxa	1	0.4462	69.279	0.0001
2	% Mayfly transformed	2	0.1030	9.759	0.0024
3	# Stonefly Taxa	3	0.1124	10.634	0.0016
4	% Collectors-Filters	4	0.0949	8.703	0.0041
5	% Mayfly	5	0.0480	4.132	0.0453
6	% Chironimid transformed	6	0.0675	5.863	0.0177
7	Hydroosychidae/Trichoptera	7	0.0800	6.957	0.0100
8	% Chironomid	8	0.0567	4.745	0.0324
9	Modified EPT	9	0.0463	3.785	0.0553
10	% Baetidae	10	0.0595	4.874	0.0302
11	# Tolerant Taxa	11	0.0454	3.618	0.0610
12 (removed)	% Chironimid	10	0.0083	0.633	0.4288
13	% Collector-Filter transformed	11	0.0518	4.155	0.0450
14	% Collector-Gatherers	12	0.0430	3.368	0.0704

Table 7 (continued)

Ecoregion=69, 23 impact sites, 25 reference sites

Step	Metric	Number entered	R square for metric	F statistic	p-value
1	# Intolerant Taxa	1	0.4093	31.877	0.0001
2	Haptobenthos/ (Haptobenthos+Herptobenthos)	2	0.1612	8.646	0.0052
3	% Stonefly	3	0.1697	8.992	0.0044
4	% True Flies transformed	4	0.1268	6.242	0.0164
5	Hydroosychidae/Trichoptera transformed	5	0.0695	3.139	0.0837
6	% Haptobenthos	6	0.1045	4.782	0.0345
7 (removed)	Haptobenthos/ (haptobenthos+herptobenthos)	5	0.0121	0.502	0.4825
8	Baetidae/Ephemeroptera trans.	6	0.0512	2.211	0.1447
9	# Beetle Taxa	7	0.0798	3.467	0.0700
10	Hydroosychidae/Trichoptera	8	0.1123	4.933	0.0322
11	% Noninsect	9	0.0659	2.682	0.1098
12 (removed)	% True Flies transformed	8	0.0009	0.035	0.8535
13	% Baetidae	9	0.0729	2.987	0.0921

Ecoregion=70, 6 impact sites, 7 reference sites

Step	Metric	Number in model	R square for metric	F statistic	p-value
1	% Haptobenthos	1	0.8478	61.284	0.0001
2	% Scrapers transformed	2	0.5390	11.691	0.0066
3	Scrapers/(Scrapers+Collector +gatherers)	3	0.5124	9.458	0.0132
4	Scrapers/(Scrapers+ Collectors) transformed	4	0.3757	4.814	0.0595
5	# Beetle Taxa	5	0.4481	5.684	0.0486
6	% Baetidae	6	0.6774	12.597	0.0121
7	% Predators	7	0.5078	5.158	0.0723
8	% Mayfly transformed	8	0.8141	17.522	0.0139
9	% Beetle transformed	9	0.9541	62.338	0.0042
10 (removed)	% Scrapers transformed	8	0.1097	0.370	0.5861
11	# True Fly Taxa	9	0.6697	6.082	0.0904

Table 8. List of ten best metrics selected for further investigation into the development of a multimetric index, with explanations and expected responses to perturbation in streams of Mid-Atlantic Highlands.

Category	Metric	Explanation	Expected Response To Perturbation
Richness	EPT Index	Number of mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) families	–
Richness	# Mayfly Taxa	Number of mayfly families	–
Composition	% EPT	Percent abundance of mayfly nymphs (Ephemeroptera), stonefly nymphs (Plecoptera) and caddisfly larvae and pupae (Trichoptera)	–
Composition	% Mayflies	Percent abundance of mayfly nymphs	–
Balance	% 5 Dominant Taxa	Percent abundance of the 5 most abundant taxa combined	+
Balance	Simpson Diversity Index	Integrates richness and evenness into a measure of general diversity	–
Tolerance	# Intolerant Taxa	Number of macroinvertebrate families with tolerance values of 5 or less	-
Tolerance	HBI (Hilsenhoff Biotic Index)	Weighted sum of total taxa by pollution tolerance	+
Trophic	% Scrapers	Percent abundance of macroinvertebrates scraping and feeding upon periphyton	–
Habit	% Haptobenthos	Percent abundance of macroinvertebrates requiring clean, coarse, firm substrates	–

Table 9. Classification rates ecoregions using a separate set of metrics for each ecoregion and the set of ten metrics. The classification rule was linear with equal priors. Misclass. refers to the number or (proportion) misclassified; Cross. miss. is the number or (proportion) misclassified using the crossvalidation method. Sample sizes for reference and impact are given below the ecoregion

Separate Analyses							
Region	Metrics	Reference Misclass	Impact Misclass	Total Misclass	Reference Cross. Miss.	Impact Cross. Miss.	Total Cross. Miss.
66 (35R) (11I)	# Intolerant Taxa % Scraper Transformed Modified EPT Baetidae/ Ephemeroptera Total Abundance % Noninsect	1 (0.028)	1 (0.091)	2 (0.044)	4 (0.114)	5 (0.455)	9 (0.196)
67 (60R) (28I)	# Mayfly Taxa % Mayfly (tr) # Stonefly Taxa % Collector Filters % Mayfly % Chironimids (tr)	5 (0.0833)	4 (0.1438)	9 (0.102)	5 (0.083)	4 (0.143)	9 (0.102)
69 (25R) (23I)	# Intolerant Taxa Haptobenthos/(Haptobenthos + Herptobenthos) % Stonefly % True Flies (tr) Hydropyschidae/ Trichoptera (tr) % Haptobenthos	1 (0.0400)	2 (0.087)	3 (0.063)	5 (0.200)	2 (0.087)	7 (0.146)
70 (7R) (6I)	% Haptobenthos % Scraper (tr) Scrapers/ (Scrapers+Collector Gathers) Scrapers/ (Scrapers + Collector Filterers)	0	0	0	0	0 (0.0)	0 (0.00)
totals		7 (0.0551)	7 (0.103)	14 (0.072)	14 (0.110)	11 (0.162)	25 (0.128)
Best 10 metrics							
66		3 (0.085)	3 (0.273)	6 (0.130)	6 (0.171)	5 (0.455)	11 (0.239)
67		6 (0.100)	2 (0.071)	8 (0.091)	8 (0.133)	6 (0.214)	14 (0.159)
69		2 (0.080)	2 (0.087)	4 (0.083)	5 (0.200)	4 (0.174)	9 (0.188)
70		0	0	0	4 (0.571)	1 (0.167)	5 (0.385)
totals		11 (0.087)	7 (0.103)	18 (0.091)	23 (0.181)	16 (0.235)	39 (0.200)

Table 10. Selection of variables separating reference site subregions using stepwise selection without 67A and 70X.

Step	Metric Entered	Partial R-square	F Statistic	p-value
1	EPT Index	0.3857	9.73	0.0001
2	# Stonefly Taxa	0.2644	5.54	0.0001
3	Hydropsychidae/Trichoptera (tr)	0.1823	3.42	0.0002
4	% Scrapers	0.1753	3.24	0.0003
5	% Beetles (tr)	0.2361	4.68	0.0001
6	% Stoneflies (tr)	0.1700	3.09	0.0005
7	% Caddisflies (tr)	0.1809	3.31	0.0002
8	% Beetles	0.1493	2.62	0.0031
9	% Noninsects	0.1381	2.38	0.0073
10	Baetidae/Ephemeroptera (tr)	0.1307	2.22	0.0127

Table 11. Number of misclassified sites for (a) clusters from canonical variate analysis and (b) metric scaling for various sets of metrics. Freq is the number of sites for each cluster, crossv refers to the crossvalidation method for predicting misclassifications.

a. Clusters from canonical variate analysis

Using % Mayflies (tr), HBI, % Stoneflies, % EPT

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	118	13	7	20	0.169	15	8	23	0.194
2	81	10	4	14	0.172	11	6	17	0.209
3	15	1	1	2	0.133	3	2	5	0.333
4	7	0	1	1	0.142	1	2	3	0.428
totals	221	24	13	37	0.167	30	18	48	0.217

Using EPT, % EPT, % Mayfliies, % 5 Dominant Taxa, HBI, % Scrapers, # Mayfly Taxa, Simpson, % Intolerant, % Haptobenthos

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	118	7	5	12	0.101	9	10	19	0.161
2	81	8	2	10	0.123	11	4	15	0.185
3	15	1	0	1	0.066	3	3	6	0.400
4	7	0	0	0	0.000	1	0	1	0.142
totals	221	16	7	23	0.104	24	17	41	0.185

Using EPT, % Scrapers (tr), HBI, % Haptobenthos, # Intolerant Taxa

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	118	11	5	16	0.135	12	6	18	0.152
2	81	6	3	9	0.111	7	5	12	0.148
3	15	0	0	0	0.000	5	0	5	0.333
4	7	0	0	0	0.000	1	0	1	0.142
totals	221	17	8	25	0.113	25	11	36	0.162

b. Clusters based on metric scaling analysis

Using EPT, # Mayfly Taxa, Simpson

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	142	15	10	25	0.176	16	10	26	0.183
2	57	5	4	9	0.157	5	6	11	0.192
3	7	0	0	0	0.000	1	0	1	0.142
4	15	2	1	3	0.200	3	2	5	0.333
totals	4	22	15	37	0.167	25	18	43	0.194

Using EPT, % Scrapers (tr), HBI, % Haptobenthos, # Intolerant Taxa

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	142	13	5	18	0.126	15-	7	22	0.154
2	57	5	1	6	0.105	5	5	10	0.175
3	7	0	0	0	0.000	1	0	1	0.142
4	15	0	0	0	0.000	5	0	5	0.333
totals	221	18	6	24	0.108	26	12	38	0.171

Using # Intolerant Taxa, % Mayflies (tr), % Macrophyte-Piercers (tr), HBI-Hydropsychidae+Chironomidae, % Stoneflies, Haptobenthos/(Haptobenthos+Herpobenthos), % EPT, HBI-Chironomidae % Haptobenthos

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	142	10	7	17	0.119	13	10	23	0.161
2	57	0	6	6	0.105	0	8	8	0.140
3	7	0	0	0	0.000	1	0	1	0.142
4	15	1	0	1	0.066	3	3	6	0.400
totals	221	11	13	24	0.108	17	21	38	0.171

Using # Mayfly Taxa, # Intolerant Taxa, % Mayflies (tr), % Macrophyte-Piercers (tr), % Stoneflies, %Haptobenthos-Hydropsychidae, % EPT, HBI-Chironomidae, % Haptobenthos

Cluster	Freq	Misclass Ref	Misclass Impact	Misclass Total	%Misclas Total	Crossv R	Crossv I	Crossv Total	%Crossv Total
1	142	9	5	14	0.098	13	9	22	0.154
2	57	0	5	5	0.087	0	8	8	0.140
3	7	0	0	0	0.000	1	0	1	0.142
4	15	0	0	0	0.000	2	4	6	0.400
totals	221	9	10	19	0.085	16	21	37	0.167

Table 12. Methods for assigning scores to metrics. RQ1 is the reference lower quartile, IQR is the interquartile range, RF1 is the reference fence (values less than zero are set to 0.1), IQ3 is the impact lower quartile and RQ3 is the reference upper quartile.

	Score			
Method	0	1	2	3
1	≤0.5*RQ1	between 0.5*RQ1 and RQ1	>RQ1	
2	≤RF1	between RF1 and IQ3	>IQ3	
3	≤IQ1	>IQ1, ≤max(RQ1,IQ3)	>IQ3	
4	(metric-Impact min)/(Reference max - Impact min)			
5	≤RF1	between RF1 and IQ1	between IQ1 and RQ3	>RQ3
6	≤RF1	between RF1 and RQ1	between RQ1 and RQ3	>RQ3

Table 13. Quantiles for relevant metrics for impact and reference sites. I=impact, R=reference, Q1=lower quantile, Q3=upper quantile, F1=lower fence. HBI and % 5 most dominant taxa were adjusted to make the metrics comparable with others (reference sites have high scores, impact sites have low scores).

Metric	IQ1	I Median	IQ3	RF1(adj)	RF1	RQ1	R Median	RQ3
EPT Index	2	5	7	0	2	8	10	12
% EPT	10.71	47.24	64.65	9.85	20.25	51.43	63.19	72.22
% 5 DominantTaxa (less 100)	-95.82	-89.29	-79.13	-104.39	-104.39	-83.18	-77.45	-69.04
HBI (negative of)	-5.75	-5.16	-4.22	-5.9	-5.56	-4.54	-4.18	-3.86
# Mayfly Taxa	0	1	3	0	0	3	4	5
% Intolerant	19.50	43.57	62.06	5.30	17.07	52.35	63.49	75.88
% Haptobenthos	24.35	65.79	83.26	44.31	51.98	75	84.11	90.34
% Mayflies	0	3.44	17.51	0.1	0.1	17.86	26.7	36.94
% Mayflies (Transformed)	0	0.19	0.43	.0022	0.11	0.44	0.543	0.65
# Intolerant Taxa	4	6.5	9	1	1	10	13	16
% Stoneflies	0	1.04	16.46	0.1	0.1	1.82	6.94	15.96
% Scrapers	0	3.41	10.7	0.1	0.1	10.07	18.03	28.32
% Scrapers (Transformed)	0	0.19	0.33	0.1	0.1	0.32	0.44	0.56
Haptobenthos/[Haptobenthos+Herpobenthos]	0.16	0.57	0.81	0.33	0.42	0.70	0.82	0.89
% Non-Insects	0	2.63	15.64	0.1	0.1	0.52	1.26	3.09
Simpson Diversity Index	0.64	0.76	0.82	0.61	0.66	0.79	0.84	0.88
# Stonefly Taxa	0	1	2	0.1	0.1	1	3	4

Table 14. Cutoffs for assigning scores for three different methods.

Method 1.

metric	0	1	2
EPT	≤4	>4	>8
% EPT	≤20.5	>20.5	>51
% 5 most dominant	≥91.5	<91.5	<83
HBI	≥5.56	<5.56	<4.5
#mayfly	≤1.5	>1.5	>3
% haptobenthos	≤37.5	>37.5	>75
% mayfly	≤8.9	>8.9	>17.8
#intolerant	≤5	>5	>10
% scraper	≤5	>5	>10
Simpson	≤0.39	>0.39	>0.78

Method 2.

metric	0	1	2
EPT	≤2	>2	>7
% EPT	≤20.25	>20.25	>64.65
% 5 most dominant	≥100	<100	<79.13
HBI	≥5.56	<5.56	<4.22
#mayfly	≤0	>0	>3
% haptobenthos	≤51.98	>51.98	>83.26
% mayfly	≤0.1	>0.1	>17.52
#intolerant	≤1	>1	>9
% scraper	≤0.1	>0.1	>10.7
Simpson	≤0.66	>0.656	>0.823

Table 14. Continued

Method 3.

metric	0	1	2
EPT	≤2	>2	>8
% EPT	≤10.71	>10.71	>64.65
% 5 most dominant	≥95.82	<95.82	<79.13
HBI	≥5.75	<5.75	<4.22
#mayfly	≤0	>0	>3
% haptobenthos	≤24.35	>24.35	>83.27
% mayfly	≤0	>0	>17.86
#intolerant	≤4	>4	>10
% scraper	≤0	>0	>10.7
Simpson	≤0.642	>0.642	>0.823

Table 15. Summary of classification results for four multimetrics with four different standardization methods for the primary ecoregions. Values reported are percentages misclassified for total (T), reference (R) and impact (I); precentages misclassified using crossvalidation (labeled CV) and the number of misclasifications.

Multimetric Index	Standardization Method	Ecoregion	%MissT	%MissR	%MissI	%CVMissT	%CVMissR	%CVMissI	TotalR	TotalI	MissR	MissI	CVMissR	CVMissI
MM1 (5 metrics)	1	66	0.239	0.200	0.364	0.239	0.200	0.364	35	11	7	4	7	4
		67	0.114	0.050	0.250	0.114	0.050	0.250	60	28	3	7	3	7
		69	0.167	0.080	0.261	0.167	0.080	0.261	25	23	2	6	2	6
		70	0.077	0.143	0.000	0.077	0.143	0.000	7	6	1	0	1	0
	2	66	0.239	0.200	0.364	0.239	0.200	0.364	35	11	7	4	7	4
		67	0.114	0.050	0.250	0.114	0.050	0.250	60	28	3	7	3	7
		69	0.167	0.120	0.217	0.167	0.120	0.217	25	23	3	5	3	5
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	3	66	0.239	0.200	0.364	0.239	0.200	0.364	35	11	7	4	7	4
		67	0.136	0.050	0.321	0.136	0.050	0.321	60	28	3	9	3	9
		69	0.167	0.120	0.217	0.167	0.120	0.217	25	23	3	5	3	5
		70	0.000	0.000	0.000	0.077	0.143	0.000	7	6	0	0	1	0
	4	66	0.174	0.143	0.273	0.174	0.143	0.273	35	11	5	3	5	3
		67	0.125	0.067	0.250	0.125	0.067	0.250	60	28	4	7	4	7
		69	0.167	0.080	0.261	0.167	0.080	0.261	25	23	2	6	2	6
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
MM5 (5 metrics)	1	66	0.239	0.171	0.455	0.239	0.171	0.455	35	11	6	5	6	5
		67	0.159	0.050	0.393	0.159	0.050	0.393	60	28	3	11	3	11
		69	0.271	0.240	0.304	0.271	0.240	0.304	25	23	6	7	6	7
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	2	66	0.283	0.257	0.364	0.283	0.257	0.364	35	11	9	4	9	4
		67	0.136	0.067	0.286	0.136	0.067	0.286	60	28	4	8	4	8
		69	0.250	0.280	0.217	0.250	0.280	0.217	25	23	7	5	7	5
		70	0.077	0.143	0.000	0.077	0.143	0.000	7	6	1	0	1	0
	3	66	0.283	0.257	0.364	0.283	0.257	0.364	35	11	9	4	9	4
		67	0.136	0.067	0.286	0.136	0.067	0.286	60	28	4	8	4	8
		69	0.250	0.280	0.217	0.250	0.280	0.217	25	23	7	5	7	5
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	4	66	0.217	0.171	0.364	0.217	0.171	0.364	35	11	6	4	6	4
		67	0.125	0.067	0.250	0.125	0.067	0.250	60	28	4	7	4	7
		69	0.167	0.160	0.174	0.167	0.160	0.174	25	23	4	4	4	4
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0

MM8 (6 metrics)	1	66	0.239	0.143	0.545	0.239	0.143	0.545	35	11	5	6	5	6
		67	0.114	0.033	0.286	0.114	0.033	0.286	60	28	2	8	2	8
		69	0.208	0.160	0.261	0.208	0.160	0.261	25	23	4	6	4	6
		70	0.077	0.143	0.000	0.077	0.143	0.000	7	6	1	0	1	0
	2	66	0.174	0.114	0.364	0.174	0.114	0.364	35	11	4	4	4	4
		67	0.125	0.050	0.286	0.125	0.050	0.286	60	28	3	8	3	8
		69	0.146	0.080	0.217	0.146	0.080	0.217	25	23	2	5	2	5
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	3	66	0.217	0.143	0.455	0.217	0.143	0.455	35	11	5	5	5	5
		67	0.125	0.050	0.286	0.125	0.050	0.286	60	28	3	8	3	8
		69	0.146	0.080	0.217	0.146	0.080	0.217	25	23	2	5	2	5
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	4	66	0.196	0.171	0.273	0.196	0.171	0.273	35	11	6	3	6	3
		67	0.114	0.067	0.214	0.114	0.067	0.214	60	28	4	6	4	6
		69	0.229	0.200	0.261	0.229	0.200	0.261	25	23	5	6	5	6
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
MM10(10 metrics)	1	66	0.239	0.143	0.545	0.239	0.143	0.545	35	11	5	6	5	6
		67	0.091	0.033	0.214	0.091	0.033	0.214	60	28	2	6	2	6
		69	0.208	0.160	0.261	0.208	0.160	0.261	25	23	4	6	4	6
		70	0.077	0.143	0.000	0.077	0.143	0.000	7	6	1	0	1	0
	2	66	0.283	0.257	0.364	0.283	0.257	0.364	35	11	9	4	9	4
		67	0.114	0.050	0.250	0.114	0.050	0.250	60	28	3	7	3	7
		69	0.188	0.160	0.217	0.188	0.160	0.217	25	23	4	5	4	5
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	3	66	0.239	0.200	0.364	0.239	0.200	0.364	35	11	7	4	7	4
		67	0.114	0.033	0.286	0.114	0.033	0.286	60	28	2	8	2	8
		69	0.188	0.160	0.217	0.188	0.160	0.217	25	23	4	5	4	5
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	4	66	0.261	0.229	0.364	0.261	0.229	0.364	35	11	8	4	8	4
		67	0.125	0.067	0.250	0.136	0.067	0.286	60	28	4	7	4	8
		69	0.250	0.240	0.261	0.250	0.240	0.261	25	23	6	6	6	6
		70	0.077	0.143	0.000	0.077	0.143	0.000	7	6	1	0	1	0

MM11 (9metrics)	1	66	0.217	0.114	0.545	0.217	0.114	0.545	35	11	4	6	4	6
		67	0.102	0.033	0.250	0.102	0.033	0.250	60	28	2	7	2	7
		69	0.208	0.200	0.217	0.208	0.200	0.217	25	23	5	5	5	5
		70	0.077	0.143	0.000	0.077	0.143	0.000	7	6	1	0	1	0
	2	66	0.283	0.229	0.455	0.283	0.229	0.455	35	11	8	5	8	5
		67	0.102	0.050	0.214	0.102	0.050	0.214	60	28	3	6	3	6
		69	0.208	0.240	0.174	0.208	0.240	0.174	25	23	6	4	6	4
		70	0.000	0.000	0.000	0.000	0.000	0.000	7	6	0	0	0	0
	3	66	0.261	0.200	0.455	0.261	0.200	0.455	35	11	7	5	7	5
		67	0.114	0.033	0.286	0.114	0.033	0.286	60	28	2	8	2	8
		69	0.188	0.160	0.217	0.188	0.160	0.217	25	23	4	5	4	5
		70	0.000	0.000	0.000	0.077	0.143	0.000	7	6	0	0	1	0
	4	66	0.261	0.200	0.455	0.261	0.200	0.455	35	11	7	5	7	5
		67	0.125	0.067	0.250	0.125	0.067	0.250	60	28	4	7	4	7
		69	0.188	0.160	0.217	0.208	0.160	0.261	25	23	4	5	4	6
		70	0.077	0.143	0.000	0.154	0.143	0.167	7	6	1	0	1	1

Table 16. Criteria for selecting categories for classification of sites.

Category	Very Good	Good	Fair	Poor
Criteria	≥ RQ3	> average of impact mean and reference mean, <RQ3	≤ average of impact mean and reference mean, > IQ1	≤ impact Q1

Table 17. Classification using method 1. Value are proportions. For Vgood, proportions indicate sites with index greater than or equal to the cutoff (third quartile for reference), for good, the index is greater than or equal to the mean of the reference and impact sites but less than RQ3, for fair, the value is smaller than the mean of the means and greater than the impact first quartile; fair is less than or equal to the impact first quartile.

MM8

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.00	0.455	0.182	0.273
66	R	0.571	0.286	0.143	0.000
cutoff		≥12	>9.8	<9.8	≤5
67	I	0.036	0.250	0.463	0.250
67	R	0.483	0.483	0.017	0.017
cutoff		≥11	>7.7	<7.7	≤2
69	I	0.00	0.261	0.478	0.261
69	R	0.280	0.560	0.160	0.000
cutoff		≥11	>6.9	<6.9	≤2
70	I	0.000	0.000	0.500	0.500
70	R	0.286	0.571	0.143	0.000
cutoff		≥10	>4.12	<4.12	≤0
total	I	0.029	0.264	0.426	0.279
total	R	0.456	0.449	0.087	0.008

MM10

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.000	0.545	0.182	0.273
66	R	0.371	0.486	0.143	0.000
cutoff		≥20	>16.5	<16.5	≤9
67	I	0.036	0.178	0.536	0.250
67	R	0.367	0.600	0.017	0.017
cutoff		≥19	>13.0	<13.0	≤3.5
69	I	0.087	0.174	0.478	0.261
69	R	0.360	0.480	0.160	0.000
cutoff		≥17	>11.7	<11.7	≤4
70	I	0.000	0.000	0.667	0.333
70	R	0.286	0.571	0.143	0.000
cutoff		≥16	>6.7	<6.7	≤0
total	I	0.044	0.221	0.471	0.265
total	R	0.362	0.543	0.086	0.008

Table 17 (continued)

MM11

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.000	0.545	0.182	0.273
66	R	0.371	0.514	0.114	0.000
cutoff		≥18	>14.57	<14.57	≤7
67	I	0.036	0.214	0.500	0.250
67	R	0.383	0.583	0.033	0.017
cutoff		≥17	>11.65	<11.65	≤3.5
69	I	0.043	0.174	0.522	0.261
69	R	0.320	0.480	0.200	0.000
cutoff		≥16	>10.26	<10.26	≤3
70	I	0.000	0.000	0.667	0.333
70	R	0.286	0.571	0.143	0.000
cutoff		≥15	>6.02	<6.02	≤0
total	I	0.029	0.235	0.471	0.265
total	R	0.362	0.543	0.087	0.008

Table 18. Classification of impact and reference sites using Method 2 multimetrics. Cutoff indicates the lower value which results in site receiving that classification (e.g. fair for ecoregion 66 and MM8 ranges from < 9.8 to > 6).

MM8

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.091	0.273	0.365	0.273
66	R	0.457	0.429	0.114	0.00
66	cutoff	≥12.0	>9.80	<9.8	≤6.0
67	I	0.036	0.250	0.500	0.214
67	R	0.567	0.383	0.033	0.167
67	cutoff	≥11.0	>7.9	<7.9	≤3
69	I	0.043	0.174	0.435	0.348
69	R	0.320	0.600	0.080	0.00
69	cutoff	≥11.0	>6.93	<6.93	≤4
70	I	0.00	0.00	0.500	0.500
70	R	0.429	0.571	0.00	0.00
70	cutoff	≥10.0	>6.0	≤6.0	≤0
total	I	0.044	0.206	0.456	0.294
total	R	0.480	0.449	0.063	0.008

MM10

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.182	0.182	0.364	0.273
66	R	0.429	0.314	0.257	0.000
66	cutoff	≥ 19.0	> 16.11	< 16.11	≤ 11
67	I	0.000	0.250	0.500	0.250
67	R	0.250	0.700	0.033	0.017
67	cutoff	≥ 18.5	> 12.9	< 12.9	≤ 5.5
69	I	0.0870	0.130	0.522	0.261
69	R	0.320	0.520	0.160	0.00
69	cutoff	≥ 17.0	> 12.5	< 12.5	≤7
70	I	0.00	0.00	1.00	0.00
70	R	0.286	0.714	0.00	0.00
70	cutoff	≥ 16.0	> 7.6	< 7.6	≤0
total	I	0.059	0.176	0.529	0.235
total	R	0.314	0.559	0.118	0.008

MM11

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.000	0.455	0.273	0.273
66	R	0.257	0.514	0.229	0.000
66	cutoff	≥ 18.0	> 14.5	< 14.5	≤ 9
67	I	0.000	0.214	0.607	0.179
67	R	0.317	0.633	0.033	0.0167
67	cutoff	≥ 17.0	> 11.7	< 11.7	≤ 6
69	I	0.043	0.130	0.565	0.261
69	R	0.320	0.440	0.240	0.000
69	cutoff	≥ 16.0	> 11.28	< 11.28	≤ 5
70	I	0.000	0.000	0.667	0.333
70	R	0.286	0.714	0.000	0.000
70	cutoff	≥ 15.0	> 7.1	< 7.1	≤ 1
total	I	0.0148	0.206	0.544	0.235
total	R	0.299	0.567	0.126	0.008

Table 19. Classification of impact and reference sites using Method 3 multimetrics. Cutoffs define a range of values for the criteria (for exampe, for ecoregion 66 and multimetric 8, fair lies between 9.8 and 6).

MM8

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.273	0.091	0.364	0.273
66	R	0.457	0.343	0.200	0.000
cutoffs		≥ 12	> 9.8	< 9.8	≤ 6
67	I	0.00	0.286	0.500	0.214
67	R	0.433	0.533	0.017	0.017
cutoffs		≥ 11	> 7.8	< 7.8	≤ 3
69	I	0.130	0.087	0.478	0.304
69	R	0.400	0.440	0.160	0.00
cutoffs		≥ 11	> 7.6	, 7.6	≤ 4
70	I	0.00	0.00	0.500	0.500
70	R	0.429	0.571	0.00	0.00
cutoffs		≥10	> 4.4	< 4.4	≤0
total	I	0.097	0.177	0.468	0.258
total	R	0.433	0.458	0.100	0.008

MM10

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.273	0.091	0.364	0.273
66	R	0.457	0.343	0.200	0.00
cutoff		≥ 19	> 16.2	< 16.2	≤ 10
67	I	0.00	0.286	0.500	0.214
67	R	0.433	0.533	0.017	0.017
cutoff		≥ 18	>12.9	< 12.9	≤ 5
69	I	0.130	0.087	0.478	0.304
69	R	0.400	0.440	0.160	0.00
cutoff		≥ 17	>12.6	< 12.6	≤ 6
70	I	0.00	0.00	0.667	0.333
70	R	0.429	0.571	0.00	0.00
cutoff		≥16	> 7.3	< 7.3	≤0
total	I	0.088	0.162	0.485	0.265
total	R	0.433	0.465	0.094	0.008

Table 19. continued.

MM11

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.00	0.455	0.273	0.273
66	R	0.314	0.486	0.200	0.00
cutoff		≥ 18	> 14.6	< 14.6	≤ 8
67	I	0.00	0.286	0.464	0.250
67	R	0.317	0.650	0.017	0.017
cutoff		≥ 17	> 11.8	< 11.8	≤ 4.5
69	I	0.043	0.174	0.478	0.304
69	R	0.320	0.520	0.160	0.00
cutoff		≥ 16	> 11.4	> 11.4	≤ 5
70	I	0.000	0.000	0.667	0.333
70	R	0.429	0.571	0.000	0.0
cutoff		≥ 15	> 6.7	< 6.7	≤ 0
total	I	0.015	0.250	0.456	0.279
total	R	0.323	0.575	0.094	0.008

Table 20. Classification of impact and reference sites using Method 4 multimetrics. Cutoffs define a range of values for the criteria (for exampe, for ecoregion 66 and multimetric 8, fair lies between 3.34 and 2.45).

MM8

Ecoregion	Status	Very Good	Good	Fair	Poor
66	I	0.000	0.273	0.455	0.273
66	R	0.257	0.571	0.171	0.000
cutoff		≥4.02	>3.34	<3.34	≤2.45
67	I	0.000	0.214	0.536	0.250
67	R	0.250	0.683	0.050	0.017
cutoff		≥3.86	>2.82	<2.82	≤1.32
69	I	0.043	0.217	0.478	0.261
69	R	0.240	0.560	0.200	0.000
cutoff		≥3.67	>2.76	<2.76	≤1.67
70	I	0.000	0.000	0.833	0.167
70	R	0.143	0.857	0.000	0.000
cutoff		≥3.24	>1.64	<1.64	≤0.05
total	I	0.015	0.206	0.529	0.250
total	R	0.244	0.638	0.110	0.008

MM10

ECOREG	STATUS	VGOOD	GOOD	FAIR	POOR
66	I	0.000	0.364	0.364	0.273
66	R	0.257	0.514	0.229	0.000
cutoff		≥6.64	>5.64	<5.64	≤4.03
67	I	0.000	0.250	0.464	0.250
67	R	0.250	0.683	0.050	0.017
cutoff		≥6.48	>4.70	<4.70	≤2.17
69	I	0.130	0.130	0.522	0.217
69	R	0.240	0.520	0.240	0.000
cutoff		≥5.82	>4.67	<4.67	≤2.74
70	I	0.000	0.000	0.667	0.333
70	R	0.286	0.714	0.000	0.000
cutoff		≥5.47	>2.88	<2.88	≤0.47
total	I	0.044	0.221	0.485	0.250
total	R	0.252	0.614	0.126	0.008

MMI1

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.000	0.455	0.273	0.273
66	R	0.229	0.571	0.200	0.000
cutoff		≥5.96	>4.95	<4.95	≤3.28
67	I	0.000	0.250	0.500	0.250
67	R	0.250	0.683	0.050	0.017
cutoff		≥5.80	>4.20	<4.20	≤2.10
69	I	0.087	0.130	0.522	0.261
69	R	0.240	0.600	0.160	0.000
cutoff		≥5.44	>3.99	<3.99	≤2.18
70	I	0.000	0.000	0.667	0.333
70	R	0.286	0.571	0.143	0.000
cutoff		≥4.97	>2.67	<2.67	≤0.47
total	I	0.029	0.221	0.485	0.264
total	R	0.244	0.630	0.118	0.008

Table 21. Classification of impact and reference sites using Method 2 multimetrics with cutoffs to improve classification in the impact regions.

MM8

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.091	0.273	0.364	0.273
66	R	0.457	0.429	0.114	0.000
66	cutoff	≥ 12.00	>9.950	>7.00	≤7.00
67	I	0.0357	0.107	0.571	0.286
67	R	0.5667	0.350	0.067	0.017
67	cutoff	≥ 11.00	>8.190	>4.00	≤4.00
69	I	0.044	0.174	0.391	0.391
69	R	0.320	0.600	0.080	0.000
69	cutoff	≥ 11.00	>7.98	>5.00	≤5.00
total	I	0.048	0.161	0.468	0.323
total	R	0.483	0.425	0.083	0.008

MM10

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.182	0.182	0.364	0.273
66	R	0.429	0.314	0.257	0.000
66	cutoff	≥ 19.00	>16.29	>12.00	≤12.00
67	I	0.0000	0.1429	0.571	0.286
67	R	0.4167	0.5000	0.0667	0.017
67	cutoff	≥ 18.00	>13.14	>6.00	≤6.00
69	I	0.087	0.130	0.438	0.348
69	R	0.320	0.520	0.1600	0.000
69	cutoff	≥ 17.00	>12.75	>7.00	≤7.00
total	I	0.065	0.145	0.484	0.306
total	R	0.400	0.450	0.142	0.008

MM11

Ecoregion	Status	VGOOD	GOOD	FAIR	POOR
66	I	0.000	0.455	0.273	0.273
66	R	0.257	0.514	0.229	0.000
66	cutoff	≥ 18.00	>14.63	>10.00	≤10.00
67	I	0.000	0.107	0.607	0.286
67	R	0.317	0.600	0.067	0.017
67	cutoff	≥ 17.00	>12.03	>6.00	≤6.00
69	I	0.044	0.130	0.435	0.391
69	R	0.320	0.440	0.240	0.000
69	cutoff	≥ 16.00	>11.52	>7.00	≤7.00
total	I	0.016	0.177	0.484	0.322
total	R	0.300	0.542	0.150	0.008

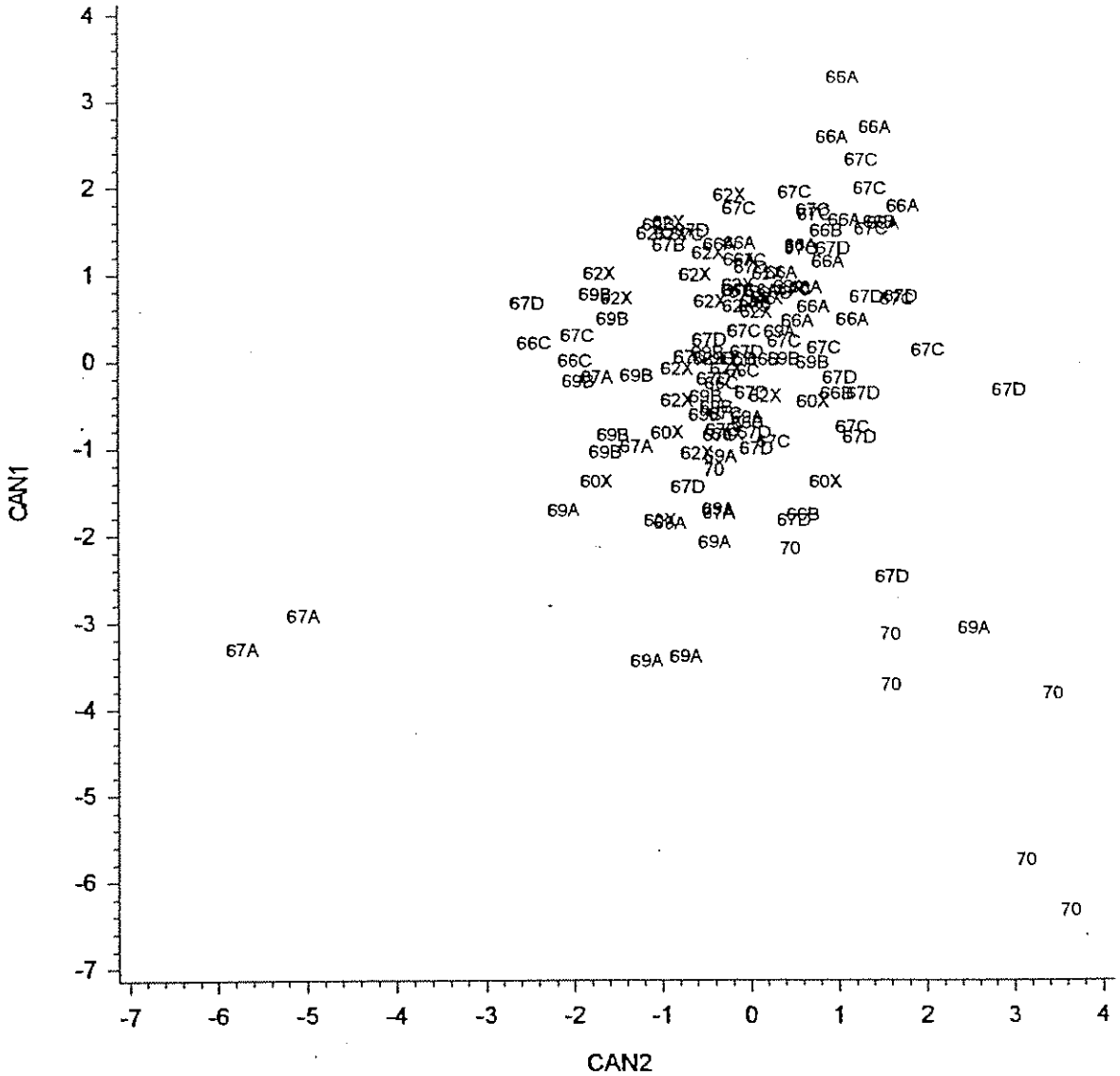


Figure 1. Plot of canonical scores for reference site data from subregions. Mixed subregions were omitted from the analysis.

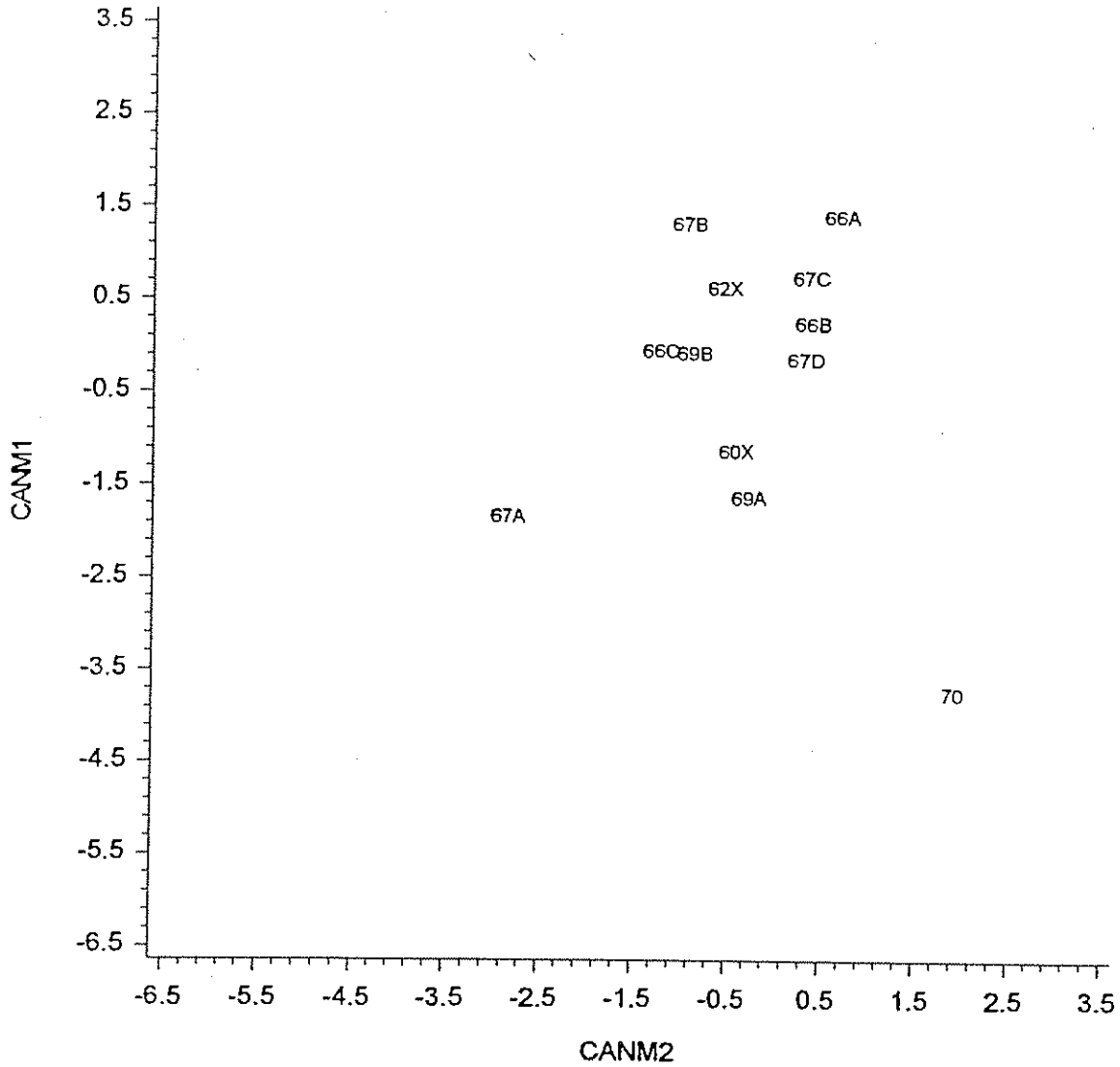


Figure 2. Plot of mean canonical scores for reference site data from subregions. Mixed subregions were omitted from the analysis.

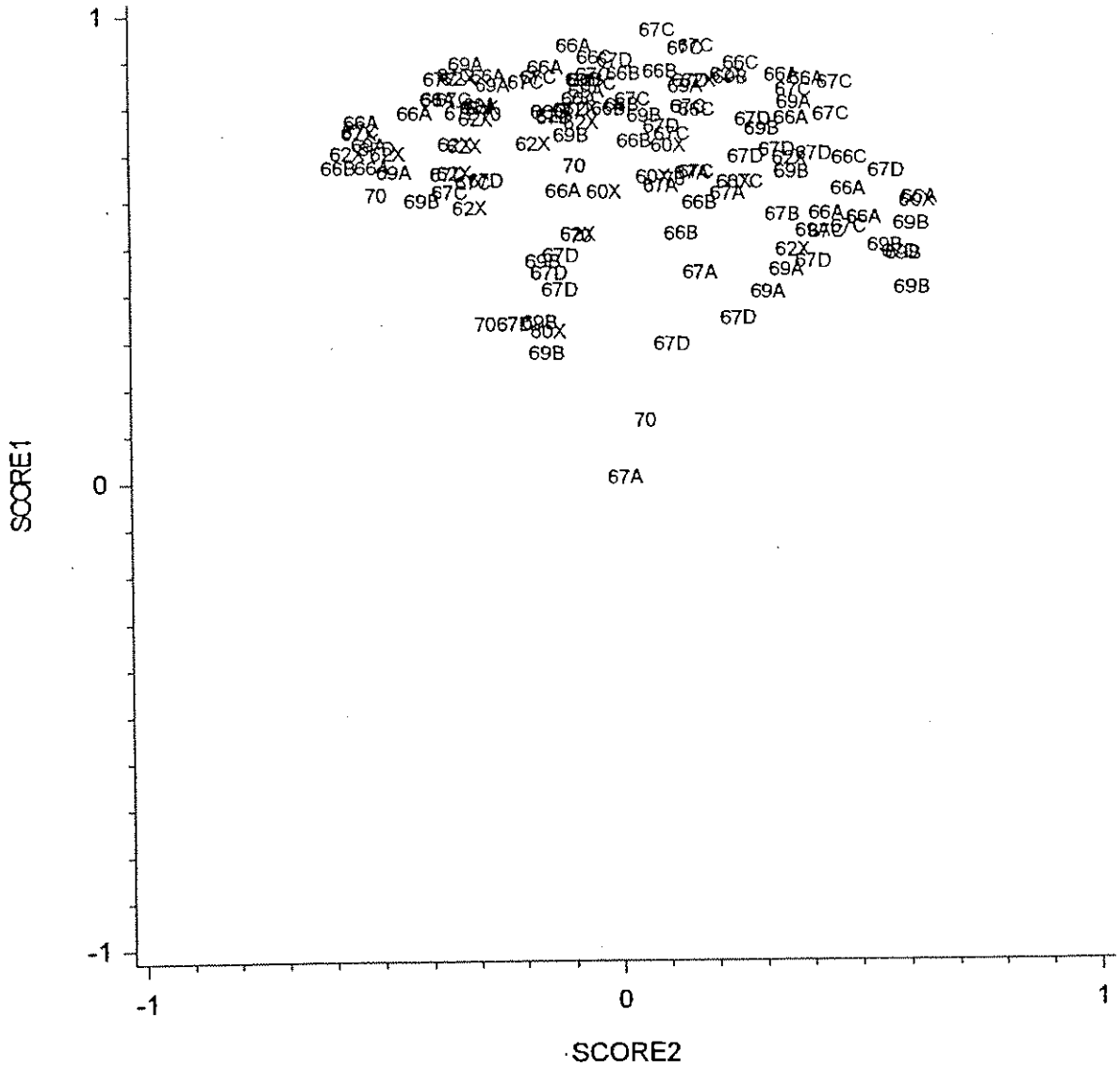


Figure 3. Plot of scores for first two components from metric scaling of cosine measure of similarity.

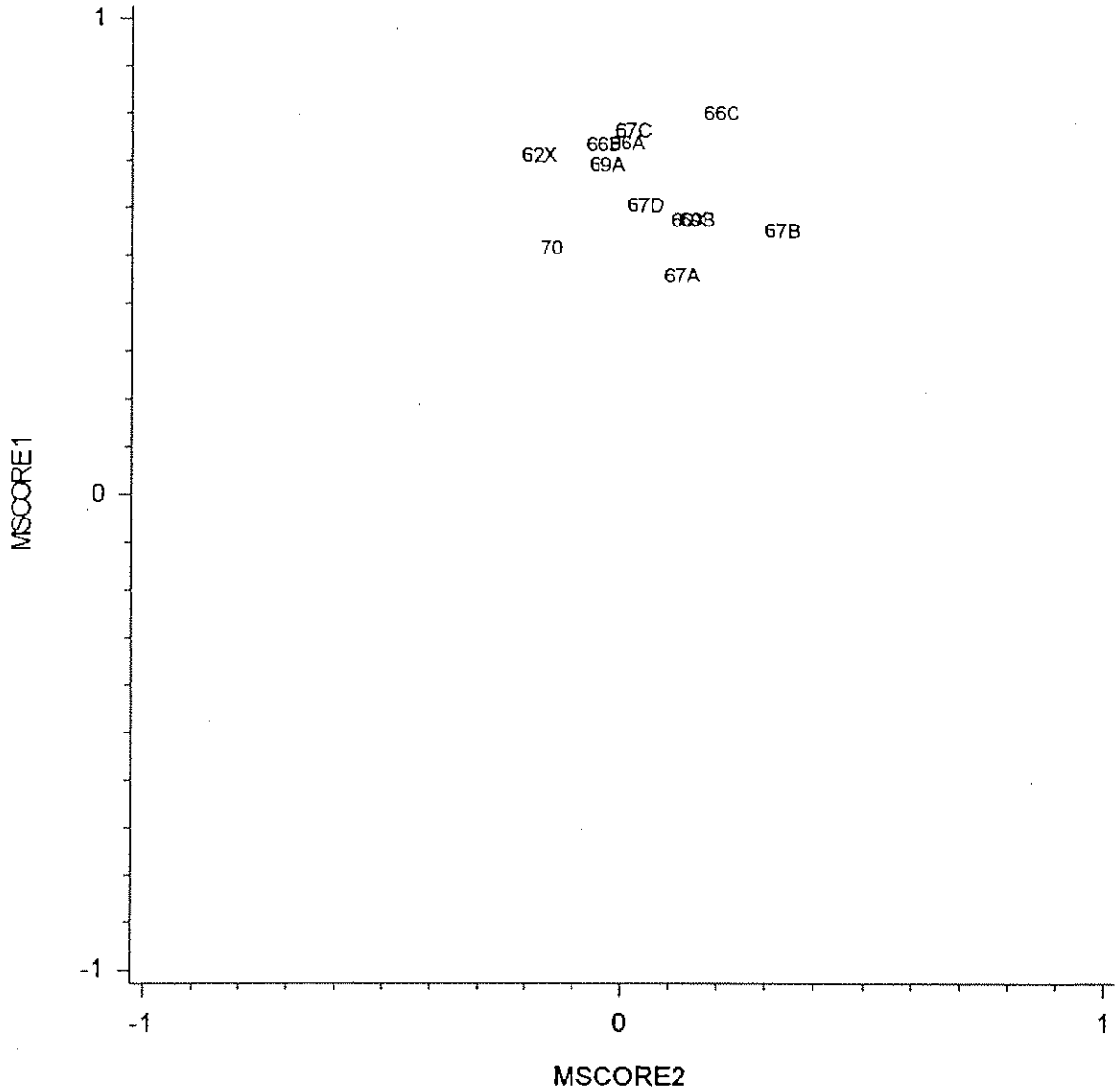
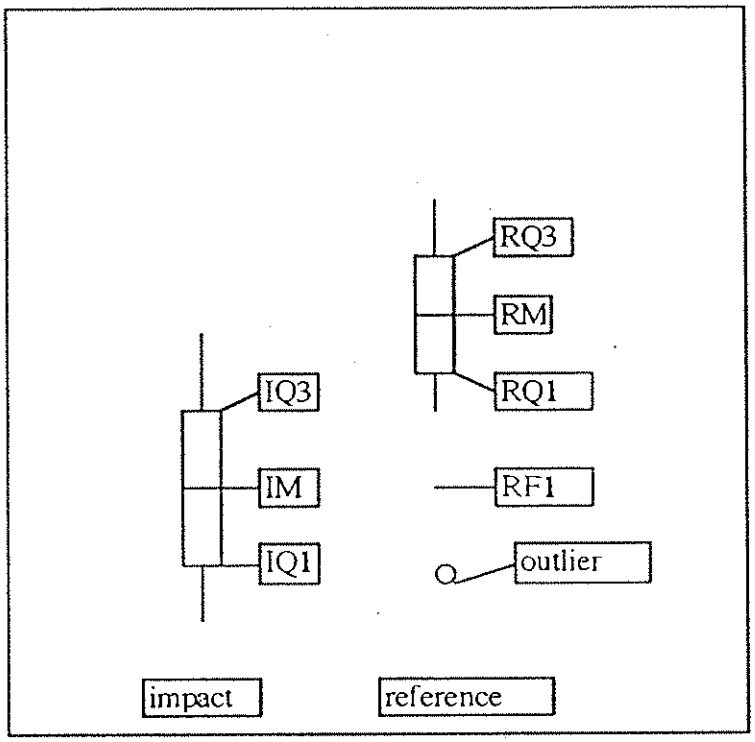


Figure 4. Plot of mean scores on first two components from metric scaling of cosine measure of similarity.

Figure 5. Illustration of boxplot summary measures for hypothetical impact and reference sites. IQ3 = Impact upper quartile; IM = Impact median; IQ1 = Impact lower quartile; RQ3 = Reference upper quartile; RM = Reference median; RQ1 = Reference lower quartile; RF1 = Reference adjusted fence (values less than 0 are set to 0.1) the fences are values which contain most of the observations if the data is normal; Outlier = Values in the reference or impact set which are extreme relative to a normal distribution (fall outside the fences).



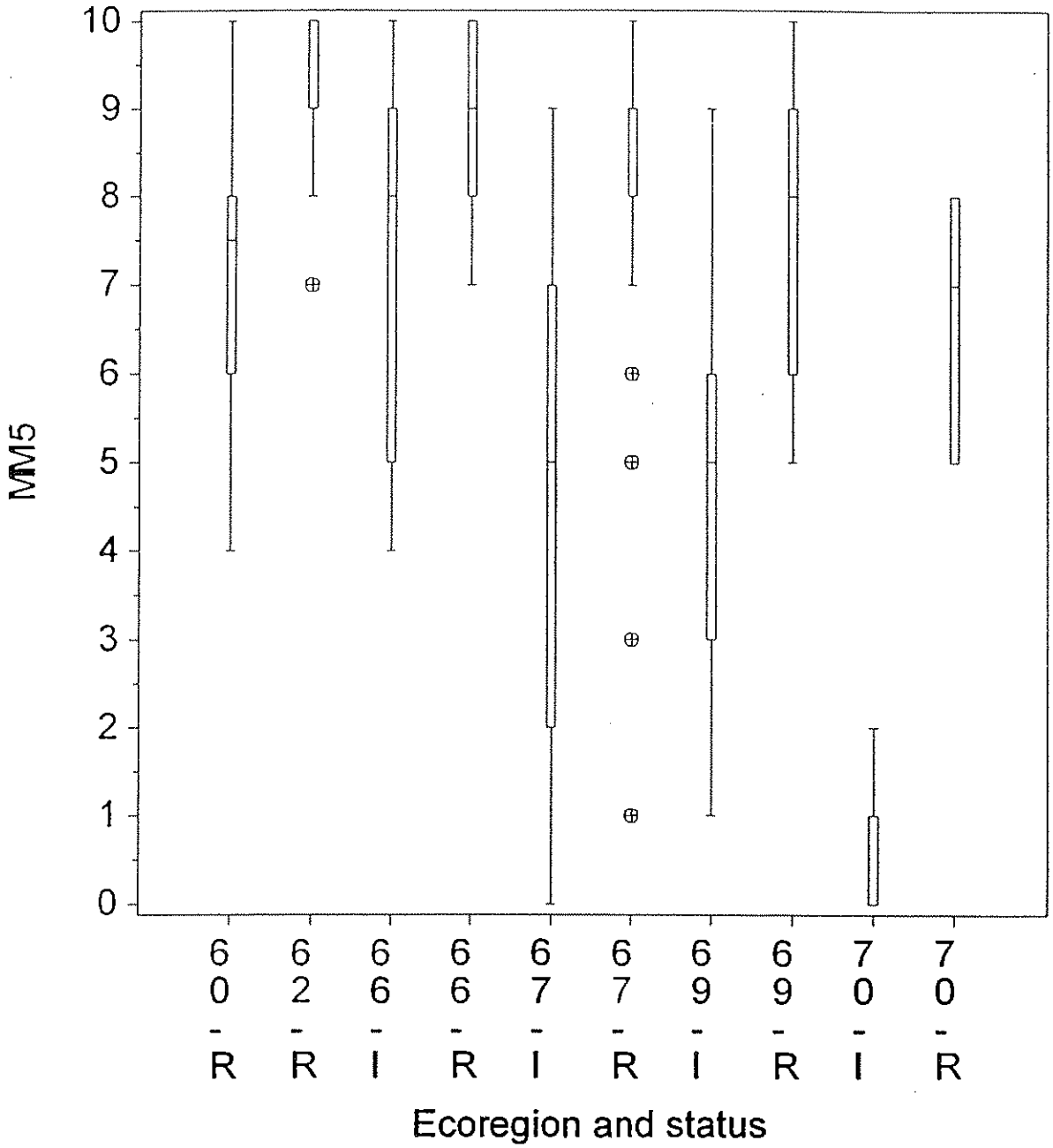


Figure 6. Boxplots of multimetric MM5 for method 3.

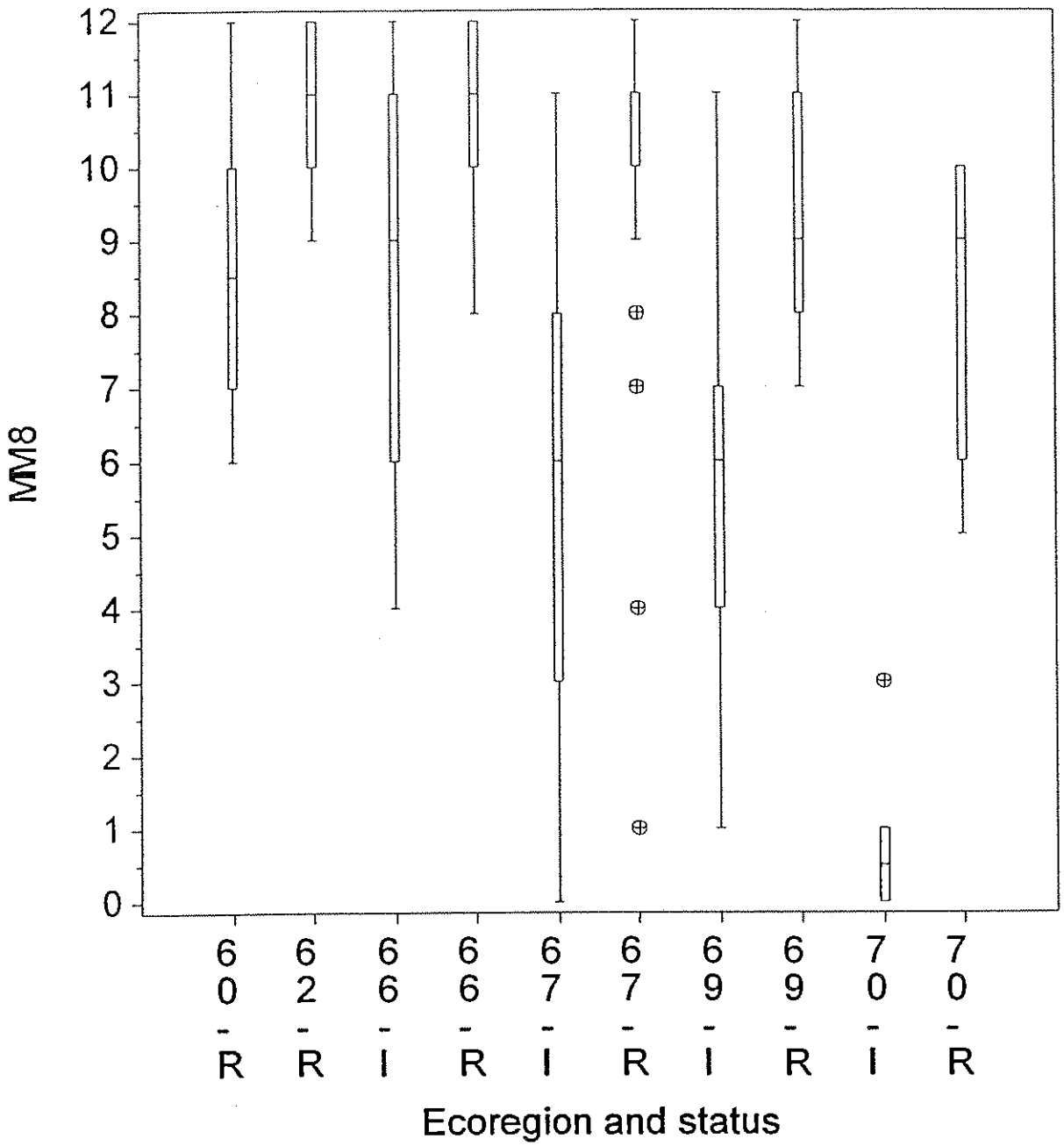


Figure 7. Boxplots of multimetric MM8 for method 3.

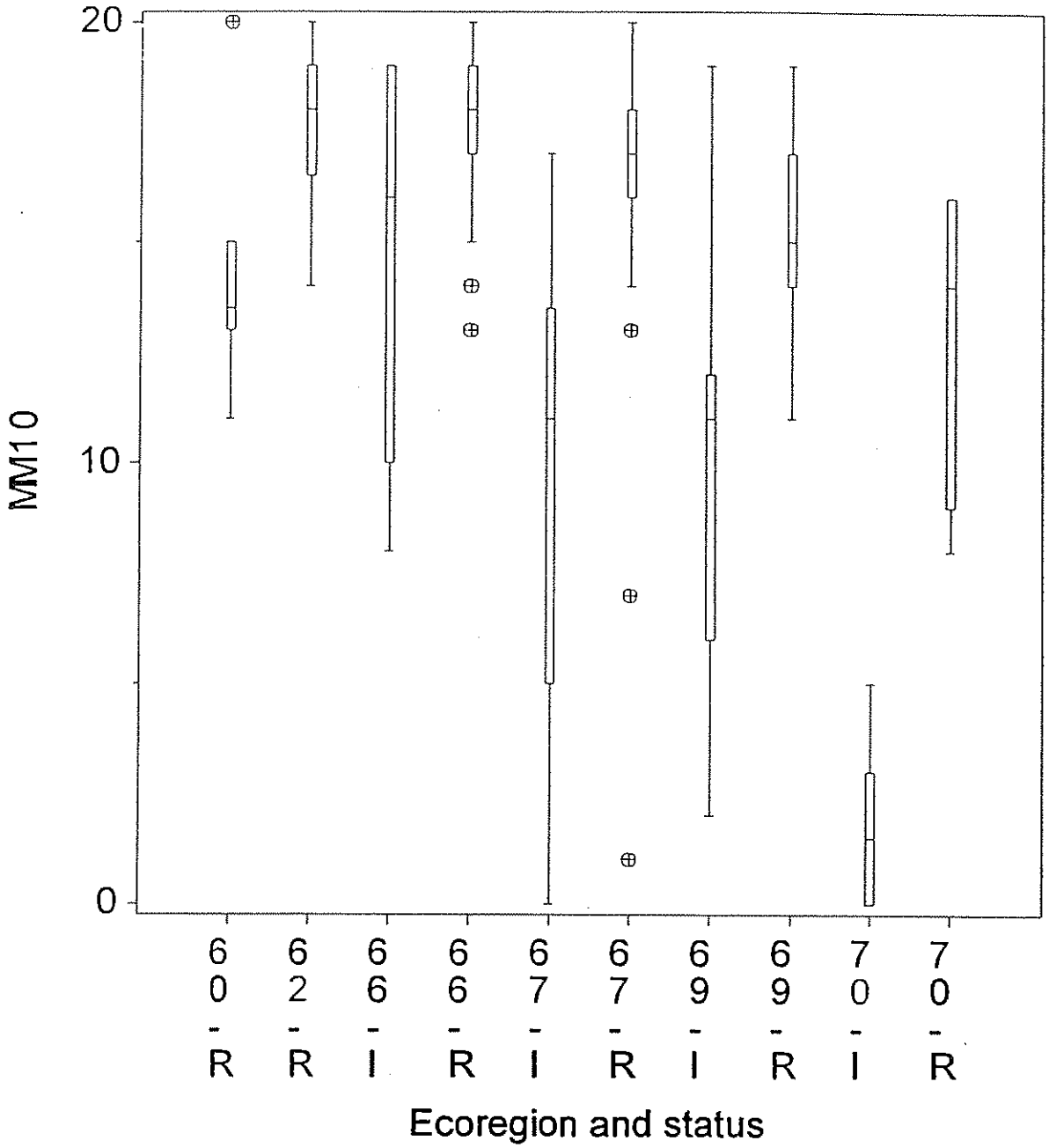


Figure 8. Boxplots of multimetric MM10 for method 3.

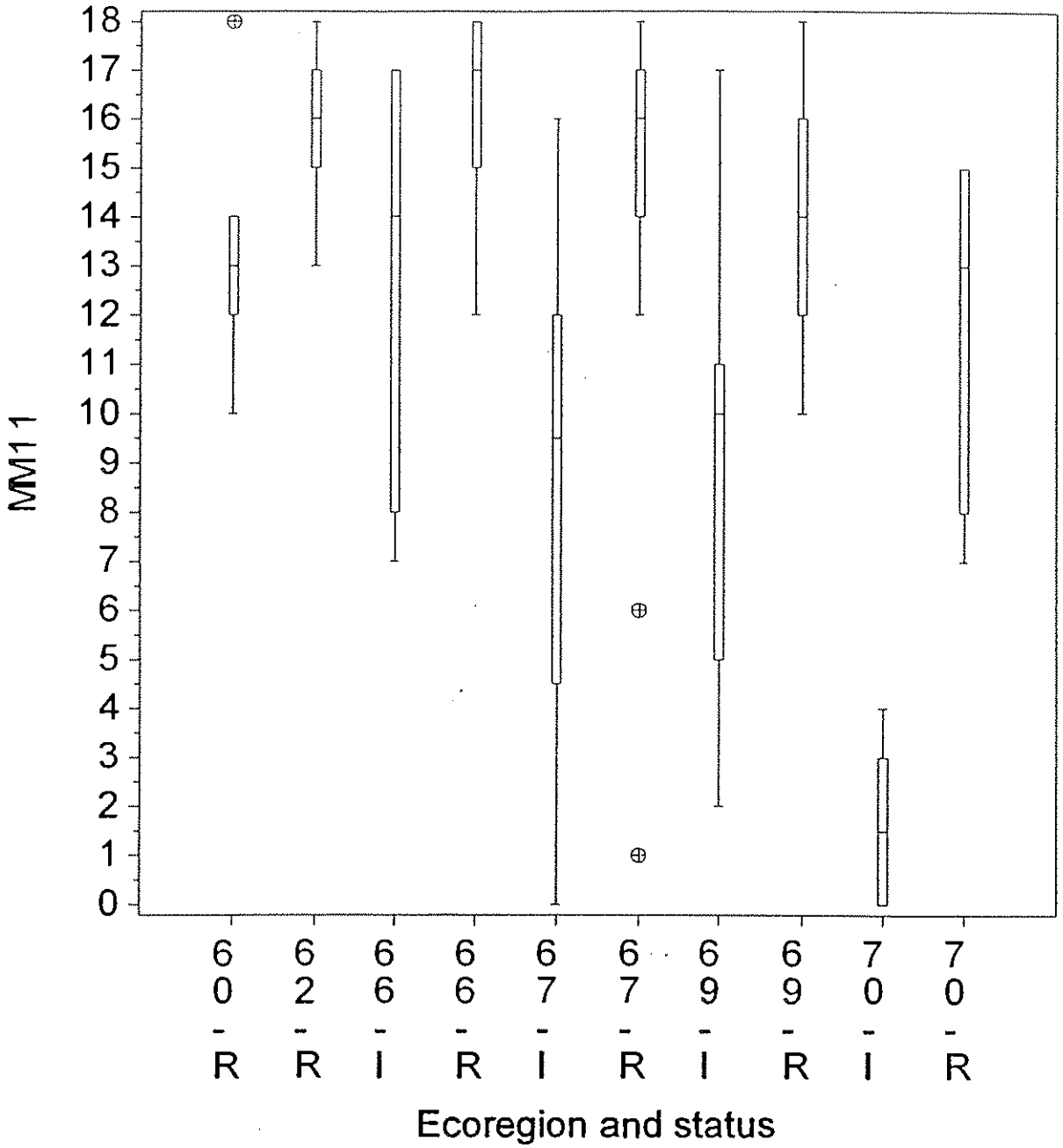


Figure 9. Boxplots of multimetric MM11 for method 3.

Appendix A. List of sites for all samples included in the historical database developed by Virginia Tech for benthic macroinvertebrates in wadeable streams of the Mid-Atlantic Highlands.

Explanation of Code:
- E=Evans' data from Western Virginia
- G=George Washington National Forest, Virginia
- J=Thomas Jefferson National Forest, Virginia
- M=Maryland DEQ
- P=Pennsylvania DER
- V=Virginia DEQ
- W=West Virginia DNR

Explanation of Ecoregion:
- A,B,C,D=Subregions within ecoregions
- M=Mixture of 2 or more subregions
- X=No subregions designated within ecoregion

Explanation of Status:
- I=Impacted
- R=Reference
- U=Unknown

Code	Status	Ecoregion	Site Information
E6A1	R	66A	Conway River; 1994
E6A2	R	66A	Hughes River; 1994
E6A3	R	66A	Piney River; 1994
E6A4	R	66A	Rose River; 1994
E6A5	R	66A	North Fork Thorton River; 1994
E6B1	I	66B	Bear Run; 1992; Acid deposition
E6B2	I	66B	Chimney Branch; 1992; Acid deposition
E6B3	I	66B	Hogback Creek; 1992; Acid deposition
E6B4	R	66B	Little Laurel Creek; 1993
E6B5	I	66B	Mine Bank Creek; 1992; Acid deposition
E6B6	I	66B	Paine Run; 1992; Acid deposition
E6B7	R	66B	Stoney Run; 1993
E6B8	I	66B	Sugar Tree; 1992; Acid deposition
E6C1	U	66C	Burks Fork; 1992; Agriculture
E6C2	U	66C	Greasy Creek; 1992; Agriculture
E6C3	U	66C	Little Indian Creek; 1992; Agriculture
E6C4	U	66C	Rush Fork; 1992; Agriculture
E7A1	R	67A	Catawba Creek; 1993
E7A2	U	67A	Mossy Creek; 1992; Agriculture
E7A3	U	67A	Sinking Creek (upper); 1992; Agriculture
E7A4	U	67A	Spout Run; 1992; Agriculture
E7A5	U	67A	Walker Creek; 1992; Agriculture
E7B1	U	67B	Elliot Creek; 1992; Agriculture
E7C1	R	67C	Wolf Creek; 1993
E7AC1	U	67M	Sinking Creek (lower); 1992; Agriculture
G6A1	R	66A	Brown Mountain Creek; 1992
G6A2	R	66A	Crabtree Creek; 1993
G6A3	R	66A	Davis Mill Creek; 1993
G6A4	R	66A	Irish Creek; 1993
G6A5	R	66A	Little Piney River; 1993

G6A6	R	66A	Meadow Creek; 1993
G6A7	R	66A	North Fork Buffalo River; 1992
G6A8	R	66A	Pedlar River; 1993
G6A9	R	66A	South Fork Piney River; 1992
G6A10	R	66A	Tye River; 1992
G6B1	I	66B	Cole's Run; 1993; Acid deposition
G6B2	I	66B	Kennedy Creek; 1993; Acid deposition
G6B3	U	66B	Rocky Roe Run; 1992; Acid mine
G6B4	U	66B	St. Mary's River; 1992; Acid deposition
G6AB1	R	66M	Big Mary's Creek; 1993
G7B1	R	67B	Falls Hollow; 1993
G7B2	U	67B	Simpson Creek; 1992; Agriculture
G7C1	U	67C	Bratton's Run; 1992; Sedimentation, Timber sale
G7C2	R	67C	Cub Run; 1993
G7C3	R	67C	Dolly Ann; 1993
G7C4	R	67C	Jackson River; 1992
G7C5	I	67C	Laurel Run; 1993; Acid deposition
G7C6	I	67C	Little Passage Creek; 1993; Acid deposition
G7C7	I	67C	Little Stony (lower); 1992; Acid deposition
G7C8	I	67C	Little Stony (upper); 1992; Acid deposition
G7C9	R	67C	Mare Run; 1993
G7C10	U	67C	Morgan Run; 1992; Acid deposition
G7C11	I	67C	Mountain Run; 1993; Acid deposition
G7C12	R	67C	Muddy Run; 1992
G7C13	R	67C	Panther Run; 1993
G7C14	I	67C	Peter's Mill Run; 1993; Acid deposition
G7C15	U	67C	Pounding Mill; 1992; Sedimentation, Timber sale
G7C16	R	67C	Smith Creek; 1993
G7C17	R	67C	Trout Run; 1992
G7D1	U	67D	Benson Run; 1992; Acid deposition
G7D2	U	67D	Black's Run/Gum Run; 1992; Sedimentation
G7D3	R	67D	Briery Branch; 1993
G7D4	U	67D	Dry River; 1992; Pipeline site
G7D5	R	67D	Hone Quarry Run; 1993
G7D6	R	67D	Jerkemtight Branch; 1993
G7D7	R	67D	Jerry's Run; 1992
G7D8	R	67D	Laurel Fork; 1992
G7D9	U	67D	Little Back Creek; 1992; Impoundment
G7D10	R	67D	Little Camp Run; 1993
G7D11	R	67D	Little River; 1993
G7D12	U	67D	North River; 1992
G7D13	U	67D	Ramsey's Draft; 1992; Acid deposition
G7D14	U	67D	Rocky Run; 1993; Sedimentation
G7D15	I	67D	Skidmore Creek; 1992
G7D16	R	67D	Wolf Run; 1993
G7AC1	U	67M	Passage Creek; 1992; Damaged riparian area

J6A1	U	66A	Cornelius Creek; 1993; Acid deposition, Grazing
J6A2	U	66A	Fallingwater Creek; 1993; Acid deposition, Grazing
J6A3	U	66A	Helton Creek; 1994; Acid deposition, Grazing
J6A4	U	66A	Hunting Creek; 1993; Acid deposition
J6A5	U	66A	Lewis Fork; 1994; Acid deposition
J6A6	U	66A	McFalls Creek; 1993; Grazing
J6A7	R	66A	Overstreet Creek; 1993
J6A8	R	66A	Reed Creek; 1993
J6B1	R	66B	Bournes Branch; 1994
J6B2	U	66B	East Fork Dry Run; 1994; Timber sale
J6B3	R	66B	Jerry's Creek; 1994
J6AB1	U	66M	Belfast Creek; 1993; 66A/B; Acid deposition
J6AC2	R	66M	Big Wilson Creek; 1994; 66A/C
J6AB3	U	66M	Fox Creek; 1994; 66A/B; Acid deposition, Grazing
J6AC4	U	66M	Little Wilson Creek; 1994; 66A/C; Acid deposition
J6AB5	R	66M	North Creek; 1993; 66A/B
J6BC6	U	66M	Whitetop Laurel Creek; 1994; 66B/C; Grazing
J7C1	R	67C	Big Stony Creek; 1993
J7C2	R	67C	Hunting Camp Creek; 1994
J7C3	U	67C	Laurel Branch; 1993; Acid deposition
J7C4	R	67C	Lick Creek; 1994
J7C5	R	67C	Little Stony Creek; 1993
J7C6	R	67C	Little Wolf Creek; 1994
J7C7	R	67C	Lovelady Creek; 1994
J7C8	U	67C	Nettle Hollow; 1993; Acid deposition
J7C9	U	67C	Nobusiness Creek; 1993; Acid deposition
J7C10	U	67C	North Fork Stony Creek; 1993; Acid deposition
J7C11	R	67C	Peak Creek; 1994
J7C12	U	67C	Roaring Fork (upper); 1994; Acid deposition
J7C13	U	67C	Roaring Fork (lower); 1994; Acid deposition
J7C14	R	67C	Roaring Run; 1993
J7C15	U	67C	Shawver's Run; 1993; Acid deposition
J7C16	R	67C	Tract Fork; 1994
J7C17	R	67C	White Rocks Branch; 1993
J7BC1	U	67M	Barbours Creek; 1993; 67B/C; Timber sale
J7BC2	U	67M	Craig Creek; 1993; 67B/C; Timber sale
J7BC3	U	67M	Cove Branch; 1993; 67B/C; Acid deposition
J7BC4	U	67M	Hipes Branch; 1993; 67B/C; Acid deposition
J7BC5	I	67M	Mill Creek; 1993; 67B/C
J7CD6	U	67M	Reed Creek; 1994; 67C/D
J7BC7	U	67M	Stony Run; 1993; 67B/C; Timber sale
J7BC8	U	67M	Wolf Branch; 1993; 67B/C; Timber sale
J9A1	U	69A	Burns Creek; 1994; Timber sale
J9A2	U	69A	Clear Creek; 1994; Timber sale
J9A3	U	69A	Cove Creek; 1994; Timber sale
J9A4	U	69A	Little Stony Creek; 1994; Timber sale

J9A5	U	69A	Poor Fork Cumberland River; 1994; Timber sale
J9A6	U	69A	Roaring Branch; 1994; Timber sale
J9A7	U	69A	Stock Creek; 1994; Timber sale
M7C01	I	67C	Braddock Run; 1990; Acid mine
M7C12	U	67C	Collier Run; 1991; Agriculture
M7C22	U	67C	Collier Run; 1992; Agriculture
M7C13	I	67C	Elk Lick Run; 1991; Stormwater
M7C23	I	67C	Elk Lick Run; 1992; Stormwater
M7C43	I	67C	Elk Lick Run; 1994; Stormwater
M7C04	U	67C	Jennings Run; 1990; Acid mine
M7C24	U	67C	Jennings Run; 1992; Acid mine
M7C44	U	67C	Jennings Run; 1994; Acid mine
M7C25	U	67C	North Branch Jennings Run; 1992; Acid mine
M7C45	U	67C	North Branch Jennings Run; 1994; Acid mine
M7C26	I	67C	Warrior Run; 1992; Stormwater
M7C46	I	67C	Warrior Run; 1994; Stormwater
M7C17	U	67C	Wills Creek; 1991; Stormwater
M7C47	U	67C	Wills Creek; 1994; Stormwater
M7D01	R	67D	Big Run; 1990
M7D21	R	67D	Big Run; 1992
M7D41	R	67D	Big Run; 1994
M7D22	I	67D	Evitts Creek ;1992; Acid mine
M7D42	I	67D	Evitts Creek; 1994; Acid mine
M7D23	U	67D	Savage River #1; 1992; Stormwater
M7D43	R	67D	Savage River #1; 1994
M7D24	R	67D	Savage River #2; 1992
M7D45	R	67D	Savage River #3; 1994
M7D26	I	67D	Seven Springs Run; 1992; Agriculture
M7D46	I	67D	Seven Springs Run; 1994; Agriculture
M7CD21	R	67M	Crabtree Creek; 1992; 67C/D
M7CD41	R	67M	Crabtree Creek; 1994; 67C/D
M7CD02	R	67M	Middle Fork; 1990; 67C/D
M7CD22	R	67M	Middle Fork; 1992; 67C/D
M7CD42	R	67M	Middle Fork; 1994; 67C/D
M7CD13	U	67M	Mill Run; 1991; 67C/D
M7CD23	U	67M	Mill Run; 1992; 67C/D
M7CD43	U	67M	Mill Run; 1994; 67C/D
M9B01	I	69B	Georges Run; 1990; Acid mine
M9B21	I	69B	Georges Run; 1992; Acid mine
M9B41	I	69B	Georges Run; 1994; Acid mine
M9B02	U	69B	Glade Run; 1990; Agriculture
M9B42	U	69B	Glade Run; 1994; Agriculture
M9B04	R	69B	Lostland Run; 1990
M9B24	R	69B	Lostland Run; 1992
M9B44	R	69B	Lostland Run; 1994
M9B05	R	69B	Nyedeggar Run; 1990

M9B25	R	69B	Nyedeggar Run; 1992
M9B45	R	69B	Nyedeggar Run; 1994
M9B06	U	69B	Shields Run; 1990; Agriculture
M9B26	U	69B	Shields Run; 1992; Agriculture
M9B46	U	69B	Shields Run; 1994; Agriculture
P6011	R	60X	Blue Eye Run; 1991
P6021	R	60X	Blue Eye Run; 1992
P6031	R	60X	Blue Eye Run; 1993
P6022	R	60X	Wysox Creek; 1992
P6032	R	60X	Wysox Creek; 1993
P6042	R	60X	Wysox Creek; 1994
P6211	R	62X	Bowman Creek; 1991
P6221	R	62X	Bowman Creek; 1992
P6231	R	62X	Bowman Creek; 1993
P6212	R	62X	Cather's Run; 1991
P6222	R	62X	Cather's Run; 1992
P6232	R	62X	Cather's Run; 1993
P6213	R	62X	East Branch Dyberry Creek; 1991
P6223	R	62X	East Branch Dyberry Creek; 1992
P6233	R	62X	East Branch Dyberry Creek; 1993
P6214	R	62X	Little Bushkill Creek; 1991
P6224	R	62X	Little Bushkill Creek; 1992
P6234	R	62X	Little Bushkill Creek; 1993
P6215	R	62X	Loyalsock Creek; 1991
P6225	R	62X	Loyalsock Creek; 1992
P6235	R	62X	Loyalsock Creek; 1993
P6245	R	62X	Loyalsock Creek; 1994
P6216	R	62X	Pine Creek; 1991
P6226	R	62X	Pine Creek; 1992
P6236	R	62X	Pine Creek; 1993
P6246	R	62X	Pine Creek; 1994
P6B11	R	66B	Mountain Creek; 1991
P6B21	R	66B	Mountain Creek; 1992
P6B31	R	66B	Mountain Creek; 1993
P6B41	R	66B	Mountain Creek; 1994
P7C11	R	67C	White Deer Creek; 1991
P7C21	R	67C	White Deer Creek; 1992
P7C31	R	67C	White Deer Creek; 1993
P7C41	R	67C	White Deer Creek; 1994
P7E11	R	67M	Sherman Creek; 1991, 67A/B/C
P7E21	R	67M	Sherman Creek; 1992; 67A/B/C
P7E31	R	67M	Sherman Creek; 1993; 67A/B/C
P7E41	R	67M	Sherman Creek; 1994; 67A/B/C
P9A11	R	69A	Indian Creek; 1991
P9A21	R	69A	Indian Creek; 1992
P9A31	R	69A	Indian Creek; 1993

P9B11	R	69B	Little Wills Creek; 1991
P9B21	R	69B	Little Wills Creek; 1992
P9B31	R	69B	Little Wills Creek; 1993
P9B41	R	69B	Little Wills Creek; 1994
P9B12	R	69B	South Branch Two Lick Creek; 1991
P9B32	R	69B	South Branch Two Lick Creek; 1993
P7011	R	70X	Thorn Creek; 1991
P7021	R	70X	Thorn Creek; 1992
P7031	R	70X	Thorn Creek; 1993
P7022	R	70X	Traverse Creek; 1992
P7023	R	70X	Whiteley Creek; 1992
P7033	R	70X	Whiteley Creek; 1993
V6B1	R	66B	Beaverdam Creek #1; 1992
V6B2	R	66B	Beaverdam Creek #2; 1992
V6C1	I	66C	Chestnut Creek #1; 1992; STP, Acid mine
V6C2	I	66C	Chestnut Creek #2; 1992; STP
V6C3	I	66C	Chestnut Creek #3; 1992; Acid mine
V6AC1	R	66M	Wilson Creek; 1992
V7A1	I	67A	Cooks Creek; 1992; Agriculture
V7A2	I	67A	Middle River; 1992; Agriculture
V7A3	R	67A	North River; 1992
V7A4	I	67A	Pleasant Run; 1992; Agriculture
V7A5	R	67A	South Fork Shenandoah River; 1992
V9A1	I	69A	Levisa Fork #1; 1992; Unknown NPS
V9A2	I	69A	Levisa Fork #2; 1992; Unknown NPS
V9A3	I	69A	Levisa Fork #3; 1992; Unknown NPS
V9A4	R	69A	Cranes Nest; 1992
V9A5	R	69A	Knox Creek; 1992
V9A6	I	69A	Slate Creek; 1992; Mining
V9A7	I	69A	South Fork Pound River; 1992; Mining, Agriculture
V9A8	R	69A	Dismal Creek #1; 1992
V9A9	R	69A	Dismal Creek #2; 1992
V9A10	R	69A	North Fork Pound River; 1992
V9A11	I	69A	Roaring Fork; 1992; Mining
W7A1	I	67A	Hoke Run#1; 1993; Agriculture
W7A2	I	67A	Hoke Run #2; 1993; Agriculture
W7A3	R	67A	Hoke Run #3; 1993
W7A4	R	67A	Unnamed Tributary of Hoke Run #1; 1993; Agriculture
W7A5	I	67A	Unnamed Tributary of Hoke Run #2; 1993; Agriculture
W7A6	I	67A	Unnamed Tributary of Hoke Run #1; 1987; Agriculture
W7A7	I	67A	Unnamed Tributary of Hoke Run #1A; 1987; Agriculture
W7A8	I	67A	Unnamed Tributary of Hoke Run #2; 1987; Agriculture
W7A9	I	67A	Unnamed Tributary of Hoke Run #2A; 1987; Agriculture
W7B1	U	67B	East Creek; 1992; Industrial effluent
W7B2	U	67B	Central Creek; 1992; Industrial effluent
W7B3	U	67B	South Creek; 1992; Industrial effluent

W7B4	U	67B	Central Creek; 1992; Industrial effluent
W7B5	U	67B	East Creek #1; 1992; Landfill, Habitat degradation
W7B6	U	67B	East Creek #2; 1992; Landfill, Habitat degradation
W7B7	U	67B	East Creek #3; 1992; Landfill, Habitat degradation
W7B8	U	67B	East Creek #4; 1992; Landfill, Habitat degradation
W7D1	R	67D	Anthony Creek #1; 1981
W7D2	R	67D	Anthony Creek #2; 1981
W7D3	R	67D	Anthony Creek #3; 1981
W7D4	R	67D	Anthony Creek #4; 1981
W7D5	R	67D	Anthony Creek #5; 1981
W7D6	R	67D	Anthony Creek #6; 1981
W7D7	R	67D	Anthony Creek #1; 1981
W7D8	R	67D	Anthony Creek #2; 1981
W7BD1	U	67M	Yokum Run; 1981
W7BD2	U	67M	Glade Run; 1981
W9A1	U	69A	Cherry River #1; 1982
W9A2	U	69A	Cherry River #2; 1982
W9A3	U	69A	Cherry River #3; 1982
W9A4	U	69A	Laurel Creek; 1982
W9A5	U	69A	Guyandotte River #1; 1982
W9A6	U	69A	Guyandotte River #2; 1982
W9A7	U	69A	Buffalo Creek #1; 1982
W9A8	U	69A	Buffalo Creek #2; 1982
W9A9	R	69A	Hominy Creek #1; 1982
W9A10	I	69A	Hominy Creek #2; 1982; Landfill
W9A11	I	69A	Hominy Creek #3; 1982; Landfill
W9A12	I	69A	Hominy Creek #4; 1982; Landfill
W9A13	I	69A	Hominy Creek #5; 1982; Landfill
W9A14	R	69A	Hominy Creek #6; 1982
W9A15	U	69A	Hominy Creek #1; July 1983
W9A16	U	69A	Hominy Creek #1; August 1983
W9A17	U	69A	Brushy Meadow Creek; July 1983
W9A18	U	69A	Brushy Meadow Creek (August 1983)
W9A19	U	69A	Hominy Creek #3; July 1983
W9A20	U	69A	Hominy Creek #3; August 1983
W9A21	U	69A	Hominy Creek #4; July 1983
W9A22	U	69A	Hominy Creek #4; August 1983
W9A23	U	69A	Hominy Creek #5; July 1983
W9A24	U	69A	Hominy Creek #5; August 1983
W9A25	U	69A	Hominy Creek #6; July 1983
W9A26	U	69A	Hominy Creek #6; August 1983
W9A27	U	69A	Hominy Creek #7; July 1983
W9A28	U	69A	Hominy Creek #7; August 1983
W9A29	U	69A	Hominy Creek #8; July 1983
W9A30	U	69A	Hominy Creek #8; August 1983
W9A31	U	69A	Hominy Creek #9; July 1983

W9A32	U	69A	Hominy Creek #9; August 1983
W9A33	U	69A	Little Ten-Mile #4; 1983
W9A34	U	69A	Little Ten-Mile #2; 1983
W9A35	U	69A	Little Ten-Mile #3; 1983
W9A36	U	69A	Little Ten-Mile #4; 1983
W9A37	U	69A	Little Ten-Mile #5; 1983
W9A38	U	69A	Little Ten-Mile #6; 1983
W9A39	U	69A	Ten-Mile #1; 1983
W9A40	U	69A	Ten-Mile #2; 1983
W9A41	U	69A	Ten-Mile #3; 1983
W9A42	U	69A	Ten-Mile #4; 1983
W9A43	U	69A	Ten-Mile #5; 1983
W9A44	U	69A	Ten-Mile #6; 1983
W9A45	U	69A	Ten-Mile #7; 1983
W9A46	U	69A	Ten-Mile #8; 1983
W9A47	I	69A	Right Fork Ten-Mile Creek #1; 1987; Mining
W9A48	I	69A	Right Fork Ten-Mile Creek #2; 1987; Mining
W9A49	I	69A	Right Fork Ten-Mile Creek #3; 1987; Mining
W9A50	I	69A	Right Fork Ten-Mile Creek #4; 1987; Mining
W9A51	R	69A	Jarrett Branch; 1984
W9A52	U	69A	Fork Creek-lower reaches #1; 15 June 1982
W9A53	U	69A	Fork Creek-lower reaches #2; 15 June 1982
W9A54	U	69A	Fork Creek-lower reaches #3; 15 June 1982
W9A55	U	69A	Fork Creek-lower reaches #4; 15 June 1982
W9A56	U	69A	Fork Creek-upper reaches #1; 15 June 1982
W9A57	U	69A	Fork Creek-upper reaches #2; 15 June 1982
W9A58	U	69A	Fork Creek-upper reaches #3; 15 June 1982
W9A59	U	69A	Fork Creek-upper reaches #4; 15 June 1982
W9A60	U	69A	Wilderness Fork of Fork Creek #1; 15 June 1982
W9A61	U	69A	Wilderness Fork of Fork Creek #2; 15 June 1982
W9A62	U	69A	Wilderness Fork of Fork Creek #3; 15 June 1982
W9A63	U	69A	Wilderness Fork of Fork Creek #4; 15 June 1982
W9A64	U	69A	Wilderness Fork of Fork Creek #5; 15 June 1982
W9A65	U	69A	Fork Creek-lower reaches #1; 16 July 1982
W9A66	U	69A	Fork Creek-lower reaches #2; 16 July 1982
W9A67	U	69A	Fork Creek-lower reaches #3; 16 July 1982
W9A68	U	69A	Fork Creek-lower reaches #4; 16 July 1982
W9A69	U	69A	Fork Creek-lower reaches #5; 16 July 1982
W9A70	U	69A	Fork Creek-upper reaches #1; 16 July 1982
W9A71	U	69A	Fork Creek-upper reaches #2; 16 July 1982
W9A72	U	69A	Fork Creek-upper reaches #3; 16 July 1982
W9A73	U	69A	Fork Creek-upper reaches #4; 16 July 1982
W9A74	U	69A	Fork Creek-upper reaches #5; 16 July 1982
W9A75	U	69A	Wilderness Fork of Fork Creek #1; 16 July 1982
W9A76	U	69A	Wilderness Fork of Fork Creek #2; 16 July 1982
W9A77	U	69A	Wilderness Fork of Fork Creek #3; 16 July 1982

W9A78	U	69A	Wilderness Fork of Fork Creek #4; 16 July 1982
W9A79	U	69A	Wilderness Fork of Fork Creek #5; 16 July 1982
W9A80	U	69A	Fork Creek-lower reaches #1; 12 Aug 1982
W9A81	U	69A	Fork Creek-lower reaches #2; 12 Aug 1982
W9A82	U	69A	Fork Creek-lower reaches #3; 12 Aug 1982
W9A83	U	69A	Fork Creek-lower reaches #4; 12 Aug 1982
W9A84	U	69A	Fork Creek-lower reaches #5; 12 Aug 1982
W9A85	U	69A	Fork Creek-upper reaches #1; 12 Aug 1982
W9A86	U	69A	Fork Creek-upper reaches #2; 12 Aug 1982
W9A87	U	69A	Fork Creek-upper reaches #3; 12 Aug 1982
W9A88	U	69A	Fork Creek-upper reaches #4; 12 Aug 1982
W9A89	U	69A	Fork Creek-upper reaches #5; 12 Aug 1982
W9A90	U	69A	Wilderness Fork of Fork Creek #1; 12 Aug 1982
W9A91	U	69A	Wilderness Fork of Fork Creek #2; 12 Aug 1982
W9A92	U	69A	Wilderness Fork of Fork Creek #3; 12 Aug 1982
W9A93	U	69A	Wilderness Fork of Fork Creek #4; 12 Aug 1982
W9A94	U	69A	Wilderness Fork of Fork Creek #5; 12 Aug 1982
W9A95	U	69A	Fork Creek-lower reaches #1; 15 Sep 1982
W9A96	U	69A	Fork Creek-lower reaches #2; 15 Sep 1982
W9A97	U	69A	Fork Creek-lower reaches #3; 15 Sep 1982
W9A98	U	69A	Fork Creek-lower reaches #4; 15 Sep 1982
W9A99	U	69A	Fork Creek-lower reaches #5; 15 Sep 1982
W9A100	U	69A	Fork Creek-upper reaches #1; 15 Sep 1982
W9A101	U	69A	Fork Creek-upper reaches #2; 15 Sep 1982
W9A102	U	69A	Fork Creek-upper reaches #3; 15 Sep 1982
W9A103	U	69A	Fork Creek-upper reaches #4; 15 Sep 1982
W9A104	U	69A	Fork Creek-upper reaches #5; 15 Sep 1982
W9A105	U	69A	Wilderness Fork of Fork Creek #1; 15 Sep 1982
W9A106	U	69A	Wilderness Fork of Fork Creek #2; 15 Sep 1982
W9A107	U	69A	Wilderness Fork of Fork Creek #3; 15 Sep 1982
W9A108	U	69A	Wilderness Fork of Fork Creek #4; 15 Sep 1982
W9A109	U	69A	Wilderness Fork of Fork Creek #5; 15 Sep 1982
W9A110	U	69A	Dunloup Creek #1; 1982
W9A111	U	69A	Dunloup Creek #2; 1982
W9B1	I	69B	Unnamed Tributary of Left Fork Sandy Creek #1; 1994, Acid mine
W9B2	I	69B	Left Fork Sandy Creek #2; 1994; Acid mine
W9B3	I	69B	Left Fork Sandy Creek #3; 1994; Acid mine
W9B4	I	69B	Left Fork Sandy Creek #4; 1994; Acid mine
W9B5	R	69B	Sandy Creek #5; 1994
W9B6	R	69B	Sandy Creek #6; 1994
W9B7	I	69B	Little Sandy Creek #7; 1994; Acid mine
W9B8	I	69B	Sandy Creek #8; 1994; Acid mine
W9B9	U	69B	Stony River #1; 1982; Mining
W9B10	U	69B	Stony River #2; 1982; Mining
W9B11	U	69B	Stony River #3; 1982; Mining
W9B12	U	69B	Stony River #4; 1982; Mining

W9B13	U	69B	Stony River #5; 1982; Mining
W9B14	U	69B	Stony River #6; 1982; Mining
W9B15	U	69B	Mill Run; 1987; Mining
W9B16	U	69B	Laurel Run; 1987; Mining
W9B17	U	69B	Stony River #1; 1987; Mining
W9B18	U	69B	Stony River #2; 1987; Mining
W9B19	U	69B	Stony River #3; 1987; Mining
W9B20	U	69B	Stony River #4; 1987; Mining
W9B21	U	69B	Stony River #5; 1987; Mining
W9B22	U	69B	Stony River #6; 1987; Mining
W9B23	U	69B	Stony River #7; 1987; Mining
W9B24	U	69B	Stony River #8; 1987; Mining
W9B25	U	69B	Stony River #9; 1987; Mining
W701	U	70X	Turkey Run #1; 1980
W702	U	70X	Turkey Run #4; 1980
W703	U	70X	Turkey Run #5; 1980
W704	U	70X	Turkey Run #6; 1980
W705	U	70X	Turkey Run #7; 1980
W706	U	70X	Britts Run; 1981; Habitat degradation
W707	U	70X	Unnamed Tributary of Coal Hollow #1; 1988; Landfill
W708	U	70X	Unnamed Tributary of Coal Hollow #2; 1988; Landfill
W709	U	70X	Unnamed Tributary of Coal Hollow #3; 1988; Landfill
W7010	U	70X	Wolf Run #1; 1982
W7011	U	70X	Wolf Run #3; 1982; Industrial effluent
W7012	U	70X	Tannery Run #4; 1982; Industrial effluent
W7013	U	70X	Tannery Run #5; 1982; Industrial effluent
W7014	U	70X	Dry Run (upper); 1989
W7015	U	70X	Dry Run (lower); 1989
W7016	R	70X	Dry Run #3; 1981
W7017	U	70X	Indian Fork #1; 1993
W7018	I	70X	Indian Fork #2; 1993; Industrial effluent
W7019	I	70X	Indian Fork #3; 1993; Industrial effluent
W7020	U	70X	Crooked Run #1; 1982
W7021	U	70X	Crooked Run #1; 1983
W7022	U	70X	Crooked Run #1A; 1983
W7023	U	70X	Crooked Run #2; 1983
W7024	U	70X	Crooked Run #2A; 1983
W7025	U	70X	Crooked Run #1; 1984
W7026	U	70X	Crooked Run #1A; 1984
W7027	U	70X	Crooked Run #2; 1984
W7028	U	70X	Crooked Run #2A; 1984
W7029	U	70X	Crooked Run #3; 1983
W7030	U	70X	Crooked Run #3A; 1983
W7031	U	70X	Crooked Run #4; 1983
W7032	U	70X	Crooked Run #4A; 1983
W7033	U	70X	Burch Run; 1982

W7034	U	70X	Big Run; 1982
W7035	I	70X	Armour Creek A; 1982; Low flow
W7036	I	70X	Armour Creek B; 1982; STP
W7037	I	70X	Armour Creek B2; 1982; STP
W7038	I	70X	Armour Creek C; 1982; STP
W7037	U	70X	Conner Run (upper); 1990

ATTACHMENT

Family Level Ecological Classifications for Calculating Metrics

Virginia Tech Department of Entomology

Family Level Ecological Classifications For Calculating Metrics
Virginia Tech Department of Entomology

TAXA	DESC 17 October 1995 (SKE)	FUNCGRP	T. VALUES	HABIT
2	PHYLUM PROTOZOA		0	
3	PHYLUM PORIFERA		0	
4	PHYLUM COELENTERATA		0	
40	CLASS HYDROZOA		0	
400	ORDER HYDROIDA		0	
4000	HYDRIDAE		0	CL
4001	CLAVIDAE		0	
5	PHYLUM PLATYHELMINTHES		0	
50	CLASS TURBELLARIA	CG	4	
506	ORDER TRICLADIDA		4	
5060	PLANARIIDAE	CG	8	GN
6	PHYLUM NEMATODA	CG	8	
6XX	NEMATODA	CG	8	BU
9	PHYLUM ROTATORIA		8	
A	PHYLUM BRYOZOA		8	
A0	CLASS ECTOPROCTA		8	
A00	ORDER PHYLACTOLAEMATA		8	
C	PHYLUM NEMERTINEA		8	CR
C0	CLASS ENOPLA		8	
C00	ORDER HOPOLONEMERTINI		8	
D	PHYLUM ANNELIDA		8	
D1	CLASS POLYCHAETA		8	
D2	CLASS OLIGOCHAETA	CG	8	BU
D20	ORDER LUMBRICULIDA		8	
D200	LUMBRICULIDAE		8	
D21	ORDER HAPLOTAXIDA		8	
D210	HAPLOTAXIDAE		8	
D211	ENCHYTRAEIDAE		8	
D212	NAIDIDAE		8	BU
D213	TUBIFICIDAE	CG	10	BU
D214	OPISTOCYSTIDAE		10	
D215	LUMBRICIDAE		10	
D216	SPARGANOPHILIDAE		10	
D22	ORDER BRANCHIOBDELLIDA		5	
D220	BRANCHIOBDELLIDAE		5	GN
D23	ORDER AEOLOSOMATIDA		5	
D230	AEOLOSOMATIDAE		5	
D3	CLASS HIRUDINEA	PR	8	GN
D30	ORDER RHYNCHOBDELLIDA		8	
D300	GLOSSIPHONIIDAE		8	
D301	PISCICOLIDAE		8	
E	PHYLUM ARTHROPODA		8	
E0	CLASS CRUSTACEA		8	
E03	ORDER CLADOCERA	CF	8	
E030	SIDIDAE		8	
E033	DAPHNIDAE		8	
E04	ORDER PODOCOPA		8	
E05	ORDER COPOPODA	CG	8	

E08	ORDER ISOPODA		8	SP
E081	ASELLIDAE	CG	8	
E09	ORDER AMPHIPODA		7	CR
E090	TALITRIDAE	CG	8	
E092	GAMMARIDAE	CG	6	
E0A	ORDER DECAPODA		5	
E0A0	CAMBARIDAE		5	GN
E1	CLASS INSECTA		5	
E10	ORDER PLECOPTERA		5	CR
E100	PTERONARCYIDAE	SH	0	CR
E101	PELTOPERLIDAE	SH	2	CR
E102	NEMOURIDAE	SH	2	CR
E103	PERLIDAE	PR	1	CR
E104	PERLODIDAE	PR	2	CR
E105	CHLOROPERLIDAE	PR	1	CR
E106	TAENIOPTERYGIDAE	SH	2	CR
E107	LEUCTRIDAE	SH	0	CR
E108	CAPNIIDAE	SH	1	CR
E11	ORDER EPHEMEROPTERA		1	
E110	EPHEMERIDAE	CG	4	BU
E111	NEOEPHEMERIDAE	CG	3	SP
E112	CAENIDAE	CG	4	SP
E113	EPHEMERELLIDAE	CG	4	CR
E114	BAETISCIDAE	CG	3	SP
E115	SIPHLONURIDAE	CG	7	CR
E116	LEPTOPHLEBIIDAE	CG	2	CR
E117	BAETIDAE	CG	4	CG
E119	HEPTAGENIIDAE	SC	4	CG
E11A	POLYMITARCYIDAE	CG	2	BU
E11B	POTAMANTHIDAE	CG	4	BU
E11C	TRICORYTHIDAE	CG	4	SP
E11D	OLIGONEURIIDAE	CF	2	SW
E12	ORDER ODONATA	PR	2	
E12A	ANISOPTERA	PR	2	
E120	CORDULEGASTRIDAE	PR	3	BU
E121	PETALURIDAE	PR	4	
E122	GOMPHIDAE	PR	1	BU
E123	MACROMIIDAE	PR	3	SP
E124	AESCHNIDAE	PR	3	CR
E125	CORDULIIDAE	PR	5	CL
E126	LIBELLULIDAE	PR	9	SP
E12B	ZYGOPTERA	PR	9	
E127	CALOPTERYGIDAE	PR	5	CL
E128	LESTIDAE	PR	9	CL
E129	COENAGRIONIDAE	PR	9	CR
E13	ORDER HEMIPTERA		9	
E130	BELOSTOMATIDAE	PR	6	CL
E131	NEPIDAE	PR	6	CL
E132	GERRIDAE	PR	8	SK

E133	MESOVELIIDAE	PR	6	SK
E134	VELIIDAE	PR	6	SK
E139	SALDIDAE	PR	6	GN
E13A	CORIXIDAE	MP	5	DV
E13B	NOTONECTIDAE	PR	5	DV
E14	ORDER MEGALOPTERA	PR	5	
E140	SIALIDAE	PR	4	SP
E141	CORYDALIDAE	PR	5	CR
E15	ORDER NEUROPTERA	PR	5	
E150	SISYRIDAE	PR	3	GN
E16	ORDER TRICHOPTERA		3	
E160	HYDROPTILIDAE	MP	6	CR
E161	HELICOPSYCHIDAE	SC	3	GN
E162	HYDROPSYCHIDAE	CF	6	CG
E163	RHYACOPHILIDAE	PR	0	CR
E164	PHILOPOTAMIDAE	CF	3	CG
E165	PSYCHOMYIIDAE	CG	2	CG
E167	LEPTOCERIDAE	CG	4	CR
E168	PHRYGANEIDAE	SH	4	CL
E16A	ODONTOCERIDAE	SC	0	CG
E16C	BRACHYCENTRIDAE	CF	1	CG
E16E	LEPIDOSTOMATIDAE	SH	1	CR
E16F	GLOSSOSOMATIDAE	SC	0	CG
E16G	LIMNEPHILIDAE	SH	4	CG
E16H	POLYCENTROPODIDAE	CF	6	CG
E16I	MOLANNIDAE	SC	6	SP
E16J	SERICOSTOMATIDAE	SH	1	SP
E17	ORDER LEPIDOPTERA	SH	1	
E170	PYRALIDAE	SH	5	CG
E171	NOCTUIDAE	SH	5	
E18	ORDER COLEOPTERA		5	
E181	HALIPLIDAE	MP	7	
E182	DYTISCIDAE	PR	6	DV
E183	GYRINIDAE	PR	5	SK
E184	HYDROPHILIDAE	PR	5	DV
E186	HYDRAENIDAE	PR	5	
E187	PSEPHENIDAE	SC	4	CG
E188	DRYOPIDAE	SC	5	CG
E189	ELMIDAE	SC	4	CG
E18A	EUBRIIDAE	SC	4	CG
E18B	LIMNICHIDAE	CG	5	CG
E18C	PTILODACTYLIDAE	SH	5	CG
E18D	STAPHYLINIDAE	PR	5	CG
E18E	CURCULIONIDAE	SH	5	CG
E19	ORDER DIPTERA		5	
E190	BLEPHARICERIDAE	SC	0	CG
E191	TANYDERIDAE		7	
E192	TIPULIDAE	SH	3	CR
E193	PSYCHODIDAE	CG	10	BU

E194	CHAOBORIDAE	PR	7	SP
E195	DIXIDAE	CG	7	CR
E196	CULICIDAE	CF	8	DV
E197	SIMULIIDAE	CF	6	CG
E198	CHIRONOMIDAE	CG	6	BU
E199	CERATOPOGONIDAE	PR	6	BU
E19A	STRATIOMYIIDAE	CG	10	SP
E19B	TABANIDAE	PR	6	BU
E19C	ATHERICIDAE	PR	2	CR
E19G	EPHYDRIDAE	CG	6	
E19H	SCIOMYZIDAE	PR	6	
E19I	DOLICHOPODIDAE	PR	4	SP
E19J	EMPIDIDAE	PR	6	CR
E19K	MUSCIDAE	PR	6	SP
E19L	PTYCHOPTERIDAE	CG	7	BU
E1A	ORDER COLLEMBOLA	CG	7	SK
E1A0	PODURIDAE	CG	7	SK
E1A2	ISOTOMIDAE	CG	7	SK
E1B	ORDER HYMENOPTERA	PR	7	
E1C	ORDER ORTHROPTERA	SH	7	SK
E1C0	TRIDACTYLIDAE	SH	7	SK
E1D	ORDER PSOCOPTERA		7	
E2	CLASS ARACHNIDA		7	
E20	ORDER ACARI (HYDRACARINA)	PR	5	CR
F	PHYLUM MOLLUSCA		5	
F0	CLASS GASTROPODA	SC	5	GN
F00	ORDER LIMNOPHILA	CG	5	GN
F000	PHYSIDAE	CG	8	SP
F001	LYMNAEIDAE	CG	7	GN
F002	PLANORBIDAE	CG	7	SP
F003	ANCYLIDAE	SC	4	CG
F01	ORDER MESOGASTROPODA		4	GN
F010	VALVATIDAE		4	GN
F012	VIVIPARIDAE	CG	3	GN
F013	HYDROBIIDAE (=BULIMIDAE)		3	GN
F014	PLEUROCERIDAE	SC	4	CG
F1	CLASS BIVALVIA (=PELECYPODA)	CF	4	BU
F10	ORDER UNIONOIDA	CF	4	BU
F101	UNIONIDAE	CF	4	BU
F11	ORDER VENEROIDA	CF	4	BU
F110	SPHAERIIDAE	CF	8	BU
F111	CORBICULIDAE	CF	8	BU

	HABIT	CODE		
	Burrowers	BU		
	Climbers	CL		
	Clingers	CG		
	Crawlers	CR		
	Divers	DV		
	Generalists	GN		
	Skaters	SK		
	Sprawlers	SP		
	FUNCTIONAL FEEDING GROUP	CODE		
	Collector Filterer	CF		
	Collector Gatherer	CG		
	Macrophyte Piercer	MP		
	Predator	PR		
	Scraper	SC		
	Shredder	SH		

DIRECTIONS FOR CALCULATING MAIS
using Excel 5.0

IMPORTANT: ALL IDENTIFICATIONS MUST BE AT THE FAMILY LEVEL, OR HIGHER, FOR THE MAIS TO BE ACCURATE.

Lower identification levels (genus, species) will cause grave errors in metric transformation.

I. There are 3 sheets in the MAIS file (MAIS-Fam.XLS).

3 sheets
1. **Data Worksheet**
2. **Metrics**
3. **Scrap**

II. Enter *Code, Taxon, Abundance, Feeding Group, Habit,* and *Tvalue* on the **Data Worksheet** using the Taxa Dictionary (Instdict.xls).

III. The **Metrics** sheet calculates the values for the MAIS, with the exception of *%5 Dominant.*

IV. To calculate *%5 Dominant*, return to the **Data Worksheet** and copy Col. C. Paste Col. C in the **Scrap** sheet in the 1st column and sort descending.

Return to the **Metrics** sheet and all values will be present.

V. The MAIS values, Total MAIS score, and Biological Condition Category will be calculated.

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
2	PHYLLUM PROTOZOA			
3	PHYLUM PORIFERA			
4	PHYLUM COELENTERATA			
40	CLASS HYDROZOA			
400	ORDER HYDROIDA			
4000	HYDRIDAE	PR	3	CL
400001	Hydra	PR	3	CL
4000018	Hydra americana	PR	3	CL
4001	CLAVIDAE			
400100	Cordylophora			
4001000	Cordylophora lacustris			
5	PHYLUM PLATYHELMINTHES			
50	CLASS TURBELLARIA			
506	ORDER TRICLADIDA			
5060	PLANARIIDAE	CG	8	SP
506001	Dugesia	CG	8	SP
5060010	Dugesia tigrina	CG	8	SP
5060011	Dugesia polychroa	CG	8	SP
6	PHYLUM NEMATODA	CG	8	BU
9	PHYLUM ROTATORIA			
A	PHYLUM BRYOZOA			
A0	CLASS ECTOPROCTA			
A00	ORDER PHYLACTOLAEMATA			
C	PHYLUM NEMERTINEA	PR	8	SP
C0	CLASS ENOPLA	PR	8	SP
C00	ORDER HOPOLONEMERTINI	PR	8	SP
C00000	Prostoma	PR	8	SP
C000000	Prostoma graecense	PR	8	SP
D	PHYLUM ANNELIDA			
D1	CLASS POLYCHAETA			
D2	CLASS OLIGOCHAETA	CG	8	BU
D20	ORDER LUMBRICULIDA	CG	8	BU
D200	LUMBRICULIDAE	CG	8	BU
D20000	Lumbriculus	CG	8	BU
D20001	Kincaidiana	CG	8	BU
D200010	Kincaidiana hexatheca	CG	8	BU
D21	ORDER HAPLOTAXIDA	CG	8	BU
D210	HAPLOTAXIDAE	CG	8	BU
D211	ENCHYTRAEIDAE	CG	8	BU
D212	NAIDIDAE	CG	8	BU
D21200	Dero	CG	10	BU
D212000	Dero obtusa	CG	10	BU
D212001	Dero nivea	CG	10	BU
D212002	Dero furcata	CG	10	BU
D21201	Pristina	CG	8	BU
D212010	Pristina osborni	CG	8	BU
D21202	Nais	CG	8	BU
D212020	Nais bretscheri	CG	6	BU
D212021	Nais communis	CG	8	BU
D212022	Nais variabilis	CG	10	BU

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
D212023	Nais pseudobtusa	CG	10	BU
D21203	Slavina	CG	10	BU
D212030	Slavina appendiculata	CG	10	BU
D21204	Stylaria	CG	8	BU
D212040	Stylaria fossularis	CG	8	BU
D212041	Stylaria lacustris	CG	8	BU
D21205	Arcteonais	CG	8	BU
D212050	Arcteonais lomondi	CG	8	BU
D21206	Chaetogaster	CG	8	BU
D212060	Chaetogaster diaphanus	CG	8	BU
D213	TUBIFICIDAE	CG	10	BU
D21300	Branchiura	CG	10	BU
D213000	Branchiura sowerbyi	CG	10	BU
D21301	Quistadrilus	CG	10	BU
D213010	Quistadrilus multisetosus	CG	10	BU
D21302	Spirosperma	CG	10	BU
D214	OPISTOCYSTIDAE	CG	10	BU
D215	LUMBRICIDAE	CG	10	BU
D216	SPARGANOPHILIDAE	CG	10	BU
D22	ORDER BRANCHIOBDELLIDA	CG	5	
D220	BRANCHIOBDELLIDAE	CG	5	
D23	ORDER AEOLOSOMATIDA			
D230	AEOLOSOMATIDAE			
D3	CLASS HIRUDINEA	PR	8	SP
D30	ORDER RHYNCHOBDELLIDA	PR	8	SP
D300	GLOSSIPHONIIDAE	PR	8	SP
D30001	Helobdella	PR	10	SP
D301	PISCICOLIDAE			
D30100	Myzobdella			
D301000	Myzobdella lugubris			
E	PHYLUM ARTHROPODA			
E0	CLASS CRUSTACEA			
E03	ORDER CLADOCERA			
E030	SIDIDAE	CF		SP
E03000	Sida	CF		SP
E030000	Sida crystallina	CF		SP
E033	DAPHNIDAE	CF		SW
E03301	Simocephalus	CF		SW
E033011	Simocephalus vetulus	CF		SW
E04	ORDER PODOCOPA			
E05	Copepoda			
E08	ORDER ISOPODA			
E081	ASELLIDAE	CG	8	SP
E08100	Lirceus	CG	8	SP
E08101	Caecidotea	CG	8	SP
E081010	Caecidotea militaris	CG	8	SP
E09	ORDER AMPHIPODA	CG		
E090	TALITRIDAE	CG	8	CR
E09000	Hyalella	CG	8	CR
E090000	Hyalella azteca	CG	8	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E092	GAMMARIDAE	CG	6	CR
E09200	Gammarus	CG	6	CR
E092004	Gammarus pseudolimnaeus	CG	6	CR
E093	CRANGONYCTIDAE	CG	6	CR
E09300	Crangonyx	CG	6	CR
E09301	Synurella	CG	6	CR
E0A	ORDER DECAPODA			
E0A0	CAMBARIDAE	GN	5	GN
E0A00	CAMBARELLINAE	GN	5	GN
E0A004	Cambarus	GN	5	GN
E0A0041	Cambarus robustus	GN	5	GN
E0A0042	Cambarus bartonii	GN	5	GN
E0A005	Orconectes	GN	5	GN
E0A0050	Orconectes obscurus	GN	5	GN
E0A0051	Orconectes rusticus	GN	5	GN
E1	CLASS INSECTA			
E10	ORDER PLECOPTERA			
E100	PTERONARCYIDAE	SH	1	CR
E10001	Pteronarcys	SH	1	CR
E100010	Pteronarcys dorsata	SH	1	CR
E100011	Pteronarcys biloba	SH	1	CR
E100012	Pteronarcys comstocki	SH	1	CR
E100013	Pteronarcys proteus	SH	1	CR
E100014	Pteronarcys scotti	SH	1	CR
E101	PELTOPERLIDAE	SH	1	CR
E10100	Peltoperla	SH	1	CR
E101000	Peltoperla arcuata	SH	1	CR
E101001	Peltoperla tarteri	SH	1	CR
E10101	Tallaperla	SH	1	CR
E101010	Tallaperla maria	SH	1	CR
E102	NEMOURIDAE	SH	3	CR
E1020	NEMOURINAE			
E10201	Prostoia	SH	5	CR
E102010	Prostoia completa	SH	5	CR
E102011	Prostoia similis	SH	5	CR
E102012	Prostoia (similis/completa)	SH	5	CR
E1021	AMPHINEMURINAE			
E10210	Amphinemura	SH	3	CR
E102100	Amphinemura wui	SH	3	CR
E102101	Amphinemura delosa	SH	3	CR
E102102	Amphinemura nigritta	SH	3	CR
E102200	Ostrocerca complexa	SH	0	CR
E102300	Soyedina carolinensis	SH	0	CR
E103	PERLIDAE	PR	1	CR
E1030	PERLINAE			
E10300	Neoperla	PR	1	CR
E103000	Neoperla clymene	PR	1	CR
E10301	Paragnetina	PR	2	CR
E103010	Paragnetina fumosa	PR	2	CR
E103011	Paragnetina immarginata	PR	2	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E103012	Paragnetina media	PR	2	CR
E10302	Agnetina (=Phasganophora)	PR	0	CR
E103020	Agnetina capitata	PR	0	CR
E1031	ACRONEURIINAE			
E10310	Perlinella	PR	1	CR
E10311	Hansonoperla	PR	0	CR
E103110	Hansonoperla appalachia	PR	0	CR
E10312	Attaneuria	PR	1	CR
E103120	Attaneuria ruralis	PR	1	CR
E10313	Acroneuria	PR	2	CR
E103130	Acroneuria abnormis	PR	2	CR
E103131	Acroneuria filicis	PR	2	CR
E103132	Acroneuria lycorias	PR	2	CR
E103133	Acroneuria evoluta	PR	2	CR
E103134	Acroneuria carolinensis	PR	2	CR
E103135	Acroneuria internata	PR	2	CR
E103136	Acroneuria perplexa	PR	2	CR
E10313X	Acroneuria n.sp.(YBC)	PR	2	CR
E10313Y	Acroneuria perplexa group	PR	2	CR
E10314	Eccoptura	PR	3	CR
E103140	Eccoptura xanthenes	PR	3	CR
E10315	Perlesta	PR	5	CR
E103150	Perlesta placida group	PR	5	CR
E10316	Beloneuria	PR	0	CR
E104	PERLODIDAE	PR	2	CR
E1040	PERLODINAE			
E10400	Isogenoides	PR	1	CR
E104000	Isogenoides hansoni	PR	1	CR
E10401	Yugus	PR	0	CR
E104010	Yugus bulbosus	PR	0	CR
E10402	Cultus	PR	2	CR
E104020	Cultus decisus	PR	2	CR
E10403	Diploperla	PR	2	CR
E104030	Diploperla duplicata	PR	2	CR
E104031	Diploperla robusta	PR	2	CR
E104032	Diploperla morgani	PR	2	CR
E104033	Diploperla kanawholensis	PR	2	CR
E10404	Remenus	PR	0	CR
E104040	Remenus bilobatus	PR	0	CR
E10405	Helopicus	PR	0	CR
E104050	Helopicus subvarians	PR	0	CR
E10406	Malirekus	PR	1	CR
E104060	Malirekus hastatus	PR	1	CR
E1041	ISOPERLINAE			
E10410	Clioperla	PR	4	CR
E104100	Clioperla clio	PR	4	CR
E10411	Isoperla	PR	2	CR
E104110	Isoperla burksi	PR	2	CR
E104111	Isoperla bilineata	PR	2	CR
E104112	Isoperla signata	PR	2	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E104113	Isoperla lata	PR	2	CR
E104114	Isoperla orata	PR	2	CR
E104115	Isoperla holochlora	PR	2	CR
E104116	Isoperla namata	PR	2	CR
E104117	Isoperla transmarina	PR	2	CR
E104118	Isoperla similis	PR	2	CR
E105	CHLOROPERLIDAE	PR	1	CR
E1050	PARAPERLINAE			
E10500	Utaperla	PR	1	CR
E1051	CHLOROPERLINAE			
E10510	Alloperla	PR	1	CR
E105100	Alloperla usa	PR	1	CR
E105101	Alloperla imbecilla	PR	1	CR
E105102	Alloperla biserrata	PR	1	CR
E105103	Alloperla nanina	PR	1	CR
E10511	Haploperla (=Hastaperla)	PR	1	CR
E105110	Haploperla brevis	PR	1	CR
E10512	Sweltsa	PR	0	CR
E105120	Sweltsa onkos	PR	0	CR
E105121	Sweltsa lateralis	PR	0	CR
E10513	Rasvena	PR	1	CR
E105130	Rasvena terna	PR	1	CR
E10514	Suwallia	PR	1	CR
E105140	Suwallia marginata	PR	1	CR
E106	TAENIOPTERYGIDAE	SH	3	CR
E1060	TAENIOPTERYGINAE			
E10600 X	Taeniopteryx	SH	5	CR
E106000	Taeniopteryx burksi	SH	5	CR
E106001	Taeniopteryx maura	SH	5	CR
E106002	Taeniopteryx ugola	SH	5	CR
E106003	Taeniopteryx parvula	SH	5	CR
E106004	Taeniopteryx metequi	SH	5	CR
E10600X	Taeniopteryx (burksi/maura)	SH	5	CR
E1061	BRACHYPTERINAE			
E10610	Strophopteryx	SC	3	CR
E106100	Strophopteryx fasciata	SC	3	CR
E106101	Strophopteryx appalachia	SC	3	CR
E10611	Taenionema	SC	3	CR
E106110	Taenionema atlanticum	SC	3	CR
E10612	Bolotoperla	SC	3	CR
E106120	Bolotoperla rossi	SC	3	CR
E10613	Oemopteryx	SC	3	CR
E106130	Oemopteryx contorta	SC	3	CR
E106131	Oemopteryx glacialis	SC	3	CR
E107	LEUCTRIDAE	SH	0	CR
E1070	LEUCTRINAE			
E10700 X	Leuctra	SH	0	CR
E107000	Leuctra ferruginea	SH	0	CR
E107001	Leuctra truncata	SH	0	CR
E107002	Leuctra sibleyi	SH	0	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E107003	Leuctra tenuis	SH	0	CR
E107004	Leuctra carolinensis	SH	0	CR
E107005	Leuctra biloba	SH	0	CR
E10701	Paraleuctra	SH	0	CR
E107010	Paraleuctra sara	SH	0	CR
E107011	Paraleuctra distinctus	SH	0	CR
E10702	Megaleuctra	SH	0	CR
E108	CAPNIIDAE	SH	1	CR
E10800	Allocapnia	SH	1	CR
E108000	Allocapnia spp.	SH	1	CR
E10801	Paracapnia	SH	1	CR
E108010	Paracapnia angulata	SH	1	CR
E11	ORDER EPHEMEROPTERA			
E110	EPHEMERIDAE	CG	4	BU
E1100	EPHEMERINAE			
E11000	Ephemera	CG	4	BU
E110000	Ephemera varia	CG	4	BU
E110001	Ephemera guttulata	CG	4	BU
E11001	Hexagenia	CG	4	BU
E110010	Hexagenia limbata	CG	4	BU
E110011	Hexagenia rigida	CG	4	BU
E110020	Litobrancha recurvata	CG	1	BU
E11010	Pentagenia	CG	4	BU
E110100	Pentagenia vittigera	CG	4	BU
E111	NEOEPHEMERIDAE	CG	2	CR
E11100	Neoephemera	CG	2	CR
E111000	Neoephemera purpurea	CG	2	CR
E112	CAENIDAE	CG	6	SP
E11200	Caenis	CG	7	SP
E112000	Caenis hilaris	CG	7	SP
E11201	Brachycercus	CG	3	SP
E112010	Brachycercus nitidus	CG	3	SP
E113	EPHEMERELLIDAE	CG	2	CR
E1130	EPHEMERELLINAE			
E11300	Attenella	CG	2	CR
E113000	Attenella attenuata	CG	2	CR
E11301	Serratella	CG	2	CR
E113010	Serratella deficiens	CG	2	CR
E113011	Serratella frisoni	CG	2	CR
E113012	Serratella serratoides	CG	2	CR
E11302	Timpanoga	CG	4	CR
E113020	Timpanoga simplex	CG	4	CR
E113021	Timpanoga lita	CG	4	CR
E11303	Drunella	SC	0	CR
E113030	Drunella cornuta	SC	0	CR
E113031	Drunella cornutella	SC	0	CR
E113032	Drunella tuberculata	SC	0	CR
E113033	Drunella walkeri	SC	0	CR
E11304	Ephemerella	CG	2	CR
E113040	Ephemerella dorothea	CG	2	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E113041	Ephemerella needhami	CG	2	CR
E113042	Ephemerella rotunda	CG	2	CR
E113043	Ephemerella invaria	CG	2	CR
E11305	Eurylophella	CG	4	CR
E113050	Eurylophella minimella	CG	4	CR
E113051	Eurylophella funeralis	CG	4	CR
E113052	Eurylophella coxalis	CG	4	CR
E114	BAETISCIDAE	CG	3	SP
E11400	Baetisca	CG	3	SP
E114000	Baetisca lacustris	CG	3	SP
E114001	Baetisca bemeri	CG	3	SP
E115	AMELETIDAE	SC	1	CG
E11500	Ameletus	SC	1	CG
E115000	Ameletus lineatus	SC	1	CG
E115001	Ameletus cryptustimulus	SC	1	CG
E11E	SIPHLONURIDAE	CG	6	CL
E11E00	Siphlonurus	CG	6	CL
E116	LEPTOPHLEBIIDAE	CG	2	CR
E11600	Leptophlebia	CG	6	SP
E11601	Paraleptophlebia	CG	1	CR
E116010	Paraleptophlebia guttata	CG	1	CR
E11602	Choroterpes	CG	6	CR
E116020	Choroterpes basalis	CG	6	CR
E11603	Habrophlebia	CG	1	CR
E116030	Habrophlebia vibrans	CG	1	CR
E11604	Habrophlebiodes	SC	1	CR
E116040	Habrophlebiodes americana	SC	1	CR
E117	BAETIDAE	CG	5	CG
E11701	Baetis	CG	5	CG
E117010	Baetis tricaudatus	CG	5	CG
E117014	Baetis flavistriga	CG	5	CG
E117016	Baetis intercalaris	CG	5	CG
E117019	Baetis dubius	CG	5	CG
E11702	Callibaetis	CG	10	CL
E11703	Centroptilum	CG	7	CG
E11704	Cloeon	CG	7	CL
E11705	Heterocloeon	SC	3	CG
E117050	Heterocloeon curiosum	SC	3	CG
E117051	Heterocloeon petersi	SC	3	CG
E11706	Acentrella	CG	5	CG
E117060	Acentrella insignificans	CG	5	CG
E117061	Acentrella ampla	CG	5	CG
E11707	Acerpenna	CG	5	CG
E117070	Acerpenna pygmaea	CG	5	CG
E117071	Acerpenna macdunnoughi	CG	5	CG
E11708	Labiobaetis	CG	5	CG
E117080	Labiobaetis ephippiatus	CG	4	CG
E117081	Labiobaetis propinquus	CG	5	CG
E1170Z	Baetis (complex)	CG	5	CG
E119	HEPTAGENIIDAE	SC	3	CG

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E1190	HEPTAGENIINAE			
E11900	Stenonema	SC	4	CG
E119000	Stenonema femoratum	SC	4	CG
E119001	Stenonema ithaca	SC	4	CG
E119002	Stenonema mediopunctatum	SC	4	CG
E119003	Stenonema pulchellum	SC	4	CG
E119004	Stenonema vicarium	SC	4	CG
E119005	Stenonema modestum	SC	4	CG
E119006	Stenonema terminatum	SC	4	CG
E119007	Stenonema mexicanum =integrum	SC	4	CG
E119008	Stenonema exiguum	SC	4	CG
E119009	Stenonema pudicum	SC	4	CG
E11901	Stenacron	CG	4	CG
E119010	Stenacron interpunctatum	CG	4	CG
E119011	Stenacron carolina	CG	4	CG
E11902	Epeorus	CG	1	CG
E119020	Epeorus humeralis	CG	1	CG
E119021	Epeorus fragilis	CG	1	CG
E119022	Epeorus pleuralis	CG	1	CG
E119023	Epeorus dispar	CG	1	CG
E11903	Cinygmula	SC	1	CG
E119030	Cinygmula subaequalis	SC	1	CG
E11904	Leucrocuta	SC	2	CG
E119040	Leucrocuta thethis	SC	2	CG
E11905	Heptagenia	SC	3	CG
E119050	Heptagenia flavescens	SC	3	CG
E119051	Heptagenia marginalis	SC	3	CG
E11906	Nixe	SC	1	CG
E11907	Rhithrogena	CG	1	CG
E11A	POLYMITARCYIDAE	CG	1	BU
E11A0	POLYMITARCYINAE			
E11A00	Ephoron	CG	1	BU
E11A000	Ephoron leukon	CG	1	BU
E11A001	Ephoron album	CG	2	BU
E11B	POTAMANTHIDAE	CG	2	BU
E11B00	Anthopotamus	CG	2	BU
E11C	LEPTOHYPHIDAE	CG	5	SP
E11C00	Tricorythodes	CG	5	SP
E11D	ISONYCHIIDAE	CF	3	CG
E11D04	Isonychia	CF	3	CG
E11D040	Isonychia bicolor group	CF	3	CG
E11D041	Isonychia bicolor	CF	3	CG
E12	ORDER ODONATA			
E120	ANISOPTERA			
E1200	CORDULEGASTRIDAE	PR	3	BU
E12000	Cordulegaster	PR	3	BU
E120000	Cordulegaster sayi	PR	3	BU
E120001	Cordulegaster maculata	PR	3	BU
E1201	PETALURIDAE	PR	4	BU
E1202	GOMPHIDAE	PR	3	BU

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E12020	Progomphus	PR	8	BU
E120200	Progomophus obscurus	PR	6	BU
E12021	Ophiogomphus	PR	4	BU
E12022	Stylogomphus	PR	4	BU
E120220	Stylogomphus albistylus	PR	6	BU
E12023	Gomphus	PR	6	BU
E12024	Dromogomphus	PR	1	BU
E120240	Dromogomphus spoliatus	PR	1	BU
E120241	Dromogomphus spinosus	PR	1	BU
E12025	Arigomphus	PR	1	BU
E12026	Hylogomphus	PR	1	BU
E120260	Hylogomphus viridifrons	PR	1	BU
E120261	Hylogomphus abbreviatus	PR	1	BU
E12027	Stylurus	PR	1	BU
E120270	Stylurus notatus	PR	1	BU
E120271	Stylurus spiniceps	PR	1	BU
E12028	Hagenius	PR	4	CR
E120280	Hagenius brevistylus	PR	4	BU
E12029	Lanthus	PR	1	BU
E120290	Lanthus parvulus	PR	1	BU
E1203	MACROMIIDAE	PR	3	SP
E12030	Macromia	PR	3	SP
E120300	Macromia taeniolata	PR	3	SP
E120301	Macromia illinoiensis	PR	3	SP
E1204	AESHNIDAE	PR	3	CR
E12040	Basiaeschna	PR	3	CR
E120400	Basiaeschna janata	PR	3	CR
E12041	Boyeria	PR	3	CR
E120410	Boyeria grafiana	PR	3	CR
E120411	Boyeria vinosa	PR	3	CR
E12042	Aeschna	PR	3	CR
E1205	CORDULIIDAE	PR	8	CL
E12050	Neurocordulia	PR	4	CL
E120500	Neurocordulia molesta	PR	4	CL
E120501	Neurocordulia virginiensis	PR	4	CL
E12051	Epicordulia	PR	5	CL
E120510	Epicordulia princeps	PR	5	CL
E12052	Tetragoneuria	PR	8	CL
E12053	Somatochlora	PR	8	CL
E1206	LIBELLULIDAE	PR	9	SP
E12060	Libellula	PR	10	SP
E12061	Sympetrum	PR	7	SP
E120610	Sympetrum vicinum	PR	7	SP
E12062	Perithemis	PR	10	SP
E12063	Celithemis	PR	9	CL
E12064	Erythemis	PR	10	SP
E120640	Erythemis simplicicollis	PR	10	SP
E12065	Pachydiplax	PR	9	SP
E120650	Pachydiplax longipennis	PR	9	SP
E12066	Plathemis	PR	9	SP

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E121	ZYGOPTERA			
E1210	CALOPTERYGIDAE	PR	7	CL
E12100	Calopteryx	PR	8	CL
E121000	Calopteryx dimidiata	PR	8	CL
E12101	Hetaerina	PR	6	CL
E1211	LESTIDAE	PR	9	CL
E12110	Lestes	PR	9	CL
E1212	COENAGRIONIDAE	PR	9	CR
E12120	Argia	PR	8	CR
E121200	Argia translata	PR	8	CR
E121201	Argia moesta	PR	8	CR
E121202	Argia tibialis	PR	8	CR
E121203	Argia apicalis	PR	8	CR
E12121	Nehallenia	PR	9	CL
E12122	Ischnura	PR	10	CL
E12123	Enallagma	PR	9	CL
E121230	Enallagma signatum	PR	9	CL
E121231	Enallagma divagans	PR	9	CL
E121232	Enallagma exsulans	PR	9	CL
E12124	Coenagrion	PR	9	CL
E12125	Enallagma/Ischnura	PR	9	CL
E13	ORDER HEMIPTERA			
E130	BELOSTOMATIDAE	PR	9	CL
E1300	BELOSTOMATINAE			
E13000	Belostoma	PR	9	CL
E131	NEPIDAE	PR	7	CL
E1310	RANATRINAE			
E13100	Ranatra	PR	7	CL
E132	GERRIDAE	PR	8	SK
E1320	GERRININAE			
E13200	Gerris	PR	8	SK
E1321	TREPOBATINAE			
E13210	Metrobates	PR	8	SK
E13211	Trepobates	PR	8	SK
E132110	Trepobates inermis	PR	8	SK
E1322	RHAGADOTARSINAE			
E13220	Rheumatobates	PR	8	SK
E132200	Rheumatobates rileyi	PR	8	SK
E133	MESOVELIIDAE	PR	8	SK
E1330	MESOVELIINAE			
E13300	Mesovelia	PR	8	SK
E134	VELIIDAE	PR	8	SK
E1340	HYDROESSINAE			
E13400	Microvelia	PR	8	SK
E134000	Microvelia americana	PR	8	SK
E1341	RHYAGOVELIINAE			
E13410	Rhagovelia	PR	8	SK
E134100	Rhagovelia obesa	PR	8	SK
E13A	CORIXIDAE	MP	9	DV
E13A0	CORIXINAE			

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E13A00	Palmacorixa	MP	9	DV
E13A01	Sigara	MP	9	DV
E13A02	Trichocorixa	PR	9	DV
E13A03	Hesperocorixa	MP	9	DV
E13B	NOTONECTIDAE	PR	9	DV
E13B0	NOTONECTINAE			
E13B01	Notonecta	PR	9	DV
E14	ORDER MEGALOPTERA			
E140	SIALIDAE	PR	7	SP
E14000	Sialis	PR	7	SP
E140000	Sialis velata	PR	7	SP
E141	CORYDALIDAE	PR	5	CR
E1410	CORYDALINAE			
E14100	Corydalus	PR	5	CR
E141000	Corydalus cornutus	PR	5	CR
E1411	CHAULIODINAE			
E14110	Chauliodes	PR	9	SP
E141100	Chauliodes pectinicornis	PR	9	SP
E141101	Chauliodes rastricornis	PR	9	SP
E14111	Nigronia	PR	4	CR
E141110	Nigronia fasciatus	PR	4	CR
E141111	Nigronia serricornis	PR	4	CR
E14112	Neohermes	PR	5	CG
E141120	Neohermes concolor	PR	5	CG
E15	ORDER NEUROPTERA			
E150	SISYRIDAE	PR	3	GN
E15000	Sisyra	PR	3	GN
E16	ORDER TRICHOPTERA			
E160	HYDROPTILIDAE	MP	6	CR
E1600	LEUCOTRICHIINAE			
E16000	Leucotrichia	SC	7	CG
E160000	Leucotrichia pictipes	SC	7	CG
E1601	HYDROPTILINAE			
E16010	Agraylea	MP	5	CL
E16011	Dibusa	SC	8	CG
E160110	Dibusa angata	SC	8	CG
E16012	Hydroptila	MP	6	CR
E160120	Hydroptila waubesiana	MP	6	CR
E16013	Ochrotrichia	CG	4	CG
E16014	Oxyethira	MP	2	CL
E16015	Stactobiella	SH	1	CG
E16016	Neotrichia	SC	8	CG
E16017	Palaeagapetus	SH	5	SP
E1602	ORTHOTRICHIINAE			
E16020	Orthotrichia	MP	8	CG
E161	HELICOPSYCHIDAE	SC	5	CR
E16100	Helicopsyche	SC	5	CR
E161000	Helicopsyche borealis	SC	5	CR
E162	HYDROPSYCHIDAE	CF	6	CG
E1620	MACRONEMATINAE			

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E16200	Macrostemum (=Macronemum)	CF	3	CG
E162000	Macrostemum zebratum	CF	3	CG
E1621	HYDROPSYCHINAE			
E16210	Hydropsyche	CF	6	CG
E162100	Hydropsyche (H.) orris	CF	6	CG
E162101	Hydropsyche (H.) leonardi	CF	6	CG
E162102	Hydropsyche (H.) hoffmani	CF	6	CG
E162103	Hydropsyche (H.) betteni	CF	6	CG
E162104	Hydropsyche (H.) dicantha	CF	6	CG
E162105	Hydropsyche (H.) frisoni ??	CF	6	CG
E162107	Hydropsyche (H.) hageni	CF	6	CG
E162108	Hydropsyche (H.) simulans	CF	6	CG
E16210G	Hydropsyche (C.) alhedra	CF	6	CG
E16210H	Hydropsyche (C.) bronta	CF	6	CG
E16210I	Hydropsyche (C.) cheilonis	CF	6	CG
E16210J	Hydropsyche (C.) macleodi	CF	6	CG
E16210K	Hydropsyche (C.) morosa	CF	6	CG
E16210L	Hydropsyche (C.) slossonae	CF	6	CG
E16210M	Hydropsyche (C.) sparna	CF	6	CG
E16210N	Hydropsyche (C.) ventura	CF	6	CG
E16210O	Hydropsyche (C.) walkeri	CF	6	CG
E16211	Cheumatopsyche	CF	6	CG
E162110	Cheumatopsyche campyla	CF	6	CG
E162111	Cheumatopsyche ela	CF	6	CG
E162112	Cheumatopsyche helma	CF	6	CG
E162113	Cheumatopsyche pettiti	CF	6	CG
E162115	Cheumatopsyche halima	CF	6	CG
E16212	Potamyia	CF	6	CG
E162120	Potamyia flava	CF	6	CG
E1622	DIPLECTRONINAE			
E16220	Diplectrona	CF	2	CG
E162200	Diplectrona modesta	CF	2	CG
E162201	Diplectrona metaqui	CF	2	CG
E16221	Homoplectra (=Aphropsyche)	CF	2	CG
E162210	Homoplectra doringa	CF	2	CG
E162300	Parapsyche apicalis	CF	2	CG
E16K	Arctopsychidae	CF	0	CG
E1K00	Arctopsyche	CF	0	CG
E163	RHYACOPHILIDAE	PR	1	CR
E1630	RHYACOPHILINAE			
E16300	Rhyacophila	PR	1	CR
E163000	Rhyacophila fuscula	PR	0	CR
E163001	Rhyacophila torva	PR	0	CR
E163002	Rhyacophila lobifera	PR	0	CR
E163003	Rhyacophila carolina	PR	0	CR
E163004	Rhyacophila invaria	PR	0	CR
E163005	Rhyacophila vibox	PR	0	CR
E163006	Rhyacophila nigrita	PR	0	CR
E163007	Rhyacophila glaberrima	PR	0	CR
E163008	Rhyacophila minor	PR	0	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E164	PHILOPOTAMIDAE	CF	2	CG
E1640	CHIMARRINAE			
E16400	Chimarra	CF	3	CG
E164000	Chimarra obscura	CF	3	CG
E164001	Chimarra socia	CF	3	CG
E164002	Chimarra aterrima	CF	3	CG
E1641	PHILOPOTAMINAE			
E16410	Wormaldia	CF	1	CG
E164100	Wormaldia moestus	CF	1	CG
E16411	Dolophilodes	CF	1	CG
E164110	Dolophilodes distinctus	CF	1	CG
E165	PSYCHOMYIIDAE	CG	3	CG
E1650	PSYCHOMYIINAE			
E16500	Psychomyia	CG	3	CG
E165000	Psychomyia flavida	CG	3	CG
E16501	Lype	SC	4	CG
E165010	Lype diversa	SC	4	CG
E167	LEPTOCERIDAE	CG	4	CR
E1670	MYSTACIDINI			
E16700	Mystacides	CG	3	CR
E167000	Mystacides sepulchralis	CG	3	CR
E16701	Triaenodes	SH	4	CR
E167010	Triaenodes injustus	SH	4	CR
E16702	Leptocerus	CG	4	CR
E16703	Setodes	CG	0	CR
E167030	Setodes incerta	CG	0	CR
E1671	OECETINI			
E16710	Oecetis	PR	4	CR
E167100	Oecetis inconspicua	PR	4	CR
E167101	Oecetis cinerascens	PR	4	CR
E167102	Oecetis avara	PR	4	CR
E1672	ATHRIPSODINI			
E16720	Ceraclea	CG	4	CR
E167200	Ceraclea cancellata	CG	4	CR
E167201	Ceraclea transversus	CG	4	CR
E167202	Ceraclea tarsipunctata	CG	4	CR
E167203	Ceraclea neffi	CG	4	CR
E1673	LEPTOCERINI			
E16730	Nectopsyche	SH	4	CR
E167300	Nectopsyche candida	SH	4	CR
E167301	Nectopsyche exquisita	SH	4	CR
E168	PHRYGANEIDAE	SH	5	CL
E16800	Ptilostomis	SH	6	CL
E16801	Agrypnia	SH	6	CL
E16802	Banksiola	SH	4	CL
E16803	Fabria	SH	4	CL
E16804	Oligostomis	PR	1	CL
E16805	Phryganea	SH	4	CL
E16A	ODONTOCERIDAE	SC	0	CG
E16A00	Psilotreta	SC	0	CG

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E16C	BRACHYCENTRIDAE	CF	1	CG
E16C00	Micrasema	SH	1	CG
E16C000	Micrasema sprulesi	SH	1	CG
E16C001	Micrasema charonis	SH	1	CG
E16C01	Brachycentrus	CF	1	CG
E16C010	Brachycentrus appalachia	CF	1	CG
E16C011	Brachycentrus incanus	CF	1	CG
E16C012	Brachycentrus lateralis	CF	1	CG
E16C013	Brachycentrus nigrosoma	CF	1	CG
E16C014	Brachycentrus numerosus	CF	1	CG
E16C015	Brachycentrus solomoni	CF	1	CG
E16C016	Brachycentrus spinae	CF	1	CG
E16C02	Adicrophleps	SH	1	CG
E16C020	Adicrophleps hitchcocki	SH	1	CG
E16E	LEPIDOSTOMATIDAE	SH	1	CR
E16E00	Lepidostoma	SH	1	CR
E16E000	Lepidostoma lydia	SH	1	CR
E16E001	Lepidostoma modestum	SH	1	CR
E16E01	Theliopsyche	SH	1	CR
E16F	GLOSSOSOMATIDAE	SC	1	CG
E16F0	GLOSSOSOMATINAE			
E16F00	Glossosoma	SC	0	CG
E16F000	Glossosoma nigrior	SC	0	CG
E16F1	AGAPETINAE			
E16F10	Agapetus	SC	0	CG
E16F2	PROTOPTILINAE			
E16F20	Protoptila	SC	3	CG
E16F21	Culoptila	SC	0	CG
E16F22	Matrioptila	SC	0	CG
E16G	LIMNEPHILIDAE	SH	4	CG
E16G1	LIMNEPHILINAE			
E16G10	Pycnopsyche	SH	4	CR
E16G11	Limnephilus	SH	4	CL
E16G12	Platycentropus	SH	4	CL
E16G13	Psychoglypha	CG	4	CL
E16G2	DICOSMOECINAE			
E16G20	Ironoquia	SH	8	SP
E16G4	APATANIIDAE	SC	1	CG
E16G40	Apatania	SC	1	CG
E16G400	Apatania praevolans	SC	1	CG
E16L	GOERIDAE	SC	0	CR
E16L00	Goera	SC	0	CR
E16M	UENOIDAE	SC	2	CG
E16M00	Neophylax	SC	2	CG
E16M000	Neophylax concinnus	SC	2	CG
E16M001	Neophylax ornatus	SC	2	CG
E16H	POLYCENTROPODIDAE	CF	5	CG
E16H0	POLYCENTROPODINAE			
E16H00	Cymellus	CF	7	SP
E16H000	Cymellus fraternus	CF	7	SP

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E16H01	Neureclipsis	CF	4	CG
E16H010	Neureclipsis crepuscularis	CF	4	CG
E16H02	Nyctiophylax	PR	3	SP
E16H020	Nyctiophylax moestus	PR	3	SP
E16H03	Polycentropus	PR	4	CG
E16H04	Cernotina	PR	4	SP
E16I	MOLANNIDAE	SC	6	SP
E16I00	Molanna	SC	6	SP
E16J	SERICOSTOMATIDAE	SH	1	SP
E16J00	Fattigia	SH	1	SP
E16J000	Fattigia pele	SH	1	SP
E16J01	Agarodes	SH	1	SP
E17	ORDER LEPIDOPTERA			
E170	PYRALIDAE	SH	5	CG
E17000	Petrophila (=Parargyractis)	SC	5	CG
E17001	Paraponyx	SH	5	GN
E171	NOCTUIDAE	SH	5	GN
E18	ORDER COLEOPTERA			
E181	HALIPLIDAE	MP	8	GN
E18100	Peltodytes	MP	8	GN
E181000	Peltodytes duodecimpunctatus	MP	8	GN
E18101	Haliplus	MP	8	GN
E182	DYTISCIDAE	PR	6	GN
E1820	COLYMBETINAE			
E18200	Laccornis	PR	6	GN
E1821	LACCOPHILINAE			
E18210	Laccophilus	PR	6	GN
E1822	HYDROPORINAE			
E18220	Hydroporus	PR	6	GN
E18221	Agabetes	PR	6	GN
E18222	Agabus	PR	8	GN
E18223	Hydrovatus	PR	8	GN
E18224	Megadytes	PR	6	GN
E183	GYRINIDAE	PR	6	GN
E1830	ENHYDRINAE			
E18300	Dineutus	PR	6	GN
E183000	Dineutus discolor	PR	6	GN
E1831	GYRININAE			
E18310	Gyrinus	PR	6	GN
E184	HYDROPHILIDAE	PR	8	GN
E1840	HYDROPHILINAE			
E18400	Tropisternus	PR	7	GN
E184000	Tropisternus lateralis	PR	7	GN
E18401	Hydrophilus	PR	7	GN
E18F	HELOPHORIDAE	SH	8	CL
E18F0	Helophorus	SH	8	CL
E1842	HYDROBIINAE			
E18420	Enochrus	CG	9	GN
E18421	Laccobius	MP	7	GN
E1843	BEROSINAE			

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E18430	Berosus	MP	8	GN
E184300	Berosus peregrinus	MP	8	GN
E18440	Paracymus	CG	8	GN
E18450	Derallus	PR	8	GN
E18460	Hydrobius	SH	8	GN
E186	HYDRAENIDAE	PR	5	CL
E18600	Hydraena	PR	5	CL
E187	PSEPHENIDAE	SC	4	CG
E18700	Psephenus	SC	4	CG
E187000	Psephenus herricki	SC	4	CG
E18701	Ectopria	SC	4	CG
E188	DRYOPIDAE	SC	5	CG
E18800	Helichus	SC	5	CG
E188000	Helichus fastigiatus	SC	5	CG
E188001	Helichus lithophilus	SC	5	CG
E188002	Helichus basalis	SC	5	CG
E189	ELMIDAE	SC	4	CG
E1890	ELIMINI			
E18900	Stenelmis	SC	5	CG
E189000	Stenelmis mera	SC	5	CG
E189001	Stenelmis concinna	SC	5	CG
E189002	Stenelmis crenata	SC	5	CG
E189003	Stenelmis musgravei	SC	5	CG
E189004	Stenelmis sandersoni	SC	5	CG
E189005	Stenelmis sexlineata	SC	5	CG
E18901	Macronychus	SC	5	CG
E189010	Macronychus glabratus	SC	5	CG
E18902	Ancyronyx	SC	6	CG
E189020	Ancyronyx variegata	SC	6	CG
E18903	Microcylloepus	SC	3	CG
E189030	Microcylloepus pusillus	SC	3	CG
E18904	Optioservus	SC	5	CG
E189040	Optioservus trivittatus	SC	5	CG
E189041	Optioservus ovalis	SC	5	CG
E189042	Optioservus immunis	SC	5	CG
E18905	Dubiraphia	SC	5	CG
E189050	Dubiraphia bivittata	SC	5	CG
E189051	Dubiraphia vittata	SC	5	CG
E189052	Dubiraphia minima	SC	5	CG
E18906	Promoresia	SC	2	CG
E189060	Promoresia elegans	SC	2	CG
E189061	Promoresia tardella	SC	2	CG
E18907	Oulimnius	SC	2	CG
E189070	Oulimnius latiusculus	SC	2	CG
E18908	Gonielmas	SC	5	CG
E18B	LUTROCHIDAE	CG	5	CG
E18B00	Lutrochus	CG	5	CG
E18B000	Lutrochus laticeps	CG	5	CG
E18C	PTILODACTYLIDAE	SH	4	CG
E18C00	Anchytarsus	SH	4	CG

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E18C000	Anchytarsus bicolor	SH	4	CG
E18D	STAPHYLINIDAE	PR	5	CG
E18E	CURCULIONIDAE	SH	5	CG
E19	ORDER DIPTERA			
E190	BLEPHARICERIDAE	SC	0	CG
E19000	Blepharicera	SC	0	CG
E191	TANYDERIDAE	CG	7	SP
E19100	Protoplasa	CG	7	SP
E191000	Protoplasa fitchii	CG	7	SP
E192	TIPULIDAE	SH	4	BU
E1920	TIPULINI			
E19200 x	Tipula	SH	5	BU
E192000	Tipula furca	SH	5	BU
E192001	Tipula abdominalis	SH	5	BU
E1921	LIMONIINI			
E19210	Antocha	CG	3	CG
E19211	Limonia	SH	6	BU
E19212	Lipsothrix	SH	3	BU
E1922	PEDICIINI			
E19220 x	Dicranota	PR	3	CR
E19221	Pedicia	PR	4	BU
E1923	HEXATOMINI			
E19230 x	Hexatoma	PR	3	CR
E192300	Hexatoma spinosa	PR	3	CR
E192301	Hexatoma fultonensis	PR	3	CR
E192302	Hexatoma cinerea	PR	3	CR
E19231	Limnophila	PR	4	BU
E19232	Pseudolimnophila	PR	7	BU
E19233	Paradelphomyia	PR	3	BU
E19234	Pilaria	PR	3	BU
E1924	ERIOPTERINI			
E19240	Gonomyia	CG	8	BU
E19241	Molophilus	CG	3	BU
E19242	Ormosia	CG	4	BU
E19243	Erioptera	CG	3	BU
E193	PSYCHODIDAE	CG	10	BU
E1930	PSYCHODINI			
E19300	Psychoda	CG	10	BU
E1931	PERICOMINI			
E19310	Telmatoscopus	CG	10	BU
E19311	Pericoma	CG	10	BU
E194	CHAOBORIDAE	PR	7	SP
E1940	CHAOBORINI			
E19400	Chaoborus	PR	7	SP
E194000	Chaoborus punctipennis	PR	7	SP
E195	DIXIDAE	CG	3	CR
E19500	Dixa	CG	3	CR
E196	CULICIDAE	CF	8	DV
E1960	ANOPHELINAE			
E19600	Anopheles	CF	8	DV

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E1961	CULICINAE			
E19610	Aedes	CG	8	DV
E19611	Culex	CF	8	DV
E19612	Culiseta (=Theobaldia)	CG	8	DV
E19613	Mansonia	CG	8	DV
E19614	Psorophora	PR	8	DV
E19615	Uranotaenia	CF	8	DV
E197	SIMULIIDAE	CF	6	CG
E1970	PROSIMULIINI			
E19700	Prosimulium	CF	4	CG
E197000	Prosimulium fontanum	CF	4	CG
E197001	Prosimulium fuscum	CF	4	CG
E197002	Prosimulium magnum complex	CF	4	CG
E197003	Prosimulium mixtum	CF	4	CG
E197004	Prosimulium mysticum	CF	4	CG
E197005	Prosimulium rhizophorum	CF	4	CG
E19701	Cnephia	CF	6	CG
E19702	Stegopterna	CF	6	CG
E197020	Stegopterna mutata complex	CF	6	CG
E1972	SIMULIINI			
E19720	Simulium	CF	6	CG
E197200	Simulium decorum	CF	6	CG
E197201	Simulium vittatum complex	CF	6	CG
E197202	Simulium jenningsi	CF	6	CG
E197203	Simulium venustum complex	CF	6	CG
E197204	Simulium tuberosum complex	CF	6	CG
E197205	Simulium luggeri	CF	6	CG
E197206	Simulium aureum complex	CF	6	CG
E197207	Simulium gouldingi	CF	6	CG
E197208	Simulium impar	CF	6	CG
E197209	Simulium pugetense	CF	6	CG
E19720A	Simulium pictipes complex	CF	6	CG
E19720B	Simulium fibrinflatum	CF	6	CG
E19720C	Simulium nyssa	CF	6	CG
E19720D	Simulium underhilli	CF	6	CG
E19720E	Simulium parnassum	CF	6	CG
E19720F	Simulium verecundum complex	CF	6	CG
E198	CHIRONOMIDAE	CG	6	BU
E1980	TANYPODINI	PR	9	SP
E19800	Tanypus	PR	9	SP
E1981	MACROPELOPIINI	PR	9	SP
E19816	Procladius	PR	9	SP
E1982	COELOTANYPODINI	PR	8	BU
E19821	Coelotanypus	PR	8	BU
E1983	PENTANEURINI	PR	7	SP
E19830	Ablabesmyia	PR	7	SP
E198300	Ablabesmyia mallochi	PR	7	SP
E198301	Ablabesmyia parajanta	PR	7	SP
E19832	Conchapelopia	PR	8	SP
E19835	Labrundinia	PR	6	SP

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E198350	Labrundinia pilosella	PR	6	SP
E19836	Larsia	PR	9	SP
E19838	Nilotanypus	PR	4	SP
E198380	Nilotanypus fimbriatus	PR	4	SP
E1983A	Pentaneura	PR	5	SP
E1983G	Zavrelimyia	PR	9	SP
E1983X	Thienemannimyia group	PR	6	SP
E1984	NATARSIINI	PR	10	SP
E19840	Natarsia	PR	10	SP
E1985	BOREOCHLINI	CG	6	SP
E19851	Lasiodiamesa	CG	6	SP
E1987	DIAMESINI	CG	6	SP
E19870	Diamesa	CG	8	SP
E19872	Pagastia	CG	2	SP
E19873	Potthastia	CG	6	SP
E198730	Potthastia longimanus	CG	6	SP
E19874	Pseudodiamesa	CG	6	SP
E19876	Sympotthastia	CG	5	SP
E198A	CORYNONEURINI	CG	6	SP
E198A0	Corynoneura	CG	6	SP
E198A00	Corynoneura scutellata	CG	6	SP
E198A1	Thienemanniella	CG	6	SP
E198B	ORTHOCLADIINI	CG	6	SP
E198B0	Cardiocladius	PR	6	BU
E198B1	Cricotopus	CG	6	BU
E198B10	Cricotopus / Orthocladius	CG	6	BU
E198B11	Cricotopus bicinctus group	CG	6	BU
E198B2	Eukiefferiella	CG	6	SP
E198B21	Eukiefferiella claripennis	CG	6	SP
E198B22	Eukiefferiella pseudomontana	CG	6	SP
E198B23	Eukiefferiella sp3	CG	6	SP
E198B24	Eukiefferiella longicalar	CG	6	SP
E198B3	Tvetenia	CG	4	SP
E198B30	Tvetenia discoloripes group	CG	4	SP
E198B31	Tvetenia bavarica group	CG	4	SP
E198B4	Nanocladius	CG	7	SP
E198B5	Psectrocladius	CG	4	SP
E198B6	Orthocladius	CG	6	SP
E198B60	Orthocladius (Euorth) type 1	CG	6	SP
E198B61	Orthocladius (Euorth)	CG	6	SP
E198B7	Rheocricotopus	CG	7	SP
E198B8	Epoicocladius	CG	0	SP
E198B80	Epoicocladius ephemerae	CG	0	SP
E198B9	Diplocladius	CG	7	SP
E198BA	Cordites	CG	6	SP
E198BB	Brillia	SH	5	BU
E198BC	Parametriocnemus	CG	4	SP
E198BC0	Parametriocnemus lundbecki	CG	4	SP
E198BD	Paraphaenocladius	CG	3	SP
E198BE	Xylotopus	SH	6	BU

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E198BE0	Xylotopus par	SH	6	BU
E198BF	Parachaetocladius	CG	0	SP
E198BG	Parakiefferiella	CG	5	SP
E198BH	Synorthocladius	CG	4	SP
E198BI	Heterotrissocladius	CG	5	SP
E198BJ	Hydrobaenus	SC	9	SP
E198C	PSEUDOCHIRONOMINI	CG	6	BU
E198C0	Pseudochironomus	CG	5	BU
E198D	CHIRONOMINI	CG	6	BU
E198D0	Chironomus	CG	10	BU
E198D1	Cryptochironomus	PR	6	SP
E198D2	Cryptotendipes	CG	6	SP
E198D20	Cryptotendipes sp1	CG	6	SP
E198D3	Demicryptochironomus	CG	2	BU
E198D5	Endochironomus	SH	8	CG
E198D50	Endochironomus nigricans	SH	8	CG
E198D6	Glyptotendipes	SH	9	BU
E198D60	Glyptotendipes lobiferus	SH	9	BU
E198D61	Glyptotendipes (Polytomus)	SH	9	BU
E198D7	Goeldichironomus	CG	8	BU
E198D70	Goeldichironomus holoprasinus	CG	8	BU
E198D9	Harnischia	CG	9	CL
E198D90	Harnischia curtilamellata	CG	9	CL
E198D9X	Harnischia complex	CG	9	CL
E198DA	Kiefferulus	CG	8	BU
E198DB	Lauterborniella	CG	8	CL
E198DC	Dicrotendipes	CG	8	BU
E198DC0	Dicrotendipes neomodestus	CG	8	BU
E198DC1	Dicrotendipes nervosus	CG	8	BU
E198DC2	Dicrotendipes modestus	CG	8	BU
E198DD	Microtendipes	CF	5	CG
E198DD0	Microtendipes caelum	CF	5	CG
E198DD1	Microtendipes pedellus	CF	5	CG
E198DI	Parachironomus	PR	9	SP
E198DI0	Parachironomus pectinatellae	PR	9	SP
E198DK	Paralauterborniella	CG	5	CG
E198DL	Paratendipes	CG	5	BU
E198DN	Phaenopsectra	SC	6	CG
E198DO	Polypedilum	SH	6	CG
E198DO0	Polypedilum fallax group	SH	6	CG
E198DQ	Stenochironomus	CG	6	BU
E198DR	Stictochironomus	CG	7	BU
E198DS	Tribelos	CG	6	BU
E198DT	Stelechomyia	SH	5	BU
E198DT0	Stelechomyia perpulchra	SH	5	BU
E198DU	Xenochironomus	PR	7	BU
E198DV	Robackia	CG	3	BU
E198DV0	Robackia claviger	CG	3	BU
E198DV1	Robackia demeijerei	CG	3	BU
E198DW	Cladopelma	CG	3	BU

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E198E	TANYTARSINI	CF	6	CG
E198E0	Cladotanytarsus	CG	4	BU
E198E3	Micropsectra	CG	2	CL
E198E5	Paratanytarsus	CG	8	SP
E198E50	Paratanytarsus dissimilis gr.	CG	8	SP
E198E6	Rheotanytarsus	CF	6	CG
E198E7	Stempellina	CG	0	CL
E198E70	Stempellina sp3 (Oliver)	CG	0	CL
E198E8	Stempellinella	CG	5	SP
E198E9	Tanytarsus	CF	7	CG
E198E90	Tanytarsus coffmani	CF	7	CG
E198E91	Tanytarsus glabrescens group	CF	7	CG
E198E92	Tanytarsus guerlus group	CF	7	CG
E198E9A	Tanytarsus (group A)	CF	7	CG
E198EA	Zavrelia group	CG	5	CL
E198F	CHIRONOMINAE/ORTHOCLADIINAE	CG	6	BU
E198G	TANYPODINAE	PR	9	SP
E198H	CHIRONOMINAE	CG	6	BU
E198J	ORTHOCLADIINAE	CG	6	BU
E199	CERATOPOGONIDAE	PR	6	BU
E1990	FORCIPOMYIINAE			
E19900	Atrichopogon	CG	6	SP
E199000	Atrichopogon peregrinus	CG	6	SP
E19901	Forcipomyia	SC	6	SP
E1991	DASYHELEINAE			
E19910	Dasyhelea	CG	6	SP
E1992	CERATOPOGONINAE			
E19920	Culicoides	PR	8	BU
E19921	Palpomyia	PR	7	BU
E199210	Palpomyia tibialis group	PR	7	BU
E19922	Bezzia	PR	6	BU
E19923	Palpomyia / Bezzia	PR	6	BU
E19924	Stilobezzia	PR	6	BU
E19A	STRATIOMYIIDAE	CG	10	SP
E19A0	OXYCERINI			
E19A00	Oxycera	CG	10	SP
E19A1	ODONTOMYIINI			
E19A10	Odontomyia	CG	10	SP
E19A2	STRATIOMYINI			
E19A20	Stratiomys	CG	8	SP
E19B	TABANIDAE	PR	7	BU
E19B0	CHRYSOPINI			
E19B00	Chrysops	CG	7	BU
E19B1	TABANINI			
E19B10	Tabanus	PR	9	BU
E19B100	Tabanus fairchildi	PR	9	BU
E19C	ATHERICIDAE	PR	2	CR
E19C00	Atherix	PR	2	CR
E19C000	Atherix lantha	PR	2	CR
E19D	Pelecorhynichidae	PR	6	CR

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
E19G	EPHYDRIDAE	CG	6	SP
E19G0	EPHYDRINI			
E19G00	Setacera	SH	6	SP
E19H	SCIOMYZIDAE	PR	6	SP
E19I	DOLICHOPODIDAE	PR	4	SP
E19I01	Rhaphium	PR	4	SP
E19I02	Hydrophorus	PR	4	SP
E19J	EMPIDIDAE	PR	6	CR
E19J0	HEMERODROMIINAE			
E19J00	Hemerodromia	PR	6	CR
E19J01	Chelifera	PR	6	SP
E19J02	Wiedemannia	PR	6	CG
E19J1	CLINOCERINAE			
E19J10	Clinocera	PR	6	CG
E19J2	EMPIDINAE			
E19J20	Rhamphomyia	PR	6	SP
E19J30	Oreogeton	PR	6	SP
E19K	MUSCIDAE	PR	8	SP
E19K0	LIMNOPHORINAE			
E19K00	Limnophora	PR	8	BU
E19K000	Limnophora aequifrons	PR	8	BU
E19L	PTYCHOPTERIDAE	CG	7	BU
E1A	ORDER COLLEMBOLA			
E1A0	PODURIDAE	CG	7	SK
E1A000	Achorutes(=Hypogastrura)	CG	7	SK
E1A2	ISOTOMIDAE	CG	7	SK
E1A200	Isotomurus	CG	7	SK
E1A2000	Isotomurus palustris	CG	7	SK
E1B	ORDER HYMENOPTERA			
E1C	ORDER ORTHROPTERA			
E1C0	TRIDACTYLIDAE	SH	7	CL
E1C000	Ellipes	SH	7	SK
E1C0000	Ellipes minuta	SH	7	SK
E1D	ORDER PSOCOPTERA			
E2	CLASS ARACHNIDA			
E20	ORDER ACARI (HYDRACARINA)	PR	6	CR
F	PHYLUM MOLLUSCA			
F0	CLASS GASTROPODA			
F00	ORDER LIMNOPHILA			
F000	PHYSIDAE	CG	8	SP
F0000	PHYSINAE			
F00000	Physa	CG	8	SP
F000000	Physa heterostropha	CG	8	SP
F00001	Physella	CG	8	SP
F001	LYMNAEIDAE	CG	9	GN
F0010	LYMNAEINAE			
F00100	Fossaria	CG	7	GN
F00101	Lymnaea	CG	7	GN
F002	PLANORBIDAE	CG	7	SP
F0020	HELISOMINI			

TAXA	DESC {1 Janruary 1999 (MDM, SWH, JRV)}	FUNCGRP	T. VALUES	HABIT
F00200	Menetus	CG	8	SP
F002000	Menetus dilatatus	CG	8	SP
F00201	Helisoma	CG	6	SP
F0021	PLANORBINI			
F00210	Gyraulus	CG	4	SP
F003	ANCYLIDAE	SC	7	CG
F0030	FERRISSINAE			
F00301	Ferrissia	SC	7	CG
F003010	Ferrissia rivularis	SC	7	CG
F01	ORDER MESOGASTROPODA			
F010	VALVATIDAE	SC	4	GN
F01000	Valvata	SC	4	GN
F012	VIVIPARIDAE	CG	6	GN
F0120	LIOPLACINAE			
F01200	Campleoma	CG	6	GN
F013	HYDROBIIDAE (=BULIMIDAE)	CG	3	GN
F0130	AMNICOLINAE			
F01300	Amnicola	CG	3	GN
F014	PLEUROCERIDAE	SC	2	CG
F01400	Pleurocera	SC	2	CG
F01401	Leptoxis	SC	2	CG
F014010	Leptoxis carinata	SC	2	CG
F01404	Elimia (=Goniobasia)	SC	4	CG
F1	CLASS BIVALVIA (=PELECYPODA)	CF	4	BU
F10	ORDER UNIONOIDA			
F101	UNIONIDAE	CF	4	BU
F10100	Fusconaia	CF	4	BU
F11	ORDER VENEROIDA			
F110	SPHAERIIDAE	CF	8	BU
F11000	Sphaerium	CF	8	BU
F110000	Sphaerium striatinum	CF	8	BU
F11001	Musculium	CF	8	BU
F110010	Musculium transversum	CF	8	BU
F11002	Eupera	CF	6	BU
F11003	Pisidium	CF	8	BU
F111	CORBICULIDAE	CF	6	BU
F11100	Corbicula	CF	6	BU
F111000	Corbicula fluminea	CF	6	BU

Data Worksheet – MAIS – central Applachia

	Code	Taxon	Abundance (n)	Feeding Group	Habit	T Value	G n*T	H n*(n-1)	I Scraper count
line 2							0	0	0
3							0	0	0
4							0	0	0
5							0	0	0
6							0	0	0
7							0	0	0
8							0	0	0
9							0	0	0

= IF(D2 = "sc", C2, 0)

= C2*(C2-1)

= F2*C2

Equations for line 2

Data Worksheet

	J	K	L	M	N	O
	Hapto count	Ephem count	Ephemeroptera	Plecoptera	Trichoptera	Intolerant count
line 2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

= IF (F2 <6, IF (C2 > 0, 1, 0), 0)

= IF (C2>0, IF (A2>= "e16", IF (A2< "e17", 1, 0), 0), 0)

= IF (C2>0, IF(A2>= "e10", IF (A2< "e11", 1, 0), 0), 0)

= IF (C2>0, IF (A2>= "e11", IF (A2 < "e12", 1, 0), 0), 0)

= IF (A2>= "e11", IF (A2< "e12", C2, 0), 0)

= IF (E2 = "cg", C2, F (E2 = "cr", C2, 0))

Metrics

Equations in Column B:

A	B	C	
Metric	Value	MAIS Value	Value
% 5 Dominant Taxa	#DIV/0!	#DIV/0!	=Scrap!D2/Scrap!D3*100
Modified HBI	#DIV/0!	#DIV/0!	=Scrap!D4/Scrap!D3
% Haptobenthos	#DIV/0!	#DIV/0!	=Scrap!D9/Scrap!D3*100
EPT Index	0	0	=COUNTIF('Data Worksheet'!L:N,">0")
# Ephemeropera	0	0	=SUM('Data Worksheet'!L:L)
% Ephemeroptera	#DIV/0!	#DIV/0!	=SUM('Data Worksheet'!K:K)/Scrap!D3*100
SDI	#DIV/0!	#DIV/0!	=1-Scrap!D5/(Scrap!D3*(Scrap!D3-1))
# Intolerant Taxa	0	0	=Scrap!D8
% Scrapers	#DIV/0!	#DIV/0!	=Scrap!D6/Scrap!D3*100
	Total	#DIV/0!	
Biological Condition Category			
#DIV/0!			

IF(C11<=7,"Very Poor",IF(AND(8<=C11,C11<=11),"POOR",IF(AND(12<=C11,C11<=15),"Good","Very Good")))

Metrics

A	B	C
Metric	Value	MAIS Value
% 5 Dominant Taxa	#DIV/0!	#DIV/0!
Modified HBI	#DIV/0!	#DIV/0!
% Haptobenthos	#DIV/0!	#DIV/0!
EPT Index	0	0
# Ephemeropera	0	0
% Ephemeroptera	#DIV/0!	#DIV/0!
SDI	#DIV/0!	#DIV/0!
# Intolerant Taxa	0	0
% Scrapers	#DIV/0!	#DIV/0!
	Total	#DIV/0!

Equations in Column C:

MAIS Value

= IF(B2 <= 79, 2, IF (B2 = 100, 0, 1))
= IF(B3 <= 4.21, 2, IF (B3 >= 5.56, 0, 1))
= IF (B4 >= 84 , 2, IF (B4 < 52, 0, 1))
= IF (B5 >= 8 , 2, IF (B5 <= 2, 0, 1))
= IF (B6 >= 4, 2, IF (B6 = 0, 0, 1))
= IF (B7 >= 18, 2, IF (B7 = 0, 0, 1))
= IF (B8 >= 0.83, 2, IF (B8 <= 0.66, 0, 1))
= IF (B9 >= 10, 2, IF (B9 <= 1, 0, 1))
= IF (B10 >= 11, 2, IF (B10 = 0, 0, 1))
= SUM (C2 : C10)

Biological Condition Category

#DIV/0!

Scrap

Equations in column D:

B	C	D		
	Sum 5 Dominant	0	=SUM(A2:A6)	
	Total Abundance	0	=SUM('Data Worksheet'!	C:C)
	Sum n*T	0	=SUM('Data Worksheet'!	G:G)
	Sum n(n-1)	0	=SUM('Data Worksheet'!	H:H)
	Sum Scraper	0	=SUM('Data Worksheet'!	I:I)
	Sum Ephemeroptera	0	=SUM('Data Worksheet'!	K:K)
	Sum Intoloerant	0	=SUM('Data Worksheet'!	O:O)
	Sum Haptobenthos	0	=SUM('Data Worksheet'!	J:J)

Data Worksheet

Code	Taxon	Abundance (n)	Feeding Group	Habit	T Value	n*T	n*(n-1)	Scraper count
E188	Dryopidae	7	SC	CG	5	35	42	7
E189	Elmidae	1	SC	CG	4	4	0	1
E0A0	Cambaridae	2	GN	GN	5	10	2	0
E198	Chironomidae	68	CG	BU	6	408	4556	0
E197	Simulidae	31	CF	CG	6	186	930	0
E133	Mesoveliidae	1	PR	SK	8	8	0	0
E081	Asellidae	1	CG	SP	8	8	0	0
F0	Physidae	2				0	2	0
E1204	Aeshnidae	4	PR	CR	3	12	12	0
E1212	Coenagrionidae	6	PR	CR	9	54	30	0
E162	Hydropsychidae	29	CF	CG	6	174	812	0
						0	0	0
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Data Worksheet

Hapto count	Ephem count	Ephemeroptera	Plecoptera	Trichoptera	Intolerant count
7	0	0	0	0	1
1	0	0	0	0	1
0	0	0	0	0	1
0	0	0	0	0	0
31	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	1
4	0	0	0	0	1
6	0	0	0	0	0
29	0	0	0	1	0
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