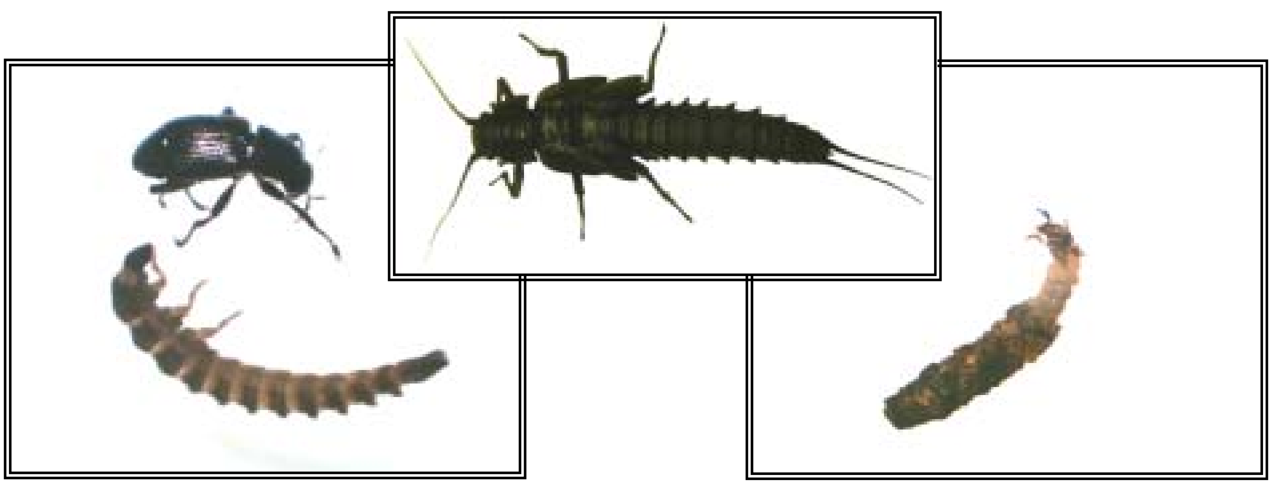
Monitoring Benthic Macrofauna

Statistical Comparison of Benthic Macroinvertebrate Identification Tools



Beauport River Enhancement Committee

March 2006

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Summary

The purpose of this study was to assess the ability to discriminate between impacted stations (agricultural and urban) and control stations for two identification levels used by volunteers by comparing them to a benchmark identification level (family). To do so, data from 43 MDDEP stations were used. The stations were separated *a priori* into control stations, agricultural stations, urban stations and test stations based on professional judgement and as subsequently confirmed by physicochemical and habitat criteria. The taxa, generally identified by genus, were placed in three identification levels (family, MDDEP volunteer and OBBN coarse-level).

The multivariate analyses using the OBBN identification level differentiated the agricultural stations from the control stations, but did not clearly differentiate two of the four urban stations from the control stations. Very few metrics could be calculated, and of that number, very few were considered good metrics. It therefore seems unlikely that an effective, multimetric index could be developed using the OBBN identification level.

The multivariate analyses based on the MDDEP identification level distinguished both agricultural stations and urban stations from the control stations. Almost all of the metrics could be calculated, and there were as many good metrics as there were at the family identification level. Therefore, the use of a multimetric index seems quite reasonable. Accordingly, the MDDEP identification level seems to be a good compromise between the OBBN and family identification levels.

Canonical variate analysis, which incorporates environmental variables, will make it possible to confirm or refute the trends observed in this study.

Introduction

The 2005 BREC study entitled "*Suivi de la macrofaune benthique: comparison de trois méthodes*," suggests that the two volunteer methods tested (MDDEP and OBBN) were successful in harvesting benthic macroinvertebrates in percentages similar to the scientific method used by the Quebec *Ministère du Développement durable, de l'Environnement et des Parcs* (MDDEP). However, the study questioned the ability of the coarse-level identification (27 taxa) used in the Ontario Benthos Biomonitoring Network Protocol Manual to distinguish between control sites and impacted sites to different degrees (Jones *et al*, 2005; BREC, 2005).

In follow-up to this study, Environment Canada would like to know whether the volunteer identification tools allow for a statistical differentiation between the quality of control sites and impacted sites. The two volunteer identification levels for benthic macroinvertebrates (MDDEP and OBBN) will be compared in terms of family identification, used as the reference.

Therefore, the purpose of this study is to assess, using statistical analyses, the effectiveness of two identification levels used by volunteers in distinguishing between control stations and impacted stations by comparing them at the benchmark identification level (family).

Materials and Methods

Data Preparation

The data were prepared by the Quebec *Ministère du Développement durable, de l'Environnement et des Parcs* (MDDEP). These data were collected in 2003, 2004 and 2005 by the MDDEP according to its scientific method. This method is used in fast-flowing streams and streams with a coarse substrate. The benthic macroinvertebrates are captured using a 600-micron kick net (20 times, 30 seconds each time, in a 100-metre station).

We have 33 different sampling stations for statistical analyses (Figure 1). However, some stations were inventoried for more than one year, and we therefore have 43 stations. These are control (reference) stations, agricultural stations, test stations and a few urban stations.

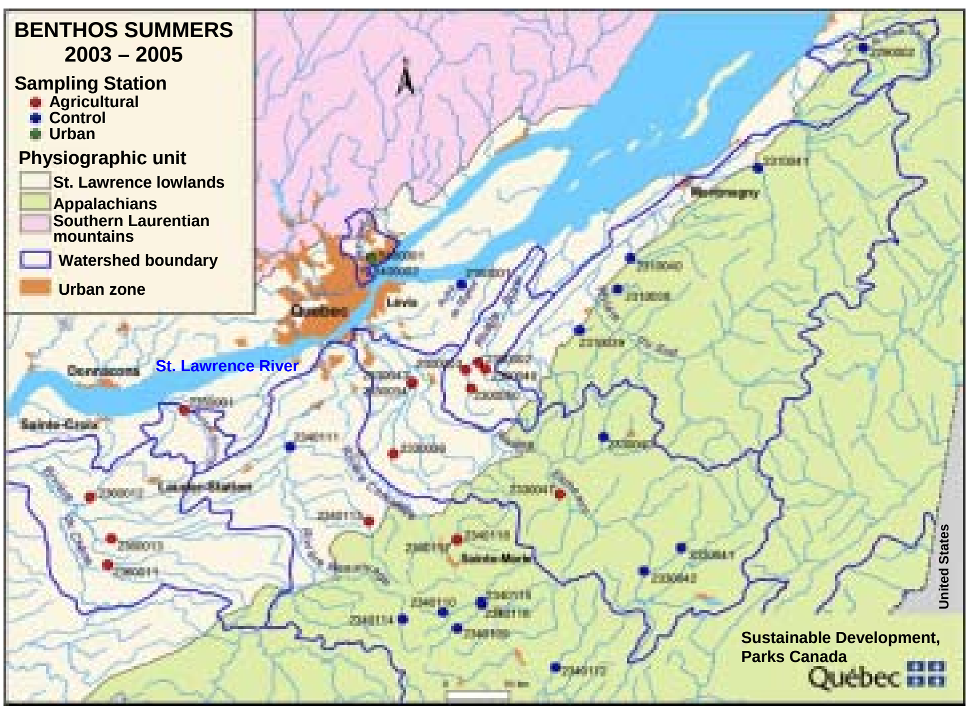


Figure 1: Location of Stations (2003-2004-2005) (Source: *Direction du suivi de l'état de l'environnement*, MDDEP)

The 43 stations were divided into four types (control, agriculture, urban and test stations) *a priori* based on professional judgement and later confirmed by physico-chemical criteria and habitat identified at each station. These criteria were chosen based on a survey of the literature. In the case of stations intended for experimental control purposes, the aim was to select those that were representative of biological conditions at sites where the effects of disturbance caused by human activity was minimal (Jones *et al*, 2005). The stations can be broken down into eighteen control stations, twelve agricultural stations, four urban stations and nine test stations (Table 1). Table 2 shows the preliminary criteria used to designate the control stations. Physico-chemical and habitat data were also considered in the selection of the agricultural stations (Table 3). These stations were well-documented by the MDDEP. Test stations are intermediate stations that cannot be defined *a priori.* Following more advanced analyses of the habitat and physico-chemical variables, some of these stations could become control stations for the St. Lawrence lowlands. These would be the least disturbed stations for the St. Lawrence lowlands.

Table 1: Four types of stations studied

Control	**Agricultural**	**Urban**	**Test**
▪ Calway	▪ Boyer sud 1 (3 years) and 2	▪ Beauport 1 (2 years) and 2 (2 years)	▪ Cugnet
▪ Des Abénaquis (3 years)	▪ Boyer nord 1 (3 years) and 2		▪ Ruisseau de l'Église
▪ Lessard 1 and 2	▪ Bras d'Henri		▪ Ruisseau de la Chute
▪ Beaurivage	▪ Le Bras 2 and 3		▪ Ruisseau Beaudet
▪ Petite rivière Sainte-Marguerite	▪ Ruisseau Fourchette		▪ Chassé
▪ Des Fleurs			▪ Du Chêne
▪ Ruisseau Sans Nom (Etchemin) (3 years)			▪ Du Domaine
▪ Ruisseau Guay			▪ Henri
▪ Nadeau			▪ Huron
▪ Desbarats			
▪ Morigeau			
▪ Des Perdrix			
▪ Trois Saumons			

Table 2: Preliminary criteria used to designate control stations (adapted from Klemm *et al*, 2003; Stribling *et al*, 1998; Waite *et al*, 2000, Major *et al*, 2000)

Criteria	Values
pH	≥ 6 OR pH < 6 and dissolved organic carbon (DOC) ≥ 8 mg/l
Total phosphorus	< 0.02 mg/l
Total nitrogen	< 0.75 mg/l
Habitat index (THSI)*	> 75% (> 150/200 points)
Width of shoreline	≥15 m
% of watershed urbanized	≤ 15%
% of watershed forested	> 50%
No waterway recovery	
No point-source discharge	

* adapted from Barbour *et al*, 1999

Table 3: Preliminary criteria used to designate impacted stations (adapted from Stribling *et al*, 1998)

Criteria	Values
pH	≤ 5
Total phosphorus	> 0.1 mg/l
Total nitrogen	> 5 mg/l
Habitat index (THSI)	< 50% (> 100/200 points)
% of watershed urbanized	> 50%

Macroinvertebrates are usually identified to the taxonomic level of the genus (BREC, 2005). Before being transposed to the desired identification level (family, MDDEP and OBBN), the taxonomic abundance record was thinned down. Indeed, although the targeted number of macroinvertebrates per station was 200, some stations contained a great deal more. Therefore, the number of macroinvertebrates was limited to 200 using the Ecosim software (Gotelli and Entsminger, 2006). The data were then transposed to three taxonomic levels: family, the MDDEP volunteer level and the OBBN coarse-level (Appendix 1: list of MDDEP and OBBN taxa). We obtained 77 different taxa at the family level, 49 taxa at the MDDEP volunteer level of a possible 73 and 24 taxa at the OBBN coarse-level of a possible 27.

Data Analysis

Environmental data were used to validate the classification of the 43 stations into one of the four categories (control, urban, agricultural and test). Box plot charts were used to present the different environmental variables. The box plots show the median, maximum and minimum values and the 25th and 75th percentiles. Physico-chemical values were not measured at the urban stations. A multivariate analysis (analysis of primary components) was performed as an exploratory exercise only for habitat data and physico-chemical data (Appendix 2). Before performing the multivariate analyses, the data were transformed to more closely resemble normal distribution. Logarithmic transformation (log 10 (x +1)) was used except in the case of percentage data, which was transformed with the arcsin square root (Roy *et al*, 2005).

Many metrics were calculated using abundance data for the three identification levels (Table 4). The tolerance ratings used for the metrics HBI, % tolerant, % intolerant and number of intolerant taxa are listed in Appendix 3. The best metrics were selected by calculating a discrimination efficiency (DE) between control stations and agricultural stations and a coefficient of variation (CV) for the control stations (Table 5, Appendix 4). The DE is the percentage of impacted stations that rank in the 25th percentile for control stations (Barbour *et al*, 1999; Major *et al*, 2001). A high DE indicates a clearer separation between the control sites and the impacted sites for a given metric. A low CV indicates a metric with greater accuracy. The best metrics (DE of 70% or more, CV of 25 or less) are presented in the findings section with box plots. The choice of discriminating DE was based on Major *et al*, 2001 and the discriminating CV was arbitrary. The box plots used show the median, maximum and minimum values, as well as the 25th and 75th percentiles.

The West Virgina Stream Condition Index (WVSCI) has been calculated for the three identification levels and four types of station (Craddock, 2005). This index combines the results of six metrics (% dominant taxon, % EPT, number of EPT taxa, % Chironomides, HBI and total number of taxa) to obtain an index of biological integrity. The index has been calibrated for Quebec based on the 18 control stations. The six metrics included in the index were calibrated using the 95th or 5th percentiles as benchmarks to obtain a score of 100% for each metric. The WVSCI separates the stations into five categories: two "poor" or "marginal" impacted categories; two "good" or "excellent" non-impacted categories; and one "grey area" that makes allowance for the margin of error in the index when it is impossible to decide between an impacted or non-impacted station. The WVSCI box plots are presented in the findings section for the three identification levels and four types of station. The box plots used show the median, maximum and minimum values, as well as the 25th and 75th percentiles. The WVSCI index value for the 43 stations based on the three identification levels is shown in Appendix 5.

Multivariate analyses (correspondence analysis) have been performed for the 43 stations and the three identification levels using PAST software (Hammer *et al*, 2006). The data were not transformed because a fractionation was performed and the master file was downsized to 200 macroinvertebrates (Rosenberg *et al*. 1999).

Table 4: List of metrics and indices for testing

	Family	**MDDEP**	**OBBN**
% EPT (Ephemera, Plecoptera and Trichoptera)	✓	✓	✓
% E (Ephemera)	✓	✓	✓
% P (Plecoptera)	✓	✓	✓
% T (Trichoptera)	✓	✓	✓
% Hydropsychidae (on T)	✓	✓	**x**
% Baetidae (on E)	✓	**x**	**x**
% Diptera	✓	✓	✓
% Chironomidae	✓	✓	✓
% Insects	✓	✓	✓
% Oligochaeta	✓	✓	✓
% Coleiotera	✓	✓	✓
% Gastropoda	✓	✓	✓
% Dominant taxon	✓	✓	✓
%Tolerant*	✓	✓	✓
% Intolerant**	✓	✓	✓
Number of taxa	✓	✓ (/73)	✓ (/27)
Number of EPT taxa	✓	✓ (/24)	✓ (/3)
Number Dipteran taxa	✓	✓ (/6)	✓ (/6)
EPT/Chironomidae	✓	✓	✓
HBI (Hilsenhoff biotic index)	✓ family	✓ family	✓ order
Shannon-Wiener	✓	✓	✓
Dominance	✓	✓	✓
Equitability	✓	✓	✓

E: ephemera, P: Plecoptera, T: trichoptera

(/ maximum value)

* tolerance rating ≥ 7

** tolerance ratings ≤ 3 (Klemm *et al*, 2002)

x: metric could not be calculated

Table 5: Discrimination efficiency (DE) and coefficients of variation (CV) of the various metrics for the three identification levels

FAMILY	DE (%)	CV
% EPT	91.67	16.43
% Ephemera	100.00	33.29
% Plecoptera	100.00	47.14
% Diptera	100.00	55.28
% Chironomidae	100.00	73.73
% Insect	100.00	5.42
% Oligochaeta	100.00	111.60
% Dominant taxa	100.00	25.76
# Taxa	100.00	10.45
# Taxa	100.00	11.83
# Taxa P	100.00	29.75
# Taxa T	100.00	18.21
EPT/chiro	100.00	80.67
% Hydropsyche on T	100.00	53.33
% Baetidae on E	41.67	74.82
% Tolerant	91.67	70.12
% Intolerant	100.00	22.65
# Intolerant taxa	100.00	17.39
HBI	100.00	16.45
Shannon-Wiener	100.00	7.39
Equitability	100.00	6.47
Dominance	100.00	26.24

MDDEP	DE (%)	CV
% EPT	91.67	16.43
% Ephemera	100.00	33.29
% Plecoptera	100.00	47.14
% Diptera	100.00	55.28
% Chironomidae	100.00	73.73
% Insect	100.00	5.42
% Oligochaeta	100.00	111.60
% Dominant taxa	100.00	25.76
# Taxa	91.67	9.54
# EPT taxa	91.67	7.94
# Taxa P	100.00	28.39
# Taxa T	91.67	14.29
EPT/chiro	100.00	80.67
% Hydropsyche on T	100.00	53.33
% Baetidae on E	**x**	**x**
% Tolerant	91.67	70.51
% Intolerant	100.00	24.27
# Intolerant taxa	100.00	13.26
HBI	100.00	15.75
Shannon-Wiener	100.00	6.93
Equitability	100.00	6.46
Dominance	100.00	24.78

OBBN	DE (%)	CV
% EPT	91.67	16.45
% Ephemera	100.00	33.34
% Plecoptera	100.00	47.10
% Diptera	100.00	55.42
% Chironomidae	100.00	73.91
% Insect	100.00	5.45
% Oligochaeta	100.00	111.64
% Dominant taxa	50.00	29.23
# Taxa	58.33	13.87
# EPT taxa	58.33	0.00
# Taxa P	58.33	0.00
# Taxa T	0.00	0.00
EPT/chiro	100.00	80.67
% Hydropsyche on T	**x**	**x**
% Baetidae on E	**x**	**x**
% Tolerant	91.67	70.31
% Intolerant	91.67	16.39
# Intolerant taxa	66.67	15.75
HBI	100.00	19.41
Shannon-Wiener	58.33	14.14
Equitability	50.00	12.96
Dominance	58.33	33.02

x: metric could not be calculated

Findings

<u>Environmental Variables</u>

Figure 2 presents the box plots on land use based on the four types of station. Land use is primarily forest at the control stations and agricultural at the agricultural stations. Urban stations consist primarily of urban and forest land. Control stations are within the standard set for land use (urban < 20% and forest > 50%, Table 2).

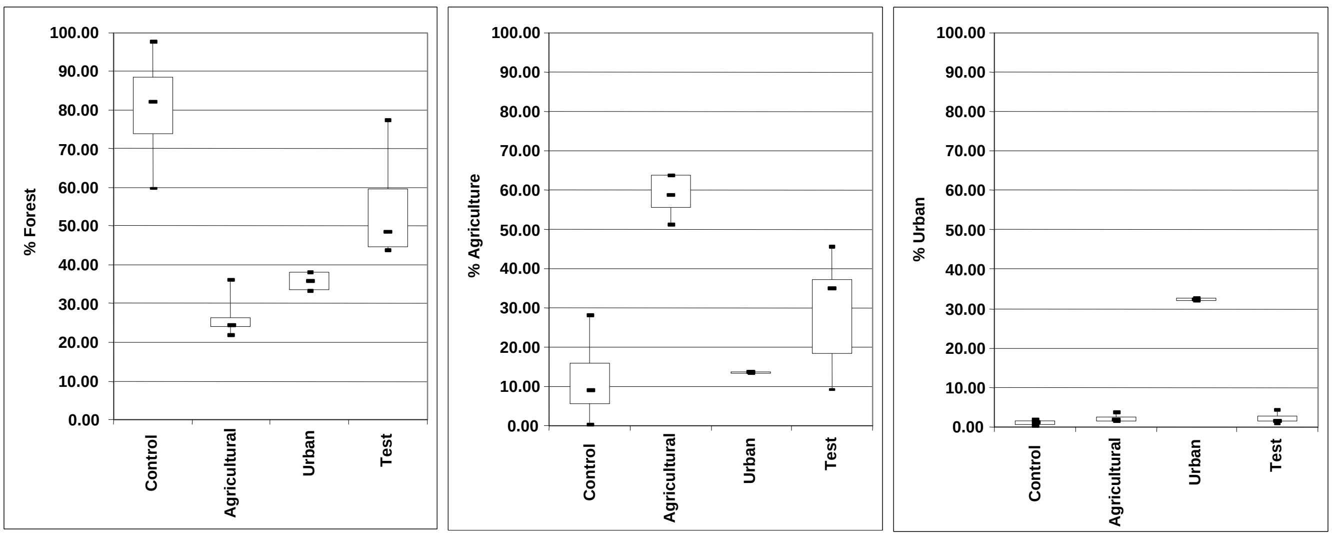


Figure 2: Box plots of the land use percentages for the drainage basin for the four types of stations (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 3 shows the box plots for altitude in meters and drainage area in square kilometres for the four types of station. The control stations are located at a higher altitude than the other types of station. However, considerable variation exists between control stations for altitude, and some are therefore at lower altitudes. The other types of station are usually at an altitude of less than 200 meters. In terms of drainage area, the control stations and agricultural stations are fairly similar. Greater variation exists in relation to the test stations. The Strahler order is usually 2 or 3 for all stations.

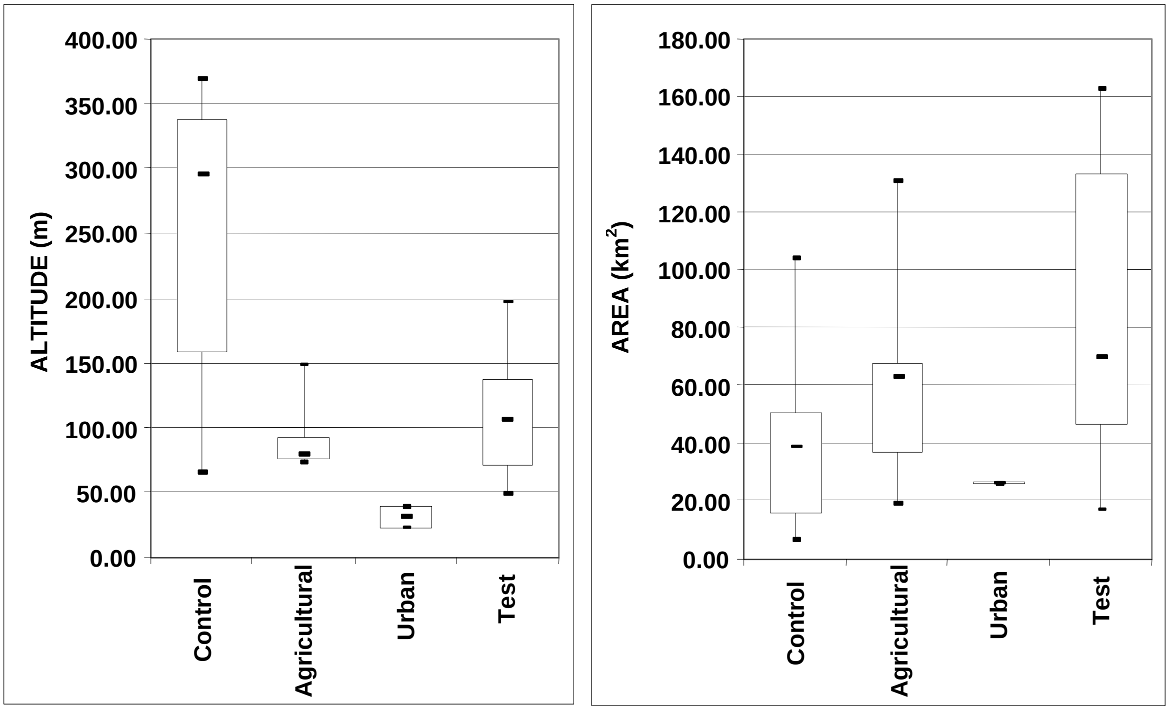


Figure 3: Box plots of altitude and drainage area for the four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 4 presents box plots for the habitat suitability index (Total HSI) and the shoreline quality index (SQI) for the four types of station. Total HSI is a general habitat suitability index including 10 parameters with a maximum value of 200 (adapted from Barbour *et al*, 1999). The control stations all had a habitat suitability index higher than 150 out of 200 points, which meets the control station criteria (Table 2). The other types of station generally had a Total HSI higher than 130/200. This means that even the impacted stations have fairly good habitat quality, since higher than 100 out of 200 points indicates an impacted station (Table 3). The SQI is an index of a station's shoreline quality out of 100 (Saint-Jacques and Richard, 1998). Control stations have a high SQI, and urban and test stations also have a high SQI. At agricultural stations, the SQI can vary a great deal, but shoreline quality is poorer.

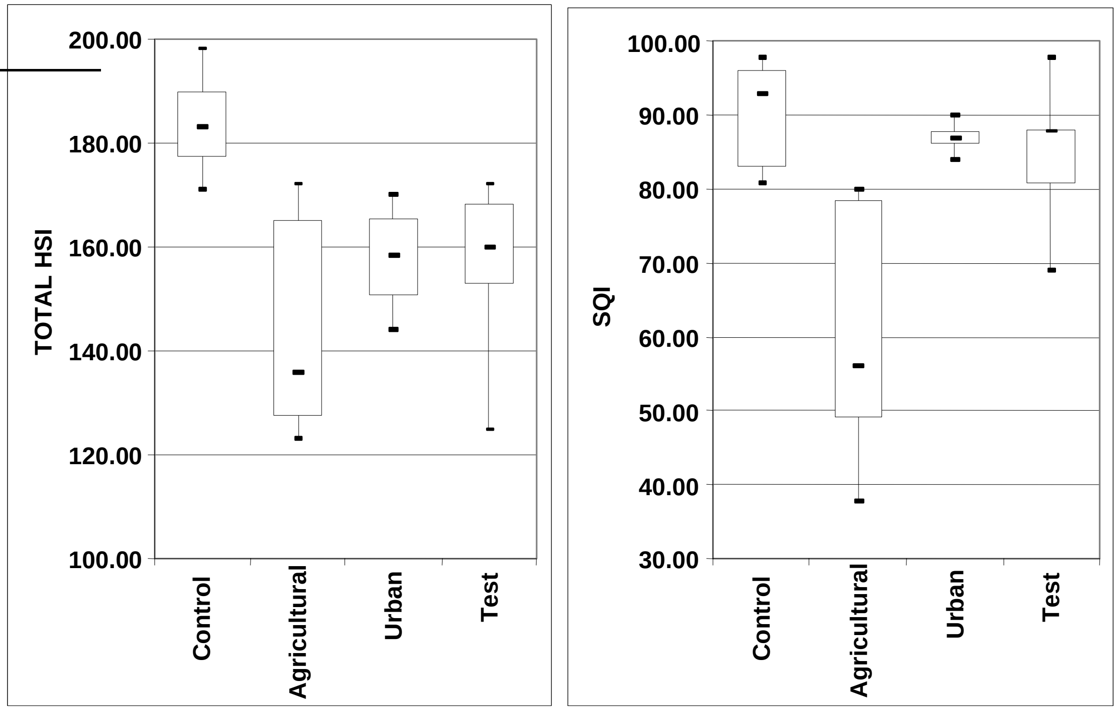


Figure 4: Box plots of habitat suitability index (HSI Total) and shoreline quality index (SQI) for the four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

The various physico-chemical variables analyzed confirm a clear separation between the control stations and the impacted stations (Figure 5).

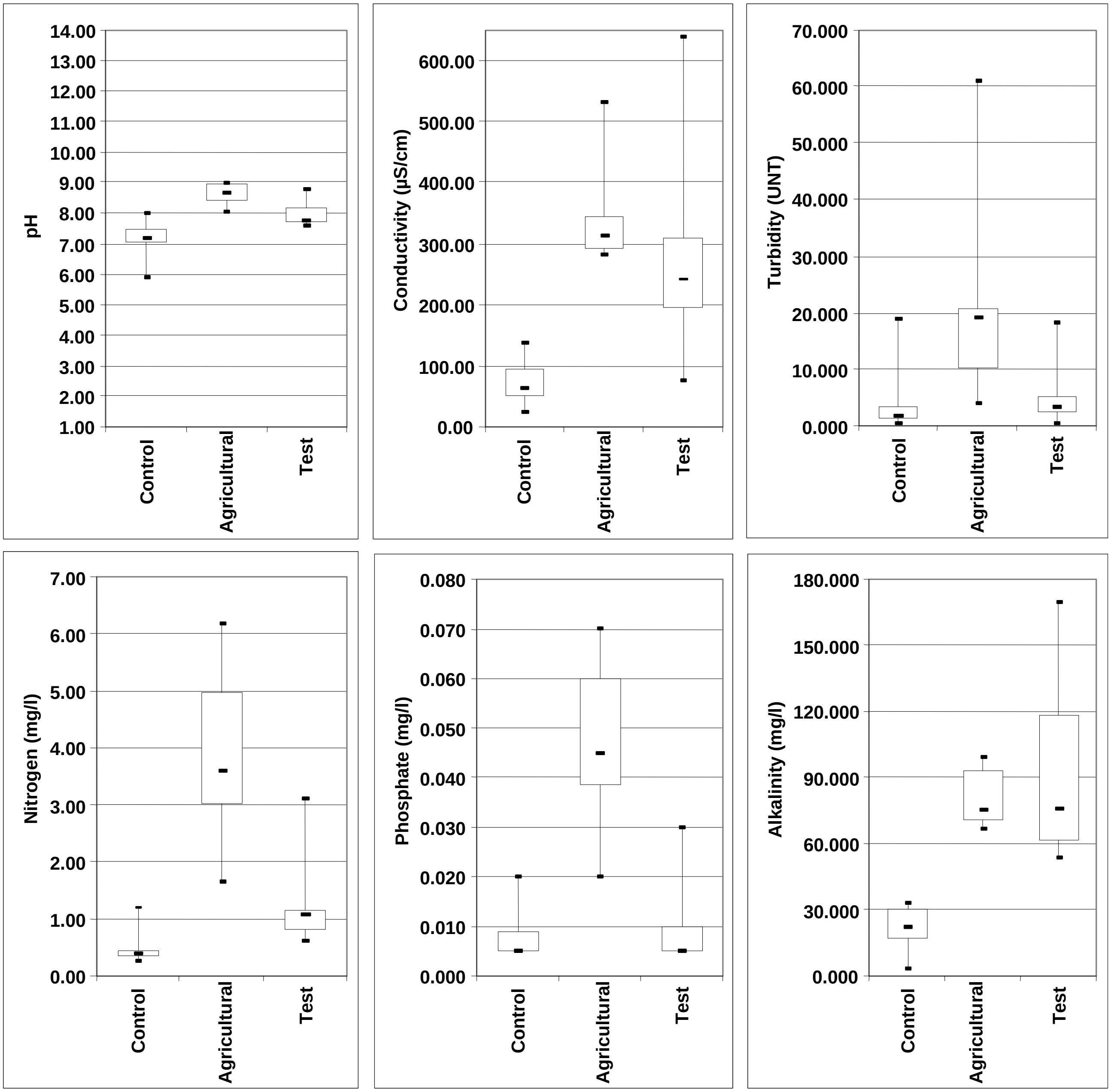


Figure 5: Box plots of the main physico-chemical variables (pH, conductivity, turbidity, total nitrogen, total phosphorus and alkalinity for the three types of station (control n = 19, agricultural n = 8 and test n = 9)

Metrics

Figure 6 shows box plots for the % EPT and percentage of insect metrics. These two metrics should decrease in response to a disturbance. The values for these two metrics are similar at the three levels of identification. Therefore, identification at the family level only is shown. The DE and CV calculations in Table 5 indicate that these are good metrics and that the distinction between control stations and agricultural stations is indeed quite clear. The % EPT metric does not allow for a clear distinction between urban stations and control stations, while the percentage of insects metric does. In both cases, the test stations are located near the control stations and are fairly easy to differentiate from the agricultural stations.

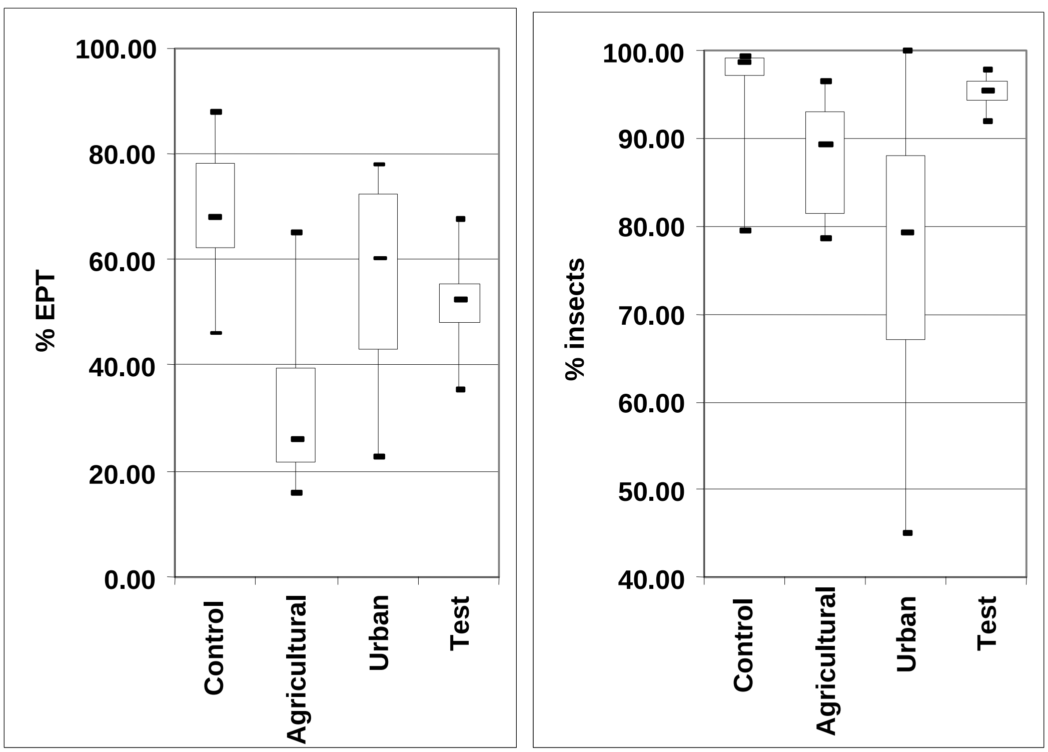


Figure 6: Box plots of % EPT (Ephemera, Plecoptera and Trichoptera) and percentage of insects metrics for the three identification levels and four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 7 presents box plots for the percentage of intolerant metric. This metric should diminish in response to a disturbance. The DE and CV calculations in Table 5 indicate that this is a good metric, and that the distinction between the control stations and agricultural stations is quite clear for the three levels of identification. It also distinguishes impacted urban stations at the family and MDDEP identification levels. As for the OBBN identification level, urban stations are partly mixed up with control stations. The test stations are located near the control stations, and stand out rather clearly from the agricultural stations.

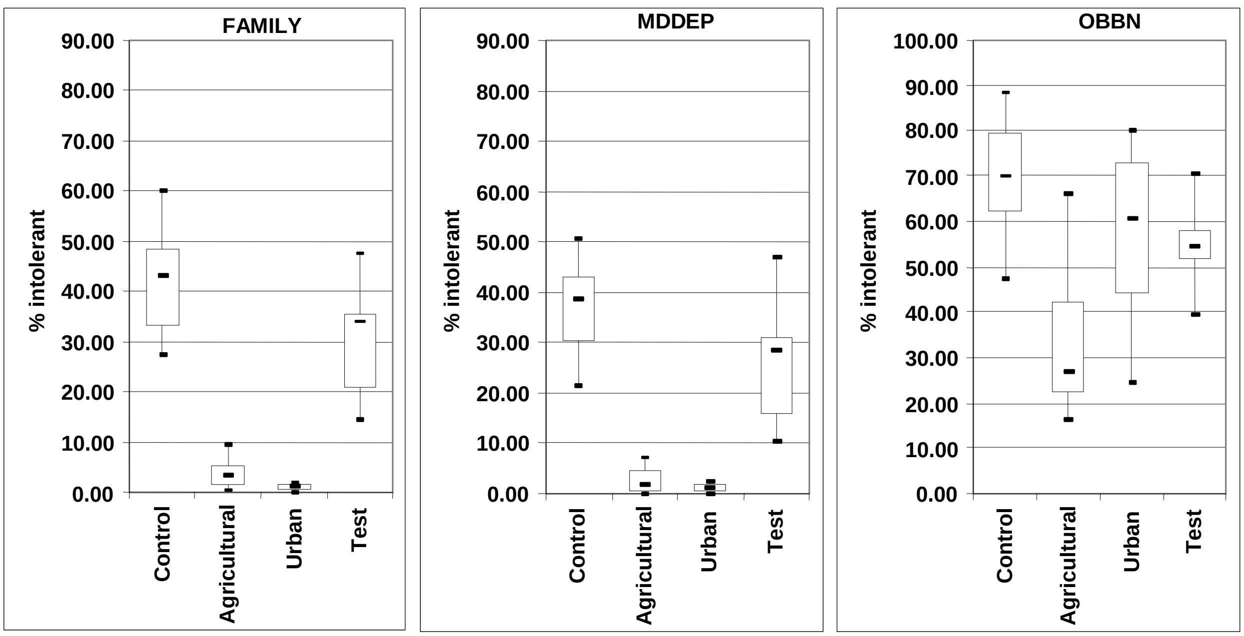


Figure 7: Box plots of percentage of intolerant metric for the three identification levels and four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 8 shows box plots for the Hilsenhoff biotic index (HBI). For this index, abundance is weighted according to tolerance for organic pollution, and the scale is therefore from 0 to 10. The results at the family identification level are completed according to the five classes of the Hilsenhoff index at the family level (Hilsenhoff, 1988). In terms of family identification, the control stations rate in the "excellent" and "very good" range, agricultural stations rank in the "somewhat poor" and "poor" range, urban stations place in the "average" and "somewhat poor" area, and test stations are in the "very good" and "good" categories. The DE and CV calculations in Table 4 indicate that this is a good index and that the distinction between control stations and agricultural stations is indeed very clear at the three identification levels. It also distinguishes between impacted urban stations at the three identification levels. The test stations are located rather close to the control stations, and stand out fairly well from the agricultural and urban stations, with the exception of urban stations for the OBBN identification level.

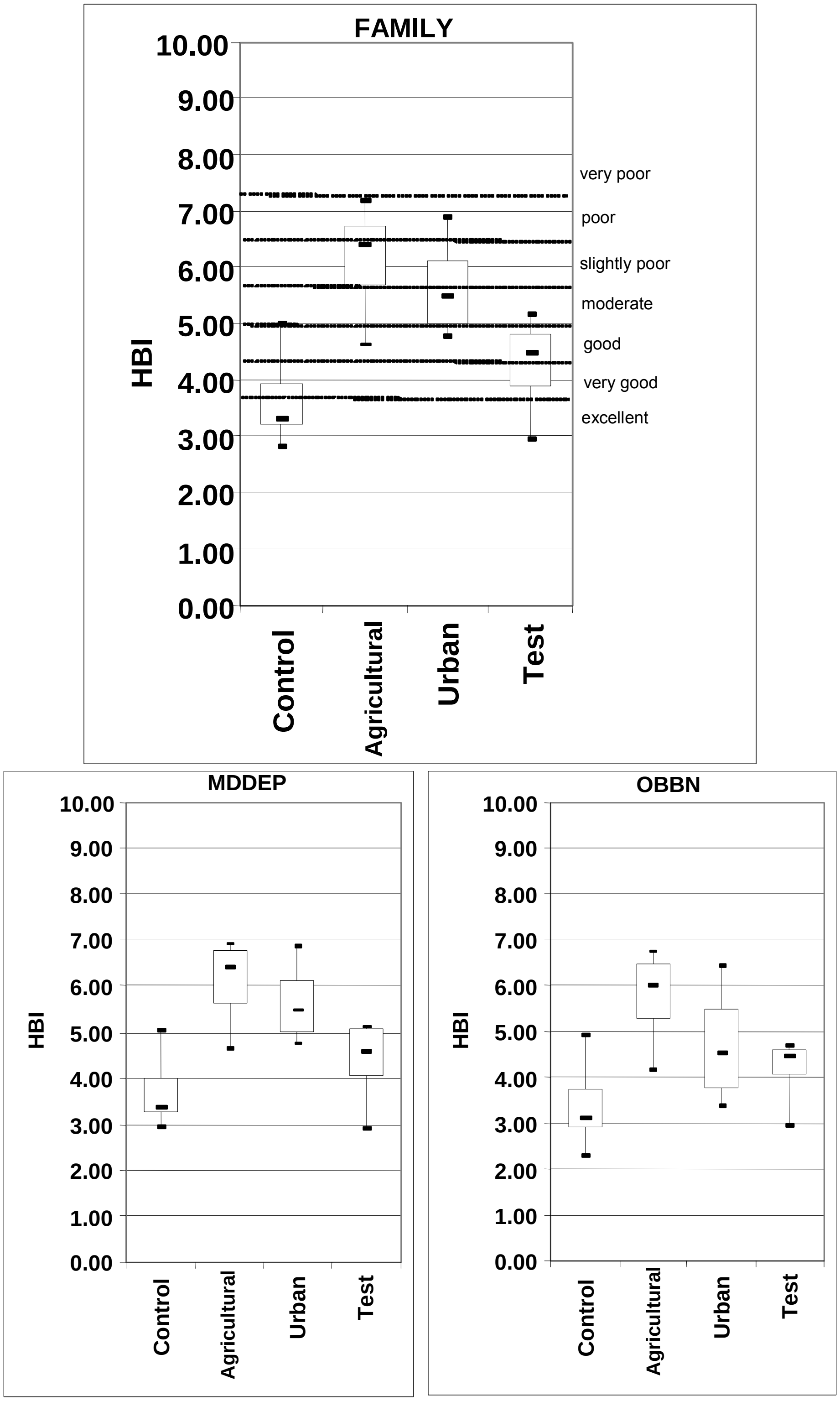


Figure 8: Box plots of the Hilsenhoff biotic index (HBI) for the three identification levels and four types of station. Ratings are presented for the HBI family (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 9 shows the box plots for the total number of taxa and number of EPT taxon. These metrics should diminish in response to a disturbance. The DE and CV calculations in Table 5 show that these are good metrics for the family and MDDEP identification levels. Indeed, the distinction between control stations and agricultural and urban stations is quite clear at these two identification levels. The OBBN identification level is not shown because these two metrics are not discriminating at this identification level. The total number of taxa metrics ranges only from 0 to 27, and only from 0 to 3 for the OBBN identification level. The test stations are located fairly close to the control stations and stand out rather clearly from the agricultural and urban stations.

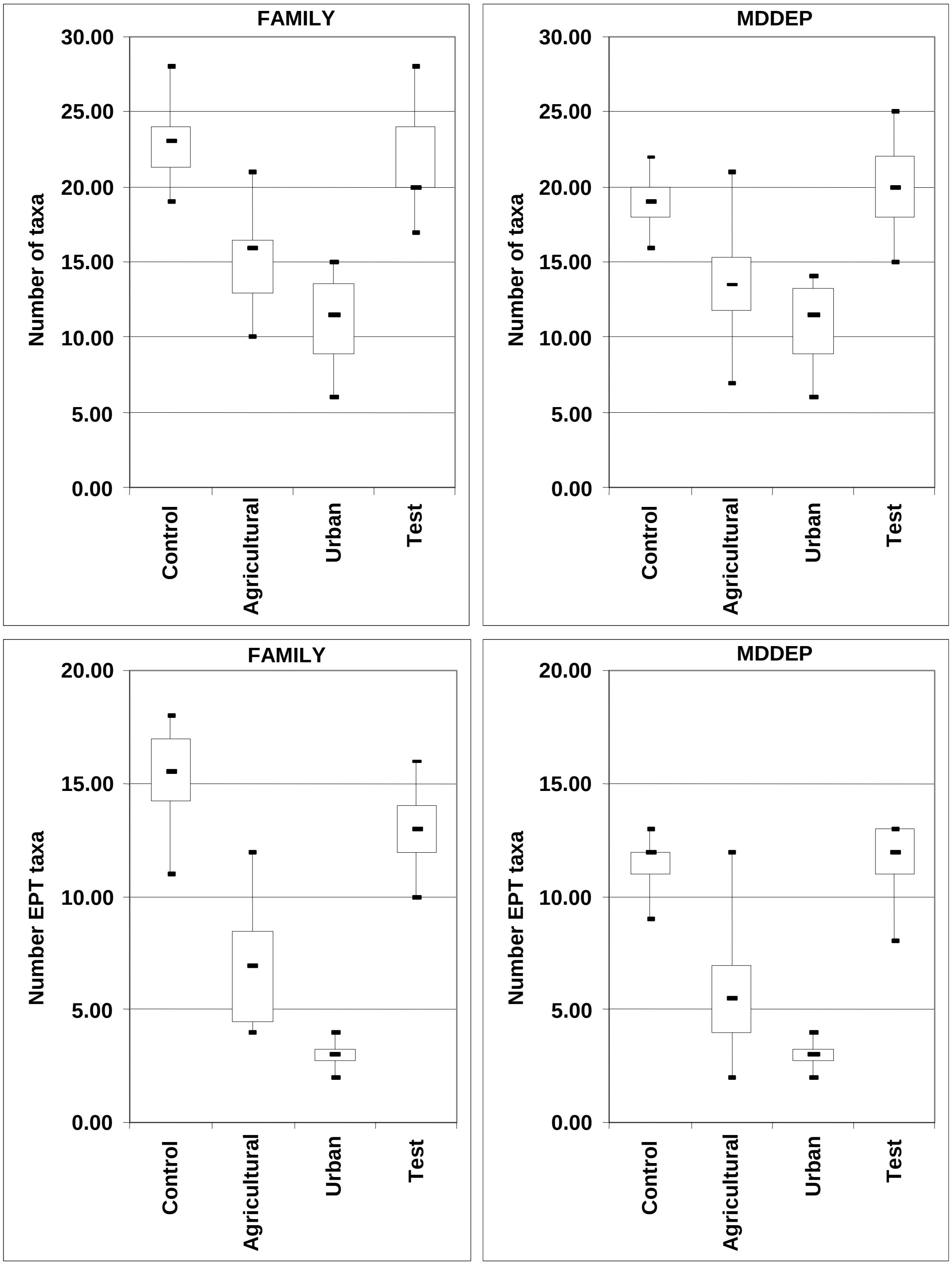


Figure 9: Box plots of total number of taxa and number of EPT (Ephemera, Plecoptera and Trichoptera) taxa metrics for the family and MDDEP identification levels and the four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 10 presents box plots for the number of intolerant taxa metric. This metric should diminish in response to a disturbance. The DE and CV calculations in Table 4 show that this is a good metric for the family and MDDEP identification levels. Indeed, the distinction between control stations and agricultural and urban stations is quite clear at these two identification levels. The OBBN identification level is not shown because this metric is not discriminating at this identification level. The test stations are fairly close to the control stations, and stand out rather clearly from the agricultural and urban stations.

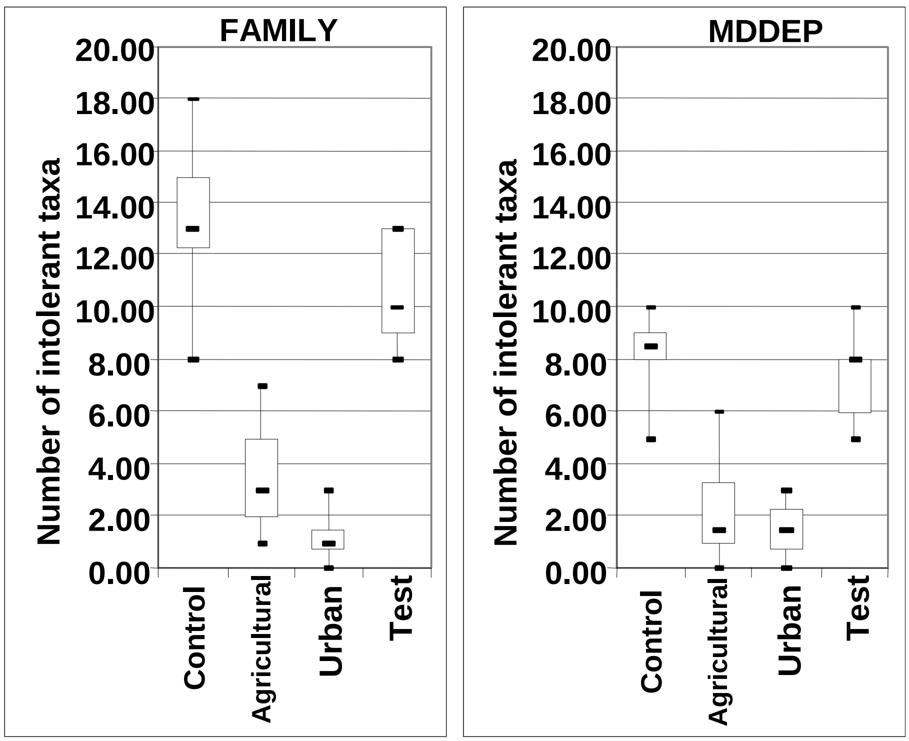


Figure 10: Box plots of number of intolerant taxa metric for the family and MDDEP identification levels and the four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Figure 11 shows the box plots for the Shannon-Wiener and Equitability indices. These indices should diminish in response to a disturbance. The DE and CV calculations in Table 4 show that these are good indicators for the family and MDDEP identification levels. Indeed, the distinction between control stations and agricultural and urban stations is quite clear for these two identification levels. The OBBN identification level is not shown because the index is not discriminating at this identification level. The test stations are fairly close to the control stations, and stand clearly apart from the agricultural and urban stations.

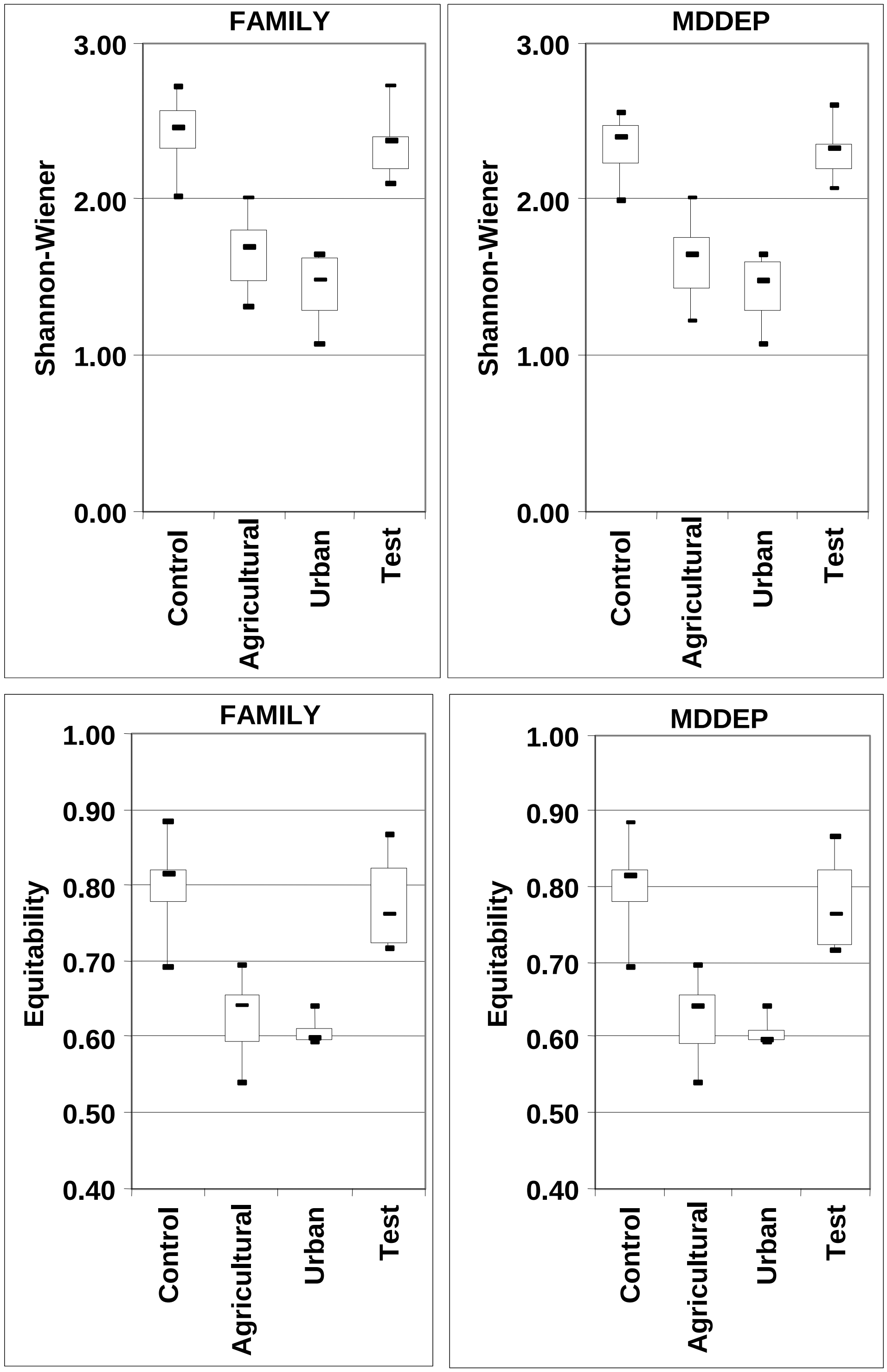


Figure 11: Box plots of the Shannon-Wiener and Equitability indices for the family and MDDEP identification levels and the four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Multimetric Index

Figure 12 shows the box plots of the West Virginia Stream Condition Index (WVSCI) for the four types of station and three levels of identification. The control stations rank in the "excellent" category for the three identification levels. The agricultural stations are primarily in the "marginal" and "poor" categories at the family identification level. The WVSCI indicates that agricultural stations are impacted. The WVSCI is quite similar at the MDDEP and family identification level used as reference. The OBBN identification level was unable to categorize agricultural stations in the impacted class or the two other identification levels. Urban stations are in the "marginal" group at the family identification level. This means that these stations are impacted. The MDDEP identification level behaves in the same ways as the family level, although this places a few stations in the "grey area." The OBBN level places urban stations in the "good" category. Test stations are primarily in the "good" category, and a few in the "excellent" category at the family identification level. The MDDEP identification level behaves in the same ways at the benchmark level (family). The OBBN identification level places the test stations exclusively in the "excellent" category. The MDDEP identification level is quite similar at the family identification level to the WVSCI. It slightly overestimates station quality. The OBBN level greatly overestimates station quality with this multimetric index.

Appendix 5 is presented as supplementary information to Figure 12. It presents the values obtained for the West Virginia Stream Condition Index (WVSCI) for each of the 43 stations at the three identification levels.

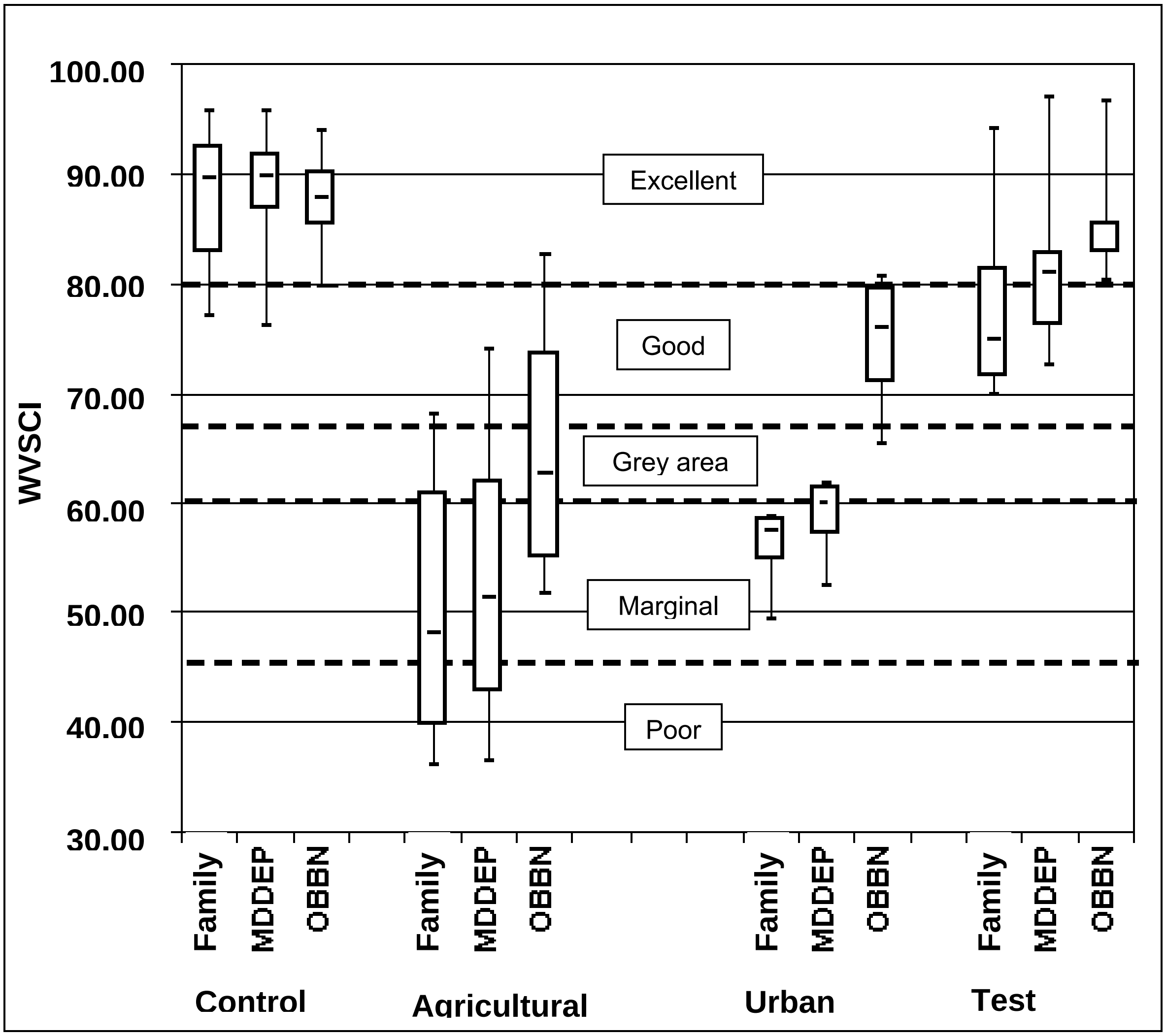
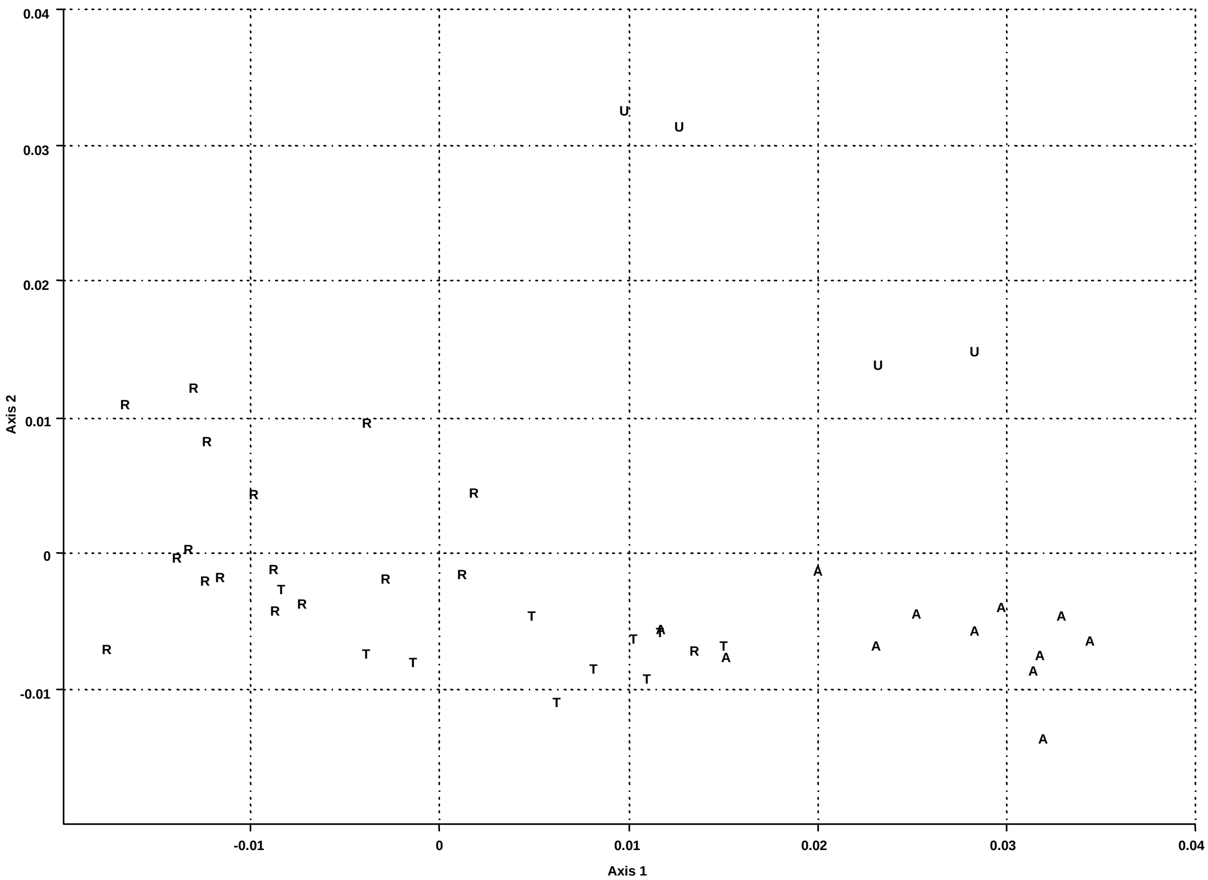


Figure 12: Box plots of the West Virginia Stream Condition Index (WVSCI) for the three identification levels and the four types of station (control n = 19, agricultural n = 12, urban n = 4 and test n = 9)

Multivariate Analyses

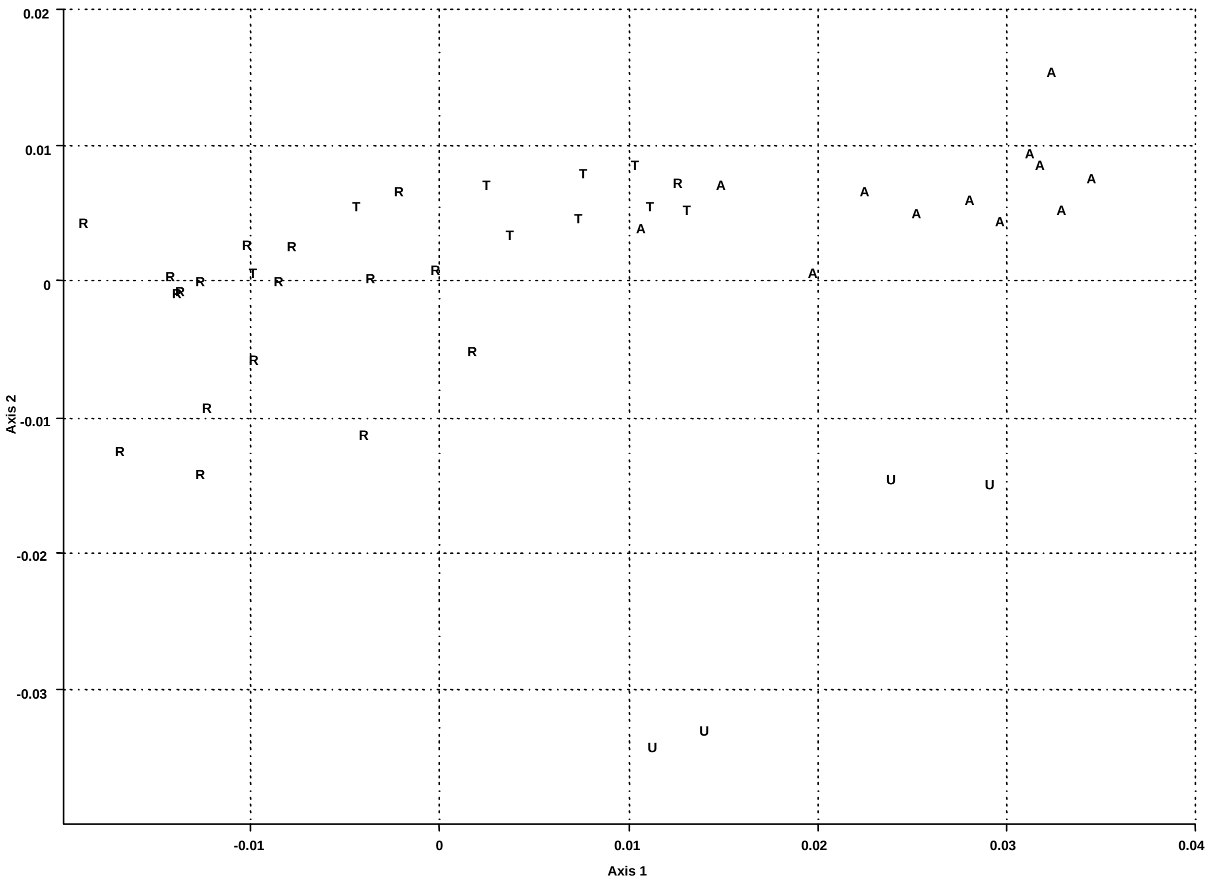
Figure 13 presents the correspondence analyses for abundance data at the taxonomic level of family for the 43 stations. The control stations (R) are mostly grouped together on the left side of the vertical axis. Only three of the 18 control stations are on the right side of the vertical axis, including one that is especially far off. The agricultural stations (A) are still more closely grouped and located in the direction opposite to control stations, in the lower right quadrant of the graph, generally away from the vertical axis. Only the agricultural stations are closer to the vertical axis. The test stations (T) are usually between the control stations and agricultural stations. A few of these test stations are directly among the collection of control stations. The four urban stations (U) behave differently than the other stations and are alone, quite distant in the top right quadrant.



Axis	Proper value	% of inertia
1	0.40937	18.976
2	0.26382	12.229
3	0.168318	7.8022
4	0.155313	7.1994

Figure 13: Analysis of correspondences for abundance data at the taxonomic level of family for the 43 stations (control = R, agricultural = A, urban = U and test = T).

Figure 14 presents a correspondence analysis for abundance data at the MDDEP taxonomic level for the 43 stations. The graph is very similar to Figure 13 (identification at the family level). Control stations (R) are generally grouped together on the left side of the vertical axis, with only one station far from the others, agricultural stations (A) are grouped in the upper right quadrant and test stations (T) generally between the two other types of station. The four urban stations (U) also behave differently and are by themselves and distant in the lower right quadrant.

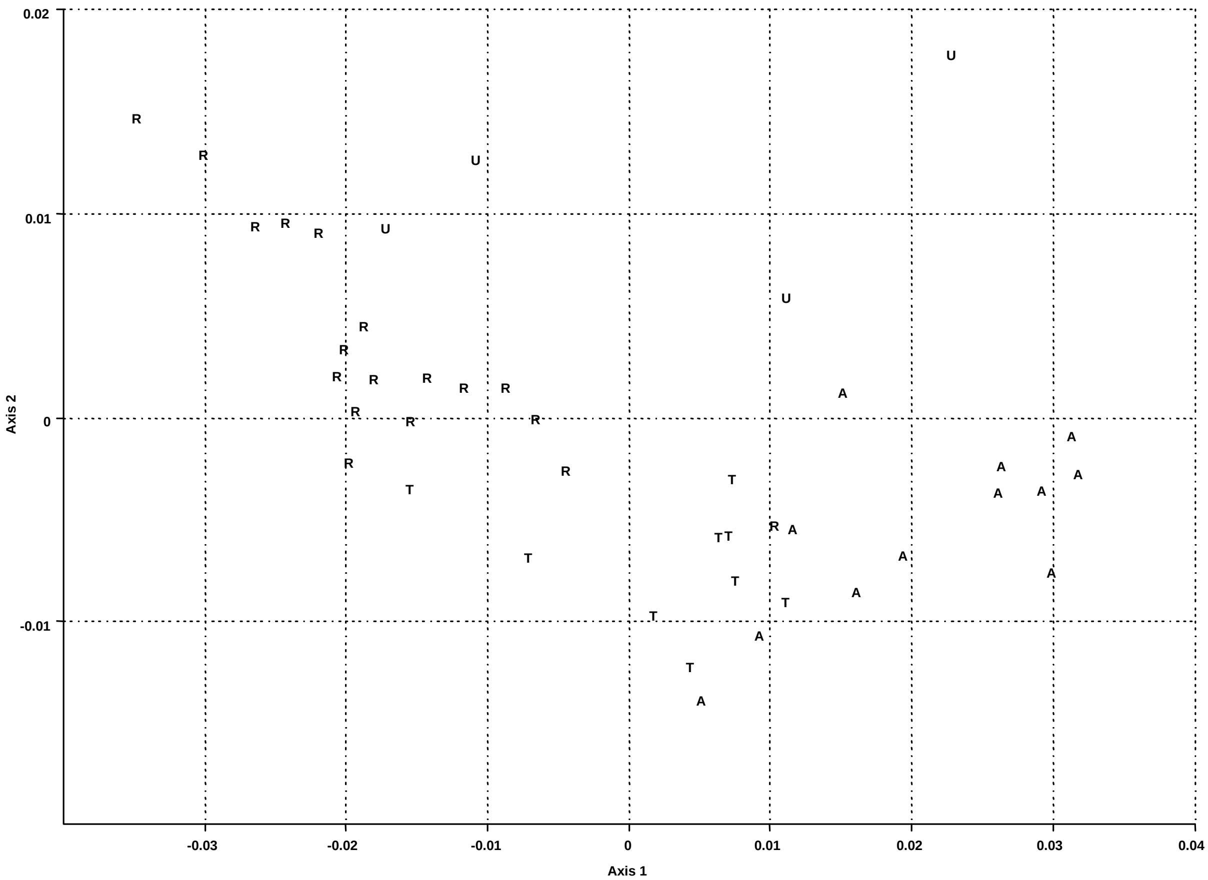


Axis	Proper value	% of inertia
1	0.9591	21,676
2	0.5294	13,848
3	0.60867	8,8073
4	0.4097	7,718

Figure 14: Analysis of correspondences for abundance data at the MDDEP volunteer taxonomic level for the 43 stations (control = R, agricultural = A, urban = U and test = T).

Figure 15 presents the correspondence analysis for abundance data at the OBBN taxonomic level for the 43 stations. The chart appears much the same as the two others (Figures 13 and 14). It includes control stations (R) grouped fairly closed on the left side of the vertical axis, with only one station really distant, agricultural stations (A) grouped in the lower right quadrant and the test stations (T), generally between the two other types of station. However, urban stations (U) are very distant: two are still isolated in the top right quadrant, but the two others are in the same quadrant as most of the control stations. It is therefore easy to confuse two of the urban stations with control stations.

The proper values for axes one to four are presented in each of the correspondence analyses (Figure 13, 14 and 15). A proper value greater than 0.5 generally indicates a positive separation among taxa on axis one (Jongman *et al*, 1995). None of the three correspondence analyses produced a proper value greater than 0.5 on axis one. However, the highest proper value on axis concerning the family identification level (0.40937), this identification level would therefore enable better separation of the taxa. The proper value of axis one at the MDDEP identification level (0.39591) approximates that of the family identification level, while the OBBN at this identification level (0.31003) is a little more remote. The separation of taxa at the OBBN identification level is therefore a little less effective.



Axis	Proper value	% of inertia
1	0.31003	37.337
2	0.13435	16.179
3	0.108519	13.069
4	0.0851508	10.255

Figure 15: Analysis of correspondences for abundance data at the OBBN coarse-level for the 43 stations (control = R, agricultural = A, urban = U and test = T).

Discussion

Environmental data confirm the professional judgement involved in selecting the four types of stations (Figure 2, 3, 4 and 5). Land use corresponds to the four types of station with control stations in forested areas (approximately 80%), agricultural stations in farm areas (approximately 60%) and urban stations in urban areas (approximately 30%) and forested areas (approximately 30%), Figure 2). The test stations consist of a mixture of forest and farmland. Habitat suitability indices (Total HSI) and shoreline quality indices (SQI) seem to show that the control stations have good habitat and shoreline quality (Figure 4). Even the impacted stations have a high habitat suitability index, partly because of the effort to choose habitat with the least possible effect on the taxonomic composition of the stations. The shoreline quality index, however, is much lower for the agricultural stations. Altitude and area are two environmental variables that present certain differences from one type of station to another (Figure 3). Many control stations are at a higher altitude than the impacted stations, which could affect taxonomic distribution. Growns *et al* (1997), however, state that there is no comparison problem for waterways at altitudes of 200 m or less, which includes some of the control stations. The drained area is similar at each type of station, although some of the test stations covered a larger drainage area. However, we must bear in mind that when we observe data on altitude and drainage area, there is very little variation at the Strahler order level for the various stations (order 2 and 3). The physico-chemical parameters measured indicate very distinct differences between the reference stations and agricultural stations (Figure 5). The control stations meet the water quality criteria (Table 2).

At the family and MDDEP identification levels, a greater number of metrics were obtained. Based on established criteria (DE of 75% or more, CV of 25 or less), 10 to 11 metrics were attractive for family and MDDEP level identification, compared to four at the OBBN identification level. This shows that the MDDEP identification level closely approximates the family identification level in relation to the use of metrics. Moreover, only one of the metrics tested (% Baetidae) could not be calculated for the MDDEP identification level (Table 4). However, it was much more difficult to work with OBBN identification metrics since the number of metrics was sometimes extremely limited and many of the metrics calculated are not good metrics according to the DE and CV (Table 5). Some metrics calculated using the OBBN identification level are considered good metrics because they can differentiate agricultural stations from control stations. However, they cannot distinguish urban stations from control stations (% EPT, Figure 5 and % intolerants, Figure 6). Taxonomic diversity metrics (number of taxa) are certainly the most limiting for the OBBN identification level. With a possibility of only 27 taxa, including just three that are sensitive EPT (Ephemera, Plecoptera and Trichoptera) macroinvertebrates, we cannot obtain relevant information on taxonomic diversity metrics. These metrics are generally used and distinguish control stations from impacted stations at the family and MDDEP identification levels (Barbour, 1999 and Figure 9 and 10). Two frequently used indices (Shannon-Wiener and Equitability) allow a clear distinction between control stations and impacted stations at the family and MDDEP identification levels (Figure 11). These indices can be calculated at the OBBN identification level, but are not considered good metrics (Table 5).

The West Virginia Stream Condition Index (WVSCI) is a multi-metric index that combines the findings of six metrics into one index. This index was developed for West Virginia, but it has been calibrated for Quebec based on data from 18 control stations for the three identification levels. This type of index incorporates many characteristics of the biological community and measures the community's overall response to environmental stress (Major *et al*, 2001). If we compare the WVSCI to the MDDEP and OBBN identification levels at the level of family, we observe that the values of this index closely approximate the MDDEP identification level (Figure 12). However, calculated using the OBBN identification level, the index overestimates impacted agricultural and urban stations. Therefore, calculation of the WVSCI index to the OBBN identification level does not adequately differentiate impacted stations from control stations. The diversity metrics used by the WVSCI appear responsible for the poor performance of the OBBN identification level since the taxon total is limited to 27 and the number of EPT taxa is limited to three. Even the possibility of developing a new multimetric index for the OBBN identification level seems unrealistic since a sufficient number of good metrics is required. Furthermore, these good metrics must respond to different environmental stress factors to produce an overall index.

The correspondence analyses performed on taxonomic abundance records reveal certain groups of stations that match their *a priori* selection fairly well. However, canonic variate analyses that incorporate environmental variables in analyses could confirm or refute these trends. The three correspondence analyses reveal a strong separation between reference sites and agricultural sites (Figures 13, 14 and 15). They also reveal a separation between urban stations and control stations for the family and MDDEP identification levels. The separation between urban stations and control stations is not as clear for OBBN identification levels, where two of the four urban stations were mixed in with control stations (Figure 15). Feio *et al* (2006) observed less sensitivity at the order identification level, an identification level more closely resembling the OBBN level. Feio *et al* (2006) indicate that the order identification level may be insufficient for detecting certain changes in benthic macroinvertebrate community composition because they are too similar at this identification level for the most representative taxa. This lack of sensitivity in the OBBN identification level for urban stations could relate to a special characteristic of these stations. Indeed, urban stations include a great deal of ephemera and trichoptera, both sensitive taxa, like the control stations. However, in urban stations, this involves only one taxon of ephemera (baetidae) and only one taxon of trichoptera (hydropsyche) whereas a wide diversity of ephemera and trichoptera are present at the control stations. Contrary to the family and MDDEP identification levels, the OBBN identification level makes no distinction among the various ephemera and trichoptera taxa.

Conclusion

The OBBN coarse-level identification certainly requires the least effort and involves the least risk of error during identification by volunteers. However, the various results seem to indicate some problems in processing and interpreting the results at this identification level. Very few metrics can be calculated, and of this number, very few seem to be good. It therefore seems unrealistic to consider developing an effective multimetric index using this identification level. Multivariate analyses remain the only data processing method that can lead to findings with this identification level. They allow a distinction between agricultural stations and control stations. However, they did not clearly distinguish two of the four urban stations from control stations.

The MDDEP volunteer identification level is more difficult and demands that volunteers make a greater effort. However, it is much easier than family level identification, and can be performed by trained volunteers. The various results show that the MDDEP identification level closely resembles the family identification level, used as a benchmark. Therefore, it is relatively easy to process data and interpret findings. Almost all of the metrics calculable at the family identification level can also be calculated at the MDDEP identification level, and as many of its metrics are good. The use of a multimetric index is quite reasonable, and multivariate analyses can distinguish among agricultural, urban and control stations.

The MDDEP identification level therefore seems an attractive compromise. It is easier to use for volunteers than the family identification level, and it provides more tools for interpreting data than the OBBN identification level.

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Appendix 1

List of Taxa

A) MDDEP list of taxa for volunteer monitoring (Moisan, in progress)

#	Order or other	Families
1	Plecoptera	Peltoperlidae
2	Plecoptera	Pteronarcyidae
3	Plecoptera	Perlidae
4	Plecoptera	GROUP 3.1 (Capniidae, Chloroperlidae, Leuctricidae, Nemouridae, Taeniopterygidae, Perlodidae)
5	Ephemera	Baetiscidae
6	Ephemera	GROUP 1.1 (Ephemeridae, Polymitarcydae)
7	Ephemera	Potamanthidae
8	Ephemera	Ephemerellidae
9	Ephemera	Leptophlebiidae
10	Ephemera	GROUP 1.2 (Caenidae, Tricorydae)
11	Ephemera	Heptageniidae
12	Ephemera	Isonychiidae
13	Ephemera	GROUP 1.3 (Ameletidae, Baetidae, Siphonuridae, Metrotopididae)
	Ephemera	Unidentified ephemera
14	Trichoptera	Helicopsychidae
15	Trichoptera	Rhyacophilidae
16	Trichoptera	GROUP 2.1 (Philopotamidae, Polycentropodidae, Psychomyiidae, Dipseudopsidae)
17	Trichoptera	Hydroptilidae
18	Trichoptera	Goeridae
19	Trichoptera	Leptoceridae
20	Trichoptera	Phryganidae
21	Trichoptera	GROUP 2.2 (Limnephilidae, Apataniidae, Lepidostomatidae, Brachycentridae, Odontoceridae, Uenoidae)
22	Trichoptera	Molannidae
23	Trichoptera	Glossosomatidae
24	Trichoptera	Hydropsychidae
	Trichoptera	Trichopteranon-identified
25	Odonata	Zygoptera
26	Odonata	Anisoptera
27	Hemiptera	Corixidae
28	Hemiptera	Notonectidae
29	Hemiptera	GERROMORPHA (Hydrometridae, Mesoveliidae, Veliidae, Gerridae)
30	Hemiptera	Naucoridae
31	Hemiptera	Belostomatidae
32	Hemiptera	Nepidae
33	Lepidoptera	
34	Megaloptera	Sialidae

35	Megaloptera	Corydalidae
36	Diptera	Ceratopogonidae
37	Diptera	Simulidae
38	Diptera	Tipulidae (partly)
39	Diptera	GROUP 5.1 (Culicidae, Chaoboridae)
40	Diptera	GROUP 5.2 (Empididae (partly), Athericidae)
41	Diptera	Chironomidae
	Diptera	Unidentified Diptera
42	Coleoptera (adult)	Haliplidae
43	Coleoptera (adult)	Gyrinidae
44	Coleoptera (adult)	Curculionnidae
45	Coleoptera (adult)	GROUP 4.2 (Elmidae, Dryopidae, Helophoridae, Hydrochidae)
46	Coleoptera (adult)	GROUP 4.1 (Hydrophilidae, Distiscidae, Noteridae)
47	Coleoptera (larva)	Psephenidae
48	Coleoptera (larva)	Elmidae, Lutrochidae
49	Coleoptera (larva)	Haliplidae, Peltodytes
50	Coleoptera (larva)	Gyrinidae
51	Coleoptera (larva)	Dystiscidae
52	Coleoptera (larva)	Hydrophilidae
	Coleoptera	Unidentified Coleoptera
53	Crayfish	
54	Isopoda	
55	Amphipoda	
56	Ostracod	
57	Cladocera	
58	Copepoda	
59	Gastropoda without operculum	Planorbidae
60	Gastropoda without operculum	Lymnaeidae
61	Gastropoda without operculum	Physidae
62	Gastropoda without operculum	Ancylidae
63	Gastropoda with operculum	Pleuroceridae, Hydrobiidae, Viviparidae, Bithyniidae, Valvatidae
64	Pelecypoda	Sphaeriidae
65	Pelecypoda	Margaririferidae, Unionidae
66	Pelecypoda	Dreissenidae (Zebra Mussel)
67	Oligochaeta	
68	Leech	
69	Planarian	
70	Nemerta	
71	Nematode	
72	Acari	
73	Tartigrade	
	Unidentified macroinvertebrates	

B) List of OBBN coarse-level taxa (Jones *et al*, 2005)

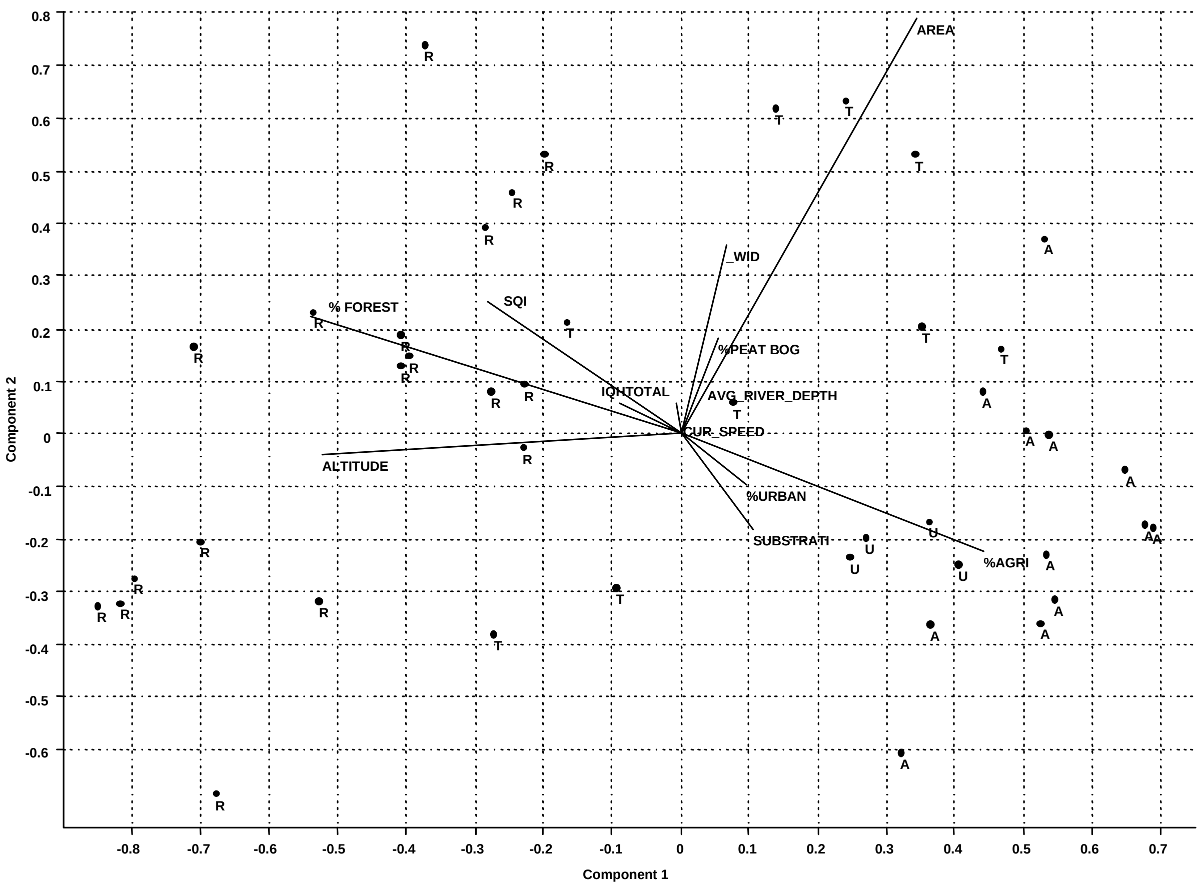
#	TAXA
1	Coelentera
2	Turbellaria
3	Nematoda
4	Oligocheta
5	Hirudinea
6	Isopoda
7	Pelecypoda
8	Amphipoda
9	Decapoda
10	Trombidiforms-Hydracarina
11	Ephemeroptera
12	Anisoptera
13	Zygoptera
14	Plecoptera
15	Hemiptera
16	Megaloptera
17	Trichoptera
18	Lepidoptera
19	Coleoptera
20	Gastropoda
21	Chironomidae
22	Tabanidae
23	Culicidae
24	Ceratopogonidae
25	Tipulidae
26	Simuliidae
27	Other Dipterans

Appendix 2

Multivariate Analyses of

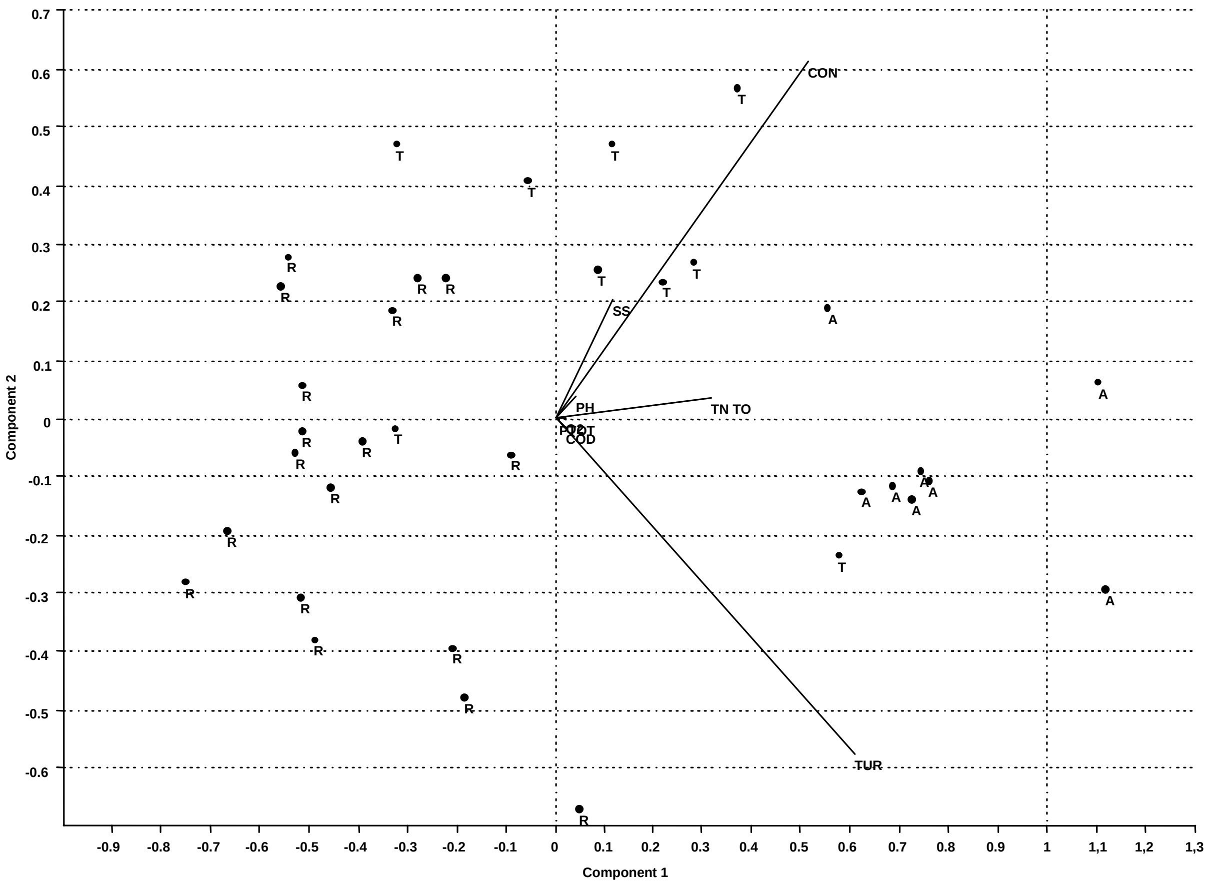
Environmental Data

Principal component analysis of the principal habitat variables for the 43 stations ((RIV_WID = river width, AVG_RIVER_DEP = average river depth, CUR_SPEED = current speed, % FOREST = % of forest land use, %AGRI = % agriculture land use, %PEAT BOG = % of peat bog land use, %URBAN = % urban area land use, SQI and SUBSTRATI= West Virginia substrate index (Craddock, 2005). (Control = R, agricultural = A, urban = U and test = T).



Factor	Proper value	% variance
1	0.22808	46.976
2	0.115597	23.808
3	0.0744676	15.337
4	0.0276154	5.6877
5	0.0167013	3.3498

Principal component analysis of the principal physico-chemical variables for 35 stations (DOC = dissolved organic carbon, O2 = dissolved oxygen. TOTN = Total phosphorus, TOTN = total nitrogen, pH, TUR = turbidity, SS = suspended solids, CON = conductivity). Eight stations (four urban and four agricultural) do not belong to the analysis because they did not have a complete record (control = R, agricultural = A, urban = U and test = T).



Factor	Proper value	% variance
1	0.286611	62.526
2	0.0844023	18.413
3	0.0475748	10.379
4	0.0267439	5.8343
5	0.0109156	2.3813

Appendix 3

Tolerance Ratings Used

Tolerance ratings used for the three identification levels (Bode *et al*, 1996; Hilsenhoff, 1988; Barbour *et al*, 1999; Mandaville, 2002 and professional judgement)

FAMILY	Tolerance
EPHEMEROPTERA	2
BAETIDAE	4
CAENIDAE	7
EPHEMERIDAE	4
EPHEMERELLIDAE	1
HEPTAGENIIDAE	4
ISONYCHIIDAE	2
LEPTOPHLEBIIDAE	2
TRICORYTHIDAE	4
TRICHOPTERA	3
APATANIIDAE	3
BRACHYCENTRIDAE	1
GLOSSOSOMATIDAE	0
GOERIDAE	3
HELICOPSYCHIDAE	3
HYDROPSYCHIDAE	4
HYDROPTILIDAE	4
LEPIDOSTOMATIDAE	1
LEPTOCERIDAE	4
LIMNEPHILIDAE	4
ODONTOCERIDAE	0
PHILOPOTAMIDAE	3
POLYCENTROPODIDAE	6
PSYCHOMYIIDAE	2
RHYACOPHILIDAE	0
PLECOPTERA	1
CAPNIIDAE	1
CHLOROPERLIDAE	1
LEUCTRIDAE	0
PELTOPERLIDAE	0
PERLIDAE	1
PERLODIDAE	2
PTERONARCYIDAE	0
TAENIOPTERYGIDAE	2
DIPTERA	x
ATHERICIDAE	2
CERATOPOGONIDAE	6
CHIRONOMIDAE	8
DIXIDAE	1
EMPIDIDAE	6
PHORIDAE	x
SIMULIIDAE	6
TABANIDAE	6
TIPULIDAE	3
CURCULIONIDAE	5
ELMIDAE	4
PSEPHENIDAE	4
AESHNIDAE	3
GOMPHIDAE	1
MESOVELIIDAE	x
VELIIDAE	6
LEPIDOPTERA	5
COSMOPTERIGIDAE	5
CORYDALIDAE	0
HYALELLIDAE	8
CLADOCERA	8
COPEPODA	8
CAMBARIDAE	6
OSTRACODA	8
ACARI	4
SPHAERIIDAE	8
ANCYLIDAE	6
LYMNAEIDAE	6
PLANORBIDAE	6
HYDROBIIDAE	8
HIRUDINEA	10
OLIGOCHAETA	8
NEMATODA	5
PLATYHELMINTHES	4
NEMERTEA	6
HYDRIDAE	5

MDDEP	Tolerance
EPHEMEROPTERA	2
Group 1.3	4
Group 1.2	5
Group 1.1	4
EPHEMERELLIDAE	1
HEPTAGENIIDAE	4
ISONYCHIIDAE	2
LEPTOPHLEBIIDAE	2
TRICHOPTERA	3
Group 2.2	2
GLOSSOSOMATIDAE	0
GOERIDAE	3
HELICOPSYCHIDAE	3
HYDROPSYCHIDAE	4
HYDROPTILIDAE	4
LEPTOCERIDAE	4
Group 2.1	4
RHYACOPHILIDAE	0
PLECOPTERA	1
Group 3.1	1
PELTOPERLIDAE	0
PERLIDAE	1
PTERONARCYIDAE	0
DIPTERA	5
Group 5.2	5
CERATOPOGONIDAE	6
CHIRONOMIDAE	8
SIMULIIDAE	6
TIPULIDAE	3
CURCULIONIDAE	5
ELMIDAE	4
PSEPHENIDAE	4
ANISOPTERA	5
Gerromorphe	x
LEPIDOPTERA	5
CORYDALIDAE	0
AMPHIPODA	7
CLADOCERA	8
COPEPODA	8
DECAPODA	6
OSTRACODA	8
ACARI	4
SPHAERIIDAE	8
ANCYLIDAE	6
LYMNAEIDAE	6
PLANORBIDAE	6
MESOGASTROPODA	7
HIRUDINEA	10
OLIGOCHAETA	8
NEMATODA	5
PLATYHELMINTHES	4
NEMERTEA	6

OBBN Taxa	Tolerance
EPHEMEROPTERA	2
TRICHOPTERA	3
PLECOPTERA	1
DIPTERA	5
CERATOPOGONIDAE	6
CHIRONOMIDAE	8
SIMULIIDAE	6
TABANIDAE	6
TIPULIDAE	3
COLEOPTERA	4
ANISOPTERA	5
HEMIPTERA	x
LEPIDOPTERA	5
MEGALOPTERA	2
AMPHIPODA	7
DECAPODA	6
ACARI	4
PELECYPODA	8
GASTROPODA	7
HIRUDINEA	10
OLIGOCHAETA	8
NEMATODA	5
PLATYHELMINTHES	4
COELENTERATA	5

Appendix 4
Formulas Used to Calculate DE and Accuracy

Discrimination efficiency (DE)

Formula: DE = 100 x (a/b)

For metrics with an expected response that diminishes as disturbances increase (for example: % EPT):

> a = number of samples in disturbed environments with a value above the 25th percentile of control station distribution.
>
> b = number of stations in disturbed environments.

For metrics with an expected response that increases as disturbances increase (ex: % Oligochaeta):

> a = number of samples in disturbed environments with a value above the 75th percentile of control station distribution.

A high DE indicates that a metric can more effectively differentiate disturbed sites from the control sites.

Accuracy

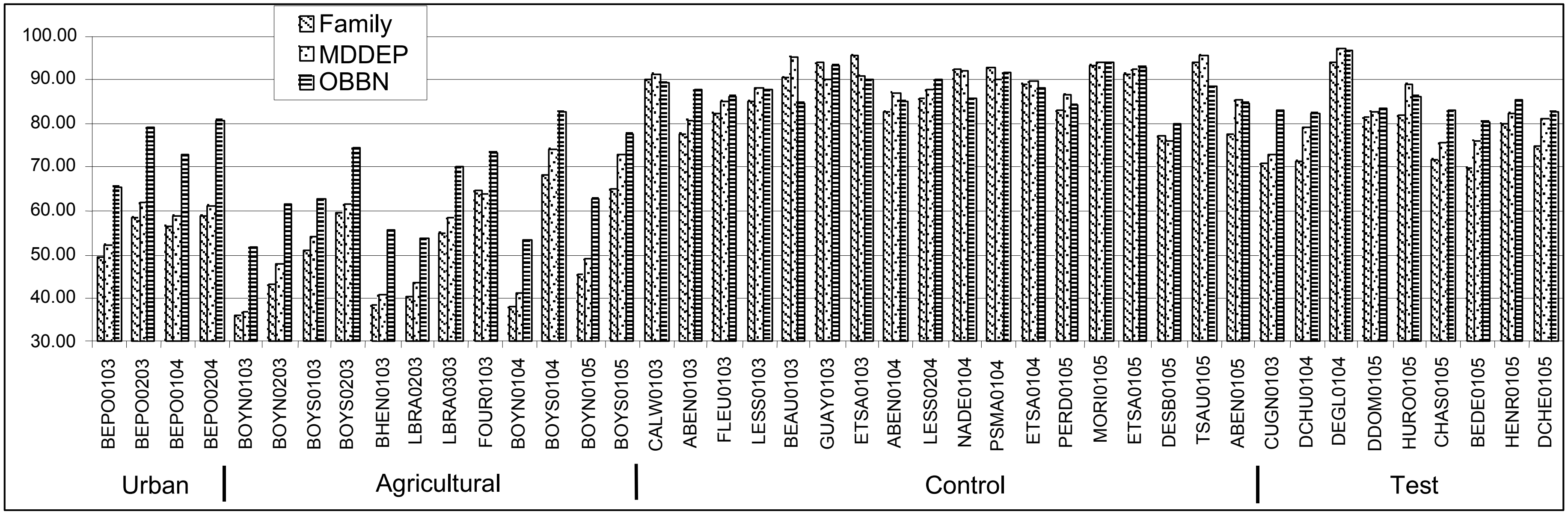
Formula: CV = Standard deviation/Average x 100

Comparison of coefficients of variation (CV) of metrics and indices.

A low value indicates greater accuracy.

Appendix 5

West Virginia Stream Condition Index (WVSCI) of Biological Integrity for the 43 Stations



West Virginia Stream Condition Index (WVSCI) of biological integrity for the 43 stations