ITEM 5

Information Request No. 5 – Information on Correlation of Macroinvertebrate and Sediment Data in Habitat Evaluation Report

The attached report, which provides supporting macroinvertebrate-related information for the Habitat Evaluation Report, was inadvertently omitted from Appendix B of the Report.

Technical Memorandum No.2:

MACROINVERTEBRATE METRICS

CHICAGO AREA WATERWAY SYSTEM

HABITAT RESTORATION EVALUATION AND IMPROVEMENT STUDY

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For

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In support of

Metropolitan Water Reclamation District of Greater Chicago

Chicago, Illinois

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Summary and Conclusion

A seven-year macroinvertebrate database was developed by the Metropolitan Water Reclamation District of Greater Chicago (District) and used herein in computing 28 candidate metrics, any one of which might potentially be used in developing a Habitat Index for the CAWS. These 28 candidates were screened for redundancy, ability to capture variance present in the CAWS reaches, and their sensitivity to sediment contamination. Five metrics are recommended for potential use by LimnoTech, Inc. in developing the CAWS Habitat Index. These are taxa richness (RICH), % Diptera (PER_DIP), % Oligochaetes (PER_OLIG), % Shredders (SHD) and Function Feeding Group Diversity (FFG_DIV).

The method of collecting the macroinvertebrate samples influences computation of the metric, correlation to sediment contamination, and ability to detect annual trends. The District uses two methods, ponar sampling and hester-dendy multi-plate sampling. The ponar method collects organisms that are living in or directly on bed sediment. The hester-dendy sampler is not sampling sediment directly, as the plate assemblies are typically held above the sediment. Discussions with District field biologists indicate that the hester-dendy samplers do sink into soft bed material if it is present at the site, but given the samplers structure, are intended to hold the sampling plates in the water column. In the CAWS, where legacy contaminants are present and clearly influence the metrics, the hester-dendy technique is sampling a population that is less exposed to environmental stress that is the ponar sampling technique. The difference apparent in the two sampling methods varies with the metric and the AWQM station.

Taxa richness (RICH) and Function Feeding Group Diversity (FFG_DIV) generally show some of the stronger correlations to sediment contamination of all metrics examined. In fact, when computed using the ponar data, these metrics show the strongest overall correlation to sediment contaminants (absolute value of mean r=0.37) of all metrics examined. And, in general, metrics computed from the ponar dataset show stronger correlations with sediment contaminants than metrics computed from the hester-dendy data.

We examined selected macroinvertebrate metrics for changes over the 2001 to 2007 monitoring period. Annual macroinvertebrate collections are made at eight stations in the CAWS. Unfortunately, all metrics from these eight stations could not be tested for trends without elaborate efforts to transform data so that model assumptions were met. Of those metrics tested, taxa richness (RICH) seems to be most sensitive to detecting changes over time in the CAWS. At the seven stations where this metric was subjected to ANCOVA, improvements in RICH were significant at four stations when measured using hester-dendy sampling data. RICH improvements were significant at only three of the seven stations when measured using ponar sampling data or the combined set. At AWQM 92 at Lockport, the sampling methods had different slopes over time, with the hester-dendy dataset showing improved RICH and the ponar dataset showing no significant change in RICH over time.

Function feeding group diversity (FFG_DIV) was also an indicator of significant positive change at two of the six sites included in the ANCOVA. At site AWQM 46 on the North Branch Chicago River, the improvements in FFG_DIV were detectable in the hester-dendy dataset and in the combined data. No FFG_DIV changes were significant when the ponar sampling data alone were analyzed. At AWQM 75 (Chicago Sanitary and Ship Canal at Cicero Avenue), the collection methods had unequal regression coefficients. If measured using the hester-dendy method, improvement is FFG_DIV over the seven year study period is significant. Conversely, the ponar method is unable to detect this change.

Background

Under contract to LimnoTech, Inc., Baetis Environmental Services, Inc. (Baetis) has been retained to analyze macroinvertebrate data collected from the Chicago Area Waterway System (CAWS) between 2001 and 2007. The analysis supports the CAWS Habitat Evaluation and Improvement Study sponsored by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). This technical memorandum is an interim deliverable, providing:

- A general review of metrics characterizing the macroinvertebrate populations and communities of the CAWS,
- A correlation analysis of macroinvertebrate metrics with sediment contamination in the CAWS,
- Recommendations for macroinvertebrates metrics that might be considered further during development of the Habitat Index by LimnoTech, Inc.
- A comparison of sampling techniques for estimating macroinvertebrate metrics, and,
- Analysis of trends in metrics during the period 2001 through 2007.

Methods and Materials

Macroinvertebrates were collected annually each summer from the CAWS from 2001-2007 by MWRDGC, with enumeration and identification by EA Engineering, Science, and Technology, Inc. (EA) of Deerfield, IL. Figure 1 shows the locations of macroinvertebrate and sediment sampling stations. Macroinvertebrate collection methods included both hester-dendy sampler (artificial substrate) and a ponar (grab) sampler. Most macroinvertebrates were identified to genus; where possible species-level identifications were completed. A detailed description of the methodology is provided by EA in their 2006 report (EA 2006). LimnoTech, Inc. compiled EA's datasets into one database for this project. Metrics in Wessel *et al.* (2008) were computed, including the Shannon Diversity Index, DIV, which was necessarily computed using the lowest taxa descriptor in the database.

Descriptive and inferential statistics were derived for the 2001-2007 macroinvertebrate database using SAS software (Vers. 9.1, SAS Institute Inc. Cary, NC). In all cases, data were examined for normality using the Shapiro-Wilks test in SAS. Because very little of the macroinvertebrate abundance data are normally distributed, nor could they be transformed to approximate a normal distribution, we commonly used nonparametric statistical methods, which are independent of the population distribution. Correlation analyses, for example, relied on Spearman correlation coefficients unless otherwise indicated. In instances where the data could be transformed to approximate a normal distribution, parametric techniques were applied. We have indicated such in the text. For all inference tests, we used a significance level, α, of 0.05.

Results and Discussion

Screening of Macroinvertebrate Metrics

The CAWS Habitat Evaluation and Improvement Study is following the general approach developed by Wessel *et al.* (2008) for developing a habitat index. Wessel *et al.* identified 26 biological attributes for evaluating macroinvertebrate communities in non-wadeable rivers in Michigan. The CAWS study began with these metrics, eliminated some that are not applicable to the CAWS because of the scarcity or absence of certain families of insects, and added others reflecting the unique nature of the artificial CAWS. Some metrics were subsequently eliminated from further evaluation because of redundancy among metrics, lack of variation in the CAWS, or lack of response to sediment contamination. Table 1 lists the attributes of Wessel *et al.* and those identified specifically for the CAWS, and reasons for recommending the metric's retention or elimination from further consideration in developing the CAWS Habitat Index. Table 1 also includes an indication of the attribute's expected response to increasing environmental perturbation (adapted from Wessel *et al*. 2008 and Barber *et al*. 1999).

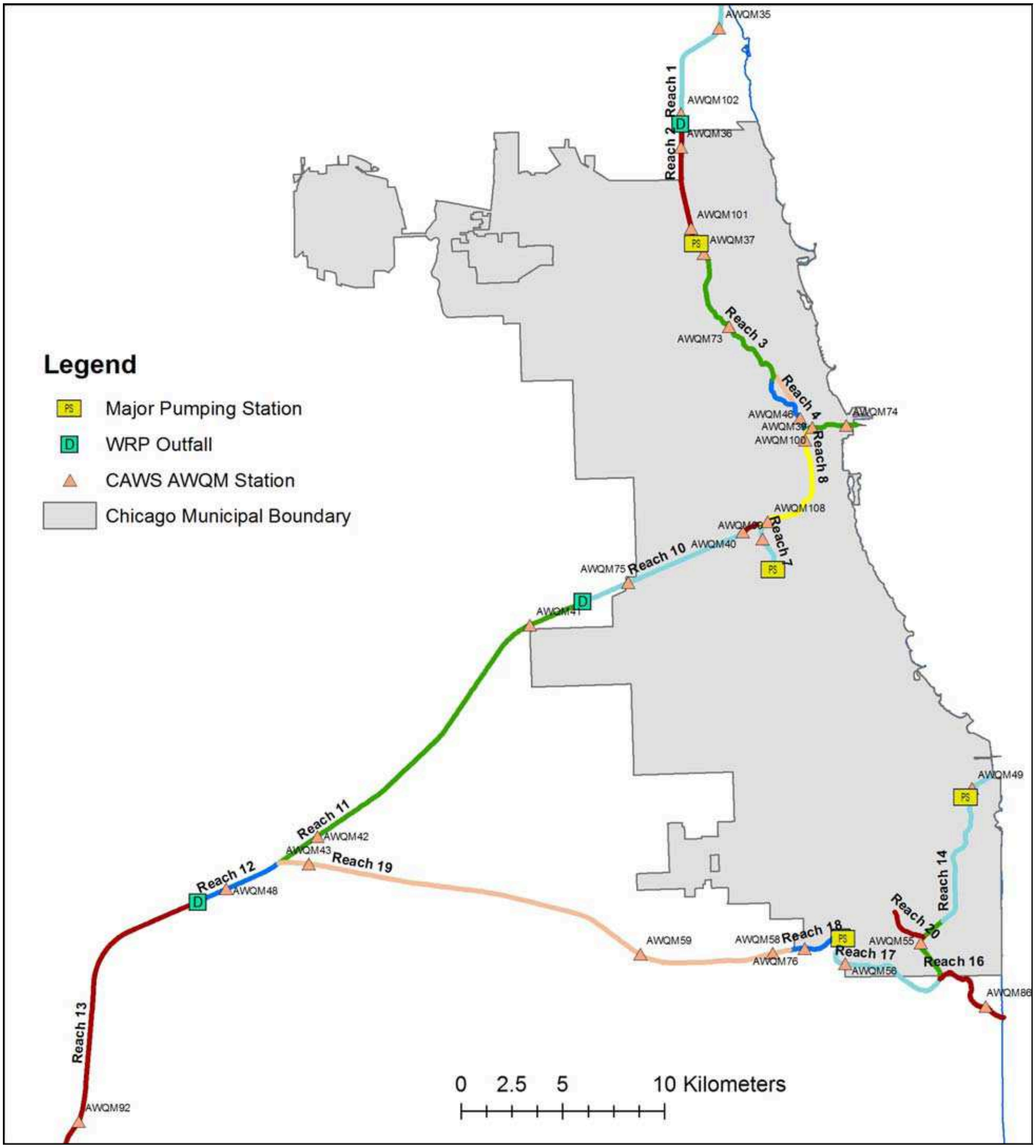

Figure 1. Locations of AWQM Stations in the Chicago Area Waterway System

Table 1
SCREENING OF BIOLOGICAL ATTRIBUTES
(adapted from Wessel *et al.* 2008)

Attribute	Code	Expected Response to Increasing Perturbation	Evaluation
Population Level			
Ephemeroptera Richness	E_RICH	−	Discarded – lack of variation
Plecoptera Richness	P_RICH	−	Discarded – not present
Tricoptera Richness	T_RICH	−	Discarded – lack of variation
EPT Richness	EPT_RICH	−	Discarded – weak correlation with sediment contamination
Diptera Richness	DIP_RICH	−	Retained
Community Level			
Total Density	TNI	+ / −	Discarded – weak correlation with sediment contamination
% Ephemeroptera	PER_E	−	Discarded – lack of variation
% Plecoptera	PER_P	−	Discarded – not present
% Tricoptera	PER_T	−	Discarded – lack of variation
% EPT	PER_EPT	−	Discarded – weak correlation with sediment contamination
% Diptera	PER_DIP	+	Retained
% Chironomidae	PER_CHIR	+	Discarded - redundant
% Oligochaeta	PER_OLIG	+	Retained
Taxa Richness	RICH	−	Retained
Shannon Diversity	DIV	−	Discarded - redundant
% Dominance	PER_DOM	+	Discarded - redundant
% Dreissena	PER_DRES	+ / −	Discarded - redundant
EPT/EPT+DIP	EPT_DIP	−	Discarded - lack of variation & redundant
Functional Group Metrics or Surrogates			
% Shredders	SHD	+ / −	Retained
% Scrapers	SCR	+ / −	Discarded – weak correlation with sediment contamination
% Collector Filterers	CF	+ / −	Discarded – redundant
% Collector Gatherers	CG	+ / −	Discarded – redundant
% Predators	PRED	+ / −	Discarded – weak correlation with sediment contamination
FFG Diversity	FFG_DIV	−	Retained
Habitat Stability FFG	HAB_STAB	−	Discarded - redundant
P/R FFG	P_R	0	Discarded - redundant
CPOM:FPOM FFG	C_FPOM		Discarded - redundant
Transport:Benthic FPOM	T_BFPOM		Discarded - redundant

These macroinvertebrate attributes, or metrics, have been computed for each of the District's AWQM stations in the CAWS from 2001 through 2007. Appendix 1 contains summary statistics for the metrics, as well as correlation analyses on these metrics grouped by ambient monitoring station. The analysis was performed first on a year by year basis (N=86), and again by grouping all seven years of data (N=23). Appendix 1 also contains summary statistics and correlation analyses for concentrations of sediment contaminants in the CAWS. Appendix 2 is a correlation matrix between sediment contamination and macroinvertebrate metric ($59 \leq N \leq 72$). Individual metrics are discussed below in the context of their correlation with other metrics, and, with sediment contamination.

At any ambient monitoring station in any given year, median EPT_RICH is 1, and the maximum ever recorded is 4. EPT_RICH in both hester-dendy and ponar samples showed no or very weak correlation to sediment contamination. No plecopterans have been found in the CAWS during the study period. Ephemeropterans and tricopterans are exceedingly scarce in the CAWS and are very nearly absent from the ponar collections. EPT_RICH is strongly correlated to T_RICH and PER_EPT ($r>0.7$). For these reasons, metrics involving the indicator taxa Ephemeroptera, Tricoptera, and Plecoptera were not recommended for consideration in the habitat index.

At any given monitoring station, DIP_RICH varied from 2 to 23 during the study year, with a mean of 9.1 and median of 9.0. Among the population-level metrics, DIP_RICH shows some of the strongest correlations with sediment contamination, notably in the ponar samples. While some redundancy is apparent to the metric RICH ($r>0.7$) that is not a population level attribute. DIP_RICH is retained for consideration in the development of the habitat index.

TNI, the number of individual organisms per m^2, varies widely between stations and between collection methods. This metric is overwhelmingly controlled by the density of oligochaetes, especially in the ponar collections. Among the ponar collections, TNI shows relatively strong correlations with bioaccumulating contaminants, namely total PCB ($r=-0.53$, $p<0.001$) and mercury ($r=-0.45$, $p<0.001$). Other correlations with sediment contamination were much weaker, and this metric is not recommended for consideration in the habitat index.

Because most dipterans in the CAWS are chironomids, PER_DIP and PER_CHIR are redundant. The more inclusive PER_DIP metric was retained for further evaluation. In station-wise and year-wise groupings, PER_DIP ranged from less than 0.05% to 48%, with a mean of 10.5% and a median of 6.6%. PER_DIP also correlated strongly with DIV, and in ponar collections, with DIV, CG, PER_OLIG, and FFG_DIV (absolute value of $r>0.7$). Spearman correlation coefficients between PER_DIP and sediment contaminants were generally higher for the ponar samples than the hester-dendy samples, and while statistically significant, all were fairly weak (r<0.3).

By abundance, oligochaetes dominate the CAWS benthic community. PER_OLIG ranged from 1% to 99%. Median PER_OLIG in hester-dendy samples was 38% while the median in ponar collections was 96%. In station-wise and year-wise groupings, PER_OLIG correlated strongly with several functional group metrics: CF, CG, FFG_DIV, HAB_STAB, and T_BFPOM (absolute value of r>0.7). However, in ponar samples where oligochaetes overwhelmingly dominated the community, PER_OLIG correlated strongly with CG, DIV, FFG_DIV and PER_DIP. Across monitoring stations, PER_OLIG is significantly correlated with several sediment contaminants, notably metals, although few correlation coefficients exceed 0.5. Interestingly, the correlation coefficients are positive, and, for Cd, Cr, Cu, Ni, Pb, and Zn are higher in magnitude for hester-dendy samples than for ponar samples. PER_OLIG is retained for consideration for developing the habitat index.

Total richness, RICH, and Shannon Diversity Index, DIV, are calculated using the lowest taxa field in the District's macroinvertebrate database. In some cases, this is not to the species level, so strictly speaking, the values of these attributes are incorrect. In station-wise and year-wise groupings, RICH ranged from 4 to 40, with a mean of 18.5 and a median of 18 taxa. DIV ranged from 0.06 to 2.10, averaged 0.82, and had a median of 0.78. Overall, these two metrics are weakly correlated (r=0.54, p<0.0001), but this correlation is strengthened when data pairs were stratified by collection method (in ponar samples, r=0.63; in hester-dendy samples, r=0.68). Both metrics show reasonably strong correlations with sediment contaminant concentrations, with RICH generally showing stronger correlations. In fact, RICH computed using ponar data shows the strongest overall correlation to sediment contaminants (absolute value of mean r=0.37) of all metrics examined. RICH is retained for consideration for developing the habitat index, while DIV is not.

PER_DRES is computed as the percentage of organisms in a sample belonging to the exotic genus *Dreissena*. In station-wise and year-wise groupings, PER_DRES ranged from 0 to 98%, had a mean of 25% and a median of 2%. Numbers of *Dreissena* sp. were usually higher in hester-dendy samples than in ponar samples. Overall, PER_DRES is rather redundant of other metrics; PER_DRES is strongly correlated with several other metrics, including CF, HAB_STAB, and T_BFPOM (r>0.7). PER_DRES is not recommended for further consideration in developing the CAWS Habitat Index.

In station-wise and year-wise groupings, SHD, ranged from 0 to 22%, averaged 1.4% and was most commonly 0.2%. Shredders are scarce in the CAWS; in hester-dendy samples SHD averaged 2.6% while SHD averaged 0.6% in ponar samples. Overall, the SHD metric shows strong correlations with C_FPOM and P_R (r>0.7); SHD also shows similar sediment contaminant correlation patterns. Of these 3 redundant metrics, SHD is recommended for possible use in developing the habitat index.

Scrapers are rarer than shredders in the CAWS, and are nearly absent from ponar samples. In station-wise and year-wise groupings, SCR ranged from 0 to 25%, and had a mean of 0.9% and a median of 0.08%. Overall, and perhaps because of their scarcity, SCR did not correlate with any other metrics in Table 1. Further, SCR had no strong correlations with sediment contaminant concentrations or texture. This metric is not recommended for further consideration.

CF ranged from 0 to 98% across all stations. Mean CF was 12.5% and median CF was 0.3%. Occasionally, high number of collector-filterers are found, particularly in hester-dendy samples. In station-wise and year-wise groupings, CF correlated strongly with CG, HAB_STAB, PER_DRES, PER_OLIG and T_BFPOM (|r|>0.7). Spearman correlation coefficients between CF and sediment contaminants were generally higher for the hester-dendy samples than the ponar samples, and while statistically significant, all were fairly weak (|r|<0.3). Therefore this metric is not recommended for further consideration.

Percent of collector-gatherers, CG, in samples ranged widely, from 1% to 100%. Mean and median CG are higher in ponar samples than in hester-dendy samples. Considering both collection methods, CG is strongly correlated with several other metrics, including PER_OLIG, PER_DRES, CF, HAB_STAB, and T_BFPOM. Spearman correlation coefficients between CG and sediment contaminants were generally higher for the hester-dendy samples than the ponar samples, and some were as high as +0.57. Because it is redundant of other metrics, most notably PER_OLIG (r=0.92), CG is not recommended for further consideration.

PRED ranged from 0.2% to 82% at the ambient monitoring stations between 2001 and 2007. Mean PRED is 8% and median PRED is 5%. Predators are much more commonly found in hester-dendy samples than in ponar samples. In station-wise and year-wise groupings, Spearman correlation coefficients suggest that PRED is redundant of FFG_DIV (r=0.71). Correlation coefficients between PRED and sediment contaminants were generally higher for the hester-dendy samples than for the ponar samples, but even so, few were greater than 0.3 in absolute value. In view of its weak correlation to sediment contaminants and redundancy with FFG_DIV, PRED is not recommended for consideration in the habitat index..

FFG_DIV measures diversity and evenness of the various functional feeding groups and is computed in the manner of the Shannon Diversity Index using the functional feeding groups shredders, scrapers, collector-filterers, collector-gathers, piercing herbivores or predators. In station-wise and year-wise groupings, FFG_DIV ranged from 4 to 33, averaged 16.1, and most commonly was 16. FFG_DIV was typically higher in hester-dendy samples than in ponar samples. Spearman correlation coefficients suggest that FFG_DIV is strongly correlated to CG, HAB_STAB, PRED, P_R, DIV and PER_OLIG ($|r|>0.7$). FFG_DIV shows several relatively high correlation coefficients with various sediment contaminants, and in fact, FFG_DIV computed from ponar samples has the second highest mean r (absolute value of mean $r=0.37$) of all metrics examined. For this reason, FFG_DIV is retained for further consideration.

HAB_STAB, the ratio of the number of scrapers and collector-filterers to the number of shredders and collector-gathers. Considering all stations and all 7 years, HAB_STAB ranges from 0 to 60%, has a mean of 3% and a median of 0%. It is strongly correlated to five other metrics: CF, CG, PER_DRES, PER_OLIG, and T_BFPOM. As such it classed as a redundant metric and discarded from further consideration.

P_R is the ratio of the numbers of shredders, scrapers and piercing herbivores to the numbers of shredders, collector-filterers and collector-gatherers. P_R ranges from 0 to 0.45, averages 0.03 and has a median of 0.005. P_R is strongly correlated with C_FPOM, DIV, FFG_DIV, and SHD. P_R has similar correlation patterns with sediment contamination as the SHD metric (generally weak, but statistically significant). P_R is discarded from further consideration because it is redundant of other metrics.

C_FPOM represents the ratio of course particulate organic matter (CPOM) eaters to fine particulate organic matter (FPOM) eaters, and is computed as the ratio of total number of shredders to the sum of collector-filterers and collector-gatherers. Because of the scarcity of shredders in the CAWS and the abundances of collector-filterers and collector-gatherers, C_FPOM is low throughout the system, ranging from 0 to 0.24. In the hester-dendy dataset, C_FPOM got as high as 1.7, but in the ponar dataset, maximum C_FPOM was 0.2. It is strongly correlated with P_R, and particularly with SHD ($r=0.996$). Like P_R, C_FPOM has similar correlation patterns with sediment contamination as SHD. C_FPOM is discarded from further consideration because of this redundancy.

T_BFPOM is computed as the ratio of the number of collecter-filterers to collector-gatherers. T_BFPOM ranges from 0 to 64, averages 2.9 and is most commonly 0.003. T_BFPOM is understandably correlated with its numerator and denominator, CF and CG, but T_BFPOM is also strongly correlated with HAB_STAB, PER_DRES and PER_OLIG. T_BFPOM is a highly redundant metric and is discarded from further consideration.

Metric Trends

The District collects macroinvertebrate data annually at eight AWQM stations in the CAWS. This seven-year record presents an opportunity to study trends in the macroinvertebrate communities of the CAWS. We identified metrics that were normally distributed for evaluation in a series of ANCOVA (Analysis of Covariance), the results of which are included in further detail in Appendix 3. Table 2 summarizes the ANCOVA, including the expected response to organic pollution (taken from Table 1), and the detected direction of the metric's trend over the seven year study period at each AWQM station. ANCOVA includes an inference test of the collection method being a significant covariate in any trend. Possible conclusions in this analysis were:

1. Hester-dendy and ponar sample collection methods have a similar trend over time (equal slopes in the regression analysis), either increasing or decreasing, or,

2. Hester-dendy and ponar sampling methods have different trends over time (unequal slopes), or,

3. Neither sampling method at an AWQM station showed a trend (slope = 0) over time.

While all metrics could not be tested for trends without more elaborate efforts to transform data so that ANCOVA model assumptions were met, taxa richness metric (RICH) seems to be most sensitive to detecting changes over time in the CAWS. At the seven stations where this metrics was subjected to ANCOVA, improvements in RICH were significant at four stations when measured using hester-dendy sampling data. RICH improvements were significant at only three of the seven stations when measured using ponar or sampling data or the combined set. At AWQM 92 at Lockport, the sampling methods had different slopes over time, with the hester-dendy dataset showing improved RICH and the ponar dataset showing no significant change in RICH over time.

Shannon Diversity Index, DIV, while not a true species-level diversity index, was an indicator of significant positive change at two of the six sites included in the ANCOVA. But, the improvements in DIV were only detectable in the hester-dendy dataset. No changes were significant over time as measured by the ponar sampling method.

Function feeding group diversity (FFG_DIV) was also an indicator of significant positive change at two of the six sites included in the ANCOVA. At site AWQM 46 on the North Branch

Chicago River, the improvements in FFG_DIV were detectable in the hester-dendy dataset or in the combined data. No FFG_DIV changes were significant when the ponar sampling data alone were analyzed. At AWQM 75 (Chicago Sanitary and Ship Canal at Cicero Avenue), the collection methods had unequal regression coefficients. If measured using by the hester-dendy method, improvement is FFG_DIV over the seven year study period is significant. Conversely, the ponar method is unable to detect this change.

In spite of the limited application of ANCOVA to the CAWS macroinvertebrate dataset, we detected some improvements in macroinvertebrate community over time from data collected by the hester-dendy sampling technique. These are shown in Table 2. The hester-dendy technique detects trends, if they exist, while the ponar technique does not detect change in our limited application of ANCOVA. Admittedly the sample collection methods are generally measuring different populations, with the ponar apparatus sampling organisms that are living in or directly on bed sediment. The hester-dendy apparatus (Figure 1) is not sampling sediment directly. Discussions with District field biologists indicate that the hester-dendy samplers do sink into soft bed material if it is present at the site, but given their structure, are intended to hold the sampling plates in the water column. In the CAWS, where legacy contaminants are present and clearly influence metrics (Appendix 2), it seems logical that the hester-dendy technique is sampling a population that is less exposed to environmental stress that is the ponar sampling technique.

Figure 2. MWRDGC's Hester-Dendy Sampling Apparatus. Organisms are removed from the plates after the samplers are left in the CAWS for 7 to 14 weeks. (Photo courtesy of Mr. Thomas Minarik, MWRDGC)

Table 2

TRENDS IN MACROINVERTEBRATE METRICS IN THE CAWS, 2001-2007

Metric	Waterway	AWQM	Expected Response	Annual Trend	
				H-D Samples	Ponar Samples
RICH	NSC	36	−	0	
	NBCR	46	−	+	
	CSSC	75	−	0	
	CSSC	92	−	+	0
	CalR	55	−	0	
	LCR	76	−	+	
	CSC	59	−	+	
DIV	NSC	36	−	0	
	CSSC	75	−	+	0
	CSSC	92	−	+	0
	LCR	76	−	0	
	CSC	59	−	0	
DIP_RICH	NBCR	46	−	0	
	CSSC	75	−	0	
	CSSC	41	−	0	
	CSSC	92	−	0	
	CalR	55	−	0	
	LCR	76	−	0	
	CSC	59	−	+	
PER_DIP	NSC	36	+	0	
	CSSC	41	+	0	
	CalR	55	+	0	
	LCR	76	+	+	0
	CSC	59	+	+	
FFG_DIV	NSC	36	−	0	
	NBCR	46	−	+	
	CSSC	75	−	+	0
	CSSC	92	−	0	
	LCR	76	−	0	
	CSC	59	−	0	

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Wessel, K.J., R.W. Merrit, J.O. Wilhelm, J.D.Allan, K.W. Cummins, and D.G. Uzarski. 2008. Biological evaluation of Michigan's non-wadeable rivers using macroinvertebrates. Aquatic Ecosystem Health & Management 11(3):335-351.

Appendix 1

SIMPLE STATISTICS AND CORRELATION ANALYSES FOR

1. MACROINVERTEBRATE METRICS BY STATION AND BY YEAR
2. MACROINVERTEBRATE METRICS BY STATION COMBINING YEARS
3. SEDIMENT CONTAMINANT CONCENTRATIONS

Combined Collection Methods

The CORR Procedure

22 Variables:	TNI RICH EPT_RICH DIV PER_OLIG E_RICH T_RICH DIP_RICH PER_EPT CF No_Samples FFG_DIV CG SCR SHD PRED P_R HAB_STAB PER_DRES PER_DIP C_FPOM T_BFPOM

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Median**	**Minimum**	**Maximum**	**Label**
TNI	86	96218	119334	57334	2799	832273	TNI
RICH	86	18.50000	7.09225	18.00000	4.00000	40.00000	
EPT_RICH	86	0.87209	0.99169	1.00000	0	4.00000	
DIV	86	0.35704	0.21699	0.33893	0.02807	0.91036	
PER_OLIG	86	67.50893	28.81562	79.50644	1.12755	98.92698	
E_RICH	86	0.23256	0.62637	0	0	3.00000	
T_RICH	86	0.73256	0.83207	1.00000	0	3.00000	
DIP_RICH	86	9.11628	4.60542	9.00000	2.00000	23.00000	
PER_EPT	86	0.43980	1.47250	0.00517	0	9.11314	
CF	86	12.46748	26.87316	0.30022	0	97.74168	
No_Samples	86	3.96512	0.23998	4.00000	2.00000	4.00000	
FFG_DIV	86	0.18428	0.12910	0.16118	0.00579	0.49775	
CG	86	76.16068	27.71394	87.25560	1.45204	99.82832	
SCR	86	0.86044	3.09612	0.08457	0	25.45562	
SHD	86	1.35502	3.17541	0.21511	0	22.03947	
PRED	86	8.07974	10.75983	5.00502	0.18242	82.39700	
P_R	86	0.02734	0.06000	0.00473	0	0.45672	
HAB_STAB	86	2.83331	11.30953	0.01100	0	59.57527	
PER_DRES	86	12.14018	26.94312	0	0	97.74168	
PER_DIP	86	10.46367	10.60038	6.26038	0.00814	47.95806	
C_FPOM	86	0.01701	0.03906	0.00226	0	0.24265	
T_BFPOM	86	2.90149	11.64200	0.00341	0	63.88519	

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Collection Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 86
Prob > |r| under H0: Rho=0

	TNI	RICH	EPT_RICH	DIV	PER_OLIG	E_RICH	T_RICH	DIP_RICH	PER_EPT	CF	No_Samples
TNI TNI	1.00000	-0.16487 0.1293	0.05486 0.6159	-0.47905 <.0001	0.15922 0.1431	-0.07806 0.4750	0.07013 0.5211	-0.12276 0.2602	-0.18799 0.0830	0.08561 0.4332	0.11317 0.2995
RICH	-0.16487 0.1293	1.00000	0.58461 <.0001	0.53321 <.0001	-0.27162 0.0114	0.32839 0.0020	0.50139 <.0001	0.86517 <.0001	0.17679 0.1035	0.08087 0.4592	0.13479 0.2160
EPT_RICH	0.05486 0.6159	0.58461 <.0001	1.00000	0.30931 0.0038	-0.38553 0.0002	0.59770 <.0001	0.87054 <.0001	0.39741 0.0002	0.22230 0.0397	0.24281 0.0243	-0.01897 0.8624
DIV	-0.47905 <.0001	0.53321 <.0001	0.30931 0.0038	1.00000	-0.48929 <.0001	0.19317 0.0748	0.30074 0.0049	0.36750 0.0005	0.35098 0.0009	0.04197 0.7012	0.05330 0.6260
PER_OLIG	0.15922 0.1431	-0.27162 0.0114	-0.38553 0.0002	-0.48929 <.0001	1.00000	-0.07786 0.4761	-0.42160 <.0001	-0.24879 0.0209	-0.17026 0.1170	-0.82587 <.0001	-0.05792 0.5963
E_RICH	-0.07806 0.4750	0.32839 0.0020	0.59770 <.0001	0.19317 0.0748	-0.07786 0.4761	1.00000	0.27875 0.0094	0.22298 0.0391	0.09479 0.3853	-0.08036 0.4620	-0.18019 0.0969
T_RICH	0.07013 0.5211	0.50139 <.0001	0.87054 <.0001	0.30074 0.0049	-0.42160 <.0001	0.27875 0.0094	1.00000	0.32750 0.0021	0.21186 0.0502	0.30097 0.0049	0.01165 0.9152
DIP_RICH	-0.12276 0.2602	0.86517 <.0001	0.39741 0.0002	0.36750 0.0005	-0.24879 0.0209	0.22298 0.0391	0.32750 0.0021	1.00000	0.07842 0.4729	0.11376 0.2970	0.09951 0.3620
PER_EPT	-0.18799 0.0830	0.17679 0.1035	0.22230 0.0397	0.35098 0.0009	-0.17026 0.1170	0.09479 0.3853	0.21186 0.0502	0.07842 0.4729	1.00000	0.03199 0.7700	0.01395 0.8986
CF	0.08561 0.4332	0.08087 0.4592	0.24281 0.0243	0.04197 0.7012	-0.82587 <.0001	-0.08036 0.4620	0.30097 0.0049	0.11376 0.2970	0.03199 0.7700	1.00000	0.06702 0.5398
No_Samples	0.11317 0.2995	0.13479 0.2160	-0.01897 0.8624	0.05330 0.6260	-0.05792 0.5963	-0.18019 0.0969	0.01165 0.9152	0.09951 0.3620	0.01395 0.8986	0.06702 0.5398	1.00000
FFG_DIV	-0.41116 <.0001	0.48597 <.0001	0.30103 0.0049	0.90112 <.0001	-0.56299 <.0001	0.20074 0.0638	0.32650 0.0022	0.35781 0.0007	0.27955 0.0091	0.19415 0.0733	-0.00983 0.9285
CG	0.05778 0.5972	-0.21349 0.0484	-0.37302 0.0004	-0.26849 0.0124	0.94615 <.0001	-0.05839 0.5933	-0.43429 <.0001	-0.22235 0.0396	-0.10512 0.3354	-0.90414 <.0001	-0.03125 0.7751
SCR	-0.16116 0.1382	0.17454 0.1080	0.20190 0.0623	0.33320 0.0017	-0.15233 0.1615	0.41578 <.0001	0.12976 0.2337	0.13546 0.2136	0.05099 0.6410	-0.04626 0.6724	0.02737 0.8025
SHD	-0.05937 0.5871	0.31313 0.0033	0.04599 0.6741	0.31845 0.0028	-0.10940 0.3160	0.05225 0.6328	0.07181 0.5111	0.38322 0.0003	-0.02701 0.8050	-0.04749 0.6641	-0.01717 0.8753

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Collection Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 86
Prob > |r| under H0: Rho=0

	FFG_DIV	CG	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	-0.41116 <.0001	0.05778 0.5972	-0.16116 0.1382	-0.05937 0.5871	-0.24418 0.0235	-0.17193 0.1134	0.28190 0.0085	0.09128 0.4033	-0.34877 0.0010	-0.08221 0.4517	0.27832 0.0095
RICH	0.48597 <.0001	-0.21349 0.0484	0.17454 0.1080	0.31313 0.0033	0.17736 0.1023	0.34597 0.0011	-0.08857 0.4174	0.07429 0.4967	0.30893 0.0038	0.32467 0.0023	-0.08440 0.4397
EPT_RICH	0.30103 0.0049	-0.37302 0.0004	0.20190 0.0623	0.04599 0.6741	0.20484 0.0585	0.24363 0.0238	0.22019 0.0416	0.23458 0.0297	0.13885 0.2023	0.08608 0.4307	0.21910 0.0427
DIV	0.90112 <.0001	-0.26849 0.0124	0.33320 0.0017	0.31845 0.0028	0.35169 0.0009	0.44388 <.0001	-0.24182 0.0249	0.03073 0.7788	0.76653 <.0001	0.31909 0.0027	-0.24112 0.0253
PER_OLIG	-0.56299 <.0001	0.94615 <.0001	-0.15233 0.1615	-0.10940 0.3160	-0.24519 0.0229	-0.20840 0.0542	-0.56361 <.0001	-0.82038 <.0001	-0.29938 0.0051	-0.15555 0.1527	-0.56229 <.0001
E_RICH	0.20074 0.0638	-0.05839 0.5933	0.41578 <.0001	0.05225 0.6328	0.20659 0.0563	0.42221 <.0001	0.00522 0.9620	-0.08544 0.4341	0.09415 0.3886	0.06905 0.5276	0.00037 0.9973
T_RICH	0.32650 0.0022	-0.43429 <.0001	0.12976 0.2337	0.07181 0.5111	0.22639 0.0361	0.20286 0.0610	0.23153 0.0320	0.29347 0.0061	0.09214 0.3988	0.12219 0.2624	0.23282 0.0310
DIP_RICH	0.35781 0.0007	-0.22235 0.0396	0.13546 0.2136	0.38322 0.0003	0.15629 0.1507	0.36603 0.0005	-0.05202 0.6343	0.11159 0.3063	0.22347 0.0386	0.40888 <.0001	-0.04591 0.6746
PER_EPT	0.27955 0.0091	-0.10512 0.3354	0.05099 0.6410	-0.02701 0.8050	0.16100 0.1386	0.03449 0.7525	-0.04977 0.6491	0.02358 0.8294	0.22818 0.0346	-0.02120 0.8464	-0.04980 0.6489
CF	0.19415 0.0733	-0.90414 <.0001	-0.04626 0.6724	-0.04749 0.6641	-0.19319 0.0747	-0.06937 0.5257	0.74916 <.0001	0.99970 <.0001	-0.12080 0.2679	-0.05823 0.5944	0.74773 <.0001
No_Samples	-0.00983 0.9285	-0.03125 0.7751	0.02737 0.8025	-0.01717 0.8753	-0.10376 0.3417	0.01110 0.9192	0.03673 0.7370	0.06627 0.5444	0.04589 0.6748	-0.00594 0.9567	0.03661 0.7379
FFG_DIV	1.00000	-0.43910 <.0001	0.34709 0.0011	0.35803 0.0007	0.41146 <.0001	0.50225 <.0001	-0.19466 0.0725	0.18468 0.0887	0.52055 <.0001	0.37789 0.0003	-0.19476 0.0723
CG	-0.43910 <.0001	1.00000	-0.09331 0.3928	-0.02696 0.8053	-0.21565 0.0461	-0.13654 0.2100	-0.65513 <.0001	-0.90055 <.0001	0.00972 0.9293	-0.08595 0.4313	-0.65386 <.0001
SCR	0.34709 0.0011	-0.09331 0.3928	1.00000	-0.03211 0.7691	0.04655 0.6704	0.82370 <.0001	-0.04913 0.6533	-0.05878 0.5909	0.18998 0.0798	-0.03118 0.7757	-0.05382 0.6226
SHD	0.35803 0.0007	-0.02696 0.8053	-0.03211 0.7691	1.00000	0.08977 0.4111	0.50383 <.0001	-0.09431 0.3877	-0.04549 0.6775	0.38327 0.0003	0.97307 <.0001	-0.09278 0.3955

Combined Collection Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 86
Prob > |r| under H0: Rho=0

	TNI	RICH	EPT_RICH	DIV	PER_OLIG	E_RICH	T_RICH	DIP_RICH	PER_EPT	CF	No_Samples
PRED	-0.24418 0.0235	0.17736 0.1023	0.20484 0.0585	0.35169 0.0009	-0.24519 0.0229	0.20659 0.0563	0.22639 0.0361	0.15629 0.1507	0.16100 0.1386	-0.19319 0.0747	-0.10376 0.3417
P_R	-0.17193 0.1134	0.34597 0.0011	0.24363 0.0238	0.44388 <.0001	-0.20840 0.0542	0.42221 <.0001	0.20286 0.0610	0.36603 0.0005	0.03449 0.7525	-0.06937 0.5257	0.01110 0.9192
HAB_STAB	0.28190 0.0085	-0.08857 0.4174	0.22019 0.0416	-0.24182 0.0249	-0.56361 <.0001	0.00522 0.9620	0.23153 0.0320	-0.05202 0.6343	-0.04977 0.6491	0.74916 <.0001	0.03673 0.7370
PER_DRES	0.09128 0.4033	0.07429 0.4967	0.23458 0.0297	0.03073 0.7788	-0.82038 <.0001	-0.08544 0.4341	0.29347 0.0061	0.11159 0.3063	0.02358 0.8294	0.99970 <.0001	0.06627 0.5444
PER_DIP	-0.34877 0.0010	0.30893 0.0038	0.13885 0.2023	0.76653 <.0001	-0.29938 0.0051	0.09415 0.3886	0.09214 0.3988	0.22347 0.0386	0.22818 0.0346	-0.12080 0.2679	0.04589 0.6748
C_FPOM	-0.08221 0.4517	0.32467 0.0023	0.08608 0.4307	0.31909 0.0027	-0.15555 0.1527	0.06905 0.5276	0.12219 0.2624	0.40888 <.0001	-0.02120 0.8464	-0.05823 0.5944	-0.00594 0.9567
T_BFPOM	0.27832 0.0095	-0.08440 0.4397	0.21910 0.0427	-0.24112 0.0253	-0.56229 <.0001	0.00037 0.9973	0.23282 0.0310	-0.04591 0.6746	-0.04980 0.6489	0.74773 <.0001	0.03661 0.7379

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Collection Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 86 Prob > |r| under H0: Rho=0	FFG_DIV	CG	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
PRED	0.41146 <.0001	-0.21565 0.0461	0.04655 0.6704	0.08977 0.4111	1.00000	0.20523 0.0580	-0.17046 0.1166	-0.19716 0.0688	0.14069 0.1963	0.26419 0.0140	-0.17024 0.1171
P_R	0.50225 <.0001	-0.13654 0.2100	0.82370 <.0001	0.50383 <.0001	0.20523 0.0580	1.00000	-0.09374 0.3906	-0.07909 0.4692	0.31908 0.0028	0.52411 <.0001	-0.09690 0.3748
HAB_STAB	-0.19466 0.0725	-0.65513 <.0001	-0.04913 0.6533	-0.09431 0.3877	-0.17046 0.1166	-0.09374 0.3906	1.00000	0.74984 <.0001	-0.21675 0.0450	-0.09741 0.3722	0.99948 <.0001
PER_DRES	0.18468 0.0887	-0.90055 <.0001	-0.05878 0.5909	-0.04549 0.6775	-0.19716 0.0688	-0.07909 0.4692	0.74984 <.0001	1.00000	-0.12722 0.2431	-0.05627 0.6069	0.74847 <.0001
PER_DIP	0.52055 <.0001	0.00972 0.9293	0.18998 0.0798	0.38327 0.0003	0.14069 0.1963	0.31908 0.0028	-0.21675 0.0450	-0.12722 0.2431	1.00000	0.36704 0.0005	-0.21659 0.0452
C_FPOM	0.37789 0.0003	-0.08595 0.4313	-0.03118 0.7757	0.97307 <.0001	0.26419 0.0140	0.52411 <.0001	-0.09741 0.3722	-0.05627 0.6069	0.36704 0.0005	1.00000	-0.09592 0.3796
T_BFPOM	-0.19476 0.0723	-0.65386 <.0001	-0.05382 0.6226	-0.09278 0.3955	-0.17024 0.1171	-0.09690 0.3748	0.99948 <.0001	0.74847 <.0001	-0.21659 0.0452	-0.09592 0.3796	1.00000

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Collection Methods

The CORR Procedure

Spearman Correlation Coefficients, N = 86
Prob > |r| under H0: Rho=0

	TNI	RICH	EPT_RICH	DIV	PER_OLIG	E_RICH	T_RICH	DIP_RICH	PER_EPT	CF	No_Samples
TNI TNI	1.00000	-0.13658 0.2099	-0.09148 0.4022	-0.55758 <.0001	0.33795 0.0015	-0.02691 0.8057	-0.07441 0.4960	-0.11987 0.2716	-0.28416 0.0080	-0.28076 0.0088	0.25187 0.0193
RICH	-0.13658 0.2099	1.00000	0.59615 <.0001	0.53778 <.0001	-0.34793 0.0010	0.33673 0.0015	0.51175 <.0001	0.85022 <.0001	0.51831 <.0001	0.38289 0.0003	0.11655 0.2852
EPT_RICH	-0.09148 0.4022	0.59615 <.0001	1.00000	0.32470 0.0023	-0.44518 <.0001	0.52837 <.0001	0.92591 <.0001	0.41710 <.0001	0.83675 <.0001	0.48323 <.0001	-0.05252 0.6311
DIV	-0.55758 <.0001	0.53778 <.0001	0.32470 0.0023	1.00000	-0.68319 <.0001	0.17355 0.1100	0.28676 0.0074	0.37109 0.0004	0.49929 <.0001	0.43891 <.0001	0.01362 0.9009
PER_OLIG	0.33795 0.0015	-0.34793 0.0010	-0.44518 <.0001	-0.68319 <.0001	1.00000	-0.14575 0.1806	-0.43565 <.0001	-0.27144 0.0115	-0.56703 <.0001	-0.71921 <.0001	-0.02656 0.8082
E_RICH	-0.02691 0.8057	0.33673 0.0015	0.52837 <.0001	0.17355 0.1100	-0.14575 0.1806	1.00000	0.28669 0.0074	0.24284 0.0243	0.31737 0.0029	0.02058 0.8508	-0.17439 0.1083
T_RICH	-0.07441 0.4960	0.51175 <.0001	0.92591 <.0001	0.28676 0.0074	-0.43565 <.0001	0.28669 0.0074	1.00000	0.33741 0.0015	0.83624 <.0001	0.51656 <.0001	-0.03665 0.7376
DIP_RICH	-0.11987 0.2716	0.85022 <.0001	0.41710 <.0001	0.37109 0.0004	-0.27144 0.0115	0.24284 0.0243	0.33741 0.0015	1.00000	0.36408 0.0006	0.21668 0.0451	0.13478 0.2160
PER_EPT	-0.28416 0.0080	0.51831 <.0001	0.83675 <.0001	0.49929 <.0001	-0.56703 <.0001	0.31737 0.0029	0.83624 <.0001	0.36408 0.0006	1.00000	0.53755 <.0001	-0.03873 0.7233
CF	-0.28076 0.0088	0.38289 0.0003	0.48323 <.0001	0.43891 <.0001	-0.71921 <.0001	0.02058 0.8508	0.51656 <.0001	0.21668 0.0451	0.53755 <.0001	1.00000	0.09652 0.3767
No_Samples	0.25187 0.0193	0.11655 0.2852	-0.05252 0.6311	0.01362 0.9009	-0.02656 0.8082	-0.17439 0.1083	-0.03665 0.7376	0.13478 0.2160	-0.03873 0.7233	0.09652 0.3767	1.00000
FFG_DIV	-0.50232 <.0001	0.48068 <.0001	0.29666 0.0055	0.91628 <.0001	-0.70140 <.0001	0.14025 0.1978	0.30003 0.0050	0.33069 0.0019	0.47262 <.0001	0.44591 <.0001	-0.06074 0.5785
CG	0.28942 0.0069	-0.35323 0.0008	-0.45904 <.0001	-0.61608 <.0001	0.92364 <.0001	-0.13431 0.2176	-0.48826 <.0001	-0.25505 0.0178	-0.56566 <.0001	-0.72483 <.0001	0.03895 0.7218
SCR	-0.31562 0.0031	0.45191 <.0001	0.25762 0.0166	0.59562 <.0001	-0.42154 <.0001	0.17221 0.1128	0.18636 0.0858	0.24986 0.0203	0.26783 0.0127	0.34446 0.0012	0.01944 0.8590
SHD	-0.30739 0.0040	0.57252 <.0001	0.18352 0.0908	0.58118 <.0001	-0.35094 0.0009	0.14383 0.1864	0.12606 0.2475	0.69386 <.0001	0.21263 0.0494	0.12687 0.2444	-0.03608 0.7415

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Collection Methods

The CORR Procedure

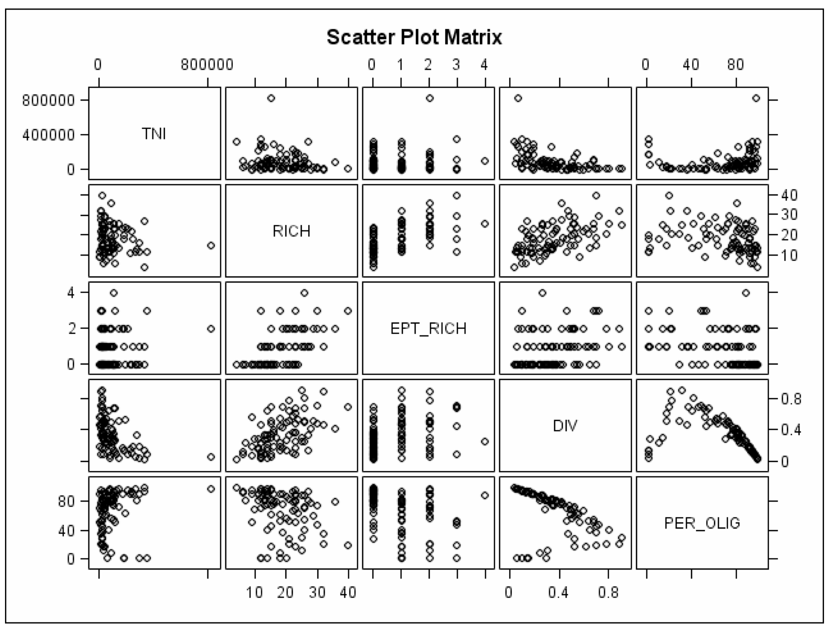
Spearman Correlation Coefficients, N = 86 Prob > |r| under H0: Rho=0											
	FFG_DIV	**CG**	**SCR**	**SHD**	**PRED**	**P_R**	**HAB_STAB**	**PER_DRES**	**PER_DIP**	**C_FPOM**	**T_BFPOM**
TNI TNI	-0.50232 <.0001	0.28942 0.0069	-0.31562 0.0031	-0.30739 0.0040	-0.33180 0.0018	-0.41575 <.0001	-0.33306 0.0017	-0.10184 0.3508	-0.51430 <.0001	-0.31934 0.0027	-0.29201 0.0064
RICH	0.48068 <.0001	-0.35323 0.0008	0.45191 <.0001	0.57252 <.0001	0.27362 0.0108	0.57982 <.0001	0.41008 <.0001	0.34723 0.0011	0.33110 0.0018	0.58179 <.0001	0.39306 0.0002
EPT_RICH	0.29666 0.0055	-0.45904 <.0001	0.25762 0.0166	0.18352 0.0908	0.13803 0.2050	0.25736 0.0167	0.46236 <.0001	0.37320 0.0004	0.16353 0.1325	0.20343 0.0603	0.49766 <.0001
DIV	0.91628 <.0001	-0.61608 <.0001	0.59562 <.0001	0.58118 <.0001	0.65747 <.0001	0.70409 <.0001	0.51837 <.0001	0.27676 0.0099	0.81392 <.0001	0.59722 <.0001	0.44711 <.0001
PER_OLIG	-0.70140 <.0001	0.92364 <.0001	-0.42154 <.0001	-0.35094 0.0009	-0.33474 0.0016	-0.48438 <.0001	-0.80054 <.0001	-0.61424 <.0001	-0.43167 <.0001	-0.37565 0.0004	-0.73812 <.0001
E_RICH	0.14025 0.1978	-0.13431 0.2176	0.17221 0.1128	0.14383 0.1864	0.16441 0.1304	0.23517 0.0293	0.05870 0.5914	-0.02365 0.8289	0.16218 0.1357	0.15176 0.1630	0.03312 0.7621
T_RICH	0.30003 0.0050	-0.48826 <.0001	0.18636 0.0858	0.12606 0.2475	0.12948 0.2347	0.20200 0.0622	0.48464 <.0001	0.39773 0.0001	0.10095 0.3550	0.14641 0.1786	0.53100 <.0001
DIP_RICH	0.33069 0.0019	-0.25505 0.0178	0.24986 0.0203	0.69386 <.0001	0.11237 0.3030	0.58339 <.0001	0.24591 0.0225	0.27354 0.0108	0.23789 0.0274	0.69644 <.0001	0.23167 0.0318
PER_EPT	0.47262 <.0001	-0.56566 <.0001	0.26783 0.0127	0.21263 0.0494	0.27832 0.0095	0.28275 0.0083	0.51309 <.0001	0.41189 <.0001	0.32807 0.0020	0.23230 0.0314	0.55156 <.0001
CF	0.44591 <.0001	-0.72483 <.0001	0.34446 0.0012	0.12687 0.2444	-0.00439 0.9680	0.23150 0.0320	0.93792 <.0001	0.83424 <.0001	0.13897 0.2019	0.14049 0.1970	0.99732 <.0001
No_Samples	-0.06074 0.5785	0.03895 0.7218	0.01944 0.8590	-0.03608 0.7415	-0.11332 0.2989	-0.10606 0.3311	0.08587 0.4318	0.14025 0.1978	-0.01276 0.9072	-0.04216 0.6999	0.08420 0.4409
FFG_DIV	1.00000	-0.73789 <.0001	0.53325 <.0001	0.58422 <.0001	0.70642 <.0001	0.72732 <.0001	0.54092 <.0001	0.33715 0.0015	0.61593 <.0001	0.60583 <.0001	0.46304 <.0001
CG	-0.73789 <.0001	1.00000	-0.36886 0.0005	-0.31754 0.0029	-0.41035 <.0001	-0.46302 <.0001	-0.79727 <.0001	-0.63227 <.0001	-0.23791 0.0274	-0.34441 0.0012	-0.74570 <.0001
SCR	0.53325 <.0001	-0.36886 0.0005	1.00000	0.32892 0.0020	0.27589 0.0101	0.65172 <.0001	0.52600 <.0001	0.26640 0.0132	0.43613 <.0001	0.33160 0.0018	0.34433 0.0012
SHD	0.58422 <.0001	-0.31754 0.0029	0.32892 0.0020	1.00000	0.28994 0.0068	0.86586 <.0001	0.20232 0.0617	0.22141 0.0405	0.50845 <.0001	0.99607 <.0001	0.14110 0.1950

The CORR Procedure

Spearman Correlation Coefficients, N = 86 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**PER_OLIG**	**E_RICH**	**T_RICH**	**DIP_RICH**	**PER_EPT**	**CF**	**No_Samples**
PRED	-0.33180 0.0018	0.27362 0.0108	0.13803 0.2050	0.65747 <.0001	-0.33474 0.0016	0.16441 0.1304	0.12948 0.2347	0.11237 0.3030	0.27832 0.0095	-0.00439 0.9680	-0.11332 0.2989
P_R	-0.41575 <.0001	0.57982 <.0001	0.25736 0.0167	0.70409 <.0001	-0.48438 <.0001	0.23517 0.0293	0.20200 0.0622	0.58339 <.0001	0.28275 0.0083	0.23150 0.0320	-0.10606 0.3311
HAB_STAB	-0.33306 0.0017	0.41008 <.0001	0.46236 <.0001	0.51837 <.0001	-0.80054 <.0001	0.05870 0.5914	0.48464 <.0001	0.24591 0.0225	0.51309 <.0001	0.93792 <.0001	0.08587 0.4318
PER_DRES	-0.10184 0.3508	0.34723 0.0011	0.37320 0.0004	0.27676 0.0099	-0.61424 <.0001	-0.02365 0.8289	0.39773 0.0001	0.27354 0.0108	0.41189 <.0001	0.83424 <.0001	0.14025 0.1978
PER_DIP	-0.51430 <.0001	0.33110 0.0018	0.16353 0.1325	0.81392 <.0001	-0.43167 <.0001	0.16218 0.1357	0.10095 0.3550	0.23789 0.0274	0.32807 0.0020	0.13897 0.2019	-0.01276 0.9072
C_FPOM	-0.31934 0.0027	0.58179 <.0001	0.20343 0.0603	0.59722 <.0001	-0.37565 0.0004	0.15176 0.1630	0.14641 0.1786	0.69644 <.0001	0.23230 0.0314	0.14049 0.1970	-0.04216 0.6999
T_BFPOM	-0.29201 0.0064	0.39306 0.0002	0.49766 <.0001	0.44711 <.0001	-0.73812 <.0001	0.03312 0.7621	0.53100 <.0001	0.23167 0.0318	0.55156 <.0001	0.99732 <.0001	0.08420 0.4409

The CORR Procedure

Spearman Correlation Coefficients, N = 86 Prob > |r| under H0: Rho=0											
	FFG_DIV	**CG**	**SCR**	**SHD**	**PRED**	**P_R**	**HAB_STAB**	**PER_DRES**	**PER_DIP**	**C_FPOM**	**T_BFPOM**
PRED	0.70642 <.0001	-0.41035 <.0001	0.27589 0.0101	0.28994 0.0068	1.00000	0.42170 <.0001	0.05587 0.6094	-0.13070 0.2303	0.50088 <.0001	0.32695 0.0021	0.02205 0.8403
P_R	0.72732 <.0001	-0.46302 <.0001	0.65172 <.0001	0.86586 <.0001	0.42170 <.0001	1.00000	0.39994 0.0001	0.25660 0.0171	0.54401 <.0001	0.87890 <.0001	0.25254 0.0190
HAB_STAB	0.54092 <.0001	-0.79727 <.0001	0.52600 <.0001	0.20232 0.0617	0.05587 0.6094	0.39994 0.0001	1.00000	0.81458 <.0001	0.18421 0.0895	0.21909 0.0427	0.94188 <.0001
PER_DRES	0.33715 0.0015	-0.63227 <.0001	0.26640 0.0132	0.22141 0.0405	-0.13070 0.2303	0.25660 0.0171	0.81458 <.0001	1.00000	0.00366 0.9733	0.22616 0.0363	0.83284 <.0001
PER_DIP	0.61593 <.0001	-0.23791 0.0274	0.43613 <.0001	0.50845 <.0001	0.50088 <.0001	0.54401 <.0001	0.18421 0.0895	0.00366 0.9733	1.00000	0.50530 <.0001	0.13653 0.2100
C_FPOM	0.60583 <.0001	-0.34441 0.0012	0.33160 0.0018	0.99607 <.0001	0.32695 0.0021	0.87890 <.0001	0.21909 0.0427	0.22616 0.0363	0.50530 <.0001	1.00000	0.15882 0.1441
T_BFPOM	0.46304 <.0001	-0.74570 <.0001	0.34433 0.0012	0.14110 0.1950	0.02205 0.8403	0.25254 0.0190	0.94188 <.0001	0.83284 <.0001	0.13653 0.2100	0.15882 0.1441	1.00000



Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Years and Combined Methods

The CORR Procedure

22 Variables:	TNI RICH EPT_RICH DIV DIP_RICH E_RICH T_RICH PER_EPT PER_OLIG CF No_Samples FFG_DIV CG SCR SHD PRED P_R HAB_STAB PER_DRES PER_DIP C_FPOM T_BFPOM

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Median**	**Minimum**	**Maximum**	**Label**
TNI	23	359771	447802	201784	18279	1929250	TNI
RICH	23	36.17391	11.20735	36.00000	14.00000	58.00000	
EPT_RICH	23	2.21739	1.75697	2.00000	0	7.00000	
DIV	23	1.44757	0.14979	1.45325	1.05568	1.65355	
DIP_RICH	23	18.52174	6.38798	19.00000	7.00000	30.00000	
E_RICH	23	0.69565	0.87567	0	0	3.00000	
T_RICH	23	1.52174	1.34400	1.00000	0	5.00000	
PER_EPT	23	0.32600	0.67360	0.03941	0	2.24466	
PER_OLIG	23	72.37697	26.08031	82.45420	2.93944	95.26159	
CF	23	10.40293	21.93816	0.43759	0.00322	94.16501	
No_Samples	23	14.82609	9.56629	8.00000	8.00000	28.00000	
FFG_DIV	23	0.18475	0.14109	0.12232	0.02411	0.49048	
CG	23	79.59693	26.22504	92.21848	3.25364	99.01195	
SCR	23	0.39724	0.59661	0.11817	0.01015	2.57188	
SHD	23	1.21138	1.77240	0.29142	0.03407	7.36632	
PRED	23	7.46130	10.84170	4.32400	0.50404	52.64873	
P_R	23	0.01959	0.02442	0.01073	0.00124	0.08745	
HAB_STAB	23	1.36872	5.82580	0.00973	0.0001882	28.04883	
PER_DRES	23	10.15801	21.98989	0.19619	0	94.14321	
PER_DIP	23	9.00137	7.30745	7.79914	0.50119	29.99341	
C_FPOM	23	0.01592	0.02611	0.00298	0.0003759	0.09477	
T_BFPOM	23	1.41645	6.01208	0.00472	0.0000329	28.94140	

Combined Years and Combined Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	TNI	RICH	EPT_RICH	DIV	DIP_RICH	E_RICH	T_RICH	PER_EPT	PER_OLIG	CF	No_Samples
TNI TNI	1.00000	0.44002 0.0356	0.32441 0.1310	0.20236 0.3544	0.36055 0.0910	0.14213 0.5177	0.33149 0.1223	-0.28121 0.1936	0.02435 0.9122	0.18702 0.3928	0.63590 0.0011
RICH	0.44002 0.0356	1.00000	0.66512 0.0005	0.86515 <.0001	0.85072 <.0001	0.20017 0.3598	0.73907 <.0001	-0.11179 0.6116	-0.25758 0.2354	0.25028 0.2494	0.68203 0.0003
EPT_RICH	0.32441 0.1310	0.66512 0.0005	1.00000	0.51291 0.0123	0.49973 0.0152	0.66539 0.0005	0.87375 <.0001	0.03479 0.8748	-0.14442 0.5109	0.11895 0.5888	0.43235 0.0394
DIV	0.20236 0.3544	0.86515 <.0001	0.51291 0.0123	1.00000	0.80423 <.0001	0.11209 0.6106	0.59749 0.0026	0.04391 0.8423	-0.28084 0.1943	0.23453 0.2814	0.35166 0.0999
DIP_RICH	0.36055 0.0910	0.85072 <.0001	0.49973 0.0152	0.80423 <.0001	1.00000	0.12719 0.5631	0.57041 0.0045	-0.10633 0.6292	-0.41376 0.0497	0.43178 0.0397	0.38908 0.0665
E_RICH	0.14213 0.5177	0.20017 0.3598	0.66539 0.0005	0.11209 0.6106	0.12719 0.5631	1.00000	0.21830 0.3170	0.12706 0.5635	0.11585 0.5986	-0.01675 0.9395	0.13990 0.5243
T_RICH	0.33149 0.1223	0.73907 <.0001	0.87375 <.0001	0.59749 0.0026	0.57041 0.0045	0.21830 0.3170	1.00000	-0.03731 0.8658	-0.26428 0.2230	0.16642 0.4479	0.47405 0.0223
PER_EPT	-0.28121 0.1936	-0.11179 0.6116	0.03479 0.8748	0.04391 0.8423	-0.10633 0.6292	0.12706 0.5635	-0.03731 0.8658	1.00000	-0.30532 0.1566	0.18202 0.4058	-0.25384 0.2425
PER_OLIG	0.02435 0.9122	-0.25758 0.2354	-0.14442 0.5109	-0.28084 0.1943	-0.41376 0.0497	0.11585 0.5986	-0.26428 0.2230	-0.30532 0.1566	1.00000	-0.85545 <.0001	-0.05968 0.7868
CF	0.18702 0.3928	0.25028 0.2494	0.11895 0.5888	0.23453 0.2814	0.43178 0.0397	-0.01675 0.9395	0.16642 0.4479	0.18202 0.4058	-0.85545 <.0001	1.00000	0.16240 0.4591
No_Samples	0.63590 0.0011	0.68203 0.0003	0.43235 0.0394	0.35166 0.0999	0.38908 0.0665	0.13990 0.5243	0.47405 0.0223	-0.25384 0.2425	-0.05968 0.7868	0.16240 0.4591	1.00000
FFG_DIV	-0.25384 0.2425	0.31714 0.1403	0.17599 0.4218	0.46169 0.0266	0.34699 0.1048	-0.15972 0.4666	0.33413 0.1192	0.49849 0.0155	-0.64892 0.0008	0.31755 0.1398	-0.02042 0.9263
CG	-0.04718 0.8307	-0.34448 0.1075	-0.21788 0.3179	-0.38287 0.0714	-0.51120 0.0127	0.06640 0.7634	-0.32810 0.1264	-0.27749 0.1999	0.96756 <.0001	-0.89444 <.0001	-0.08322 0.7058
SCR	-0.20902 0.3385	0.00045 0.9984	-0.08873 0.6872	0.01108 0.9600	-0.12955 0.5558	-0.10341 0.6387	-0.04862 0.8256	-0.15519 0.4795	-0.13731 0.5321	-0.05258 0.8117	-0.00631 0.9772
SHD	-0.04144 0.8511	0.22880 0.2937	0.17771 0.4172	0.39011 0.0657	0.35349 0.0980	0.11032 0.6163	0.16043 0.4646	0.56219 0.0052	-0.25825 0.2341	0.03409 0.8773	-0.15286 0.4862

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Years and Combined Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	FFG_DIV	CG	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	-0.25384 0.2425	-0.04718 0.8307	-0.20902 0.3385	-0.04144 0.8511	-0.20160 0.3563	-0.16191 0.4605	0.35663 0.0948	0.19086 0.3830	-0.35283 0.0987	-0.10822 0.6231	0.35572 0.0958
RICH	0.31714 0.1403	-0.34448 0.1075	0.00045 0.9984	0.22880 0.2937	0.25080 0.2484	0.27727 0.2002	0.20041 0.3592	0.24814 0.2536	-0.20731 0.3426	0.27146 0.2102	0.20154 0.3564
EPT_RICH	0.17599 0.4218	-0.21788 0.3179	-0.08873 0.6872	0.17771 0.4172	0.25608 0.2382	0.20192 0.3555	0.10442 0.6354	0.11571 0.5991	-0.18890 0.3880	0.22694 0.2977	0.10579 0.6310
DIV	0.46169 0.0266	-0.38287 0.0714	0.01108 0.9600	0.39011 0.0657	0.34262 0.1095	0.43366 0.0387	0.11163 0.6121	0.23183 0.2871	-0.20882 0.3390	0.42299 0.0443	0.11324 0.6069
DIP_RICH	0.34699 0.1048	-0.51120 0.0127	-0.12955 0.5558	0.35349 0.0980	0.29515 0.1715	0.38213 0.0719	0.31072 0.1490	0.43345 0.0388	-0.24752 0.2548	0.40977 0.0522	0.31320 0.1456
E_RICH	-0.15972 0.4666	0.06640 0.7634	-0.10341 0.6387	0.11032 0.6163	-0.11873 0.5895	0.01553 0.9439	0.06851 0.7561	-0.01444 0.9479	-0.10062 0.6478	0.05390 0.8070	0.06782 0.7585
T_RICH	0.33413 0.1192	-0.32810 0.1264	-0.04862 0.8256	0.16043 0.4646	0.41213 0.0507	0.25384 0.2425	0.09187 0.6768	0.16067 0.4640	-0.18139 0.4075	0.26155 0.2280	0.09411 0.6693
PER_EPT	0.49849 0.0155	-0.27749 0.1999	-0.15519 0.4795	0.56219 0.0052	0.24300 0.2639	0.42439 0.0436	-0.05659 0.7976	0.17383 0.4276	0.33544 0.1176	0.47185 0.0230	-0.05557 0.8012
PER_OLIG	-0.64892 0.0008	0.96756 <.0001	-0.13731 0.5321	-0.25825 0.2341	-0.52015 0.0110	-0.42539 0.0430	-0.62085 0.0016	-0.85173 <.0001	-0.18839 0.3893	-0.38087 0.0730	-0.62404 0.0015
CF	0.31755 0.1398	-0.89444 <.0001	-0.05258 0.8117	0.03409 0.8773	0.10605 0.6301	0.06531 0.7672	0.86077 <.0001	0.99981 <.0001	-0.16136 0.4620	0.07257 0.7421	0.86221 <.0001
No_Samples	-0.02042 0.9263	-0.08322 0.7058	-0.00631 0.9772	-0.15286 0.4862	-0.11372 0.6054	-0.18446 0.3995	0.24527 0.2593	0.16197 0.4603	-0.13799 0.5301	-0.18678 0.3935	0.24399 0.2619
FFG_DIV	1.00000	-0.61045 0.0020	0.24970 0.2505	0.52977 0.0093	0.67863 0.0004	0.68753 0.0003	-0.11040 0.6160	0.31215 0.1470	0.32759 0.1270	0.60632 0.0022	-0.10730 0.6261
CG	-0.61045 0.0020	1.00000	0.02088 0.9247	-0.26605 0.2198	-0.53024 0.0093	-0.40030 0.0584	-0.67507 0.0004	-0.89221 <.0001	0.04427 0.8410	-0.39894 0.0593	-0.67861 0.0004
SCR	0.24970 0.2505	0.02088 0.9247	1.00000	-0.11029 0.6164	-0.08131 0.7123	0.15861 0.4698	-0.11687 0.5954	-0.05527 0.8022	0.54531 0.0071	-0.12256 0.5775	-0.11908 0.5884
SHD	0.52977 0.0093	-0.26605 0.2198	-0.11029 0.6164	1.00000	0.45262 0.0301	0.90695 <.0001	-0.11637 0.5970	0.03480 0.8748	0.31590 0.1420	0.94389 <.0001	-0.11401 0.6045

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Years and Combined Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	TNI	RICH	EPT_RICH	DIV	DIP_RICH	E_RICH	T_RICH	PER_EPT	PER_OLIG	CF	No_Samples
PRED	-0.20160 0.3563	0.25080 0.2484	0.25608 0.2382	0.34262 0.1095	0.29515 0.1715	-0.11873 0.5895	0.41213 0.0507	0.24300 0.2639	-0.52015 0.0110	0.10605 0.6301	-0.11372 0.6054
P_R	-0.16191 0.4605	0.27727 0.2002	0.20192 0.3555	0.43366 0.0387	0.38213 0.0719	0.01553 0.9439	0.25384 0.2425	0.42439 0.0436	-0.42539 0.0430	0.06531 0.7672	-0.18446 0.3995
HAB_STAB	0.35663 0.0948	0.20041 0.3592	0.10442 0.6354	0.11163 0.6121	0.31072 0.1490	0.06851 0.7561	0.09187 0.6768	-0.05659 0.7976	-0.62085 0.0016	0.86077 <.0001	0.24527 0.2593
PER_DRES	0.19086 0.3830	0.24814 0.2536	0.11571 0.5991	0.23183 0.2871	0.43345 0.0388	-0.01444 0.9479	0.16067 0.4640	0.17383 0.4276	-0.85173 <.0001	0.99981 <.0001	0.16197 0.4603
PER_DIP	-0.35283 0.0987	-0.20731 0.3426	-0.18890 0.3880	-0.20882 0.3390	-0.24752 0.2548	-0.10062 0.6478	-0.18139 0.4075	0.33544 0.1176	-0.18839 0.3893	-0.16136 0.4620	-0.13799 0.5301
C_FPOM	-0.10822 0.6231	0.27146 0.2102	0.22694 0.2977	0.42299 0.0443	0.40977 0.0522	0.05390 0.8070	0.26155 0.2280	0.47185 0.0230	-0.38087 0.0730	0.07257 0.7421	-0.18678 0.3935
T_BFPOM	0.35572 0.0958	0.20154 0.3564	0.10579 0.6310	0.11324 0.6069	0.31320 0.1456	0.06782 0.7585	0.09411 0.6693	-0.05557 0.8012	-0.62404 0.0015	0.86221 <.0001	0.24399 0.2619

Combined Years and Combined Methods

The CORR Procedure

Pearson Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	FFG_DIV	CG	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
PRED	0.67863 0.0004	-0.53024 0.0093	-0.08131 0.7123	0.45262 0.0301	1.00000	0.67742 0.0004	-0.10256 0.6414	0.10194 0.6435	0.12425 0.5722	0.69795 0.0002	-0.09691 0.6600
P_R	0.68753 0.0003	-0.40030 0.0584	0.15861 0.4698	0.90695 <.0001	0.67742 0.0004	1.00000	-0.12976 0.5551	0.06487 0.7687	0.40930 0.0524	0.96000 <.0001	-0.12638 0.5656
HAB_STAB	-0.11040 0.6160	-0.67507 0.0004	-0.11687 0.5954	-0.11637 0.5970	-0.10256 0.6414	-0.12976 0.5551	1.00000	0.86102 <.0001	-0.24989 0.2502	-0.09645 0.6615	0.99998 <.0001
PER_DRES	0.31215 0.1470	-0.89221 <.0001	-0.05527 0.8022	0.03480 0.8748	0.10194 0.6435	0.06487 0.7687	0.86102 <.0001	1.00000	-0.16762 0.4446	0.07297 0.7407	0.86247 <.0001
PER_DIP	0.32759 0.1270	0.04427 0.8410	0.54531 0.0071	0.31590 0.1420	0.12425 0.5722	0.40930 0.0524	-0.24989 0.2502	-0.16762 0.4446	1.00000	0.26638 0.2192	-0.25060 0.2488
C_FPOM	0.60632 0.0022	-0.39894 0.0593	-0.12256 0.5775	0.94389 <.0001	0.69795 0.0002	0.96000 <.0001	-0.09645 0.6615	0.07297 0.7407	0.26638 0.2192	1.00000	-0.09248 0.6747
T_BFPOM	-0.10730 0.6261	-0.67861 0.0004	-0.11908 0.5884	-0.11401 0.6045	-0.09691 0.6600	-0.12638 0.5656	0.99998 <.0001	0.86247 <.0001	-0.25060 0.2488	-0.09248 0.6747	1.00000

Correlation Analysis Using Benthic Metrics, 2001-2007
Combined Years and Combined Methods

The CORR Procedure

Spearman Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	TNI	RICH	EPT_RICH	DIV	DIP_RICH	E_RICH	T_RICH	PER_EPT	PER_OLIG	CF	No_Samples
TNI TNI	1.00000	0.47428 0.0222	0.29034 0.1790	0.23715 0.2759	0.29980 0.1646	0.26263 0.2260	0.21177 0.3320	-0.14441 0.5109	0.26087 0.2293	-0.20751 0.3421	0.67150 0.0005
RICH	0.47428 0.0222	1.00000	0.65607 0.0007	0.88230 <.0001	0.85814 <.0001	0.14665 0.5043	0.69460 0.0002	0.32624 0.1287	-0.29970 0.1647	0.45401 0.0295	0.69365 0.0002
EPT_RICH	0.29034 0.1790	0.65607 0.0007	1.00000	0.54203 0.0075	0.59770 0.0026	0.57910 0.0038	0.83290 <.0001	0.45858 0.0277	-0.23949 0.2711	0.29288 0.1750	0.31830 0.1388
DIV	0.23715 0.2759	0.88230 <.0001	0.54203 0.0075	1.00000	0.82012 <.0001	0.01791 0.9354	0.60756 0.0021	0.34026 0.1121	-0.34684 0.1049	0.59585 0.0027	0.38691 0.0682
DIP_RICH	0.29980 0.1646	0.85814 <.0001	0.59770 0.0026	0.82012 <.0001	1.00000	0.16327 0.4566	0.56761 0.0047	0.28075 0.1944	-0.31962 0.1371	0.49059 0.0175	0.39101 0.0651
E_RICH	0.26263 0.2260	0.14665 0.5043	0.57910 0.0038	0.01791 0.9354	0.16327 0.4566	1.00000	0.10077 0.6473	0.00217 0.9922	0.16279 0.4580	-0.17744 0.4180	0.02389 0.9138
T_RICH	0.21177 0.3320	0.69460 0.0002	0.83290 <.0001	0.60756 0.0021	0.56761 0.0047	0.10077 0.6473	1.00000	0.53356 0.0087	-0.31046 0.1494	0.44308 0.0342	0.44565 0.0331
PER_EPT	-0.14441 0.5109	0.32624 0.1287	0.45858 0.0277	0.34026 0.1121	0.28075 0.1944	0.00217 0.9922	0.53356 0.0087	1.00000	-0.52226 0.0106	0.63798 0.0011	0.13125 0.5505
PER_OLIG	0.26087 0.2293	-0.29970 0.1647	-0.23949 0.2711	-0.34684 0.1049	-0.31962 0.1371	0.16279 0.4580	-0.31046 0.1494	-0.52226 0.0106	1.00000	-0.79348 <.0001	-0.10349 0.6384
CF	-0.20751 0.3421	0.45401 0.0295	0.29288 0.1750	0.59585 0.0027	0.49059 0.0175	-0.17744 0.4180	0.44308 0.0342	0.63798 0.0011	-0.79348 <.0001	1.00000	0.05292 0.8105
No_Samples	0.67150 0.0005	0.69365 0.0002	0.31830 0.1388	0.38691 0.0682	0.39101 0.0651	0.02389 0.9138	0.44565 0.0331	0.13125 0.5505	-0.10349 0.6384	0.05292 0.8105	1.00000
FFG_DIV	-0.24111 0.2677	0.39219 0.0642	0.30203 0.1613	0.48518 0.0189	0.32012 0.1365	-0.15899 0.4687	0.41224 0.0506	0.59941 0.0025	-0.75889 <.0001	0.68676 0.0003	0.17875 0.4145
CG	0.11166 0.6120	-0.44214 0.0346	-0.35898 0.0925	-0.49802 0.0156	-0.42072 0.0456	0.11829 0.5909	-0.46364 0.0259	-0.63502 0.0011	0.86957 <.0001	-0.83992 <.0001	-0.21697 0.3200
SCR	-0.27569 0.2029	0.27695 0.2008	-0.02339 0.9156	0.35672 0.0948	0.12686 0.5641	-0.30007 0.1642	0.19584 0.3705	-0.00099 0.9964	-0.42095 0.0455	0.41304 0.0501	0.13348 0.5437
SHD	-0.34091 0.1114	0.19634 0.3692	0.12559 0.5680	0.46739 0.0245	0.34192 0.1103	-0.24527 0.2593	0.18350 0.4020	0.40455 0.0555	-0.43379 0.0386	0.39328 0.0634	-0.17287 0.4302

The CORR Procedure

Spearman Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

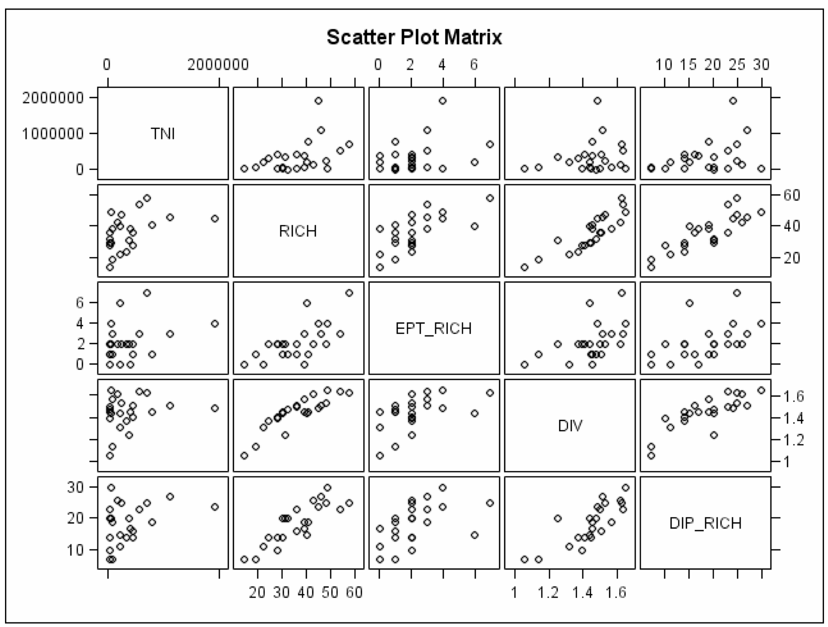
	FFG_DIV	CG	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	-0.24111 0.2677	0.11166 0.6120	-0.27569 0.2029	-0.34091 0.1114	-0.09190 0.6767	-0.42787 0.0417	-0.27372 0.2063	-0.10965 0.6185	-0.46542 0.0252	-0.33597 0.1170	-0.21640 0.3213
RICH	0.39219 0.0642	-0.44214 0.0346	0.27695 0.2008	0.19634 0.3692	0.16370 0.4555	0.22206 0.3085	0.38032 0.0734	0.43628 0.0374	-0.00346 0.9875	0.19090 0.3829	0.43818 0.0365
EPT_RICH	0.30203 0.1613	-0.35898 0.0925	-0.02339 0.9156	0.12559 0.5680	0.24915 0.2516	0.14695 0.5034	0.22474 0.3025	0.17003 0.4380	-0.09203 0.6762	0.12000 0.5855	0.29186 0.1766
DIV	0.48518 0.0189	-0.49802 0.0156	0.35672 0.0948	0.46739 0.0245	0.16897 0.4409	0.48518 0.0189	0.52372 0.0103	0.60207 0.0024	0.06423 0.7709	0.45751 0.0282	0.58696 0.0032
DIP_RICH	0.32012 0.1365	-0.42072 0.0456	0.12686 0.5641	0.34192 0.1103	-0.05352 0.8084	0.28890 0.1812	0.44004 0.0356	0.52788 0.0096	-0.08573 0.6973	0.33152 0.1223	0.46779 0.0244
E_RICH	-0.15899 0.4687	0.11829 0.5909	-0.30007 0.1642	-0.24527 0.2593	-0.04992 0.8210	-0.17147 0.4340	-0.23387 0.2828	-0.28409 0.1889	-0.10907 0.6203	-0.24527 0.2593	-0.16170 0.4610
T_RICH	0.41224 0.0506	-0.46364 0.0259	0.19584 0.3705	0.18350 0.4020	0.27397 0.2059	0.20561 0.3466	0.40556 0.0549	0.33081 0.1231	-0.10846 0.6223	0.17682 0.4196	0.42920 0.0410
PER_EPT	0.59941 0.0025	-0.63502 0.0011	-0.00099 0.9964	0.40455 0.0555	0.47972 0.0205	0.36499 0.0868	0.54995 0.0066	0.53232 0.0089	0.25816 0.2343	0.41741 0.0475	0.64491 0.0009
PER_OLIG	-0.75889 <.0001	0.86957 <.0001	-0.42095 0.0455	-0.43379 0.0386	-0.41304 0.0501	-0.54150 0.0076	-0.81621 <.0001	-0.75607 <.0001	-0.51976 0.0110	-0.43281 0.0391	-0.80138 <.0001
CF	0.68676 0.0003	-0.83992 <.0001	0.41304 0.0501	0.39328 0.0634	0.23814 0.2739	0.43775 0.0367	0.95850 <.0001	0.91656 <.0001	0.25494 0.2404	0.39427 0.0627	0.99802 <.0001
No_Samples	0.17875 0.4145	-0.21697 0.3200	0.13348 0.5437	-0.17287 0.4302	0.15523 0.4794	-0.12642 0.5654	0.03175 0.8856	0.05813 0.7922	-0.03822 0.8625	-0.16758 0.4447	0.03822 0.8625
FFG_DIV	1.00000	-0.86561 <.0001	0.34387 0.1081	0.59387 0.0028	0.72431 <.0001	0.66897 0.0005	0.63538 0.0011	0.71670 0.0001	0.48221 0.0198	0.60968 0.0020	0.69960 0.0002
CG	-0.86561 <.0001	1.00000	-0.25198 0.2461	-0.39921 0.0591	-0.48320 0.0195	-0.43775 0.0367	-0.79051 <.0001	-0.83930 <.0001	-0.21344 0.3281	-0.40119 0.0578	-0.85178 <.0001
SCR	0.34387 0.1081	-0.25198 0.2461	1.00000	0.12253 0.5775	0.02569 0.9074	0.43676 0.0372	0.53360 0.0087	0.35835 0.0931	0.48617 0.0187	0.10771 0.6247	0.41107 0.0513
SHD	0.59387 0.0028	-0.39921 0.0591	0.12253 0.5775	1.00000	0.34387 0.1081	0.88538 <.0001	0.35079 0.1008	0.50687 0.0136	0.47826 0.0210	0.99802 <.0001	0.39723 0.0605

The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**E_RICH**	**T_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**No_Samples**
PRED	-0.09190 0.6767	0.16370 0.4555	0.24915 0.2516	0.16897 0.4409	-0.05352 0.8084	-0.04992 0.8210	0.27397 0.2059	0.47972 0.0205	-0.41304 0.0501	0.23814 0.2739	0.15523 0.4794
P_R	-0.42787 0.0417	0.22206 0.3085	0.14695 0.5034	0.48518 0.0189	0.28890 0.1812	-0.17147 0.4340	0.20561 0.3466	0.36499 0.0868	-0.54150 0.0076	0.43775 0.0367	-0.12642 0.5654
HAB_STAB	-0.27372 0.2063	0.38032 0.0734	0.22474 0.3025	0.52372 0.0103	0.44004 0.0356	-0.23387 0.2828	0.40556 0.0549	0.54995 0.0066	-0.81621 <.0001	0.95850 <.0001	0.03175 0.8856
PER_DRES	-0.10965 0.6185	0.43628 0.0374	0.17003 0.4380	0.60207 0.0024	0.52788 0.0096	-0.28409 0.1889	0.33081 0.1231	0.53232 0.0089	-0.75607 <.0001	0.91656 <.0001	0.05813 0.7922
PER_DIP	-0.46542 0.0252	-0.00346 0.9875	-0.09203 0.6762	0.06423 0.7709	-0.08573 0.6973	-0.10907 0.6203	-0.10846 0.6223	0.25816 0.2343	-0.51976 0.0110	0.25494 0.2404	-0.03822 0.8625
C_FPOM	-0.33597 0.1170	0.19090 0.3829	0.12000 0.5855	0.45751 0.0282	0.33152 0.1223	-0.24527 0.2593	0.17682 0.4196	0.41741 0.0475	-0.43281 0.0391	0.39427 0.0627	-0.16758 0.4447
T_BFPOM	-0.21640 0.3213	0.43818 0.0365	0.29186 0.1766	0.58696 0.0032	0.46779 0.0244	-0.16170 0.4610	0.42920 0.0410	0.64491 0.0009	-0.80138 <.0001	0.99802 <.0001	0.03822 0.8625

The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	FFG_DIV	**CG**	**SCR**	**SHD**	**PRED**	**P_R**	**HAB_STAB**	**PER_DRES**	**PER_DIP**	**C_FPOM**	**T_BFPOM**
PRED	0.72431 <.0001	-0.48320 0.0195	0.02569 0.9074	0.34387 0.1081	1.00000	0.36858 0.0835	0.14723 0.5026	0.23574 0.2789	0.49506 0.0163	0.37253 0.0800	0.25000 0.2499
P_R	0.66897 0.0005	-0.43775 0.0367	0.43676 0.0372	0.88538 <.0001	0.36858 0.0835	1.00000	0.48419 0.0192	0.50189 0.0147	0.62549 0.0014	0.88340 <.0001	0.45257 0.0301
HAB_STAB	0.63538 0.0011	-0.79051 <.0001	0.53360 0.0087	0.35079 0.1008	0.14723 0.5026	0.48419 0.0192	1.00000	0.88117 <.0001	0.27866 0.1979	0.34684 0.1049	0.95850 <.0001
PER_DRES	0.71670 0.0001	-0.83930 <.0001	0.35835 0.0931	0.50687 0.0136	0.23574 0.2789	0.50189 0.0147	0.88117 <.0001	1.00000	0.18391 0.4009	0.50687 0.0136	0.91855 <.0001
PER_DIP	0.48221 0.0198	-0.21344 0.3281	0.48617 0.0187	0.47826 0.0210	0.49506 0.0163	0.62549 0.0014	0.27866 0.1979	0.18391 0.4009	1.00000	0.49012 0.0176	0.25791 0.2348
C_FPOM	0.60968 0.0020	-0.40119 0.0578	0.10771 0.6247	0.99802 <.0001	0.37253 0.0800	0.88340 <.0001	0.34684 0.1049	0.50687 0.0136	0.49012 0.0176	1.00000	0.39822 0.0598
T_BFPOM	0.69960 0.0002	-0.85178 <.0001	0.41107 0.0513	0.39723 0.0605	0.25000 0.2499	0.45257 0.0301	0.95850 <.0001	0.91855 <.0001	0.25791 0.2348	0.39822 0.0598	1.00000



The CORR Procedure

20 Variables:	TNI RICH EPT_RICH DIV DIP_RICH PER_EPT PER_OLIG CF CG No_Samples FFG_DIV SCR SHD PRED P_R HAB_STAB PER_DRES PER_DIP C_FPOM T_BFPOM

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Median**	**Minimum**	**Maximum**	**Label**
TNI	23	221158	318439	118502	7005	1441758	TNI
RICH	23	16.39130	9.35045	14.00000	3.00000	36.00000	
EPT_RICH	23	0.21739	0.51843	0	0	2.00000	
DIV	23	0.15420	0.18577	0.07221	0.01804	0.74585	
DIP_RICH	23	9.26087	5.87148	9.00000	1.00000	24.00000	
PER_EPT	23	0.00895	0.03077	0	0	0.14467	
PER_OLIG	23	91.35721	13.17719	97.42745	55.52653	99.43875	
CF	23	4.25546	10.21064	0.26213	0	38.56345	
CG	23	92.55118	11.93602	98.00863	59.83935	99.74067	
No_Samples	23	7.47826	4.86985	4.00000	4.00000	14.00000	
FFG_DIV	23	0.10042	0.11930	0.04813	0.01291	0.44658	
SCR	23	0.02267	0.04576	0	0	0.18090	
SHD	23	0.85926	2.52421	0.08353	0	12.13994	
PRED	23	2.26839	2.70338	1.09126	0	9.89225	
P_R	23	0.00927	0.02654	0.00135	0	0.12737	
HAB_STAB	23	0.06293	0.16231	0.00263	0	0.64302	
PER_DRES	23	3.89117	10.24459	0.00674	0	38.29663	
PER_DIP	23	3.80215	5.98636	1.21594	0.39347	27.16539	
C_FPOM	23	0.00984	0.03029	0.0008624	0	0.14596	
T_BFPOM	23	0.06506	0.16569	0.00263	0	0.64445	

The CORR Procedure

Pearson Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
TNI TNI	1.00000	0.29694 0.1688	0.01595 0.9424	-0.28005 0.1956	0.22312 0.3061	-0.10459 0.6348	0.29358 0.1739	-0.26301 0.2253	0.29949 0.1650	0.42406 0.0437	-0.30404 0.1584
RICH	0.29694 0.1688	1.00000	0.43174 0.0397	0.55849 0.0056	0.93445 <.0001	0.44196 0.0347	-0.42165 0.0451	0.27271 0.2080	-0.39271 0.0638	0.67749 0.0004	0.46724 0.0246
EPT_RICH	0.01595 0.9424	0.43174 0.0397	1.00000	0.28540 0.1868	0.30904 0.1513	0.87126 <.0001	-0.25428 0.2417	0.34493 0.1070	-0.29826 0.1669	0.58709 0.0032	0.26543 0.2209
DIV	-0.28005 0.1956	0.55849 0.0056	0.28540 0.1868	1.00000	0.70483 0.0002	0.44040 0.0355	-0.94123 <.0001	0.72704 <.0001	-0.89769 <.0001	0.04203 0.8490	0.97567 <.0001
DIP_RICH	0.22312 0.3061	0.93445 <.0001	0.30904 0.1513	0.70483 0.0002	1.00000	0.37122 0.0812	-0.53961 0.0079	0.29584 0.1705	-0.47227 0.0229	0.45963 0.0273	0.59363 0.0028
PER_EPT	-0.10459 0.6348	0.44196 0.0347	0.87126 <.0001	0.44040 0.0355	0.37122 0.0812	1.00000	-0.40975 0.0522	0.50830 0.0133	-0.45880 0.0277	0.40725 0.0538	0.41701 0.0477
PER_OLIG	0.29358 0.1739	-0.42165 0.0451	-0.25428 0.2417	-0.94123 <.0001	-0.53961 0.0079	-0.40975 0.0522	1.00000	-0.89914 <.0001	0.98815 <.0001	0.02702 0.9026	-0.98086 <.0001
CF	-0.26301 0.2253	0.27271 0.2080	0.34493 0.1070	0.72704 <.0001	0.29584 0.1705	0.50830 0.0133	-0.89914 <.0001	1.00000	-0.94194 <.0001	-0.00017 0.9994	0.82509 <.0001
CG	0.29949 0.1650	-0.39271 0.0638	-0.29826 0.1669	-0.89769 <.0001	-0.47227 0.0229	-0.45880 0.0277	0.98815 <.0001	-0.94194 <.0001	1.00000	-0.00520 0.9812	-0.96135 <.0001
No_Samples	0.42406 0.0437	0.67749 0.0004	0.58709 0.0032	0.04203 0.8490	0.45963 0.0273	0.40725 0.0538	0.02702 0.9026	-0.00017 0.9994	-0.00520 0.9812	1.00000	0.01593 0.9425
FFG_DIV	-0.30404 0.1584	0.46724 0.0246	0.26543 0.2209	0.97567 <.0001	0.59363 0.0028	0.41701 0.0477	-0.98086 <.0001	0.82509 <.0001	-0.96135 <.0001	0.01593 0.9425	1.00000
SCR	0.06583 0.7654	0.63019 0.0013	0.89414 <.0001	0.35720 0.0943	0.46510 0.0253	0.79777 <.0001	-0.28667 0.1848	0.32926 0.1250	-0.32138 0.1348	0.61736 0.0017	0.30280 0.1602
SHD	-0.17337 0.4289	0.41034 0.0518	-0.01093 0.9605	0.79381 <.0001	0.65119 0.0008	0.06013 0.7852	-0.66590 0.0005	0.33554 0.1175	-0.55889 0.0056	-0.10064 0.6478	0.71293 0.0001
PRED	-0.15958 0.4670	0.25927 0.2322	-0.07115 0.7470	0.56017 0.0054	0.39718 0.0606	-0.04609 0.8346	-0.42733 0.0420	0.08947 0.6848	-0.38450 0.0701	-0.02008 0.9275	0.54471 0.0072
P_R	-0.17278 0.4305	0.42499 0.0432	0.01015 0.9633	0.80295 <.0001	0.66195 0.0006	0.08082 0.7139	-0.67342 0.0004	0.34437 0.1076	-0.56765 0.0047	-0.08658 0.6944	0.72103 0.0001
HAB_STAB	-0.24665 0.2566	0.23883 0.2724	0.32937 0.1249	0.67496 0.0004	0.24598 0.2579	0.48433 0.0192	-0.86869 <.0001	0.99607 <.0001	-0.91982 <.0001	-0.00237 0.9915	0.78371 <.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	0.06583 0.7654	-0.17337 0.4289	-0.15958 0.4670	-0.17278 0.4305	-0.24665 0.2566	-0.24742 0.2550	-0.23635 0.2776	-0.17012 0.4377	-0.25126 0.2475
RICH	0.63019 0.0013	0.41034 0.0518	0.25927 0.2322	0.42499 0.0432	0.23883 0.2724	0.27531 0.2036	0.36620 0.0857	0.39865 0.0595	0.25402 0.2422
EPT_RICH	0.89414 <.0001	-0.01093 0.9605	-0.07115 0.7470	0.01015 0.9633	0.32937 0.1249	0.34653 0.1053	-0.09073 0.6806	-0.02088 0.9247	0.32709 0.1277
DIV	0.35720 0.0943	0.79381 <.0001	0.56017 0.0054	0.80295 <.0001	0.67496 0.0004	0.72153 0.0001	0.79745 <.0001	0.78450 <.0001	0.70337 0.0002
DIP_RICH	0.46510 0.0253	0.65119 0.0008	0.39718 0.0606	0.66195 0.0006	0.24598 0.2579	0.30205 0.1613	0.61743 0.0017	0.64135 0.0010	0.27327 0.2071
PER_EPT	0.79777 <.0001	0.06013 0.7852	-0.04609 0.8346	0.08082 0.7139	0.48433 0.0192	0.50973 0.0130	-0.00185 0.9933	0.04515 0.8379	0.48397 0.0193
PER_OLIG	-0.28667 0.1848	-0.66590 0.0005	-0.42733 0.0420	-0.67342 0.0004	-0.86869 <.0001	-0.89699 <.0001	-0.63497 0.0011	-0.65897 0.0006	-0.88826 <.0001
CF	0.32926 0.1250	0.33554 0.1175	0.08947 0.6848	0.34437 0.1076	0.99607 <.0001	0.99726 <.0001	0.23895 0.2722	0.32840 0.1260	0.99855 <.0001
CG	-0.32138 0.1348	-0.55889 0.0056	-0.38450 0.0701	-0.56765 0.0047	-0.91982 <.0001	-0.93908 <.0001	-0.53067 0.0092	-0.55146 0.0064	-0.93357 <.0001
No_Samples	0.61736 0.0017	-0.10064 0.6478	-0.02008 0.9275	-0.08658 0.6944	-0.00237 0.9915	-0.00256 0.9908	-0.14517 0.5087	-0.10643 0.6289	-0.00758 0.9726
FFG_DIV	0.30280 0.1602	0.71293 0.0001	0.54471 0.0072	0.72103 0.0001	0.78371 <.0001	0.81723 <.0001	0.71920 0.0001	0.70560 0.0002	0.80683 <.0001
SCR	1.00000	0.02661 0.9041	-0.01777 0.9359	0.04980 0.8215	0.31438 0.1440	0.33178 0.1220	-0.03271 0.8822	0.01086 0.9608	0.31138 0.1481
SHD	0.02661 0.9041	1.00000	0.46708 0.0246	0.99971 <.0001	0.26727 0.2176	0.33971 0.1128	0.89023 <.0001	0.99968 <.0001	0.31219 0.1470
PRED	-0.01777 0.9359	0.46708 0.0246	1.00000	0.46816 0.0243	0.05747 0.7945	0.08683 0.6936	0.78344 <.0001	0.46689 0.0247	0.07819 0.7229
P_R	0.04980 0.8215	0.99971 <.0001	0.46816 0.0243	1.00000	0.27580 0.2027	0.34861 0.1030	0.88943 <.0001	0.99898 <.0001	0.32059 0.1358
HAB_STAB	0.31438 0.1440	0.26727 0.2176	0.05747 0.7945	0.27580 0.2027	1.00000	0.99505 <.0001	0.17719 0.4186	0.26038 0.2302	0.99885 <.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
PER_DRES	-0.24742 0.2550	0.27531 0.2036	0.34653 0.1053	0.72153 0.0001	0.30205 0.1613	0.50973 0.0130	-0.89699 <.0001	0.99726 <.0001	-0.93908 <.0001	-0.00256 0.9908	0.81723 <.0001
PER_DIP	-0.23635 0.2776	0.36620 0.0857	-0.09073 0.6806	0.79745 <.0001	0.61743 0.0017	-0.00185 0.9933	-0.63497 0.0011	0.23895 0.2722	-0.53067 0.0092	-0.14517 0.5087	0.71920 0.0001
C_FPOM	-0.17012 0.4377	0.39865 0.0595	-0.02088 0.9247	0.78450 <.0001	0.64135 0.0010	0.04515 0.8379	-0.65897 0.0006	0.32840 0.1260	-0.55146 0.0064	-0.10643 0.6289	0.70560 0.0002
T_BFPOM	-0.25126 0.2475	0.25402 0.2422	0.32709 0.1277	0.70337 0.0002	0.27327 0.2071	0.48397 0.0193	-0.88826 <.0001	0.99855 <.0001	-0.93357 <.0001	-0.00758 0.9726	0.80683 <.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
PER_DRES	0.33178 0.1220	0.33971 0.1128	0.08683 0.6936	0.34861 0.1030	0.99505 <.0001	1.00000	0.23830 0.2735	0.33259 0.1210	0.99782 <.0001
PER_DIP	-0.03271 0.8822	0.89023 <.0001	0.78344 <.0001	0.88943 <.0001	0.17719 0.4186	0.23830 0.2735	1.00000	0.88874 <.0001	0.21703 0.3199
C_FPOM	0.01086 0.9608	0.99968 <.0001	0.46689 0.0247	0.99898 <.0001	0.26038 0.2302	0.33259 0.1210	0.88874 <.0001	1.00000	0.30549 0.1563
T_BFPOM	0.31138 0.1481	0.31219 0.1470	0.07819 0.7229	0.32059 0.1358	0.99885 <.0001	0.99782 <.0001	0.21703 0.3199	0.30549 0.1563	1.00000

The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
TNI TNI	1.00000	0.37327 0.0794	0.18583 0.3959	-0.28557 0.1865	0.32738 0.1273	0.16746 0.4450	0.31818 0.1390	-0.53116 0.0091	0.35573 0.0957	0.42662 0.0423	-0.37747 0.0758
RICH	0.37327 0.0794	1.00000	0.34686 0.1049	0.48663 0.0185	0.96993 <.0001	0.33634 0.1166	-0.43713 0.0370	0.21011 0.3359	-0.37723 0.0760	0.66878 0.0005	0.39753 0.0603
EPT_RICH	0.18583 0.3959	0.34686 0.1049	1.00000	0.16185 0.4606	0.23697 0.2763	0.99773 <.0001	-0.15885 0.4691	0.16201 0.4602	-0.22779 0.2959	0.62614 0.0014	0.17833 0.4156
DIV	-0.28557 0.1865	0.48663 0.0185	0.16185 0.4606	1.00000	0.53671 0.0083	0.15401 0.4829	-0.99506 <.0001	0.65875 0.0006	-0.97036 <.0001	0.13762 0.5312	0.97530 <.0001
DIP_RICH	0.32738 0.1273	0.96993 <.0001	0.23697 0.2763	0.53671 0.0083	1.00000	0.22667 0.2983	-0.48165 0.0200	0.19365 0.3760	-0.39931 0.0591	0.53195 0.0090	0.43552 0.0378
PER_EPT	0.16746 0.4450	0.33634 0.1166	0.99773 <.0001	0.15401 0.4829	0.22667 0.2983	1.00000	-0.15251 0.4872	0.17810 0.4162	-0.22278 0.3069	0.62472 0.0014	0.17344 0.4287
PER_OLIG	0.31818 0.1390	-0.43713 0.0370	-0.15885 0.4691	-0.99506 <.0001	-0.48165 0.0200	-0.15251 0.4872	1.00000	-0.67359 0.0004	0.97925 <.0001	-0.12386 0.5734	-0.98617 <.0001
CF	-0.53116 0.0091	0.21011 0.3359	0.16201 0.4602	0.65875 0.0006	0.19365 0.3760	0.17810 0.4162	-0.67359 0.0004	1.00000	-0.68348 0.0003	0.08265 0.7077	0.67458 0.0004
CG	0.35573 0.0957	-0.37723 0.0760	-0.22779 0.2959	-0.97036 <.0001	-0.39931 0.0591	-0.22278 0.3069	0.97925 <.0001	-0.68348 0.0003	1.00000	-0.15138 0.4905	-0.97332 <.0001
No_Samples	0.42662 0.0423	0.66878 0.0005	0.62614 0.0014	0.13762 0.5312	0.53195 0.0090	0.62472 0.0014	-0.12386 0.5734	0.08265 0.7077	-0.15138 0.4905	1.00000	0.12386 0.5734
FFG_DIV	-0.37747 0.0758	0.39753 0.0603	0.17833 0.4156	0.97530 <.0001	0.43552 0.0378	0.17344 0.4287	-0.98617 <.0001	0.67458 0.0004	-0.97332 <.0001	0.12386 0.5734	1.00000
SCR	0.39039 0.0655	0.64786 0.0008	0.73654 <.0001	0.35785 0.0936	0.57624 0.0040	0.72784 <.0001	-0.32532 0.1298	0.20004 0.3601	-0.35088 0.1007	0.79289 <.0001	0.31138 0.1481
SHD	-0.32970 0.1245	0.39702 0.0607	-0.00301 0.9891	0.58193 0.0036	0.46411 0.0257	-0.00751 0.9729	-0.56207 0.0052	0.59543 0.0027	-0.48362 0.0194	0.04149 0.8509	0.54618 0.0070
PRED	-0.04941 0.8229	0.48515 0.0190	0.11090 0.6144	0.82708 <.0001	0.53125 0.0091	0.09420 0.6690	-0.82806 <.0001	0.26212 0.2270	-0.80632 <.0001	0.22019 0.3127	0.82708 <.0001
P_R	-0.27142 0.2103	0.43226 0.0394	0.16225 0.4595	0.59931 0.0025	0.48334 0.0195	0.15589 0.4775	-0.58098 0.0036	0.61725 0.0017	-0.51511 0.0119	0.15176 0.4894	0.56464 0.0050
HAB_STAB	-0.49815 0.0156	0.25650 0.2374	0.22784 0.2958	0.69533 0.0002	0.23394 0.2827	0.23780 0.2746	-0.71114 0.0001	0.98936 <.0001	-0.72498 <.0001	0.13765 0.5311	0.71164 0.0001

The CORR Procedure

Spearman Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

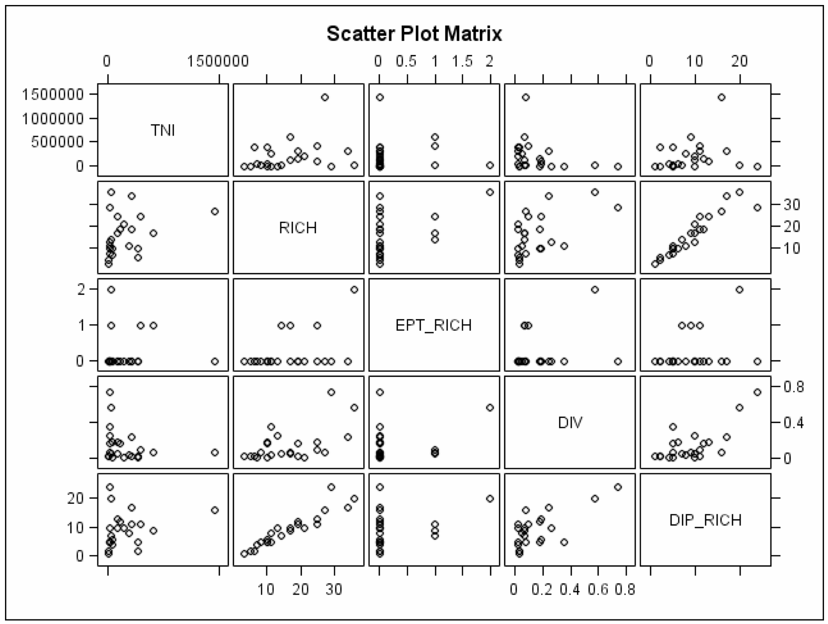
	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	0.39039 0.0655	-0.32970 0.1245	-0.04941 0.8229	-0.27142 0.2103	-0.49815 0.0156	-0.57148 0.0044	-0.13933 0.5261	-0.32970 0.1245	-0.53116 0.0091
RICH	0.64786 0.0008	0.39702 0.0607	0.48515 0.0190	0.43226 0.0394	0.25650 0.2374	0.27477 0.2045	0.44010 0.0356	0.39702 0.0607	0.21011 0.3359
EPT_RICH	0.73654 <.0001	-0.00301 0.9891	0.11090 0.6144	0.16225 0.4595	0.22784 0.2958	-0.10794 0.6240	-0.01798 0.9351	-0.00301 0.9891	0.16201 0.4602
DIV	0.35785 0.0936	0.58193 0.0036	0.82708 <.0001	0.59931 0.0025	0.69533 0.0002	0.67300 0.0004	0.85079 <.0001	0.58193 0.0036	0.65875 0.0006
DIP_RICH	0.57624 0.0040	0.46411 0.0257	0.53125 0.0091	0.48334 0.0195	0.23394 0.2827	0.28845 0.1819	0.55903 0.0056	0.46411 0.0257	0.19365 0.3760
PER_EPT	0.72784 <.0001	-0.00751 0.9729	0.09420 0.6690	0.15589 0.4775	0.23780 0.2746	-0.10769 0.6248	-0.01346 0.9514	-0.00751 0.9729	0.17810 0.4162
PER_OLIG	-0.32532 0.1298	-0.56207 0.0052	-0.82806 <.0001	-0.58098 0.0036	-0.71114 0.0001	-0.66044 0.0006	-0.83696 <.0001	-0.56207 0.0052	-0.67359 0.0004
CF	0.20004 0.3601	0.59543 0.0027	0.26212 0.2270	0.61725 0.0017	0.98936 <.0001	0.83502 <.0001	0.43323 0.0389	0.59543 0.0027	1.00000 <.0001
CG	-0.35088 0.1007	-0.48362 0.0194	-0.80632 <.0001	-0.51511 0.0119	-0.72498 <.0001	-0.63951 0.0010	-0.76680 <.0001	-0.48362 0.0194	-0.68348 0.0003
No_Samples	0.79289 <.0001	0.04149 0.8509	0.22019 0.3127	0.15176 0.4894	0.13765 0.5311	-0.04373 0.8429	0.05505 0.8030	0.04149 0.8509	0.08265 0.7077
FFG_DIV	0.31138 0.1481	0.54618 0.0070	0.82708 <.0001	0.56464 0.0050	0.71164 0.0001	0.66044 0.0006	0.82115 <.0001	0.54618 0.0070	0.67458 0.0004
SCR	1.00000	0.22652 0.2986	0.33345 0.1200	0.36456 0.0872	0.27427 0.2054	0.01969 0.9289	0.27188 0.2095	0.22652 0.2986	0.20004 0.3601
SHD	0.22652 0.2986	1.00000	0.23138 0.2881	0.97561 <.0001	0.62578 0.0014	0.67425 0.0004	0.40517 0.0551	1.00000 <.0001	0.59543 0.0027
PRED	0.33345 0.1200	0.23138 0.2881	1.00000	0.25805 0.2345	0.30887 0.1516	0.30249 0.1607	0.83498 <.0001	0.23138 0.2881	0.26212 0.2270
P_R	0.36456 0.0872	0.97561 <.0001	0.25805 0.2345	1.00000	0.66337 0.0006	0.62746 0.0014	0.40466 0.0555	0.97561 <.0001	0.61725 0.0017
HAB_STAB	0.27427 0.2054	0.62578 0.0014	0.30887 0.1516	0.66337 0.0006	1.00000	0.82079 <.0001	0.43094 0.0401	0.62578 0.0014	0.98936 <.0001

The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
PER_DRES	-0.57148 0.0044	0.27477 0.2045	-0.10794 0.6240	0.67300 0.0004	0.28845 0.1819	-0.10769 0.6248	-0.66044 0.0006	0.83502 <.0001	-0.63951 0.0010	-0.04373 0.8429	0.66044 0.0006
PER_DIP	-0.13933 0.5261	0.44010 0.0356	-0.01798 0.9351	0.85079 <.0001	0.55903 0.0056	-0.01346 0.9514	-0.83696 <.0001	0.43323 0.0389	-0.76680 <.0001	0.05505 0.8030	0.82115 <.0001
C_FPOM	-0.32970 0.1245	0.39702 0.0607	-0.00301 0.9891	0.58193 0.0036	0.46411 0.0257	-0.00751 0.9729	-0.56207 0.0052	0.59543 0.0027	-0.48362 0.0194	0.04149 0.8509	0.54618 0.0070
T_BFPOM	-0.53116 0.0091	0.21011 0.3359	0.16201 0.4602	0.65875 0.0006	0.19365 0.3760	0.17810 0.4162	-0.67359 0.0004	1.00000 <.0001	-0.68348 0.0003	0.08265 0.7077	0.67458 0.0004

The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0									
	SCR	**SHD**	**PRED**	**P_R**	**HAB_STAB**	**PER_DRES**	**PER_DIP**	**C_FPOM**	**T_BFPOM**
PER_DRES	0.01969 0.9289	0.67425 0.0004	0.30249 0.1607	0.62746 0.0014	0.82079 <.0001	1.00000	0.45216 0.0303	0.67425 0.0004	0.83502 <.0001
PER_DIP	0.27188 0.2095	0.40517 0.0551	0.83498 <.0001	0.40466 0.0555	0.43094 0.0401	0.45216 0.0303	1.00000	0.40517 0.0551	0.43323 0.0389
C_FPOM	0.22652 0.2986	1.00000 <.0001	0.23138 0.2881	0.97561 <.0001	0.62578 0.0014	0.67425 0.0004	0.40517 0.0551	1.00000	0.59543 0.0027
T_BFPOM	0.20004 0.3601	0.59543 0.0027	0.26212 0.2270	0.61725 0.0017	0.98936 <.0001	0.83502 <.0001	0.43323 0.0389	0.59543 0.0027	1.00000



The CORR Procedure

20 Variables:	TNI RICH EPT_RICH DIV DIP_RICH PER_EPT PER_OLIG CF CG No_Samples FFG_DIV SCR SHD PRED P_R HAB_STAB PER_DRES PER_DIP C_FPOM T_BFPOM

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Median**	**Minimum**	**Maximum**	**Label**
TNI	23	138613	238441	46499	7712	1079540	TNI
RICH	23	30.60870	9.82917	32.00000	13.00000	52.00000	
EPT_RICH	23	2.08696	1.67639	2.00000	0	7.00000	
DIV	23	0.60299	0.22942	0.55813	0.32885	1.02597	
DIP_RICH	23	14.65217	4.96907	15.00000	6.00000	23.00000	
PER_EPT	23	0.82809	1.87207	0.11299	0	8.36485	
PER_OLIG	23	45.06056	27.35953	53.15830	0.71292	81.13127	
CF	23	14.72820	27.10586	0.28652	0	96.52576	
CG	23	63.70813	30.62309	78.57188	0.99343	97.56198	
No_Samples	23	7.34783	4.70598	4.00000	4.00000	14.00000	
FFG_DIV	23	0.26921	0.13939	0.25064	0.04143	0.50075	
SCR	23	1.14128	1.60119	0.25369	0.01516	5.77843	
SHD	23	2.97618	6.30570	0.74744	0.02490	29.08760	
PRED	23	14.71323	14.22294	12.90619	0.44139	67.51323	
P_R	23	0.05387	0.08689	0.03813	0.00106	0.41557	
HAB_STAB	23	4.72977	19.40937	0.02143	0.0007921	93.48969	
PER_DRES	23	14.56463	27.13582	0.14207	0	96.50582	
PER_DIP	23	20.98064	14.80008	16.40628	0.33867	48.71948	
C_FPOM	23	0.05242	0.14495	0.01030	0.0002816	0.69881	
T_BFPOM	23	4.99821	20.18199	0.00357	0	97.16391	

The CORR Procedure

Pearson Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
TNI TNI	1.00000	0.12613 0.5663	-0.01474 0.9468	-0.20503 0.3480	0.10885 0.6210	-0.18651 0.3942	-0.21115 0.3335	0.53952 0.0079	-0.32665 0.1282	0.57828 0.0038	-0.27785 0.1993
RICH	0.12613 0.5663	1.00000	0.68905 0.0003	0.56457 0.0050	0.82722 <.0001	0.00009 0.9997	-0.35466 0.0968	0.15629 0.4764	-0.33234 0.1213	0.63199 0.0012	0.54516 0.0071
EPT_RICH	-0.01474 0.9468	0.68905 0.0003	1.00000	0.31423 0.1442	0.44579 0.0330	0.09792 0.6567	-0.19049 0.3840	-0.03156 0.8863	-0.23170 0.2874	0.35898 0.0925	0.38447 0.0701
DIV	-0.20503 0.3480	0.56457 0.0050	0.31423 0.1442	1.00000	0.44831 0.0319	0.40514 0.0551	-0.54399 0.0073	0.03486 0.8745	-0.25312 0.2439	0.03684 0.8675	0.80829 <.0001
DIP_RICH	0.10885 0.6210	0.82722 <.0001	0.44579 0.0330	0.44831 0.0319	1.00000	-0.07314 0.7402	-0.43028 0.0404	0.34984 0.1018	-0.41509 0.0489	0.34752 0.1042	0.40182 0.0574
PER_EPT	-0.18651 0.3942	0.00009 0.9997	0.09792 0.6567	0.40514 0.0551	-0.07314 0.7402	1.00000	-0.26630 0.2194	-0.01940 0.9300	-0.22909 0.2931	-0.23858 0.2729	0.44122 0.0351
PER_OLIG	-0.21115 0.3335	-0.35466 0.0968	-0.19049 0.3840	-0.54399 0.0073	-0.43028 0.0404	-0.26630 0.2194	1.00000	-0.74008 <.0001	0.90662 <.0001	0.05897 0.7893	-0.59002 0.0030
CF	0.53952 0.0079	0.15629 0.4764	-0.03156 0.8863	0.03486 0.8745	0.34984 0.1018	-0.01940 0.9300	-0.74008 <.0001	1.00000	-0.84187 <.0001	0.13180 0.5489	0.14183 0.5186
CG	-0.32665 0.1282	-0.33234 0.1213	-0.23170 0.2874	-0.25312 0.2439	-0.41509 0.0489	-0.22909 0.2931	0.90662 <.0001	-0.84187 <.0001	1.00000	-0.03382 0.8783	-0.46922 0.0239
No_Samples	0.57828 0.0038	0.63199 0.0012	0.35898 0.0925	0.03684 0.8675	0.34752 0.1042	-0.23858 0.2729	0.05897 0.7893	0.13180 0.5489	-0.03382 0.8783	1.00000	0.05225 0.8128
FFG_DIV	-0.27785 0.1993	0.54516 0.0071	0.38447 0.0701	0.80829 <.0001	0.40182 0.0574	0.44122 0.0351	-0.59002 0.0030	0.14183 0.5186	-0.46922 0.0239	0.05225 0.8128	1.00000
SCR	-0.20434 0.3497	0.45488 0.0292	0.28906 0.1810	0.58919 0.0031	0.27778 0.1994	-0.16740 0.4452	-0.17654 0.4204	-0.12218 0.5787	0.03030 0.8908	0.08964 0.6842	0.34081 0.1115
SHD	-0.04513 0.8380	0.18586 0.3958	0.18151 0.4072	0.44191 0.0348	0.21554 0.3233	0.77577 <.0001	-0.21049 0.3350	-0.10894 0.6207	-0.13854 0.5284	-0.08826 0.6888	0.45164 0.0305
PRED	-0.20394 0.3506	0.16396 0.4547	0.38254 0.0716	0.11463 0.6025	-0.01401 0.9494	0.23105 0.2888	-0.33068 0.1233	-0.09721 0.6590	-0.39789 0.0601	-0.12858 0.5587	0.43813 0.0365
P_R	-0.11818 0.5912	0.31722 0.1402	0.29344 0.1742	0.58954 0.0031	0.27466 0.2047	0.76807 <.0001	-0.29146 0.1772	-0.13040 0.5532	-0.18215 0.4055	-0.07646 0.7288	0.55359 0.0061
HAB_STAB	0.85237 <.0001	-0.06121 0.7815	-0.12311 0.5757	-0.21496 0.3246	0.04507 0.8382	-0.09057 0.6811	-0.40220 0.0571	0.69839 0.0002	-0.50459 0.0141	0.20401 0.3505	-0.32973 0.1244

The CORR Procedure

Pearson Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	-0.20434 0.3497	-0.04513 0.8380	-0.20394 0.3506	-0.11818 0.5912	0.85237 <.0001	0.54046 0.0078	-0.35077 0.1008	-0.07794 0.7237	0.84972 <.0001
RICH	0.45488 0.0292	0.18586 0.3958	0.16396 0.4547	0.31722 0.1402	-0.06121 0.7815	0.15182 0.4892	0.03827 0.8624	0.15451 0.4815	-0.05983 0.7863
EPT_RICH	0.28906 0.1810	0.18151 0.4072	0.38254 0.0716	0.29344 0.1742	-0.12311 0.5757	-0.03755 0.8649	-0.07912 0.7197	0.16762 0.4446	-0.11968 0.5865
DIV	0.58919 0.0031	0.44191 0.0348	0.11463 0.6025	0.58954 0.0031	-0.21496 0.3246	0.03085 0.8889	0.66631 0.0005	0.41660 0.0480	-0.21806 0.3175
DIP_RICH	0.27778 0.1994	0.21554 0.3233	-0.01401 0.9494	0.27466 0.2047	0.04507 0.8382	0.34814 0.1035	0.00845 0.9695	0.14827 0.4996	0.04895 0.8245
PER_EPT	-0.16740 0.4452	0.77577 <.0001	0.23105 0.2888	0.76807 <.0001	-0.09057 0.6811	-0.02274 0.9180	0.32265 0.1332	0.84324 <.0001	-0.09125 0.6788
PER_OLIG	-0.17654 0.4204	-0.21049 0.3350	-0.33068 0.1233	-0.29146 0.1772	-0.40220 0.0571	-0.73731 <.0001	-0.07917 0.7195	-0.22676 0.2981	-0.40912 0.0526
CF	-0.12218 0.5787	-0.10894 0.6207	-0.09721 0.6590	-0.13040 0.5532	0.69839 0.0002	0.99995 <.0001	-0.40600 0.0546	-0.10904 0.6204	0.70262 0.0002
CG	0.03030 0.8908	-0.13854 0.5284	-0.39789 0.0601	-0.18215 0.4055	-0.50459 0.0141	-0.83931 <.0001	0.32269 0.1332	-0.17092 0.4355	-0.51373 0.0122
No_Samples	0.08964 0.6842	-0.08826 0.6888	-0.12858 0.5587	-0.07646 0.7288	0.20401 0.3505	0.12990 0.5547	-0.24827 0.2533	-0.12407 0.5727	0.19970 0.3609
FFG_DIV	0.34081 0.1115	0.45164 0.0305	0.43813 0.0365	0.55359 0.0061	-0.32973 0.1244	0.13792 0.5303	0.28218 0.1921	0.42810 0.0416	-0.32733 0.1274
SCR	1.00000	-0.12883 0.5580	-0.06514 0.7678	0.13893 0.5272	-0.15466 0.4810	-0.12650 0.5652	0.38333 0.0710	-0.12581 0.5673	-0.15881 0.4692
SHD	-0.12883 0.5580	1.00000	0.15269 0.4867	0.95559 <.0001	-0.10812 0.6234	-0.10998 0.6174	0.43264 0.0392	0.97735 <.0001	-0.10884 0.6211
PRED	-0.06514 0.7678	0.15269 0.4867	1.00000	0.21291 0.3294	-0.17233 0.4317	-0.10030 0.6488	-0.15137 0.4905	0.20723 0.3427	-0.16036 0.4648
P_R	0.13893 0.5272	0.95559 <.0001	0.21291 0.3294	1.00000	-0.13716 0.5326	-0.13317 0.5447	0.50138 0.0148	0.95782 <.0001	-0.13794 0.5302
HAB_STAB	-0.15466 0.4810	-0.10812 0.6234	-0.17233 0.4317	-0.13716 0.5326	1.00000	0.69876 0.0002	-0.33560 0.1175	-0.08349 0.7049	0.99985 <.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
PER_DRES	0.54046 0.0078	0.15182 0.4892	-0.03755 0.8649	0.03085 0.8889	0.34814 0.1035	-0.02274 0.9180	-0.73731 <.0001	0.99995 <.0001	-0.83931 <.0001	0.12990 0.5547	0.13792 0.5303
PER_DIP	-0.35077 0.1008	0.03827 0.8624	-0.07912 0.7197	0.66631 0.0005	0.00845 0.9695	0.32265 0.1332	-0.07917 0.7195	-0.40600 0.0546	0.32269 0.1332	-0.24827 0.2533	0.28218 0.1921
C_FPOM	-0.07794 0.7237	0.15451 0.4815	0.16762 0.4446	0.41660 0.0480	0.14827 0.4996	0.84324 <.0001	-0.22676 0.2981	-0.10904 0.6204	-0.17092 0.4355	-0.12407 0.5727	0.42810 0.0416
T_BFPOM	0.84972 <.0001	-0.05983 0.7863	-0.11968 0.5865	-0.21806 0.3175	0.04895 0.8245	-0.09125 0.6788	-0.40912 0.0526	0.70262 0.0002	-0.51373 0.0122	0.19970 0.3609	-0.32733 0.1274

The CORR Procedure

Pearson Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
PER_DRES	-0.12650 0.5652	-0.10998 0.6174	-0.10030 0.6488	-0.13317 0.5447	0.69876 0.0002	1.00000	-0.40653 0.0542	-0.11059 0.6154	0.70298 0.0002
PER_DIP	0.38333 0.0710	0.43264 0.0392	-0.15137 0.4905	0.50138 0.0148	-0.33560 0.1175	-0.40653 0.0542	1.00000	0.41691 0.0478	-0.34186 0.1104
C_FPOM	-0.12581 0.5673	0.97735 <.0001	0.20723 0.3427	0.95782 <.0001	-0.08349 0.7049	-0.11059 0.6154	0.41691 0.0478	1.00000	-0.08378 0.7039
T_BFPOM	-0.15881 0.4692	-0.10884 0.6211	-0.16036 0.4648	-0.13794 0.5302	0.99985 <.0001	0.70298 0.0002	-0.34186 0.1104	-0.08378 0.7039	1.00000

The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
TNI TNI	1.00000	0.22871 0.2939	0.11630 0.5972	-0.23221 0.2863	0.01142 0.9587	-0.12760 0.5618	0.01383 0.9500	0.03805 0.8631	-0.08794 0.6899	0.79909 <.0001	-0.04644 0.8333
RICH	0.22871 0.2939	1.00000	0.64243 0.0009	0.51980 0.0110	0.84673 <.0001	0.38503 0.0696	-0.36287 0.0888	0.50136 0.0148	-0.39258 0.0639	0.61126 0.0019	0.50495 0.0140
EPT_RICH	0.11630 0.5972	0.64243 0.0009	1.00000	0.36623 0.0857	0.46762 0.0244	0.45799 0.0280	-0.33359 0.1198	0.29158 0.1770	-0.39378 0.0630	0.23796 0.2742	0.51976 0.0110
DIV	-0.23221 0.2863	0.51980 0.0110	0.36623 0.0857	1.00000	0.47480 0.0221	0.61424 0.0018	-0.57115 0.0044	0.39783 0.0601	-0.47233 0.0229	-0.00235 0.9915	0.80237 <.0001
DIP_RICH	0.01142 0.9587	0.84673 <.0001	0.46762 0.0244	0.47480 0.0221	1.00000	0.32165 0.1345	-0.43805 0.0366	0.52509 0.0101	-0.44153 0.0349	0.34637 0.1054	0.42464 0.0434
PER_EPT	-0.12760 0.5618	0.38503 0.0696	0.45799 0.0280	0.61424 0.0018	0.32165 0.1345	1.00000	-0.53907 0.0079	0.57086 0.0044	-0.53907 0.0079	0.08064 0.7146	0.58655 0.0033
PER_OLIG	0.01383 0.9500	-0.36287 0.0888	-0.33359 0.1198	-0.57115 0.0044	-0.43805 0.0366	-0.53907 0.0079	1.00000	-0.75315 <.0001	0.89427 <.0001	0.05057 0.8188	-0.60375 0.0023
CF	0.03805 0.8631	0.50136 0.0148	0.29158 0.1770	0.39783 0.0601	0.52509 0.0101	0.57086 0.0044	-0.75315 <.0001	1.00000	-0.77045 <.0001	0.17056 0.4365	0.46948 0.0238
CG	-0.08794 0.6899	-0.39258 0.0639	-0.39378 0.0630	-0.47233 0.0229	-0.44153 0.0349	-0.53907 0.0079	0.89427 <.0001	-0.77045 <.0001	1.00000	-0.05880 0.7899	-0.66897 0.0005
No_Samples	0.79909 <.0001	0.61126 0.0019	0.23796 0.2742	-0.00235 0.9915	0.34637 0.1054	0.08064 0.7146	0.05057 0.8188	0.17056 0.4365	-0.05880 0.7899	1.00000	0.06821 0.7571
FFG_DIV	-0.04644 0.8333	0.50495 0.0140	0.51976 0.0110	0.80237 <.0001	0.42464 0.0434	0.58655 0.0033	-0.60375 0.0023	0.46948 0.0238	-0.66897 0.0005	0.06821 0.7571	1.00000
SCR	-0.30929 0.1510	0.41238 0.0505	0.13568 0.5371	0.56028 0.0054	0.40527 0.0551	0.02077 0.9251	-0.24111 0.2677	0.22090 0.3111	-0.13043 0.5530	-0.02646 0.9046	0.38834 0.0671
SHD	-0.35474 0.0967	0.33069 0.1233	0.24790 0.2541	0.62253 0.0015	0.54781 0.0068	0.23838 0.2734	-0.34881 0.1028	0.24463 0.2606	-0.28261 0.1914	-0.22520 0.3015	0.60079 0.0024
PRED	0.08794 0.6899	0.11832 0.5908	0.46366 0.0259	0.33202 0.1217	-0.10877 0.6213	0.32344 0.1322	-0.21047 0.3351	-0.05782 0.7933	-0.36858 0.0835	0.00353 0.9873	0.64032 0.0010
P_R	-0.25000 0.2499	0.55396 0.0061	0.38766 0.0676	0.70158 0.0002	0.62628 0.0014	0.21958 0.3141	-0.34387 0.1081	0.32765 0.1270	-0.31621 0.1416	0.00176 0.9936	0.66304 0.0006
HAB_STAB	-0.05336 0.8089	0.43416 0.0385	0.21423 0.3263	0.42688 0.0422	0.52198 0.0106	0.42235 0.0447	-0.82609 <.0001	0.92365 <.0001	-0.79249 <.0001	0.02117 0.9236	0.44960 0.0314

The CORR Procedure

Spearman Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
TNI TNI	-0.30929 0.1510	-0.35474 0.0967	0.08794 0.6899	-0.25000 0.2499	-0.05336 0.8089	0.07816 0.7230	-0.32312 0.1326	-0.37352 0.0792	0.00741 0.9732
RICH	0.41238 0.0505	0.33069 0.1233	0.11832 0.5908	0.55396 0.0061	0.43416 0.0385	0.52815 0.0096	0.06139 0.7808	0.33317 0.1203	0.49195 0.0171
EPT_RICH	0.13568 0.5371	0.24790 0.2541	0.46366 0.0259	0.38766 0.0676	0.21423 0.3263	0.15208 0.4885	0.03826 0.8624	0.29074 0.1783	0.31046 0.1494
DIV	0.56028 0.0054	0.62253 0.0015	0.33202 0.1217	0.70158 0.0002	0.42688 0.0422	0.41186 0.0508	0.62846 0.0013	0.63142 0.0012	0.38794 0.0674
DIP_RICH	0.40527 0.0551	0.54781 0.0068	-0.10877 0.6213	0.62628 0.0014	0.52198 0.0106	0.64621 0.0009	0.01589 0.9426	0.53589 0.0084	0.51118 0.0127
PER_EPT	0.02077 0.9251	0.23838 0.2734	0.32344 0.1322	0.21958 0.3141	0.42235 0.0447	0.50456 0.0141	0.14243 0.5168	0.27003 0.2127	0.56987 0.0045
PER_OLIG	-0.24111 0.2677	-0.34881 0.1028	-0.21047 0.3351	-0.34387 0.1081	-0.82609 <.0001	-0.72953 <.0001	-0.06719 0.7607	-0.37451 0.0783	-0.77292 <.0001
CF	0.22090 0.3111	0.24463 0.2606	-0.05782 0.7933	0.32765 0.1270	0.92365 <.0001	0.91715 <.0001	-0.18186 0.4063	0.25500 0.2403	0.99209 <.0001
CG	-0.13043 0.5530	-0.28261 0.1914	-0.36858 0.0835	-0.31621 0.1416	-0.79249 <.0001	-0.74857 <.0001	0.22332 0.3057	-0.31621 0.1416	-0.78527 <.0001
No_Samples	-0.02646 0.9046	-0.22520 0.3015	0.00353 0.9873	0.00176 0.9936	0.02117 0.9236	0.19797 0.3652	-0.18581 0.3960	-0.23990 0.2702	0.12645 0.5653
FFG_DIV	0.38834 0.0671	0.60079 0.0024	0.64032 0.0010	0.66304 0.0006	0.44960 0.0314	0.44794 0.0321	0.27866 0.1979	0.62846 0.0013	0.47541 0.0219
SCR	1.00000	0.34289 0.1092	-0.00198 0.9929	0.70257 0.0002	0.38933 0.0663	0.17136 0.4343	0.55929 0.0055	0.36759 0.0844	0.21794 0.3178
SHD	0.34289 0.1092	1.00000	0.13043 0.5530	0.83004 <.0001	0.24605 0.2578	0.37579 0.0772	0.40810 0.0532	0.98913 <.0001	0.25945 0.2319
PRED	-0.00198 0.9929	0.13043 0.5530	1.00000	0.18379 0.4012	-0.04051 0.8544	-0.11624 0.5974	0.02569 0.9074	0.18676 0.3935	-0.01235 0.9554
P_R	0.70257 0.0002	0.83004 <.0001	0.18379 0.4012	1.00000	0.35968 0.0918	0.37078 0.0816	0.48024 0.0204	0.83696 <.0001	0.33556 0.1175
HAB_STAB	0.38933 0.0663	0.24605 0.2578	-0.04051 0.8544	0.35968 0.0918	1.00000	0.86882 <.0001	-0.10968 0.6183	0.25791 0.2348	0.93057 <.0001

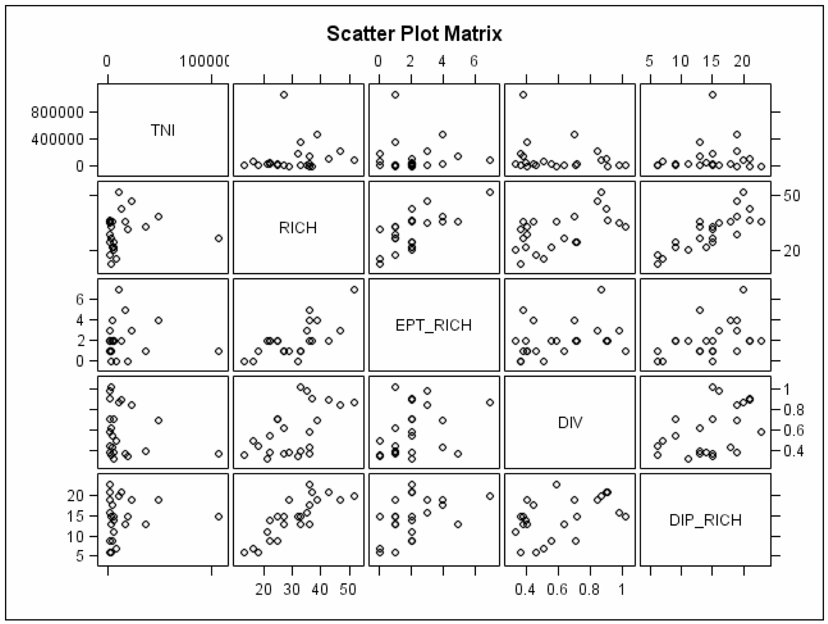
The CORR Procedure

Spearman Correlation Coefficients, N = 23 Prob > |r| under H0: Rho=0											
	TNI	**RICH**	**EPT_RICH**	**DIV**	**DIP_RICH**	**PER_EPT**	**PER_OLIG**	**CF**	**CG**	**No_Samples**	**FFG_DIV**
PER_DRES	0.07816 0.7230	0.52815 0.0096	0.15208 0.4885	0.41186 0.0508	0.64621 0.0009	0.50456 0.0141	-0.72953 <.0001	0.91715 <.0001	-0.74857 <.0001	0.19797 0.3652	0.44794 0.0321
PER_DIP	-0.32312 0.1326	0.06139 0.7808	0.03826 0.8624	0.62846 0.0013	0.01589 0.9426	0.14243 0.5168	-0.06719 0.7607	-0.18186 0.4063	0.22332 0.3057	-0.18581 0.3960	0.27866 0.1979
C_FPOM	-0.37352 0.0792	0.33317 0.1203	0.29074 0.1783	0.63142 0.0012	0.53589 0.0084	0.27003 0.2127	-0.37451 0.0783	0.25500 0.2403	-0.31621 0.1416	-0.23990 0.2702	0.62846 0.0013
T_BFPOM	0.00741 0.9732	0.49195 0.0171	0.31046 0.1494	0.38794 0.0674	0.51118 0.0127	0.56987 0.0045	-0.77292 <.0001	0.99209 <.0001	-0.78527 <.0001	0.12645 0.5653	0.47541 0.0219

The CORR Procedure

Spearman Correlation Coefficients, N = 23
Prob > |r| under H0: Rho=0

	SCR	SHD	PRED	P_R	HAB_STAB	PER_DRES	PER_DIP	C_FPOM	T_BFPOM
PER_DRES	0.17136 0.4343	0.37579 0.0772	-0.11624 0.5974	0.37078 0.0816	0.86882 <.0001	1.00000	-0.22347 0.3054	0.35775 0.0937	0.90713 <.0001
PER_DIP	0.55929 0.0055	0.40810 0.0532	0.02569 0.9074	0.48024 0.0204	-0.10968 0.6183	-0.22347 0.3054	1.00000	0.41206 0.0507	-0.18087 0.4089
C_FPOM	0.36759 0.0844	0.98913 <.0001	0.18676 0.3935	0.83696 <.0001	0.25791 0.2348	0.35775 0.0937	0.41206 0.0507	1.00000	0.27477 0.2045
T_BFPOM	0.21794 0.3178	0.25945 0.2319	-0.01235 0.9554	0.33556 0.1175	0.93057 <.0001	0.90713 <.0001	-0.18087 0.4089	0.27477 0.2045	1.00000



Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

25 Variables:											
DDx	SVOC	VOC	CN	AVS	As	Cd	Cr	Cu	Fe	Pb	Hg
Ni	Ag	SEM	SEM_AVS	Zn	Heptachlor_epoxide	Total_PCB	NH3_N	Tot_Phos	clay	gravel	
sand	silt										

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Median**	**Minimum**	**Maximum**
DDx	86	148.10975	163.93943	116.09758	9.52744	1095
SVOC	78	159341	497970	53291	2868	3652353
VOC	85	146.21795	865.41195	40.33885	21.51463	8020
CN	82	1.95096	2.77954	0.87532	0	15.58542
AVS	63	26.30032	42.10495	8.66000	0.24000	273.40000
As	81	1.51358	2.15770	0.50000	0	10.30000
Cd	82	6.65126	13.99237	3.49000	0.20000	121.87000
Cr	82	86.92561	77.91650	63.95000	12.80000	580.85000
Cu	82	150.05890	136.72495	101.55000	8.70000	825.40000
Fe	79	22919	9309	21727	3921	51809
Pb	82	256.71061	230.46992	181.70000	21.36000	1255
Hg	82	0.85720	1.17186	0.48665	0	6.39700
Ni	82	39.14512	28.57443	30.24500	6.60000	204.60000
Ag	79	2.55354	5.08267	0.74500	0	34.80000
SEM	65	54.19267	169.83660	10.20000	0.18000	1030
SEM_AVS	59	4.87216	12.43565	0.80679	0.01363	88.79310
Zn	82	563.46110	426.26106	484.26500	64.00000	2427
Heptachlor_epoxide	86	7.32170	5.65586	5.53405	2.00000	36.00000
Total_PCB	82	1763	2664	749.00000	5.37866	13722
NH3_N	80	96.16916	176.16207	43.34971	1.29326	1400
Tot_Phos	81	2495	2841	1750	3.70000	19994
clay	64	9.41094	10.19695	4.95000	0.80000	48.00000

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Median**	**Minimum**	**Maximum**
gravel	64	3.95312	6.67713	1.00000	0	35.80000
sand	64	64.06875	23.43388	70.00000	7.40000	97.80000
silt	64	22.55313	17.21450	20.70000	0	63.00000

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	DDx	SVOC	VOC	CN	AVS	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Ag
DDx	1.00000 86	0.64334 <.0001 78	0.40089 0.0002 84	0.32601 0.0032 80	-0.01471 0.9089 63	0.13014 0.2499 80	0.67022 <.0001 80	0.46485 <.0001 80	0.69391 <.0001 80	-0.24357 0.0316 78	0.48896 <.0001 80	0.50098 <.0001 80	0.47954 <.0001 80	0.58924 <.0001 78
SVOC	0.64334 <.0001 78	1.00000 78	0.37435 0.0007 78	0.42722 <.0001 78	-0.03979 0.7588 62	-0.06264 0.5858 78	0.65492 <.0001 78	0.58301 <.0001 78	0.70852 <.0001 78	0.03074 0.7893 78	0.61677 <.0001 78	0.56652 <.0001 78	0.59466 <.0001 78	0.63649 <.0001 78
VOC	0.40089 0.0002 84	0.37435 0.0007 78	1.00000 85	0.43043 <.0001 79	0.00786 0.9517 62	-0.11687 0.3050 79	0.23190 0.0397 79	0.35045 0.0015 79	0.36692 0.0009 79	0.09900 0.3885 78	0.43714 <.0001 79	0.43606 <.0001 79	0.12982 0.2542 79	0.44772 <.0001 79
CN	0.32601 0.0032 80	0.42722 <.0001 78	0.43043 <.0001 79	1.00000 82	0.18539 0.1458 63	-0.26957 0.0149 81	0.53125 <.0001 82	0.53541 <.0001 82	0.42495 <.0001 82	0.17313 0.1271 79	0.53395 <.0001 82	0.37609 0.0005 82	0.46135 <.0001 82	0.39717 0.0003 79
AVS	-0.01471 0.9089 63	-0.03979 0.7588 62	0.00786 0.9517 62	0.18539 0.1458 63	1.00000 63	-0.04341 0.7355 63	0.10818 0.3987 63	0.10926 0.3940 63	0.00806 0.9500 63	0.08645 0.5041 62	0.23707 0.0614 63	0.04750 0.7116 63	-0.01395 0.9136 63	0.17684 0.1691 62
As	0.13014 0.2499 80	-0.06264 0.5858 78	-0.11687 0.3050 79	-0.26957 0.0149 81	-0.04341 0.7355 63	1.00000 81	-0.03308 0.7694 81	-0.18217 0.1036 81	-0.01788 0.8741 81	-0.29751 0.0082 78	-0.13008 0.2471 81	0.24356 0.0284 81	-0.15902 0.1562 81	0.14748 0.1946 79
Cd	0.67022 <.0001 80	0.65492 <.0001 78	0.23190 0.0397 79	0.53125 <.0001 82	0.10818 0.3987 63	-0.03308 0.7694 81	1.00000 82	0.80979 <.0001 82	0.81293 <.0001 82	0.05247 0.6460 79	0.68869 <.0001 82	0.62089 <.0001 82	0.76255 <.0001 82	0.54925 <.0001 79
Cr	0.46485 <.0001 80	0.58301 <.0001 78	0.35045 0.0015 79	0.53541 <.0001 82	0.10926 0.3940 63	-0.18217 0.1036 81	0.80979 <.0001 82	1.00000 82	0.71170 <.0001 82	0.43273 <.0001 79	0.72318 <.0001 82	0.56330 <.0001 82	0.78970 <.0001 82	0.53045 <.0001 79
Cu	0.69391 <.0001 80	0.70852 <.0001 78	0.36692 0.0009 79	0.42495 <.0001 82	0.00806 0.9500 63	-0.01788 0.8741 81	0.81293 <.0001 82	0.71170 <.0001 82	1.00000 82	0.01534 0.8933 79	0.69713 <.0001 82	0.67512 <.0001 82	0.61388 <.0001 82	0.66678 <.0001 79
Fe	-0.24357 0.0316 78	0.03074 0.7893 78	0.09900 0.3885 78	0.17313 0.1271 79	0.08645 0.5041 62	-0.29751 0.0082 78	0.05247 0.6460 79	0.43273 <.0001 79	0.01534 0.8933 79	1.00000 79	0.32374 0.0036 79	0.01161 0.9191 79	0.28985 0.0096 79	0.00519 0.9640 78
Pb	0.48896 <.0001 80	0.61677 <.0001 78	0.43714 <.0001 79	0.53395 <.0001 82	0.23707 0.0614 63	-0.13008 0.2471 81	0.68869 <.0001 82	0.72318 <.0001 82	0.69713 <.0001 82	0.32374 0.0036 79	1.00000 82	0.65060 <.0001 82	0.54014 <.0001 82	0.67005 <.0001 79

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	SEM	SEM_AVS	Zn	Heptachlor_epoxide	Total_PCB	NH3_N	Tot_Phos	clay	gravel	sand	silt
DDx	0.13781 0.2736 65	0.08177 0.5381 59	0.51285 <.0001 80	0.44120 <.0001 86	0.32591 0.0028 82	0.56570 <.0001 78	0.48143 <.0001 79	0.04131 0.7459 64	-0.15763 0.2135 64	-0.18900 0.1347 64	0.24445 0.0516 64
SVOC	0.36703 0.0029 64	0.20723 0.1185 58	0.63562 <.0001 78	0.34751 0.0018 78	0.49200 <.0001 78	0.52926 <.0001 78	0.61999 <.0001 77	0.24969 0.0466 64	-0.08200 0.5195 64	-0.23401 0.0627 64	0.24573 0.0503 64
VOC	0.28127 0.0244 64	0.16712 0.2099 58	0.48861 <.0001 79	0.59297 <.0001 84	0.29456 0.0080 80	0.52707 <.0001 79	0.57094 <.0001 78	0.41849 0.0006 64	-0.28472 0.0226 64	-0.53411 <.0001 64	0.61888 <.0001 64
CN	0.49321 <.0001 65	0.13370 0.3127 59	0.64086 <.0001 82	0.34375 0.0018 80	0.46502 <.0001 80	0.37807 0.0005 80	0.67022 <.0001 81	0.35062 0.0045 64	-0.19484 0.1229 64	-0.35961 0.0035 64	0.40078 0.0010 64
AVS	0.21052 0.0977 63	-0.61568 <.0001 59	0.24792 0.0501 63	-0.06097 0.6350 63	-0.05895 0.6463 63	0.13792 0.2851 62	0.29358 0.0206 62	-0.00402 0.9753 62	-0.13292 0.3031 62	0.01035 0.9364 62	-0.01335 0.9180 62
As	0.08967 0.4775 65	0.23660 0.0712 59	-0.16200 0.1485 81	-0.12848 0.2560 80	-0.10790 0.3408 80	0.13981 0.2191 79	-0.14427 0.2017 80	-0.59673 <.0001 64	-0.01289 0.9195 64	0.49346 <.0001 64	-0.37763 0.0021 64
Cd	0.40690 0.0008 65	0.12791 0.3343 59	0.79253 <.0001 82	0.17768 0.1148 80	0.45583 <.0001 80	0.43496 <.0001 80	0.63795 <.0001 81	0.15470 0.2222 64	-0.20516 0.1039 64	-0.05576 0.6616 64	0.12901 0.3096 64
Cr	0.47295 <.0001 65	0.16803 0.2033 59	0.83667 <.0001 82	0.15561 0.1681 80	0.56171 <.0001 80	0.35653 0.0012 80	0.64990 <.0001 81	0.36486 0.0030 64	-0.19403 0.1245 64	-0.24495 0.0511 64	0.29693 0.0172 64
Cu	0.39273 0.0012 65	0.23338 0.0753 59	0.72003 <.0001 82	0.27980 0.0120 80	0.46261 <.0001 80	0.57901 <.0001 80	0.58869 <.0001 81	0.22394 0.0753 64	-0.27575 0.0274 64	-0.16657 0.1883 64	0.28106 0.0245 64
Fe	0.24712 0.0490 64	0.09545 0.4760 58	0.37051 0.0008 79	0.07847 0.4947 78	0.29223 0.0094 78	-0.08644 0.4488 79	0.19779 0.0826 78	0.60105 <.0001 64	-0.05265 0.6795 64	-0.49457 <.0001 64	0.44269 0.0002 64
Pb	0.60437 <.0001 65	0.23489 0.0733 59	0.84014 <.0001 82	0.37833 0.0005 80	0.56397 <.0001 80	0.51441 <.0001 80	0.68947 <.0001 81	0.33294 0.0072 64	-0.29605 0.0175 64	-0.32682 0.0084 64	0.41936 0.0006 64

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	DDx	SVOC	VOC	CN	AVS	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Ag
Hg	0.50098 <.0001 80	0.56652 <.0001 78	0.43606 <.0001 79	0.37609 0.0005 82	0.04750 0.7116 63	0.24356 0.0284 81	0.62089 <.0001 82	0.56330 <.0001 82	0.67512 <.0001 82	0.01161 0.9191 79	0.65060 <.0001 82	1.00000 82	0.47919 <.0001 82	0.65007 <.0001 79
Ni	0.47954 <.0001 80	0.59466 <.0001 78	0.12982 0.2542 79	0.46135 <.0001 82	-0.01395 0.9136 63	-0.15902 0.1562 81	0.76255 <.0001 82	0.78970 <.0001 82	0.61388 <.0001 82	0.28985 0.0096 79	0.54014 <.0001 82	0.47919 <.0001 82	1.00000 82	0.40122 0.0002 79
Ag	0.58924 <.0001 78	0.63649 <.0001 78	0.44772 <.0001 79	0.39717 0.0003 79	0.17684 0.1691 62	0.14748 0.1946 79	0.54925 <.0001 79	0.53045 <.0001 79	0.66678 <.0001 79	0.00519 0.9640 78	0.67005 <.0001 79	0.65007 <.0001 79	0.40122 0.0002 79	1.00000 79
SEM	0.13781 0.2736 65	0.36703 0.0029 64	0.28127 0.0244 64	0.49321 <.0001 65	0.21052 0.0977 63	0.08967 0.4775 65	0.40690 0.0008 65	0.47295 <.0001 65	0.39273 0.0012 65	0.24712 0.0490 64	0.60437 <.0001 65	0.70488 <.0001 65	0.32994 0.0073 65	0.42000 0.0006 64
SEM_AVS	0.08177 0.5381 59	0.20723 0.1185 58	0.16712 0.2099 58	0.13370 0.3127 59	-0.61568 <.0001 59	0.23660 0.0712 59	0.12791 0.3343 59	0.16803 0.2033 59	0.23338 0.0753 59	0.09545 0.4760 58	0.23489 0.0733 59	0.47450 0.0001 59	0.12086 0.3618 59	0.19649 0.1393 58
Zn	0.51285 <.0001 80	0.63562 <.0001 78	0.48861 <.0001 79	0.64086 <.0001 82	0.24792 0.0501 63	-0.16200 0.1485 81	0.79253 <.0001 82	0.83667 <.0001 82	0.72003 <.0001 82	0.37051 0.0008 79	0.84014 <.0001 82	0.57302 <.0001 82	0.64498 <.0001 82	0.62937 <.0001 79
Heptachlor_epoxide	0.44120 <.0001 86	0.34751 0.0018 78	0.59297 <.0001 84	0.34375 0.0018 80	-0.06097 0.6350 63	-0.12848 0.2560 80	0.17768 0.1148 80	0.15561 0.1681 80	0.27980 0.0120 80	0.07847 0.4947 78	0.37833 0.0005 80	0.26552 0.0173 80	0.02396 0.8329 80	0.41113 0.0002 78
Total_PCB	0.32591 0.0028 82	0.49200 <.0001 78	0.29456 0.0080 80	0.46502 <.0001 80	-0.05895 0.6463 63	-0.10790 0.3408 80	0.45583 <.0001 80	0.56171 <.0001 80	0.46261 <.0001 80	0.29223 0.0094 78	0.56397 <.0001 80	0.45378 <.0001 80	0.57923 <.0001 80	0.31407 0.0051 78
NH3_N	0.56570 <.0001 78	0.52926 <.0001 78	0.52707 <.0001 79	0.37807 0.0005 80	0.13792 0.2851 62	0.13981 0.2191 79	0.43496 <.0001 80	0.35653 0.0012 80	0.57901 <.0001 80	-0.08644 0.4488 79	0.51441 <.0001 80	0.62452 <.0001 80	0.32928 0.0029 80	0.71981 <.0001 79
Tot_Phos	0.48143 <.0001 79	0.61999 <.0001 77	0.57094 <.0001 78	0.67022 <.0001 81	0.29358 0.0206 62	-0.14427 0.2017 80	0.63795 <.0001 81	0.64990 <.0001 81	0.58869 <.0001 81	0.19779 0.0826 78	0.68947 <.0001 81	0.56855 <.0001 81	0.46364 <.0001 81	0.68358 <.0001 78
clay	0.04131 0.7459 64	0.24969 0.0466 64	0.41849 0.0006 64	0.35062 0.0045 64	-0.00402 0.9753 62	-0.59673 <.0001 64	0.15470 0.2222 64	0.36486 0.0030 64	0.22394 0.0753 64	0.60105 <.0001 64	0.33294 0.0072 64	0.00283 0.9823 64	0.32339 0.0091 64	0.21743 0.0844 64

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	SEM	SEM_AVS	Zn	Heptachlor_epoxide	Total_PCB	NH3_N	Tot_Phos	clay	gravel	sand	silt
Hg	0.70488 <.0001 65	0.47450 0.0001 59	0.57302 <.0001 82	0.26552 0.0173 80	0.45378 <.0001 80	0.62452 <.0001 80	0.56855 <.0001 81	0.00283 0.9823 64	-0.17945 0.1559 64	-0.05941 0.6410 64	0.19311 0.1263 64
Ni	0.32994 0.0073 65	0.12086 0.3618 59	0.64498 <.0001 82	0.02396 0.8329 80	0.57923 <.0001 80	0.32928 0.0029 80	0.46364 <.0001 81	0.32339 0.0091 64	-0.02234 0.8609 64	-0.18698 0.1390 64	0.16264 0.1991 64
Ag	0.42000 0.0006 64	0.19649 0.1393 58	0.62937 <.0001 79	0.41113 0.0002 78	0.31407 0.0051 78	0.71981 <.0001 79	0.68358 <.0001 78	0.21743 0.0844 64	-0.46029 0.0001 64	-0.35954 0.0035 64	0.49579 <.0001 64
SEM	1.00000 65	0.58591 <.0001 59	0.50870 <.0001 65	0.16731 0.1828 65	0.53042 <.0001 65	0.49364 <.0001 64	0.67083 <.0001 64	0.04944 0.6980 64	-0.19743 0.1179 64	-0.00135 0.9915 64	0.14265 0.2608 64
SEM_AVS	0.58591 <.0001 59	1.00000 59	0.10275 0.4387 59	0.11309 0.3938 59	0.40076 0.0017 59	0.26100 0.0478 58	0.23504 0.0757 58	-0.01844 0.8907 58	-0.02386 0.8589 58	0.07937 0.5537 58	0.05159 0.7005 58
Zn	0.50870 <.0001 65	0.10275 0.4387 59	1.00000 82	0.35566 0.0012 80	0.56661 <.0001 80	0.49193 <.0001 80	0.79003 <.0001 81	0.43247 0.0004 64	-0.36771 0.0028 64	-0.40345 0.0009 64	0.49897 <.0001 64
Heptachlor_epoxide	0.16731 0.1828 65	0.11309 0.3938 59	0.35566 0.0012 80	1.00000 86	0.17522 0.1154 82	0.42963 <.0001 78	0.46794 <.0001 79	0.38763 0.0016 64	-0.31765 0.0105 64	-0.56884 <.0001 64	0.61158 <.0001 64
Total_PCB	0.53042 <.0001 65	0.40076 0.0017 59	0.56661 <.0001 80	0.17522 0.1154 82	1.00000 82	0.29412 0.0090 78	0.43145 <.0001 79	0.42159 0.0005 64	-0.05788 0.6496 64	-0.39585 0.0012 64	0.37475 0.0023 64
NH3_N	0.49364 <.0001 64	0.26100 0.0478 58	0.49193 <.0001 80	0.42963 <.0001 78	0.29412 0.0090 78	1.00000 80	0.65655 <.0001 79	0.07723 0.5441 64	-0.39948 0.0011 64	-0.19165 0.1292 64	0.38673 0.0016 64
Tot_Phos	0.67083 <.0001 64	0.23504 0.0757 58	0.79003 <.0001 81	0.46794 <.0001 79	0.43145 <.0001 79	0.65655 <.0001 79	1.00000 81	0.32601 0.0091 63	-0.40335 0.0010 63	-0.34696 0.0053 63	0.48476 <.0001 63
clay	0.04944 0.6980 64	-0.01844 0.8907 58	0.43247 0.0004 64	0.38763 0.0016 64	0.42159 0.0005 64	0.07723 0.5441 64	0.32601 0.0091 63	1.00000 64	-0.10446 0.4114 64	-0.83036 <.0001 64	0.72124 <.0001 64

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	DDx	SVOC	VOC	CN	AVS	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Ag
gravel	-0.15763 0.2135 64	-0.08200 0.5195 64	-0.28472 0.0226 64	-0.19484 0.1229 64	-0.13292 0.3031 62	-0.01289 0.9195 64	-0.20516 0.1039 64	-0.19403 0.1245 64	-0.27575 0.0274 64	-0.05265 0.6795 64	-0.29605 0.0175 64	-0.17945 0.1559 64	-0.02234 0.8609 64	-0.46029 0.0001 64
sand	-0.18900 0.1347 64	-0.23401 0.0627 64	-0.53411 <.0001 64	-0.35961 0.0035 64	0.01035 0.9364 62	0.49346 <.0001 64	-0.05576 0.6616 64	-0.24495 0.0511 64	-0.16657 0.1883 64	-0.49457 <.0001 64	-0.32682 0.0084 64	-0.05941 0.6410 64	-0.18698 0.1390 64	-0.35954 0.0035 64
silt	0.24445 0.0516 64	0.24573 0.0503 64	0.61888 <.0001 64	0.40078 0.0010 64	-0.01335 0.9180 62	-0.37763 0.0021 64	0.12901 0.3096 64	0.29693 0.0172 64	0.28106 0.0245 64	0.44269 0.0002 64	0.41936 0.0006 64	0.19311 0.1263 64	0.16264 0.1991 64	0.49579 <.0001 64

Correlation Matrix for CAWS Sediment Data
By Station ID and Year

The CORR Procedure

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	SEM	SEM_AVS	Zn	Heptachlor_epoxide	Total_PCB	NH3_N	Tot_Phos	clay	gravel	sand	silt
gravel	-0.19743 0.1179 64	-0.02386 0.8589 58	-0.36771 0.0028 64	-0.31765 0.0105 64	-0.05788 0.6496 64	-0.39948 0.0011 64	-0.40335 0.0010 63	-0.10446 0.4114 64	1.00000 64	0.20096 0.1113 64	-0.52924 <.0001 64
sand	-0.00135 0.9915 64	0.07937 0.5537 58	-0.40345 0.0009 64	-0.56884 <.0001 64	-0.39585 0.0012 64	-0.19165 0.1292 64	-0.34696 0.0053 63	-0.83036 <.0001 64	0.20096 0.1113 64	1.00000 64	-0.89860 <.0001 64
silt	0.14265 0.2608 64	0.05159 0.7005 58	0.49897 <.0001 64	0.61158 <.0001 64	0.37475 0.0023 64	0.38673 0.0016 64	0.48476 <.0001 63	0.72124 <.0001 64	-0.52924 <.0001 64	-0.89860 <.0001 64	1.00000 64

Appendix 2

SPEARMAN CORRELATION MATRIX FOR MACROINVERTEBRATE METRICS AND SEDIMENT CONTAMINANT CONCENTRATIONS

Appendix 2

SPEARMAN CORRELATION MATRIX FOR MACROINVERTEBRATE METRICS AND SEDIMENT CONTAMINATION CONCENTRATIONS

Note: | r values| greater than 0.231 have p-values < 0.05

	NH3_N	Tot_Phos	CN	Hg	Cd	Cr	Cu	Fe	Ni	Pb	Zn	Hv_Mtls	Ag	As	AVS	SEM	SEM_AVS	gravel	sand	silt	clay	Heptachlor_epoxide	Total_PCB	DDx	SVOC	VOC
TNI - PN	-0.223	-0.124	-0.040	-0.451	-0.085	-0.204	-0.247	-0.212	-0.274	-0.334	-0.195	-0.277	-0.250	-0.104	0.209	-0.427	-0.573	-0.116	0.076	-0.057	-0.137	-0.049	-0.534	-0.058	-0.298	-0.128
TNI - HD	-0.117	-0.262	-0.117	-0.426	-0.070	-0.031	-0.157	0.060	0.079	-0.240	-0.099	-0.145	-0.318	-0.283	0.126	-0.301	-0.407	0.069	0.228	-0.247	-0.119	-0.334	-0.146	-0.154	-0.119	-0.379
RICH - PN	-0.430	-0.551	-0.440	-0.597	-0.608	-0.548	-0.565	0.057	-0.559	-0.530	-0.524	-0.594	-0.352	0.002	-0.074	-0.630	-0.354	0.016	0.021	-0.073	-0.160	-0.079	-0.643	-0.352	-0.548	-0.223
RICH - HD	-0.151	-0.024	-0.050	0.156	-0.357	-0.314	-0.355	0.104	-0.482	-0.230	-0.236	-0.273	-0.144	0.305	0.106	0.146	0.152	-0.265	0.146	-0.005	-0.246	0.065	-0.297	-0.265	-0.335	-0.010
EPT_RICH - PN	-0.172	-0.239	-0.121	-0.104	-0.218	-0.210	-0.250	-0.055	-0.199	-0.168	-0.164	-0.195	-0.191	-0.180								-0.131	-0.124	-0.240	-0.226	-0.116
EPT_RICH - HD	-0.225	-0.146	-0.147	-0.161	-0.368	-0.350	-0.330	0.061	-0.362	-0.226	-0.240	-0.309	-0.134	0.065	-0.170	-0.095	0.098	-0.111	-0.019	0.054	-0.167	0.140	-0.326	-0.251	-0.338	0.001
DIV - PN	-0.419	-0.439	-0.289	-0.434	-0.587	-0.443	-0.530	0.223	-0.390	-0.416	-0.383	-0.465	-0.391	-0.102	-0.213	-0.358	-0.075	0.111	-0.146	0.045	0.036	-0.061	-0.241	-0.406	-0.420	-0.115
DIV - HD	0.073	0.121	0.091	-0.057	-0.200	-0.238	-0.265	-0.224	-0.346	-0.148	-0.117	-0.203	-0.001	0.308	-0.076	-0.004	0.034	-0.080	0.023	0.043	-0.340	0.288	-0.206	0.018	-0.135	0.148
DIP_RICH - PN	-0.299	-0.447	-0.452	-0.488	-0.512	-0.467	-0.430	0.111	-0.487	-0.409	-0.410	-0.471	-0.204	0.108	-0.033	-0.565	-0.312	-0.009	-0.001	-0.035	-0.153	-0.028	-0.570	-0.250	-0.432	-0.226
DIP_RICH - HD	-0.081	-0.038	-0.197	-0.104	-0.269	-0.285	-0.200	0.169	-0.410	-0.136	-0.164	-0.166	-0.037	0.345	0.120	0.022	0.057	-0.211	0.026	0.050	-0.126	0.130	-0.251	-0.109	-0.218	0.009
PER_EPT - PN	-0.172	-0.239	-0.121	-0.230	-0.218	-0.211	-0.250	-0.055	-0.199	-0.168	-0.164	-0.195	-0.191	-0.180								-0.131	-0.124	-0.240	-0.226	-0.116
PER_EPT - HD	-0.130	-0.012	0.001	0.032	-0.294	-0.282	-0.289	0.033	-0.301	-0.148	-0.168	-0.243	-0.173	0.136	-0.265	0.073	0.272	-0.060	0.035	0.069	-0.165	0.269	-0.122	-0.204	-0.285	0.159
PER_OLIG - PN	0.367	0.350	0.234	0.402	0.519	0.385	0.203	-0.298	0.327	0.364	0.300	0.383	0.347	0.116	0.178	0.291	0.082	-0.066	0.191	-0.099	-0.085	0.037	0.183	0.370	0.349	0.086
PER_OLIG - HD	0.163	0.286	0.175	0.380	0.593	0.560	0.580	0.054	0.618	0.407	0.427	0.532	0.321	0.002	0.056	0.035	0.012	0.048	-0.041	0.021	0.259	-0.203	0.427	0.410	0.488	-0.068
PER_DRES - PN	-0.327	-0.342	-0.177	-0.155	-0.405	-0.232	-0.280	0.259	-0.282	-0.152	-0.300	-0.272	-0.170	-0.310	-0.185	-0.099	-0.008	0.195	-0.313	0.182	0.268	0.103	-0.168	-0.323	-0.183	0.023
PER_DRES - HD	-0.308	-0.125	0.020	-0.219	-0.339	-0.185	-0.304	0.331	-0.316	-0.060	-0.137	-0.159	-0.313	-0.351	0.074	0.272	0.137	0.007	-0.109	0.087	0.217	0.137	-0.126	-0.488	-0.324	0.045
PER_DIP - PN	-0.169	-0.172	-0.169	-0.282	-0.452	-0.335	-0.379	0.274	-0.363	-0.205	-0.174	-0.264	-0.175	0.114	-0.037	-0.240	-0.097	-0.099	-0.168	0.170	-0.005	0.107	-0.178	-0.244	-0.283	0.020
PER_DIP - HD	0.294	0.218	0.141	-0.047	-0.091	-0.146	-0.104	-0.310	-0.206	0.009	0.030	-0.040	0.191	0.208	0.082	-0.052	-0.122	-0.181	-0.150	0.173	-0.166	0.345	-0.124	0.283	0.075	0.267
CF - PN	-0.391	-0.296	-0.089	-0.115	-0.333	-0.152	-0.254	0.277	-0.229	-0.193	-0.278	-0.246	-0.320	-0.140	-0.213	0.033	0.172	0.092	-0.087	0.035	0.135	-0.120	-0.012	-0.359	-0.280	-0.093
CF - HD	-0.208	-0.108	0.102	-0.093	-0.419	-0.317	-0.393	0.143	-0.409	-0.158	-0.227	-0.279	-0.300	-0.154	-0.151	0.399	0.396	-0.015	0.072	-0.007	-0.084	0.124	-0.079	-0.539	-0.334	0.120
CG - PN	0.335	0.235	0.117	0.357	0.472	0.293	0.467	-0.319	0.271	0.272	0.200	0.291	0.303	0.209	0.167	0.184	0.010	-0.028	0.250	-0.159	-0.170	-0.018	0.102	0.390	0.269	0.015
CG - HD	0.343	0.317	0.199	0.370	0.509	0.474	0.572	-0.089	0.528	0.406	0.402	0.499	0.363	0.020	0.107	0.037	0.025	-0.057	-0.107	0.110	0.189	-0.058	0.343	0.574	0.444	0.132
SCR - PN	-0.303	-0.321	-0.259	-0.283	-0.311	-0.196	-0.261	-0.058	-0.094	-0.366	-0.294	-0.302	-0.238	-0.123	-0.103	-0.323	-0.185	0.150	0.006	-0.060	-0.080	-0.199	-0.187	-0.201	-0.210	-0.130
SCR - HD	0.167	0.139	0.174	0.110	-0.183	-0.016	-0.098	0.069	-0.167	-0.009	-0.041	-0.043	0.081	0.311	-0.025	0.406	0.394	-0.183	0.071	0.070	-0.181	0.069	0.044	-0.055	-0.050	0.217
SHD - PN	-0.328	-0.427	-0.463	-0.269	-0.432	-0.328	-0.280	0.166	-0.273	-0.266	-0.342	-0.327	-0.201	-0.013	-0.138	-0.300	-0.039	0.095	-0.009	0.039	-0.030	-0.183	-0.164	-0.275	-0.312	-0.333
SHD - HD	0.048	0.081	-0.145	-0.099	-0.255	-0.300	-0.231	-0.007	-0.414	-0.061	-0.114	-0.131	0.097	0.218	0.088	-0.048	-0.099	-0.049	-0.094	0.063	0.077	0.231	-0.217	-0.047	0.009	0.034
PRED - PN	-0.174	-0.048	-0.002	-0.294	-0.337	-0.203	-0.357	0.286	-0.183	-0.178	-0.057	-0.182	-0.172	-0.133	-0.055	-0.317	-0.196	-0.003	-0.306	0.235	0.149	0.147	-0.133	-0.179	-0.158	0.136
PRED - HD	-0.275	-0.180	-0.087	-0.257	-0.115	-0.179	-0.288	-0.130	-0.162	-0.299	-0.199	-0.300	-0.168	0.245	-0.188	-0.363	-0.170	0.122	0.305	-0.298	-0.409	-0.141	-0.255	-0.189	-0.188	-0.241
P_R - PN	-0.404	-0.509	-0.491	-0.352	-0.490	-0.390	-0.366	0.132	-0.293	-0.346	-0.400	-0.397	-0.287	-0.105	-0.153	-0.331	-0.058	0.141	-0.001	-0.071	-0.030	-0.234	-0.198	-0.363	-0.367	-0.323
P_R - HD	0.080	0.075	-0.033	-0.095	-0.263	-0.263	-0.240	0.050	-0.406	-0.062	-0.106	-0.134	0.098	0.247	0.039	0.073	0.051	0.023	-0.026	0.023	-0.118	0.202	-0.150	-0.121	0.011	0.072
C_FPOM - PN	-0.328	-0.427	-0.463	-0.269	-0.432	-0.328	-0.280	0.166	-0.273	-0.266	-0.342	-0.327	-0.201	-0.013	-0.138	-0.300	-0.039	0.095	-0.009	-0.039	-0.030	-0.183	-0.164	-0.275	-0.312	-0.333
C_FPOM - HD	-0.010	0.060	-0.123	-0.145	-0.249	-0.321	-0.248	-0.013	-0.427	-0.092	-0.123	-0.157	0.067	0.238	0.044	-0.104	-0.093	-0.022	-0.052	0.025	-0.098	0.217	-0.224	-0.089	-0.020	0.017
FFG_DIV - PN	-0.427	-0.570	-0.452	-0.568	-0.589	-0.537	-0.541	0.043	-0.527	-0.535	-0.530	-0.597	-0.336	0.012	-0.089	-0.655	-0.372	0.067	0.006	-0.074	-0.145	-0.100	-0.624	-0.327	-0.518	-0.238
FFG_DIV - HD	-0.114	0.022	-0.041	-0.133	-0.314	-0.292	-0.294	0.076	-0.445	-0.194	-0.207	-0.234	-0.127	0.295	0.113	0.146	0.157	-0.271	0.166	-0.023	-0.263	0.104	-0.276	-0.205	-0.283	0.009

Appendix 3

ANALYSIS OF COVARIANCE

Appendix 3

ANALYSIS OF COVARIANCE

Analysis of Covariance, or ANCOVA, is a general linear model (GLM) with a continuous response variable and one or more factor variables. ANCOVA involves features of both Analysis of variance (ANOVA) and regression for continuous variables. ANCOVA tests whether certain factors have an effect on the response variable after removing the variance for which predictors (covariates) account. The inclusion of covariates generally increases statistical power because it accounts for some of the variability.

The variables of interest in this study measure macroinvertebrate population, community, or functional group structure under one or the other of two methods of sampling, over a period of seven years. ANCOVA is a parametric technique which attempts to make allowance for imbalances between groups and in this instance would try to determine whether there is an annual trend in a metric, independent of any differences in the influence of collection method that may exist. The regression model(s) involve(s) an interaction term between the categorical variable 'Method_Code' (X_{i1}) and the discrete variable'Year' (X_{i2}):

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i1} X_{i2} + \varepsilon_i$$

There are eight AWQM stations in the CAWS that have macroinvertebrate samples collected annually, by both hester-dendy and ponar methods. From this subset of AWQM stations, we reviewed the distributions of macroinvertebrates metrics and selected those that are normal. From this set of data, we ran a series of ANOVA/ANCOVA models to successively test the following:

1. Differences in a metric for the two collection methods, without consideration of 'Years' (Figure A3.1). The significance of this is reflected in the column labeled 'Method_Code' ANOVA p-value in Table 1. If a p-value exceeds 0.05, then we conclude that there is no difference between the collection methods for the dependent variable at that AWQM station.

2. Checking homogeneity of slope for 'Year' versus the dependent variable (Figure A3.2). This is performed by testing the significance of the interaction term and whether there are different regression coefficients for the two collection methods. The results of this are in the column labeled 'Method'x'Year' p-value in Table 1. Here, if the p-value exceeds 0.05, then we conclude that there is no significant difference in the metric-year relationship as a function of collection method.

3. Plotting residuals against the fitted response variables and against Year to visually check the assumptions of model. In some cases, we identified heteroskedacity (non-constant variance) or lack of normality in the residuals. No remedial measures have been attempted at this time. Where heteroskedacity or other indications existed to suggest an inappropriate model, we did not interpret results.

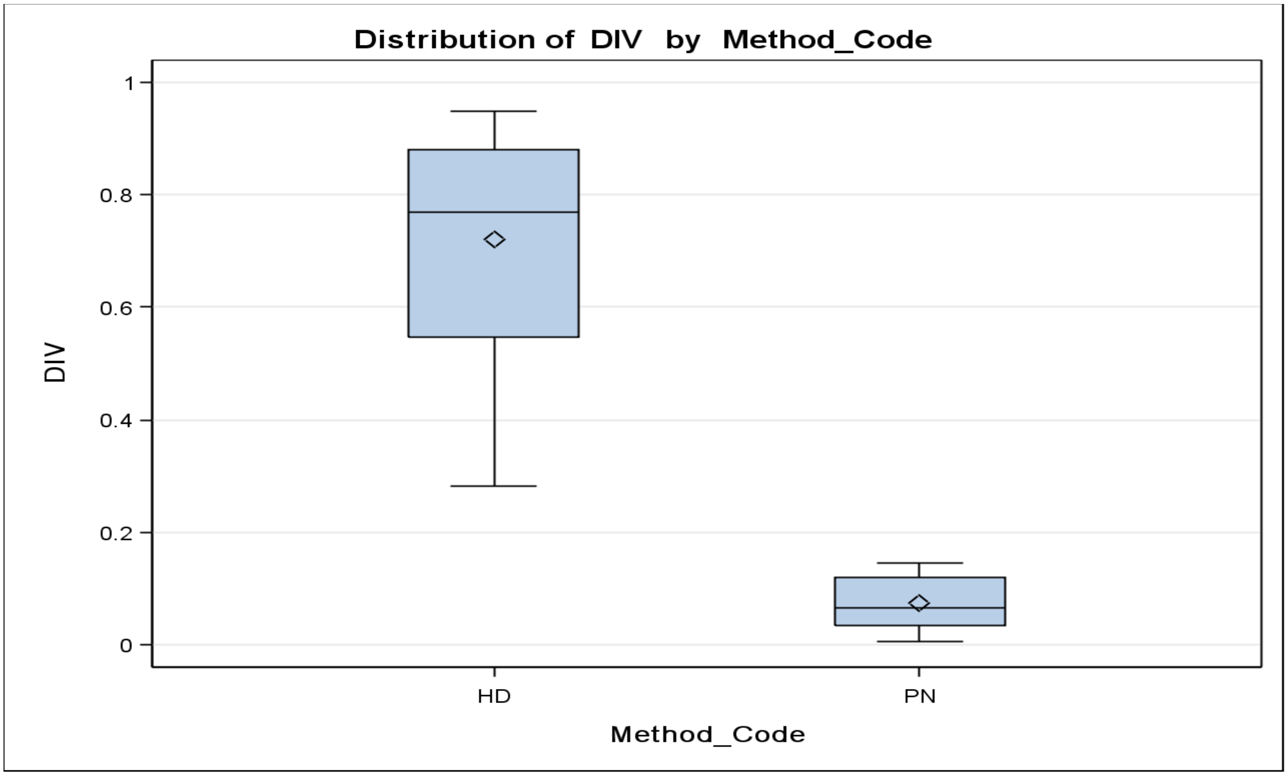


Figure A3. 1 Box-and-whiskers plot of Shannon Diversity Index at AWQM92, Chicago Sanitary and Ship Canal at Lockport, by Collection Method.

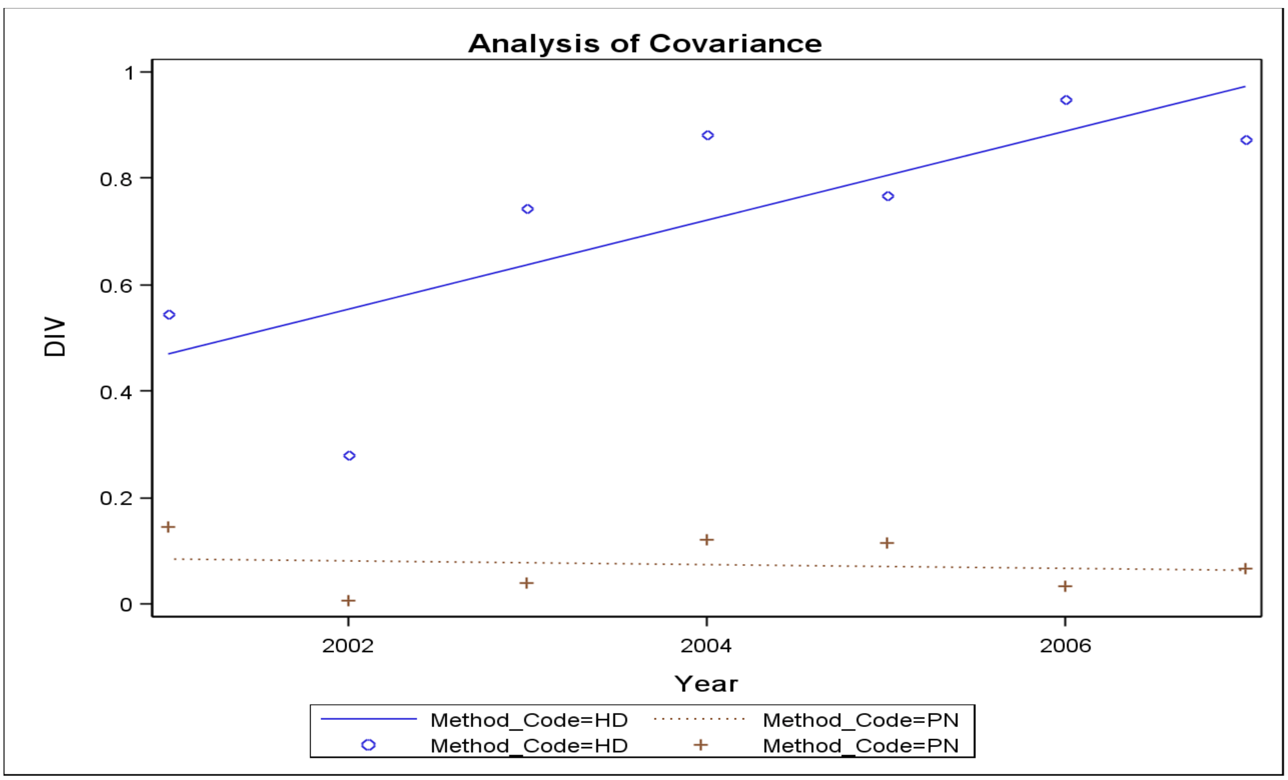


Figure A3. 2 Plot of Shannon Diversity Index at AWQM92, Chicago Sanitary and Ship Canal at Lockport, by Collection Method, 2001 through 2007.

4. When the interaction term was negligible, we removed it from the model and ran the ANCOVA and computed least square means (LSMeans) for the metric for each collection method, adjusting for the covariate.

Table A3.1 provides a summary of the ANCOVA modeling for eight annually-monitoring AWQM stations.

North Shore Channel at Touhy Avenue

North Shore Channel at Touhy Avenue, AWQM 36, is just downstream of the North Side Water Reclamation Plant discharge. Five metrics were found to be normally distributed at AWQM 36 and were tested using the ANCOVA approach described above. Four community-level metrics (RICH, DIV, PER_OLIG, and PER_DIP) and one functional group metric, FFG_DIV, were tested. No trends in these metrics over the 7 year study period were found to be significant. But, for all metrics, the method used to collect the sample appears to be measuring a different population of macroinvertebrates, that is, after accounting for the covariate, the metric mean for ponar samples is significantly different from hester-dendy samples ($p<0.05$). LSmeans for these metrics are given in Table A3.2.

Table A3.2
LEAST SQUARE MEANS FOR 5 METRICS AT AWQM 36

Metric	Hester-Dendy LSMean	Ponar LSMean
RICH	16.1	10.9
DIV	0.59	0.14
PER_OLIG	47.8	92.8
PER_DIP	21.9	4.1
FFG_DIV	0.31	0.08

North Branch Chicago River at Grand Avenue

North Branch Chicago River at Grand Avenue, AWQM 46, is downstream of Goose Island and upstream of the confluence with the Chicago River. At AWQM 46, we found that the total number of individuals in a sample, TNI, to be poorly influenced by the collection method, but to have a significant annual trend. Combining the methods, mean TNI in samples collected at AWQM 46 is 28,558 per square meter, and this mean is decreasing each year (slope = -6,615, $p=0.0282$). Given that most of the organisms in samples from this station are oligochaetes, and many oligochaetes are indicators of organic pollution (e.g. Tubificidae, but the oligochaetes have not been identified below the Order level) this may suggest improved water quality during the study period.

Two other metrics, RICH, and FFG_DIV at AWQM 46 have significant annual trends, but the collection method is a significant factor in calculating means. Both of these metrics show increasing values over the study period, again suggesting improved environmental conditions. LSMeans are given in Table A3.3. The metric DIP_RICH has no annual trend, but the sample collection method is a significant factor in determining the mean.

SUMMARY OF ANALYSES OF COVARIANCE (ANCOVA)

Station_Description	Station_ID	Dependent Variable	Method_Code ANOVA p-value	'Method'x'Year' p-value	Residual Diagnostics	'Year' p-value	'Method_Code' p-value	H-D LSMean	Ponar LSMean
North Shore Channel at Touhy Avenue	AWQM36	RICH	0.0300	0.1886	Random, normal	0.0894	0.0206	16.1	10.9
North Shore Channel at Touhy Avenue	AWQM36	DIV	<0.0001	0.1400	Random, normal	0.3740	<0.0001	0.59	0.14
North Shore Channel at Touhy Avenue	AWQM36	PER_OLIG	<0.0001	0.9146	Random, normal	0.6687	<0.0001	47.8	92.8
North Shore Channel at Touhy Avenue	AWQM36	PER_DIP	0.0022	0.1715	Random, normal	0.3263	0.0025	21.9	4.1
North Shore Channel at Touhy Avenue	AWQM36	FFG_DIV	0.0001	0.0903	Random, normal	0.7058	0.0002	0.31	0.08
North Branch Chicago River at Grand Avenue	AWQM46	TNI	0.7663	0.7434	Random, normal	0.0351	0.7261	26,578	30,538
North Branch Chicago River at Grand Avenue	AWQM46	RICH	0.0023	0.0680	Random, normal	0.0391	0.0009	12.7	5.6
North Branch Chicago River at Grand Avenue	AWQM46	DIV	0.0003	0.0014	Heteroskedacity present				
North Branch Chicago River at Grand Avenue	AWQM46	DIP_RICH	0.0134	0.1396	Random, normal	0.1962	0.0120	5.7	2.3
North Branch Chicago River at Grand Avenue	AWQM46	PER_OLIG	0.0015	0.0297	Heteroskedacity present				
North Branch Chicago River at Grand Avenue	AWQM46	CG	0.0069	0.0369	Heteroskedacity present				
North Branch Chicago River at Grand Avenue	AWQM46	PRED	0.0018	0.2587	Heteroskedacity present				
North Branch Chicago River at Grand Avenue	AWQM46	PER_DIP	0.0002	0.0444	Heteroskedacity present				
North Branch Chicago River at Grand Avenue	AWQM46	FFG_DIV	0.0003	0.0670	Random, normal	0.0366	<0.0001	0.17	0.03
Chicago Sanitary and Ship Canal at Cicero Avenue	AWQM75	RICH	0.0010	0.1737	Random, normal	0.1908	0.0009	11.3	4.1
Chicago Sanitary and Ship Canal at Cicero Avenue	AWQM75	DIV	0.0120	0.0025	Random, normal	0.0456	0.0057	0.38	0.10
Chicago Sanitary and Ship Canal at Cicero Avenue	AWQM75	DIP_RICH	0.0012	0.7744	Random, normal	0.6184	0.0018	4.3	1.4
Chicago Sanitary and Ship Canal at Cicero Avenue	AWQM75	PER_OLIG	0.0197	0.0169	Heteroskedacity present				
Chicago Sanitary and Ship Canal at Cicero Avenue	AWQM75	CG	0.0503	0.048	Heteroskedacity present				
Chicago Sanitary and Ship Canal at Cicero Avenue	AWQM75	FFG_DIV	0.0834	0.0174	Random, normal	0.1597	0.0725	0.18	0.08
Chicago Sanitary and Ship Canal at Harlem Avenue	AWQM41	DIV	0.0057	0.0161	Heteroskedacity present				
Chicago Sanitary and Ship Canal at Harlem Avenue	AWQM41	DIP_RICH	0.0034	0.4405	Random, normal	0.1307	0.0026	5.0	2.3
Chicago Sanitary and Ship Canal at Harlem Avenue	AWQM41	SHD	0.5017	0.9992	Not normal				
Chicago Sanitary and Ship Canal at Harlem Avenue	AWQM41	C_FPOM	0.5565	0.8733	Random, normal	0.9813	0.5741	0.0014	0.0020
Chicago Sanitary and Ship Canal at Harlem Avenue	AWQM41	PER_DIP	0.0089	0.0892	Random, normal	0.0604	0.0047	10.0	1.8
Chicago Sanitary and Ship Canal at Lockport	AWQM92	RICH	<0.0001	0.0486	Random, normal	0.1003	<0.0001	20.1	5.7
Chicago Sanitary and Ship Canal at Lockport	AWQM92	DIV	<0.0001	0.0228	Possible heteroskedacity	0.0758	<0.0001	0.72	0.07
Chicago Sanitary and Ship Canal at Lockport	AWQM92	DIP_RICH	0.0111	0.3907	Possible heteroskedacity	0.3042	0.0117	7.3	2.3
Chicago Sanitary and Ship Canal at Lockport	AWQM92	PER_OLIG	0.0002	0.0058	Possible heteroskedacity	0.0364	<0.0001	32.0	96.8
Chicago Sanitary and Ship Canal at Lockport	AWQM92	CG	0.0004	0.0302	Possible heteroskedacity	0.0583	0.0002	49.2	97.2
Chicago Sanitary and Ship Canal at Lockport	AWQM92	FFG_DIV	<0.0001	0.2447	Possible heteroskedacity	0.1662	<0.0001	0.34	0.05
Calumet River at 130th Street	AWQM55	TNI	0.0036	0.7394	Probable heterskedacity	0.7008	0.0055	179,500	6,041
Calumet River at 130th Street	AWQM55	RICH	0.6890	0.4750	Random, normal	0.7287	0.6916	9.8	10.4
Calumet River at 130th Street	AWQM55	DIP_RICH	0.1252	0.7022	Random, normal	0.8390	0.1461	4.0	6.3
Calumet River at 130th Street	AWQM55	PER_DIP	0.0073	0.7600	Possible heteroskedacity	0.7256	0.0107	0.7	5.5
Little Calumet River at Halsted Street	AWQM76	TNI	0.4739	0.1091	Probable heterskedacity	0.3326	0.4747	33,121	45,426
Little Calumet River at Halsted Street	AWQM76	RICH	0.0339	0.9185	Random, normal	0.0309	0.0155	18.6	11.1
Little Calumet River at Halsted Street	AWQM76	DIV	0.0003	0.6022	Random, normal	0.0544	0.0001	0.62	0.18
Little Calumet River at Halsted Street	AWQM76	DIP_RICH	0.3642	0.6320	Random, normal	0.1041	0.3279	7.0	5.1
Little Calumet River at Halsted Street	AWQM76	CG	<0.0001	0.1086	Heteroskedacity present				
Little Calumet River at Halsted Street	AWQM76	PRED	0.0009	0.2359	Heteroskedacity present				
Little Calumet River at Halsted Street	AWQM76	PER_DIP	0.0077	0.0130	Probable heterskedacity	0.0119	0.0017	19.8	3.3
Little Calumet River at Halsted Street	AWQM76	FFG_DIV	<0.0001	0.5157	Random, normal	0.1519	<0.0001	0.39	0.10
Calumet-Sag Channel at Cicero Avenue	AWQM59	RICH	<0.0001	0.2528	Random, normal	0.0018	<0.0001	19.0	7.4
Calumet-Sag Channel at Cicero Avenue	AWQM59	DIV	<0.0001	0.5394	Random, normal	0.0855	<0.0001	0.71	0.23
Calumet-Sag Channel at Cicero Avenue	AWQM59	DIP_RICH	0.0010	0.3857	Random, normal	0.0191	0.0002	8.7	3.3
Calumet-Sag Channel at Cicero Avenue	AWQM59	CG	0.0273	0.1315	Possible heteroskedacity	0.4959	0.0317	63.5	86.5
Calumet-Sag Channel at Cicero Avenue	AWQM59	PRED	0.7906	0.1907	Random, normal	0.2622	0.7877	8.5	9.6
Calumet-Sag Channel at Cicero Avenue	AWQM59	PER_DIP	0.0019	0.0759	Random, normal	0.0054	0.0002	44.3	10.9
Calumet-Sag Channel at Cicero Avenue	AWQM59	FFG_DIV	0.0152	0.4266	Random, normal	0.7748	0.0200	0.34	0.17

Blue rows indicate that 'Year' is a significant factor for predicting a metric at a station, but collection method is not important.

Red rows indicate that neither collection method nor 'Year' is significant.

Table A3.3
LEAST SQUARE MEANS FOR THREE METRICS AT AWQM 46

Metric	Hester-Dendy LSMean	Ponar LSMean
RICH	12.7	5.6
DIP_RICH	5.7	2.3
FFG_DIV	0.17	0.03

Chicago Sanitary and Ship Canal at Cicero Avenue

Chicago Sanitary and Ship Canal at Cicero Avenue, AWQM 75, is just upstream of the Stickney Water Reclamation Plant discharge. Two community-level metrics, RICH and DIP_RICH, showed similar patterns; there are no significant trends in these metrics over the 7 year study period. But, for both metrics, the method used to collect the sample is an important and significant, factor. In other words, the metric mean for ponar samples is significantly different from hester-dendy samples ($p<0.05$). LSmeans for these metrics are given in Table A3.4.

Table A3.4
LEAST SQUARE MEANS FOR TWO METRICS AT AWQM 75

Metric	Hester-Dendy LSMean	Ponar LSMean
RICH	11.3	4.1
DIP_RICH	4.3	1.4
DIV	0.38	0.10

The model of Shannon Diversity Index, DIV, at AWQM 75 indicates significant annual and collection method factors ($p<0.05$). Further, the coefficients in the regression lines are not equivalent, suggesting that the annual trends differ by collection method (Figure A3.3). DIV as measured by the hester-dendy method has a significant increasing trend (slope=+0.1 per year, $p=0.0045$), whereas the ponar data has no significant slope over the time period being studied ($p=0.6946$).

Chicago Sanitary and Ship Canal at Harlem Avenue

Chicago Sanitary and Ship Canal at Harlem Avenue, AWQM 41, is just downstream of the Stickney Water Reclamation Plant discharge. At this monitoring station, DIP_RICH and PER_DIP had no significant trends over the study period, but the method used to collect the sample appears to be a significant factor in evaluation of these metrics. The means for ponar samples are significantly different from hester-dendy samples ($p<0.05$). LSmeans for these metrics are given in Table A3.5. The functional group metric C_FPOM is insensitive to collection method and has no temporal trend.

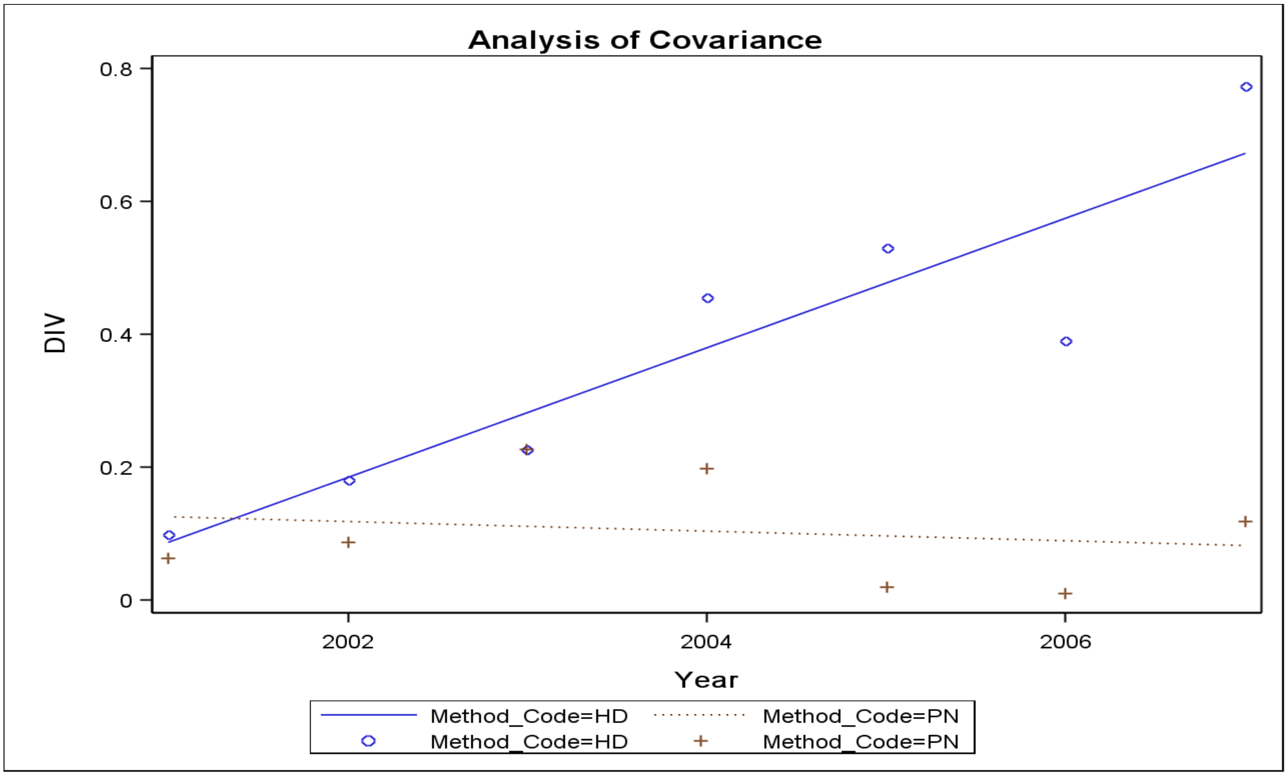


Figure A3. 3 Plot of Shannon Diversity Index (DIV) at AWQM 75, Chicago Sanitary and Ship Canal at Cicero Avenue, By Collection Method, 2001 through 2007

Table A3.5
LEAST SQUARE MEANS FOR TWO METRICS AT AWQM 41

Metric	Hester-Dendy LSMean	Ponar LSMean
DIP_RICH	5.0	2.3
PER_DIP	10.0	1.8

Chicago Sanitary and Ship Canal at Lockport

Chicago Sanitary and Ship Canal at Lockport, AWQM 92, is the most downstream monitoring point before the CAWS joins the Des Plaines River. Only one metric, RICH, was amenable to ANCOVA without more involved remedial measures to stabilize residual variance. The ‘Method’x’Year’ term is significant (p=0.0486), suggesting that the regression coefficients for the two collections methods are not equivalent (Figure A3.2). Similar to our observation at the upstream stations near Stickney, AWQM 41 and AWQM 75, DIV as measured by the hester-dendy method has a significant increasing trend (slope=+0.1 per year, p=0.0418). Conversely the ponar data shows no significant slope over the time period being studied (p=0.7351).

Calumet River at 130th Street

Calumet River at 130th Street, AWQM 55, is upstream of the Calumet Water Reclamation Plant discharge and downstream of SEPA No. 1. Two of the metrics examined here, RICH and DIP_RICH, are insensitive to collection method, and, have no temporal trend over the 7-year study period. Two other metrics have probable or possible heteroskedacity, so their conclusions should be viewed with caution: TNI and PER_DIP have no trends over time, and, metric means are dependent upon the collection method. LSMeans for TNI and PER_DIP at AWQM 55 are tabulated below.

Table A3.6
LEAST SQUARE MEANS FOR TWO METRICS AT AWQM 55

Metric	Hester-Dendy LSMean	Ponar LSMean
TNI	179,500	6,041
PER_DIP	0.7	5.5

Little Calumet River at Halsted Street

Little Calumet River at Halsted Street, AWQM 76, is just downstream of the Calumet Water Reclamation Plant discharge. At AWQM 76, we found that the total number of individuals in a sample, TNI, and dipteran richness, DIP-RICH to be poorly influenced by the collection method and lacked any annual trend. Combining collection methods and years, mean TNI in samples collected at AWQM 76 is 39,273 per square meter and mean DIP_RICH is 6.1.

Annual trends are significant at AWQM 76 in two metrics: RICH and PER_DIP, the latter having unequal slopes for the two collection methods. The method of collection is an important factor in mean RICH and mean PER_DIP. There is a significant increase in RICH as measured by either method (Figure A3.4); the regression lines for the two collection methods have equal slopes (p=0.9185). PER_DIP likewise shows an increasing annual trend (Figure A3.5), but the slopes of the regression lines for the two collection methods are not equal (p=0.0130), and only the hester-dendy method shows a trend statistically different from zero. Table A3.7 includes LSMeans for these two metrics.

Annual trends are not significant in DIV or FFG_DIV. The method of sample collection however is a significant factor in estimating these two metrics. LSMeans for DIV or FFG_DIV are included in Table A3.7.

Table A3.7
LEAST SQUARE MEANS FOR FOUR METRICS AT AWQM 76

Metric	Hester-Dendy LSMean	Ponar LSMean
RICH	18.6	11.1
PER_DIP	19.8	3.3
DIV	0.62	0.18
FFG_DIV	0.39	0.10

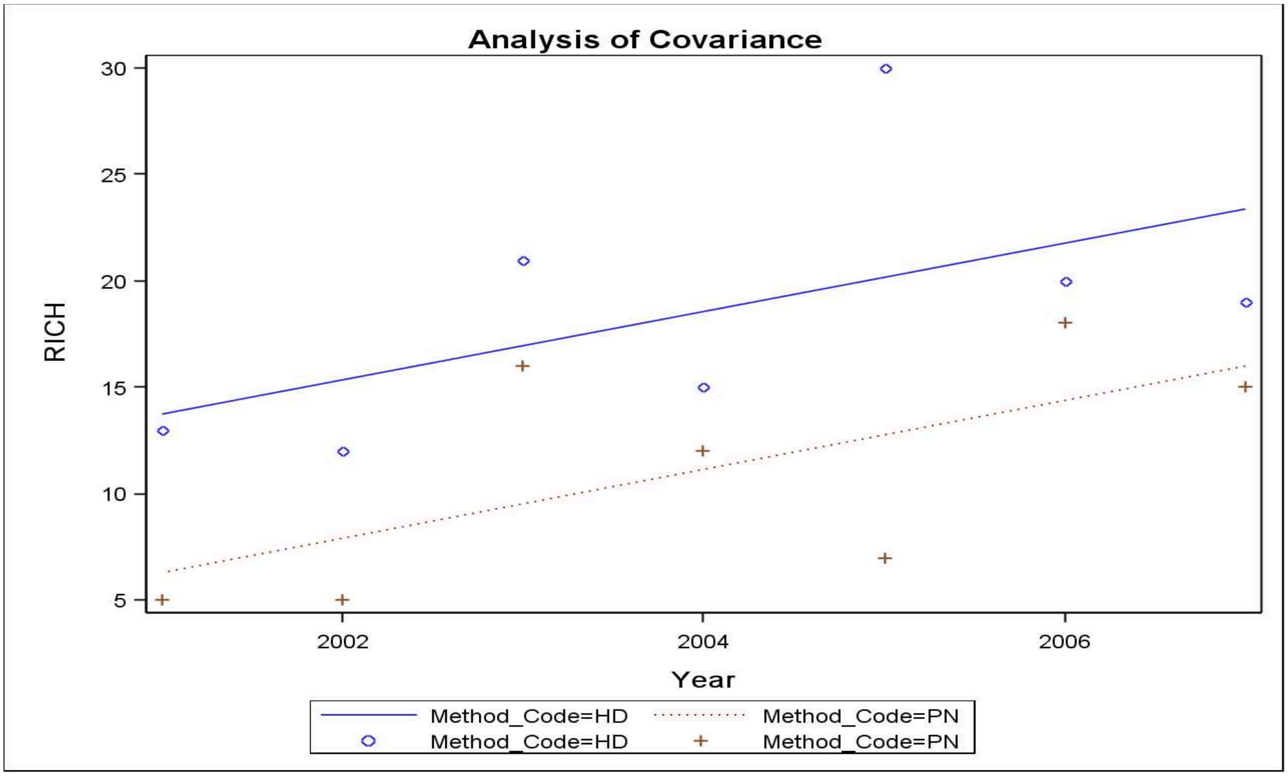


Figure A3. 4 Plot of Taxa Richness (RICH) at AWQM 76, Little Calumet River at Halsted Street, By Collection Method, 2001 through 2007

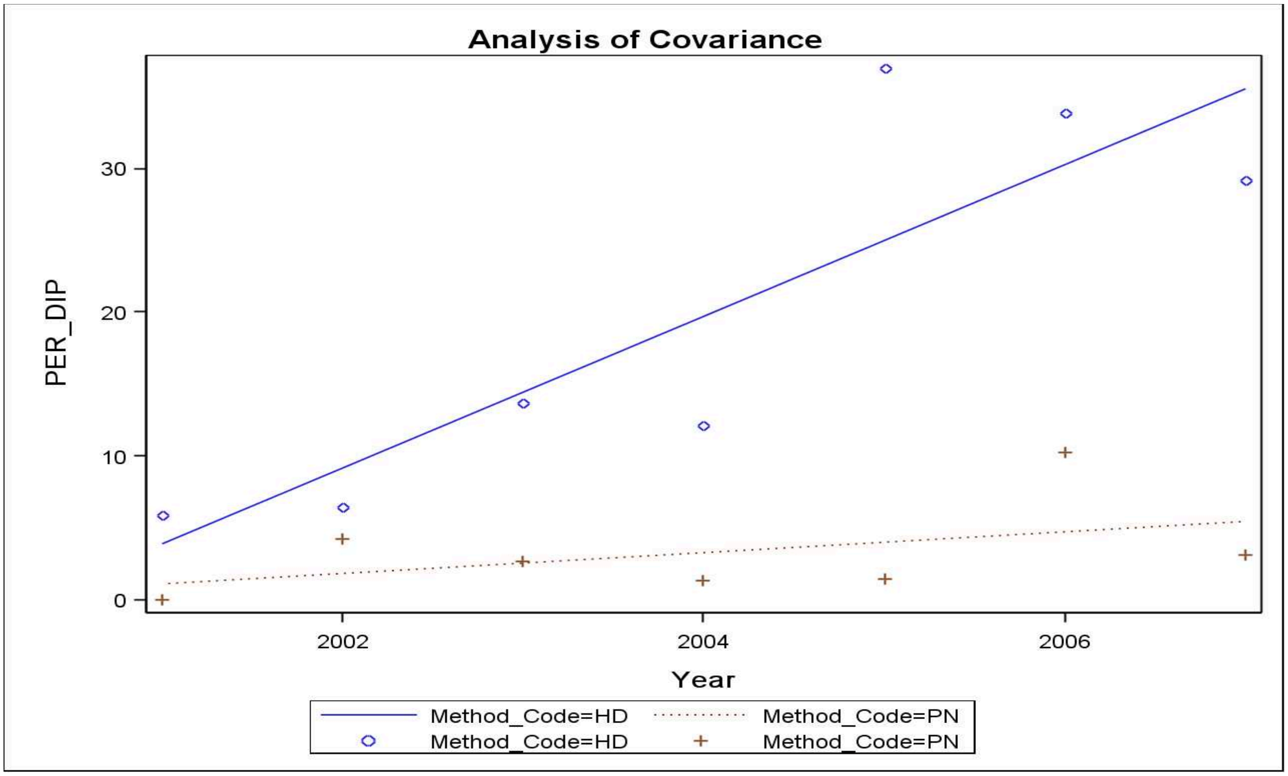


Figure A3. 5 Plot of Percent Dipterans (PER_DIP) at AWQM 76, Little Calumet River at Halsted Street, By Collection Method, 2001 through 2007

Cal-Sag Channel at Cicero Avenue

Cal-Sag Channel at Cicero Avenue is identified as AWQM 59 by the District. It is well downstream of the Calumet Water Reclamation Plant discharge. The metrics RICH, DIP_RICH, and PER_DIP have significant positive trends (equal slopes), suggesting improved water quality conditions. These metrics vary with sample collection method. LSMeans are tabulated below.

Shannon Diversity (DIV), Collector-gatherers (CG), and FFG_DIV showed no significant trend over the study period. The method of sample collection is, however, a significant factor, and mean metrics are different depending upon the technique used to collect the sample. LSMeans are tabulated below.

The metric percent predators, PRED, is poorly influenced by the collection method and lacked any annual trend. Combining collection methods and years, mean PRED in samples collected at AWQM 59 is 9.0.

Table A3.8
LEAST SQUARE MEANS FOR FIVE METRICS AT AWQM 59

Metric	Hester-Dendy LSMean	Ponar LSMean
RICH	19.0	7.4
DIP_RICH	8.7	3.3
PER_DIP	44.3	10.9
DIV	0.71	0.23
FFG_DIV	0.34	0.17

ITEM 6

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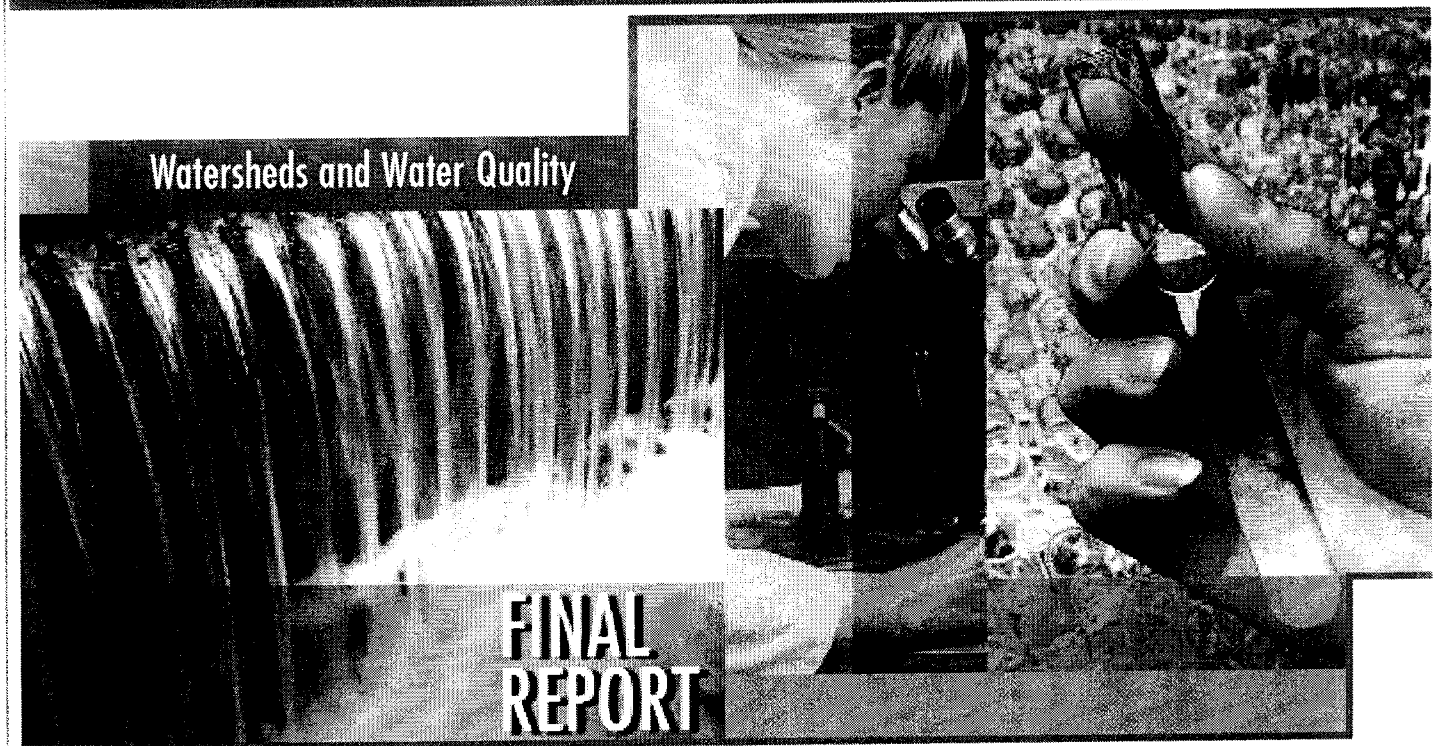

FINAL REPORT

Factors for Success in Developing Use Attainability Analyses

Co-published by
IWA Publishing

- Open-water fish and shellfish designated use;
- Deep-water seasonal fish and shellfish designated use; and
- Deep-channel seasonal refuge designated use.

Different DO, chlorophyll *a* and water clarity criteria were derived to specifically support these individual designated uses and were given temporal application. For example, open-water fish and shellfish use applies all year round, whereas migratory fish spawning and nursery use specific criteria apply from February 1 through May 31 (R-5).

The Chesapeake Bay UAA was conducted with the intention of adopting consistent, attainable standards across the four jurisdictions sharing the Bay's tidal waters, providing a common, scientifically based definition of restored Bay water quality (S&T-1, S&T-5, PA-1). This was successfully accomplished.

The cost of this 3-year UAA effort was nearly one million dollars, not considering the multi-million dollar monitoring and modeling effort that had preceded and supported this UAA (F-4). The key factors leading to the success of this UAA were the extensive and early involvement of and outreach to stakeholders, agencies and communities throughout the watershed (S&T-1, L-5, R-3, R-4, and PA-1). The application of the watershed and hydrodynamic/water quality models, and the use of a unique technology (paleoecological record review), supported definition of natural conditions and the determination that current uses were not attainable (S&T-4).

5.4 Cuyahoga River Ship Channel

The Cuyahoga River is located in Northeast Ohio and empties into Lake Erie. Throughout most of the last century the Cuyahoga River (Figure 5-4) has been plagued with high-profile pollution, having caught fire several times before the inception of the Clean Water Act in 1972. In the lower reach of the Cuyahoga River is the commercial Cuyahoga Ship Channel, which plays an important role in the economy of Cleveland, Ohio. Because of its pollution problems, U.S. EPA classified the lower reaches of the Cuyahoga River as one of 43 Great Lakes Areas of Concern.

The Cuyahoga River Ship Channel's history of human impact has left it extremely low in DO levels. Without forfeiting its use as a navigable ship channel, the Cuyahoga River Ship Channel is incapable of supporting a warmwater habitat aquatic life use designation year round. Ohio EPA, together with the Cuyahoga Remedial Action Plan (RAP) Coordinating Committee, conducted a UAA to appropriately assign an aquatic life use to the channel (S&T-1). The end result was a site-specific partial use designation and corresponding water quality criterion that recognized both the existing use of the channel for commercial shipping and its seasonal use by migratory fish.

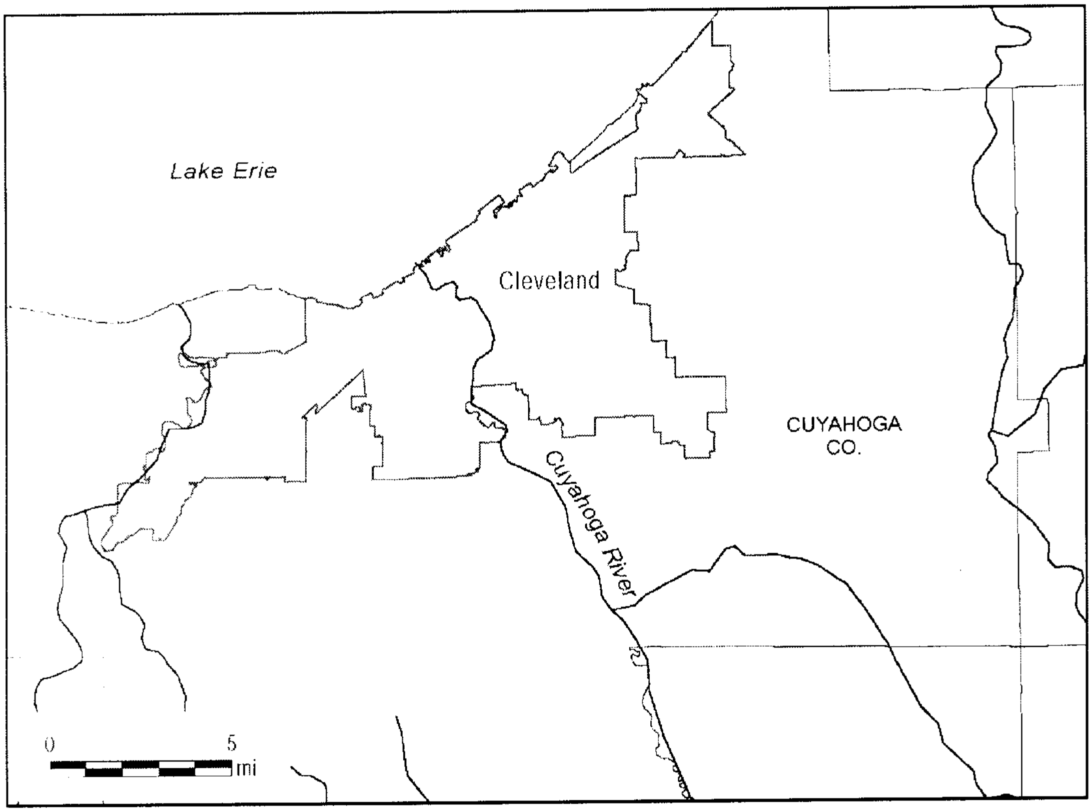

Figure 5-4. Cuyahoga River Study Area.

5.4.1 Background

During the 1970s, Ohio EPA temporarily designated some of its most polluted waterways as limited warmwater habitat use. The limited warmwater habitat use has less stringent criteria than the warmwater habitat use assigned to healthier waters. It was the intent of Ohio EPA to reassign these waters to a more appropriate use (e.g., warmwater habitat) after federal grant monies were made available to better treat the sources of pollution (i.e., wastewater treatment plants). When the grant money came in, most waterbodies (but not the Cuyahoga River) were upgraded to higher uses through the UAA process. In fact, this reassessment of waterbodies designated with the limited warmwater habitat use was the impetus for what has evolved to be a very efficient and well-defined rule making process for UAAs in Ohio. Ohio's streamlined process uses biocriteria to classify tiered aquatic life uses (R-1). Further discussion on Ohio's approach is provided in Chapter 6.0.

Unfortunately, the Cuyahoga River Ship Channel was overlooked and was never reassessed for its appropriate aquatic life use. Finally, after strong encouragement from U.S. EPA, Ohio EPA moved forward with a UAA to determine the channel's appropriate use.

5.4.2 Conducting the UAA

Ohio EPA developed the Cuyahoga RAP Coordinating Committee to oversee the remedial activities of the Cuyahoga River, including the Cuyahoga Ship Channel UAA process (L-5). The Cuyahoga RAP Coordinating Committee is made up of a 33-member task force including local, state, and federal agencies, business and industry representatives, and community interest groups. The RAP process was developed as part of the Great Lakes Water

Quality Agreement (1985) between Canada and the United States to restore the designated uses of the Areas of Concern.

Together, the Cuyahoga RAP Coordinating Committee and Ohio EPA studied the Cuyahoga River Ship Channel: historical records were assessed; the Army Corps of Engineers conducted fish surveys; and hydraulic studies, benthic surveys, fish electroshocking, and field surveys were conducted. From these studies, it was clear that the Channel habitat was stressed because of low DO levels (i.e., DO occasionally reached 1 mg/l and lower). The studies also discovered that during the spring months when flows were higher, the channel is used by fish as a migratory route. Therefore, careful consideration was needed to protect this aquatic life resource.

Ohio EPA led the effort to determine what it would take to get the channel to meet the Warmwater Habitat use (24-h average DO = 5 mg/l; minimum DO = 4 mg/l) by extensively modeling the Cuyahoga River Ship Channel using the Water Quality Analysis Simulation Program (WASP4; version 4; Ambrose et al., 1988) model (S&T-4). The results of the modeling effort were that the 23-foot deep, slow-moving channel (the retention time for the 5.6-mile course is about 10 days) would need to be decreased to a river depth of twelve feet to achieve the DO criteria. However, at this shallow depth the channel would not be able to be used for commercial shipping. The modeling results also showed that it would not be possible to restore the ship channel to conditions similar to other Lake Erie River mouths because of considerable human-induced alteration that already existed.

In addition to the modeling, a simple cost-benefit analysis was developed to understand the consequences of eliminating the channel. The results of the cost-benefit analysis made it clear that the two major steel companies that employed thousands of locals and other smaller businesses would be devastated if the ship channel were to be eliminated (S&T-5).

Because of the obvious impracticability of removing deep-water navigation from the channel, Ohio EPA proposed a new use based on Factor 3 (human caused conditions or sources of pollution prevent the attainment of the use) (F-1). Public outreach efforts and the involvement of the Cuyahoga RAP Coordinating Committee from the beginning and throughout the entire process, together with the partnership Ohio EPA had forged with the committee, led to a relatively smooth and noncontroversial UAA process.

5.4.3 Resolution

The finding that "irretrievable human induced conditions" [Ohio Administrative Code (OAC) 3745-1-26] precluded the attainment of the warmwater habitat use, together with the fact that the channel is a migratory fish passage in the spring, required that a special use designation for the Cuyahoga Ship Channel be developed that addressed the existence of both of these conditions. The final aquatic life use designation for the Cuyahoga River Ship Channel is as follows:

- During the months of June through January, when river flow is low, the use shall be limited resource water – navigation maintenance; and
- During the months of February through May, when the river flow is high, the use shall be fish passage. Fish passage is defined as "rivers and or other waterbodies that have been the subject of use attainability analysis and have been found to be incapable of supporting and maintaining a balanced, integrated, adaptive community

of water organisms but are capable of supporting the passage of warmwater fish during migratory periods."

A new criterion also had to be developed that supported the new use. From the studies and the modeling, it was found that the DO level that supported the existing condition of the ship channel was a minimum DO of 1.5 mg/l during June through January, and during the remaining months of the year whenever the river flow is less than 703 cubic feet per second. During the months of February through May whenever the river flow equals or exceeds 703 cubic feet per second, the criteria are the same as the warmwater habitat criteria (24-h average DO = 5 mg/l; minimum DO = 4 mg/l), with the exception that the biological criteria do not apply.

While establishing the new use and criteria for the Cuyahoga River Ship Channel, it was fully recognized that the DO criteria would not always be met. Consequently, the Cuyahoga RAP Coordinating Committee was held responsible for utilizing the TMDL approach to progress towards attainment of the DO criteria (S&T-6). As recognized by Ohio rules (OAC 3745-1-26), the TMDL approach must be used to enhance the DO of the ship channel "through means other than additional point and nonpoint source load reductions." Therefore, the Cuyahoga RAP Coordinating Committee is now working on alternatives such as implementing off channel re-aeration, sediment remediation, and flow augmentation to raise DO levels in the ship channel.

The Cuyahoga River Ship Channel flows through the heart of Cleveland, Ohio. Many people have a special interest in the fate of the channel, yet each person's interest is not the same. Without the support and coordination of the Cuyahoga RAP Coordinating Committee, which included 33 members representing stakeholders from business and industry, watershed and community groups, and regulatory agencies, this process could have been dead before it even started (PA-1). With everyone at the table from the beginning, the interests of all parties have been addressed in a conciliatory process (PA-4).

5.5 Spokane River

The Spokane River UAA (Figure 5-5) was initiated by a consortium of nine municipal and industrial dischargers. These parties were facing a Washington Department of Ecology ("Ecology") TMDL process that was heading in a direction that would require the dischargers to remove all their discharges from the river during the June through October time period (S&T-6, PA-6). Preliminary estimates of $700M to $1B for all point sources to comply with this requirement was a major driver for the UAA (PA-6), but the sponsors also believed that the water quality standards that the TMDL was trying to achieve were not appropriate or attainable. This is a useful case study because it reinforces most of the findings and recommendations of this WERF research project.

5.5.1 Background

The UAA was initiated in early 2003 by nine sponsors, consisting of local industrial and municipal dischargers to the Spokane River from the Lake Coeur d'Alene outlet in Idaho to Long Lake Reservoir Dam in Washington (see Figure 5-5). The need for the dischargers to "get out of the river" from Ecology's perspective was primarily driven by the aquatic life designated uses and associated D) criteria, one of which was that the cumulative effect of dischargers cannot cause the DO concentration to decrease by more than 0.2 mg/l in lakes and reservoirs, including in the lower layer in a stratified reservoir like Long Lake Reservoir (F-5, PA-6). Because Ecology's model predicted that the cumulative effect of the dischargers would violate these

ITEM 7

Information Request No. 7 – Revised Cyanide Calculations Excluding Brook Trout

Chairman Girard requested that MWRD calculate the Criterion Continuous Concentration (CCC) or chronic cyanide standard, excluding not only rainbow trout, but brook trout as well. Both are coldwater fish species that would not be able to live in the CAWS. The next most cyanide sensitive fish species according to USEPA guidance document references would be the largemouth bass. Including the largemouth bass and black crappie and excluding the rainbow trout and brook trout, the chronic cyanide standard would be 10.9 µg/L. In comparison, the General Use chronic cyanide water quality standard in 5.2 µg/L and the site specific standard for most General Use waterways in Cook County is 10 µg/L.

ITEM 8

Devon and Webster Instream Aeration Stations (IAS) Operation Procedure

Operation of the instream aeration stations (IASs) is generally based on DO in the NSC and NBCR determined by the M&O DO monitoring stations in those waterways. When the DO at certain station reach trigger levels (below), blowers are started until the maximum number of blowers (3) are in service. Devon IAS operation is based on the DO at NBPS and Webster IAS operation is based on DO at Ohio St. Additionally, after a CSO discharge at NBPS both IASs are run for 24 hours at maximum output (3 blowers). During times when conditions do not dictate blower operations, each station is run for 1 hour each night to attempt to keep the plate diffusers from getting fouled.

For both stations, Webster controlled by Ohio St. DO, Devon controlled by NBPS DO:
All blowers off when DO > 5.5
One (1) blower i/s when DO < 5.5
Two (2) blowers i/s when DO < 5.0
Three (3) blowers i/s when DO < 4.5

Also, if three blowers are required at Webster then Devon follows this plan:
One blower i/s when DO at NBPS is <7.5
Two blowers i/s when DO at NBPS is < 6.5
Three blowers i/s when DO at NBPS is < 6.0

April through October, three (3) blower i/s for 24-hours after a diversion at NBPS.

Instream Aeration Station Operation Summary for May 1 to October 31, 2005

Aeration Station	Hourly Average Number of Blower in Operation	Operating Hours			
		Number of Blowers in Service			
		(0)	(1)	(2)	(3)
Webster	1.74	1010	687	1156	1563
Devon	1.29	1473	1158	798	987

Date	Time	SEPA 1								SEPA 2							SEPA 3								SEPA 4									SEPA 5									Lockport			
		Pumps				D.O. Probes				Pumps		U.W.		D.O. Probes			Pumps				D.O. Probes				Pumps					D.O. Probes				Pumps					D.O. Probes				D.O. Probes			
		1	2	3	4	1	2	3	Avg	1	2	1	2	1	2	Avg	1	2	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	Avg
4/2/09	7:00AM						comm fail			✓		✓		7.8	7.8	7.8	Out of Service				5.2	3.7	4.3	4.4	✓					6.6	5.8	4.9	5.8	✓						comm fail				comm fail		
4/3/09	7:00AM		✓				comm fail			✓		✓		7.2	7.1	7.2					6.9	5.2	5.9	6.0	✓					6.5	5.8	5.3	5.9	✓					4.2	6.6	6.0	5.6		comm fail		
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4/7/09	7:00AM															0.0								0.0									0.0									0.0				0.0
4/8/09	7:00AM		✓			10.0				✓		✓		9.3	10.0	9.7					4.7	4.9	7.1	5.6	✓					10.0	10.0	6.8	8.9	✓					10.0			10.0		comm fail		
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4/10/09	7:00AM		✓			10.0				✓		✓		8.2	9.9	9.1					4.6	3.7	4.2	4.2	✓					8.6	9.0	5.6	7.7	✓							9.8	9.8		comm fail		
4/13/09	7:00AM		✓		.	11.7				✓		✓		8.0	10.0	9.0					4.2	5.3	5.0	4.8	✓					8.7	9.3	5.4	7.8	✓					6.9	8.9	8.4	8.1	7.2	5.6		6.4
4/14/09	7:00AM		✓			11.7				✓		✓		7.9	9.9	8.9					4.0	5.1	4.2	4.4	✓					8.3	9.5	5.6	7.8	✓					6.8	8.4	8.0	7.7		comm fail		
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4/17/09	7:00AM		✓			9.6				✓		✓		9.0	9.9	9.5					3.7	3.4	3.7	3.6	✓					7.7	8.4	4.6	6.9	✓					7.0	8.0	8.0	7.7		comm fail		
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4/21/09	7:00AM		✓	✓		2.7				✓		✓		10.0	9.6	9.8					3.5	3.0	2.7	3.1	✓					7.6	7.7	3.0	6.1	✓					9.5	7.5	7.6	8.2		comm fail		
4/22/09	7:00AM		✓	✓		2.5				✓	✓	✓		10.0	9.7	9.9					3.4	3.4	2.5	3.1					✓	7.2	7.6	4.2	6.3		✓				9.4	7.6	7.6	8.2		comm fail		
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4/27/09	7:00AM			✓		6.2				✓				10.0	9.4	9.7					3.0	2.8	3.1	3.0					✓	6.1	6.3	2.9	5.1			✓			9.5	6.5	6.2	7.4		comm fail		
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4/30/09	7:00AM			✓		7.4				✓				10.0	8.7	9.4					2.4	1.9	1.6	2.0					✓	6.3	6.6	4.0	5.6			✓			10.0	6.4	6.2	7.5		comm fail		
5/1/09	7:00AM			✓		7.3				✓				9.5	9.1	9.3	Out of Service				2.8	2.6	3.2	2.9					✓	5.0	5.5	2.2	4.2			✓			10.0	6.4	6.4	7.6		comm fail		
5/4/09	7:00AM			✓		7.6				✓			✓	9.4	8.9	9.2	✓				5.3	4.7	4.8	4.9					✓	5.0	5.5	1.9	4.1				✓		10.0	6.3	6.1	7.5	2.7	4.5	5.4	4.2
5/5/09	7:00AM			✓		6.2				✓			✓	9.4	8.8	9.1	✓				7.3	6.3	7.2	6.9					✓	5.8	5.9	5.6	5.8				✓		8.6	6.2	6.2	7.0	2.1	3.4	4.1	3.2

Date	Time	SEPA 1								SEPA 2							SEPA 3								SEPA 4									SEPA 5									Lockport			
		Pumps				D.O. Probes				Pumps		U.W.		D.O. Probes			Pumps				D.O. Probes				Pumps					D.O. Probes				Pumps					D.O. Probes				D.O. Probes			
		1	2	3	4	1	2	3	Avg	1	2	1	2	1	2	Avg	1	2	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	Avg
5/6/09	7:00AM			✔		5.9				✔			✔	9.2	8.6	8.9	✔				7.2	6.0	7.2	6.8					✔	5.8	5.9	5.6	5.8				✔		8.6	6.2	6.2	7.0	comm fail			
5/7/09	7:00AM			✔		6.0				✔			✔	9.0	8.5	8.8	✔				7.4	6.5	6.5	6.8					✔	5.4	5.5	4.9	5.3				✔		8.1	5.8	5.5	6.5	comm fail			
5/8/09	7:00AM			✔		5.9				✔			✔	9.2	8.6	8.9	✔				7.4	6.2	6.5	6.7					✔	5.6	5.7	5.0	5.4				✔		7.2	4.3	4.5	5.3	comm fail			
5/11/09	7:00AM		✔			5.6				✔			✔	9.4	8.8	9.1	✔				4.8	5.0	5.2	5.0					✔	5.4	5.6	4.8	5.3				✔		8.3	5.4	5.7	6.5	comm fail			
5/12/09	7:00AM		✔			5.6				✔			✔	8.0	7.7	7.9	✔				5.4	5.5	5.2	5.4					✔	6.1	6.8	5.9	6.3				✔		8.1	5.6	5.8	6.5	2.5	3.7	3.5	3.3
5/13/09	7:00AM		✔			5.3				✔				8.1	7.5	7.8	✔				5.3	6.1	5.3	5.6					✔	5.8	6.3	5.1	5.7				✔		9.9	6.2	6.8	7.6	comm fail			
5/14/09	7:00AM		✔			5.0				✔				7.6	7.5	7.6	✔				4.8	5.1	4.5	4.8					✔	5.6	5.1	4.3	5.0				✔		8.4	5.0	5.5	6.3	comm fail			
5/15/09	8:30AM		✔			5.1				✔		✔		8.6	8.0	8.3	✔				4.8	5.0	4.8	4.9					✔	5.0	4.8	3.7	4.5				✔		9.1	4.5	5.4	6.3	3.2	4.9	2.9	3.6
5/18/09	7:00AM		✔			5.2				✔		✔		9.0	8.8	8.9	✔				5.2	6.0	4.9	5.4					✔	5.5	5.4	3.5	4.8				✔		8.3	5.1	5.2	6.2	3.0	3.7	2.6	3.1
5/19/09	7:00AM		✔			7.6				✔		✔		8.7	8.1	8.4	✔				7.6	6.4	6.4	6.8					✔	5.9	5.4	5.2	5.5				✔		6.9	5.6	5.3	5.9	2.7	2.7	2.1	2.5
5/20/09	7:00AM		✔			7.8				✔		✔		8.0	7.4	7.7		✔			5.4	6.2	7.0	6.2					✔	5.9	5.4	5.1	5.5	✔					5.3	5.4	5.1	5.3	3.8	4.3	4.0	4.0
5/21/09	7:00AM		✔			7.9				✔		✔		8.4	7.7	8.1		✔			5.2	5.7	6.5	5.8					✔	5.7	5.7	5.1	5.5	✔					7.4	5.4	5.5	6.1	3.6	4.4	4.4	4.1
5/22/09	7:00AM		✔			7.9				✔		✔		7.0	6.3	6.7		✔			5.2	5.0	4.9	5.0					✔	5.2	5.0	4.9	5.0	✔					6.7	5.1	5.1	5.6	2.4	3.4	3.6	3.2
5/25/09	7:00AM					MEMORIAL DAY										0.0								0.0									0.0									0.0				0.0
5/26/09	7:00AM		✔			7.6				✔		✔		7.6	6.9	7.3		✔			5.4	6.0	6.2	5.9					✔	5.0	5.1	3.5	4.5	✔					6.5	4.7	4.3	5.2	3.0	4.6	3.0	3.5
5/27/09	7:00AM		✔			7.4				✔		✔		8.1	7.5	7.8		✔			5.3	5.6	6.6	5.8					✔	5.8	5.9	5.3	5.7	✔					6.9	5.4	5.8	6.0	4.6	4.2	4.1	4.3
5/28/09	7:00AM		✔			7.4				✔			✔	6.8	6.0	6.4		✔			4.3	4.3	5.5	4.7					✔	4.9	5.1	3.1	4.4	✔					6.5	5.4	5.8	5.9	3.4	3.3	3.3	3.3
5/29/09	7:00AM		✔			7.4				✔			✔	7.5	6.6	7.1		✔			4.4	4.3	5.7	4.8					✔	3.7	3.9	2.8	3.5	✔					6.4	5.4	5.8	5.9	1.9	2.1	2.3	2.1
6/1/09	7:00AM		✔			7.2				✔			✔	6.3	5.5	5.9	✔	✔			4.5	4.6	6.4	5.2					✔	3.9	4.1	3.3	3.8	✔	✔				6.8	5.4	5.8	6.0	1.2	3.2	3.3	2.6
6/2/09	7:00AM		✔			7.0				✔			✔	6.0	5.8	5.9	✔	✔			6.9	5.2	6.6	6.2					✔	3.9	4.1	3.3	3.8	✔	✔				5.8	5.4	5.8	5.7	1.8	3.2	3.0	2.7
6/3/09	7:00AM		✔			7.0				✔			✔	6.2	5.9	6.1	✔	✔			5.9	4.5	5.5	8.0					✔	4.6	4.8	3.5	4.3	✔	✔				4.9	5.4	5.8	5.4	1.7	3.3	3.1	2.7
6/4/09	7:00AM		✔			7.2				✔			✔	6.7	6.4	6.6	✔	✔			6.2	4.7	5.9	5.6					✔	4.6	4.9	3.2	4.2	✔	✔				5.6	5.9	5.8	5.8	2.9	3.2	3.3	3.1
6/5/09	7:00AM		✔			7.2				✔			✔	6.2	5.9	6.1	✔	✔			6.2	4.6	5.7	5.5					✔	4.8	4.7	3.5	4.3	✔	✔				5.9	5.4	5.8	5.7	1.9	3.2	2.9	2.7
6/8/09	7:00AM		✔			7.4				✔			✔	5.6	5.4	5.5	✔	✔			6.2	4.8	5.5	5.5					✔	4.6	4.8	3.7	4.4	✔	✔				5.6	5.4	5.8	5.6	2.0	3.1	2.5	2.5
6/9/09	7:00AM		✔			7.7				✔			✔	6.4	6.2	6.3	✔	✔			7.0	7.1	8.9	7.7					✔	6.3	6.4	4.8	5.8	✔			✔		6.5	5.4	5.8	5.9	1.8	2.5	1.9	2.1

Date	Time	SEPA 1								SEPA 2							SEPA 3								SEPA 4									SEPA 5									Lockport			
		Pumps				D.O. Probes				Pumps		U.W.		D.O. Probes			Pumps				D.O. Probes				Pumps					D.O. Probes				Pumps					D.O. Probes				D.O. Probes			
		1	2	3	4	1	2	3	Avg	1	2	1	2	1	2	Avg	1	2	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	Avg
6/10/09	7:00AM		✓			7.6				✓			✓	6.0	5.9	6.0	✓	✓			5.5	4.3	5.1	5.0					✓	4.3	4.3	3.1	3.9	✓			✓		4.8	5.4	5.7	5.3	1.8	3.0	2.4	2.4
6/11/09	7:00AM		✓			7.7				✓			✓	6.8	6.5	6.7	✓	✓			4.9	5.0	5.7	5.2					✓	4.9	4.7	3.7	4.4	✓			✓		5.4	5.4	5.8	5.5	2.0	3.4	2.5	2.6
6/12/09	7:00AM		✓			7.5				✓			✓	7.0	6.6	6.8	✓	✓			4.9	5.1	6.2	5.4					✓	5.1	4.8	3.9	4.6	✓			✓		6.1	5.4	5.8	5.8	2.4	4.5	4.1	3.7
6/15/09	7:00AM		✓			7.3				✓			✓	6.3	6.1	6.2	✓	✓			5.0	5.3	5.5	5.3					✓	5.4	4.9	4.4	4.9	✓			✓		6.1	5.4	5.8	5.8	2.3	4.3	3.7	3.4
6/16/09	7:00AM		✓			7.6				✓			✓	5.8	6.0	5.9	✓	✓			6.8	5.8	5.3	6.0					✓	5.9	5.5	4.8	5.4	✓			✓		6.3	5.4	5.8	5.8	1.9	3.6	2.9	2.8
6/17/09	7:00AM		✓			7.5				✓			✓	6.8	6.8	6.8	✓	✓			6.5	5.6	5.1	5.7					✓	5.5	5.3	4.6	5.1	✓			✓		6.7	5.4	5.8	6.0	1.9	3.8	3.3	3.0
6/18/09	7:00AM		✓			6.9				✓			✓	6.5	6.3	6.4	✓	✓			6.6	5.6	5.2	5.8					✓	5.3	5.0	4.4	4.9	✓			✓		6.1	5.4	5.8	5.8	2.9	4.4	3.8	3.7
6/19/200	7:00AM		✓			6.7				✓			✓	6.6	6.2	6.4	✓	✓			6.8	5.8	4.9	5.8					✓	5.0	4.8	4.0	4.6	✓			✓		5.6	5.4	5.8	5.6	2.8	4.2	3.9	3.6
6/22/09	7:00AM		✓			4.2				✓			✓	6.2	6.5	6.4	✓	✓			6.7	5.4	4.2	5.4					✓	4.9	4.6	2.3	3.9	✓			✓		5.4	5.4	5.8	5.5	0.3	1.5	1.3	1.0
6/23/09	7:00AM		✓			3.7				✓				6.4	6.0	6.2	✓	✓			6.4	5.1	4.2	5.2	✓					4.7	4.2	2.3	3.7	✓			✓		5.3	5.4	5.8	5.5	1.8	3.1	2.8	2.6
6/24/09	7:00AM		✓			3.8				✓				4.8	5.3	5.1	✓	✓			6.4	5.1	3.9	5.1	✓					4.3	4.1	2.0	3.5	✓			✓		5.4	5.4	5.8	5.5	2.3	3.5	3.2	3.0
6/25/09	7:00AM		✓			3.6				✓				5.6	5.6	5.6	✓	✓			6.5	5.1	4.2	5.3	✓					4.5	4.2	2.3	3.7	✓			✓		5.4	5.4	5.8	5.5	1.2	3.5	3.1	2.6
6/26/09	7:00AM		✓			3.5				✓		✓		6.3	5.8	6.1	✓	✓			6.7	5.4	4.6	5.6	✓					4.4	4.2	1.9	3.5	✓			✓		5.3	5.4	5.8	5.5	1.6	3.6	3.2	2.8
6/29/09	7:00AM		✓			3.4				✓		✓		5.2	5.9	5.6	✓	✓			6.6	5.7	4.9	5.7	✓					5.0	5.0	4.6	4.9	✓			✓		5.9	5.4	5.8	5.7	0.9	2.5	2.0	1.8
6/30/09	7:00AM		✓			1.2				✓		✓		6.3	6.3	6.3	✓	✓			6.7	6.1	5.9	6.2	✓					6.1	5.0	5.5	5.5	✓			✓	✓	5.9	5.4	5.8	5.7	1.5	3.0	2.5	2.3
7/1/09	7:00AM		✓			0.3				✓		✓		5.7	5.9	5.8	✓	✓			6.3	5.7	5.4	5.8	✓					6.3	4.9	5.6	5.6	✓			✓		6.0	5.4	5.8	5.7	0.7	3.1	3.0	2.3
7/2/09	7:00AM		✓			0.1				✓		✓		5.5	5.5	5.5	✓			✓	6.2	5.6	5.5	5.8	✓					5.8	4.3	4.7	4.9	✓			✓		5.6	5.4	5.8	5.6	0.7	2.6	2.2	1.8
7/3/09	7:00AM					INDEPENDENCE DAY										0.0								0.0									0.0									0.0				0.0
7/6/09	7:00AM		✓							✓				5.2	5.5	5.4	✓			✓	6.5	5.7	5.1	5.8	✓					6.1	4.4	4.5	5.0	✓			✓		5.3	5.4	5.8	5.5	1.5	4.0	3.2	2.9
7/7/09	7:00AM		✓							✓				5.0	5.7	5.4	✓			✓	6.8	5.9	5.6	6.1	✓					6.0	4.7	5.1	5.3	✓			✓		5.5	5.4	5.8	5.6	2.1	4.1	2.8	3.0
7/8/09	7:00AM		✓							✓				5.0	5.8	5.4	✓			✓	6.8	5.9	5.3	6.0					✓	5.9	5.7	5.0	5.5	✓			✓		5.7	5.4	5.8	5.6	1.6	3.4	3.8	2.9
7/9/09	7:00AM		✓							✓				5.4	5.0	5.2	✓			✓	6.7	5.7	5.3	5.9					✓	5.9	4.3	4.8	5.0	✓			✓		5.7	5.4	5.8	5.6	2.2	3.1	3.1	2.8
7/10/09	7:00AM		✓							✓			✓	6.6	6.4	6.5	✓			✓	6.9	5.8	5.5	6.1					✓	5.8	4.4	5.2	5.1		✓		✓		5.7	5.4	5.8	5.6	2.1	3.5	3.1	2.9
7/13/09	7:00AM															0.0								0.0									0.0									0.0				0.0

Date	Time	SEPA 1 Pumps 1	SEPA 1 Pumps 2	SEPA 1 Pumps 3	SEPA 1 Pumps 4	SEPA 1 D.O. Probes 1	SEPA 1 D.O. Probes 2	SEPA 1 D.O. Probes 3	SEPA 1 D.O. Probes Avg	SEPA 2 Pumps 1	SEPA 2 Pumps 2	SEPA 2 U.W. 1	SEPA 2 U.W. 2	SEPA 2 D.O. Probes 1	SEPA 2 D.O. Probes 2	SEPA 2 D.O. Probes Avg	SEPA 3 Pumps 1	SEPA 3 Pumps 2	SEPA 3 Pumps 4	SEPA 3 Pumps 5	SEPA 3 D.O. Probes 1	SEPA 3 D.O. Probes 2	SEPA 3 D.O. Probes 3	SEPA 3 D.O. Probes Avg	SEPA 4 Pumps 1	SEPA 4 Pumps 2	SEPA 4 Pumps 3	SEPA 4 Pumps 4	SEPA 4 Pumps 5	SEPA 4 D.O. Probes 1	SEPA 4 D.O. Probes 2	SEPA 4 D.O. Probes 3	SEPA 4 D.O. Probes Avg	SEPA 5 Pumps 1	SEPA 5 Pumps 2	SEPA 5 Pumps 3	SEPA 5 Pumps 4	SEPA 5 Pumps 5	SEPA 5 D.O. Probes 1	SEPA 5 D.O. Probes 2	SEPA 5 D.O. Probes 3	SEPA 5 D.O. Probes Avg	Lockport D.O. Probes 1	Lockport D.O. Probes 2	Lockport D.O. Probes 3	Lockport D.O. Probes Avg
7/14/09	7:00AM			✔		8.3				✔			✔	7.5	7.6	7.6	✔			✔	6.9	6.4	6.9	6.7					✔	6.8	5.4	5.6	5.9		✔		✔		5.9	5.4	5.8	5.7	1.1	2.1	2.0	1.7
7/15/09	7:00AM			✔		9.4				✔			✔	7.0	7.1	7.1	✔			✔	7.6	7.2	6.2	7.0					✔	7.3	5.8	7.0	6.7		✔	✔			6.5	5.4	5.8	5.9	2.1	3.3	2.6	2.7
7/16/09	7:00AM			✔		8.8				✔			✔	6.1	6.1	6.1	✔			✔	6.5	6.0	5.4	6.0					✔	6.9	5.1	5.9	6.0		✔	✔			6.7	5.4	5.8	6.0	0.9	2.6	2.2	1.9
7/17/09	7:00AM			✔		8.5				✔			✔	6.5	6.1	6.3	✔			✔	7.0	6.2	6.3	6.5					✔	7.0	5.6	7.2	6.6	✔	✔	✔			7.6	5.4	5.8	6.3	0.9	2.9	2.1	2.0
7/20/09	7:00AM			✔		7.9				✔			✔	6.9	5.2	6.1	✔			✔	6.6	5.8	5.1	5.8					✔	6.4	4.6	5.5	5.5	✔	✔	✔			6.2	5.4	5.8	5.8	0.8	2.8	1.9	1.8
7/21/09	7:00AM			✔		8.0				✔			✔	7.3	5.2	6.3	✔			✔	7.5	6.6	6.0	6.7					✔	6.8	4.6	5.6	5.7	✔	✔	✔			6.4	5.4	5.8	5.9	1.2	3.1	4.2	2.8
7/22/09	7:00AM			✔		8.1				✔			✔	6.4	4.8	5.6	✔			✔	7.0	6.2	5.4	6.2					✔	6.8	5.0	6.5	6.1	✔	✔	✔			7.2	5.4	5.8	6.1	1.5	3.5	3.7	2.9
7/23/09	7:00AM			✔		8.1				✔			✔	5.9	4.6	5.3	✔			✔	7.0	6.1	5.1	6.1					✔	6.6	4.1	5.9	5.5	✔	✔	✔			7.1	5.4	5.8	6.1	2.1	3.6	3.8	3.2
7/24/08	7:00AM			✔		7.9				✔			✔	5.9	4.8	5.4				✔	6.5	5.7	4.7	5.6					✔	6.6	4.2	6.3	5.7	✔	✔	✔			7.4	5.4	5.8	6.2	2.2	3.8	4.3	3.4
7/27/09	7:00AM			✔		7.5				✔			✔	5.7	3.7	4.7				✔	6.5	5.5	4.9	5.6					✔	6.3	3.9	5.5	5.2	✔	✔	✔			6.8	5.4	5.8	6.0	1.9	2.7	4.1	2.9
7/28/09	7:00AM			✔		7.3				✔			✔	6.3	6.8	6.6				✔	6.0	6.0	5.6	5.9	✔					6.5	6.5	6.4	6.5	✔	✔	✔			7.1	5.4	5.8	6.1	1.7	2.7	3.7	2.7
7/29/09	7:00AM			✔		7.4				✔		✔		7.3	6.9	7.1				✔	6.3	6.2	5.8	6.1	✔					6.5	6.0	6.3	6.3	✔	✔	✔			7.3	5.4	5.8	6.2	no comm			
7/30/09	7:00AM															0.0								0.0									0.0									0.0				0.0
7/31/09	7:00AM			✔		7.5				✔				6.3	6.4	6.4				✔	6.6	6.2	5.6	6.1	✔					6.3	6.4	5.8	6.2	✔	✔	✔			6.6	5.4	5.8	5.9	2.3	5.6	4.4	4.1
8/3/09	7:00AM			✔		7.3				✔			✔	6.4	7.0	6.7				✔	5.5	5.6	4.6	5.2	✔					6.3	4.5	5.3	5.4	✔	✔	✔			6.6	5.4	5.8	5.9	1.9	3.4	2.7	2.7
8/4/09	7:00AM			✔		7.1				✔			✔	6.4	7.1	6.8				✔	5.1	5.5	4.5	5.0	✔					6.6	4.8	5.5	5.6	✔	✔	✔			6.2	5.4	5.8	5.8	1.5	3.0	3.8	2.8
8/5/09	7:00AM			✔		7.1				✔			✔	6.5	7.2	6.9				✔	5.4	5.7	4.6	5.2	✔					6.4	2.3	5.4	4.7	✔	✔	✔			6.1	5.4	5.8	5.8	4.1	3.5	4.1	3.9
8/6/09	9:00AM			✔		7.5				✔			✔	6.6	7.3	7.0				✔	5.5	5.3	4.3	5.0	✔					6.5	2.7	5.6	4.9	✔	✔	✔			6.6	5.4	5.8	5.9	1.9	3.9	4.1	3.3
8/7/09	7:00AM			✔		7.9				✔			✔	5.9	7.0	6.5				✔	5.7	4.8	3.9	4.8	✔					6.5	3.2	5.7	5.1	✔	✔	✔			7.0	5.4	5.8	6.1	1.6	3.4	4.0	3.0
8/10/09	7:00AM			✔		8.8				✔			✔	5.7	6.2	6.0				✔	5.1	4.5	3.0	4.2	✔					5.5	3.5	4.6	4.5	✔	✔	✔			5.6	5.4	5.8	5.6	1.8	3.2	3.5	2.8
8/11/09	7:00AM			✔		7.0				✔			✔	6.6	7.1	6.9				✔	6.9	6.9	4.5	6.1	✔					5.8	4.8	5.1	5.2	✔	✔	✔			6.0	5.4	5.8	5.7	0.9	2.4	3.2	2.2
8/12/09	7:00AM			✔		7.4				✔			✔	7.6	6.9	7.3				✔	6.8	6.7	4.4	6.0	✔					6.7	5.6	6.5	6.3	✔	✔	✔			6.4	7.1	6.4	6.6	1.8	3.8	3.7	3.1
8/13/09	7:00AM			✔		8.0				✔			✔	7.0	6.7	6.9				✔	7.4	6.8	3.5	5.9	✔					5.5	4.0	4.7	4.7	✔	✔	✔			7.0	5.4	5.8	6.1	2.0	3.9	3.8	3.2
8/14/09	7:00AM			✔		8.1				✔			✔	7.4	7.2	7.3				✔	7.4	6.7	3.1	5.7	✔					6.9	7.4	8.3	7.5	✔	✔	✔			10.0	5.4	5.8	7.1	2.3	3.3	3.9	3.2
8/17/09	7:00AM			✔		7.1				✔				5.0	6.4	5.7				✔	5.8	5.4	2.0	4.4	✔					6.6	5.2	6.3	6.0	✔	✔	✔			8.3	5.4	5.8	6.5	3.0	4.6	4.7	4.1

Date	Time	SEPA 1 Pumps 1	SEPA 1 Pumps 2	SEPA 1 Pumps 3	SEPA 1 Pumps 4	SEPA 1 D.O. Probes 1	SEPA 1 D.O. Probes 2	SEPA 1 D.O. Probes 3	SEPA 1 D.O. Probes Avg	SEPA 2 Pumps 1	SEPA 2 Pumps 2	SEPA 2 U.W. 1	SEPA 2 U.W. 2	SEPA 2 D.O. Probes 1	SEPA 2 D.O. Probes 2	SEPA 2 D.O. Probes Avg	SEPA 3 Pumps 1	SEPA 3 Pumps 2	SEPA 3 Pumps 4	SEPA 3 Pumps 5	SEPA 3 D.O. Probes 1	SEPA 3 D.O. Probes 2	SEPA 3 D.O. Probes 3	SEPA 3 D.O. Probes Avg
8/18/09	7:00AM			✓		8.2				✓				6.2	6.5	6.4				✓	4.5	4.7	1.8	3.7
8/19/09	7:00AM			✓		8.7				✓				6.1	6.9	6.5	✓				5.5	5.6	1.9	4.3
8/20/09	7:00AM			✓		8.5				✓				4.7	6.0	5.4	✓				4.4	4.7	1.6	3.6
8/21/09	7:00AM			✓		8.5				✓				6	7.2	6.6	✓				4.4	4.8	1.6	3.6
8/24/09	7:00AM			✓		9.3				✓				4.9	7.4	6.2	✓				5.2	5.2	1.6	4.0
8/25/08	7:00AM			✓		9.3				✓				4.1	6.4	5.3	✓				5.1	5.0	1.6	3.9
8/26/08	7:00AM			✓		10.0				✓				6.9	7.4	7.2	✓				5.7	6.2	5.5	5.8
8/27/08	7:00AM			✓		10.0				✓				7.0	7.5	7.3	✓				5.8	6.4	5.7	6.0
8/28/08	7:00AM			✓		10.0				✓				7.5	7.9	7.7	✓				5.9	6.3	5.9	6.0
8/31/09	7:00AM			✓		9.8				✓				4.4	6.7	5.6	✓				5.1	5.7	5.3	5.4
9/1/09	7:00AM			✓		10.0				✓				2.8	7.3	5.1	✓				5.7	6.1	5.8	5.9
9/2/09	7:00AM			✓		9.6				✓		✓		4.0	7.1	5.6	✓				6.0	6.3	6.1	6.1
9/3/09	7:00AM			✓		9.3				✓		✓		2.3	6.6	4.5	✓				5.9	6.3	5.8	6.0
9/4/09	7:00AM			✓		9.4				✓		✓		2.3	7.1	4.7	✓				5.9	6.4	5.7	6.0
9/8/09	7:00AM			✓		9.4				✓				1.7	7.3	4.5	✓				6.0	6.3	5.8	6.0
9/9/09	7:00AM			✓		9.2				✓				1.6	6.7	4.2	✓				5.6	6.0	5.7	5.8
9/10/09	7:00AM			✓		9.1				✓				1.6	6.6	4.1	✓				5.7	6.1	5.8	5.9
9/11/09	7:00AM			✓		9.0				✓				1.3	6.9	4.1	✓				5.7	6.2	5.5	5.8
9/14/09	7:00AM			✓		8.7					✓			5.4	5.8	5.6	✓				5.7	5.9	5.5	5.7
9/15/09	7:00AM			✓		7.2					✓			7.2	7.0	7.1	✓				6.3	6.6	6.1	6.3
9/16/09	7:00AM			✓		7.3					✓			8.3	7.3	7.8	✓				6.3	6.6	6.0	6.3
9/17/09	7:00AM			✓		7.3					✓			8.9	7.1	8.0	✓				6.5	5.0	4.9	5.5
9/18/09	7:00AM			✓		7.4					✓			8.0	7.0	7.5	✓				6.2	6.4	5.8	6.1
9/21/09	7:00AM			✓		7.2					✓			8.2	6.4	7.3	✓				6.0	6.5	5.5	6.0

Date	Time	SEPA 4 Pumps 1	SEPA 4 Pumps 2	SEPA 4 Pumps 3	SEPA 4 Pumps 4	SEPA 4 Pumps 5	SEPA 4 D.O. Probes 1	SEPA 4 D.O. Probes 2	SEPA 4 D.O. Probes 3	SEPA 4 D.O. Probes Avg	SEPA 5 Pumps 1	SEPA 5 Pumps 2	SEPA 5 Pumps 3	SEPA 5 Pumps 4	SEPA 5 Pumps 5	SEPA 5 D.O. Probes 1	SEPA 5 D.O. Probes 2	SEPA 5 D.O. Probes 3	SEPA 5 D.O. Probes Avg	Lockport D.O. Probes 1	Lockport D.O. Probes 2	Lockport D.O. Probes 3	Lockport D.O. Probes Avg
8/18/09	7:00AM	✓					6.3	4.6	5.6	5.5	✓	✓	✓			8.0	5.4	5.8	6.4	2.2	2.7	4.7	3.2
8/19/09	7:00AM						2.8	1.7	1.0	1.8	✓	✓		✓		7.8	5.4	5.8	6.3	2.7	2.9	4.6	3.4
8/20/09	7:00AM			**weed control**			1.8	1.7	0.5	1.3	✓	✓		✓		5.3	5.4	5.8	5.5	3.0	3.1	4.5	3.5
8/21/09	7:00AM						2.3	0.4	0.9	1.2	✓	✓		✓		5.6	5.4	5.8	5.6	2.2	2.8	4.0	3.0
8/24/09	7:00AM	✓					5.8	4.1	5.2	5.0	✓			✓		6.1	5.4	5.8	5.8	2.1	2.8	4.5	3.1
8/25/08	7:00AM	✓					5.6	4.0	4.9	4.8	✓			✓		5.6	5.4	5.8	5.6	2.2	3.4	4.8	3.5
8/26/08	7:00AM	✓					6.3	5.8	5.7	5.9						3.3	5.4	5.8	4.8	2.9	3.6	4.7	3.7
8/27/08	7:00AM	✓					5.7	4.5	4.9	5.0			**weed control**			4.0	5.4	5.8	5.1	3.8	4.0	4.8	4.2
8/28/08	7:00AM	✓					6.5	6.3	5.5	6.1						4.0	5.4	5.8	5.1	2.3	3.8	4.5	3.5
8/31/09	7:00AM	✓					6.0	5.1	5.1	5.4	✓					5.4	5.4	5.8	5.5	2.3	3.5	4.4	3.4
9/1/09	7:00AM	✓					5.7	5.1	4.9	5.2	✓					5.4	5.4	5.8	5.5	2.2	3.2	3.8	3.1
9/2/09	7:00AM	✓					5.7	4.7	5.1	5.2	✓					5.5	5.4	5.8	5.6	3.0	3.6	4.0	3.5
9/3/09	7:00AM	✓				✓	6.8	6.7	5.1	6.2	✓					5.8	5.4	5.8	5.7	2.5	2.7	4.3	3.2
9/4/09	7:00AM	✓				✓	6.5	6.6	4.9	6.0	✓					6.1	5.4	5.8	5.8	2.5	3.4	4.1	3.3
9/8/09	7:00AM					✓	6.4	6.2	4.8	5.8	✓					5.7	5.4	5.8	5.6	2.8	3.4	3.9	3.4
9/9/09	7:00AM					✓	6.6	5.8	4.8	5.7	✓					5.8	5.4	5.8	5.7	2.6	3.8	4.2	3.5
9/10/09	7:00AM					✓	6.4	5.4	4.8	5.5	✓					5.7	5.4	5.8	5.6				0.0
9/11/09	7:00AM					✓	6.4	5.1	4.6	5.4	✓					5.6	5.4	5.8	5.6	2.7	3.3	3.3	3.1
9/14/09	7:00AM					✓	5.9	1.0	4.2	3.7	✓					5.0	5.4	5.8	5.4	2.1	1.6	2.4	2.0
9/15/09	7:00AM					✓	6.6	5.2	4.8	5.5	✓	✓				5.2	5.4	5.8	5.5	2.0	1.5	2.4	2.0
9/16/09	7:00AM					✓	5.3	5.4	5.8	5.5	✓	✓				5.3	5.4	5.8	5.5	1.4	4.8	2.4	2.9
9/17/09	7:00AM					✓	6.5	5.0	4.9	5.5	✓	✓	✓			5.1	5.4	5.8	5.4	2.5	5.0	2.0	3.2
9/18/09	7:00AM					✓	6.6	5.2	4.9	5.6	✓	✓	✓			5.1	5.4	5.8	5.4	2.1	5.0	2.0	3.0
9/21/09	7:00AM					✓	6.1	4.8	5.7	5.5	✓	✓	✓			5.2	5.4	5.8	5.5	1.8	0.4	2.5	1.6

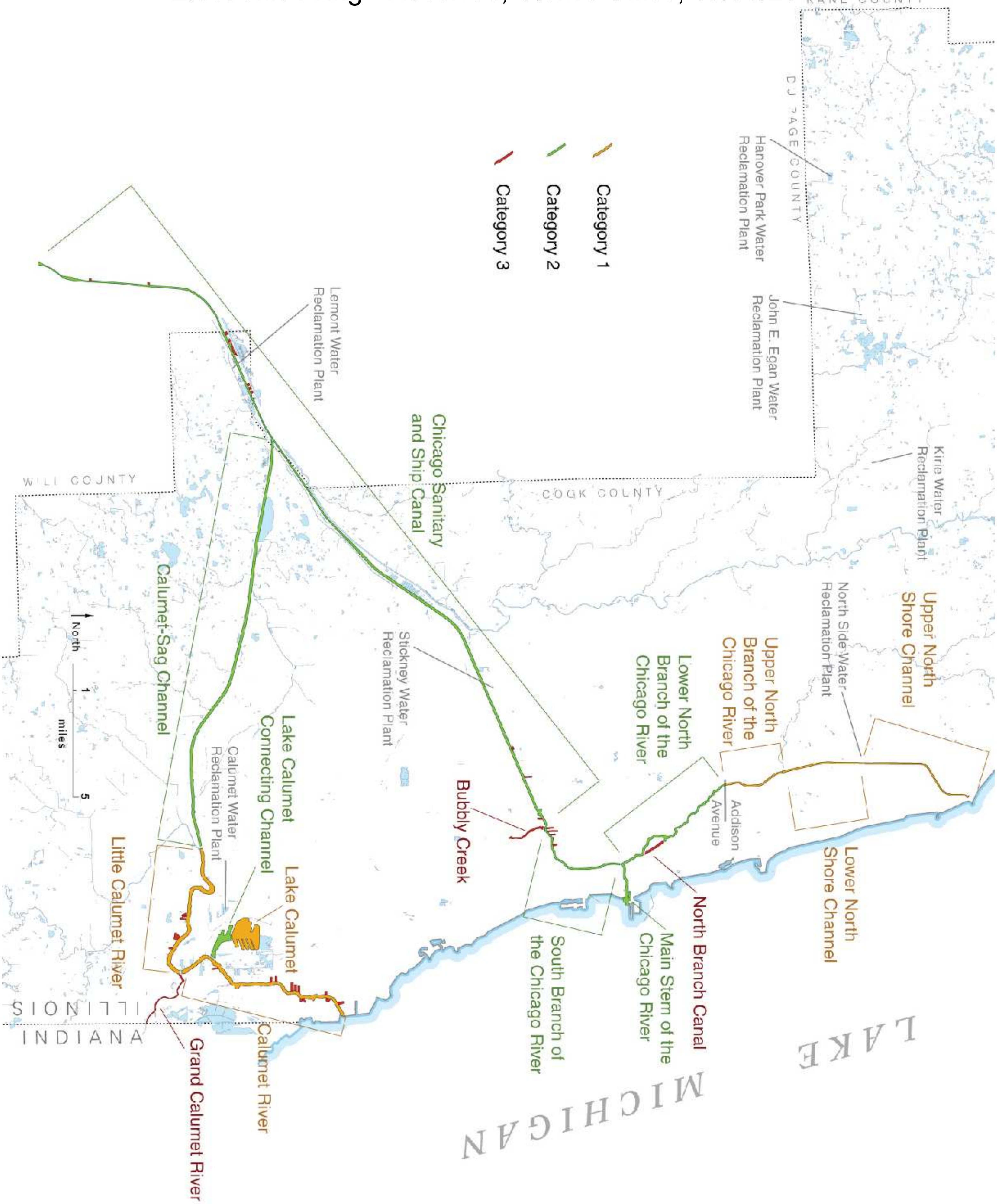
Date	Time	SEPA 1								SEPA 2							SEPA 3								SEPA 4									SEPA 5									Lockport			
		Pumps				D.O. Probes				Pumps		U.W.		D.O. Probes			Pumps				D.O. Probes				Pumps					D.O. Probes				Pumps					D.O. Probes				D.O. Probes			
		1	2	3	4	1	2	3	Avg	1	2	1	2	1	2	Avg	1	2	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg	1	2	3	Avg
9/22/09	7:00AM			✔		7.2					✔			8.1	6.7	7.4	✔				6.0	6.2	4.9	5.7					✔	6.2	4.7	5.5	5.5	✔	✔	✔			4.3	5.4	5.8	5.2	1.6	1.6	2.1	1.8
9/23/09	7:00AM			✔		7.1					✔	✔		7.9	6.5	7.2	✔				5.9	6.2	5.1	5.7				✔		5.8	4.2	5.1	5.0	✔	✔	✔			4.6	5.4	5.8	5.3	1.5	1.8	3.5	2.3
9/24/09	7:00AM			✔		7.0					✔	✔		7.6	6.1	6.9	✔				5.6	5.9	4.5	5.3				✔		5.7	4.2	5.1	5.0	✔	✔	✔			4.6	5.4	5.8	5.3	2.0	1.6	3.0	2.2
9/25/09	7:00AM			✔		7.0					✔			7.6	6.2	6.9	✔				5.6	5.9	4.4	5.3				✔		5.7	4.1	4.9	4.9	✔	✔	✔			4.5	5.4	5.8	5.2	2.1	2.5	3.2	2.6
9/28/09	7:00AM			✔		5.5				✔				9.1	7.4	8.3	✔				5.7	6.0	4.7	5.5				✔		5.8	4.5	5.1	5.1	✔	✔	✔			4.5	5.4	5.8	5.2	2.2	4.1	2.7	3.0
9/29/09	7:00AM			✔		7.2				✔			✔	8.8	6.7	7.8	✔				5.9	6.1	5.5	5.8				✔		6.4	4.8	5.2	5.5	✔	✔	✔			5.0	5.4	5.8	5.4	2.1	3.2	3.2	2.8
9/30/09	7:00AM			✔		8.1				✔				7.1	7.4	7.3	✔				6.6	7.0	6.6	6.7				✔		6.9	6.3	7.4	6.9	✔	✔	✔			6.4	5.4	5.8	5.9	2.5	5.1	3.4	3.7
10/1/09	7:00AM			✔		8.2				✔				6.9	7.2	7.1	✔				6.6	7.0	6.5	6.7				✔		6.8	6.1	7.6	6.8	✔	✔	✔			6.6	5.4	5.8	5.9	2.2	3.5	2.8	2.8
10/2/09	7:00AM			✔		5.9				✔				6.3	6.4	6.4	✔				6.5	7.0	6.4	6.6				✔		7.0	6.4	8.0	7.1	✔	✔	✔			6.4	5.4	5.8	5.9	2.4	6.0	3.9	4.1
10/5/09	7:00AM			✔		5.2				✔				7.3	7.1	7.2	✔				6.6	7.0	6.5	6.7				✔		6.8	6.3	8.1	7.1	✔	✔	✔			5.9	5.4	5.8	5.7	2.7	5.9	3.6	4.1
10/6/09	7:00AM			✔		4.9				✔				7.2	6.7	7.0	✔				6.5	7.0	6.2	6.6				✔		6.8	6.2	8.7	7.2	✔	✔	✔			6.0	5.4	5.8	5.7	3.8	6.0	4.5	4.8
10/7/09	7:00AM			✔		5.3				✔				6.9	7.2	6.5	✔				6.9	7.2	6.5	6.9				✔		7.1	6.5	9.4	7.7		✔	✔			6.9	5.4	5.8	6.0	3.3	5.8	4.2	4.4
10/8/09	7:00AM			✔		4.8				✔				7.4	7.4	7.4		✔			6.6	7.0	6.2	6.6				✔		6.9	6.6	9.7	7.7	✔		✔			6.9	5.4	5.8	6.0	2.5	6.3	3.9	4.2
10/9/09	7:00AM			✔		5.2				✔				9.5	7.3	8.4	✔				6.6	7.0	6.3	6.6				✔		6.8	5.8	8.8	7.1	✔		✔			6.6	5.4	5.8	5.9	2.8	5.7	3.9	4.1
10/12/09	7:00AM			✔		4.3				✔				9.8	8.1	9.0	✔				7.2	7.2	6.8	7.1				✔		6.9	3.1	9.4	6.5	✔		✔			6.6	5.4	5.8	5.9	2.7	4.9	2.9	3.5
10/13/09	7:00AM			✔		10.0				✔				7.7	8.2	8.0	✔				7.8	7.6	7.8	7.7				✔		8.2	0.0	5.9	7.1	✔		✔			6.8	5.4	5.8	6.0	3.0	5.1	3.5	3.9
10/14/09	7:00AM			✔		10.0				✔				9.3	9.4	9.4	✔				8.0	7.8	8.0	7.9				✔		8.5	0.0	6.2	7.4	✔		✔			7.5	5.4	5.8	6.2	3.2	5.0	4.1	4.1
10/15/09	7:00AM			✔		10.0				✔				9.4	9.9	9.7	✔				7.9	7.8	7.9	7.9				✔		8.5	10.0	6.3	8.3			✔			7.8	5.4	5.8	6.3	3.0	5.9	4.2	4.4
10/16/09	7:00AM			✔		10.0				✔				9.6	9.6	9.6	✔				7.5	7.6	7.4	7.5				✔		8.3	10.0	6.2	8.2			✔			7.5	5.4	5.8	6.2	3.2	5.7	4.4	4.4
10/19/09	7:00AM			✔		6.0				✔				10.0	9.6	9.8	✔				7.4	7.9	6.9	7.4				✔		8.3	9.7	5.7	7.9			✔			7.4	5.4	5.8	6.2	3.7	4.8	4.0	4.2
10/20/09	7:00AM			✔		5.2				✔				9.6	9.6	9.6	✔				7.6	8.3	7.2	7.7				✔		8.2	10.0	5.8	8.0			✔			7.2	5.4	5.8	6.1	4.2	6.4	6.1	5.6
10/21/09	7:00AM			✔		4.8				✔				9.6	9.8	9.7	✔				7.7	8.0	7.2	7.6				✔		8.1	9.9	5.6	7.9			✔			7.1	5.4	5.8	6.1	3.2	5.4	5.9	4.8
10/22/09	7:00AM			✔		4.2				✔				7.9	8.1	8.0	✔				7.0	7.7	6.3	7.0				✔		8.1	9.8	5.6	7.8			✔			6.3	5.4	5.8	5.8	3.1	6.3	5.8	5.1
10/23/09	7:00AM															0.0																	0.0									0.0				0.0
10/26/09	7:00AM			✔		10.0				✔				9.8	8.6	9.2	✔				7.4	7.8	6.5	7.2				✔		7.3	8.6	4.9	6.9			✔			5.7	5.4	5.8	5.6	1.5	3.6	3.7	2.9

Date	Time	SEPA 1								SEPA 2						
		Pumps				D.O. Probes				Pumps		U.W.		D.O. Probes		
		1	2	3	4	1	2	3	Avg	1	2	1	2	1	2	Avg
10/27/09	7:00AM			✓		8.3				✓				8.3	8.4	8.4
10/28/09	7:00AM			✓		9.1				✓				8.6	8.7	8.7
10/29/09	7:00AM			✓		9.0				✓				9.4	9.7	9.6
10/30/09	7:00AM															0.0
11/2/09	7:00AM			✓		8.4				✓				8.9	9.0	9.0
11/3/09	7:00AM					6.2	shut down			✓				8.3	8.5	8.4
11/4/09	7:00AM					6.5				✓				7.9	8.9	8.4
11/5/09	7:00AM													shut down		
11/6/09	7:00AM															

Date	Time	SEPA 3								SEPA 4								
		Pumps				D.O. Probes				Pumps					D.O. Probes			
		1	2	4	5	1	2	3	Avg	1	2	3	4	5	1	2	3	Avg
10/27/09	7:00AM	✓				7.1	6.6	6.4	6.7				✓		7.5	6.6	7.3	7.1
10/28/09	7:00AM	✓				6.9	7.4	6.3	6.9				✓		6.9	6.0	6.4	6.4
10/29/09	7:00AM	✓				6.4	6.1	5.6	6.0				✓		7.0	6.1	6.5	6.5
10/30/09	7:00AM																	0.0
11/2/09	7:00AM	✓				6.8	6.7	5.6	6.4				✓		6.1	5.4	5.5	5.7
11/3/09	7:00AM	✓				7.3	7.0	6.3	6.9				✓		6.8	5.9	6.4	6.4
11/4/09	7:00AM	✓				6.3	6.3	5.1	5.9				✓		6.8	6.0	6.4	6.4
11/5/09	7:00AM						shut down									shut down		
11/6/09	7:00AM																	

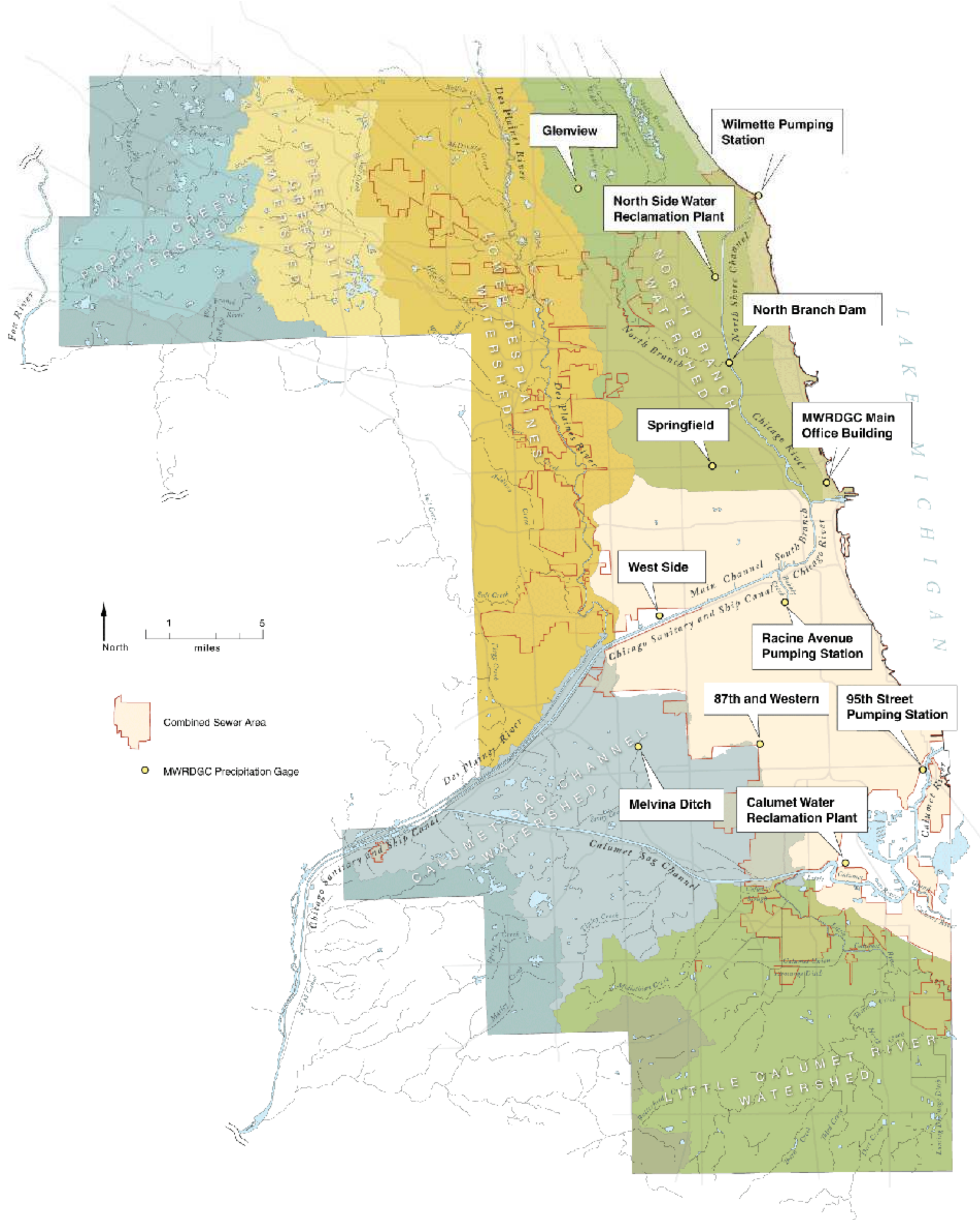
Date	Time	SEPA 5									Lockport			
		Pumps					D.O. Probes				D.O. Probes			
		1	2	3	4	5	1	2	3	Avg	1	2	3	Avg
10/27/09	7:00AM			✓			6.2	5.4	5.8	5.8	2.1	3.5	4.3	3.3
10/28/09	7:00AM			✓			6.5	5.4	5.8	5.9	1.9	3.9	4.3	3.4
10/29/09	7:00AM			✓			5.8	5.4	5.8	5.7	2.9	5.8	6.1	4.9
10/30/09	7:00AM									0.0				0.0
11/2/09	7:00AM			✓			4.6	5.4	5.8	5.3	1.1	2.8	2.3	2.1
11/3/09	7:00AM			✓			0.0	5.4	5.8	5.6		no probes		0.0
11/4/09	7:00AM			✓			0.0	5.4	5.8	5.6				0.0
11/5/09	7:00AM							shut down		0.0				0.0
11/6/09	7:00AM									0.0				0.0

ITEM 9


Category 1
Category 2
Category 3
KANE COUNTY
DU PAGE COUNTY
COOK COUNTY
WILL COUNTY
ILLINOIS
INDIANA
LAKE MICHIGAN
Hanover Park Water Reclamation Plant
John E. Egan Water Reclamation Plant
Kirie Water Reclamation Plant
North Side Water Reclamation Plant
Stickney Water Reclamation Plant
Calumet Water Reclamation Plant
Lemont Water Reclamation Plant
Upper North Shore Channel
Lower North Shore Channel
Upper North Branch of the Chicago River
Lower North Branch of the Chicago River
North Branch Canal
Addison Avenue
Main Stem of the Chicago River
South Branch of the Chicago River
Bubbly Creek
Chicago Sanitary and Ship Canal
Calumet-Sag Channel
Lake Calumet Connecting Channel
Lake Calumet
Little Calumet River
Calumet River
Grand Calumet River
North
1
miles
5

ITEM 10

Electronic Filing - Received, Clerk's Office, 09/08/2011



ITEM 11

Information Request No. 11 – Temperature Factors Assessed in Preparation of Habitat Evaluation Report

The temperature factors assessed in preparation of the Habitat Evaluation Report (PC #284) are listed on pages 24-27 of Appendix C of that Report.

ITEM 12

Revised as of 01/11/2002

Mineral-substrate Spawner column changed to Mineral-substrate Spawner (excluding tolerant species); thus, creek chub and white sucker are left blank even though they are mineral-substrate spawners

Suckermouth minnow: Generalist feeder changed from "yes" to blank; Mineral-substrate spawner changed from blank to "yes"

Banded sculpin: Tolerance changed from blank to "yes"

-added column, "Native Benthic Invertivore"

Table 2. Illinois stream-fish species categorized by family, native status, trophic, reproductive, or tolerance group used to create metrics for revised Illinois IBIs. All categorizations apply to subadult and adult life stages of fish. "Specialist" refers to species that typically feed on two or fewer of the following four food types; "generalist" species feed on three or more food types: 1) detritus 2) algae or plants 3) invertebrates (excluding adult crayfish) 4) adult crayfish, vertebrates, or fish fluids (some lampreys). "Invertivore" refers to species that feed primarily on type-3 foods. "Benthic" species are those that feed primarily on foods associated with the stream bottom and that have adaptations for doing so (e.g., protrusile lips in suckers). "Mineral-substrate spawners" are species that require relatively silt-free, mineral substrates (e.g., clean sand to boulder) for deposition and successful development of eggs. "Mineral-substrate spawners" in this table exclude species whose Tolerance = "tolerant". Species categorized as BINV, SBI, GEN, or LIT0T are indicated with a "yes".

Common Name	Scientific Name	Family	Native Status	Native Benthic Invertivore	Specialist, Benthic Invertivore (SBI)	Generalist Feeder (GEN)	Mineral-substrate Spawner, excluding tolerants (LIT0T)	Tolerance
sea lamprey	*Petromyzon marinus*	Petromyzontidae	non-native		--	--	yes	–
silver lamprey	*Ichthyomyzon unicuspis*	Petromyzontidae	--		--	--	yes	–
northern brook lamprey	*Ichthyomyzon fossor*	Petromyzontidae	--		--	--	yes	intolerant
chestnut lamprey	*Ichthyomyzon castaneus*	Petromyzontidae	--		--	--	yes	–
American brook lamprey	*Lampetra appendix*	Petromyzontidae	--		--	--	yes	intolerant
least brook lamprey	*Lampetra aepyptera*	Petromyzontidae	--		--	--	yes	intolerant
lake sturgeon	*Acipenser fulvescens*	Acipenseridae	--	yes	yes	--	yes	–
shovelnose sturgeon	*Scaphirhynchus platorynchus*	Acipenseridae	--	yes	yes	--	yes	–
pallid sturgeon	*Scaphirhynchus albus*	Acipenseridae	--	yes	--	--	yes	intolerant
paddlefish	*Polyodon spathula*	Polyodontidae	--		--	--	yes	–
alligator gar	*Atractosteus spatula*	Lepisosteidae	--		--	--	--	–
shortnose gar	*Lepisosteus platostomus*	Lepisosteidae	--		--	--	--	–
longnose gar	*Lepisosteus osseus*	Lepisosteidae	--		--	--	--	–
spotted gar	*Lepisosteus oculatus*	Lepisosteidae	--		--	--	--	–
bowfin	*Amia calva*	Amiidae	--		--	--	--	–
American eel	*Anguilla rostrata*	Anguillidae	--		--	--	--	–
alewife	*Alosa pseudoharengus*	Clupeidae	non-native		--	--	--	–
skipjack herring	*Alosa chrysochloris*	Clupeidae	--		--	--	--	–
Alabama shad	*Alosa alabamae*	Clupeidae	--		--	--	--	–
gizzard shad	*Dorosoma cepedianum*	Clupeidae	--		--	yes	--	–

threadfin shad	*Dorosoma petenense*	Clupeidae	non-native		--	yes	--	–
goldeye	*Hiodon alosoides*	Hiodontidae	--		--	--	--	–
mooneye	*Hiodon tergisus*	Hiodontidae	--		--	--	--	–
brook trout	*Salvelinus fontinalis*	Salmonidae	--		--	--	yes	intolerant
brown trout	*Salmo trutta*	Salmonidae	non-native		--	--	yes	–
rainbow trout	*Oncorhynchus mykiss*	Salmonidae	non-native		--	--	yes	–
rainbow smelt	*Osmerus mordax*	Osmeridae	non-native		--	--	--	–
central mudminnow	*Umbra limi*	Umbridae	--		--	--	--	–
grass pickerel	*Esox americanus*	Esocidae	--		--	--	--	–
northern pike	*Esox lucius*	Esocidae	--		--	--	--	–
muskellunge	*Esox masquinongy*	Esocidae	--		--	--	--	–

(Table 2. continued)

Common Name	Scientific Name	Family	Native Status		Specialist, Benthic Invertivore (SBI)	Generalist Feeder (GEN)	Mineral-substrate Spawner (LIT0T)	Tolerance
grass carp	*Ctenopharyngodon idella*	Cyprinidae	non-native		--	yes	--	–
bighead carp	*Hypophthalmichthys nobilis*	Cyprinidae	non-native		--	yes	--	–
silver carp	*Hypophthalmichthys molitrix*	Cyprinidae	non-native		--	yes	--	–
goldfish	*Carassius auratus*	Cyprinidae	non-native		--	yes	--	tolerant
common carp	*Cyprinus carpio*	Cyprinidae	non-native		--	yes	--	tolerant
rudd	*Scardinius erythrophthalmus*	Cyprinidae	non-native		--	yes	--	tolerant
golden shiner	*Notemigonus crysoleucas*	Cyprinidae	--		--	yes	--	tolerant
southern redbelly dace	*Phoxinus erythrogaster*	Cyprinidae	--		--	yes	yes	intolerant
creek chub	*Semotilus atromaculatus*	Cyprinidae	--		--	yes	--	tolerant
lake chub	*Couesius plumbeus*	Cyprinidae	--		--	--	--	–
hornyhead chub	*Nocomis biguttatus*	Cyprinidae	--		--	--	yes	intolerant
river chub	*Nocomis micropogon*	Cyprinidae	--		--	--	yes	intolerant
central stoneroller	*Campostoma anomalum*	Cyprinidae	--		--	--	yes	–
largescale stoneroller	*Campostoma oligolepis*	Cyprinidae	--		--	--	yes	–
suckermouth minnow	*Phenacobius mirabilis*	Cyprinidae	--	yes	--	--	yes	–
blacknose dace	*Rhinichthys atratulus*	Cyprinidae	--		--	yes	yes	–
longnose dace	*Rhinichthys cataractae*	Cyprinidae	--		--	--	yes	–
flathead chub	*Platygobio gracilis*	Cyprinidae	--		--	--	--	–
sicklefin chub	*Macrhybopsis meeki*	Cyprinidae	--		--	--	--	–
sturgeon chub	*Macrhybopsis gelida*	Cyprinidae	--		--	--	--	–
silver chub	*Macrhybopsis storeriana*	Cyprinidae	--	yes	yes	--	--	intolerant
gravel chub	*Erimystax x-punctatus*	Cyprinidae	--	yes	--	--	yes	intolerant

(Table 2. continued)

Common Name	Scientific Name	Family	Native Status		Specialist, Benthic Invertivore (SBI)	Generalist Feeder (GEN)	Mineral-substrate Spawner (LIT0T)	Tolerance
speckled chub	*Macrhybopsis aestivalis*	Cyprinidae	--	yes	yes	--	--	intolerant
Mississippi silvery minnow	*Hybognathus nuchalis*	Cyprinidae	--		--	--	--	–
western silvery minnow	*Hybognathus argyritis*	Cyprinidae	--		--	--	--	–
plains minnow	*Hybognathus placitus*	Cyprinidae	--		--	--	--	–
brassy minnow	*Hybognathus hankinsoni*	Cyprinidae	--		--	yes	--	–
cypress minnow	*Hybognathus hayi*	Cyprinidae	--		--	--	--	intolerant
striped shiner	*Luxilus chrysocephalus*	Cyprinidae	--		--	yes	yes	–
common shiner	*Luxilus cornutus*	Cyprinidae	--		--	yes	yes	–
redfin shiner	*Lythrurus umbratilis*	Cyprinidae	--		--	yes	yes	–
rosefin shiner	*Lythrurus ardens*	Cyprinidae	--		--	yes	yes	–
ribbon shiner	*Lythrurus fumeus*	Cyprinidae	--		--	yes	--	–
bluehead shiner	*Pteronotropis hubbsi*	Cyprinidae	--		--	--	--	–
spotfin shiner	*Cyprinella spiloptera*	Cyprinidae	--		--	yes	--	–
steelcolor shiner	*Cyprinella whipplei*	Cyprinidae	--		--	--	--	–
blacktail shiner	*Cyprinella venusta*	Cyprinidae	--		--	--	--	–
red shiner	*Cyprinella lutrensis*	Cyprinidae	--		--	yes	--	tolerant
pugnose minnow	*Opsopoeodus emiliae*	Cyprinidae	--		--	yes	--	intolerant
fathead minnow	*Pimephales promelas*	Cyprinidae	--		--	yes	--	tolerant
bluntnose minnow	*Pimephales notatus*	Cyprinidae	--		--	yes	--	tolerant
bullhead minnow	*Pimephales vigilax*	Cyprinidae	--		--	yes	--	–
pugnose shiner	*Notropis anogenus*	Cyprinidae	--		--	yes	--	intolerant
emerald shiner	*Notropis atherinoides*	Cyprinidae	--		--	--	--	–
river shiner	*Notropis blennius*	Cyprinidae	--		--	--	--	–
bigeye shiner	*Notropis boops*	Cyprinidae	--		--	--	--	intolerant
ghost shiner	*Notropis buchanani*	Cyprinidae	--		--	--	--	–
silverjaw minnow	*Notropis buccatus*	Cyprinidae	--		--	yes	--	–
ironcolor shiner	*Notropis chalybaeus*	Cyprinidae	--		--	--	yes	intolerant
bigmouth shiner	*Notropis dorsalis*	Cyprinidae	--	yes	--	yes	--	–
blackchin shiner	*Notropis heterodon*	Cyprinidae	--		--	--	--	intolerant
blacknose shiner	*Notropis heterolepis*	Cyprinidae	--		--	--	--	intolerant
spottail shiner	*Notropis hudsonius*	Cyprinidae	--		--	yes	--	–
sand shiner	*Notropis stramineus*	Cyprinidae	--		--	yes	--	–
Ozark minnow	*Notropis nubilus*	Cyprinidae	--		--	--	--	intolerant

rosyface shiner	*Notropis rubellus*	Cyprinidae	--		--	--	yes	intolerant
silverband shiner	*Notropis shumardi*	Cyprinidae	--		--	--	--	–
taillight shiner	*Notropis maculatus*	Cyprinidae	--		--	--	--	intolerant
weed shiner	*Notropis texanus*	Cyprinidae	--		--	yes	--	intolerant
mimic shiner	*Notropis volucellus*	Cyprinidae	--		--	yes	--	–
channel shiner	*Notropis wickliffi*	Cyprinidae	--		--	--	--	--
bigeye chub	*Hybopsis amblops*	Cyprinidae	--	yes	yes	--	--	intolerant
pallid shiner	*Hybopsis amnis*	Cyprinidae	--		--	--	--	intolerant
bigmouth buffalo	*Ictiobus cyprinellus*	Catostomidae	--		--	yes	--	–
smallmouth buffalo	*Ictiobus bubalus*	Catostomidae	--	yes	--	yes	--	–
black buffalo	*Ictiobus niger*	Catostomidae	--	yes	--	yes	--	–
quillback	*Carpiodes cyprinus*	Catostomidae	--		--	yes	--	–
river carpsucker	*Carpiodes carpio*	Catostomidae	--		--	yes	--	–
highfin carpsucker	*Carpiodes velifer*	Catostomidae	--		--	yes	--	intolerant
blue sucker	*Cycleptus elongatus*	Catostomidae	--	yes	yes	--	yes	intolerant
white sucker	*Catostomus commersoni*	Catostomidae	--		--	yes	--	tolerant
longnose sucker	*Catostomus catostomus*	Catostomidae	--	yes	yes	--	yes	–
spotted sucker	*Minytrema melanops*	Catostomidae	--	yes	--	yes	yes	intolerant
creek chubsucker	*Erimyzon oblongus*	Catostomidae	--		--	yes	yes	–
lake chubsucker	*Erimyzon sucetta*	Catostomidae	--		--	yes	--	–
northern hog sucker	*Hypentelium nigricans*	Catostomidae	--	yes	yes	--	yes	intolerant
greater redhorse	*Moxostoma valenciennesi*	Catostomidae	--	yes	yes	--	yes	intolerant
river redhorse	*Moxostoma carinatum*	Catostomidae	--	yes	yes	--	yes	–
shorthead redhorse	*Moxostoma macrolepidotum*	Catostomidae	--	yes	yes	--	yes	–
black redhorse	*Moxostoma duquesnei*	Catostomidae	--	yes	yes	--	yes	intolerant
golden redhorse	*Moxostoma erythrurum*	Catostomidae	--	yes	yes	--	yes	–
silver redhorse	*Moxostoma anisurum*	Catostomidae	--	yes	yes	--	yes	–
channel catfish	*Ictalurus punctatus*	Ictaluridae	--		--	yes	--	–
blue catfish	*Ictalurus furcatus*	Ictaluridae	--		--	--	--	–
white catfish	*Ameiurus catus*	Ictaluridae	non-native		--	yes	--	–
yellow bullhead	*Ameiurus natalis*	Ictaluridae	--		--	yes	--	tolerant
black bullhead	*Ameiurus melas*	Ictaluridae	--		--	yes	--	–
brown bullhead	*Ameiurus nebulosus*	Ictaluridae	--		--	yes	--	–
flathead catfish	*Pylodictis olivaris*	Ictaluridae	--		--	--	--	–
stonecat	*Noturus flavus*	Ictaluridae	--	yes	--	--	--	–
tadpole madtom	*Noturus gyrinus*	Ictaluridae	--	yes	yes	--	--	–
freckled madtom	*Noturus nocturnus*	Ictaluridae	--	yes	yes	--	--	–

slender madtom	*Noturus exilis*	Ictaluridae	--	yes	yes	--	--	intolerant
northern madtom	*Noturus stigmosus*	Ictaluridae	--	yes	yes	--	--	intolerant
mountain madtom	*Noturus eleutherus*	Ictaluridae	--	yes	yes	--	--	intolerant
brindled madtom	*Noturus miurus*	Ictaluridae	--	yes	yes	--	--	intolerant

(Table 2. continued)

Common Name	Scientific Name	Family	Native Status		Specialist, Benthic Invertivore (SBI)	Generalist Feeder (GEN)	Mineral-substrate Spawner (LIT0T)	Tolerance
trout-perch	*Percopsis omiscomaycus*	Percopsidae	--	yes	yes	--	--	–
pirate perch	*Aphredoderus sayanus*	Aphredoderidae	--		--	--	--	–
spring cavefish	*Forbesella agassizi*	Amblyopsidae	--		--	--	--	–
burbot	*Lota lota*	Gadidae	--		--	--	yes	–
banded killifish	*Fundulus diaphanus*	Fundulidae	--		--	--	--	–
northern studfish	*Fundulus catenatus*	Fundulidae	--		--	--	yes	–
starhead topminnow	*Fundulus dispar*	Fundulidae	--		--	--	--	–
blackstripe topminnow	*Fundulus notatus*	Fundulidae	--		--	--	--	–
blackspotted topminnow	*Fundulus olivaceus*	Fundulidae	--		--	--	--	–
mosquitofish	*Gambusia affinis*	Poeciliidae	--		--	--	--	–
brook silverside	*Labidesthes sicculus*	Atherinidae	--		--	--	--	–
inland silverside	*Menidia beryllina*	Atherinidae	non-native		--	--	--	–
brook stickleback	*Culaea inconstans*	Gasterosteidae	--		--	--	--	–
ninespine stickleback	*Pungitius pungitius*	Gasterosteidae	--		--	--	--	–
threespine stickleback	*Gasterosteus aculeatus*	Gasterosteidae	non-native		--	--	--	–
banded sculpin	*Cottus carolinae*	Cottidae	--	yes	yes	--	--	intolerant
mottled sculpin	*Cottus bairdi*	Cottidae	--	yes	yes	--	--	intolerant
striped bass	*Morone saxatilis*	Moronidae	non-native		--	--	--	–
white bass	*Morone chrysops*	Moronidae	--		--	--	--	–
yellow bass	*Morone mississippiensis*	Moronidae	--		--	--	--	–
white perch	*Morone americana*	Moronidae	non-native		--	--	--	–
banded pygmy sunfish	*Elassoma zonatum*	Centrarchidae	--		--	--	--	–
flier	*Centrarchus macropterus*	Centrarchidae	--		--	--	--	–
black crappie	*Pomoxis nigromaculatus*	Centrarchidae	--		--	--	--	–
white crappie	*Pomoxis annularis*	Centrarchidae	--		--	--	--	–
rock bass	*Ambloplites rupestris*	Centrarchidae	--		--	--	yes	–
largemouth bass	*Micropterus salmoides*	Centrarchidae	--		--	--	--	–
spotted bass	*Micropterus punctulatus*	Centrarchidae	--		--	--	--	–
smallmouth bass	*Micropterus dolomieu*	Centrarchidae	--		--	--	yes	intolerant

warmouth	*Lepomis gulosus*	Centrarchidae	--		--	--	--	–
green sunfish	*Lepomis cyanellus*	Centrarchidae	--		--	yes	--	tolerant
bantam sunfish	*Lepomis symmetricus*	Centrarchidae	--		--	--	--	–
spotted sunfish	*Lepomis punctatus*	Centrarchidae	--		--	--	--	–
bluegill	*Lepomis macrochirus*	Centrarchidae	--		--	yes	--	–
redear sunfish	*Lepomis microlophus*	Centrarchidae	--		--	--	--	–
pumpkinseed	*Lepomis gibbosus*	Centrarchidae	--		--	--	--	–
longear sunfish	*Lepomis megalotis*	Centrarchidae	--		--	--	--	–
orangespotted sunfish	*Lepomis humilis*	Centrarchidae	--		--	--	--	–

(Table 2. continued)

Common Name	Scientific Name	Family	Native Status		Specialist, Benthic Invertivore (SBI)	Generalist Feeder (GEN)	Mineral-substrate Spawner (LIT0T)	Tolerance
walleye	*Stizostedion vitreum*	Percidae	--		--	--	yes	–
sauger	*Stizostedion canadense*	Percidae	--		--	--	yes	–
yellow perch	*Perca flavescens*	Percidae	--		--	--	--	–
blackside darter	*Percina maculata*	Percidae	--	yes	yes	--	yes	–
dusky darter	*Percina sciera*	Percidae	--	yes	yes	--	yes	–
river darter	*Percina shumardi*	Percidae	--	yes	yes	--	yes	–
stargazer darter	*Percina uranidea*	Percidae	--	yes	yes	--	yes	–
gilt darter	*Percina evides*	Percidae	--	yes	yes	--	yes	intolerant
slenderhead darter	*Percina phoxocephala*	Percidae	--	yes	yes	--	yes	intolerant
logperch	*Percina caprodes*	Percidae	--	yes	yes	--	yes	–
crystal darter	*Ammocrypta asprella*	Percidae	--	yes	yes	--	yes	intolerant
western sand darter	*Ammocrypta clara*	Percidae	--	yes	yes	--	yes	intolerant
eastern sand darter	*Ammocrypta pellucida*	Percidae	--	yes	yes	--	yes	intolerant
johnny darter	*Etheostoma nigrum*	Percidae	--	yes	yes	--	--	–
bluntnose darter	*Etheostoma chlorosomum*	Percidae	--	yes	yes	--	--	–
greenside darter	*Etheostoma blennioides*	Percidae	--	yes	yes	--	--	–
harlequin darter	*Etheostoma histrio*	Percidae	--	yes	yes	--	--	intolerant
banded darter	*Etheostoma zonale*	Percidae	--	yes	yes	--	--	intolerant
bluebreast darter	*Etheostoma camurum*	Percidae	--	yes	yes	--	yes	intolerant
rainbow darter	*Etheostoma caeruleum*	Percidae	--	yes	yes	--	yes	intolerant
mud darter	*Etheostoma asprigene*	Percidae	--	yes	yes	--	--	–
orangethroat darter	*Etheostoma spectabile*	Percidae	--	yes	yes	--	yes	–
spottail darter	*Etheostoma squamiceps*	Percidae	--	yes	yes	--	--	–
stripetail darter	*Etheostoma kennicotti*	Percidae	--	yes	yes	--	--	–

fantail darter	*Etheostoma flabellare*	Percidae	--	yes	yes	--	--	–
least darter	*Etheostoma microperca*	Percidae	--	yes	yes	--	--	–
cypress darter	*Etheostoma proeliare*	Percidae	--	yes	yes	--	--	–
slough darter	*Etheostoma gracile*	Percidae	--	yes	yes	--	--	–
Iowa darter	*Etheostoma exile*	Percidae	--	yes	yes	--	--	intolerant
fringed darter	*Etheostoma crossopterum*	Percidae	--	yes	yes	--	--	–
freshwater drum	*Aplodinotus grunniens*	Sciaenidae	--		--	--	--	–
round goby	*Neogobius melanostomus*	Gobiidae	non-native		--	--	--	–
oriental weatherfish	*Misgurnus anguillicaudatus*	Cobitidae	non-native		--	--	--	–

ITEM 13

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Development of a Multimetric Index for Assessing the Biological Condition of the Ohio River

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Abstract.—The use of fish communities to assess environmental quality is common for streams, but a standard methodology for large rivers is as yet largely undeveloped. We developed an index to assess the condition of fish assemblages along 1,580 km of the Ohio River. Representative samples of fish assemblages were collected from 709 Ohio River reaches, including 318 ''least-impacted'' sites, from 1991 to 2001 by means of standardized nighttime boat-electrofishing techniques. We evaluated 55 candidate metrics based on attributes of fish assemblage structure and function to derive a multimetric index of river health. We examined the spatial (by river kilometer) and temporal variability of these metrics and assessed their responsiveness to anthropogenic disturbances, namely, effluents, turbidity, and highly embedded substrates. The resulting Ohio River Fish Index (ORFIn) comprises 13 metrics selected because they responded predictably to measures of human disturbance or reflected desirable features of the Ohio River. We retained two metrics (the number of intolerant species and the number of sucker species [family Catostomidae]) from Karr's original index of biotic integrity. Six metrics were modified from indices developed for the upper Ohio River (the number of native species; number of great-river species; number of centrarchid species; the number of deformities, eroded fins and barbels, lesions, and tumors; percent individuals as simple lithophils; and percent individuals as tolerant species). We also incorporated three trophic metrics (the percent of individuals as detritivores, invertivores, and piscivores), one metric based on catch per unit effort, and one metric based on the percent of individuals as nonindigenous fish species. The ORFIn declined significantly where anthropogenic effects on substrate and water quality were prevalent and was significantly lower in the first 500 m below point source discharges than at least-impacted sites nearby. Although additional research on the temporal stability of the metrics and index will likely enhance the reliability of the ORFIn, its incorporation into Ohio River assessments still represents an improvement over current physicochemical protocols.

Protecting the biological integrity of aquatic ecosystems is a fundamental goal of water resource policy in the United States and is mandated by the U.S. Water Pollution Control Act Amendment of 1972 and its reauthorizations. Achieving this goal requires, among other things, scientifically sound protocols for assessing biotic condition, including monitoring designs, sampling methods, and analytical tools. However, biological monitoring and assessment remain weakly implemented for many aquatic systems (Karr 1991; Karr and Chu 1999), and few states have developed quantitative criteria for assessing the biotic status of water bodies (Southerland and Stribling 1995). Instead, physicochemical measures of condition focused on the success of pollution abatement programs are emphasized over biological ones (Adler 1995; Sparks 1995). Environmental assessments of large rivers exemplify this deemphasis of biotic condition (Karr 1985a).

Large-floodplain rivers (hereafter called great rivers) are distinctive in terms of their ecological operation and how humans have modified them. River components, including catchments, are physically and biologically connected along longitudinal, lateral, and vertical dimensions (Vannotte et al. 1980; Ward and Stanford 1995). Great rivers are subject to a variety of stressors, including impoundments that alter the flow regimes of water and sediments (Ward and Stanford 1989; Bayley 1995), pollution and land use practices that alter water quality and temperature, and intensive agriculture and wetlands reclamation that interrupt the connectivity of the floodplain and its associated wetlands (Bayley 1995) and thereby disrupt energy flow (Power et al. 1995). In great rivers, the disruption of the natural hydrologic and sediment regimes is evident in channelization (Braaten and Guy 1999), impoundment by dams (Dynesius and Nilsson 1994; Pearson and Krumholz 1984; Ligon et al. 1995), inundation and embayment of backwaters and tributaries (Stalnaker et al. 1989), isolation and loss of wetlands, water withdrawal for irrigation and industrial uses, and excessive loading of fine sediment via land use in their catchments (Berkman and Rabeni 1987; Carlson and Muth 1989; Ebel et al. 1989; Poff et al. 1997). Flow regulation has cascading effects on all aspects of the ecological structure and function of rivers, including altered sediment transport and temperature regimes, reduced production, fewer native species, and more nonnative species (Ward and Stanford 1995; Stanford et al. 1996; Poff et al. 1997). As such, assessments of biological integrity for large rivers should indicate substantial impairment from the cumulative stressors of great-river basins.

Great rivers are also distinctive in the difficulties associated with assessing their biotic condition. Foremost among these are their size and the spatial scales over which habitat patches and biota are distributed. Scale has important implications for defining reference conditions and sampling biotic assemblages. Unlike smaller water bodies, which are typically replicated across a given region, large rivers are typically unique, at least within the jurisdiction of a typical (e.g., state or province) management agency. This lack of comparable replicates severely limits the development of region-specific reference conditions, which commonly provide a basis for biotic assessments (Hughes 1995), and forces a disproportionate reliance on historical accounts and expert judgment to define assessment benchmarks. This difficulty is exacerbated by the virtual absence of only slightly modified reaches from most large rivers; thus, even pseudoreplicate reference reaches are largely unavailable for comparison. Consequently, unless historical accounts are very explicit, which is rare, attributing observed patterns of variation (physicochemical or biological) to natural as opposed to anthropogenic sources might be arbitrary. Nevertheless, biological benchmarks can be defined on the basis of a general understanding of the ecology of riverine species and historical faunal conditions and by comparing the assemblage structure and function at anthropogenically impacted sites with those from relatively unimpacted sites. As such, they can substantially improve environmental assessments of large rivers.

The biotic assemblages of large water bodies are difficult to sample thoroughly. Fish sampling protocols for small streams commonly apply uniform sampling effort to the entire volume of multiple habitat units (e.g., riffles and pools), which collectively provides a ''sample'' (McCormick et al. 2001). In contrast, there are no sampling technologies that can thoroughly sample a single habitat unit of a large river, let alone be uniformly applicable to multiple unit types. All available sampling gears have strong biases with respect to taxa, habitat morphology, or water conditions (e.g., clarity and conductivity). Even if thorough sampling were technologically feasible, the cost (monetary and biotic) of sampling a major portion of the fishes in a large river would generally be prohibitive. Thus, biotic assessments of large rivers are necessarily based on relatively small samples with strong, but often predictable, biases.

Analytical tools that efficiently convey biological information to both biologists and nonbiologists are crucial to the implementation of biological monitoring programs. Over the past two decades, multimetric indices (Karr et al. 1986; Karr 1991) have been developed in many areas to serve this function. These tools typically integrate information on many attributes of a biotic community (one attribute per metric) into a numerical index scaled to reflect the ecological health of the community.

A major strength of this approach is its broad ecological foundation, with individual metrics representing selected aspects of the taxonomic and functional composition of the biotic community. This enables detection of a broader array of human impacts than is possible using only physicochemical measures of water quality, including the impacts on flow regime, habitat structure, and biotic interactions (Yoder and Smith 1999). However, the sensitivity and general applicability of multimetric indices are contingent on appropriate customization during their development. In particular, the component metrics and their scoring criteria should reflect system-specific attributes of natural biotic communities and the system-specific responses of those communities to human impacts. For example, dozens of metrics have been substituted for Karr's (1981) original metrics in applications to different ecosystems (Simon and Lyons 1995). This flexibility enhances the ability of multimetric indices to accurately measure environmental degradation. Most adaptations of multimetric indices to new ecosystems, including those for large rivers (Simon and Emery 1995; Emery et al. 1999; Gammon and Simon 2000), have relied largely on expert knowledge and intuition. However, recently developed protocols call for increasing reliance on empirical relations to select metrics and derive scoring criteria (Barbour et al. 1995; Hughes et al. 1998; Karr and Chu 1999; Angermeier et al. 2000).

Species that are native to great rivers have life history traits that enable them to survive and reproduce in a highly fluctuating environment (Dettmers et al. 2001). Sampling considerations (Simon and Sanders 1999), metric development and testing (Simon 1992; Simon and Emery 1995; Simon and Stahl 1998; Emery et al. 1999), and the variability of index of biotic integrity (IBI) metrics (Gammon and Simon 2000) complicate the assessment of great-river fish assemblages. Reash (1999) cited the distinctive abiotic features and unique biological characteristics of large rivers as factors that complicate metric development for great-river bioassessment. The unique nature of great rivers and the lack of other systems of comparable size hinder development of a reference condition based on a reference site approach (Hughes et al. 1986; Hughes 1995). Recent studies have addressed the development of biological indicators for assessing the condition and ecological health of great rivers (Hickman and McDonough 1996; McDonough and Hickman 1999; Simon and Sanders 1999; Lyons et al. 2001). The purpose of this research was to develop an assessment tool that would detect impairment from known sources of impact and assess the biological condition of the aquatic resources of the main-stem Ohio River. We attempted to include metrics that represented measures of habitat protection, antidegradation, and ecosystem restoration in the Ohio River. We describe three major steps in the development process: (1) defining reference conditions, (2) selecting metrics and analyzing the relationships between these metrics and human impacts on water and substrate quality, and (3) setting metric scoring criteria. We also identify research topics that would enhance index performance.

Methods

Study area.—The Ohio River begins at the confluence of the Monongahela and Allegheny rivers (river kilometer [rkm] 0) and flows southwesterly for 1,578 km through six states into the Mississippi River (Figure 1). The Ohio River crosses four ecoregions (the Western Allegheny Plateau, Interior Plateau, Interior River Lowland, and Mississippi Alluvial Plain [Omernik 1987]). Nearly 10% of the U.S. population, more than 25 million people, resides in the Ohio River basin. The Ohio River has over 600 permitted discharges to its waters under the National Pollutant Discharge and Elimination System, including ones from industry, power generating facilities, and municipalities. Between 1885 and 1927, the Ohio River was impounded by 50 low-head navigation dams (Pearson and Pearson 1989). Currently, 20 high-lift dams provide a 2.75-m minimum depth for commercial navigation, which transports approximately 250 million tons of cargo annually.

Trautman (1981) relates accounts from early settlers along the Ohio River describing abundant shifting sandbars, sandbanks, rock and gravel bars, and bedrock and rock ledges as well as clean bottoms and clear water except during floods. Degradation of the Ohio River occurred initially as a result of logging, agriculture, mining, and sewage effluent (Taylor 1989; Lowman 2000). Water quality in the Ohio River declined between 1810 and 1960 as a result of deforestation, increased agricultural activities, and increases in mining, industrialization, and urban sprawl that led to increases in mean turbidity, total dissolved solids, chlorides, nitrates, and sulfates. Acid mine drainage resulted in degradation of the upper 161 km of the river before 1950 (Pearson and Krumholz 1984). Pearson and Krumholz (1984) and Lowman (2000) documented the decline of pollution-sensitive species and the dominance of pollution-tolerant species.

Site selection.—From 1991 to 2001, the Ohio River Valley Water Sanitation Commission sampled 709 sites along the entire 1,578-km length of the Ohio River. Each 500-m zone incorporated the predominant habitat types within a pool, ranging from shallow, sandy shorelines with no cover to rocky shorelines with a variety of cover types and variable depths. Samples were collected during summer and fall (from early July until late October) when the river was at stable low to moderate flow.

Habitat and water quality data.—Physical habitat data were collected from each 500-m zone. Depth and substrate composition were measured at six longitudinal transects (spaced at 100-m intervals along the shoreline) that were divided into ten 3-m lengths. Visual estimates of the in-channel area containing woody debris (e.g., brush, logs, and stumps), habitat unit (right or left descending bank, inside or outside bend or straight channel), riparian land use and the occurrence and proximity of riparian human disturbances (e.g., roads, buildings, industry, and agriculture), and bank stability were recorded. Water quality data (pH, temperature, dissolved oxygen, conductivity, and Secchi depth) were measured at a single point in each sample area.

Electrofishing.—Fish were collected by nighttime DC boat electrofishing. Sanders (1991) and Simon and Sanders (1999) found that electrofishing success (measured by species richness and abundance) was greater at night than during the day. Electrofishing was conducted on a single shoreline over a linear distance of 500 m using a serpentine travel route within the zone to incorporate all available habitat types (Gammon 1998; Simon and Sanders 1999). Simon and Sanders (1999) found that 500 m was long enough to capture sufficient numbers of species to characterize biological integrity but not biological diversity. Fish were collected in 709 site visits using a Smith-Root Type 6A (350-V, 8-A) electrofishing unit deployed on a 5.5-m johnboat. Amperage was maintained by varying the pulse width according to individual site conditions. We varied the pulse width to obtain an 8-A output for at least 1,500 s. Because boat electrofishing was most effective when employed within 30 m of the shoreline (i.e.,

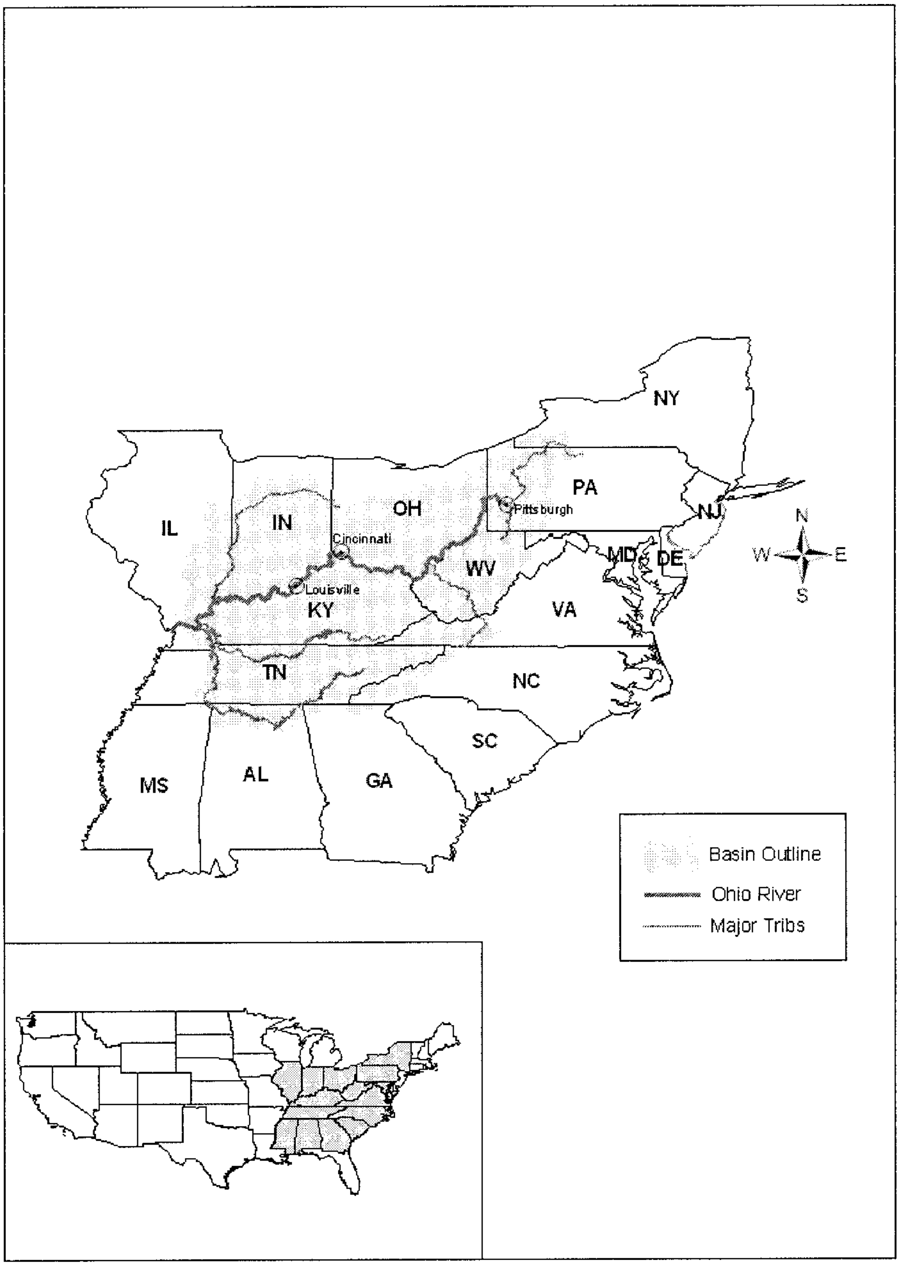

FIGURE 1.—Map of the main-stem Ohio River (dark line) and its tributaries.

at depths less than 4 m), sampling was conducted only under stable, low-flow conditions at a stage level within 1 m of ''normal flat pool'' and when Secchi depths were at least 0.3 m. Every attempt was made to capture all observed fish using 6.35-mm-mesh nets; captured fish were placed in an onboard holding tank for later processing. The mesh size of the nets was selected to avoid capturing young-of-year individuals; if captured, individuals less than 20 mm (standard length) were not identified. At the conclusion of site sampling, fish were identified to species, counted, and inspected for deformities, eroded fins and barbels, lesions, and tumors (DELT anomalies; Sanders et al. 1999). All fish were released except for small species (e.g., minnows [Cyprinidae], darters *Eth-*

TABLE 1.—Metrics rejected in the evaluation process, by reason for rejection. Lists 1 and 2 comprise groups of species created for test purposes; see text for descriptions of other species groups. The acronym OEPA is for the Ohio Environmental Protection Agency.

Failed range test	Failed redundancy test	Failed responsiveness test
Number of darter species	Number of species	Catch per unit effort (species; list 1)
Number of minnow species	Number of bass and crappie species	Catch per unit effort (species; list 2)
Proportion of great-river species (biomass)	Number of sunfish species excluding basses	Proportion of great-river species
Number of hybrids	Proportion of hybrids	Proportion of large-river species
Proportion of sensitive species	Number of round-bodied suckers	Proportion of round-bodied suckers (biomass)
Proportion of fish with DELT anomalies[a]	Proportion of round-bodied suckers (number)	Proportion of deep-bodied suckers (numbers)
	Proportion of round-bodied suckers (species)	Proportion deep-bodied suckers (biomass)
	Number of deep-bodied sucker species	Proportion of sucker biomass
	Proportion of green sunfish	Number of sensitive species
	Proportion of intolerant species	Proportion of tolerant species (list 2)
	Proportion of nonnative individuals	Proportion of tolerant species (list 1; biomass)
	Proportion of omnivores (biomass; OEPA)	Proportion of tolerant species (list 2; biomass)
	Proportion of omnivores (biomass; new list)	Proportion of insectivores (OEPA)
	Proportion of omnivores (new list)	Proportion of tolerant species (OEPA)
	Proportion of omnivores (OEPA)	Proportion of top piscivores (list 1)
	Number of catfish and sucker species	Proportion of carnivores (OEPA)
	Number of piscivores (list 1)	
	Number of piscivores (list 2)	
	Number of piscivore species (list 1)	
	Number of piscivore species (list 2)	

[a] Deformities, eroded fins and barbels, lesions, and tumors.

eostoma and *Percina* spp., and madtoms *Noturus* spp.), which were retained for laboratory identification using regional fish references (Trautman 1981; Etnier and Starnes 1993; Jenkins and Burkhead 1994; Simon 1999a).

Reference data set.—With its long history of flow alteration and water quality impairment, the Ohio River lacks reference sites representative of pristine conditions. In adopting criteria reflective of the least-impacted conditions, we recognized that most of the changes to the Ohio River are permanent alterations of the system (i.e., hydrologic and channel modifications associated with dams; Ward and Stanford 1989). Metric scoring was conducted on a data set of 318 least-impacted sites. We selected these sites according to the following criteria: (1) they were at least 1 km upstream or downstream from the restricted areas in the vicinity of navigational dams; (2) they were at least 1.61 km downstream from any point source discharge; and (3) they were at least 500 m from any tributary mouth. We eliminated sites with other sources of disturbance in the electrofishing zone (e.g., barge fleeting operations, boating activity, docks or mooring sites, and artificial structures such as pipes or other metal debris in the water). Of the 709 sites sampled, 391 failed to meet the criteria for least-impacted condition and were retained as test sites for metric calibration to evaluate metric response.

Metric selection.—All species collected were classified into various taxonomic, tolerance, feeding, and reproductive guilds (Appendix 1) using regional references (Trautman 1981; Etnier and Starnes 1993; Jenkins and Burkhead 1994; Simon 1999a) and consultation with professional ichthyologists and fisheries biologists. We developed a set of 55 candidate metrics incorporating the original metrics described by Karr (1981), modifications suggested by Miller et al. (1988), the Ohio Environmental Protection Agency (1989), Hughes and Oberdorff (1999), and Emery et al. (1999), and new metrics developed specifically for this study (including various combinations of species that were designated as lists 1−3). The metrics chosen for the Ohio River Fish Index (ORFIn) focus on six areas of fish assemblage structure and function: species richness, pollution tolerance, breeding habits, feeding habits, fish health, and abundance. The metrics were chosen to reflect biological and habitat integrity, trophic complexity, and future restoration and recovery.

The evaluation process followed Hughes et al. (1998) and McCormick et al. (2001) in that we examined each candidate metric for its scoring range, variability, responsiveness, and redundancy. Metrics were rejected (Table 1) if they failed a range test (i.e., if their raw values were between 0 and 2 species or were otherwise too small to provide a range of response to disturbance). We used Spearman correlations and scatter plots to test the responsiveness of the remaining candidate metrics to physical habitat structure and water quality. We retained metrics with significant correlations ($r > 0.15$; $P < 0.001$) for which scatter plots reflected the predicted responses to physical habitat and water quality variables (Hughes et al. 1998). We tested for redundancy among metrics and rejected one metric of any pair with a high Pearson's correlation ($r > 0.75$). In such cases, we consulted regional fish references, professional ichthyologists, and fisheries biologists and retained the metric more representative of the Ohio River fish assemblage than of other systems. We retained some metrics, such as the number of great-river species (a smaller subset of large-river taxa), the number of DELT anomalies, and percent individuals as nonindigenous species, because we believed that they reflect historical conditions or they constitute important measures of recovery or represent direct measures of individual health or biological pollution. We tested the response of each metric to a multivariate (principal components analysis) axis of disturbance that represented a gradient of abiotic conditions derived from 11 habitat and 5 water quality variables. Repeat sampling was conducted at 8 locations in Markland Pool (rkm 702–855) and 6 locations in Greenup Pool (rkm 450–549) and in a riverwide outfall study at 11 effluent locations (Emery et al. 2002) to assess signal-to-noise ratios.

Scoring procedures.—We performed linear regressions of the species richness metrics on river kilometer, which we used as a surrogate for watershed area (Figure 2). Historical records and surveys showed that 10 species have been extirpated from the Ohio River and many others have declined due to human impacts (Pearson and Krumholz 1984). To account for these historical changes in fish assemblage structure, we used the maximum value for observed species richness (interpreted as the y-intercept) for the maximum observed line (MOL) for scoring species richness metrics instead of the 95th percentile (Fausch et al. 1984). The MOL was drawn through the data and parallel to the regression line. The area below the MOL was evenly trisected into regions providing scores of 1, 3, or 5.

Large numbers of individuals of some schooling species can distort the responsiveness of percentage metrics. Because gizzard shad and emerald shiners can occur unpredictably and in large numbers (Simon and Emery 1995; Simon and Sanders 1999), we excluded them from the calculations of

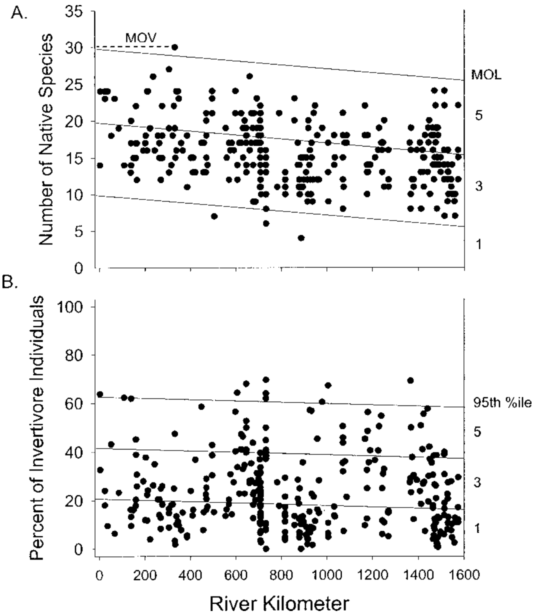

FIGURE 2.—Examples of scoring criteria for the **(A)** richness and **(B)** percentage metrics. The line labeled MOV points to the maximum observed value, which was used as the y-intercept; that labeled MOL represents the maximum observed line drawn parallel to the regression line with river kilometer as the dependent variable. The 95th percentile line in (B) is also parallel to the regression line.

percentile metrics; however, both species are included in species richness metrics. Each percentile metric was scored following the methods described by Fausch et al. (1984). That is, the data for each metric were plotted against river kilometer and a line was drawn at the 95th percentile; the area beneath the line was then trisected into regions representing scores of 1, 3, and 5. In cases where fewer than 50 individuals were collected (after removing gizzard shad, emerald shiners, tolerant fishes, nonindigenous species, and hybrids), all proportional metrics were scored as 1 (Yoder and Rankin 1995). In the event that no individuals in a particular metric category were collected, the metric was scored as 0.

Results

We rejected 6 metrics because they failed our range test, 20 metrics because they were redundant with other metrics, and 16 metrics because they were not responsive to anthropogenic disturbance (Table 1). None of the final metrics selected for consideration failed the signal-to-noise test. We selected 13 metrics, each of which was signifi-

TABLE 2.—Spearman correlations of fish assemblage metrics and Ohio River Fish Index (ORFIn) scores with habitat and water quality variables. Habitat data were available for 166 ''least-impacted'' sites, but water quality data were available for only 66 sites. All correlations are significant at the 0.0001 level.

	Variable				
Metric and index	Mean depth	% boulder	% cobble	% gravel	% coarse substrate
Native species	0.41	0.43	0.44	0.33	0.43
Intolerant species	0.39	0.49	0.51	0.43	0.57
Sucker species	0.15		19	0.24	0.23
Centrarchid species	0.47	0.29	0.47	0.27	0.41
Great-river species		0.12			
% Piscivores	0.21			−0.27	
% Invertivores	0.23		0.22	−0.27	0.19
% Detritivores				−0.18	−0.22
% Tolerant species	0.19			0.15	0.2
% Lithophils	0.18				0.2
% Nonindigenous species			−0.19		
Number of DELT anomalies[b]		0.14	0.19	0.24	
CPUE[c]				0.19	
ORFIn	0.34	0.17	0.39	0.31	0.43

[a] First principal components axis of abiotic conditions (see text).
[b] Deformities, eroded fins and barbels, lesions, and tumors.
[c] Catch per unit effort.

cantly correlated ($P < 0.0001$, $r > 0.2$) with one or more of the habitat or chemical variables, and from these we calculated the ORFIn (Table 2). In a separate study, Emery et al. (2002) found that native-species richness, intolerant-species richness, sucker species richness, centrarchid species richness, great-river-species richness and the proportions of top piscivores, invertivores, and simple lithophils were lower at outfall sites than at reference sites. The proportion of detritivores, catch per unit effort (CPUE), and the number of DELT anomalies were higher at outfall sites than at reference sites (Emery et al. 2002).

The first principal component axis of abiotic conditions explained 42% of the variability and was strongly and positively correlated with fine substrates ($r = 0.95$) and negatively correlated with depth ($r = -0.59$), coarse substrates ($r = -0.86$ to -0.56), water clarity ($r = -0.4$), and conductivity ($r = -0.3$). Correlations of fish assemblage metrics with the first principal component axis reflected their response to critical habitat features. The number of native, centrarchid, and intolerant species increased in areas with high-quality habitat characterized by greater depth, coarse substrates, and high water clarity (Table 2). Among the proportional metrics, the proportions of simple lithophils, nonindigenous species, invertivores, and piscivores declined and the proportions of detritivores and tolerant species increased with measures of habitat disturbance associated with increased fine sediments and embeddedness (Table 2).

Metric Descriptions

Native-species richness was modified from Karr's (1981) species richness metric. It focuses on native-species diversity (Simon and Lyons 1995; Hughes and Oberdorff 1999) by excluding nonindigenous species and hybrids that indicate a loss of biological integrity. The number of native species decreases with river kilometer as species found primarily in the upper 500 km of the Ohio River disappear downstream. Changes in river geomorphology from a high-gradient, constrained-floodplain system to a low-gradient floodplain system are accompanied by the replacement of round-bodied suckers and other species associated with higher-gradient river systems by a more depauperate fauna (Emery et al. 1999). The number of native species was greater at deeper sites with coarse substrates (cobble, boulder, and gravel) than at shallower sites with more sand and fines and was greater at sites with good water clarity and cooler temperatures and more available cover (Table 2). Native species declined with degraded water quality (Emery et al. 2002) and at sites with abundant sand and fines and highly embedded substrates (Table 2). We expected the number of native species to decline with increased environmental disturbance (Karr 1981; Karr et al. 1986).

The number of intolerant species is intended to

TABLE 2.—Extended.

Variable									
% sand and fines	% highly embedded substrate	% total woody cover	% submerged vegetation	% overhanging vegetation	Secchi depth	Dissolved oxygen	Temperature	Conductivity	PC 1[a]
−0.42	−0.43	0.23	0.28	0.23	0.17		−0.24	0.26	−0.36
−0.56	−0.57		0.24		0.27	0.28	0.18	0.3	−0.53
−0.24	−0.23	0.16	0.16				−0.31	−0.26	
−0.41	−0.41	0.31	0.22	0.23	0.15		−0.27	0.31	−0.34
		0.18					−0.25		
−0.19	−0.42	0.22					−0.25	0.17	
0.22	0.2			0.17	−0.15		0.19		0.29
−0.21	−0.2	0.25		0.22				0.18	
−0.16							−0.34		
−0.24	0.22	0.26			−0.27		−0.16		
−0.26	−0.25				−0.19	−0.21			
	−0.3								
−0.42	−0.43		0.2		0.23	0.21	−0.25	0.22	−0.56

distinguish areas of the highest quality. Species that are especially sensitive to anthropogenic stressors are the first to be eliminated and the last to return to the reach. Only species that are highly sensitive to habitat disturbance, toxins, and thermal and nutrient stressors are included in this metric. Species that are sensitive to only one type of stressor are not included (Appendix 1). Karr et al. (1986) warned that designating too many species as intolerant would prevent this metric from discriminating among the highest-quality areas and recommended that a maximum of 10% of the fauna be included in this classification. Our list contains 22 species, although 3 of these species have not been collected in the river using electrofishing techniques. The total number of intolerant species decreased with river kilometer. The number of intolerant species decreased significantly with degraded water quality (Emery et al. 2002) and at sites with increased sand, fines, and highly embedded substrates (Table 2). This metric reflected the highest levels of biological integrity and was expected to increase with improved water and habitat quality.

The number of sucker (Catostomidae) species was one of the original IBI metrics proposed by Karr et al. (1986) for small streams and rivers. Suckers are a major component of the Ohio River fish fauna (Emery et al. 1999). Round-bodied suckers, such as *Moxostoma*, *Hypentelium*, *Cycleptus*, *Catostomus*, and *Minytrema* spp., are generally sensitive to habitat and water quality degradation (Karr 1981; Trautman 1981; Karr et al. 1986), and their long life span provides a metric influenced by long-term environmental changes (Emery et al. 1999). Decreases in the round-bodied sucker distribution in the lower reaches of the Ohio River suggest that redhorse suckers are not a major component of the structure of the great-river fish assemblage (Emery et al. 1999). In contrast, Emery et al. (1999) reported that the relative abundance and diversity of deep-bodied sucker species, such as *Carpiodes* spp. and *Ictiobus* spp., increased in the lower Ohio River. The number of sucker species was significantly correlated with coarse substrates and the presence of submerged vegetation, woody cover, and conductivity, and negatively correlated with elevated temperature, an abundance of sand and fines, and generally degraded abiotic conditions (Table 2). We expected sucker species to decline with increased disturbance (Karr 1981).

The number of centrarchid species was modified from Karr's (1981) metric (the number of sunfish species) to include the black basses (*Micropterus* spp.), which are the dominant centrarchids in Ohio River pool habitats. The number of centrarchid species did not change significantly with river kilometer. It was greater at deeper sites over coarse substrates and at sites with abundant woody or vegetative cover and lower at shallower sites with more sand, fines, or highly embedded substrates (Table 2). Centrarchid species richness declined with increased turbidity and water temperature. This metric should decline with the degradation of pool habitat.

The number of great-river species represents the fish species that are expected to predominate in great rivers (Pflieger 1971; Simon 1992; Simon and Emery 1995) and to decline with the loss of associated floodplain habitat (Appendix 1). Great-river species have declined in the Ohio River because of hydrologic modification and poor water quality (Pearson and Krumholz 1984; Pearson and Pearson 1989; Poff et al. 1997). The number of great-river species was not strongly correlated with any abiotic variables (Table 2) but was retained because it expresses historical conditions in the river. We expected that the number of great-river species would increase with improvements in water quality and restoration of floodplain habitats.

Percent top piscivores was modified from Karr's (1981) percent top carnivore metric. Top piscivores represent the top of the aquatic food web and should be those that no other fishes feed on. We selected only species that feed exclusively on vertebrates or crayfish as adults (Appendix 1). Species that switch among prey items during ontogeny (e.g., smallmouth bass) are included, but adult species that eat both macroinvertebrates and fish (e.g., green sunfish) were excluded. The percentage of top piscivores in the Ohio River increased slightly with river kilometer. It also increased with increased depth and woody cover but declined with increased water temperature (Table 2). We expected the percentage of top piscivores to decrease with habitat degradation in the absence of any intensive stocking program.

Percent invertivores was modified from Karr's (1981) proportion of cyprinid insectivores metric to measure the proportion of specialized sight feeders in the assemblage (Goldstein and Simon 1999; Appendix 1). A scarcity of insectivorous fish species may reflect a disturbance that has reduced the production of benthic insects. The proportion of invertivores ranged from 0% to 100% and decreased with river kilometer. It was higher at deeper sites with coarse substrates (cobble) and lower at sites with more sand and fines and higher temperature (Table 2). We expected the percentage of invertivores to decline with increased disturbance.

Percent detritivores replaced the percent omnivores metric of Karr et al. (1986) because the original metric did not discriminate between species that switched between food types or were behaviorally plastic in feeding ecology as a result of disturbance (Goldstein and Simon 1999). The percentage of detritivores increased with increasing proportions of sand and fine substrates and higher water temperature (Table 2). The percentage of detritivores should have increased as habitat quality declined and the abundance of ultrafine-particulate organic matter increased.

Percent tolerant individuals is meant to represent the worst conditions in the Ohio River prior to the implementation of the Clean Water Act of 1972. Historical lock chamber data (Lowman 2000; Emery et al. 2002) revealed fish assemblage patterns associated with widespread water quality degradation that are still seen in the most impaired areas of the river. Tolerant species are becoming increasingly scarce as the impacts of degradation become more localized, allowing riverwide recolonization by more-sensitive species (Emery et al. 1999). The percentage of tolerant individuals increased with degraded water quality (increased turbidity and low dissolved oxygen; Table 2). We expected the percentage of tolerant individuals to increase with increased disturbance.

Percent simple lithophils represents the reproductive guilds that are sensitive to substrate disturbance and degradation (Ohio Environmental Protection Agency 1989; Simon 1999b). Simple lithophils decreased with river kilometer, presumably for lack of habitat given that coarse substrates become less common in the lower segments of the river. Emery et al. (1999) related the decrease to the absence of redhorse species in the lower river. As expected, the percentage of simple lithophils declined with increased sand and fine substrates (Table 2). They also declined with increased temperature. We expected the percentage of simple lithophils to decrease with the loss of clean substrates for spawning.

Percent nonindigenous individuals measures the degree to which nonindigenous species and hybrids have reduced biological integrity in the Ohio River. Many nonindigenous species increase at degraded sites because the behavioral and ecological mechanisms of species segregation are disrupted (Courtenay and Stauffer 1984; Fuller et al. 2000). The percentage of nonindigenous species was significantly correlated with increased turbidity (Table 2). We retained this metric to document the increasing impacts of nonindigenous and hybrid species in the Ohio River.

The number of DELT anomalies measures the effects of contaminants, diet, and overcrowding (Sanders et al. 1999). We chose the number rather than the percentage of such anomalies (which the Ohio Environmental Protection Agency employs) because of the greater number of individuals captured at great-river sites and the scarcity of DELT anomalies observed. Karr (1981) considered a high proportion of disease to be a reflection of the low-

TABLE 3.—Scoring criteria based on the maximum observed line adjusted for river kilometer (rkm) or the actual value of the unscored metric. For each metric, the letter "X" represents the actual recorded value for that metric.

Metric	Score 1	Score 3	Score 5
Number of species	$X \leq (-0.0046 \cdot (rkm) + 48.28) \cdot 0.33$	$(-0.0046 \cdot (rkm) + 48.28) \cdot 0.33 < X < (-0.0046 \cdot (rkm) + 48.28) \cdot 0.66$	$X \geq (-0.0046 \cdot (rkm) + 48.28) \cdot 0.66$
Number of sucker species	$X \leq (-0.0035 \cdot (rkm) + 14.48) \cdot 0.33$	$(-0.0035 \cdot (rkm) + 14.48) \cdot 0.33 < X < (-0.0035 \cdot (rkm) + 14.48) \cdot 0.66$	$X \geq (-0.0035 \cdot (rkm) + 14.48) \cdot 0.66$
Number of centrarchid species	$X < 3$	$3 \leq X < 6$	$X \geq 6$
Number of great-river species	$X < 2$	$2 \leq X \leq 3$	$X > 3$
Number of intolerant species	$X \leq (-0.004 \cdot (rkm) + 12.87) \cdot 0.33$	$(-0.004 \cdot (rkm) + 12.87) \cdot 0.33 < X < (-0.004 \cdot (rkm) + 12.87) \cdot 0.66$	$X \geq (-0.004 \cdot (rkm) + 12.87) \cdot 0.66$
% Tolerant individuals	$X > 6.66$	$3.33 < X \leq 6.66$	$X \leq 3.33$
% Simple lithophilic individuals	$X \leq (-0.0237 \cdot (rkm) + 105.09) \cdot 0.33$	$(-0.0237 \cdot (rkm) + 105.09) \cdot 0.33 < X < (-0.0237 \cdot (rkm) + 105.09) \cdot 0.66$	$X \geq (-0.0237 \cdot (rkm) + 105.09) \cdot 0.66$
% Nonnative individuals	$X > 8.58$	$4.3 < X \leq 8.58$	$X \leq 4.3$
% Detritivorous individuals	$X \geq (-0.006 \cdot (rkm) + 51.49) \cdot 0.66$	$(-0.006 \cdot (rkm) + 51.49) \cdot 0.33 < X < (-0.006 \cdot (rkm) + 51.49) \cdot 0.66$	$X \leq (-0.006 \cdot (rkm) + 51.49) \cdot 0.33$
% Invertivorous individuals	$X \leq (-0.0335 \cdot (rkm) + 138.4) \cdot 0.33$	$(-0.0335 \cdot (rkm) + 138.4) \cdot 0.33 < X < (-0.0335 \cdot (rkm) + 138.4) \cdot 0.66$	$X \geq (-0.0335 \cdot (rkm) + 138.4) \cdot 0.66$
% Piscivorous individuals	$X \leq (-0.0047 \cdot (rkm) + 96.56) \cdot 0.33$	$(-0.0047 \cdot (rkm) + 96.56) \cdot 0.33 < X < (-0.0047 \cdot (rkm) + 96.56) \cdot 0.66$	$X \geq (-0.0047 \cdot (rkm) + 96.56) \cdot 0.66$
Number of DELT anomalies	$X \geq 4$	$2 \leq X < 4$	$X < 2$
CPUE	$X \leq (-0.018 \cdot (rkm) + 740.29) \cdot 0.33$	$(-0.018 \cdot (rkm) + 740.29) \cdot 0.33 < X < (-0.018 \cdot (rkm) + 740.29) \cdot 0.66$	$X \geq (-0.018 \cdot (rkm) + 740.29) \cdot 0.66$

est extreme in biological integrity. These anomalies are absent or occur infrequently in areas with high water quality, but their occurrence increases at impacted sites (Mills et al. 1993; Baumann et al. 1987; Ohio Environmental Protection Agency 1989; Sanders et al. 1999). We expected low levels of DELT anomalies because of improvements in water quality since the 1970s (Emery et al. 1999). Despite the rarity of DELT anomalies, we retained this metric to capture any future degradation or impacts specifically associated with point- and non-point-source pollution. The number of DELT anomalies increased with increased turbidity and at sites with low dissolved oxygen (Table 2).

Our CPUE metric, namely, that for species list 3, was modified from Karr's (1981) number of individuals metric. The number of fish is a measure of community productivity. However, because it is difficult to obtain a quantitative measure of fish abundance in open systems such as the Ohio River, we employ CPUE for a standard sampling technique. We believe that an increase in abundance reflects greater biological integrity, although nutrient inputs often exaggerate the productivity of the reach by causing an increase in abundance. Specific taxa often respond in a predictable manner to this type of stimulation. These increases have been accounted for in our CPUE metric by removing the species designated as tolerant, nonindigenous, and hybrids (Appendix 1).

Index Scoring and Responsiveness

We generated the scoring calculations for each of the 13 metrics (Table 3). Metrics that were significantly correlated with river kilometer were adjusted by the regression equations for those metrics. The sum of the scores of the 13 metrics resulted in ORFIn scores that ranged from 7 to 59 (mean ± SD, 30.4 ± 11.8). The potential range is 0–65. The ORFIn scores from nonoutfall sites were significantly higher than those from sites within the first 500 m of point source of chemical, thermal, and wastewater effluents (analysis of variance [ANOVA]: $F = 8.127$; $P < 0.05$; Figure 3). The mean ORFIn scores showed a pattern of recovery over a distance of 300 m downstream (methods described in Emery and Thomas 2002). The ORFIn scores were lowest at shallow sites with sand and fine substrates (ANOVA; $P < 0.05$) and highest at deeper sites with coarse substrates, clear water, and cooler temperatures (Table 2; Figure 4).

Discussion

Because they exhibit diverse morphological, ecological, behavioral, and evolutionary adaptations to their natural habitat, fish species are particularly effective indicators of the condition of aquatic systems (Karr et al. 1986; Fausch et al. 1990; Simon and Lyons 1995). Human disturbance of streams and landscapes alters key attributes of

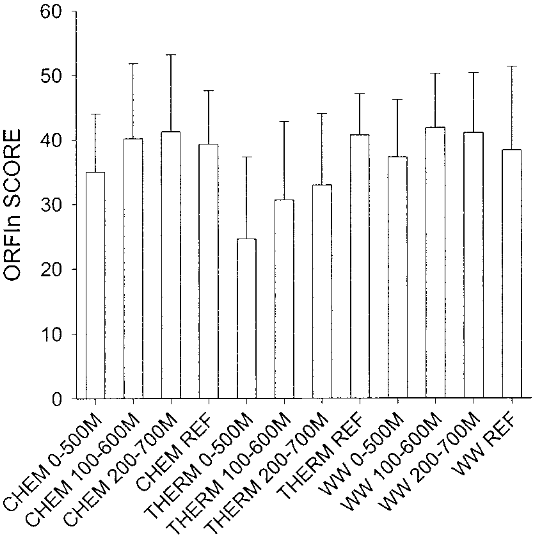

FIGURE 3.—Mean Ohio River Fish Index (ORFIn) scores (+SD) for three overlapping 500-m electrofishing zones affected by chemical (CHEM), thermal (THERM), or wastewater (WW) point source discharges and control sites (REF) not affected by point source discharges.

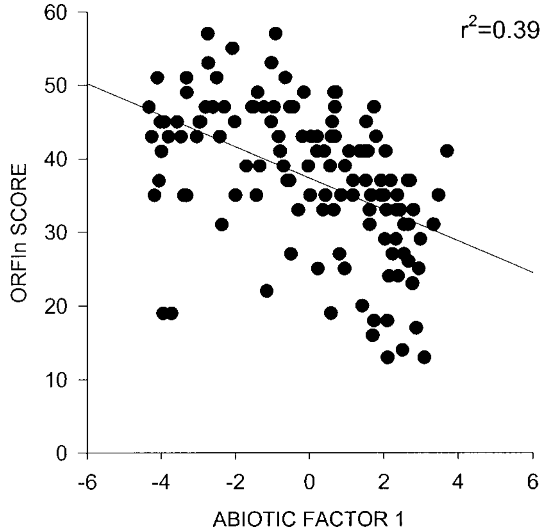

FIGURE 4.—Regression of ORFIn scores on a multivariate axis of abiotic variables ($P < 0.001$). Sites on the left (negative) side of the *x*-axis have better water quality and physical habitat conditions (i.e., they are deeper and have coarser substrates, lower turbidity, and higher dissolved oxygen) than sites on the right (positive) side of the axis.

aquatic ecosystems, namely, water quality, habitat structure, hydrological regime, energy flow, and biological interactions (Karr and Dudley 1981). We were able to identify fish assemblage variables that were strongly correlated with degraded substrate quality and water quality variables that reflected anthropogenic disturbance. In our analyses, the strongest correlations between ORFIn metrics and environmental variables were with those measures that described the heterogeneity of depth, substrate quality, dissolved oxygen, and temperature. Nine metrics that we expected to be sensitive to disturbance decreased with degraded substrate quality. Three metrics that we expected to be relatively insensitive to disturbance increased with increased pH and turbidity. Seven metrics decreased as disturbance (measured by a multivariate axis of substrate and water quality) increased. The resulting IBI for the Ohio River was significantly correlated with an aggregate (multivariate) measure of habitat quality that represented different types and intensities of anthropogenic disturbance.

This approach may be applied to other large rivers, particularly those that have comparable evolutionary histories (i.e., large Midwestern rivers) and similar fish assemblages. The identification of least-impacted sites, particularly the incorporation of a criterion for a minimum distance from point source discharges and hydrologic modifications, should be transferable to any large river system. The assemblage classifications may differ because of local adaptations of fish assemblages to prevailing natural conditions. However, researchers developing multimetric indices of biotic integrity may elect to adopt metrics that reflect past conditions (e.g., the percentage of tolerant individuals), metrics that are likely to respond to future water quality improvement (e.g., the number of intolerant species) or degradation (e.g., the percentage of tolerant individuals and the number of DELT anomalies), or metrics that are likely to reflect ecosystem restoration (e.g., the number of great-river species).

Additional efforts to assess the nutrient loadings or trophic status of the Ohio River and to relate changes in land use to conditions in the Ohio River and trends in water quality to changes in the fish assemblage could provide a more defensible way to define least-impacted conditions. We could not test the response of ORFIn metrics to nutrient loading because we lacked the data to assess the relationship between nutrient chemistry and fish assemblages. However, we did find that ORFIn scores increased with increasing distance from point sources associated with municipal wastewater treatment plants. While these results are consistent with those of Karr et al. (1985b), we cannot directly attribute the decline in ORFIn scores to a particular constituent of the effluent. Comparison of the ORFIn results with those of the modified Index of Well Being (Ohio Environmental Protection Agency 1989) may be used to indirectly assess the responses of fish assemblages to nutrient loading.

Many great-river systems have been hydrologically modified, leading to physicochemical and biotic alterations (Ward and Stanford 1989; Ligon et al. 1995; Poff et al. 1997). Water quality degradation as a result of point- and non-point-source pollution further impacts the ecological integrity of large rivers such as the Ohio (Sparks et al. 1990; Bayley 1995). Clearly, the lack of reference sites representing minimally disturbed conditions affected the metric selection and calibration process. The impoundment of the Ohio River has interrupted the abiotic processes (erosion, sedimentation, and floodplain inundation) and biotic processes (colonization and succession from refugia) that enable it to maintain and restore itself (Gore and Shields 1995; Ligon et al. 1995; Sparks 1995; Poff et al. 1997). Such alterations tend to reduce the abundance and diversity of fishes (Schlosser 1991; Ligon et al. 1995). Loss of biological diversity as a result of the introduction of nonindigenous species (Courtenay and Stauffer 1984), loss of endangered and threatened species (Carlson and Muth 1989), habitat fragmentation (Dynesius and Nilsson 1994; Ward and Stanford 1995; Pringle 1997; Pringle et al. 2000), and declining genetic diversity (Nehlsen et al. 1991) have imperiled the aquatic assemblages of great rivers. However, despite the pervasive and persistent disturbance of the Ohio River by these factors, we were able to identify least-impacted sites that had little evidence of poor water quality or degraded habitat and to verify their status with the ORFIn. The relationship of the ORFIn to habitat variables suggests the need to include calibration of the ORFIn scores with specific habitat classes. Such modifications should improve the ability of the ORFIn to detect water quality impairment.

This research describes an approach for determining least-impacted conditions in the Ohio River and provides a set of fish assemblage metrics that may be applied to the development of IBIs for other great-river systems. By selecting sites that were not immediately influenced by the hydrologic modifications of dams or by point source discharges, we minimized the impacts of human disturbance on our selected sampling reaches. We developed fish assemblage metrics that represent the diversity of native-fish assemblages, preimpoundment conditions, and the impacts associated with the introduction of nonindigenous species as well as important elements of food web structure.

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Appendix: Guild Assignments for Fish Assemblages

TABLE A.1.—Guild assignments for fish assemblages used in metric development for the Ohio River Fish Index. The abbreviation GRS stands for great-river species. Trophic categories are detritivore (D), invertivore (I), and piscivore (P). Reproductive guild designates whether species are simple lithophils (SL) or not. The list includes species collected by electrofishing on the Ohio River since 1991 along with species deemed important based on the possibility of their occurrence in future collections. Species assignments were made by consulting regional fish references as well as professional ichthyologists and fisheries biologists.

Species	Family	GRS	Tolerance	Trophic category	Reproductive guild	Alien
Ohio lamprey *Ichthyomyzon bdellium*	Petromyzontidae		Intolerant			
Chestnut lamprey *I. castaneus*						
Silver lamprey *I. unicuspis*		X				
Lake sturgeon *Acipenser fulvescens*	Acipenseridae	X		I	SL	
Shovelnose sturgeon *Scaphirhynchus platorynchus*		X		I	SL	
Paddlefish *Polyodon spathula*	Polyodontidae	X	Intolerant		SL	
Spotted gar *Lepisosteus oculatus*	Lepisosteidae			P		
Longnose gar *L. osseus*				P		
Shortnose gar *L. platostomus*		X		P		
Alligator gar *L. spatula*		X		P		
Bowfin *Amia calva*	Amiidae			P		
Goldeye *Hiodon alosoides*	Hiodontidae	X	Intolerant			
Mooneye *H. tergisus*		X	Intolerant			
American eel *Anguilla rostrata*	Anguillidae	X				
Skipjack herring *Alosa chrysochloris*	Clupeidae	X		P		
Alewife *A. pseudoharengus*					X	
Gizzard shad *Dorosoma cepedianum*				D		
Central stoneroller *Campostoma anomalum*	Cyprinidae					
Goldfish *Carassius auratus*			Tolerant	D		X
Grass carp *Ctenopharyngodon idella*			Tolerant			X
Red shiner *Cyprinella lutrensis*			Tolerant			X
Spotfin shiner *C. spiloptera*						
Steelcolor shiner *C. whipplei*				I		
Common carp *Cyprinus carpio*			Tolerant	D		X
Cypress minnow *Hybognathus hayi*						
Mississippi silvery minnow *H. nuchalis*		X				
Bighead carp *Hypophthalmichthys nobilis*			Tolerant			X
Striped shiner *Luxilus chrysocephalus*				I		
Speckled chub *Macrhybopsis aestivalis*		X		I		
Silver chub *M. storeriana*		X		I	SL	
Hornyhead chub *Nocomis biguttatus*				I		
River chub *N. micropogon*						
Golden shiner *Notemigonus crysoleucas*			Tolerant			
Bigeye chub *Notropis amblops*			Intolerant	I	SL	
Emerald shiner *N. atherinoides*				I		
River shiner *N. blennius*		X		I	SL	
Silverjaw minnow *N. buccatus*				I		
Ghost shiner *N. buchanani*		X		I		
Spottail shiner *N. hudsonius*				I		

TABLE A.1.—Continued.

Species	Family	GRS	Tolerance	Trophic category	Reproductive guild	Alien
Silver shiner *N. photogenis*						
Rosyface shiner *N. rubellus*			Intolerant	I		
Silverband shiner *N. shumardi*						
Sand shiner *N. stramineus*			Intolerant			
Mimic shiner *N. volucellus*			Intolerant	I		
Channel shiner *N. wickliffi*		X				
Suckermouth minnow *Phenacobius mirabilis*				I		
Bluntnose minnow *Pimephales notatus*			Tolerant	D		
Fathead minnow *P. promelas*			Tolerant	D		
Bullhead minnow *P. vigilax*						
Blacknose dace *Rhinichthys atratulus*					SL	
River carpsucker *Carpiodes carpio*	Catostomidae			D		
Quillback *C. cyprinus*				D		
Highfin carpsucker *C. velifer*				D		
White sucker *Catostomus commersoni*			Tolerant	I/D	SL	
Blue sucker *Cycleptus elongatus*		X	Intolerant	I	SL	
Northern hog sucker *Hypentelium nigricans*			Intolerant	I	SL	
Smallmouth buffalo *Ictiobus bubalus*				D		
Bigmouth buffalo *I. cyprinellus*				D		
Black buffalo *I. niger*				D		
Spotted sucker *Minytrema melanops*				I	SL	
Silver redhorse *Moxostoma anisurum*				I	SL	
River redhorse *M. carinatum*			Intolerant	I	SL	
Black redhorse *M. duquesnei*			Intolerant	I	SL	
Golden redhorse *M. erythrurum*				I	SL	
Shorthead redhorse *M. macrolepidotum*			Intolerant	I	SL	
Grass Pickerel *Esox americanus vermiculatus*	Esocidae			P		
Northern pike *E. lucius*				P		
Muskellunge *E. masquinongy*				P		
White catfish *Ameiurus catus*	Ictaluridae					X
Black bullhead *A. melas*			Tolerant			
Yellow bullhead *A. natalis*			Tolerant			
Brown bullhead *A. nebulosus*			Tolerant			
Blue catfish *Ictalurus furcatus*		X				
Channel catfish *I. punctatus*						
Mountain madtom *Noturus eleutherus*				I		
Slender madtom *N. exilis*				I		
Stonecat *N. flavus*			Intolerant	I		
Tadpole madtom *N. gyrinus*				I		
Brindled madtom *N. miurus*				I		
Freckled madtom *N. nocturus*				I		
Northern madtom *N. stigmosus*				I		
Flathead catfish *Pylodictis olivaris*				P		
Trout perch *Percopsis omiscomaycus*	Percopsidae			I		
Pirate perch *Aphredoderus sayanus*	Aphredoderidae			I		
Banded killifish *Fundulus diaphanus*	Fundulidae			I		X
Blackstripe topminnow *F. notatus*				I		
Western mosquitofish *Gambusia affinis*	Poeciliidae			I		
Brook silverside *Labidesthes sicculus*	Atherinidae			I		
Inland silverside *Menidia beryllina*						X
White perch *Morone americana*	Percichthyidae			P		
White bass *M. chrysops*				P		
Yellow bass *M. mississippiensis*			Intolerant	P		
Striped bass *M. saxatilis*				P		X
Rock bass *Ambloplites rupestris*	Centrarchidae			P		
Green sunfish *Lepomis cyanellus*			Tolerant	I		
Pumpkinseed *L. gibbosus*				I		
Warmouth *L. gulosus*				I		
Orangespotted sunfish *L. humilis*				I		
Bluegill *L. macrochirus*				I		
Longear sunfish *L. megalotis*				I		
Redear sunfish *L. microlophus*				I		X
Smallmouth bass *Micropterus dolomieu*			Intolerant	P		
Spotted bass *M. punctulatus*				P		

TABLE A.1.—Continued.

Species	Family	GRS	Tolerance	Trophic category	Reproductive guild	Alien
Largemouth bass *M. salmoides*				P		
White crappie *Pomoxis annularis*				P		
Black crappie *P. nigromaculatus*				I		
Crystal darter *Ammocrypta asprella*	Percidae	X		I		
Eastern sand darter *A. pellucida*				I	SL	
Mud darter *Etheostoma asprigene*				I		
Greenside darter *E. blennioides*			Intolerant	I		
Rainbow darter *E. caeruleum*				I	SL	
Bluebreast darter *E. camurum*			Intolerant	I		
Bluntnose darter *E. chlorosoma*				I		
Fantail darter *E. flabellare*				I		
Johnny darter *E. nigrum*				I		
Orangethroat darter *E. spectabile*				I	SL	
Variegate darter *E. variatum*			Intolerant	I		
Banded darter *E. zonale*			Intolerant	I		
Yellow perch *Perca flavescens*						
Logperch *Percina caprodes*			Intolerant	I	SL	
Channel darter *P. copelandi*		X	Intolerant	I	SL	
Blackside darter *P. maculata*				I	SL	
Slenderhead darter *P. phoxocephala*			Intolerant	I	SL	
Duskey darter *P. sciera*			Intolerant	I	SL	
River darter *P. shumardi*		X		I	SL	
Sauger *Stizostedion canadense*				P	SL	
Walleye *S. vitreum*				P	SL	
Freshwater drum *Aplodinotus grunniens*	Sciaenidae					
Striped mullet *Mugil cephalus*	Mugilidae					X

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ELECTROFISHING IN BOATABLE RIVERS: DOES SAMPLING DESIGN AFFECT BIOASSESSMENT METRICS?

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Abstract. Data were collected from 60 boatable sites using an electrofishing design that permitted comparisons of the effects of designs and distances on fish assemblage metrics. Sites were classified *a priori* as Run-of-the-River (ROR) or Restricted Flow (RF). Data representing four different design options (i.e., 1000 and 2000 m for both single and paired banks) were extracted from the dataset and analyzed. Friedman tests comparing metric values among the designs detected significant differences for all richness metrics at both types of sites and for catch per unit effort and percent tolerant species at ROR sites. Richness metrics were generally higher for the two 2000-m designs than for the two 1000-m designs. When plotted against cumulative electrofishing distance, the percent change in metrics declined sharply within approximately 1000 m, after which metrics usually varied by less than 10%. These data demonstrate that designs electrofishing 1000 m of shoreline are sufficient for bioassessments on boatable rivers similar to those in this study, regardless of whether the shoreline is along a single bank or distributed equally among paired banks. However, at sites with depths greater than 4 m, it may be advisable to employ nighttime electrofishing or increase day electrofishing designs to 2000 m.

Keywords: bioassessment, biocriteria, biological criteria, boatable, electrofishing, fish surveys, large, monitoring, rivers

1. Introduction

Since the U.S. Environmental Protection Agency (EPA) endorsed the use of biological indicators to assess environmental conditions and ecological health (U.S. EPA, 1990a,b), there has been tremendous growth in their use among agencies that assess aquatic resources (Davis *et al.*, 1996). Fish assemblages are among the indicators frequently used in bioassessments (Barbour *et al.*, 1999; Simon, 1999; McCormick and Peck, 2000), and the advantages and disadvantages of using fish assemblages for bioassessments have been discussed extensively (Hocutt, 1981; Karr, 1981; Reynolds, 1983; Fausch *et al.*, 1990; Yoder and Rankin, 1995; Bayley and Dowling, 1993; Barbour *et al.*, 1999; Simon, 1999; McCormick and Peck, 2000). In addition, correlations have been successfully demonstrated between fish indices of biotic integrity (IBIs) and human activities that influence streams and rivers (e.g., Karr *et al*., 1985; Berkman *et al*., 1986; Leonard and Orth, 1986; Ohio EPA, 1987a, 1999; Steedman, 1988; Karr, 1991; Yoder and Rankin, 1995). Although IBIs have been widely applied in wadeable streams and are slowly gaining popularity for the assessment of large rivers, their application in large rivers has been relatively limited (Hughes and Gammon, 1987; Oberdorff and Hughes, 1992; Simon, 1999; Lyons *et al*., 2001).

Electrofishing is commonly used to collect fish for bioassessments because it is widely considered to be the single most comprehensive and effective method for collecting fishes in streams and rivers (Vincent, 1971; Gammon, 1973, 1976; Novotny and Priegel, 1974; Ohio EPA, 1987b; Davis *et al*., 1996; Barbour *et al*., 1999; Simon and Sanders, 1999). Although a wide variety of field electrofishing designs are currently in use, studies that compare these designs are limited. Variables that may be important in evaluating performance characteristics of a given field design include the spatial extent and relationship of habitat features, the spatial coherence of an assemblage, the local (alpha) diversity, and spatial and temporal distributions of fishes.

This study was undertaken to: (1) compare commonly used boat-based electrofishing designs; (2) determine the sampling distance at which the values of common bioassessment metrics begin to stabilize; and (3) study the influence of physical site characteristics on the designs. The compared designs are quantitative and serve the purpose of supporting bioassessment and monitoring activities. The primary goal of this study was to develop a Large River Bioassessment Protocol (LR-BP) that will provide states, regions, tribes, and other federal agencies needing methods with the ability to effectively use fish assemblages to evaluate the condition of large rivers, an integral part of achieving water quality for all surface waters.

2. Methods

2.1. Study Area

We collected data during a single season (summer, 1999) from the Great Miami ($n = 20$), Scioto ($n = 20$), Kentucky ($n = 10$) and Green rivers ($n = 10$), each of which is a major tributary of the Ohio River (Figure 1). These sites were classified *a priori* into two general types of sites. The first type of sites were those that were either free flowing or associated with low-head dams that store rather than regulate waters. These sites were termed Run-of-the-River (ROR) sites. The second type of site sampled was that heavily influenced by navigational lock-and-dam structures built to support commercial traffic. These were termed Restricted Flow (RF) sites.

The Great Miami and Scioto rivers flow principally through agricultural and forested lands with some sections flowing through major urban and industrial corridors before reaching the Ohio River. Both rivers have sections with exposed riffles and rapids and sections with restricted flow, but are both generally shallower than the Kentucky and Green rivers and, therefore, largely ROR sites.

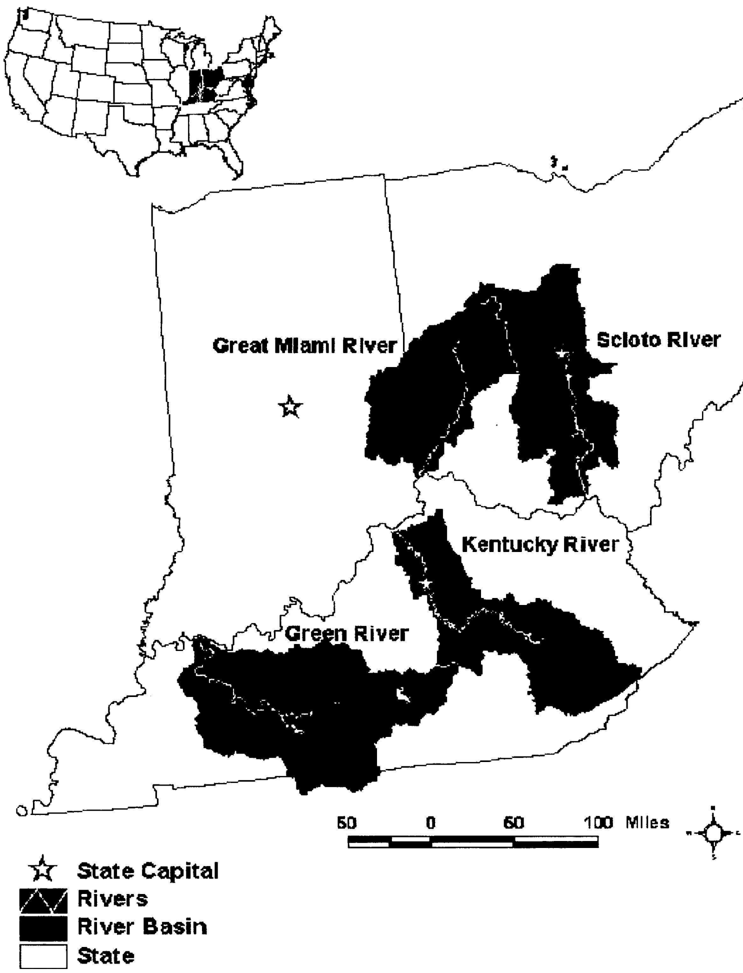

Figure 1. Sample sites on the Great Miami, Scioto, Kentucky and Green rivers, all major tributaries in the Ohio River basin.

The Kentucky River has a series of 14 lock-and-dam structures that span the length of the mainstem, rendering it completely impounded. The mainstem of the Green River has six lock-and-dam structures, the most upstream of which is at river kilometer (rkm) 292.5. Above the influence of this dam, the river is free flowing with significant areas of exposed riffles and rapids until rkm 330.1, where a dam for a large reservoir is located. As a result of impoundment, most sections of the Kentucky and Green rivers are much deeper than those of the Great Miami and Scioto rivers and therefore RF sites. However, those above rkm 292.5 on the Green River are ROR sites. Additional physical attributes of each basin and dominant land uses are summarized in Table I.

Sampling locations on the Great Miami and Scioto rivers were selected from existing Ohio EPA sampling sites. Sites for the Kentucky and Green rivers were

TABLE I
Descriptive characteristics and dominant land uses of basins

River	Length (km)	Drainage area (km^2)	Average stream gradient (cm/km)	Predominant land use and influences	Physiographic regions
Great Miami	274	13,947	73.9	*Upper*: agriculture *Middle*: urban, industrial, dams, channelization *Lower*: agriculture, gravel mining	Till plains and interior plateau (lowest portion)
Scioto	370	16,879	43.6	*Upper*: agriculture, some urban *Middle*: gravel and sand mining *Lower*: forested, limited agriculture	*Upper*: till plains *Middle*: glaciated and unglaciated Allegheny plateaus *Lower*: unglaciated Allegheny plateau
Kentucky	410	18,130	13.3	14 locks and dams *Upper*: forestry, coal mining, limited agriculture *Middle*: agriculture, urban *Lower*: forest and agriculture	*Upper*: Eastern Kentucky Coal Field *Middle and lower*: bluegrass
Green	532	23,040	NA	*Upper*: agriculture *Middle*: agriculture, locks and dams *Lower*: agriculture, locks and dams, strip mining	*Upper and middle*: Mississippian Plateau *Lower*: Western Kentucky Coal Field

chosen based on known boat ramp locations and a review of land-use maps. Sites were well distributed along the length of the main stem of each river and included a mixture of habitat types. For site-specific reach placement, we attempted to avoid obvious stressors, such as major outfalls, stream confluences, and bridges, because the effects of these features were not the focus of this study and their inclusion would influence comparisons among field designs.

2.2. Electrofishing methods

An electrofishing design was devised that permitted the concomitant collection of data to compare the effects of four designs and distance alternatives on metrics in a single pass of the study area (Figure 2). The design included electrofishing on both banks and consisted of 13 intermediate fish processing points.

On one bank, the distance electrofished was 40 times the wetted width (after McCormick and Hughes, 2000) to a maximum of 2000 m. Based on our experiences and personal communications with local, state, regional and national assessment communities, 2000 m was considered to be the longest logistically acceptable electrofishing distance a program could consider for rivers of this type. Reach lengths exceeding 2000 m may also have encompassed ranges of influences that were too broad to be synoptic. The total shore distance on this bank was divided into 10 zones (Figure 2) delineated by transects spanning the width of the stream and labeled "A" to "K" (after McCormick and Hughes, 2000). The downstream endpoint of the

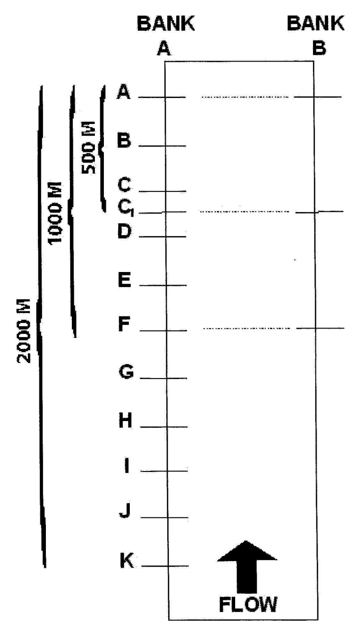

Figure 2. Electrofishing design used in study.

sample reach was transect “A”. From that point, each of the remaining transects was a distance equal to 1/10 of the designated reach length upstream of the previous transects. In most cases, this distance was 200 m. Electrofishing began at transect “K” and fish were processed at each transect “J” to “A” and at 500 m upstream of transect “A”. When the river was greater than 50 m wide, this additional processing point was designated as transect “C1”. On the opposite bank, 1000 m were electrofished with collected fish being processed at points that were 500 and 1000 m upstream of transect “A”.

Electrofishing was conducted following the methods of McCormick and Hughes (2000). Sampling proceeded in a downstream direction along the main-channel riparian habitat of each bank at a speed near or, if velocities were low, slightly exceeding the river velocity (Reynolds, 1983; Ohio EPA, 1989; McCormick and Hughes, 2000). At each of the processing points, all fish were identified and then retained in holding nets. After electrofishing had been completed on both banks, all fish were released with the exception of representative vouchers of specimens that needed to be identified in the laboratory.

All sampling was conducted during the low and stable-flow index period of mid-June to early October (Ohio EPA, 1989; Lazorchak *et al*., 2000; Moulton *et al*., 2002). This index period has been suggested and widely accepted based on the assumption that it increases the likelihood that samples throughout a study unit can be collected under similar flow conditions (Gilliom *et al*., 1995).

Data representing four different design options were extracted from the electrofishing dataset. The first design (SB-1000) used data collected along a single bank for 1000 m. The second design (PB-1000) used data collected along 500 m of paired banks (1000 m total shoreline). The third design (SB-2000) used data collected along a single bank for 2000 m, and the fourth design (PB-2000) used data collected along 1000 m of paired banks (2000 m total shoreline) (Figure 2).

All sample reaches with wetted widths less than 50 m were excluded from the analysis dataset. Consequently, all sites included in the dataset had reach lengths of 2000 m on one bank, 1000 m on the opposite bank and 13 processing points across the reach. This resulted in uniform design comparisons across all sites.

2.3. Physical habitat

To study the influence of physical site characteristics on the comparisons, habitat data were collected using the methods designed by Kaufmann (2000) for use in the EMAP-SW large river projects. Protocols of this approach are divided into channel and riparian/littoral measurements, and are integrated across 11 transects (A–K) for reach characterization. Transects used for electrofishing were used for the collection of these data. Habitat assessment techniques of these protocols are weighted toward quantitative measures. Physical habitat variables were calculated using descriptions and formulas in Kaufmann *et al*. (1999).

2.4. Analysis

To validate our *a priori* classification of sites as ROR or RF, we described natural variation in the physical habitat characteristics of sites using principal components analysis (PCA). Variables included in the analysis were mean shore depth, mean thalweg depth, range of thalweg depth, mean wetted width, bankfull height, mean temperature, mean width–depth ration, percent sand, percent gravel, percent cobble and larger substrate in thalweg, and number of substrates at a site. The first two principal components were plotted to look for separation of sites by impoundment class.

To compare the relative performance of the four-electrofishing designs tested in this study, we analyzed 12 fish metrics. These metrics were: (1) catch-per-unit-effort (CPUE); (2) number of taxa (excluding exotic species); (3) number of sunfish taxa; (4) number of sucker taxa; (5) number of intolerant taxa; (6) percent round-bodied suckers; (7) percent omnivores; (8) percent insectivores and invertivores; (9) percent carnivores; (10) percent tolerant individuals; (11) percent simple lithophils and (12) percent individuals with deformities, eroded fins, lesions, and tumors (DELT anomalies). These metrics were selected because of their wide use as effective metrics in the bioassessment of boatable rivers (Ohio EPA, 1987b; Simon, 1992, 1994). Multiple sources were consulted to determine the trophic status of collected species, and the designations used (Appendix) conformed largely to summaries in Barbour *et al*. (1999).

A nonparametric, repeated measures analysis of variance (i.e., the Friedman test) with associated multiple comparison procedures (Hollander and Wolfe, 1999) was used to compare electrofishing designs based on metric values. The Friedman test was used because most metric distributions were neither normal nor transformable to normality.

To examine the effect of electrofishing distance on metrics, we ran Monte Carlo simulations, which minimized the effect of influential sections within a sampling reach. In each simulation, the 10 individually processed, 200-m sections electrofished along a single bank within a site were randomly ordered. Then, each metric was calculated for progressively longer distances encompassing from 1 to 10 sections. This process was repeated 100 times for each site. For each metric, we calculated the percent change in metric value between successively longer sections of river. We plotted the mean percent change in metric value against the distance electrofished for each site as a way to identify patterns across sites. These analyses were run separately for the ROR and RF sites.

3. Results

Data were collected at 60 river sites. At each of these sites, fish were collected and processed at sub-sites to produce individual datasets for analysis. Seven sites were excluded because of anomalous or missing physical habitat or fish information. An additional four sites with wetted widths less than 50 m were excluded to allow for

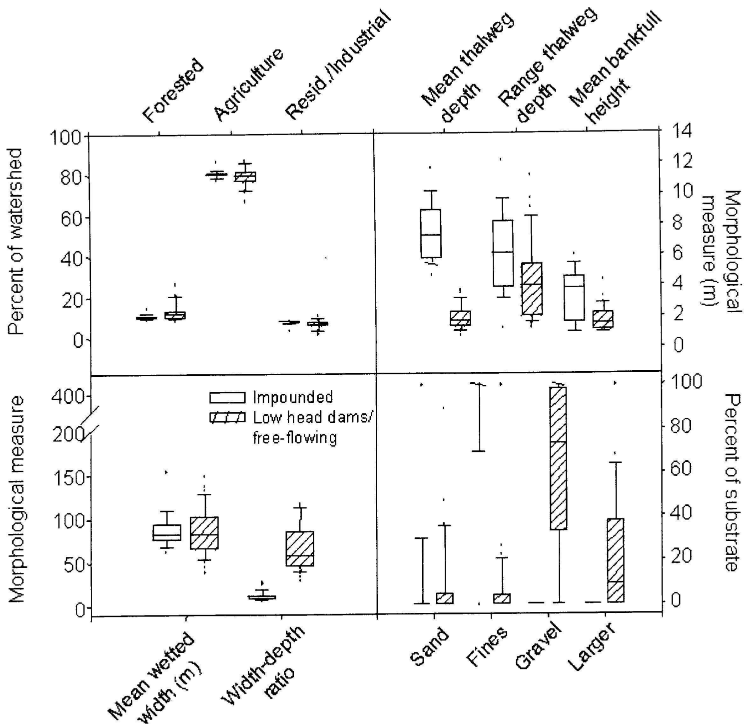

Figure 3. Physical site characteristics of sample sites used in analysis.

more straightforward statistical comparison of designs. For comparisons among designs, data from 49 sites and 637 individual datasets remained for analysis. Physical site characteristics included in analysis are summarized in Figure 3. Eighty-nine species in 15 families were identified from the 28,100 fish collected (Appendix).

The first axis of the PCA on physical habitat variables explained approximately 37% of the variation (Table II; Figure 4). The two variables with the highest loadings on the first axis were mean width–depth ratio and mean thalweg depth. Sites separated along the first PCA axis, corresponding to sites having a mean thalweg depth of more than 4 m (RF sites) or less than 4 m (ROR sites). These results validated our *a priori* separation of sites into ROR and RF sites and justified separate analyses by impoundment class.

Friedman tests comparing metric values among the four designs detected a significant difference for CPUE and percent tolerant species at ROR sites (Table III). Box plots comparing metric distributions among designs are presented in Figure 5. Significant differences were also detected among designs for all richness metrics at both ROR and RF sites, although the differences were not always detected in the multiple comparisons (e.g., number of sunfish taxa and number of intolerant species at RF sites). The only percentage metric with a significant difference among designs was percent tolerant individuals at ROR sites. However, the

TABLE II

Principal components analysis weights of physical habitat variables ($N = 48$; one site excluded because of missing substrate data point)

Variable	Axis 1[a]	Axis 2[b]
Mean wetted width	0.009	0.091
Bank full height	0.323	0.244
Mean water temperature	0.338	–0.003
Mean thalweg depth	0.490	–0.051
Mean width-depth ratio	–0.435	0.104
Range of thalweg depth	0.291	0.157
Number of substrates	–0.291	0.390
Percent sand in thalweg	–0.052	0.760
Percent gravel in thalweg	–0.381	–0.355
Percent cobble and larger in thalweg	–0.184	0.196

[a]Eigenvalues: $\lambda = 3.70$; % variance: 37.0%.
[b]Eigenvalues: $\lambda = 1.40$; % variance: 14.0%.

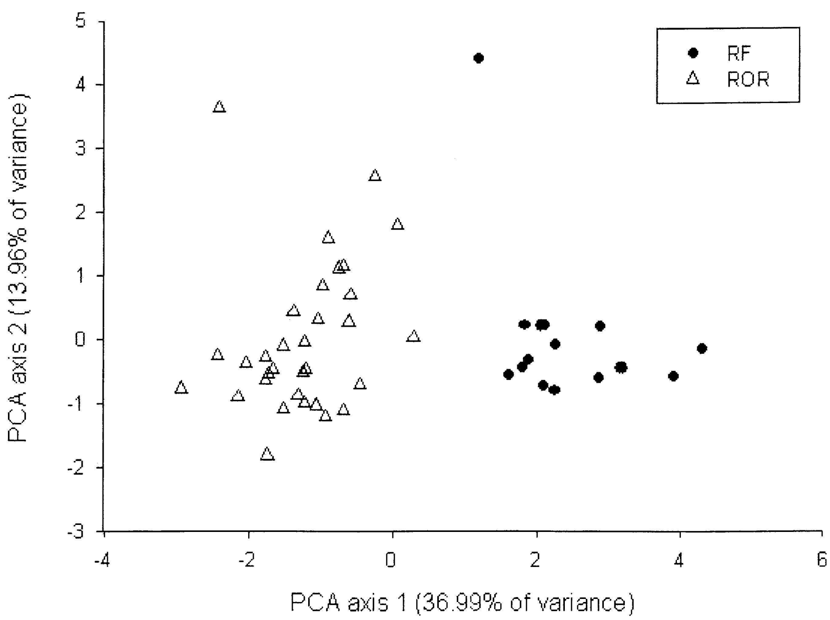

Figure 4. Principle component analysis showing the separation of sites along the first axis, which corresponded to grouping sites as having a mean thalweg depth of greater than 4 m (RF sites) or less than 4 m (ROR sites).

metric values were relatively low and likely have little interpretive value for this study.

In general, the richness metric values of the PB-2000 and SB-2000 designs were higher than those of the SB-1000 and PB-1000 designs. No significant differences

TABLE III

Comparison of metric values among four electrofishing designs (by river classification group) using Friedman tests (bolded if significant at 0.05) and multiple comparisons (∝ = 0.05)

Metric	Group	S'	p-value	SB-1000	PB-1000	SB-2000	PB-2000
CPUE	**ROR**	**13.65**	**0.003**	**AB**	**B**	**A**	**AB**
	RF	5.67	0.129				
No. taxa	**ROR**	**71.77**	**<0.001**	**A**	**A**	**B**	**B**
	RF	**41.00**	**<0.001**	**A**	**A**	**B**	**B**
No. sunfish taxa	**ROR**	**24.56**	**<0.001**	**AB**	**A**	**CB**	**C**
	RF	**13.22**	**0.004**	A	A	A	A
No. sucker taxa	ROR	**40.41**	**<0.001**	**A**	**A**	**B**	**B**
	RF	**21.55**	**<0.001**	**A**	**A**	**B**	**B**
No. intolerant taxa	**ROR**	**42.22**	**<0.001**	**A**	**A**	**B**	**B**
	RF	**8.39**	**0.039**	A	A	A	A
% Round-bodied suckers	ROR	0.72	0.868				
	RF	1.69	0.639				
% Omnivores	ROR	4.39	0.222				
	RF	0.89	0.829				
% Insectivores + invertivores	ROR	3.93	0.269				
	RF	0.73	0.865				
% Carnivores	ROR	5.05	0.168				
	RF	1.00	0.801				
% Tolerant	**ROR**	**11.36**	**0.010**	**A**	**B**	**AB**	**AB**
	RF	1.81	0.613				
% Simple lithophils	ROR	3.12	0.374				
	RF	1.76	0.624				
% DELT anomalies	ROR	4.46	0.216				
	RF	7.57	0.056				

were detected between designs of equal shoreline distance electrofished for any of the richness metrics (i.e., SB-1000 *vs*. PB-1000 and SB-2000 *vs*. PB-2000).

For the examination of the effect of sampling distance on metrics, an additional five sites were excluded due to variance in transect delineation. These included sites where logistical constraints did not permit the delineation of transects at their assigned locations and some suffering from human error. Forty-four sites remained for inclusion in the analysis.

Plots of percent change in metrics by the distance electrofished along one bank demonstrated a sharp decline in changes in metrics within approximately 1000 m in ROR and RF sites (Figure 6). After 1000 m, the degree of variation in metric value was usually less than 10%.

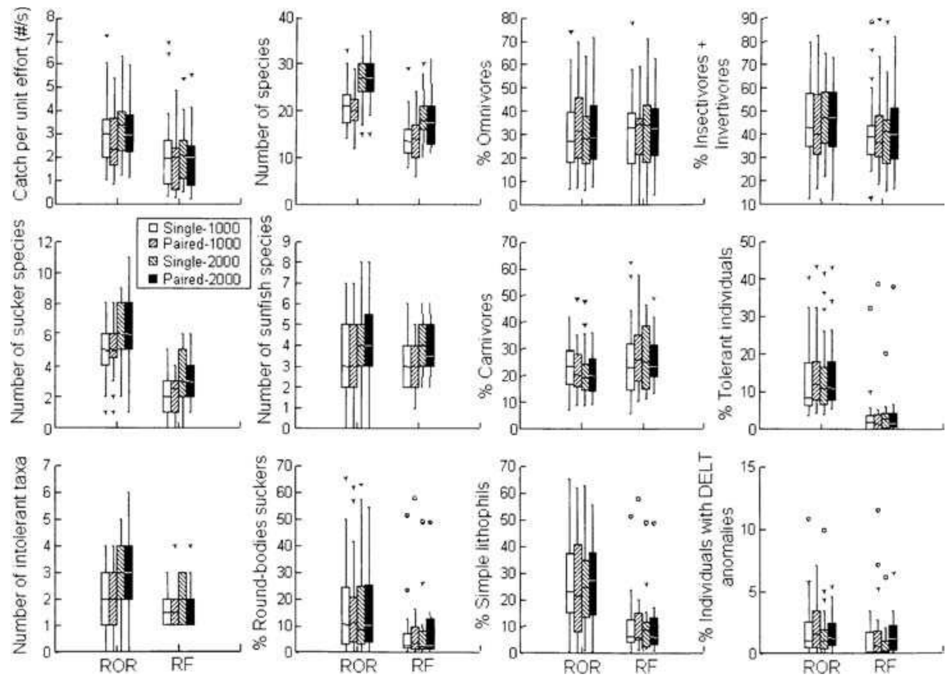

Figure 5. Box and whisker plots of mean metrics values compared across four electrofishing designs.

Percent change in the percent round-bodied suckers metric was slightly more variable with distance, especially in RF sites. However, the overall percent change was relatively low, usually below 15% for ROR and RF sites within 1000–1200 m, respectively. There was very little change in percent omnivores, percent carnivores, and percent insectivores and invertivores beyond 600 m for sites in either impoundment class. Plots for RF sites were more variable than those for ROR sites, particularly for number of sucker taxa.

4. Discussion

4.1. Design comparisons

The designs compared in this study are quantitative and have the purpose of supporting bioassessment and monitoring activities of states, regions, tribes and other agencies. They have been designed to collect samples that are as unbiased and representative as possible within the logistical realities of fieldwork and constraints of time and budget and are indicative of the ecological condition of a site when compared to sites of known condition. This sampling approach is not appropriate for qualitative studies that strive to maximize the number of species as a measure of local (alpha) diversity, although data collected using quantitative methods could be used to supplement qualitative investigations.

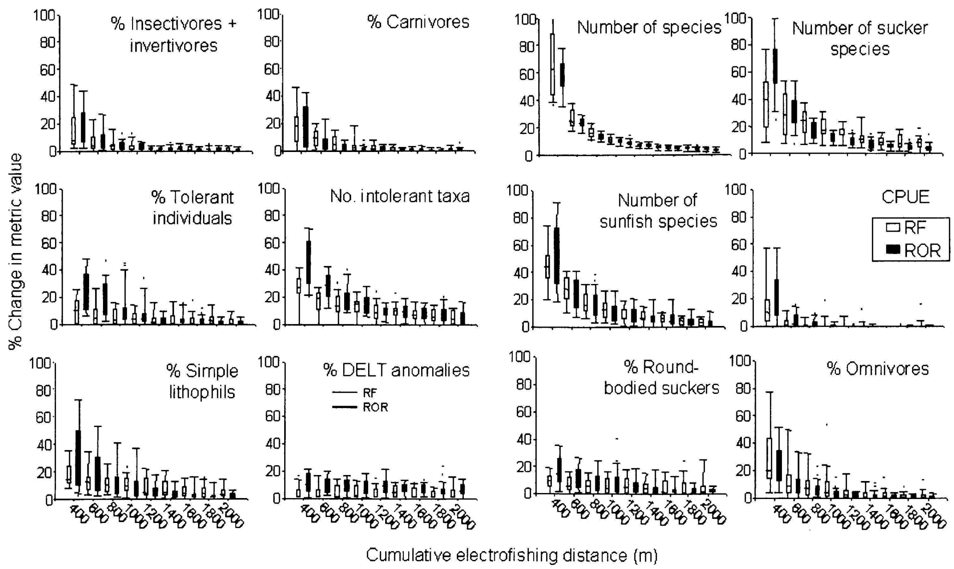

Figure 6. Plots of percent change in metrics by the number of sections electrofished along one bank.

A structured, quantitative sampling approach seeks to be as consistent as possible through time and space, and be scientifically sound. A sampling approach that is more qualitative could be considered to be consistent in that the field scientist seeks to collect as many species as possible as a measure of local diversity, but the ability to maximize species collection can vary greatly as a function of experience, enthusiasm, and attention to detail, as well as logistical constraints. Additionally, the structured and consistent nature of a quantitative sampling approach offers the feature of equal time allocation at sites, a desirable feature for planning and budgeting.

Most standardized electrofishing sampling designs for flowing waters are either fixed-distance or proportional-distance approaches (Barbour *et al.*, 1999). The fixed distance selected may be arbitrary, based on features of an overall study design, or based on species accumulation curves. When species accumulation curves are used, the length of stream that must be electrofished before the curve of an encountered species reaches an asymptotic point, or approaches it so that the effort required to collect additional species is not justified, must first be determined at a pool of sites (Penczak and Zalewski, 1973, 1981; Angermeier and Karr, 1986; Angermeier and Schlosser, 1989; Yoder and Smith, 1999). Then, the fixed distance in which the consistently collected proportion of the population that is deemed necessary for bioassessment purposes can be determined. Fixed-distance designs have the logistical advantages of controlling for the total effort expended at a single reach and limiting the number of field-based decisions, because field personnel need only know a single point to establish the electrofishing zone.

Proportional-distance methods, as described by Lyons (1992), may be "established arbitrarily and based solely on physical features of the stream segment, such as a set number of riffle-pool sequences or a multiple of the mean stream width", or set based on species curves (e.g., Karr *et al.*, 1986; Lazorchak *et al.*, 2000). One example of this approach was demonstrated by Lyons (1992) where it was concluded that a stream reach of 35 times the mean stream width, or a length equal to three complete riffle-pool sequences, ensured that the cumulative number of species captured approached or exceeded an asymptotic level. Other examples recommend sampling for a distance equal to either 40 or 100 times the wetted width (McCormick and Hughes, 2000) or 85 times the wetted width (Hughes *et al.*, 2002). Although scientifically sound for their intended application, logistical issues arise when such designs are applied at sites differing from those for which they were intended (e.g., raftable streams; Hughes *et al.*, 2002) or where the river is excessively wide. This problem can be largely overcome by establishing a maximum sample reach distance (Moulton *et al.*, 2002).

Another issue encountered with proportional-distance methods is the variability associated with determination of the width of the river that will be used as the multiplier to establish site total reach length. Not only do individuals disagree on how and where this value should be determined, but fluctuations in flow status among repeat visits to a site also create discrepancies during analysis. While neither of these issues negates the validity or utility of this approach, they are issues that must be acknowledged.

We conducted this study to determine the electrofishing sampling distance required to produce robust measures of condition in boatable rivers of the study region. The electrofishing design we used for this study permitted the concomitant collection of data for two purposes in a single pass of the study area. This resulted in some datasets being subsets of others, but avoided the problem of observed differences being the result of differences among the river sections sampled for each design. Thus, when examining the results of the richness metrics, the significant differences detected between the PB-2000 and SB-2000 designs when compared to the SB-1000 and PB-1000 are logical. An increased electrofishing distance increases the likelihood of encountering species that occur less frequently or less randomly in the river. However, the importance of these results is that in both the ROR and RF sites, the richness metric results were not significantly different among electrofishing designs of equal shoreline distance (i.e., SB-1000 *vs.* PB-1000 and SB-2000 *vs.* PB-2000). This could lead to the conclusion that total shoreline distance electrofished has more bearing on results than whether a design is single- or paired-banked. However, this conclusion is not supported by the findings for CPUE.

The Friedman test of CPUE metric values at ROR sites detected significant differences among designs, but contrary to the richness metrics, shoreline distance does not explain these results. However, if the mean CPUE values by design are ordered by increasing magnitude (Table IV), we see the trend that as the total

TABLE IV
Mean CPUE metric values at ROR sites of tested electrofishing designs ordered in increasing mean magnitude

Design	SB-1000	PB-1000	PB-2000	SB-2000
Total shoreline electrofished (m)	1000	1000	2000	2000
Mean CPUE value	2.2	3.0	3.0	3.5
Linear river distance electrofished (m)	500	1000	1000	2000

number of linear river meters (not the total number of shore-line meters) sampled by the design increases, the CPUE increases. We explored the possibility that these findings could be explained by the increased likelihood of encountering shoaling species (e.g., gizzard shad *Dorosoma cepedianum* and emerald shiners *Notropis atherinoides*) that are often sporadically collected in large numbers (Simon and Sanders, 1999), but exclusion of these species from the analysis did not change the significance of results. Other possible explanations for this observation are still being explored.

The percentage metrics were very consistent across designs. The only significant difference detected was for percent tolerant species at ROR sites. No logical explanation for the detected differences has been determined. However, the metric values are relatively low and likely have little interpretive value. The consistent performance of the percentage metrics across designs does suggest that they may be of the highest utility when attempting to make future comparisons between different designs.

4.2. Distance effects

Examination of the effect of distance on metric values showed that at a reach span of approximately 1000 m along one bank, metrics changed relatively little with additional electrofishing. In addition, when only considering ROR sites, most metrics showed very little change between electrofishing 800 and 1000 m.

At the RF sites, some metrics (e.g., percent round-bodied suckers and number of sucker taxa) did not level off as well as they did for the ROR sites. This observation is likely a result of the diel movements of some fish species from near-shore during the night, to off-shore or deeper waters during the day (Sanders, 1991, and cited references). As a result, the daytime collection of such species may be sporadic and limited to individuals on exploratory forays. Our study used a daytime main-channel riparian habitat electrofishing design, and would, therefore, be susceptible to these realities. The sucker species seem to be especially prone to such movements (Sanders, 1991), which is evident in our results. Consequently, the daytime collection of species prone to diel movements at RF sites could be considered disruptive to analyses. At a minimum, metric values dependent on such species should be interpreted with caution.

Unfortunately, capturing this diel variation with night electrofishing is problematic. Night electrofishing can produce undue fatigue, pose possible safety risks, or be fiscally unfeasible (Graham, 1986) and is usually avoided if satisfactory results can be obtained through daytime sampling. Our data suggest that in these systems, at depths greater than 4 m, the diel movements of fish significantly impact the quality of daytime electrofishing results to the extent that the consideration of night electrofishing is justified. A depth criterion comparable to this is likely applicable to other river systems.

After electrofishing 180 km among four rivers, collecting 28,100 fish, and running 52,800 simulations, we arrived at the following conclusions.

1) Fixed-distance electrofishing designs of logistically practical and safe distances are sufficient for bioassessments on boatable river sites like those in this study.
2) Depth plays a critical role in the response of fish assemblages to electrofishing and the resulting metric values. For example, at sites less than 4 m, a daytime main-channel, border design that electrofishes 1000 m along a single bank or 500 m on paired bank is sufficient to characterize sites for bioassessment purposes. At sites greater than 4 m, results were more variable.
3) At sites greater than 4 m, we suggest that a switch from daytime to night electrofishing be considered. If night electrofishing is not feasible, we suggest increasing the electrofishing distance at these sites to a 1000-m paired-banks design or a 2000-m single-bank design. In addition, metrics based on fish species prone to diel movements should be interpreted with caution.

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Appendix: Fishes collected during the study "trophic status" and "special designation" classifications follow Barbour *et al.* (1999)

Latin name	Common name	Trophic status	Special designation
Petromyzondidae	Lampreys		
Lampetra appendix	American brook lamprey	Filter	
Ichthyomyzon bdellium	Ohio lamprey	Piscivore	
Ichthyomyzon unicuspis	Silver lamprey	Piscivore	
Lepisosteidae	Gars		
Lepisosteus osseus	Longnose gar	Piscivore	
Lepisosteus oculatus	Spotted gar	Piscivore	
Lepisosteus platostomus	Shortnose gar	Piscivore	
Amiidae	Bowfins		
Amia calva	Bowfin	Piscivore	
Clupeidae	Herrings		
Alosa chrysochloris	Skipjack herring	Piscivore	
Dorosoma cepedianum	Gizzard shad	Omnivore	
Hiodontidae	Mooneyes		
Hiodon tergisus	Mooneye	Insectivore	
Esocidae	Pikes		
Esox lucius	Northern pike	Piscivore	
Esox masquinongy	Muskellunge	Piscivore	
Cyprinidae	Minnows		
Cyprinus carpio	Common carp	Omnivore	Exotic
Carassius auratus	Goldfish	Omnivore	Exotic
Notemigonus crysoleucas	Golden shiner	Omnivore	
Semotilus atromaculatus	Creek chub	Generalist	
Nocomis micropogon	River chub	Insectivore	
Notropis rubellus	Rosyface shiner	Insectivore	
Notropis atherinoides	Emerald shiner	Insectivore	
Notropis stramineus	Sand shiner	Insectivore	
Notropis volucellus	Mimic shiner	Insectivore	
Notropis blennius	River shiner	Insectivore	
Notropis boops	Bigeye shiner	Insectivore	
Notropis photogenis	Silver shiner	Insectivore	
Phenacobius mirabilis	Suckermouth minnow	Insectivore	
Campostoma anomalum	Central stoneroller	Herbivore	
Pimephales notatus	Bluntnose minnow	Omnivore	
Pimephales vigilax	Bullhead minnow	Omnivore	
Cyprinella spiloptera	Spotfin shiner	Insectivore	
Cyprinella whipplei	Steelcolor shiner	Insectivore	

(*Continued on next page*)

Latin name	Common name	Trophic status	Special designation
Erimystax dissimilis	Streamline chub	Insectivore	
Erimystax x-punctatus	Gravel chub	Insectivore	
Luxilus chrysocephalus	Striped shiner	Insectivore	
Lythrurus ardens	Rosefin shiner	Insectivore	
Catostomidae	Suckers		
Catostomus commersoni	White sucker	Omnivore	Round-bodied
Carpiodes cyprinus	Quillback	Omnivore	
Carpiodes carpio	River carpsucker	Omnivore	
Carpiodes velifer	Highfin carpsucker	Omnivore	
Moxostoma macrolepidotum	Shorthead redhorse	Insectivore	Round-bodied
Moxostoma anisurum	Silver redhorse	Insectivore	Round-bodied
Moxostoma carinatum	River redhorse	Insectivore	Round-bodied
Moxostoma duquesnei	Black redhorse	Insectivore	Round-bodied
Moxostoma erythrurum	Golden redhorse	Insectivore	Round-bodied
Hypentelium nigricans	Northern hog sucker	Insectivore	Round-bodied
Cycleptus elongatus	Blue sucker	Insectivore	Round-bodied
Ictiobus bubalus	Smallmouth buffalo	Insectivore	
Ictiobus cyprinellus	Bigmouth buffalo	Insectivore	
Ictiobus niger	Black buffalo	Insectivore	
Minytrema melanops	Spotted sucker	Insectivore	Round-bodied
Ictaluridae	Catfishes		
Ictalurus punctatus	Channel catfish	Piscivore	
Noturus flavus	Stonecat	Insectivore	
Noturus miurus	Brindled madtom	Insectivore	
Pylodictis olivaris	Flathead catfish	Piscivore	
Ameiurus natalis	Yellow bullhead	Insectivore	
Ameiurus nebulosus	Brown bullhead	Insectivore	
Poecillidae	Mosquitofishes		
Gambusia affinis	Western mosquitofish	Insectivore	Exotic
Atherinidae	Silversides		
Labidesthes sicculus	Brook silverside	Insectivore	
Cottidae	Sculpins		
Cottus carolinae	Banded sculpin	Insectivore	
Percichthyidae	Temperate basses		
Morone saxatilis	Striped bass	Piscivore	Exotic
Morone chrysops	White bass	Piscivore	
Centrarchidae	Sunfishes		
Ambloplites rupestris	Rock bass	Piscivore	Blackbass
Lepomis cyanellus	Green sunfish	Insectivore	Sunfish
Lepomis gulosus	Warmouth	Piscivore	Sunfish

(*Continued on next page*)

Latin name	Common name	Trophic status	Special designation
Lepomis macrochirus	Bluegill	Insectivore	Sunfish
Lepomis gibbosus	Pumpkinseed	Insectivore	Sunfish
Lepomis humilis	Orangespotted sunfish	Insectivore	Sunfish
Lepomis megalotis	Longear sunfish	Insectivore	Sunfish
Lepomis microlophus	Redear sunfish	Insectivore	Sunfish
Micropterus dolomieu	Smallmouth bass	Piscivore	Blackbass
Micropterus punctulatus	Spotted bass	Piscivore	Blackbass
Micropterus salmoides	Largemouth bass	Piscivore	Blackbass
Pomoxis annularis	White crappie	Piscivore	Blackbass
Pomoxis nigromaculatus	Black crappie	Piscivore	Blackbass
Percidae	Perches		
Etheostoma nigrum	Johnny darter	Insectivore	
Etheostoma acuticeps	Sharphead darter	Insectivore	
Etheostoma blennioides	Greenside darter	Insectivore	
Etheostoma caeruleum	Rainbow darter	Insectivore	
Etheostoma camurum	Bluebreast darter	Insectivore	
Etheostoma tippecanoe	Tippecanoe darter	Insectivore	
Etheostoma zonale	Banded darter	Insectivore	
Perca flavescens	Yellow perch	Insectivore	
Percina caprodes	Logperch	Insectivore	
Percina sciera	Dusky darter	Insectivore	
Percina evides	Gilt darter	Insectivore	
Percina maculata	Blackside darter	Insectivore	
Percina phoxocephala	Slenderhead darter	Insectivore	
Stizostedion vitreum	Walleye	Piscivore	
Stizostedion canadense	Sauger	Piscivore	
Sciaenidae	Drums		
Aplodinotus grunniens	Freshwater drum	Invertivore	

(*Continued*)

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