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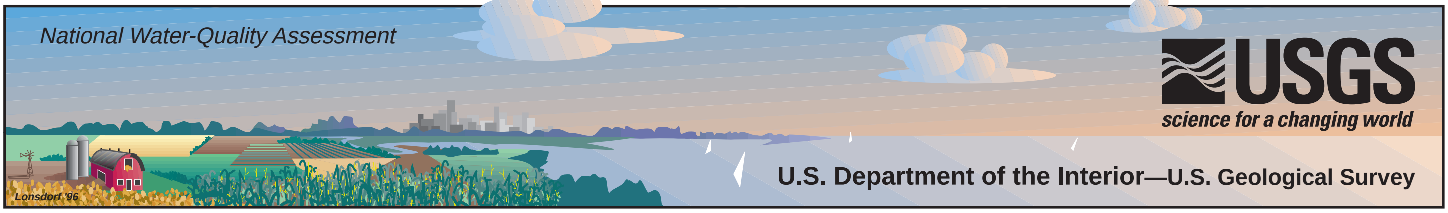


Feasibility of Combining Two Aquatic Benthic Macroinvertebrate Community Databases for Water-Quality Assessment

by Bernard N. Lenz

Introduction

An important part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program is the analysis of existing data in each of the NAWQA study areas. The Wisconsin Department of Natural Resources (WDNR) has an extensive aquatic benthic macroinvertebrate communities in streams (benthic invertebrates) database maintained by the University of Wisconsin–Stevens Point. This database has data which date back to 1984 and includes data from streams within the Western Lake Michigan Drainages (WMIC) study area (fig. 1). This report looks at the feasibility of USGS scientists supplementing the data they collect with data from the WDNR database when assessing water quality in the study area.

Approach and Analysis

The benthic invertebrate data in the WDNR database and benthic invertebrate data collected by the USGS from the WMIC study area were examined for environmental effects. Relations between benthic invertebrates and seasonality, sampling location, and environmental setting were explored using linear regression, box plots, and Wilcoxon ANOVA procedure (SAS Institute, Inc., 1990). Trends and bias within the individual databases could be attributed to a few variables. These trends and bias in the databases were eliminated by subdividing data based on these variables.

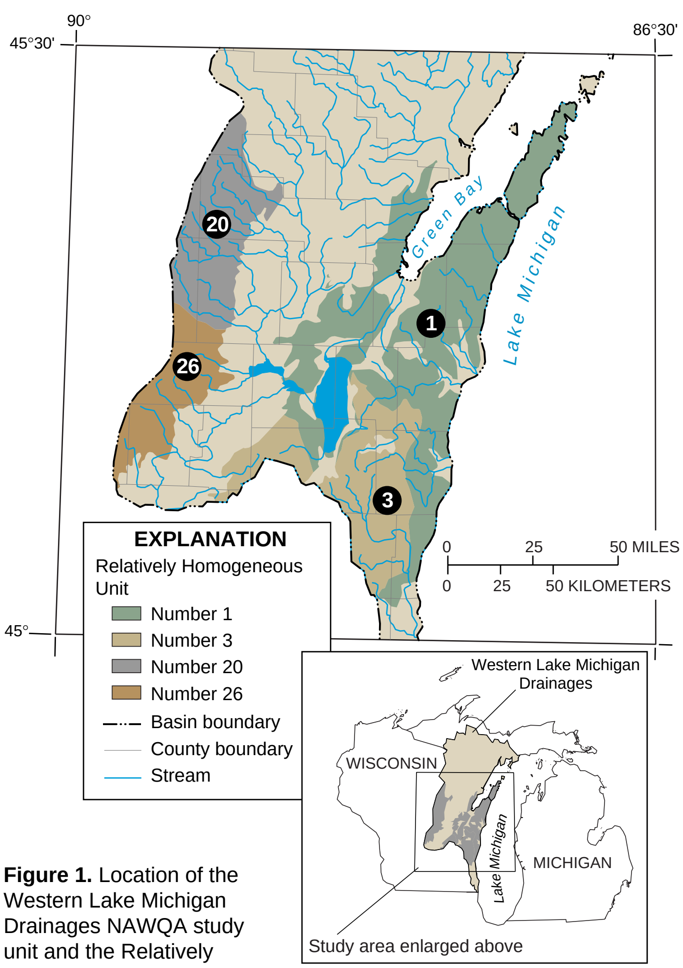


Figure 1. Location of the Western Lake Michigan Drainages NAWQA study unit and the Relatively Homogeneous Units that are the focus of this study.

Databases

Data were collected for the WDNR database using standard WDNR protocols (Lenz and Miller, 1996) and were processed by the Benthic Macroinvertebrate Laboratory at the University of Wisconsin–Stevens Point in a rapid-assessment style that is designed to quickly obtain quantitative information about the health and distribution of the benthic invertebrate population in streams. The database has an associated computerized "Bug Program" that generates richness, enumeration, community diversity and similarity measures, which are useful for statistical analysis. The habitat and water-quality data in the WDNR database are categorical, qualitative estimates; environmental variables are given a value of 1 for not present, 2 for insignificant, or 3 for significant.

USGS benthic invertebrate data were collected in the spring of 1995 using kick samples in coarse substrate riffles as part of a WMIC NAWQA study of benchmark streams in agricultural areas (Rheaume and others, 1996). Processing of samples and calculation of benthic invertebrate measures were performed at the University of Wisconsin–Stevens Point laboratory using the same techniques that were used for the WDNR data.

Water-quality data were from four sources: the USGS database QWDATA, the United States Environmental Protection Agency database STORET, a low flow synoptic sampling by the USGS in 1995, and sampling at WMIC NAWQA benchmark stream sites at the same time as the 1995 benthic invertebrate collection.

The benthic invertebrate data from the WDNR database were paired with water-quality data from the USGS QWDATA or the USEPA STORET database. Water-quality and invertebrate data at each paired site were collected during the same season, on the same stream and had no tributaries or major pollution sources between them. Only water-quality data collected during stable, low-flow conditions were used in the pairings. Sites were not used if these conditions could not be met. Benthic invertebrate data from the USGS database were paired with water- quality data collected concurrently at each site as part of another study (Rheaume, 1996).

The WMIC NAWQA study area has previously been divided into 28 "Relatively Homogeneous Units" (RHU) with similar land use, bedrock, and surficial deposits because it was believed that these factors have a direct effect on water quality (Robertson and Saad, 1993). The USGS collected benthic invertebrate data from streams in four agricultural RHU's that differed in bedrock and surficial geology. RHU 1 (clayey surficial deposits over carbonate bedrock) and RHU 3 (sandy-till surficial deposits over carbonate bedrock) are in adjacent agricultural areas in the Southwestern

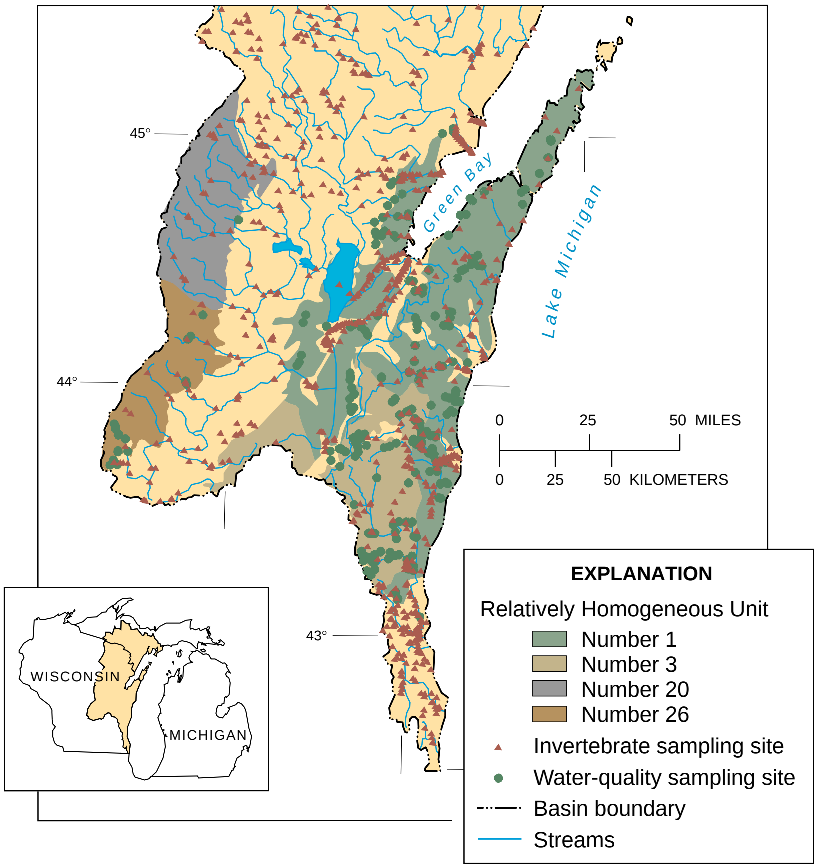


Figure 2. Location of invertebrate and water-quality sampling sites in RHU's 1, 3, 20, and 26.

Wisconsin Till Plains ecoregion. RHU 20 (sandy/sand and gravel surficial deposits over igneous and metamorphic bedrock) and RHU 26 (sandy/sand and gravel surficial deposits over sandstone) are in adjacent areas of agricultural land and mixed forest in the North Central Hardwood Forest ecoregion. Data from paired sites within these four RHU's were used to compare benthic invertebrate data to the water-quality data. The number of sites with data available from each database for the four RHU's analyzed in this study are shown in table 1. Sampling sites are shown in figure 2.

Twenty-two water-quality sites matched with WDNR benthic invertebrate sites using the previously mentioned method of site matching. Finding matching water-quality sites was difficult because the typical benthic invertebrate study sites in the WDNR database were located on streams with much smaller drainages than the streams from which most of the water-quality data were collected. Additionally, many of the water-quality sites were sampled prior to 1984 and were therefore excluded from this analysis.

Of the 22 paired sites, 9 were matched with water-quality sites that were each sampled once during a low-flow study of small drainage basins performed by the USGS in July 1995. Eight benthic invertebrate sites were matched with water-quality sites that were sampled by the U.S. Environmental Protection Agency (USEPA). USGS streamflow records from gaging stations on streams near these sites were used to ensure that these were low-flow samples. Two benthic invertebrate sites matched sites that had large amounts of USGS water-quality and discharge data available. Water-quality data that were collected during low-flow conditions closest to the time of the paired benthic invertebrate collection were used at these sites. Additionally, three benthic invertebrate sites matched USGS water-quality sites where only specific conductance and hydrogen ion concentrations were known. An average of all values of these parameters reported for each site was used because there was no flow data available and values did not vary significantly at the sites. For the 20 USGS paired sites, the benthic invertebrate and water-quality data were collected concurrently.

Benthic invertebrate measures, which are known water-quality indicators, including species richness, generic richness, Hilsenhoff's Biotic Index (HBI) and Family Level Biotic Index (FBI), Margalef's Diversity Index (MDI) and EPT Enumeration Metric (percent Ephemeroptera, Plecoptera, and Trichoptera) were determined.

Normalcy tests of the paired water-quality and benthic invertebrate data sets showed non-normal distribution of the data; therefore, nonparametric statistical procedures were used for additional analysis. Correlations between these measures and water quality were examined. Benthic invertebrate measures and water-quality data at each paired site were also compared using regression analysis. Separate regressions were made using benthic invertebrate data from each database, one using WDNR benthic invertebrate data and one using the USGS benthic invertebrate data. Additionally, regressions were made with the data separated by habitat and seasonality variables determined to be significant in the first part of this study. The location and slope of the regression line for the WDNR and USGS data were compared to determine if the benthic invertebrate data in each database predict streamwater quality similarly. Water-quality parameters used in the analysis were specific conductance, pH, and nutrient concentrations.

Environmental Effects on Benthic Invertebrate Communities

The life cycles of most benthic invertebrates include both an aquatic and a terrestrial phase. Seasonal variables such as temperature, light, and stream discharge control when benthic invertebrates emerge from the aquatic phase into the terrestrial phase (Merritt and Cummins, 1996). Various species of benthic invertebrates emerge during different seasons. In Wisconsin, emergence occurs from February through November with the majority of species emerging in April through July. As each successive species emerges, the benthic invertebrate community structure changes. This also changes the value of benthic invertebrate measures calculated from these communities; thus, the timing of sample collection is important. Benthic invertebrate samples are typically collected in early spring or fall when the greatest diversity of benthic invertebrates can be collected and identified. Of the 298 WDNR benthic invertebrate samples from the 283 WDNR sites in this study, 141 were collected in spring, 19 in summer, 132 in fall, and 6 in winter (15 sites were sampled in both the spring and fall).

The effect of season on WDNR benthic invertebrate communities is shown in figure 3A–C. Species diversity, as measured by Margalef's Diversity Index (fig. 3A), was highest in the spring when most of the benthic invertebrates are near maturity but have not yet emerged as adults. The mean value of Hilsenhoff's Biotic Index (HBI), a measure of a benthic inverte-

Table 1. Number of sites from which data were available and number of sites paired for four agricultural Relatively Homogeneous Units in the Western Lake Michigan Drainages.

Data Source	Sites in RHU 1 (number paired)	Sites in RHU 3 (number paired)	Sites in RHU 20 (number paired)	Sites in RHU 26 (number paired)	Total sites (number paired)
		BENTHIC INVERTEBRATE DATA			
WDNR Database	167 (16)	94 (2)	1 (0)	21 (4)	283 (22)
USGS Database	5 (5)	4 (4)	5 (5)	6 (6)	20 (20)
		WATER QUALITY DATA			
USGS-QWDATA	49 (4)	11 (0)	11 (0)	3 (1)	74 (5)
USEPA-STORET	191 (7)	47 (0)	15 (0)	10 (1)	263 (8)
USGS Low Flow Synoptic	12 (5)	8 (2)	5 (0)	2 (2)	17 (9)
WMIC NAWQA Benchmark Streams	5 (5)	4 (4)	5 (5)	6 (6)	20 (20)

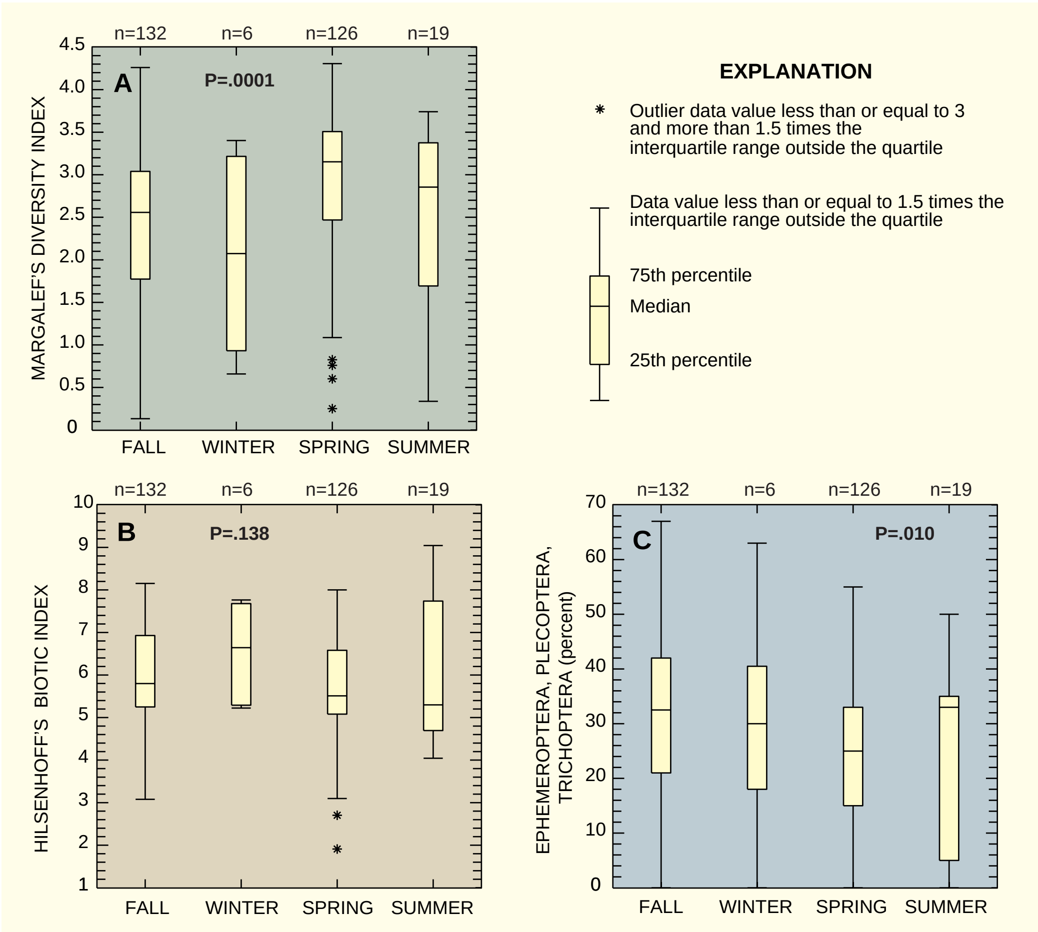
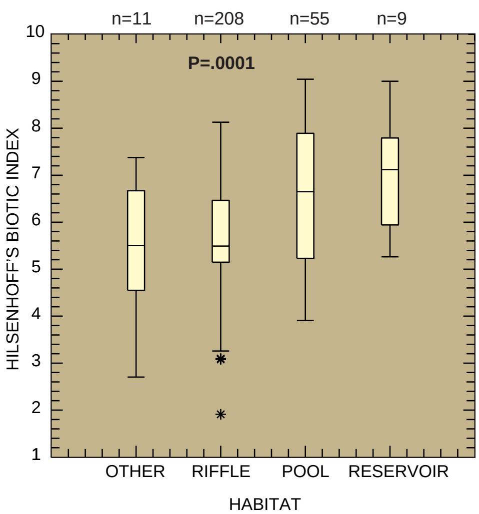


Figure 3. Boxplot showing the effects of seasonality on benthic invertebrate community measures. (P values from Wilcoxon ANOVA procedure; n, sample number)



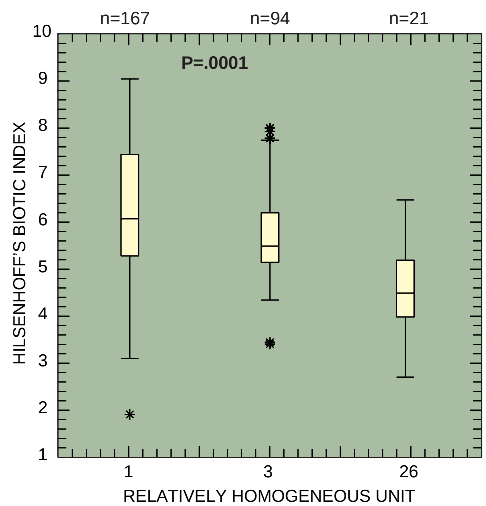


Figure 4. (left) Boxplot showing the effects of habitat on benthic invertebrates. See "explanation" above.

(P values from Wilcoxon ANOVA procedure; n, sample number)

Figure 5. (right) Boxplot showing the effects of Relatively Homogeneous Units on benthic invertebrates. See "explanation" above.

brate communities' tolerance to organic pollution, was highest in fall and winter (fig. 3B) indicating poor water quality at these times because many of the benthic invertebrates rated as "intolerant" by the index had emerged and only small, unidentifiable, early instar larvae of these intolerant species predominated the benthic invertebrate community. However, this seasonal effect is less dramatic for stoneflies. The mean value of percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) remained high during fall and winter (fig. 3C), indicating good water quality. This can be attributed to stonefly larvae, from the order Plecoptera, which grow quickly and are among the first to become large enough to be easily collected and identified in the fall.

The effects of in-stream habitat and environmental setting on WDNR benthic invertebrate data were also examined. Low HBI values indicate benthic invertebrates found in riffle habitat are less tolerant of pollution than those found in pool habitat (fig. 4). Riffles typically have coarse substrate, higher dissolved-oxygen concentrations and lower embeddedness, providing a better environment for benthic invertebrates than pools, which typically have fine substrate and are more embedded. RHU 1 and 3 had higher HBI scores than RHU 26 (fig. 5), indicating poorer water quality in RHU 1 and 3. Increased sediment, pesticide, and nutrient concentrations associated with increased agricultural runoff caused by the presence of finer grained surficial deposits in RHU 1 and 3 may have had detrimental effects on the benthic invertebrate communities (Pajak, 1994).

Due to the variability in community measures from the effects of seasonality, habitat, and RHU on benthic invertebrates, additional analyses were performed only on data that were collected from riffle habitat in the spring and fall.

Qualitative estimates of habitat and water quality found in the WDNR database rely heavily on the experience and objectivity of the observers (see "DATABASES" section, page one). Trend and regression analyses be-

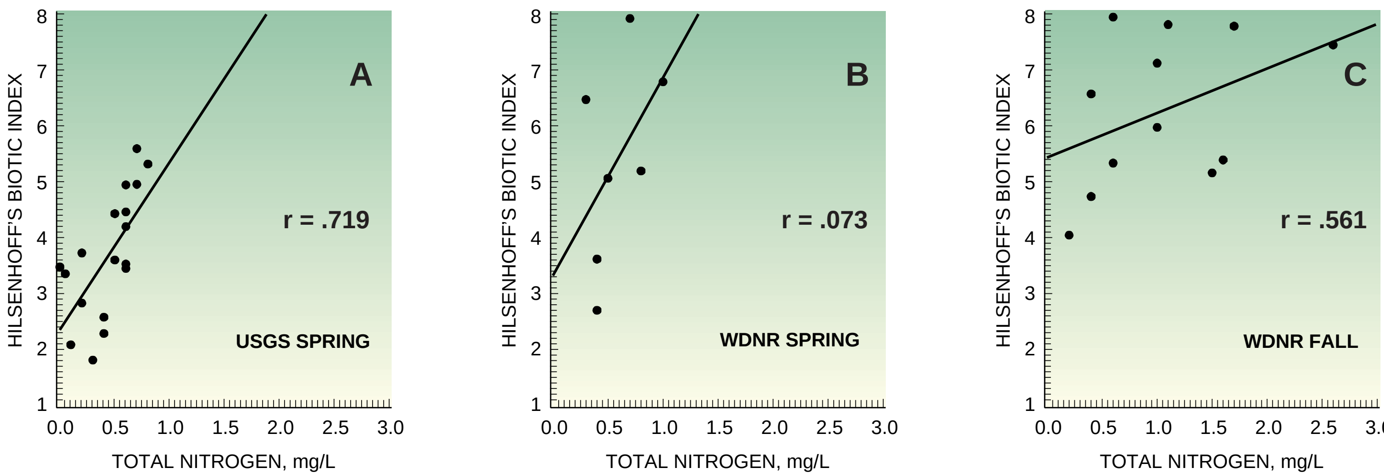


Figure 6. Linear regressions of Hilsenhoff's Biotic Index to total nitrogen for three different data sets.

tween the WDNR benthic invertebrate data and these qualitative habitat and water-quality data yielded few results. It was determined that the qualitative data contained in the WDNR database would not be useful for this study.

Comparison of Water Quality—Benthic Invertebrate Relations from the Two Databases

The limited number of paired data sites prevents understanding some of the more subtle relations in the data. However, the relations that were observed for the USGS (spring), WDNR spring, and WDNR fall data, including both the statistically significant and insignificant correlations and trends, confirm current understanding of the environmental tolerances and water-quality needs of benthic invertebrates.

HBI and FBI were positively correlated with total nitrogen concentrations for USGS spring data (r =0.719, 0.703) (fig. 6A). Additionally, EPT was negatively correlated with total nitrogen concentrations (r =-0.700), and HBI was negatively correlated with dissolved nitrogen concentrations (r =-0.606). Similar trends were seen in the WDNR spring data (fig. 6B), but they were not statistically significant due to a low sample number for those data. These correlations indicate benthic invertebrate measures do predict water quality at the paired sites.

Other trends were repeated in all three data sets but were not statistically significant. These included an apparent correlation of nutrient concentrations to benthic invertebrate measures, although the strength and slope of these correlations varied. Correlations were strongest in measures based on tolerance values. This was expected because tolerance values are based on the tolerance of benthic invertebrate species to elevated nutrient concentrations and an associated lower dissolved-oxygen concentration in the stream. Diversity measures generally were negatively correlated to total phosphorus concentrations, which may indicate that increased phosphorus concentrations favor only a limited number of benthic invertebrate species.

The slopes of the linear regression lines for many of the benthic invertebrate measures and water-quality data were similar for the spring data in both the USGS and the WDNR benthic invertebrate databases. However, the slope of the regression line for the WDNR fall data are consistently different than those from the spring collections. The HBI regressions with total nitrogen are shown in figure 6 for comparison. The varying slope of the regression lines between the spring and fall data indicate that benthic invertebrate measures calculated from the WDNR data predict water quality differently at different seasons. These results indicate benthic invertebrate data collected at different seasons should not be combined when using the data for water-quality assessment.

Summary

Benthic invertebrate measures in this study are related to factors such as seasonality, habitat, and RHU. If these relations are not considered when analyzing benthic invertebrate data, then the accuracy of the water-quality prediction will be compromised. The benthic invertebrate measures used in this analysis appear to be accurate indicators of nutrient concentrations in the streams studied within RHU's 1, 3, 20, and 26 of the WMIC study unit. Precise quantitative predictions of the actual water chemistry in these streams cannot be made using benthic invertebrate measures because of the many factors, other than water quality, that affect benthic invertebrate communities. Based on the limited paired data available, the USGS and WDNR benthic invertebrate databases appear to be similar in their ability to predict water quality using common benthic invertebrate measures calculated from data collected in riffles.

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