In cooperation with the Chester County Water Resources Authority

ASSESSMENT OF STREAM QUALITY USING BIOLOGICAL INDICES AT SELECTED SITES IN THE BIG ELK AND OCTORARO CREEK BASINS, CHESTER COUNTY, PENNSYLVANIA, 1981-97

INTRODUCTION

In 1970, the Chester County Water Resources Authority (Pennsylvania) and the U.S. Geological Survey (USGS) established a long-term water-quality network with the goal of assessing the quality of streams in the county and understanding stream changes in response to urbanization using benthic-macroinvertebrate data (Lium, 1977). This database represents one of the longest continuous water-quality data sets in the country. Benthic macroinvertebrates are aquatic insects, such as mayflies, caddisflies, riffle beetles, and midges, and other invertebrates that live on the stream bottom. Benthic macroinvertebrates are useful in evaluating stream quality because their habitat preference and low motility cause them to be affected directly by substances that enter the aquatic system. By evaluating the diversity and community structure of benthic-macroinvertebrate populations, a determination of stream quality can be made.

Between 1981 and 1997, the water-quality network consisted of 43 sites in 5 major basins in Chester County—Delaware, Schuylkill, Brandywine, Big Elk and Octoraro, and Red and White Clay. Benthic-macroinvertebrate, water-chemistry, and habitat data were collected each year in October or November during base-flow conditions (Reif, 1999; 2000). Using these data, Reif (2002) evaluates the overall water-quality condition of Chester County streams. This Fact Sheet summarizes the key findings from Reif (2002) for streams in the Big Elk and Octoraro Creek Basins. These streams include **East Branch Big Elk Creek** (site 31), **West Branch Big Elk Creek** (site 32), **East Branch Octoraro Creek** (site 33) and **Valley Creek** (site 34) (fig. 1). This summary includes an analysis of stream conditions based on benthic-macroinvertebrate samples and an analysis of trends in stream conditions for the 17-year study period.

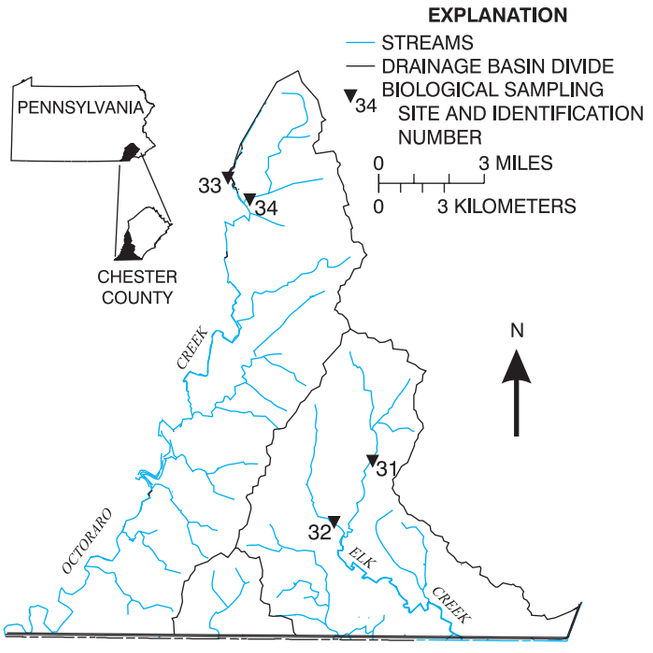

Figure 1. Location of sampling sites in the Big Elk and Octoraro Creek Basins, Chester County, Pennsylvania.

STUDY APPROACH

The analysis of overall stream quality on the basis of benthic-macroinvertebrate sampling uses biological metrics. Each biological metric is a mathematical expression of a different aspect of the benthic-macroinvertebrate community and how it relates to overall stream quality. By examining each biological metric, an evaluation of the overall stream quality can be made. The following biological metrics were used in the analysis: taxa richness, Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness, percent EPT, and Hilsenhoff's biotic index (HBI).

Taxa richness is a measure of the number of different kinds of organisms (taxa) in a collection. Richness measures the overall diversity of the biological community sampled. **EPT taxa richness** is the total number of taxa within the "pollution sensitive" orders **E**phemeroptera (mayflies), **P**lecoptera (stoneflies), and **T**richoptera (caddisflies). Taxa richness and EPT taxa richness will decrease with decreasing water quality (Weber, 1973). **Percent EPT** is the total number of EPT individuals divided by the total number of individuals in the sample.

The **HBI** is based on an organism's relative sensitivity to stream-quality conditions. The HBI uses assigned tolerance values that range from 0 to 10. A 0 is assigned to organisms least tolerant of organic pollution, and a 10 is assigned to organisms most tolerant of organic pollution. Species intermediate in their tolerance of organic pollution were assigned intermediate values (Hilsenhoff, 1982). Tolerance values are from the genus and species-level biotic index developed by the State of New York (Bode, 1991). HBI values from 0 to 4.5 are associated with nonimpacted sites, 4.51 to 6.50 with slightly impacted sites, 6.51 to 8.50 with moderately impacted sites, and 8.51 to 10 with severely impacted sites (Bode, 1993).

STREAM-QUALITY DESIGNATION CRITERIA

Streams in the network were designated as nonimpacted, slightly impacted, moderately impacted, or severely impacted on the basis of median biological metric values from 1981 to 1997 (table 1). Stream-quality refers to the overall condition of the physical habitat, water chemistry, and biological communities in the stream.

Nonimpacted: Biological metrics indicate excellent stream quality. The benthic-macroinvertebrate community is diverse, and the community is dominated by "pollution sensitive" and facultative

Table 1. *Stream-quality assessment criteria for Chester County, Pennsylvania, streams (adapted from Bode, 1993)*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera: HBI, Hilsenhoff's biotic index; >, greater than]

Stream-quality assessment	Taxa richness	EPT taxa richness	HBI
Nonimpacted	>30	>10	0 - 4.50
Slightly impacted	21 - 30	6 - 10	4.5 - 6.50
Moderately impacted	11 - 20	2 - 5	6.51 - 8.50
Severely impacted	0 - 10	0 - 1	8.51 - 10

organisms. "Pollution sensitive" organisms include the EPT taxa and generally are intolerant of degraded stream quality. Facultative organisms can survive under a wide range of stream conditions. Water quality and habitat conditions at nonimpacted sites are not limiting the benthic-macroinvertebrate community. Nonimpacted sites include pristine habitats and those receiving inputs that minimally affect the benthic-macroinvertebrate community.

Slightly Impacted: Biological metrics indicate good stream quality. The benthic-macroinvertebrate community is less diverse than at nonimpacted sites but still contains mayflies, caddisflies, and possibly some stoneflies. The community structure typically is dominated by a few taxa including caddisflies, elmids (riffle beetles), and chironomids. Water-quality and habitat conditions are having an effect on the benthic-macroinvertebrate community. Slightly impacted sites commonly are receiving some wastewater inputs and (or) agricultural/urban runoff.

Moderately Impacted: Biological metrics indicate fair stream quality. The benthic-macroinvertebrate community is disturbed and noticeably altered from a nonimpacted site. Mayflies and stoneflies are rare, and caddisfly taxa may be limited. The benthic-macroinvertebrate community is dominated by "pollution tolerant" and facultative organisms including chironomids and oligochaetes (aquatic earthworms). One or a few groups usually dominate the community. Water-quality and habitat conditions are having a major effect on the benthic-macroinvertebrate community. Moderately impacted sites commonly are receiving heavy wastewater inputs and (or) agricultural/urban runoff.

Severely Impacted: Biological metrics indicate poor stream quality. The benthic-macroinvertebrate community is severely limited with poor diversity. Mayflies, stoneflies, and caddisflies are rare, and the community usually is dominated by chironomids and aquatic earthworms. The community may have low numbers of individuals or high numbers of a few taxa. Severely impacted sites commonly are receiving inputs of a toxin or have extremely low concentrations (less than 4.0 mg/L) of dissolved oxygen. Water-quality and habitat conditions are having a severe effect on the benthic-macroinvertebrate community. Severely impacted sites commonly are receiving heavy wastewater inputs and agricultural/urban runoff.

STREAM-QUALITY ASSESSMENT

Two sites were sampled in the Big Elk Creek Basin (sites 31 and 32) and two sites in the Octoraro Creek Basin (sites 33 and 34). The drainage area of each site is approximately 11 mi^2 (square miles), and the basins are dominated by agricultural land use. Stream-quality assessments based on calculated biological metrics are presented in table 2 and figure 2.

The East Branch (site 31) and West Branch Big Elk Creek (site 32) were designated as slightly impacted on the basis of taxa richness and HBI values and as nonimpacted on the basis of EPT taxa richness (table 2, figs. 2 and 3). The high HBI values are because of a high number of "pollution tolerant" organisms relative to reference conditions, including chironomids and crane flies. The high number of "pollution tolerant" organisms along with the increasing concentrations of nutrients indicate that organic enrichment is negatively affecting the benthic-macroinvertebrate communities in the Big Elk Creek Basin. Organic enrichment can cause increased algal blooms that decay and result in low concentrations of dissolved oxygen and poor stream-bottom habitat (U.S. Geological Survey, 1999).

Both sites in the Big Elk Creek Basin had a decrease in taxa richness and EPT taxa richness starting in 1994. The decrease in organisms was most noticeable at site 31 where EPT taxa richness declined from 13 in 1992 to 3 in 1996 (fig. 4). Chemical data indicate that the concentrations of ammonia and phosphorus occasionally are high. Phosphorus concentrations ranged from 0.02 to 0.89 mg/L (milligrams per liter) between 1981 and 1997 (fig. 4).

The East Branch Octoraro Creek (site 33) and Valley Creek (site 34) were designated as slightly impacted on the basis of taxa richness and HBI values and as nonimpacted on the basis of EPT taxa richness (table 2, figs. 2 and 3). In general, sites in these two basins have invertebrate communities similar to sites in the Big Elk Creek Basin. However, the invertebrate communities in the two major basins in southeastern Chester County are not as diverse and healthy as the Brandywine Creek Basin or the streams draining to the Schuylkill River.

Table 2. *Designation of water quality and median values of taxa richness, EPT taxa richness, Hilsenhoff's biotic index, and percent EPT for sites in the Big Elk and Octoraro Creek Basins, Chester County, Pennsylvania, 1981-97*

[EPT, Ephemeroptera, Plecoptera, and Trichoptera]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	Hilsenhoff's biotic index	Percentage of EPT individuals
		East Branch Big Elk Creek			
		Slightly impacted	Nonimpacted	Slightly impacted	
01494900	31	23	11	5.32	28
		West Branch Big Elk Creek			
		Slightly impacted	Nonimpacted	Slightly impacted	
01494950	32	25	13	4.86	52
		East Branch Octoraro Creek			
		Slightly impacted	Nonimpacted	Slightly impacted	
01578340	33	25	11	4.66	56
		Valley Creek			
		Slightly impacted	Nonimpacted	Slightly impacted	
01578343	34	28	13	4.87	49

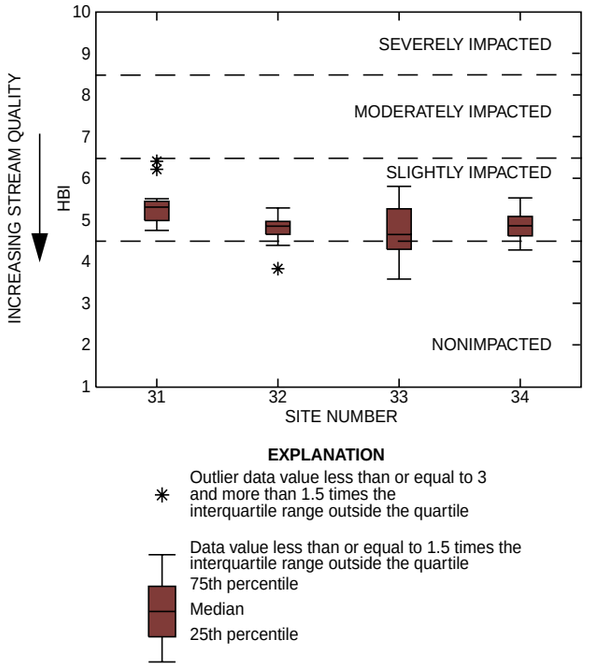

Figure 2. Hilsenhoff's biotic index (HBI) values from sites in the Big Elk (sites 31 and 32) and Octoraro Creek (sites 33 and 34) Basins, Chester County, Pennsylvania, 1981-97.

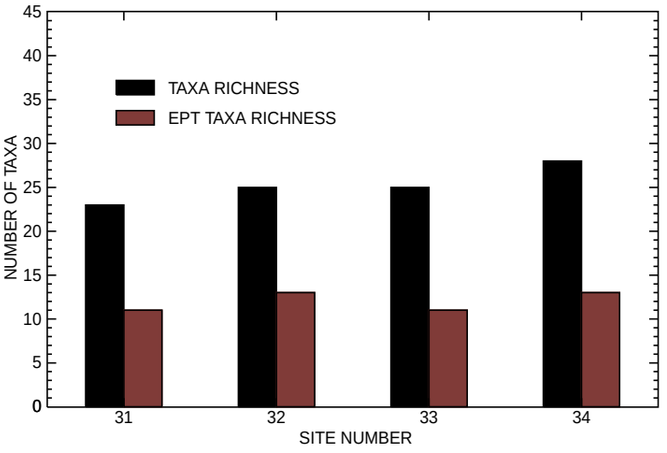

Figure 3. Median values of taxa richness and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness at sites in the Big Elk (sites 31 and 32) and Octoraro Creek (sites 33 and 34) Basins, Chester County, Pennsylvania, 1981-97.

TRENDS IN BENTHIC-MACROINVERTEBRATE AND CHEMICAL DATA

The Mann-Kendall test was used to detect trends from 1981 through 1997 in HBI values at the sites in the Big Elk and Octoraro Creek Basins (Helsel and Hirsch, 1997). A decreasing trend in HBI values indicates improving stream quality, and an increasing trend indicates deteriorating stream quality.

All four sites had increasing trends in nitrate concentrations between 1981 and 1997. Despite the increasing nitrate concentrations, three of the four sites (sites 31, 32, and 33) had a decreasing trend in HBI values indicating improved stream quality. The most likely reason for the improved stream quality is decreasing trends in ammonia concentrations at these sites between 1981 and 1997. The decreased ammonia concentrations can lead to increased concentrations of dissolved oxygen, which can decrease HBI values (U.S. Geological Survey, 1999). In contrast, site 34 had increasing ammonia concentrations and HBI values. This trend is an indication that the increasing ammonia is causing lower concentrations of dissolved oxygen and is resulting in increased HBI values.

Both of the Big Elk Creek sites (sites 31 and 32) had a sudden drop in taxa from all groups of benthic macroinvertebrates that may be a response to toxic contaminants such as pesticides.

During the 17-year study, the benthic-macroinvertebrate community at the East Branch Octoraro Creek (site 33) occasionally had high numbers of "pollution tolerant" organisms including chironomids, black flies, aquatic worms, and crane flies, but these high numbers were offset by a large population of "pollution sensitive" organisms. The inconsistent number of "pollution tolerant" organisms caused the HBI value to fluctuate (fig. 5), but it generally was lower since 1987 indicating improving stream quality; taxa richness and EPT taxa richness were steady since 1982. Chemical data indicate increasing concentrations of nitrate and major ions and decreasing concentrations of ammonia and phosphorus. The nitrate concentrations increased from 5.10 mg/L in 1981 to 9.0 mg/L in 1997 (fig. 5). Heavy agriculture in the basin is the major source of the nutrient enrichment. Despite the increased nitrate concentrations, the benthic-macroinvertebrate data indicate improved stream quality. The improved stream quality most likely is related to the decreased ammonia concentrations, which can lead to increased concentrations of dissolved oxygen and decreased toxicity (U.S. Geological Survey, 1999).

Valley Creek (site 34) had inconsistent benthic-macroinvertebrate and water-chemistry data from 1981 to 1997. The benthic-macroinvertebrate community occasionally had high numbers of "pollution tolerant" organisms including chironomids, black flies, worms, and crane flies. Biological metrics were variable, indicating changing stream conditions. Water chemistry at site 34 also was highly variable; nitrate concentrations ranged from 4.4 to 8.7 mg/L, ammonia concentrations ranged from 0.05 to 0.34 mg/L, and phosphorus concentrations ranged from 0.03 to 0.12 mg/L. Nitrate concentrations increased and phosphorus concentrations decreased since 1981 in a pattern similar to the East Branch Octoraro Creek. However,

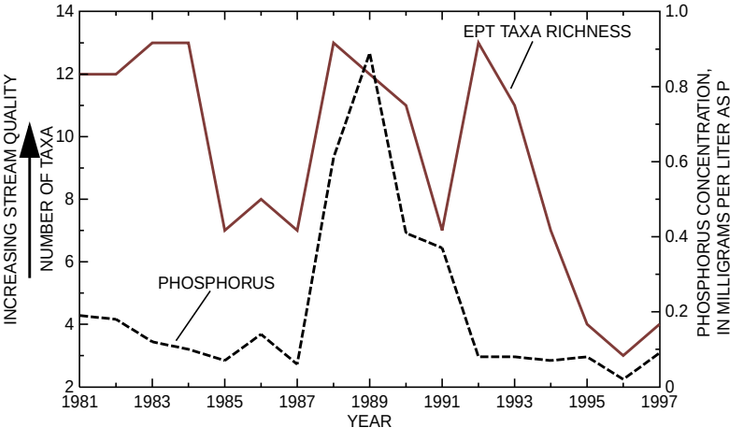

Figure 4. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness and phosphorus concentrations from East Branch Big Elk Creek (site 31), Chester County, Pennsylvania, 1981-97.

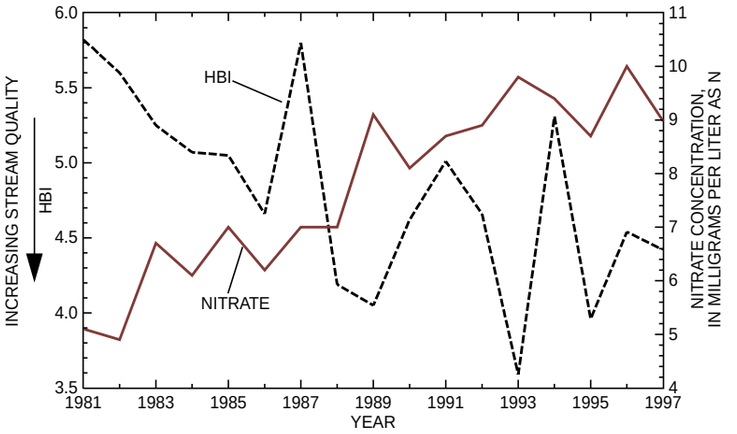

Figure 5. Hilsenhoff's biotic index (HBI) and nitrate concentrations from East Branch Octoraro Creek (site 33), Chester County, Pennsylvania, 1981-97.

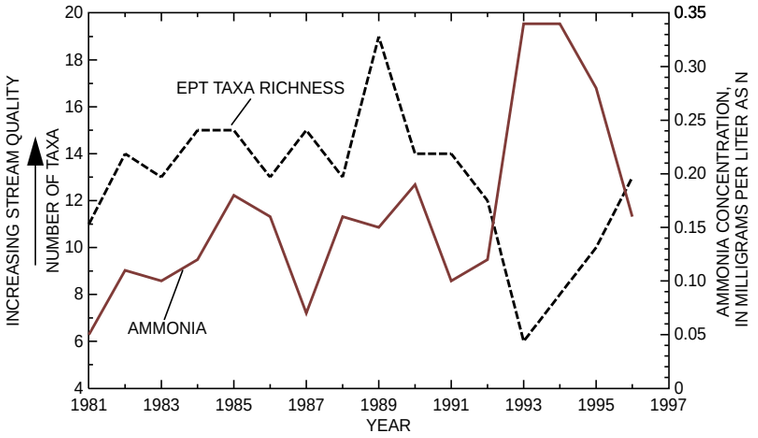

Figure 6. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness and ammonia concentrations at Valley Creek (site 34), Chester County, Pennsylvania, 1981-96.

ammonia concentrations increased at site 34 from 0.05 mg/L in 1981 to a maximum of 0.34 mg/L in 1994 when EPT values were decreasing (fig. 6). An increase in ammonia can lead to a decrease in concentrations of dissolved oxygen, which can negatively effect the benthic-macroinvertebrate communities (U.S. Geological Survey, 1999). Field observations of habitat at the site indicate the stream bottom was subjected to heavy sedimentation. The nutrient enrichment is most likely from heavy agriculture and a small wastewater treatment plant upstream of the site.

SUMMARY

The sites in the Big Elk (sites 31 and 32) and East Branch Octoraro Creek Basins (sites 33 and 34) in Chester County, Pa., had water chemistry and benthic-macroinvertebrate community structure that was different from reference conditions, based on a study completed by the U.S. Geological Survey, in cooperation with the Chester County Water Resources Authority. The streams in both basins had higher concentrations of nutrients and major ions, and the concentration of nitrate has been increasing since 1981. The benthic-macroinvertebrate community contained high numbers of "pollution tolerant" organisms indicating degraded stream conditions. The calculated biological metrics indicate improving stream quality at sites 31 and 32 in the Big Elk Creek Basin and site 33 on the East Branch Octoraro Creek but degrading stream quality at site 34 on Valley Creek. Increasing ammonia concentrations and elevated phosphorus concentrations (above the reference site) at site 34 may be degrading the water chemistry and stream-bottom habitat, which can be a cause of the increasing HBI values.

—Andrew G. Reif

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