

In cooperation with the Chester County Water Resources Authority

ASSESSMENT OF STREAM QUALITY USING BIOLOGICAL INDICES AT SELECTED SITES IN THE DELAWARE RIVER BASIN, 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 preferences 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 Delaware River Basin. These streams include **Darby Creek** (site 17), **Crum Creek** (site 19), **Ridley Creek** (sites 20 and 21), **East Branch Chester Creek** (sites 22-24, and 51), and **Goose Creek** (site 25) (fig. 1). This summary includes an analysis of stream conditions on the basis of benthic-macroinvertebrate samples and an analysis of trends in stream conditions for the 17-year study period.

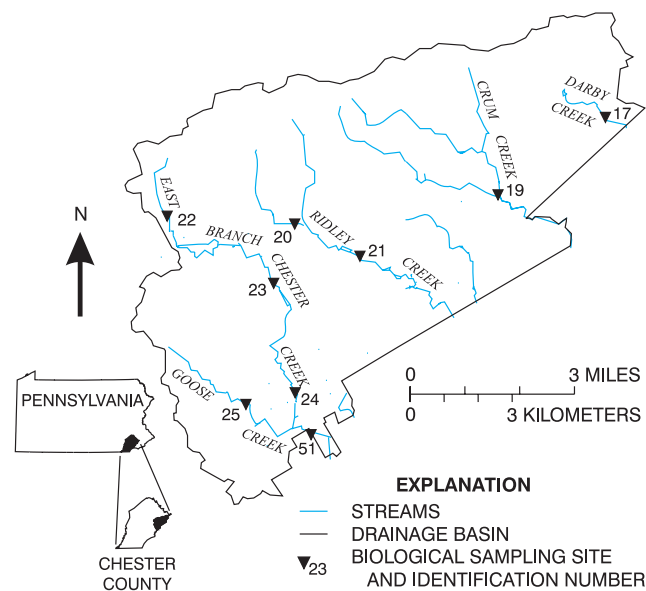


Figure 1. Location of sampling sites in the Delaware River Basin, Chester County, Pennsylvania.

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 Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (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.

Table 1. Stream-quality assessment criteria for Chester County streams, Pennsylvania (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	4.51 - 6.50
Moderately impacted	11 - 20	2 - 5	6.51 - 8.50
Severely impacted	0 - 10	0 - 1	8.51 - 10

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

The sites in the Delaware River Basin are small headwater streams, each draining less than 20 mi² (square miles). These streams are in areas of suburban land use with greater than 5 percent impervious cover. Sites 24, 25, and 51, in the East Branch Chester Creek Basin, also are affected by wastewater-treatment discharges. Stream-quality assessments based on calculated biological metrics are presented in table 2 and figure 2.

Sites in the Darby, Crum, Ridley, and upper East Branch Chester Creek Basins generally were designated as slightly impacted in taxa richness and HBI and were nonimpacted in EPT taxa richness (table 2). The benthic-macroinvertebrate samples collected from Darby (site 17), Ridley (site 20), and East Branch Chester Creeks (site 22) were highly variable in total number of individuals and total taxa between 1981 and 1997, which resulted in a slightly impacted designation (table 2, figs. 2 and 3). Water chemistry at these sites indicates stable conditions with concentrations of nutrients similar to the reference site (fig. 4). A lack of stable substrate and susceptibility to flow fluctuation, potentially from increased peak flows caused by urbanization, are the most likely causes of the variable benthic-macro-

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 Delaware River Basin, Chester County, Pennsylvania, 1981-97 [EPT; Ephemeroptera, Plecoptera, Trichoptera]

U.S. Geological Survey station identification number	Site number	Taxa richness	EPT taxa richness	Hilsenhoff's biotic index	Percent EPT
Darby Creek					
01475300	17	Slightly impacted 28	Nonimpacted 13	Slightly impacted 4.60	56
Crum Creek					
01475840	19	Nonimpacted 32	Nonimpacted 16	Slightly impacted 5.21	44
Ridley Creek					
01476430	20	Slightly impacted 26	Nonimpacted 11	Slightly impacted 4.87	37
01476435	21	Slightly impacted 30	Nonimpacted 16	Slightly impacted 4.63	58
East Branch Chester Creek					
01476790	22	Slightly impacted 21	Slightly impacted 10	Nonimpacted 4.06	64
01476830	23	Slightly impacted 29	Nonimpacted 13	Slightly impacted 5.25	41
01476835	24	Slightly impacted 26	Nonimpacted 12	Slightly impacted 4.91	41
01476848	51	Slightly impacted 23	Slightly impacted 7	Slightly impacted 5.45	37
Goose Creek					
01476840	25	Moderately impacted 17	Moderately impacted 5	Slightly impacted 5.52	12

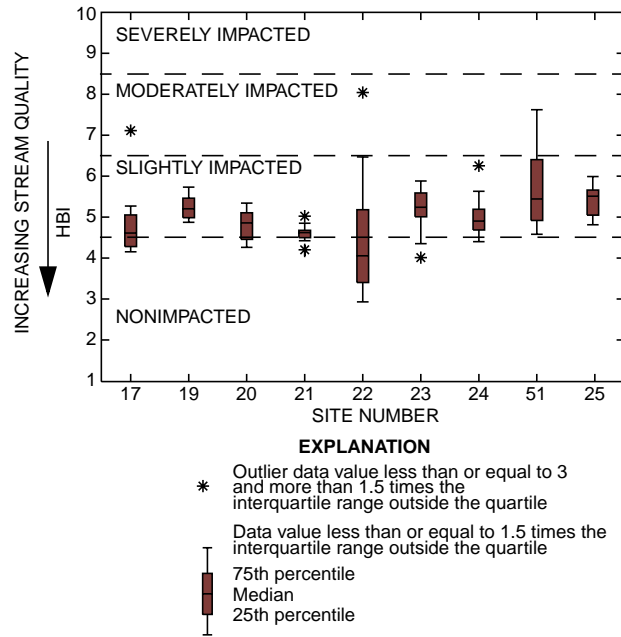


Figure 2. Hilsenhoff's biotic index (HBI) values from sites in the Delaware River Basin, Chester County, Pennsylvania, 1981-97.

invertebrate communities. The level of impervious surface present in these small basins can cause degraded conditions (Schueler, 1995). Although the benthic-macroinvertebrate communities varied over time, they generally contained numerous "pollution sensitive" organisms (fig. 3). The presence of numerous "pollution sensitive" organisms indicates that the water quality is sufficient to maintain these organisms and that another factor such as unstable habitat may be causing the variable benthic-macroinvertebrate communities at sites 17, 20, and 22.

Samples collected from site 19 on Crum Creek, site 21 on Ridley Creek, and site 23 on East Branch Chester Creek contained more consistent benthic-macroinvertebrate communities with increased taxa richness and EPT taxa richness than samples collected at sites 17, 20, and 22 (fig. 3). These sites have similar chemical data but because of increased stream size, sites 19, 21, and 23 have more consistent stream-bottom habitat and flow conditions. Although these sites have more

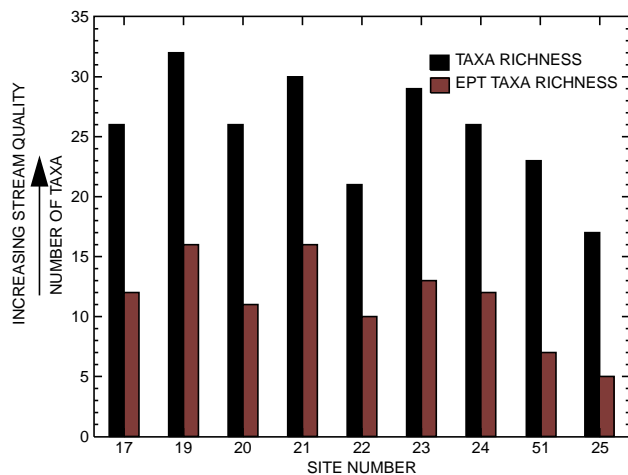


Figure 3. Median values of taxa richness and Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness at sites in the Delaware River Basin, Chester County, Pennsylvania, 1981-97.

consistent and diverse benthic-macroinvertebrate communities than sites 17, 20, and 22, they are still designated as slightly impacted on the basis of HBI values (table 2, fig. 2).

Sites 24 and 51 on the East Branch Chester Creek and site 25 on Goose Creek, a tributary to East Branch Chester Creek, receive wastewater-treatment discharge. Site 24 has a variable benthic-macroinvertebrate community and occasionally elevated concentrations of ammonia and phosphorus above reference levels, indicating an unstable chemical and biological environment. Phosphorus concentrations were slightly, but consistently, above the U.S. Environmental Protection Agency's (USEPA) recommended limit of 0.10 mg/L (U.S. Environmental Protection Agency, 1986) (fig. 4).

The benthic-macroinvertebrate communities at sites 25 and 51 are affected by organic pollution from a larger wastewater-treatment discharge than site 24. The benthic-macroinvertebrate communities were designated as slightly or moderately impacted and are dominated by "pollution tolerant" organisms including worms, midges, black flies, flatworms, and crane flies. These sites have the lowest taxa and EPT taxa richness numbers and the highest HBI values of the sites sampled in the Delaware River Basin (figs. 2 and 3). Sites 25 and 51 consistently have ammonia concentrations elevated above other sites in the Delaware River Basin, nitrate concentrations near or above the USEPA drinking-water standard of 10 mg/L (U.S. Environmental Protection Agency, 1994), and phosphorus concentrations 10 to 50 times the USEPA's recommended limit of 0.10 mg/L (fig. 4) (U.S. Environmental Protection Agency, 1986). Based on field observations, nutrient enrichment appears to be causing excessive plant growth that is degrading the water quality and habitat at these sites.

The assessment of benthic-macroinvertebrate communities in the Delaware River Basin in Chester County indicates that unstable habitat and susceptibility to flow fluctuation, potentially caused by urbanization, are causing degraded stream quality in the headwaters of Darby, Ridley, and Chester Creeks. These effects are reduced but still present in larger downstream parts of the streams. The data also indicate elevated concentrations of nutrients from wastewater-treatment discharges are causing degraded stream quality in Goose Creek and East Branch Chester Creek below Goose Creek.

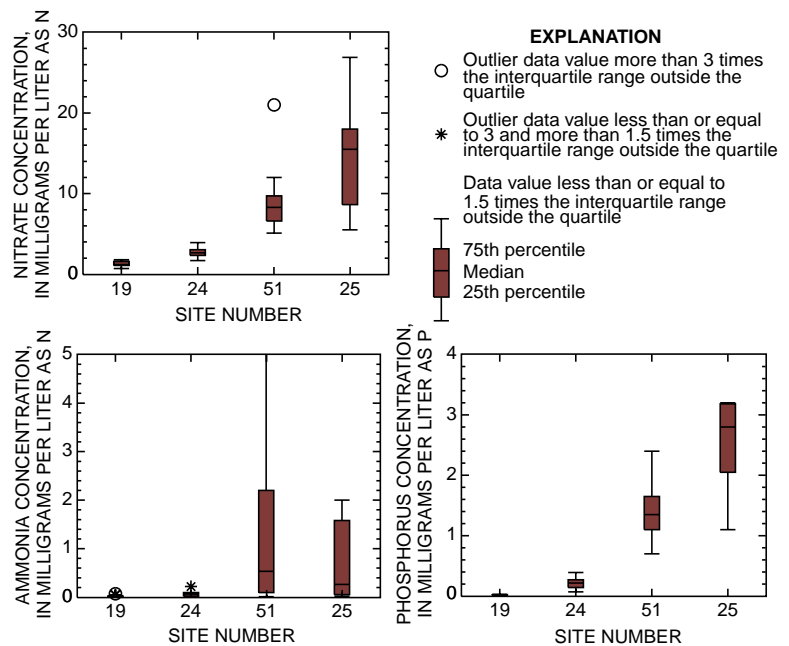


Figure 4. Nitrate, ammonia, and phosphorus concentrations from the Crum Creek (site 19), East Branch Chester Creek at Westtown (site 24), East Branch Chester Creek below Goose Creek (site 51), and Goose Creek (site 25), Chester County, Pennsylvania, 1981-97.

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 Delaware River Basin (Helsel and Hirsch, 1997). A decreasing trend in HBI indicates improving stream quality, and an increasing trend indicates deteriorating stream quality.

Three of the nine sites (sites 24, 51, and 25) had a decreasing trend in HBI values and in concentrations of ammonia and phosphorus between 1981 and 1997. The trend was statistically significant at sites 51 and 25. The decreasing concentrations of ammonia and phosphorus are improving the stream quality, which is reflected in the decreasing HBI values (fig. 5). These sites all receive wastewater-treatment discharge, and the improving conditions are from improved wastewater-treatment processing. Although the trends at these sites are indicating improved stream quality, sites 51 and 25 have nitrate concentrations near or above the USEPA drinking-water standard of 10 mg/L, phosphorus concentrations 10 to 50 times the USEPA's recommended limit of 0.10 mg/L (fig. 4), and HBI values among the highest of all streams sampled in Chester County.

Six of the nine sites (sites 17, 19, and 20-23) had increasing trends in HBI values, three of them statistically significant (sites 19, 22, and 23). At most of these sites, unstable habitat, potentially from increased peak flows caused by urbanization, is the most likely cause of the increasing trend in HBI values. Site 22 was affected severely by the precipitation of manganese from the discharge of an air stripper that was treating contaminated ground water. The manganese precipitate affected the benthic-macroinvertebrate community from 1987 through 1990 (Reif, 2002, p. 17). The site was designated as nonimpacted prior to 1989 and the benthic community did not fully recover until 1997.

SUMMARY

Overall, analysis of the sites in the Delaware River Basin by the U.S. Geological Survey, in cooperation with the Chester County Water Resources Authority, indicates that from 1981 to 1997, the sites affected by wastewater-treatment discharge have improved water chemistry and benthic-macroinvertebrate communities indicating

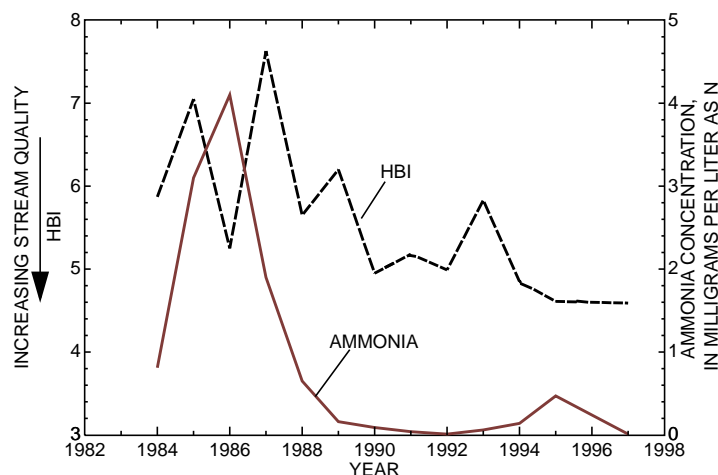


Figure 5. Hilsenhoff's biotic index (HBI) values and ammonia concentrations from East Branch Chester Creek below Goose Creek (site 51), 1982-97.

better stream quality. Although improving, these sites remain substantially degraded because of heavy nutrient loads that are negatively impacting the biological, chemical, and physical properties of the streams. Sites not associated with wastewater-treatment discharge indicate declining stream quality because of the unstable stream bottom and susceptibility to flow fluctuation, potentially from increased peak flows caused by urbanization.

—Andrew G. Reif

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