

are abandoned mine land sites and problem areas, depicted in black (Figure 3). Prominent watersheds in Ecoregion 67 include Sherman, Conodoguinet, Penns, Middle, Shamokin, Mahanoy, Mahantango, Wiconisco, Swatara, and Yellow Breeches Creeks. The city of Sunbury, Pa., is also located within Ecoregion 67.

Many agencies and environmental organizations throughout the Lower Susquehanna River Subbasin are working to restore and protect local and regional watersheds, including SRBC. Other local entities, such as county conservation districts, land conservation groups, and volunteer groups, protect and conserve land and water resources in the subbasin.

METHODS

DATA COLLECTION

Sampling of Year-1 sites provides a point-in-time picture of stream characteristics throughout the whole Lower Susquehanna Subbasin. Samples were collected using a slightly modified version of USEPA's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (RBP III) (Barbour and others, 1999).

From April to July 2011, SRBC staff sampled 99 of the 104 sites throughout the Lower Susquehanna Subbasin slated for study. Appendix A contains a list with the sample site number, the station name (designated by approximate stream mile), the latitude and longitude, a description of the sampling location, the drainage size, and the reference category. Seven new sites were added for the 2011 survey: CABB 0.1 on Cabbage Run Branch, CODO 15.5 on Codorus Creek, EMAH 23.5 on Mahantango Creek, RATT 1.0 on Rattling Creek, SPRG 4.4 on Spring Creek, UNTD 0.5 on an unnamed tributary to Deer Creek, and WICO 27.0 on Wiconisco Creek. The reference category designation was based on subcoregions and grouped according to similarities between subcoregions as described in Traver (1997). Macroinvertebrate samples were collected at 96 sites. In a year marked by record precipitation, no macroinvertebrate samples were collected on Codorus Creek at CODO 25.5, Conestoga River at CNTG 0.9, or Swatara Creek at SWAT 21.7 because of high water. Likewise, no macroinvertebrate or water quality sampling was conducted on the mainstem sites because of perpetual high water conditions caused by a continuous succession of rain events, including Hurricane Irene and Tropical Storm Lee. A physical habitat assessment was conducted at the sites where a macroinvertebrate sample was collected.

WATER QUALITY

Field chemistry analysis was done at the time of sampling, and water samples from each sampling site were also collected for laboratory analysis. A list of the field and laboratory parameters and their units is found in Table 1. A multi-meter YSI sonde was used to collect all field chemistry parameters (temperature, conductivity, pH, and dissolved oxygen) simultaneously. The probes of all meters were rinsed with distilled water and sample water prior to collection of water quality data, and calibrations were conducted as detailed in the Quality Assurance Project Plan (QAPP). At stations with no USGS gage, flow measurements were made by field personnel using a FlowTracker and standard USGS procedures (Buchanan and Somers, 1969). Water samples were collected using depth-integrated water sampling methods (Guy and Norman, 1969) and were iced and delivered to ALS Environmental in Middletown, Pa.

MACROINVERTEBRATES

Benthic macroinvertebrates (organisms that live on the stream bottom, including aquatic insects, crayfish, clams, snails, and worms) were collected using a slightly modified version of RBP III (Barbour and others, 1999).

Table 1. Water Quality Parameters Sampled in the Lower Susquehanna Subbasin

Field Parameters	
Flow (instantaneous cfs ^a)	Conductivity (µmhos/cm ^c)
Temperature (°C)	Dissolved Oxygen (mg/l ^b)
pH	
Laboratory Analysis	
Alkalinity (mg/l)	Total Magnesium (mg/l)
Total Dissolved Solids (mg/l)	Total Sodium (mg/l)
Total Suspended Solids (mg/l)	Chloride (mg/l)
Total Nitrogen (mg/l)	Sulfate (mg/l)
Nitrite-N (mg/l)	Total Iron (mg/l)
Nitrate-N (mg/l)	Total Manganese (mg/l)
Turbidity (NTU ^d)	Total Aluminum (mg/l)
Total Organic Carbon (mg/l)	Total Phosphorus (mg/l)
Total Hardness (mg/l)	Total Orthophosphate (mg/l)
Total Calcium (mg/l)	Hot Acidity (mg/l)
^a cfs = cubic feet per second ^b mg/l = milligram per liter ^c µmhos/cm = micromhos per centimeter ^d NTU = nephelometric turbidity units	

In Pennsylvania, macroinvertebrate sampling was conducted using PADEP's Semi-Quantitative (PADEP-RBP) Method (PADEP, 2009a). Forty-four targeted sites were sampled prior to May 1, 2011, because of possible limestone influence (PADEP, 2009b) in order to collect *Ephemera* nymphs (mayflies) before they emerge as adults in May and June. *Ephemera* mayflies



SRBC staff processing a macroinvertebrate sample in the field.

are sensitive ecological indicator taxa that tend to be found in healthy limestone streams.

Remaining Pennsylvania streams were sampled from May through July 2011. Six D-frame (500-micron mesh) samples were obtained at each 100-meter station reach by collecting the dislodged material loosened through disturbance of the substrate of six representative riffle/run areas. The six D-frame samples were composited into one sample, which was

preserved in 95-percent denatured ethyl alcohol and returned to SRBC's lab for processing. Each sample was then subsampled, with approximately 200 (\pm 20 percent) organisms picked.

In Maryland, macroinvertebrate sampling was conducted using Maryland Department of Natural Resource's (MDNR's) Maryland Biological Stream Survey (MBSS) protocol (MDNR, 2010) for the spring index period. Twenty D-frame (540-micron mesh) samples were obtained from a proportionate variety of habitat representative of a 75-meter reach. The twenty D-frame samples were composited into one sample, which was preserved in 95-percent denatured ethyl alcohol and returned to SRBC's lab for processing. Each sample was then subsampled, with approximately 120 organisms picked.

For all samples, organisms were identified to genus when possible, except for midges, which were identified to family, and worms, which were identified to class.

HABITAT

Habitat conditions were also evaluated using a modified version of RBP III (Plafkin and others, 1989; Barbour and others, 1999). Physical stream characteristics relating to substrate, pool, and riffle composition, shape of the channel, conditions of the banks, and the riparian zone were rated on a scale of 0-20, with 20 being optimal. Other observations were noted regarding recent precipitation events, substrate material composition,

surrounding land use, and any other relevant features in the watershed.

DATA ANALYSIS

Water quality was assessed by examining field and laboratory parameters that included nutrients, major ions, and metals (Table 1). The data were compared to water quality levels of concern based on current state and federal regulations, background levels for uninfluenced streams, or references for approximate tolerances of aquatic life (Table 2). The difference between each value and the level of concern value from Table 2 was calculated for each site. If the measured value exceeded the level of concern value, the difference between the two was listed. If the measured value did not exceed the level of concern value, the difference was listed as zero. An average of all the differences for each site was calculated. All sites that received a score of zero (no parameters exceeded the limits) were classified as higher quality. Sites that had a percentage value between zero and one were classified as middle quality, and sites that had a percentage value greater than one were classified as lower quality.

Seven reference categories were created for macroinvertebrate and habitat data analysis. All the sites were divided into small (<100 square miles), medium (100 to 500 square miles), and large (>500 square miles) drainage areas. The sites were grouped again according to ecoregions and subcoregions (Omernik, 1987; Omernik, 1992). Those sites less than 100 square miles were grouped by subcoregion due to the smaller size of the watersheds. Sites that represented drainage areas greater than 100 square miles were grouped by ecoregion since they often covered an area with more than one subcoregion and were designated with a letter "L" (Appendix A). Some of the subcoregions were combined due to similarity of the subcoregions and limited number of sites for ease of analysis. Based on the location of the sampling sites, the seven reference categories used were: 64ac, 64d, 64L, 67a, 67b, 67cd, and 67L. Mainstem sites were placed in a separate River reference category, but since no River sites were sampled during 2011 because of high flows, this reference category was not analyzed in this survey. The site on Mountain Creek (MNTN 3.0) was grouped with 67cd since no other sites were located within subcoregion 66b. One reference site was chosen in each of the seven reference categories, primarily based on the results of the macroinvertebrate metrics, and secondarily based on habitat and water quality scores, to represent the best combination of conditions within each category.

Benthic macroinvertebrate samples were analyzed using seven metrics mainly derived from RBP III: (1) taxonomic richness; (2) modified Hilsenhoff Biotic Index; (3) percent Ephemeroptera; (4) percent contribution of dominant taxon; (5) number of Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa;

Table 2. Water Quality Standards and Levels of Concern

Parameters	Limits	Reference Codes	References
Based on state water quality standards:			
Temperature	≤ 30.5 °C	a	a. http://www.pacode.com/secure/data/025/chapter93/s93.7.html b. http://www.pacode.com/secure/data/025/chapter93/s93.8c.html c. http://www.dec.ny.gov/regs/4590.html#16132 d. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-3.htm
Dissolved Oxygen	≥ 4 mg/l	a	
pH	≥ 6.0 and ≤ 9.0	a	
Alkalinity	≥ 20 mg/l	a	
Total Chloride	≤ 250 mg/l	a	
Total Dissolved Solids	≤ 500 mg/l	c	
Total Sulfate	≤ 250 mg/l	a	
Total Iron	≤ 1500 µg/l	a	
Total Manganese	≤ 1000 µg/l	a	
Total Aluminum	≤ 750 µg/l	b	
Total Magnesium	≤ 35 mg/l	c	
Total Sodium	≤ 20 mg/l	c	
Total Suspended Solids	≤ 25 mg/l	a	
Turbidity	≤ 50 NTU	d	
Based on background levels or aquatic life tolerances:			
Conductivity	≤ 800 µmhos/cm	e	e. http://www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm f. http://water.usgs.gov/pubs/circ/circ1225/images/table.html g. http://www.uky.edu/WaterResources/Watershed/KRB_AR/krww_parameters.htm h. Hem (1970) i. Based on archived data at SRBC
Total Nitrogen	≤ 1 mg/l	f	
Total Nitrate	≤ 0.6 mg/l	f	
Total Nitrite	≤ 1 mg/l	c	
Total Phosphorus	≤ 0.1 mg/l	g	
Total Orthophosphate	≤ 0.02 mg/l	f	
Total Organic Carbon	≤ 10 mg/l	h	
Total Hardness	≤ 300 mg/l	g	
Acidity	≤ 20 mg/l	i	
Calcium	≤ 100 mg/l	i	

(6) percent Chironomidae; and (7) Shannon-Wiener Diversity Index. Each site's metric scores were compared to the scores at its corresponding reference site, and a biological condition category of nonimpaired, slightly impaired, moderately impaired, or severely impaired was assigned based on RBP III methods. The same reference sites were used in the analysis for the habitat scores. The ratings for each habitat condition were totaled, and a percentage score of the reference site was calculated. The percentages were used to assign a habitat condition category of excellent, supporting, partially supporting, or nonsupporting to each site.



Ephemerella mayflies are a sensitive ecological indicator taxa that tend to be found in healthy limestone streams. Photo credit: Robert Henricks