Basin Geography

The Susquehanna River basin is the largest river basin on the east coast of the United States, draining 27,510 square miles. The Susquehanna River originates at Otsego Lake, N.Y., and flows 444 miles through New York, Pennsylvania, and Maryland to the Chesapeake Bay at Havre de Grace, Md.

The study area is located in the Upper Susquehanna Subbasin, which encompasses an area of approximately 4,950 square miles. The subbasin is sparsely populated, with only one large city, Binghamton, N.Y., and several small population centers, such as Sayre, Pa., and Waverly, N.Y. The subbasin lies almost entirely within the Northern Appalachian Plateau and Uplands Region (Wood, 1996). This ecoregion is characterized by low hills covered with hardwood forests and open valleys of scattered agricultural lands. The fertile, but rocky, soils were deposited by receding glaciers during the Wisconsinan Age.

The Upper Susquehanna Subbasin includes the drainage areas of several large rivers: the Chenango; Otselic; Sangerfield; Tioughnioga; Unadilla; and Susquehanna. Forests cover approximately 60 percent of the Upper Susquehanna Subbasin. Agriculture, the second leading land use, covers about 36 percent of available land in the subbasin (Stoe, 1999).

Study Area

SRBC staff conducted the pilot project on the Susquehanna River between Windsor, N.Y., and Sayre, Pa., during September 2002 (Figure 1). This stretch of river was chosen because background biological information from SRBC's interstate streams monitoring program (LeFevre and Sitlinger, 2003) is available for a 13-year period from three stations: Windsor and Conklin, N.Y., and Sayre, Pa. Biological and habitat data are collected annually at these sites, while water quality information is collected quarterly. The 10 sampling sites on this 76-mile stretch of river (Table 1) were selected so that data collected during this survey could be compared with past data collected by SRBC and to document the possible changes in the riverine biota throughout this stretch of river.

METHODS

Field and Laboratory Methods

Data collection

During September 23-26, 2002, SRBC staff collected samples from the Susquehanna River between Windsor, N.Y., and Sayre, Pa. Macroinvertebrate samples were collected at eight of the ten proposed sites. High river flows at the time of sampling precluded collection at sites SUSQ 8 and SUSQ 9 and reduced the collection effort at several other sites. River flows quadrupled during the study from base flow conditions that were present at the time of sampler placement. Habitat was rated, and chemical water quality samples were collected at the sites where a macroinvertebrate sample was collected.

Samples were labeled with the site number (SUSQ 1 through SUSQ 10), the type of equipment used (VBS for vacuum benthic sampler, RBP for rapid bioassessment protocol, RS for rock basket sampler, and HD for multi-plate sampler), and the location of the sampler with relation to the site (sampler one at the left bank and sampler five at the right bank). For example, a vacuum benthic sample taken at SUSQ 2 in the middle of the river would be designated as 2VBS3.

The field crew consisted of six members, three of which were trained biologists. Additionally, three members of the field crew had received SCUBA training prior to the sampling effort. All members of the field crew had CPR and Basic First Aid training. Latitude and longitude were recorded using a hand-held Global Positioning System unit at all sites.

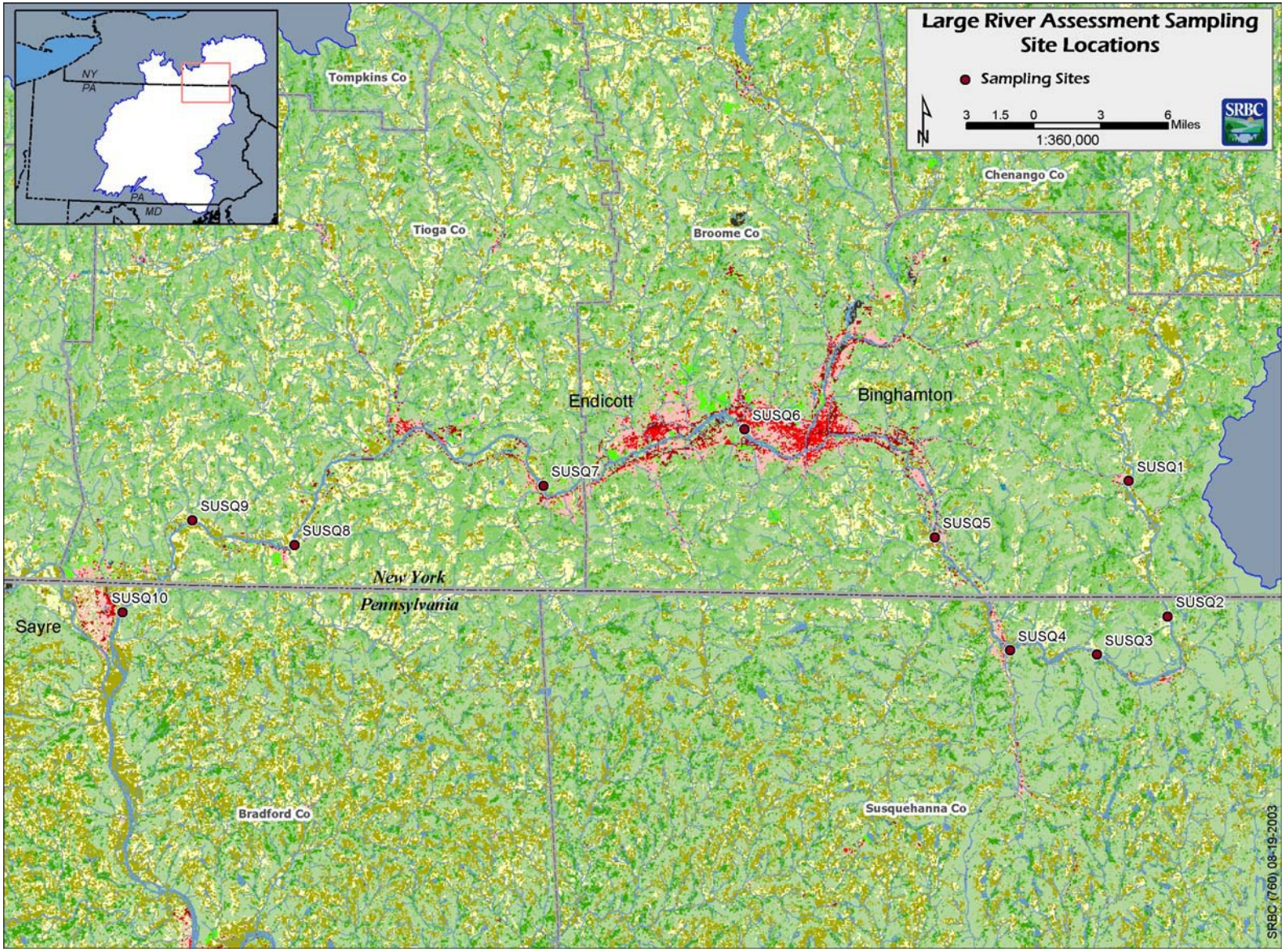

Figure 1. Large River Assessment Sampling Site Locations

Table 1. Susquehanna River Station Locations

Station Number	County/State	USGS Quad	Latitude	Longitude	Site Description
SUSQ 365/SUSQ 1	Broome/N.Y	Windsor, N.Y.	42.0747	-75.6351	Susquehanna River at Windsor, N.Y.
SUSQ 359/SUSQ 2	Susquehanna/Pa.	Susquehanna, Pa.	41.9910	-75.6023	Susquehanna River at PF&BC Oakland access along Rt. 92, upstream of Oakland, Pa.
SUSQ 356/SUSQ 3	Susquehanna/Pa.	Great Bend, Pa.	41.9612	-75.6620	Susquehanna River at PF&BC Great Bend access along SR1010, upstream of Hallstead, Pa.
SUSQ 350/SUSQ 4	Susquehanna/Pa.	Great Bend, Pa.	41.9636	-75.7377	Susquehanna River at Hallstead, Pa., at I-81 bridge
SUSQ 344/SUSQ 5	Broome/N.Y.	Binghamton East, N.Y.	42.0347	-75.8017	Susquehanna River at Veteran's River Park at Kirkwood, N.Y.
SUSQ 334/SUSQ6	Broome/N.Y.	Binghamton West, N.Y.	42.1026	-75.9687	Susquehanna River at fishing access site in Binghamton, N.Y.
SUSQ 327/SUSQ 7	Tioga/N.Y.	Apalachin, N.Y.	42.0653	-76.1426	Susquehanna River at fishing access site near Apalachin, N.Y.
SUSQ 322/SUSQ 8	Tioga/N.Y.	Owego, N.Y.	42.0250	-76.3625	Susquehanna River at Town of Nichols Fishing Access along East River Drive, near Nichols, N.Y.
SUSQ 312/ SUSQ 9	Tioga/N.Y.	Barton, N.Y.	42.0400	-76.4464	Susquehanna River at Barton Fishing Access along East Barton Road, Barton, N.Y.
SUSQ 300/ SUSQ 10	Bradford/Pa.	Sayre, Pa.	41.9819	-76.5065	Susquehanna River downstream of Lockhart Street bridge in Sayre, Pa.

Chemical water quality

Water samples were collected at each sampling site to measure nutrient and metal concentrations in the river. Field water quality measurements included water temperature, dissolved oxygen, conductivity, pH, alkalinity and acidity. Temperature was measured with a field thermometer in degrees Celsius. Dissolved oxygen was measured with a YSI 55 meter that was calibrated at the beginning of every day when samples were collected, and conductivity was measured with a Cole-Parmer Model 1481 meter. A Cole-Parmer Model 5996 meter that was calibrated at the beginning of each sampling day and randomly checked throughout the day was used to measure pH. Alkalinity was determined by titrating a known volume of sample water to pH 4.5 with 0.02 N sulfuric acid (H_2SO_4). Acidity was measured by titrating a known volume of sample water to pH 8.3 with 0.02 N sodium hydroxide (NaOH).

A list of laboratory parameters is located in Table 2. Laboratory samples consisted of one 500-ml bottle of raw water and two 250-ml bottles of acidified water. One of the 250-ml bottles was acidified with nitric acid (HNO_3) for metal analyses. The other 250-ml bottle was acidified with H_2SO_4 for nutrient analyses. Samples were iced and shipped to the Pennsylvania Department of Environmental Protection (Pa. DEP), Bureau of Laboratories, in Harrisburg, Pa., for analysis.

Physical habitat

The physical habitat conditions were evaluated at each site using a modified version of RBP III (Plafkin and others, 1989; Barbour and others, 1999). A total of 11 physical stream characteristics relating to substrate, pool and riffle composition, channel morphology, streambank condition, and the riparian area were rated on a scale of 0-20, with 20 considered optimal and used to calculate a site-specific habitat score. Physical habitat assessments were performed for riffle/run or glide/pool areas, depending on stream type. Other characteristics, such as stream type, weather conditions, substrate material, land use, and other important stream features also were noted at the time of sampling. Tables 3 (riffle/run habitat) and 4 (glide/pool habitat) summarize the criteria used to evaluate physical habitat.

Macroinvertebrates

Staff collected benthic macroinvertebrate samples using four separate methodologies to determine the proper methods of biologically assessing the large rivers of the basin. Each methodology is described in detail below.

Table 2. Parameters for Laboratory Analysis

Parameter	
Specific Conductance, µmhos/cm[a]	Total Suspended Solids (TSS), mg/l
pH, S.U.[b]	Total Sodium, mg/l
Alkalinity, mg/l[c]	Total Potassium, mg/l
Total Nitrogen, mg/l	Total Chloride, mg/l
Total Ammonia, mg/l	Total Sulfate, mg/l
Total Nitrite, mg/l	Total Fluoride, mg/l
Total Nitrate, mg/l	Total Copper, µg/l[d]
Total Phosphorus, mg/l	Total Iron, µg/l
Total Orthophosphate, mg/l	Total Lead, µg/l
Total Organic Carbon (TOC), mg/l	Total Manganese, µg/l
Total Hardness, mg/l	Total Nickel, µg/l
Total Calcium, mg/l	Total Zinc, µg/l
Total Magnesium, mg/l	Total Aluminum, µg/l

[a] µmhos/cm = micromhos per centimeter
[b] S.U. = Standard Units
[c] mg/l = milligrams per liter
[d] µg/l = micrograms per liter

Table 3. Riffle/Run Habitat Assessment Criteria

HABITAT PARAMETER	CATEGORY			
	OPTIMAL (20-16)	SUBOPTIMAL (15-11)	MARGINAL (10-6)	POOR (5-0)
1. Epifaunal Substrate	Well-developed riffle/run; riffle is as wide as stream and length extends 2 times the width of stream; abundance of cobble	Riffle is as wide as stream but length is less than 2 times width; abundance of cobble; boulders and gravel common	Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; some cobble present	Riffle or run virtually nonexistent; large boulders and bedrock prevalent; cobble lacking
2. Instream Cover	> 50% mix of boulders, cobble, submerged logs, undercut banks or other stable habitat	30–50% mix of boulder, cobble, or other stable habitat; adequate habitat	10–30% mix of boulder, cobble, or other stable habitat; habitat availability less than desirable	<10% mix of boulder, cobble, or other stable habitat; lack of habitat is obvious
3. Embeddedness	Gravel, cobble, and boulder particles are 0–25% surrounded by fine sediments	Gravel, cobble, and boulder particles are 25–50% surrounded by fine sediments	Gravel, cobble, and boulder particles are 50–75% surrounded by fine sediments	Gravel, cobble, and boulder particles are >75% surrounded by fine sediments
4. Velocity/Depth Regimes	All 4 velocity/depth regimes present (slow/deep, slow/shallow, fast/deep, fast/shallow)	Only 3 of 4 regimes present (if fast/shallow is missing, score lower than if missing other regimes)	Only 2 of 4 regimes present (if fast/shallow or slow/shallow are missing, score low)	Dominated by 1 velocity/depth regime
5. Sediment Deposition	Little or no enlargement of islands or point bars and <5% of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from coarse gravel; 5–30% of the bottom affected; slight deposition in pools	Moderate deposition of new gravel, coarse sand on old and new bars; 30–50% of the bottom affected; sediment deposits at obstructions; moderate deposition of pools prevalent	Heavy deposits of fine material, increased bar development; >50% of the bottom changing frequently; pools almost absent due to sediment deposition
6. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed	Water fills >75% of the available channel; or <25% of channel substrate exposed	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed	Very little water in channel and mostly present as standing pools
7. Channel Alteration	No channelization or dredging present	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (>20 yr) may be present, but not recent	New embankments present on both banks; and 40-80% of stream reach channelized and disrupted	Banks shored with gabion or cement; >80% of the reach channelized and disrupted
8. Frequency of Riffles	Occurrence of riffles relatively frequent; distance between riffles divided by the width of the stream equals 5 to 7; variety of habitat	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream equals 7 to 15	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the stream width is between 15-25	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is >25
9. Condition of Banks (score each bank 0-10)	Banks stable; no evidence of erosion or bank failure; little potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable, 30-60% of banks in reach have areas of erosion; high erosion potential during floods	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; on side slopes, 60-100% of bank has erosional scars
10. Vegetative Protective Cover (score each bank 0-10)	>90% of the streambank surfaces covered by vegetation; vegetative disruption through grazing or mowing minimal	70-90% of the streambank surfaces covered by vegetation; disruption evident but not affecting full plant growth potential to any great extent	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation	<50% of the steambank surfaces covered by vegetation; disruption is very high; vegetation removed to 5 cm or less
11. Riparian Vegetative Zone Width (score each bank 0-10)	Width of riparian zone >18 meters; human activities (i.e. parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally	Width of riparian zone 6-12 meters; human activities have impacted zone only minimally	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities

Table 4. Glide/Pool Habitat Assessment Criteria

HABITAT PARAMETER	CATEGORY			
	OPTIMAL (20-16)	SUBOPTIMAL (15-11)	MARGINAL (10-6)	POOR (5-0)
1. Epifaunal Substrate	Preferred benthic substrate abundant throughout stream site and at stage to allow full colonization (i.e. log/snags that are not new fall and not transient)	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently disturbed or removed	Substrate unstable or lacking
2. Instream Cover	> 50% mix of snags, submerged logs, undercut banks or other stable habitat; rubble, gravel may be present	30-50% mix of stable habitat; adequate habitat for maintenance of populations	10-30% mix of stable habitat; habitat availability less than desirable	Less than 10% stable habitat; lack of habitat obvious
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present	All mud or clay or sand bottom; little or no root mat; no submerged vegetation	Hard-pan clay or bedrock; no root mat or vegetation
4. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present	Majority of pools large-deep; very few shallow	Shallow pools much more prevalent than deep pools	Majority of pools small-shallow or pools absent
5. Sediment Deposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of island or point bars	20-50% affected; moderate accumulation; substantial sediment movement only during major storm event; some new increase in bar formation	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial movement during storm events	Channelized; mud, silt, and/or sand in braided or non-braided channels; pools almost absent due to substantial sediment deposition
6. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed	Water fills >75% of the available channel; or <25% of channel substrate exposed	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed	Very little water in channel and mostly present as standing pools
7. Channel Alteration	No channelization or dredging present	Some channelization present, usually in areas of bridge abutments; evidence of past channelization (>20 yr) may be present, but not recent	New embankments present on both banks; and 40-80% of stream reach channelized and disrupted	Banks shored with gabion or cement; >80% of the reach channelized and disrupted
8. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line	Channel straight; waterway has been channelized for a long time
9. Condition of Banks (score each bank 0-10)	Banks stable; no evidence of erosion or bank failure; side slopes generally <30%; little potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; side slopes up to 40% on one bank; slight erosion potential in extreme floods; 5-30% of bank in reach has areas of erosion	Moderately unstable; moderate frequency and size of erosional areas; side slopes up to 60% on some banks; high erosion potential during extremely high flow; 30-60% of bank in reach has areas of erosion	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; on side slopes; side slopes >60% common; 60-100% of bank has erosional scars
10. Vegetative Protective Cover (score each bank 0-10)	>90% of the streambank surfaces covered by vegetation; vegetative disruption through grazing or mowing minimal	70-90% of the streambank surfaces covered by vegetation; disruption evident but not affecting full plant growth potential to any great extent	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation	<50% of the steambank surfaces covered by vegetation; disruption is very high; vegetation removed to 5 cm or less
11. Riparian Vegetative Zone Width (score each bank 0-10)	Width of riparian zone >18 meters; human activities (i.e. parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally	Width of riparian zone 6-12 meters; human activities have impacted zone only minimally	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities

Vacuum Benthic Sampler (VBS)

A vacuum benthic sampler (Figure 2), operated by a SCUBA diver, can be very useful in sampling large rivers and can be used on a variety of substrates (Brown and others, 1987). For this project, three field crew members had SCUBA training prior to sample collection.

With this collecting method, five riffle/run areas were targeted at each site, where available. If riffle/run areas were not present, samples were taken in a transect across the stream bottom. The sampler was lowered to the river bottom by a helper in a boat, and the diver positioned the sampler in the appropriate sampling area. The diver settled the sampler on the bottom, the helper activated the pump, and the diver vacuumed the substrate into a net bag. Substrate was removed to a depth of approximately five centimeters over a time period of five minutes. Large organisms, such as crayfish and hellgrammites, also were hand-collected in a separate net bag for inclusion in the total sample. The collecting bag and its contents were placed in a jar labeled with the site information and method of collection. The jar was filled with 95 percent ethanol so that the final concentration was at least 70 percent ethanol. The capped sample bottles were taken back to the laboratory to await analysis (Gale and Thomas, 1975).

Rock Basket (RS)

The second method was a rock substrate basket sampler (Figure 3). Rock basket samplers are useful in assessing areas that are too deep to sample with traditional RBP methods (Merritt and others, 1996).

A wire basket filled with natural river rocks from the sampling area was placed in a run area, where possible, to ensure a constant flow of water running through the sampler. Before the baskets were placed in the river, they were attached to a concrete block for stabilization and a float for marking the sampler location. Five such baskets were located on a transect across the river and left in place for six weeks to allow colonization. Samplers were placed by hand during August 12–15, 2002. Sites were chosen across the transect based on depth, velocity, substrate, and cover within the transect. To retrieve the substrates, the baskets were separated from the concrete blocks and placed in a collecting bag while still under water by a SCUBA diver. The net was brought to shore, and all macroinvertebrates were rinsed from the substrate and placed in a jar labeled with site information and method of collection. The jar was filled with 95 percent ethanol so that the final concentration was at least 70 percent ethanol. The capped sample bottles were taken back to the laboratory to await analysis.

Multiplate Sampler (HD)

Additionally, at the request of Pa. DEP, multiplate samplers (Figure 4) were placed in conjunction with the rock baskets mentioned above at each of the sites to produce information regarding colonization of each type of artificial substrate sampler and their comparability. Three multi-plate samplers were deployed at each of the sampling stations (at the right and left banks and in the middle of the river). The multiplate samplers were retrieved by a SCUBA diver and processed in the same manner as the rock baskets.

Modified Rapid Bioassessment Protocol (RBP)

SRBC has used this procedure for sampling throughout the basin since 1992. Including this methodology provides a link to past assessments in the river. The USEPA RBP III methodology (Barbour and others, 1999) was used in riffle areas, where present. When no riffle/run area was present, this methodology was used along the banks of the river and around the edges of islands. In riffle/run areas, samples were collected at both sides of the river, and at three internal sites for a total of five sites across the riffle/run area, where possible.

Figure 2. Benthic Vacuum Sampler Used in River Assessment Project (from Brown and others, 1987)

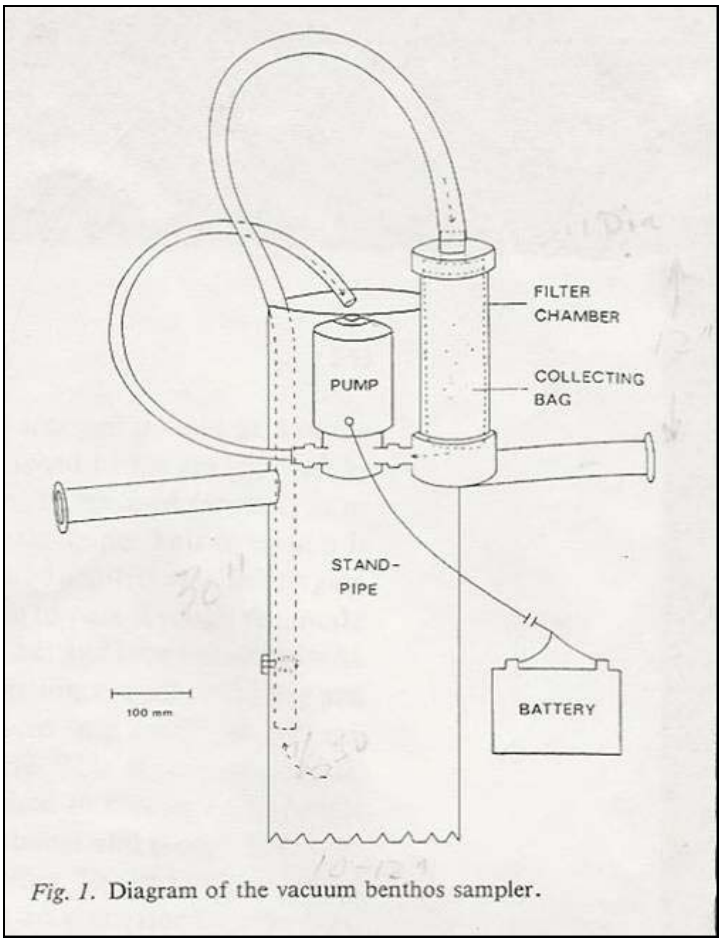

Figure 3. Rock Baskets Used in River Assessment Project

Figure 4. Multi-plate Samplers Used in River Assessment Project

Sampling was conducted by placing a one meter square kick screen perpendicular to the current and disrupting the substrate so dislodged macroinvertebrates are carried into the screen. All collected specimens were preserved in 95 percent ethanol and returned to SRBC offices for identification and enumeration.

After sampling was completed at a given site, all equipment that came in contact with the sample was rinsed thoroughly, examined carefully and picked free of algae or debris before sampling at the next site. Additional organisms that were found on examination were placed into the sample containers.

Subsampling and sorting procedures were based on the 1999 RBP document (Barbour and others, 1999). In the laboratory, composite samples were sorted into 200-organism subsamples, when possible, using a gridded pan and a random numbers table. The organisms contained in the subsamples were identified to genus (except Chironomidae and Oligochaeta), when possible, and enumerated. Benthic macroinvertebrates were identified by professional biologists, with a minimum of a Master of Science degree in biology, skilled at recognizing most benthos to the family level by sight, and to the genus level with appropriate keys.

Data Analysis

Chemical water quality

Chemical water quality was assessed by examining field and laboratory parameters. Limit values were obtained for each parameter based on current state and federal regulations or references for aquatic life tolerances (Table 5, from LeFevre, 2003).

Table 5. Water Quality Limits and References

Parameter	Limit	Reference Code
Temperature	> 25°C	a,f
Dissolved oxygen	< 4 mg/l	a,g
Conductivity	> 800 μmhos/cm	d
pH	6 – 9	c,f
Alkalinity	< 20 mg/l	a,g
Nitrogen	>1.0 mg/l	k,l,m
Ammonia	>0.2 mg/l	f
Nitrite	> 1.0 mg/l	f
Nitrate	> 1.0 mg/l	e,i
Phosphorus	> 0.1 mg/l	e
Orthophosphate	> 0.05 mg/l	m
TOC	> 10 mg/l	b
Hardness	> 300 mg/l	e
Magnesium	> 35 mg/l	j
TSS	> 15 mg/l	h
Sodium	> 20 mg/l	j
Potassium	> 30 mg/l	b
Chloride	> 150 mg/l	a
Sulfate	> 250 mg/l	a
Fluoride	> 2.0 mg/l	a
Copper	> 12 μg/l	e
Iron	> 1,500 μg/l	a
Lead	> 1.0 μg/l	e
Manganese	> 1,000 μg/l	a
Nickel	> 158 μg/l	d
Zinc	> 106 μg/l	e
Aluminum	> 200 mg/l	c

a: http://www.pacode.com/secure/data/025/chapter93/s93.7.html
b: Hem (1970)
c: Gagen and Sharpe (1987) and Baker and Schofield (1982)
d: http://www.uky.edu/WaterResources/Watershed/KRB_AR/wq_standards.htm
e: http://www.uky.edu/WaterResources/Watershed/KRB_AR/krww_parameters.htm
f: http://www.hach.com/h2ou/h2wtrqual.htm
g: http://sites.state.pa.us/PA_Exec/Fish_Boat/education/catalog/pondstream.pdf
h: http://www.deq.state.va.us/pdf/watrregs/fish.pdf
i: http://www.fisheries.org/publications/bookpdf/aquaticmethods.pdf
j: http://www.dec.state.ny.us/website/regs/703.htm
k: http://water.usgs.gov/pubs/circ/circ1225/images/table.html
l: http://www.ecan.govt.nz/Land/pdf%20files/sheet13.pdf
m: http://h2osparc.wq.ncsu.edu/info/

Macroinvertebrate analysis

In-depth statistical analyses comparing the overall sampling methods, both between and within sites, could not be performed due to a reduced data collection effort from high waters precluding sampling at two of the sites and reducing the amount of information collected at most of the other sites. However, basic metrics for macroinvertebrates were calculated and assessments of the sites were performed. Benthic macroinvertebrate samples were assessed using procedures described by Barbour and others (1999), Klemm and others (1990), and Plafkin and others (1989). Using these methods, staff calculated a series of biological indexes for each type of sampler at each station. The metrics used in this survey are summarized in Table 6. Metric 2 (Shannon-Wiener Diversity Index) followed the methods described in Klemm and others (1990), and all other metrics were derived from Barbour and others (1999).

Three approaches were used to assess the 84 samples produced by the large river assessment project to evaluate how an IBI-type analysis compares to use of a reference site (the best available suite of biological conditions at a single site) or a reference condition (the combined best overall score for each metric) for impairment decisions. To produce the IBI analysis (Approach 1), the 75th and 25th percentiles of the highest value for each metric were used to determine a biological condition score. A score of six was given to each metric that was greater than the 75th percentile, a score of three was given to metrics that were between the 75th and 25th percentiles, a score of zero was given to those metrics that had values less than the 25th percentile. A total biological score of 28 or greater received a nonimpaired designation, scores of 27 through 14 received a partially impaired designation, and scores of less than 14 received a severely impaired designation.

The reference site approach (Approach 2) entails determining the best available biological condition at a single site. To determine the best available conditions, each metric score was ranked against all other scores for that metric. The rankings were then averaged to determine which site contained the best available overall conditions of the 84 samples collected. For this analysis, staff determined that 1VBS2 (a vacuum benthic sample taken at SUSQ1, second sample from the left) contained the best overall suite of biological conditions. The 200-organism subsample data were used to generate scores for each of the seven metrics. Scores for metrics 1-4 were converted to a biological condition score, based on the percent similarity of the metric score, relative to the metric score of the reference site. Scores for metrics 5-7 were based on set scoring criteria developed for the percentages (Plafkin and others, 1989; Ohio Environmental Protection Agency, 1987). The sum of the biological condition scores constituted the total biological score for the sample site, and total biological scores were used to assign each site to a biological condition category (Table 7).

The third appraoch was the use of reference conditions. For this technique, the best score for each metric was determined. Each site was then compared against the highest score for each metric. To determine levels of impairment, the same protocol was used as in the reference site approach.

Physical habitat analysis

Habitat assessment scores of sample sites were compared to those of the reference site (SUSQ 1) to classify each sample site into a habitat condition category (Table 8).

Table 6. Summary of Metrics Used to Evaluate the Overall Biological Integrity of River Benthic Macroinvertebrate Communities

Metric	Description
1. Taxonomic Richness (a)	The total number of taxa present in the 200-organism subsample. Number decreases with increasing disturbance or stress.
2. Shannon-Wiener Diversity Index (b)	A measure of biological community complexity based on number of equally or nearly equally abundant taxa in the community. Index value decreases with increasing stress.
3. Hilsenhoff Biotic Index (a)	A measure of the organic pollution tolerance of a benthic macroinvertebrate community. Index value increases with increasing stress.
4. EPT Index (a)	The total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa present in the 200-organism subsample. The index decreases with increasing stress.
5. Percent Ephemeroptera (a)	The percentage of Ephemeroptera in a 200-organism subsample. Percentage decreases with increasing stress.
6. Percent Dominant Taxa (a)	A measure of community balance at the lowest positive taxonomic level. Percentage increases with increasing stress.
7. Percent Chironomidae (a)	The percentage of Chironomidae in a 200-organism subsample. Percentage increases with increasing stress.

Sources: (a) Barbour and others, 1999
(b) Klemm and others, 1990

Table 7. Summary of Criteria Used to Classify the Biological Conditions of Sample Sites

SAMPLING AND ANALYSIS

↓
↓

TOTAL BIOLOGICAL SCORE DETERMINATION

Metric	Biological Condition Scoring Criteria			
	6	4	2	0
1. Taxonomic Richness (a)	> 80%	79-60%	59-40%	<40%
2. Shannon Diversity Index (a)	> 75%	74-50%	49-25%	<25%
3. Hilsenhoff Biotic Index (b)	> 85%	84-70%	69-50%	<50%
4. EPT Index (a)	> 90%	89-80%	79-70%	< 70%
5. Percent Ephemeroptera (c)	> 25%	10-25%	1-9%	< 1%
6. Percent Chironomidae (c)	< 5%	5-20%	21-35%	>35%
7. Percent Dominant Taxa (c)	< 20%	20-30%	31-40%	>40%
Total Biological Score (d)				

↓
↓

BIOASSESSMENT

Percent Comparability of Study and Reference Site Total Biological Scores (e)	Biological Condition Category
>83%	Nonimpaired
79-54	Slightly Impaired
50-21	Moderately Impaired
<17%	Severely Impaired

(a) Score is study site value/reference site value X 100
(b) Score is reference site value/study site value X 100.
(c) Scoring Criteria evaluate actual percentage contribution, not percent comparability to the reference station.
(d) Total Biological Score = the sum of Biological Condition Scores assigned to each metric
(e) Values obtained that are intermediate to the indicated ranges will require subjective judgment as to the correct placement into a biological condition category.

Table 8. Summary of Criteria Used to Classify the Habitat Conditions of Sample Sites

DETERMINATION OF HABITAT ASSESSMENT SCORES				
Parameter	Habitat Parameter Scoring Criteria			
	Excellent	Good	Fair	Poor
Epifaunal Substrate	20-16	15-11	10-6	5-0
Instream Cover	20-16	15-11	10-6	5-0
Embeddedness/Pool Substrate	20-16	15-11	10-6	5-0
Velocity/Depth Regimes/Pool Variability	20-16	15-11	10-6	5-0
Sediment Deposition	20-16	15-11	10-6	5-0
Channel Flow Status	20-16	15-11	10-6	5-0
Channel Alteration	20-16	15-11	10-6	5-0
Frequency of Riffles/Channel Sinuosity	20-16	15-11	10-6	5-0
Condition of Banks (a)	20-16	15-11	10-6	5-0
Vegetative Protective Cover (a)	20-16	15-11	10-6	5-0
Riparian Vegetative Zone Width (a)	20-16	15-11	10-6	5-0
Habitat Assessment Score (b)				

↓

↓

HABITAT ASSESSMENT	
Percent Comparability of Study and Reference Site Habitat Assessment Scores	Habitat Condition Category
>90%	Excellent (comparable to reference)
89-75	Supporting
74-6	Partially Supporting
<60	Nonsupporting

(a) Combined score of each bank
(b) Habitat Assessment Score = Sum of Habitat Parameter Scores