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LOWER ESOPUS CREEK

Biological Stream Assessment

February 1, 2015

BIOLOGICAL STREAM ASSESSMENT

Lower Esopus Creek
Ulster County, New York
Lower Hudson River Basin

Survey date: March 31, 2011
Report date: February 1, 2015

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Stream: Lower Esopus Creek

River Basin: Lower Hudson River

Reach: Olivebridge, NY

Background

The Stream Biomonitoring Unit conducted a biological assessment of water quality at three locations on the Lower Esopus Creek downstream of the Ashokan Reservoir in the area of Olivebridge, New York, March 31, 2011. The sustained use of the Ashokan release channel after heavy rainfall during the fall of 2010 led to prolonged releases of turbid water to the lower Esopus Creek. The survey was initiated at the request of Department of Environmental Conservation (NYSDEC) Central Office staff to assess impacts to aquatic life resulting from these turbid water releases.

To characterize water quality and assess any impacts to aquatic life, benthic macroinvertebrate communities were collected via replicated traveling kick samples from riffle areas at each location. Methods used are described in the Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State (NYSDEC, 2014) and summarized in the appendices of this document. The contents of each sample were field-inspected to determine major groups of organisms present, and then preserved in alcohol for laboratory inspection of 100-specimen subsamples from each replicate sample. Results of biological community metrics were evaluated between sampling locations using Biological Impairment Criteria (Bode et al. 1990) to identify statistically significant impact. Expected variability in the results of benthic macroinvertebrate community samples is presented in Smith and Bode (2004).

Results and Conclusions

1. Results of the biological survey suggest water quality conditions range from non- to slightly impacted in the Lower Esopus Creek, indicating aquatic life is fully supported. However, typical of large impoundments (e.g. lakes, reservoirs) the Ashokan Reservoir acts as a major barrier limiting macroinvertebrate colonization of the Lower Esopus Creek immediately downstream of the reservoir but upstream of the confluence with the reservoir release channel. The presence of the reservoir cuts off the Lower Esopus Creek from Upper Esopus Creek invertebrate recruitment, both through aerial colonization and in-stream drift.

2. Habitat assessment at the location immediately downstream of the confluence with the release channel indicated altered habitat due to changes in velocity/depth regimes, sediment deposition, and channel flow status.

3. Continued use of the release channel should require routine biological monitoring to ensure any impacts on aquatic life are identified early to allow effective remediation. Detailed characterization of substrates to measure the deposition and source of sediments in this reach of the Lower Esopus Creek over time is also recommended.

Discussion

The Esopus Creek is a 425 square mile watershed located in the Catskill Mountains of New York State and is divided into an upper and lower section by the presence of the Ashokan Water Supply Reservoir (Figure 1). The Lower Esopus Creek (169 mi^2 watershed) flows approximately 30 miles from the outlet of the Ashokan Reservoir near Olivebridge, NY until it reaches its confluence with the western shore of the Hudson River (LEWP 2015).

Water is released from the Ashokan Reservoir through a concrete channel in a controlled manner into the Lower Esopus Creek. Recently managed releases from the reservoir have attempted to accommodate large runoff events from the Upper Esopus Creek watershed in an effort to reduce flood risks to downstream communities. In these cases the releases create capacity in the west basin of the reservoir thereby providing greater storage of runoff and enhanced flood protection. However, storm runoff entering the Ashokan Reservoir from the Upper Esopus Creek watershed is often turbid due to significant stream bank erosion, bank slope failures, and in-stream scour in that watershed. The New York City Department of Environmental Protection (DEP) and New York State Department of Environmental Conservation (DEC) have been working to address these issues to reduce suspended sediment and improve water clarity throughout the Esopus Creek watershed.

Water from the Ashokan Reservoir can also enter the lower Esopus Creek as a result of spillage over the east basin spillway into spillway channel. Water from the Ashokan release channel converges with the water from the east basin spillway channel at a point referred to as the spillway confluence, and from there flows to the lower Esopus Creek.

DEC has established an interim Ashokan release protocol for use of the Ashokan release channel. This interim protocol provides for discharge mitigation and operational releases. Therefore, the interim protocol establishes community releases, or year round minimum releases, for summer and winter and sets a Conditional Seasonal Storage Objective (CSSO) rule curve that specifies water elevation goals (voids to improve flood attenuation) within Ashokan Reservoir for every month of the year. Generally, this curve will establish a seasonally variable void in Ashokan Reservoir that balances water supply best practices with the likelihood of increased flood attenuation. In addition, the interim protocol enables operational releases for turbidity control to be conducted should they be necessary. The impacts of turbidity in the release water and the volume of water in the releases from the reservoir on benthic macroinvertebrate communities is the focus of this investigation.

Turbid runoff from the Upper Esopus Creek entering the Ashokan Reservoir may translate into turbid reservoir releases into the Lower Esopus Creek during or in anticipation of high flow events. The DEC is concerned with the potential effects of turbid water releases on aquatic habitats and biological communities in the Lower Esopus Creek downstream of the reservoir. Therefore, the DEC's Stream Biomonitoring Unit (SBU) conducted a rapid assessment survey of benthic macroinvertebrate communities immediately downstream of the confluence of the release channel with the Lower Esopus Creek (Figure 2). The objective of this investigation was to assess impacts, if any, on benthic macroinvertebrate communities from turbid water releases frequently occurring during the period of October 2010 to February 2011. The survey focused on the reach most affected by the releases; upstream of the Route 28A bridge in Olivebridge, downstream to the State University of New York at New Paltz Ashokan Camp property in Olivebridge (Figure 2). Three locations were selected for sampling of benthic macroinvertebrate communities, ESOP-00 located upstream of the reservoir release channel confluence with the Lower Esopus Creek, ESOP-A downstream of the confluence, and ESOP-B downstream of the impoundments at the Ashokan Camp property (Figure 2, Table 1).

At each location four replicate kick samples from riffle areas of the stream bed were collected for processing of benthic macroinvertebrate communities. Field sampling and laboratory processing of samples were conducted by the DEC's SBU following the Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State (NYSDEC, 2014). Biological Assessment Profile (BAP) scores, however, should be considered in need of future verification because samples for this survey were collected outside the normal sampling index period of July through September. Replicated samples were collected to facilitate evaluation of biological impairment criteria which is a statistical comparison of macroinvertebrate community results between upstream reference (ESOP-00) and downstream affected locations (ESOP-A and -B) (Bode et al. 1990). To ensure proper comparison of benthic macroinvertebrate communities sampling locations must fit within specific ranges of physical conditions between sites. These include ± 3 substrate Phi units and within 50% embeddedness, current speed, and canopy cover when compared to the upstream reference location (Bode et al. 1990). All sites fell within the specified criteria. This indicated benthic macroinvertebrate communities would not be significantly different between sampling locations as a result of changes in basic habitat condition. Therefore any changes in community condition documented could be attributed to disturbance rather than natural variance. The data used in these site comparisons are summarized in Tables 2-3 and Figure 3.

Evaluation of benthic macroinvertebrate communities resulted in no violation of biological impairment criteria as a result of the Ashokan Reservoir release channel. Community metrics including species richness (spp.), Hilsenhoff's biotic index (HBI), Ephemeroptera/Plecoptera/Trichoptera richness (EPT), and the BAP were calculated and compared between sites ESOP-00, A, and B following the criteria in Bode et al. (1990). The results of each metric for all replicate samples fell well within the allowed variance between upstream reference and downstream effected locations. In addition to looking for significant community changes via impairment criteria evaluation, characterizing individual site condition was also done. The mean score for each metric was calculated for each sampling location and the average BAP score was used to characterize average site condition of benthic macroinvertebrate communities. The results suggest slight impacts (BAP = 5.67-7.09) to benthic macroinvertebrate communities at the most upstream location (ESOP-00), no impact (BAP = 7.61-8.79) at the location immediately downstream of the confluence with the release channel (ESOP-A), and slight impact (BAP = 6.49-8.03) at the Ashokan Camp property (ESOP-B) (Figure 5). The slight impact assessment at the upstream location (ESOP-00) may be the result of limited recruitment caused by the presence of the reservoir rather than water quality disturbance.

Limitations on macroinvertebrate colonization likely explain the improvement in benthic macroinvertebrate communities immediately downstream of the confluence with the reservoir release channel. The Ashokan Reservoir is a major barrier to macroinvertebrate colonization of the Lower Esopus Creek. Its presence cuts off the Lower Esopus Creek from Upper Esopus Creek invertebrate recruitment, both through aerial colonization and in-stream drift. As a result Lower Esopus Creek macroinvertebrate communities must reestablish themselves beginning with the reach that encompasses ESOP-00 immediately downstream of the reservoir and upstream of the reservoir release channel (Figure 2). This in effect, creates a benthic macroinvertebrate community reflective of a small, first order, headwater stream with low species richness and dominance by only a few intolerant organisms. The structural difference in this community is reflected in the low Percent Model Affinity score (PMA) for this site. At

ESOP-00, in addition to *Simulium* sp., the community was dominated by Nemouridae, a family of intolerant spring emerging stoneflies which made up as much as 66% of one replicate at this site (Table 5). The majority of the remaining community at this site was composed of various intolerant and facultative taxa of midge larvae (Diptera: Chironomidae) (Table 5). Macroinvertebrate community composition shows consistently high sample proportions (30-50%) of black fly larvae (*Simulium* sp., *Prosimulium* sp.) at each location reflecting the early spring sampling period in which the survey was conducted. The remainder of the communities at each site are dominated by pollution intolerant mayflies, stoneflies, and caddisflies with higher proportions of these groups at ESOP-A and -B with the exception of the stoneflies.

Changes in habitat conditions downstream of the reservoir release channel support findings related to limitations on colonization outlined above. Although BAP scores suggest an improvement to non-impacted conditions (due to improved colonization) at ESOP-A, habitat alterations decline downstream of the release channel as noted by the results of the habitat assessment (Figure 4). Specifically, this site scored worse for alterations to velocity/depth regime, sediment deposition, and channel flow status. These are observations that reflect the effect of the turbid water releases on in-stream habitat; increased settling of fine sediment, scour removing heterogeneous substrates, and inconsistent water levels. Given these results it would be expected macroinvertebrate communities would parallel these negative alterations to habitat. However, the opposite is true when compared to the upstream location ESOP-00 even though habitat assessment of this site suggests significantly better habitat for aquatic biota (Figure 4). The distance between ESOP-00 and -A is short, the presence of the release channel approximately doubles the watershed area available for macroinvertebrate recruitment. The increased watershed area alone likely accounts for a large part of the increase in species richness and diversity of other taxonomic groups (Figure 5).

Although aquatic life is fully supported in the surveyed reach of the Lower Esopus Creek the assessment at ESOP-A did signify substantially altered habitat. As previously mentioned the worst alterations to habitat were related to disturbance of velocity/depth regime, sediment deposition, and channel flow status (Figure 4, Table 4). As the reservoir release channel is the only major change in the watershed that exists between ESOP-00 and -A it is likely these alterations are in some part due to the turbid, high velocity releases that were occurring prior to this biological survey. Velocity and depth regime and channel flow status were all assessed low due to the visible and frequent changes in water levels at ESOP-A. These changes were evident from scour and erosional scaring along stream banks. During release events, the stream channel becomes flooded and maintains a high velocity but steady flow turning the entire channel into one long run with little variation. Conversely, during periods when these large volume releases are not ongoing the channel resembles summer base flow conditions. This frequent fluctuation in stream flow has the potential to cause future impacts to the benthic macroinvertebrate communities by continually creating a dynamic set of disturbance to flow regime and filling interstitial space with fine sediment, limiting habitat availability if left to continue indefinitely. Sediment deposition was assessed low because significant areas of fine new sediment could be observed deposited on substrates in slow moving areas of the stream such as small pools and along channel edges. It is not surprising that the pebble count data collected did not reflect this fine sediment deposition (Figure 3). Standard procedures require the pebble count be conducted within the riffle where benthic macroinvertebrate samples are collected. Therefore we do not expect fine sediment deposition in erosional habitats such as these except in extreme cases. Over time however, it is possible that the turbid reservoir releases may result in enough fine sediment deposition that it is measurable even in erosional zones.

In addition to the benthic macroinvertebrate communities, habitat assessment, and pebble count data, the SBU also collected turbidity and velocity measurements both before (3/29/11) and the day of (3/31/11) the biological survey. On 3/29/11 the DEP was reducing its release from the reservoir into the release channel from a maximum of approximately 600 mgd to approximately 360 mgd at the time of sampling (Personal communication: Kenneth Kosinski, DEC 3/31/11). On 3/31/11 the release event was completed and only minimum volumes were being released through the channel. The in-stream turbidity and channel velocities measured on both of these sampling days reflect stark differences between reservoir release and non-release event days. Turbidity at ESOP-A increased 6.5 times and velocity as much as 8 times between release and non-release event days (Figure 6). Changes were still notable although less dramatic further downstream at ESOP-B where turbidity increased 3.5 times and velocity increased 2 times (Figure 6). Although much further downstream, the effects of the reservoir releases are measurable at ESOP-B. The series of small impoundments immediately upstream ESOP-B likely attenuate flows and turbidity during reservoir release events before reaching this location (Figure 2). When compared with the upstream control site (ESOP-00) similar large differences in turbidity and velocity are observed (figure 6).

Based on the present survey, violations to biological impairment criteria do not exist. Although outside the index period, data suggest water quality conditions range from non- to slightly impacted, which indicates aquatic life is fully supported in the reach (Figure 5). However, physical assessments at the location immediately downstream of the confluence with the release channel indicate altered habitat due to alterations to velocity/depth regime, sediment deposition, and channel flow status (Figure 4, Table 4). Turbidity and velocity measurements recorded during a turbid, high velocity release event from the reservoir on 3/29/11 suggest distinct increases in both compared to data collected during a non-release period 3/31/11. The same is true when compared to the upstream control site. Although biological communities did not show signs of alteration resulting from reservoir releases at the time of this survey, continued disturbance may result in diminished biological condition. If reservoir water level management requires continued releases of the nature surrounding the time of this survey continued routine biological monitoring is recommended. Continued monitoring will make sure prolonged releases do not eventually cause impairment of the biological community. Specifically, this should include detailed characterization of substrates to measure the deposition of fine sediments in this reach of the Lower Esopus Creek.

Literature Cited

Bode, R. W., M. A. Novak, and L. E. Abele. 1990. Biological Impairment Criteria for Flowing Waters in New York State. Division of Water, NewYork State Department of Environmental Conservation, 625 Broadway, Albany, New York, Technical Report, 110 pages.

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Smith, A. J., and R. W. Bode. 2004. Analysis of Variability in New York State Benthic Macroinvertebrate Samples. Division of Water, NewYork State Department of Environmental Conservation, 625 Broadway, Albany, New York, Technical Report, 43 pages.

Figure 1. Overview map, Esopus Creek watershed.

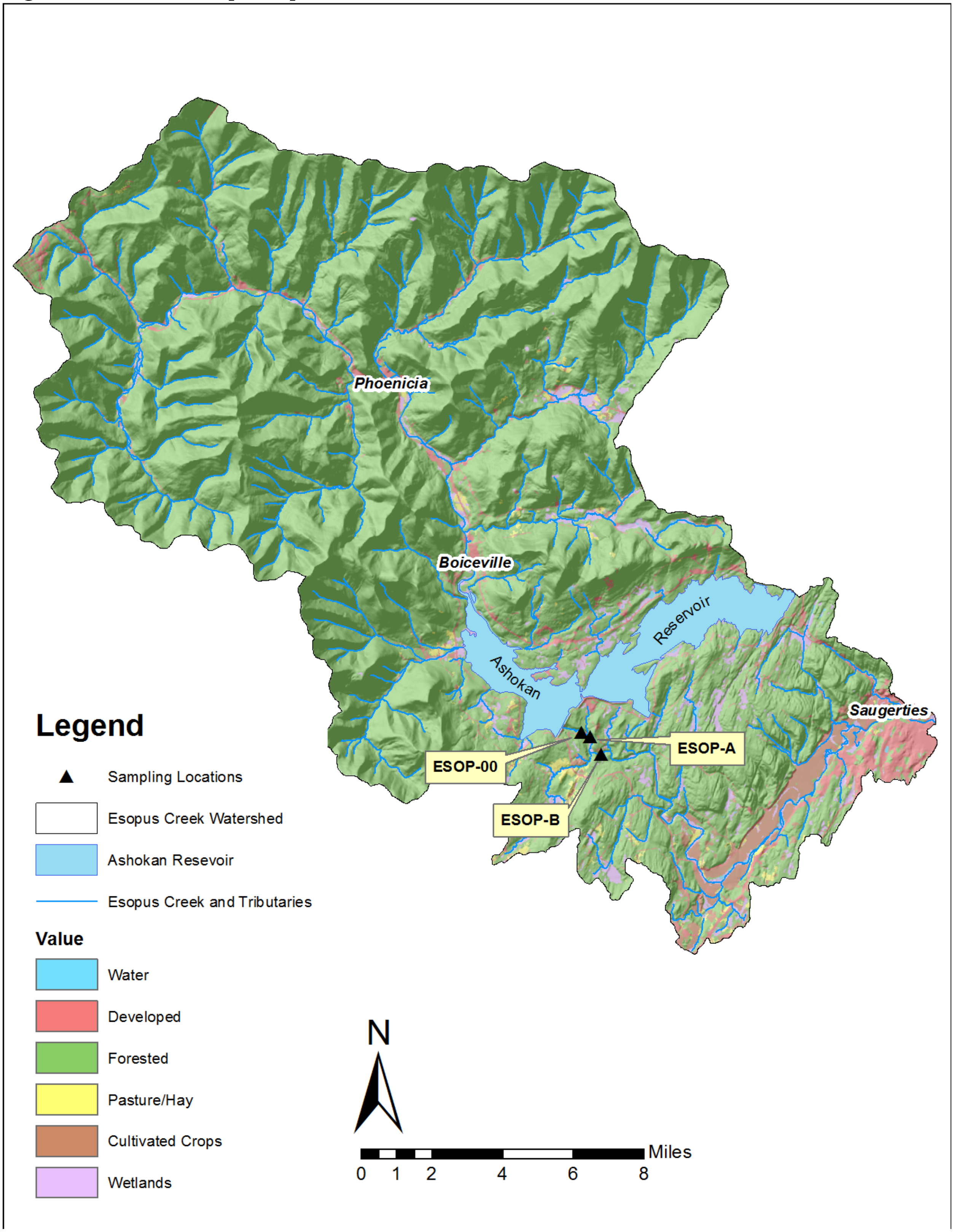


Figure 2. Site location map, Lower Esopus Creek, Stations 00, A, and B.

Table 1. Survey locations on the Lower Esopus Creek.

Station	Location
ESOP-00	Olivebridge, Upstream of Rte 28A bridge Above influence of reservoir discharge Latitude: 41.93592 Longitude: -74.20897
ESOP-A	Olivebridge, Downstream of Rte 28A bridge Below confluence of Lower Esopus and reservoir discharge Latitude: 41.93404 Longitude: -74.20405
ESOP-B	Olivebridge, Ashokan Camp Property 50m downstream of covered bridge Latitude: 41.92690 Longitude: -74.19798

Figure 3. Pebble count analysis from the Lower Esopus Creek. The dominant substrates in the river were rubble, coarse gravel and gravel.

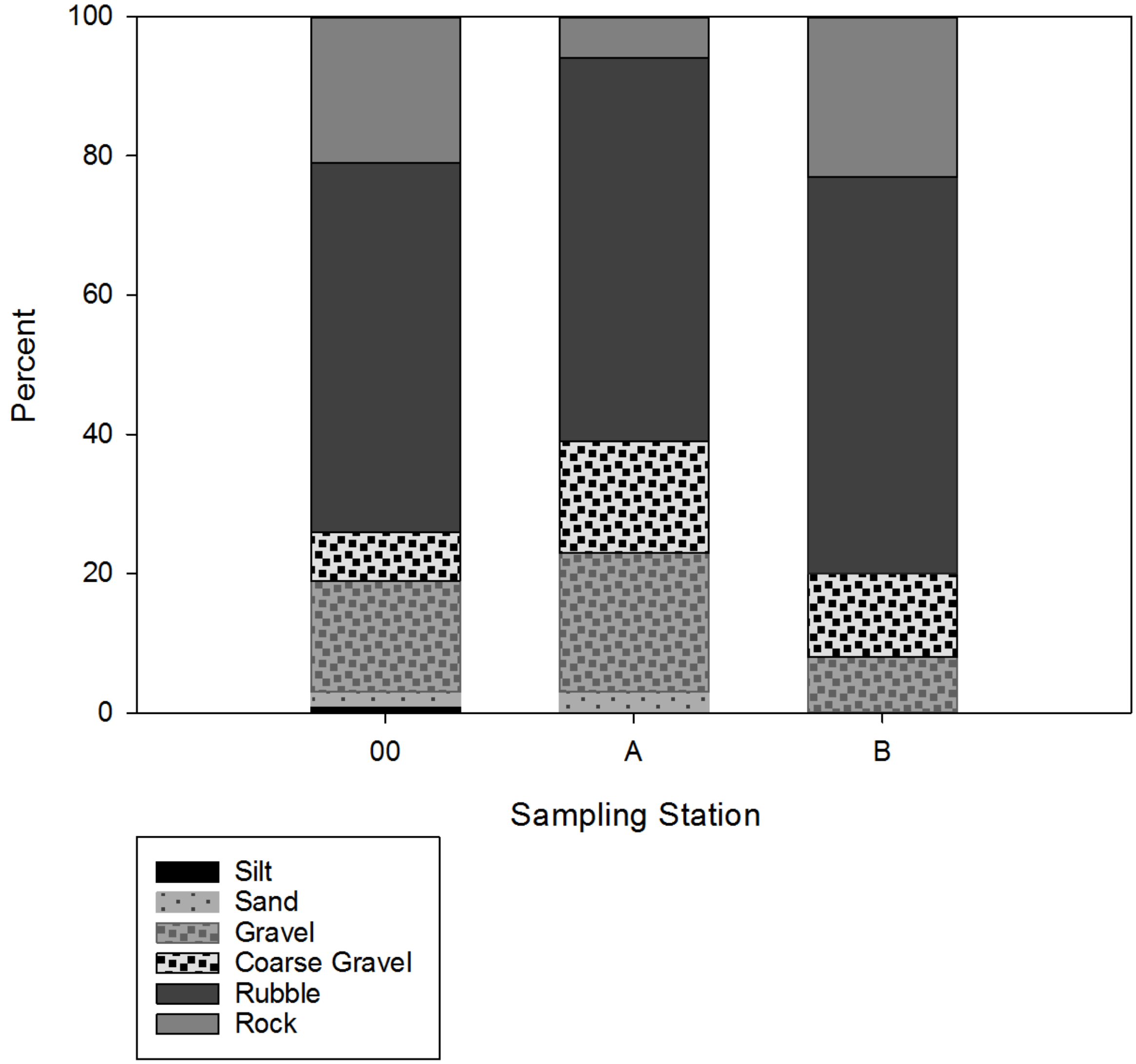


Table 2. Summary of substrate particle sizes recorded from pebble counts in the Lower Esopus Creek. Values are calculated as a proportion of the total from a random count of 100 pebbles in the stream reach. Coarse Gravel is abbreviated as C. Gravel.

Station	Silt	Sand	Gravel	C. Gravel	Rubble	Rock	Phi Score
ESOP-00	0.01	0.02	0.16	0.07	0.53	0.21	-1.142
ESOP-A	0.00	0.03	0.20	0.16	0.55	0.06	-1.015
ESOP-B	0.00	0.00	0.08	0.12	0.57	0.23	-1.229

Table 3. Summary of physical attributes measured at each sampling location on the Lower Esopus Creek.

Station	Depth (m)	Width (m)	Current (cm/sec)	Embed. (%)	Temp. (°C)	Conduct. (µmhos)	pH	DO (mg/L)	DO Sat. (%)
ESOP-00	0.05	2	40	25	4.08	140	7.26	12.21	93
ESOP-A	0.8	8	20	25	4.55	145	7.31	12.79	99
ESOP-B	0.3	10	60	50	4.97	82	6.98	13.20	103

Table 4. Summary of physical habitat attribute scores* used in calculating the Habitat Model Affinity (Figure 4) at locations on the Lower Esopus Creek.

ESOP-00	17	19	10	20	17	18	19	18	20	20
ESOP-A	11	12				17	15	12	16	19
ESOP-B	16	11	14	19	17	15	19	19	18	20

* The following attributes are ranked on a scale from 0 (poor) - 20 (optimal). Epi. Cover = Epifaunal substrate cover, Embed. = Embeddedness, Vel/Dep Reg. = Velocity Depth Regime, Sed. Dep. = Sediment Deposition, Flow Status = Channel Flow Status, Chan. Alt. = Channel Alteration, Rif. Freq. = Riffle Frequency, Bank Stab. = Bank Stability, Bank Veg. = Bank Vegetative Cover, Rip. Width = Riparian Corridor Width. Values of 10 or below are highlighted to identify those parameters ranked as marginal or poor.

Figure 4. Habitat assessment scores for each sampling location on the Lower Esopus Creek.

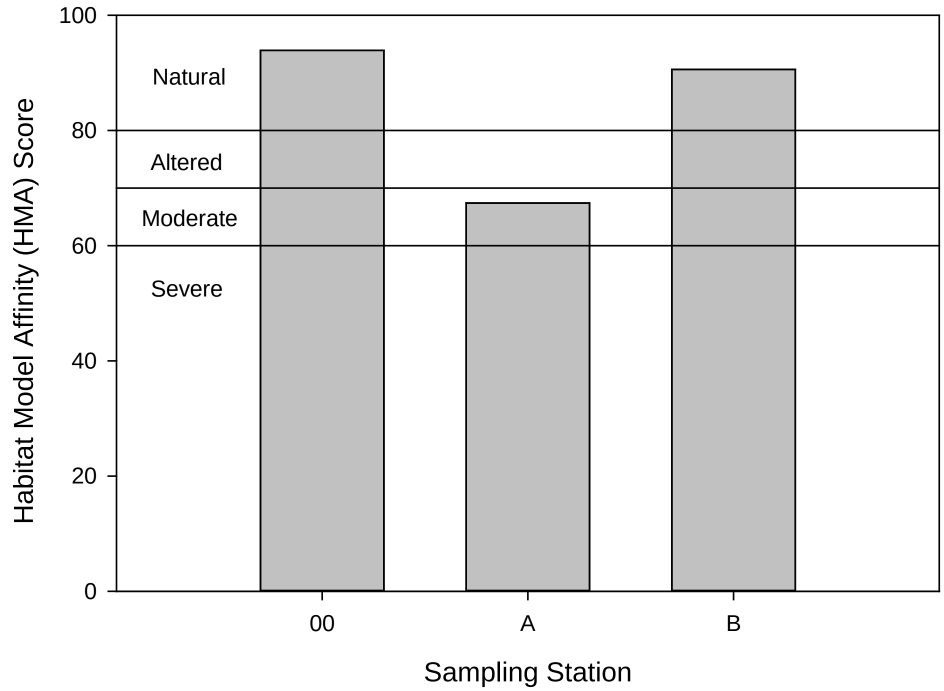


Figure 5. Biological Assessment Profile (BAP) of index values, Lower Esopus Creek, 2011. Values are plotted on a normalized scale of water quality. The BAP represents the mean of the five values for each site, representing species richness (Spp), Ephemeroptera, Plecoptera, Trichoptera richness (EPT), Hilsenhoff's Biotic Index (HBI), Percent Model Affinity (PMA), and the Nutrient Biotic Index for phosphorus (NBI-P). See Appendix IV for a more complete explanation.

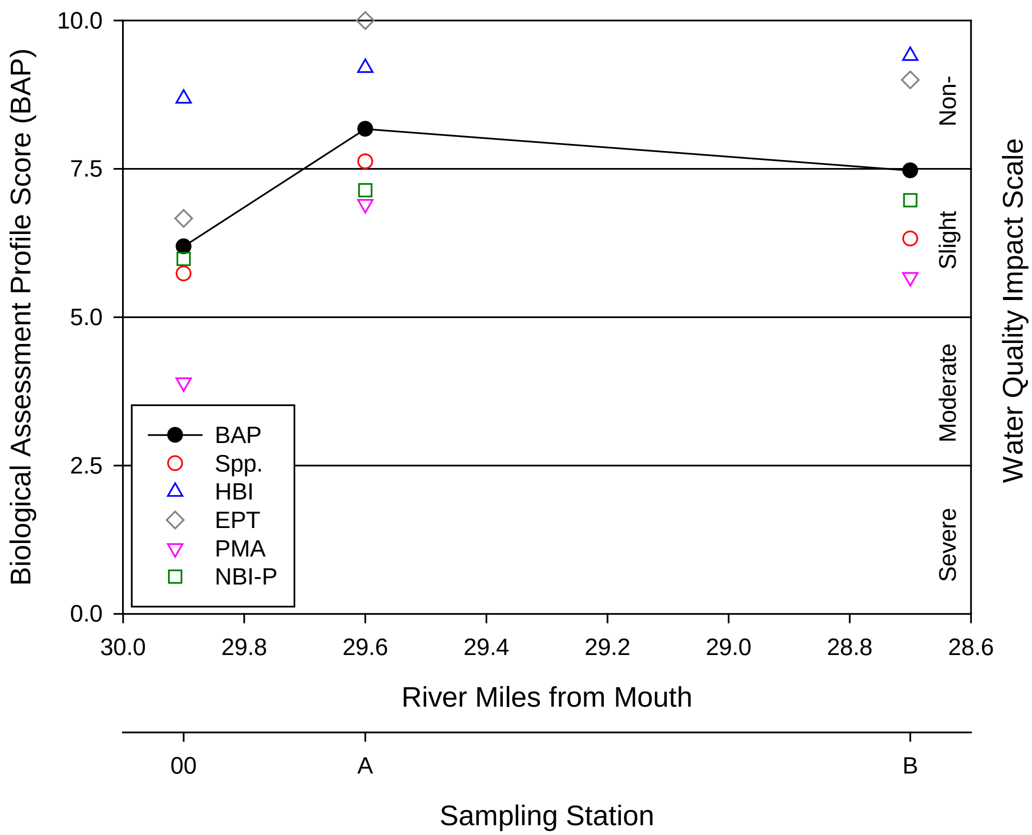


Figure 6. Turbidity and velocity measurements from 3/29/11 during a turbid, high velocity reservoir release event and 3/31/11 during a non-release period on the Lower Esopus Creek. Major differences exist during the two periods compared between dates and with the upstream control site (ESOP-00). The effects of the release event can be observed far downstream at ESOP-B even after the stream flows through a series of small impoundments between ESOP-A and –B (Figure 2).

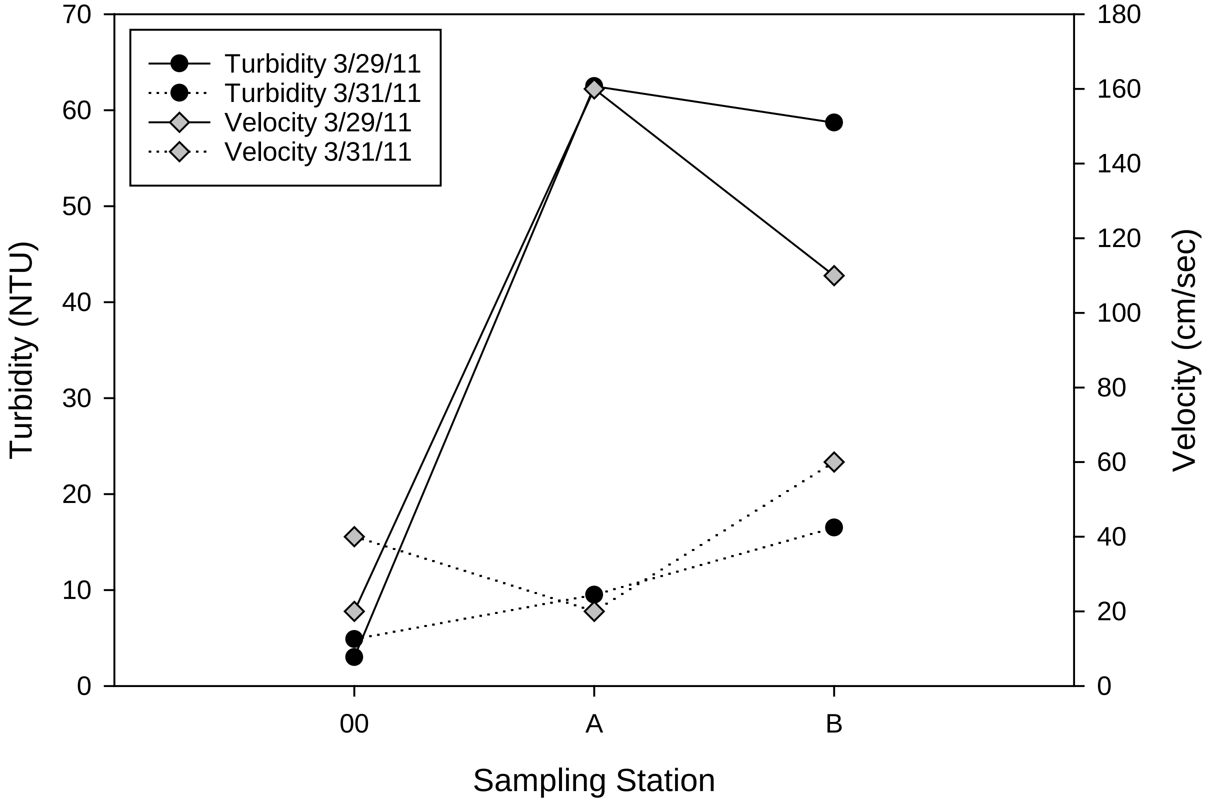


Table 5. Macroinvertebrate species collected in the Lower Esopus Creek, 2011.

Genus species	**Location - Station, Replicate**								
	ESOP 00, 1	**ESOP 00, 2**	**ESOP 00, 3**	**ESOP A, 1**	**ESOP A, 2**	**ESOP A, 3**	**ESOP B, 1**	**ESOP B, 2**	**ESOP B, 3**
Acentrella sp.							2	1	1
Acroneuria abnormis	1	1		3	2		1		
Acroneuria carolinensis			1	3	3	9	1	2	
Acroneuria sp.								1	
Amphinemura sp.					2		1		
Baetis tricaudatus				3	5	2	2	3	3
Boyeria sp.			1						
Cardiocladius obscurus							1		2
Ceratopsyche sparna				1	1	1			
Cheumatopsyche sp.	1			4	6	3	1	1	
Chimarra aterrima?	1			4	13	4	3		1
Chimarra obscura								1	
Corydalus cornutus									1
Corynoneura sp.	1								
Crangonyx sp.		1							
Cricotopus sp.			1						
Cricotopus triannulatus					1	1			
Diamesa sp.	3	1		1	1	1			
Dicrotendipes sp.								1	
Diplectrona sp.	1		1	1	1		1		
Epeorus sp.				10	7	4	7	9	8
Ephemerella sp.				2	2	1			
Eukiefferiella devonica gr.					1		1		
Eukiefferiella sp.				1					1
Helichus sp.				1					
Heterotrissocladius sp.	1	1	1						
Hydrobaenus sp.						1			
Hydropsyche betteni				1	3	5		2	2
Ironoquia sp.	1								
Isonychia sp.				15	7	10	4	1	6
Isoperla sp.			3	3	3	1	3	14	5
Leptophlebia sp.		1	1						
Leucrocuta sp.							1		1
Leuctra sp.							1		
Maccaffertium sp.	1		4	2	2	3	2		7
Maccaffertium terminatum		4							
Micropsectra sp.		1	1	1		1	3	1	2
Nanocladius sp.									1
Neophylax sp.									1
Nigronia serricornis				3	4	2			1
Optioservus fastiditus	1								

Genus species	Location - Station, Replicate								
	ESOP 00, 1	ESOP 00, 2	ESOP 00, 3	ESOP A, 1	ESOP A, 2	ESOP A, 3	ESOP B, 1	ESOP B, 2	ESOP B, 3
Orthocladius rivulorum				1	1				3
Orthocladius dubitatus					1		3		1
Orthocladius obumbratus			2		1				
Orthocladius oliverei				3					
Orthocladius sp.						1			2
Paragnetina media				3		1			
Paraleptophlebia sp.	2	2	11	6	2	2	3	2	3
Parametriocnemus sp.	2		2					4	4
Platycentropus sp.			1						
Polycentropus sp.		1			1	2			
Polypedilum aviceps			1		1	1			
Prosimulium sp.		40	40	22	24	38	40	40	28
Rhyacophila carolina?		1	1						
Rhyacophila fuscula				1					
Rhyacophila sp.	1								
Simulium sp.	40	12	10					1	
Siphlonurus sp.			2	1					
Stenelmis sp.					1				
Synorthocladius sp.	1								
Thienemannimyia gr. spp.	1	2					1		
Tipula sp.	1								
Tvetenia bavarica gr.				1			1	2	
Tvetenia sp.	11	9	2						1
Undetermined Cambaridae		1		1					
Undetermined Chloroperlidae							1		
Undetermined Diamesinae				1					
Undetermined Lumbriculidae							1		
Undetermined Nemouridae	26	21	11	1	4	5	15	14	14
Undetermined Orthocladiinae						1			
Undetermined Psychodidae			1						
Undetermined Tanytarsini	1								
Undetermined Tipulidae			1						
Undetermined Turbellaria	1								
Wiedemannia sp.	1	1	1						1

Appendix I. Biological Methods for Kick Sampling

A. Rationale: The use of the standardized kick sampling method provides a biological assessment technique that lends itself to rapid assessments of stream water quality.

B. Site Selection: Sampling sites are selected based on these criteria: (1) The sampling location should be a riffle with a substrate of rubble, gravel and sand; depth should be one meter or less, and current speed should be at least 0.4 meter per second. (2) The site should have comparable current speed, substrate type, embeddedness, and canopy cover to both upstream and downstream sites to the degree possible. (3) Sites are chosen to have a safe and convenient access.

C. Sampling: Macroinvertebrates are sampled using the standardized traveling kick method. An aquatic net is positioned in the water at arms' length downstream and the stream bottom is disturbed by foot, so that organisms are dislodged and carried into the net. Sampling is continued for a specified time and distance in the stream. Rapid assessment sampling specifies sampling for five minutes over a distance of five meters. The contents of the net are emptied into a pan of stream water. The contents are then examined, and the major groups of organisms are recorded, usually on the ordinal level (e.g., stoneflies, mayflies, caddisflies). Larger rocks, sticks, and plants may be removed from the sample if organisms are first removed from them. The contents of the pan are poured into a U.S. No. 30 sieve and transferred to a quart jar. The sample is then preserved by adding 95% ethyl alcohol.

D. Sample Sorting and Subsampling: In the laboratory, the sample is rinsed with tap water in a U.S. No. 40 standard sieve to remove any fine particles left in the residues from field sieving. The sample is transferred to an enamel pan and distributed homogeneously over the bottom of the pan. A small amount of the sample is randomly removed with a spatula, rinsed with water, and placed in a petri dish. This portion is examined under a dissecting stereomicroscope and 100 organisms are randomly removed from the debris. As they are removed, they are sorted into major groups, placed in vials containing 70 percent alcohol, and counted. The total number of organisms in the sample is estimated by weighing the residue from the picked subsample and determining its proportion of the total sample weight.

E. Organism Identification: All organisms are identified to the species level whenever possible. Chironomids and oligochaetes are slide-mounted and viewed through a compound microscope; most other organisms are identified as whole specimens using a dissecting stereomicroscope. The number of individuals in each species and the total number of individuals in the subsample are recorded on a data sheet. All organisms from the subsample are archived (either slide-mounted or preserved in alcohol). If the results of the identification process are ambiguous, suspected of being spurious, or do not yield a clear water quality assessment, additional subsampling may be required.

Appendix II. Macroinvertebrate Community Parameters

1. Species Richness: the total number of species or taxa found in a sample. For subsamples of 100-organisms each that are taken from kick samples, expected ranges in most New York State streams are: greater than 26, non-impacted; 19-26, slightly impacted; 11-18, moderately impacted, and less than 11, severely impacted.

2. EPT Richness: the total number of species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) found in an average 100-organisms subsample. These are considered to be clean-water organisms, and their presence is generally correlated with good water quality (Lenat, 1987). Expected assessment ranges from most New York State streams are: greater than 10, non-impacted; 6-10, slightly impacted; 2-5, moderately impacted, and 0-1, severely impacted.

3. Hilsenhoff Biotic Index: a measure of the tolerance of organisms in a sample to organic pollution (sewage effluent, animal wastes) and low dissolved oxygen levels. It is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10). For the purpose of characterizing species' tolerance, intolerant = 0-4, facultative = 5-7, and tolerant = 8-10. Tolerance values are listed in Hilsenhoff (1987). Additional values are assigned by the NYS Stream Biomonitoring Unit. The most recent values for each species are listed in Quality Assurance document, Bode et al. (2002). Impact ranges are: 0-4.50, non-impacted; 4.51-6.50, slightly impacted; 6.51-8.50, moderately impacted, and 8.51-10.00, severely impacted.

4. Percent Model Affinity: a measure of similarity to a model, non-impacted community based on percent abundance in seven major macroinvertebrate groups (Novak and Bode, 1992). Percentage abundances in the model community are: 40% Ephemeroptera; 5% Plecoptera; 10% Trichoptera; 10% Coleoptera; 20% Chironomidae; 5% Oligochaeta; and 10% Other. Impact ranges are: greater than 64, non-impacted; 50-64, slightly impacted; 35-49, moderately impacted, and less than 35, severely impacted.

5. Nutrient Biotic Index: a measure of stream nutrient enrichment identified by macroinvertebrate taxa. It is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals with assigned tolerance values. Tolerance values ranging from intolerant (0) to tolerant (10) are based on nutrient optima for Total Phosphorus (listed in Smith, 2005). Impact ranges are: 0-5.00, non-impacted; 5.01-6.00, slightly impacted; 6.01-7.00, moderately impacted, and 7.01-10.00, severely impacted.

Appendix III. Levels of Water Quality Impact in Streams

The description of overall stream water quality based on biological parameters uses a four-tiered system of classification. Level of impact is assessed for each individual parameter and then combined for all parameters to form a consensus determination. Four parameters are used: species richness, EPT richness, biotic index, and percent model affinity (see Appendix II). The consensus is based on the determination of the majority of the parameters. Since parameters measure different aspects of the macroinvertebrate community, they cannot be expected to always form unanimous assessments. The assessment ranges given for each parameter are based on subsamples of 100-organisms each that are taken from macroinvertebrate riffle kick samples. These assessments also apply to most multiplate samples, with the exception of percent model affinity.

1. *Non-impacted*: Indices reflect very good water quality. The macroinvertebrate community is diverse, usually with at least 27 species in riffle habitats. Mayflies, stoneflies, and caddisflies are well represented; EPT richness is greater than 10. The biotic index value is 4.50 or less. Percent model affinity is greater than 64. Nutrient Biotic Index is 5.00 or less. Water quality should not be limiting to fish survival or propagation. This level of water quality includes both pristine habitats and those receiving discharges which minimally alter the biota.

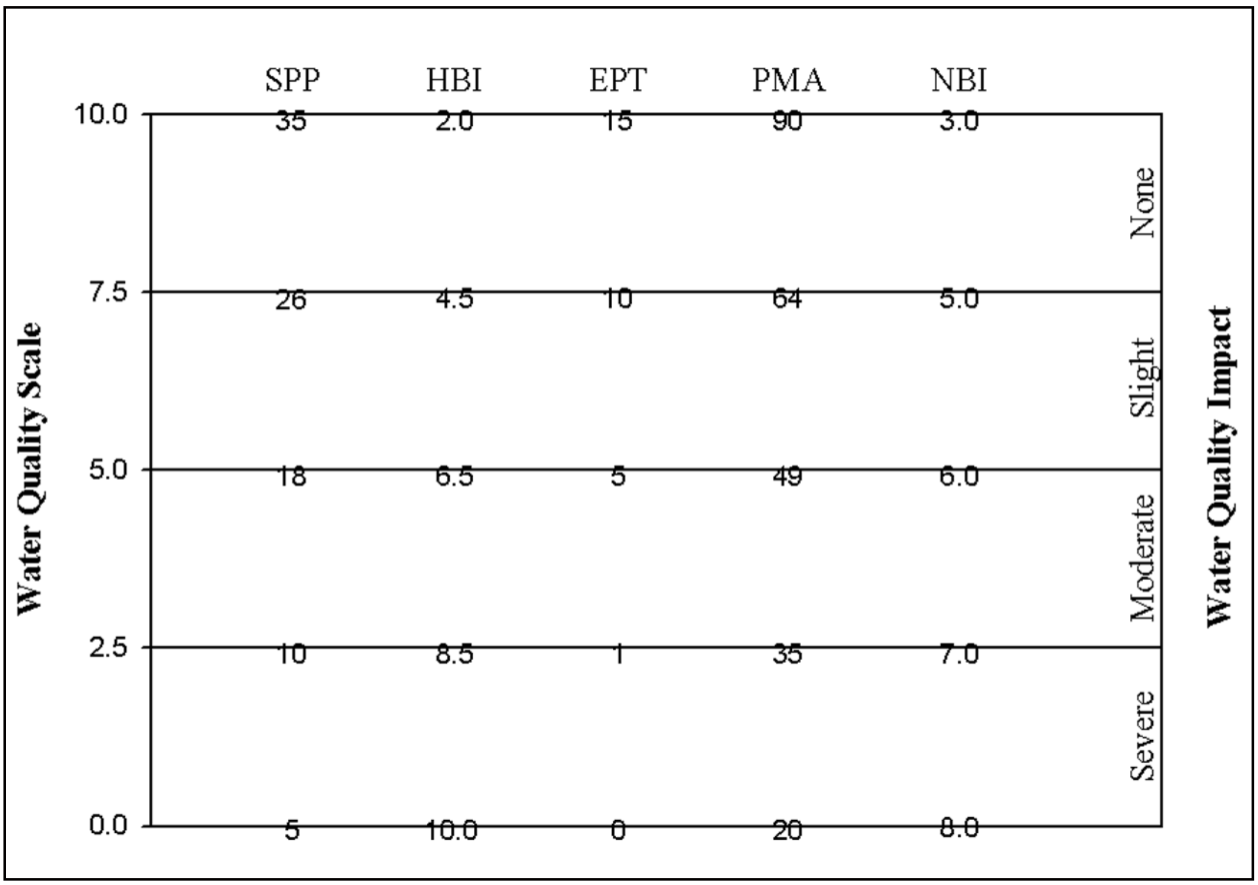
2. *Slightly impacted*: Indices reflect good water quality. The macroinvertebrate community is slightly but significantly altered from the pristine state. Species richness is usually 19-26. Mayflies and stoneflies may be restricted, with EPT richness values of 6-10. The biotic index value is 4.51-6.50. Percent model affinity is 50-64. Nutrient Biotic Index is 5.01-6.00. Water quality is usually not limiting to fish survival, but may be limiting to fish propagation.

3. *Moderately impacted*: Indices reflect poor water quality. The macroinvertebrate community is altered to a large degree from the pristine state. Species richness is usually 11-18 species. Mayflies and stoneflies are rare or absent, and caddisflies are often restricted; the EPT richness is 2-5. The biotic index value is 6.51-8.50. Percent model affinity is 35-49. Nutrient Biotic Index is 6.01-7.00. Water quality often is limiting to fish propagation, but usually not to fish survival.

4. *Severely impacted*: Indices reflect very poor water quality. The macroinvertebrate community is limited to a few tolerant species. Species richness is 10 or fewer. Mayflies, stoneflies and caddisflies are rare or absent; EPT richness is 0-1. The biotic index value is greater than 8.50. Percent model affinity is less than 35. Nutrient Biotic Index is greater than 7.00. The dominant species are almost all tolerant, and are usually midges and worms. Often, 1-2 species are very abundant. Water quality is often limiting to both fish propagation and fish survival.

Appendix IV-A. Biological Assessment Profile: Conversion of Index Values to a 10-Scale

The Biological Assessment Profile (BAP) of index values, developed by Phil O'Brien, Division of Water, NYSDEC, is a method of plotting biological index values on a common scale of water quality impact. Values from the five indices -- species richness (SPP), EPT richness (EPT), Hilsenhoff Biotic Index (HBI), Percent Model Affinity (PMA), and Nutrient Biotic Index (NBI)-- defined in Appendix II are converted to a common 0-10 scale using the formulae in the Quality Assurance document (Bode, et al., 2002), and as shown in the figure below.



Appendix IV-B. Biological Assessment Profile: Plotting Values

To plot survey data:

1. Position each site on the x-axis according to miles or tenths of a mile upstream of the mouth.
2. Plot the values of the four indices for each site as indicated by the common scale.
3. Calculate the mean of the four values and plot the result. This represents the assessed impact for each site.

Example data:

	Station 1		Station 2	
	metric value	10-scale value	metric value	10-scale value
Species richness	20	5.59	33	9.44
Hilsenhoff Biotic Index	5.00	7.40	4.00	8.00
EPT richness	9	6.80	13	9.00
Percent Model Affinity	55	5.97	65	7.60
Nutrient Biotic Index	6.0	5.0	6.0	5.0
Average		6.152 (slight)		7.8 (non-)

Appendix V. Water Quality Assessment Criteria

Non-Navigable Flowing Waters

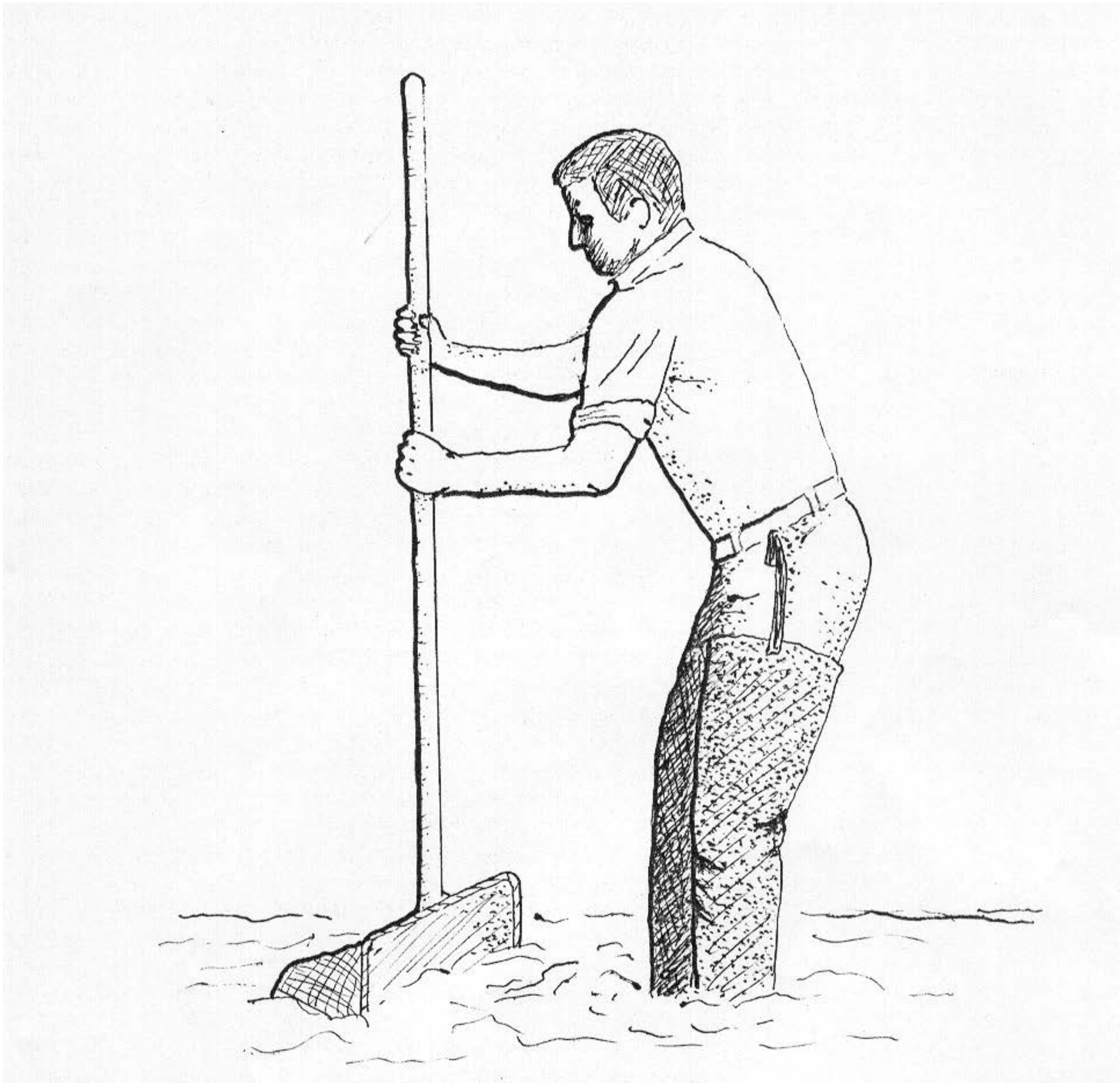
	Species Richness	Hilsenhoff Biotic Index	EPT Value	Percent Model Affinity*	Nutrient Biotic Index
Non-Impacted	>26	0.00-4.50	>10	>64	<5.00
Slightly Impacted	19-26	4.51-6.50	6-10	50-64	5.01-6.00
Moderately Impacted	11-18	6.51-8.50	2-5	35-49	6.01-7.00
Severely Impacted	0-10	8.51-10.00	0-1	<35	>7.01

* Percent model affinity criteria used for traveling kick samples but not for multiplate samples.

Navigable Flowing Waters

	Species Richness	Hilsenhoff Biotic Index	EPT Richness	Species Diversity
Non-Impacted	>21	0.00-7.00	>5	>3.00
Slightly Impacted	17-21	7.01-8.00	4-5	2.51-3.00
Moderately Impacted	12-16	8.01-9.00	2-3	2.01-2.50
Severely Impacted	0-11	9.01-10.00	0-1	0.00-2.00

Appendix VI. The Traveling Kick Sample



Rocks and sediment in a riffle are dislodged by foot upstream of a net. Dislodged organisms are

⟵current

carried by the current into the net. Sampling continues for five minutes, as the sampler gradually moves downstream to cover a distance of five meters

Appendix VII-A. Aquatic Macroinvertebrates Usually Indicative of Good Water Quality

Mayfly nymphs are often the most numerous organisms found in clean streams. They are sensitive to most types of pollution, including low dissolved oxygen (less than 5 ppm), chlorine, ammonia, metals, pesticides, and acidity. Most mayflies are found clinging to the undersides of rocks.

MAYFLIES

Stonefly nymphs are mostly limited to cool, well-oxygenated streams. They are sensitive to most of the same pollutants as mayflies, except acidity. They are usually much less numerous than mayflies. The presence of even a few stoneflies in a stream suggests that good water quality has been maintained for several months.

STONEFLIES

Caddisfly larvae often build a portable case of sand, stones, sticks, or other debris. Many caddisfly larvae are sensitive to pollution, although a few are tolerant. One family spins nets to catch drifting plankton, and is often numerous in nutrient-enriched stream segments.

CADDISFLIES

The most common beetles in streams are riffle beetles (adult and larva pictured) and water pennies (not shown). Most of these require a swift current and an adequate supply of oxygen, and are generally considered clean-water indicators.

BEETLES

Appendix VII-B. Aquatic Macroinvertebrates Usually Indicative of Poor Water Quality

Midges are the most common aquatic flies. The larvae occur in almost any aquatic situation. Many species are very tolerant to pollution. Large, red midge larvae called "bloodworms" indicate organic enrichment. Other midge larvae filter plankton, indicating nutrient enrichment when numerous.

MIDGES

Black fly larvae have specialized structures for filtering plankton and bacteria from the water, and require a strong current. Some species are tolerant of organic enrichment and toxic contaminants, while others are intolerant of pollutants.

BLACK FLIES

The segmented worms include the leeches and the small aquatic worms. The latter are more common, though usually unnoticed. They burrow in the substrate and feed on bacteria in the sediment. They can thrive under conditions of severe pollution and very low oxygen levels, and are thus valuable pollution indicators. Many leeches are also tolerant of poor water quality.

WORMS

Aquatic sowbugs are crustaceans that are often numerous in situations of high organic content and low oxygen levels. They are classic indicators of sewage pollution, and can also thrive in toxic situations.

Digital images by Larry Abele, New York State Department of Environmental Conservation, Stream Biomonitoring Unit.

SOWBUGS

Appendix VIII. The Rationale of Biological Monitoring

Biological monitoring refers to the use of resident benthic macroinvertebrate communities as indicators of water quality. Macroinvertebrates are larger-than-microscopic invertebrate animals that inhabit aquatic habitats; freshwater forms are primarily aquatic insects, worms, clams, snails, and crustaceans.

Concept:
Nearly all streams are inhabited by a community of benthic macroinvertebrates. The species comprising the community each occupy a distinct niche defined and limited by a set of environmental requirements. The composition of the macroinvertebrate community is thus determined by many factors, including habitat, food source, flow regime, temperature, and water quality. The community is presumed to be controlled primarily by water quality if the other factors are determined to be constant or optimal. Community components which can change with water quality include species richness, diversity, balance, abundance, and presence/absence of tolerant or intolerant species. Various indices or metrics are used to measure these community changes. Assessments of water quality are based on metric values of the community, compared to expected metric values.

Advantages:
The primary advantages to using macroinvertebrates as water quality indicators are that they:

- are sensitive to environmental impacts
- are less mobile than fish, and thus cannot avoid discharges
- can indicate effects of spills, intermittent discharges, and lapses in treatment
- are indicators of overall, integrated water quality, including synergistic effects
- are abundant in most streams and are relatively easy and inexpensive to sample
- are able to detect non-chemical impacts to the habitat, e.g. siltation or thermal changes
- are vital components of the aquatic ecosystem and important as a food source for fish
- are more readily perceived by the public as tangible indicators of water quality
- can often provide an on-site estimate of water quality
- can often be used to identify specific stresses or sources of impairment
- can be preserved and archived for decades, allowing for direct comparison of specimens
- bioaccumulate many contaminants, so that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain

Limitations:
Biological monitoring is not intended to replace chemical sampling, toxicity testing, or fish surveys. Each of these measurements provides information not contained in the others. Similarly, assessments based on biological sampling should not be taken as being representative of chemical sampling. Some substances may be present in levels exceeding ambient water quality criteria, yet have no apparent adverse community impact.

Appendix IX. Glossary

Anthropogenic: caused by human actions

Assessment: a diagnosis or evaluation of water quality

Benthos: organisms occurring on or in the bottom substrate of a waterbody

Bioaccumulate: accumulate contaminants in the tissues of an organism

Biomonitoring: the use of biological indicators to measure water quality

Community: a group of populations of organisms interacting in a habitat

Drainage basin: an area in which all water drains to a particular waterbody; watershed

Electrofishing: sampling fish by using electric currents to temporarily immobilize them, allowing capture

EPT richness: the number of taxa of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) in a sample or subsample

Eutrophic: high nutrient levels normally leading to excessive biological productivity

Facultative: occurring over a wide range of water quality; neither tolerant nor intolerant of poor water quality

Fauna: the animal life of a particular habitat

Impact: a change in the physical, chemical, or biological condition of a waterbody

Impairment: a detrimental effect caused by an impact

Index: a number, metric, or parameter derived from sample data used as a measure of water quality

Intolerant: unable to survive poor water quality

Longitudinal trends: upstream-downstream changes in water quality in a river or stream

Macroinvertebrate: a larger-than-microscopic invertebrate animal that lives at least part of its life in aquatic habitats

Mesotrophic: intermediate nutrient levels (between oligotrophic and eutrophic) normally leading to moderate biological productivity

Multiplate: multiple-plate sampler, a type of artificial substrate sampler of aquatic macroinvertebrates

Non Chironomidae/Oligochaeta (NCO) richness: the number of taxa neither belonging to the family Chironomidae nor the subclass Oligochaeta in a sample or subsample

Oligotrophic: low nutrient levels normally leading to unproductive biological conditions

Organism: a living individual

PAHs: Polycyclic Aromatic Hydrocarbons, a class of organic compounds that are often toxic or carcinogenic.

Rapid bioassessment: a biological diagnosis of water quality using field and laboratory analysis designed to allow assessment of water quality in a short turn-around time; usually involves kick sampling and laboratory subsampling of the sample

Riffle: wadeable stretch of stream usually with a rubble bottom and sufficient current to have the water surface broken by the flow; rapids

Species richness: the number of macroinvertebrate taxa in a sample or subsample

Station: a sampling site on a waterbody

Survey: a set of samplings conducted in succession along a stretch of stream

Synergistic effect: an effect produced by the combination of two factors that is greater than the sum of the two factors

Tolerant: able to survive poor water quality

Trophic: referring to productivity