

Macroinvertebrate Survey Report
Upper Bushkill Creek
Northampton County, PA



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To the Bushkill Stream Conservancy

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Summary

Macroinvertebrate sampling was conducted March 29, 2008, at two sites on the upper Bushkill Creek, Northampton County, PA. The sampling sites, Site #1 and Site #2, corresponded to the same locations on Bushkill Creek found to support naturally-reproducing populations of brook trout by a fish survey conducted in 2007.

Macroinvertebrate sampling and assessment followed Pennsylvania Department of Environmental Protection (PA DEP) protocols. Using PA DEP's Benthic Index of Biotic Integrity (IBI) for Wadeable Freestone Streams as an evaluative tool, the collected and sub-sampled macroinvertebrate assemblage from Site #1 scored 80.1 on the IBI. The collected and sub-sampled macroinvertebrate assemblage from Site #2 scored 78.97. An IBI score of 80 or greater is the benchmark required for consideration of High Quality/Exceptional Value (HQ/EV) Aquatic Life Use (ALU) antidegradation designations.

Using the Biological Condition Gradient (BCG) for Freestone (Non-Calcareous) Streams of Pennsylvania, a tier or biological condition class was determined using the macroinvertebrate assemblage for each sampling site. Site #1 had the required characteristics of a Tier 2 condition described as outstanding condition waters having a natural condition with minimal ecosystem changes. Site #2, missing one Tier 2 qualification rule, was designated a Tier 3, or good condition waters.

Macroinvertebrate indicator species were used to classify each site's community type based on the genus-level macroinvertebrate communities defined by the Pennsylvania Aquatic Community Classification Project. Although each site had representative species indicators of several community types, the genus-level stream community "High Quality Small Stream" best describes both Site #1 and Site #2.

The presence of high quality macroinvertebrates, reflected in the IBI and BCG Tier results, and the occurrence of naturally-reproducing brook trout populations at the assessed sites may warrant further evaluation of portions of the upper Bushkill Creek by PA DEP biologists for possible consideration of Exceptional Value (EV) designated use.

Introduction

The water use designation of a stream has implications for its conservation and legal protection. Bushkill Creek, Northampton County and its tributaries are designated as HQ-CWF (High Quality Waters-Cold Water Fish) in The Pennsylvania Code Title 25, Section 93.9c. Drainage List C. HQ and Exceptional Value (EV) are special protection aquatic life designated uses requiring that new or expanded activities do not degrade existing water quality (Royer et al. 2007).

Water use designations of HQ and EV are, in part, determined by the benthic macroinvertebrate assemblage present at the stream reach scale. Benthic macroinvertebrates are animals with no backbone, such as insects, crustaceans, mollusks and annelids, visible to the naked eye, and living on the stream bottom.

The types of macroinvertebrates collected from a stream reach and their ecological characteristics may be used to assess a stream's biological condition, health, or biological integrity. This is because different types of macroinvertebrates vary in their tolerance to stream conditions, as does their response to stressors (physical, chemical, or biological factors that negatively impact populations).

For example, a more natural or native condition with biological integrity is generally indicated by a macroinvertebrate community having a greater proportion of intolerant, sensitive species (requiring healthy stream conditions to maintain populations) compared to tolerant species, able to maintain populations under stressed conditions. Conversely, a sample dominated by tolerant macroinvertebrates and containing few, if any, intolerant macroinvertebrates would generally indicate a greatly altered and impacted biological condition lacking biological integrity.

Linked to the biological condition of a system, biological integrity has been defined as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a composition and diversity comparable to that of the natural habitats of the region" (Frey 1977). Biological integrity is expected in areas with no or minimal human influence (Karr and Chu 2000).

The use of macroinvertebrates as environmental indicators can allow for a direct quantification of changes in ecological attributes along a gradient of biological conditions, caused by increasing levels of stressors often associated with human activities (Davies and Jackson 2006).

Over the years, the Pennsylvania Department of Environmental Protection (PA DEP) has developed macroinvertebrate protocols for sampling and assessing a stream's biological condition. The most recent (November 2007) PA DEP macroinvertebrate assessment protocols developed for freestone streams is "A Benthic Index of Biotic Integrity for Wadeable Freestone Streams in Pennsylvania."

Utilizing this Index of Biological Integrity (IBI) to evaluate a stream's macroinvertebrate community, the PA DEP has set criteria for use attainment thresholds or benchmarks based on the numeric score of a stream's macroinvertebrate assemblage on the IBI.

The PA DEP has set IBI scoring benchmarks of ≥ 80 as a qualifier for special protection use status of High Quality (HQ) and Exceptional Value (EV). Several other factors in addition to IBI scores (reviewed in the results-discussion section of this report) are also considered in determining candidacy and to distinguish between EV and HQ uses. A score of ≥ 63 would support the use attainment benchmarks of Cold Water Fishery (CWF), Trout Stocked Stream (TSF), and Warm Water Fishery (WWF). Scores < 63 indicate degraded streams (Chalfant 2007).

A preliminary Biological Condition Gradient (BCG) for Freestone (Non-Calcareous) Streams of Pennsylvania has also been recently developed by state biologists to identify the tier or biological condition class of a stream reach along a stressor gradient using macroinvertebrates. Six tiers describing the changes in aquatic community structure and function with increasing stress, range from tier 1 (undisturbed natural condition) to tier 6 (severely degraded condition).

Specific kinds of macroinvertebrates, as significant indicator species, can also classify stream communities, as was done by The Pennsylvania Aquatic Community Classification (PACC) Project to help describe "patterns in aquatic biodiversity for the purpose of prioritizing conservation activities and informing aquatic resource management" (Walsh et al. 2007a).

Using specific sets of statistically significant indicator species, the PACC describes the habitat, stream quality rating, community rarity, threats and conservation recommendations for 12 genus-level stream community types. Conservation recommendations for a community type can provide a useful guide for management decisions.

This survey documents the macroinvertebrate assemblages at two sites on the upper Bushkill Creek. The assemblages were used to assess the biological condition of the sites and determine whether the stream reaches sampled could potentially meet IBI scoring benchmarks required for EV candidacy, and, therefore, warrant future evaluation by PA DEP biologists.

Sampling Sites

Two stream reaches in the Upper Bushkill Creek watershed were selected for macroinvertebrate sampling and assessment. The two sampling sites (Site #1 and Site #2) corresponded to the same reaches in which naturally-reproducing brook trout (*Salvelinus fontinalis*) populations were found during a fish survey conducted on Bushkill Creek in 2007 (Leonhardt 2007).

Site #1 is located on the east (Katellen) branch, and site #2 on the west (Bender's Junction) branch of the upper Bushkill Creek (see Map 1).

The survey sampling sites, depending on definition, can be described as low to moderate gradient wadeable stream reaches (Site #1 ~ .9% gradient and Site #2 ~.6% gradient) having a series of riffle, run, and pool habitats. With primarily shale substrate, the stream reaches could be considered freestone. The substrate size at the sites ranged from mostly boulder and cobble, to pebble, gravel, with some sand and little silt.

Bushkill Creek Site #1 is a 2nd order stream (USGS quadrangle 7.5 minute series map) receiving water from a large, red maple-highbush blueberry swamp and flowing through mature secondary broadleaf deciduous forest.

Bushkill Creek site #2 is a 1st Order stream (USGS quadrangle 7.5 minute series map) flowing through mostly mature, secondary broadleaf deciduous forest, with sections lined by eastern hemlock and giant rhododendron.

Both sampling sites were slightly above base-flow during the time of sampling in late March, 2008. The two sampling sites were located on private land, requiring land owner permission prior to sampling.

Methods

Macroinvertebrate sampling was conducted March 29, 2008. Field sampling and lab methods followed the procedure for antidegradation surveys described in Appendix A of “A Benthic Index of Biotic Integrity for Wadeable Freestone Streams in Pennsylvania” (Chalfant 2007).

All macroinvertebrate samples at the sampling reaches, approximately 100 meters in length, were collected using a D-frame net with 500-micron mesh. Sample collection was spread out over the entire reach, with six of the best riffle habitat areas of different depths (fast and slow) and substrate types chosen for sampling.

At each of the six riffles per sampling reach, the substrate within an approximately one square meter area was disturbed immediately upstream of the net by kicking for about 1 minute to an approximate depth of 10 cm. The resulting six “D-frame efforts” for each sampling reach were composited into one sample container and preserved with 95% ethanol.

Prior to the sub-sampling, each composited sample from the sampling reach was rinsed in a standard USGS No. 35 sieve to remove fine materials and residual preservative. The composited sample was then placed in a 28-square gridded pan (Pan 1) 14” x 8” x 2” in size, and stirred after water was added to the depth of the sample. A 2” x 2” grid was randomly selected using a 28 random number set, and all debris and organisms were entirely removed from the grid with a tubular 4 inch² grid cutter and placed in a second gridded pan (Pan 2). All identifiable organisms from the grid were floated, entirely picked, counted, and sub-totaled. This procedure was repeated until 4 randomly selected grids had been sub-sampled and 200 organisms (\pm 20%) were obtained from Pan 2.

Nearly all of the sub-sampled macroinvertebrates were identified to the genus-level with several individuals identified to the family level, the lowest level of taxonomy for which they could be confidently identified.

To assess the biological condition of the two sampling sites, the identified, macroinvertebrate taxa from the sub-samples were applied to the PA DEP’s Benthic Index of Biotic Integrity (IBI) for Wadeable Freestone Streams, and the Biological Condition Gradient (BCG) for Freestone (Non-Calcareous) Streams of Pennsylvania. Stream community type evaluation was based on the presence of genus-level macroinvertebrate indicator species as defined by the Pennsylvania Aquatic Community Classification Project.

Results and Discussion

The macroinvertebrate sub-samples from Site #1 and Site #2 contained a total of 27 taxa each, with individual organisms totaling 219 in the Site #1 sub-sample and 177 in the Site #2 sub-sample. The two sites had 17 taxa that were the same, with 10 different taxa being found at each site for a combined total of 37 taxa identified from the two sites. A table for each site summarizing the macroinvertebrate taxa and their attributes can be found in Appendix A.

Using PA DEP's Benthic Index of Biotic Integrity (IBI) for Wadeable Freestone Streams as an evaluative tool, the collected and sub-sampled macroinvertebrate assemblage from Site #1 scored 80.1 on the IBI. The collected and sub-sampled macroinvertebrate assemblage from Site #2 scored 78.97. A table containing the IBI metric values and scores for Site #1 and #2 can be found in Appendix B-1.

The IBI consists of 6 metrics, each a measurable, ecologically-based attribute of macroinvertebrate populations that predictably change (numerically increasing or decreasing) in response to increased human-associated stressors. Summing the numeric scores of the metrics produces a single score representing the site's level of biological integrity. A table containing an explanation of the 6 metrics and their expected response to stressors is found in Appendix B-2.

The PA DEP has established use attainment thresholds or benchmarks based on IBI scores in assessing Aquatic Life Use (ALU) antidegradation designations such as High Quality (HQ) and Exceptional Value (EV) waters. An IBI score of 80 or greater is the antidegradation candidacy benchmark required as a qualifier for special protection status of EV and HQ (Chalfant 2007).

Other factors besides IBI scores are considered when determining antidegradation candidacy and to distinguish between EV and HQ uses. Chapter 93.4b.(b) of the Pennsylvania Code: *Qualifying as an Exceptional Value Water* states that a water qualifies as EV if it is a surface water of exceptional ecological significance or if it qualifies as an HQ water and meets one or more of several conditions, including "the water is an outstanding national, state, regional, or local water source."

To further assess the biological condition of the two sampling sites, the macroinvertebrate sub-samples were analyzed using the Biological Condition Gradient (BCG) for Freestone (Non-Calcareous) Streams of Pennsylvania (Gerritsen and Jessup 2007).

Incorporating a series of potential decision rules, the BCG identifies six conceptual resource condition tiers or biological condition classes of a stream reach along a general

stressor gradient ranging from a tier 1 native or natural condition, to a severely degraded tier 6 condition.

The biological condition required to support an ALU for a specific water body can be described in terms of BCG tiers (Davies and Jackson 2006). “For example, the biological condition associated with wild brook trout reproduction requires a very high-quality stream and may be defined as a narrow range of nearly natural BCG tiers, while the biological condition needed to support warm water recreational fisheries may span a broader range of conditions” (Chalfant 2007).

“The antidegradation candidacy benchmark of an IBI score greater than or equal to 80.0 approximates the separation between BCG tier 2 conditions and less pristine conditions” (Chalfant 2007). Because there is no clear consensus as to whether a pristine (no human impacts) tier 1 condition actually exists in Pennsylvania, accordingly, “the biological criterion for EV waters could be BCG Tier 2 or better” (Gerritsen and Jessup 2007).

Site #1 had the required characteristics of a Tier 2 condition, and Site #2, missing just one of the six Tier 2 qualification rules, but meeting all Tier 3 rules, was designated a Tier 3 condition. Tier 1 and Tier 2 have been described as “outstanding condition waters” having a native or natural condition with minimal ecosystem changes, and Tier 3 described as “good condition waters” (Gerritsen and Jessup 2007). Tables containing the BCG Tier Assessments for Site #1 and #2 can be found in Appendix C-1, and descriptions of BCG taxa attributes and BCG resource condition tiers can be found in Appendix C-2.

In addition to the presence of wild brook trout reproduction, high-quality streams in Pennsylvania can also be identified by the presence of macroinvertebrate indicator species in combination with habitat characteristics.

Macroinvertebrate indicator species from the two sampling sites were used to classify each site’s community type based on the genus-level macroinvertebrate communities defined by the Pennsylvania Aquatic Community Classification Project (PACC). The PACC used statistically significant indicator values of macroinvertebrate taxa to assist in classifying 12 genus-level stream communities.

Although both sampling sites had representative macroinvertebrate species indicators of several potential PACC genus-level stream community types, the combination of expected community indicator species, and predicted average values for taxa richness, number of EPT (mayfly, stonefly and caddisfly) taxa, number of intolerant taxa, and stream/watershed characteristics best describe the two sites as a “High Quality Small Stream Community.” The

PACC describes the High Quality Stream Community as a “strong indicator of a high quality, naturally functioning small stream system” (Walsh et al. 2007a).

It should be noted that the term “high quality” as used by the PACC depicts a stream community type found in reaches having little watershed disturbance, and should not be confused with the HQ Aquatic Life Use (ALU) antidegradation designation.

Two of the five main community indicators for the High Quality Small Stream Community were relatively abundant in both sub-samples: the mayfly *Epeorus*, having the highest significant indicator species value for the community, and *Rhyacophila*, a caddisfly (Walsh et al. 2007b).

The Site #1 sub-sample also had another of the main community indicators, *Pteronarcys*, a stonefly. Both *Epeorus* and *Pteronarcys* have an assigned pollution tolerance value of 0 (most intolerant value) by the PA DEP (Chalfant 2007) and a thermal preference for colder-cooler waters (Poff et al. 2006), a water temperature characteristic of the High Quality Small Stream Community.

Tables listing the significant indicator taxa for a High Quality Small Stream Community and several other stream community types, and the indicator taxa of these communities present in the two sub-samples can be found in Appendix D. Photos of *Epeorus*, *Pteronarcys*, and the mayfly *Ameletus*, another highly sensitive, cold-cool water macroinvertebrate (Poff et al. 2006) present in the Site #1 sub-sample, can be found in Appendix E.

The presence of a high proportion of intolerant, sensitive, macroinvertebrate taxa (reflected in the IBI, BCG Tier, and PACC stream community assessment results) and the occurrence of naturally-reproducing brook trout populations (recently added to the Pennsylvania Wildlife Action Plan as a species of greatest conservation need) indicates the existence of nearly natural biological conditions of high water quality and ecological significance at the two sampling reaches.

These findings may warrant further evaluation of portions of the upper Bushkill Creek by PA DEP biologists for possible consideration of Exceptional Value (EV) designated use.

Acknowledgements

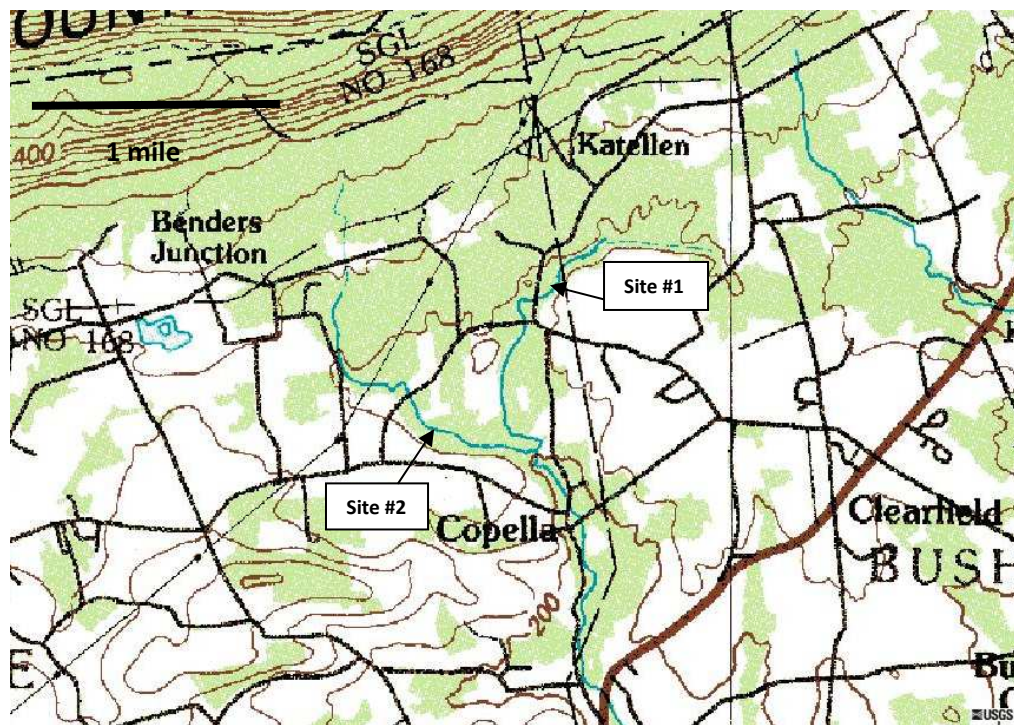
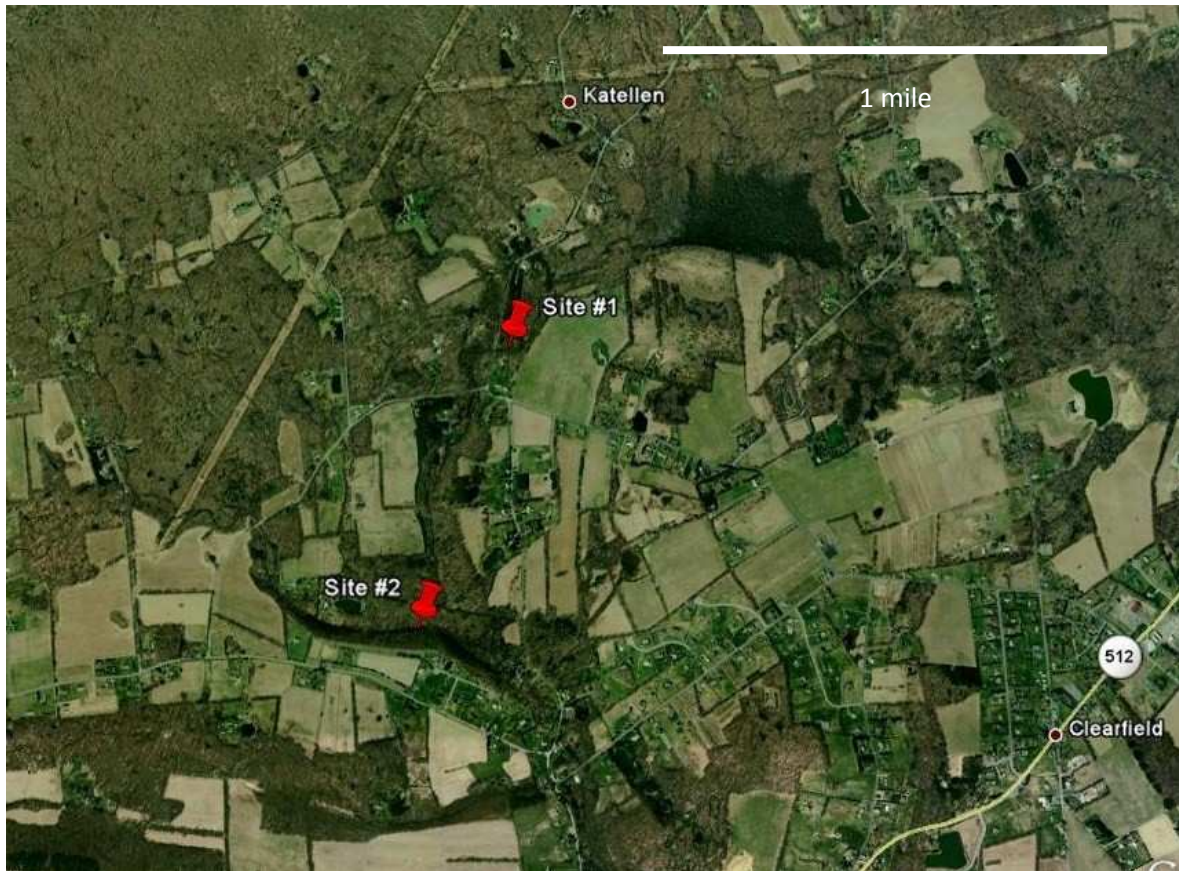
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MAP 1: Upper Bushkill Creek Macroinvertebrate Survey Sampling Site Locations



(Image sources: Top Map: *Google satellite image (USGS and PA DCNR)*. Bottom Map: *USGS topographical map Wind Gap Quadrant*)

Appendix B-1

Bushkill Creek Site #1 Macroinvertebrate Sub-sample 3/29/08 Index of Biological Integrity¹ (IBI) Metric Values and Score

Metric	Standardized Equation	Observed Metric Value	Standardized Metric Score	Adjusted Standardized Metric Score (Maximum= 1.000)
Modified Beck's Index	Observed value/39	28	.718	.718
EPT Taxa Richness	Observed value/23	17	.739	.739
Total Taxa Richness	Observed value/35	27	.771	.771
Shannon Diversity Index	Observed value/2.90	2.36	.814	.814
Hilsenhoff Biotic Index	(10-observed)/ (10-1.78)	2.77	.880	.880
Percent Intolerant Individuals	Observed value/92.5	81.7	.883	.883
Average of adjusted standardized core metric scores x 100 = IBI Score =				80.1

¹Index of Biotic Integrity for Wadeable, Freestone Streams in Pennsylvania

Bushkill Creek Site #2 Macroinvertebrate Sub-sample 3/29/08 Index of Biological Integrity¹ (IBI) Metric Values and Score

Metric	Standardized Equation	Observed Metric Value	Standardized Metric Score	Adjusted Standardized Metric Score (Maximum= 1.000)
Modified Beck's Index	Observed value/39	24	.615	.615
EPT Taxa Richness	Observed value/23	17	.739	.739
Total Taxa Richness	Observed value/35	27	.771	.771
Shannon Diversity Index	Observed value/2.90	1.79	.617	.617
Hilsenhoff Biotic Index	(10-observed)/ (10-1.78)	1.81	.996	.996
Percent Intolerant Individuals	Observed value/92.5	96.6	1.044	1.000
Average of adjusted standardized core metric scores x 100 = IBI Score =				78.97

¹Index of Biotic Integrity for Wadeable, Freestone Streams in Pennsylvania

Appendix B-2

Index of Biological Integrity (IBI) for Wadeable, Freestone Streams in Pennsylvania An explanation¹ of the IBI's 6 metrics and their expected response to stressors

Metric Name	Type of Metric	Description	Expected Response to Increasing Anthropogenic (Human-associated) Stress
Modified Beck's Index	Taxonomic Composition (relative abundance, identity, sensitivity, dominance)	A weighted count of taxa with pollution tolerance values of 0, 1, or 2 in a sub-sample.	Decrease
EPT Taxa Richness	Community Structure (taxonomic diversity)	A count of the number of taxa belonging to the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) in a sub-sample.	Decrease
Total Taxa Richness	Community Structure	A count of the total number of taxa in a sub-sample, or total taxa richness.	Decrease
Shannon Diversity Index	Taxonomic Composition	Measures taxonomic richness and evenness of individuals across taxa of a sub-sample.	Decrease
Hilsenhoff Biotic Index	Taxonomic Composition	Calculated as an average pollution tolerance value weighted by the number of individuals of each taxa in the sub-sample.	Increase
Percent Intolerant Individuals	Taxonomic Composition	The percentage of individuals with pollution tolerance values of five or less in a sub-sample.	Decrease

¹ Table terms and descriptions derived from Chalfant 2007

Appendix C-1

Biological Condition Gradient² (BCG) Tier Assessment Bushkill Creek Site #1 Macroinvertebrate Sub-Sample 3/29/08

Characteristic	Site #1 Macroinvertebrate Data	Quantitative Tier Rule
Total Taxa	27	Tier 2: Total taxa >25 genera
Total Individuals	219	Tier 2: Total Individuals > 50% of target (200)
Taxa (II)	6	Tier 2: Taxa (II) > 33% of Taxa (III) (Bushkill Creek Site #1 = 50%)
Taxa (II + III)	18 (6 +12)	Tier 2: Taxa (II + III) > 50% of all taxa (Bushkill Creek Site #1 = 66.7%)
Abundance (II + III)	136	Tier 2: Abundance (II + III) > 50% of sample (Bushkill Creek Site #1 = 62.1%)
Individuals (V)	2	Tier 2: Individuals (V) < 25% (Bushkill Creek Site #1 = .91%)
BCG Resource Condition Tier		Considered Tier 2 for Macroinvertebrates (All Tier 2 Quantitative Rules Apply)

Biological Condition Gradient² (BCG) Tier Assessment Bushkill Creek Site #2 Macroinvertebrate Sub-Sample 3/29/08

Characteristic	Site #2 Macroinvertebrate Data	Quantitative Tier Rule
Total Taxa	27	Tier 2: Total taxa >25 genera
Total Individuals	177	Tier 2: Total Individuals > 50% of target (200)
Taxa (II)	4	Fails Tier 2: Taxa (II) > 33% of Taxa (III) (Bushkill Creek Site #2 = 26.7%) Passes Tier 3: Taxa (II) >0 taxa
Taxa (II + III)	19 (4+15)	Tier 2: Taxa (II + III) > 50% of all taxa (Bushkill Creek Site #2 = 70.4%)
Abundance (II + III)	165	Tier 2: Abundance (II + III) > 50% of sample (Bushkill Creek Site #2 = 93.2%)
Individuals (V)	1	Tier 2: Individuals (V) < 25% (Bushkill Creek Site #2 = .56%)
Indicator Taxa	.56% 17 taxa	Tier 3 Rules Hydropsyche < 20% abundance EPT taxa > = 12 taxa
BCG Resource Condition Tier		Considered Tier 3 for Macroinvertebrates (Failed one Tier 2 Rule; meets all Tier 3 rules)

² Appendix G - Pennsylvania Tiered Aquatic Life Use Workshop Report: "Identification of the Biological Condition Gradient for Freestone (Non-Calcareous) Streams of Pennsylvania" February 2007

Appendix C-2

Biological Condition Gradient (BCG) Taxa Attribute and Resource Condition Tier Descriptions

BCG Taxa Attributes ²

BCG Resource Condition Tiers²

Taxa Type	Taxa Attribute	Resource Condition Tier	Tier Description
I	Endemic, Rare	1	Natural or native condition
II	Highly Sensitive	2	Minimal changes in biotic community structure and ecosystem function
III	Intermediate Sensitive	3	Evident changes in biotic community structure; minimal changes in ecosystem function
IV	Intermediate Tolerant	4	Moderate changes in biotic community structure; minimal changes in ecosystem function
V	Tolerant	5	Major changes in biotic community: moderate changes in ecosystem function
VI	Exotic, Invasive	6	Severe changes in biotic community structure: major loss of ecosystem function
x	unassigned		

² Appendix G - Pennsylvania Tiered Aquatic Life Use Workshop Report: "Identification of the Biological Condition Gradient for Freestone (Non-Calcareous) Streams of Pennsylvania" February 2007

Appendix D

Bushkill Creek Site #1 and Site #2 Sub-Samples 3/29/08 Significant Macroinvertebrate Indicator Species/Genus-Level Macroinvertebrate Stream Communities

High Quality Small Stream Community	Site #1	Site #2	High Quality Headwater Stream Community	Site #1	Site #2	Forested Headwater Stream Community	Site #1	Site #2	Common Small Stream Community	Site #1	Site #2
Insecta Ephemeroptera Heptageniidae <i>Epeorus</i>	X	X	Insecta Plecoptera Nemouridae <i>Amphinemura</i>	X	X	Insecta Plecoptera Chloroperlidae <i>Alloperla</i>			Insecta Ephemeroptera Heptageniidae <i>Stenonema</i>	X	
Insecta Plecoptera Perlodidae <i>Isoperla</i>			Insecta Trichoptera Lepidostomatidae <i>Lepidostoma</i>			Insecta Diptera Tipulidae <i>Tipula</i>	X	X	Insecta Coleoptera Psephenidae <i>Psephenus</i>		X
Insecta Coleoptera Elmidae <i>Oulimnius</i>			Insecta Plecoptera Leuctridae <i>Leuctra</i>	X		Insecta Ephemeroptera Ameletidae <i>Ameletus</i>	X		Insecta Trichoptera Philopotamidae <i>Chimarra</i>	X	X
Insecta Plecoptera Pteronarcyidae <i>Pteronarcys</i>	X		Insecta Diptera Simuliidae <i>Prosimulium</i>	X	X				Insecta Trichoptera Glossosomatidae <i>Glossosoma</i>		
Insecta Trichoptera Rhyacophiliidae <i>Rhyacophila</i>	X	X	Insecta Diptera Tabanidae <i>Chrysops</i>						Insecta Ephemeroptera Isonychiidae <i>Isonychia</i>		X
Insecta Trichoptera Hydropsychidae <i>Diplectrona</i>			Insecta Diptera Tipulidae <i>Limnophila</i>						Insecta Trichoptera Hydropsychidae <i>Macrosternum</i>		
Insecta Plecoptera Perlidae <i>Acroneuria</i>	X	X	Insecta Trichoptera Limnephiliidae <i>Pycnopsyche</i>						Insecta Megaloptera Sialidae <i>Sialis</i>		
Insecta Ephemeroptera Heptageniidae <i>Cinygmula</i>			Insecta Diptera Tipulidae <i>Pseudolimnophila</i>						Insecta Odonata Gomphidae <i>Stylogomphus</i>	X	
Insecta Plecoptera Chloroperlidae <i>Sweltsa</i>		X	Insecta Odonata Cordulegastridae <i>Cordulegaster</i>						Insecta Megaloptera Corydalidae <i>Corydalus</i>		
Insecta Diptera Tipulidae <i>Hexatoma</i>	X	X	Insecta Plecoptera Nemouridae <i>Ostracera</i>	X					Insecta Odonata Gomphidae <i>Arigomphus</i>		
Insecta Ephemeroptera Leptophlebiidae <i>Paraleptophlebia</i>	X	X	Insecta Diptera Tipulidae <i>Molophilus</i>						Insecta Plecoptera Perlidae <i>Eccoptura</i>		
Insecta Odonata Gomphidae <i>Lanthus</i>		X									
Insecta Diptera Tipulidae <i>Dicranota</i>		X									
Insecta Trichoptera Uenoiidae <i>Neophylax</i>	X	X									
Insecta Diptera Empididae <i>Chelifera</i>											
Insecta Trichoptera Hydropsychidae <i>Parapsyche</i>											
Insecta Coleoptera Psephenidae <i>Ectopria</i>											
Insecta Plecoptera Perlodidae <i>Yugus</i>											
Insecta Plecoptera Chloroperlidae <i>Haploperla</i>		X									

X = present in sample

Note:

Indicator species for each stream community type listed down column from highest to lowest significant indicator values (from Walsh et al. 2007b).

Species present in samples designated as Cold stenothermal or cool eurythermal

All other species present in samples designated as Cool/warm eurythermal (from Poff et al. 2006).

Appendix E

Upper Bushkill Creek Highly Sensitive Cold/Cool Water Macroinvertebrate Indicator Species



Mayfly larva: *Epeorus*



Mayfly larva: *Ameletus*



Stonefly larva: *Pteronarcys*

