Summary Results for Shale Hills Critical Zone Unit, Spring/Summer 2012 Benthic Macroinvertebrate Survey

By

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The term ‘benthic macroinvertebrate’ means ‘bottom-living’ organism lacking a backbone and being large enough to be retained by mesh sizes of ~200-500 mm (Rosenberg and Resh 1993). Aquatic insects and other macroinvertebrates are an important component of intermittent stream communities. However, streams with periodic flows are rarely the subject of ecological studies, especially biological assessments, due in part to the assumption that such habitats are depauperate when compared to larger stream systems (Collins et al. 2007). In fact, the PA Code Title 25 defines the primary difference between a perennial stream and an intermittent stream as the ability of the former to support a benthic macroinvertebrate community consisting of at least two taxa (PADEP 2003)—implying that intermittent streams are incapable of supporting these communities. Yet, aquatic macroinvertebrates display multiple strategies for surviving in such harsh environments.

In addition to the woodland and streamside amphibian community survey, we collected benthic macroinvertebrates in order to provide a more comprehensive analysis of both the diversity and biological condition of the stream community residing within the Susquehanna Shale Hills Critical Zone Unit (hereafter referred to as Shale Hills). The objectives of this semi-quantitative study were to 1) provide a summary list of the taxa present, along with ecological descriptions of intermittent stream fauna; and 2) conduct a biological assessment consisting of diversity indices and an index of biotic integrity.

Methods

We collected eight benthic macroinvertebrate samples on May 22, 2012 using a D-frame dip net (0.3 m width, 500 µ mesh) along randomly selected depositional (n=4) and erosional (n=4) habitats. Erosional habitats were shallower and depositional areas contained more organic debris, but overall the physical differences between these habitats were miniscule, given the small size of the stream (Figure 1). In addition, standard water quality measurements (specific conductivity, temperature, and pH) were also collected prior to sampling. For benthic sampling, the net was placed facing upstream and large cobble and other debris were inspected for organisms, rinsed, and removed. Given sufficient depth, the remaining substrate was disturbed via the kick method; for shallower areas hands were used to disturb the substrate. The contents of the net were dumped into a sieve bucket (500 µ mesh), rinsed, and larger debris was inspected and discarded. The remaining sample contents were transferred to containers and preserved in 70% EtOH. Each sample was preserved and processed separately, in order to evaluate the efficiency of the sampling effort. Following transport to the laboratory, each sample was sorted in entirety and all specimens were identified to the lowest taxonomic resolution possible using a dissecting microscope. Most identifications were to genus level. Exceptions include the class Oligochaeta (aquatic worms), order Acariformes (water mites), and family Chironomidae (midges).

a.)

b.)

Figure 1. Erosional (a) and depositional (b) habitats sampled for macroinvertebrates.

Results

<u>Sampling Effort</u>

We used PCORD to evaluate sampling effort (McCune and Mefford 2011). In other words, did we collect enough samples to describe the entire community? Species area curves plot the average number of species observed in different sampling extents by taking repeated random samples of increasing size from the species matrix. It then presents the average number of species occurring in a sample of a given size, as well as a distance matrix of the average distance among sample units (Peck 2010). If no new species are found as new samples are added, the species area curve will flatten to an asymptote (slope = 0); however, this is difficult to achieve in cases where many species occur rarely in the dataset. This is the case in Figure 2, which shows the species area curve for the Shale Hills sampling event. Thirteen of the 32 total taxa collected occurred only once in the dataset (i.e. unique to a plot). Although in some instances this may imply that these taxa do not belong to the community and were inadvertently collected, this is rarely the case with aquatic macroinvertebrates. The majority of these taxa lack the ability to disperse in their aquatic stage. The exceptions are certain species of snails, fingernail clams, and water mites, all of which have been known to hitch rides on terrestrial wildlife (and people), as well as the diving beetles, which may undergo adult flights in search of other aquatic habitats. Overall, we can assume that eight samples were sufficient to properly describe the biological diversity and condition of this stream.

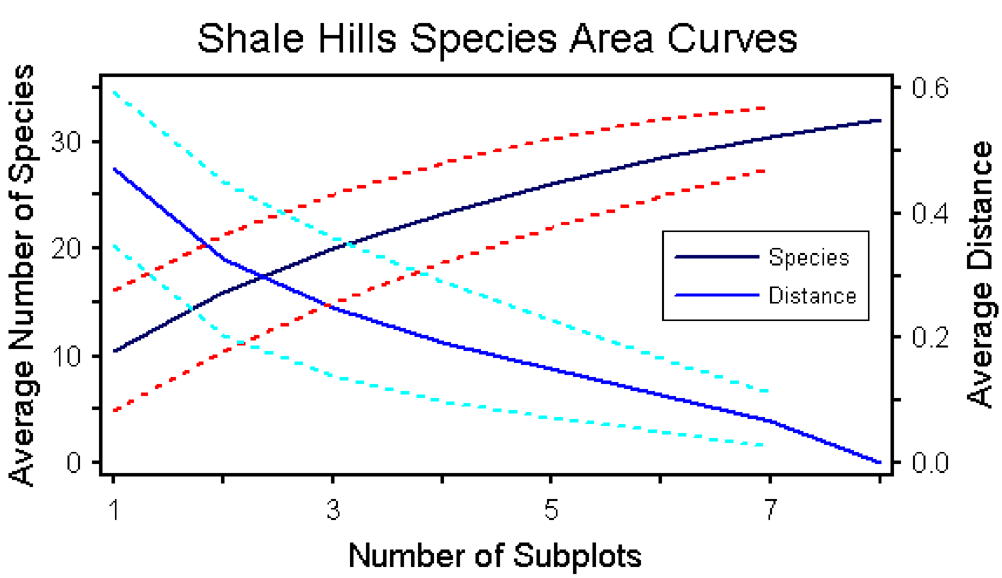

Figure 2. Species area curve (and related distance curve) showing the average number of species collected with successive sampling events.

Ecological Summary

A total of 562 individuals representing 32 different taxa (12 orders, 25 families) were collected from the small intermittent stream. Both habitat types contained similar abundance (243 and 319 individuals collected from erosional and depositional habitats, respectively) and richness (23 taxa in each habitat type). Table 2 displays the raw macroinvertebrate data. The small, pronggill mayfly genus *Paraleptophlebia,* rolled winged stoneflies (genus *Leuctra*), and chironomid midges were the most abundant taxa present in all plots. The stoneflies *Amphinemura* and *Isoperla,* as well as the caddisfly *Lepidostoma* and several genera of cranefly (Tipulidae) were also well-represented.

Flow patterns are one of the major factors regulating the distribution of aquatic fauna, and intermittent stream fauna differ from those of perennial streams primarily by their ability to survive dry periods (Collins et al. 2007). The stream fauna collected fit the description for intermittent streams in Bode et al. (2002) and generally consisted of (1) species which survive in pools or by burrowing into moist substrates (e.g., crayfish, snails, midges, and some caddisflies), (2) species with egg or larval periods adapted for drought conditions (e.g., stoneflies), and (3) specialized inhabitants of temporary waters (e.g., caddisflies *Lepidostoma* and *Neophylax*). Table 1 provides an ecological summary of the various mechanisms by which some of the taxa collected at Shale Hills have adapted to survive in intermittent streams.

Table 1. Summary of the various physiological, behavioral, and life cycle strategies for surviving drought in intermittent habitats.

Survival Strategy	Example Taxa	Reference
Rapid Growth	*Paraleptophlebia* spp., *Leuctra*spp.	Williams (2006)
Drought Resistant Eggs	*Ameletus* spp.	Clifford (1966), Williams (2006)
Diapause	*Amphinemura* spp., *Leuctra* spp., Chironomidae	Harper (1973), Harper (1990)
Adaptive Life Cycles	*Lepidostoma* sp., *Neophylax concinnus*	Clifford (1966)
Active Migration	*Hydroporus* spp.	Clifford (1966)
Burrowing	*Cordulegaster obliqua, Pisidium* spp., *Hydroporus* spp.	Clifford (1996), Barlow et al. (2009)
Interstitial/Hyporheic Zone	*Isoperla spp., Leuctra spp.*	Clifford (1966)
Desiccation Resistance	*Pisidium* spp.	Williams (2006)

Table 2. Summary of macroinvertebrates (number of individuals) collected from erosional and depositional stream habitats in Shale Hills (May 22, 2012).

				EROSIONAL HABITAT				DEPOSITIONAL HABITAT			
GROUP	FAMILY	GENUS/SPECIES	COMMON NAME	17E	29E	69E	74E	45D	102D	117D	138D
OLIGOCHAETA			Aquatic worm	3	5	1	0	1	0	0	5
GASTROPODA	Physidae	*Physella*	Pouch snail	0	1	0	0	0	0	0	0
BIVALVIA	Sphaeriidae	*Pisidium*	Fingernail clam	0	0	0	0	0	0	17	0
ACARIFORMES			Water mite	0	0	0	0	0	1	0	0
DECAPODA	Cambaridae	*Cambarus bartonii*	Crayfish	0	0	0	0	1	1	0	0
EPHEMEROPTERA	Baetidae	*Baetis*	Small minnow mayfly	0	2	2	2	0	0	0	0
EPHEMEROPTERA	Ephemerellidae	*Ephemerella dorothea*	Spiny crawler mayfly	0	19	0	1	0	0	0	0
EPHEMEROPTERA	Ephemerellidae	*Eurylophella*	Spiny crawler mayfly	0	1	0	0	0	0	1	0
EPHEMEROPTERA	Leptophlebiidae	*Paraleptophlebia*	Pronggill mayfly	30	49	5	12	11	19	6	16
EPHEMEROPTERA	Ameletidae	*Ameletus*		0	0	1	0	1	0	0	0
ODONATA	Cordulegastridae	*Cordulegaster obliqua*	Arrowhead spiketail	2	0	0	0	1	0	0	0
MEGALOPTERA	Sialidae	*Sialis*	Alderfly	0	0	0	1	0	0	0	0
PLECOPTERA	Leuctridae	*Leuctra*	Rolled winged stonefly	1	4	14	14	2	1	17	18
PLECOPTERA	Nemouridae	*Amphinemura*		4	5	4	2	0	0	8	0
PLECOPTERA	Chloroperlidae	*Sweltsa*	Green stonefly	1	0	0	0	0	0	0	0
PLECOPTERA	Perlodidae	*Isoperla*	Perlodid stonefly	1	7	4	3	0	0	1	0
TRICHOPTERA	Lepidostomatidae	*Lepidostoma*		6	0	0	0	1	6	20	37
TRICHOPTERA	Molannidae	*Molanna*		0	0	0	0	0	0	2	0
TRICHOPTERA	Limnephilidae	*Pycnopsyche*	Northern caddisfly	0	0	0	0	0	2	0	0
TRICHOPTERA	Uenoidae	*Neophylax*		0	0	0	1	0	0	0	0
COLEOPTERA	Dytiscidae	*Hydroporus*	Diving beetle	0	0	0	0	0	0	1	0
COLEOPTERA	Dytiscidae	*Hydroporus/Lioporeus*	Diving beetle	0	0	0	0	1	0	0	0
DIPTERA	Chironomidae		Midge	4	7	3	5	4	32	20	40
DIPTERA	Ceratopogonidae	*Bezzia/Palpomyia*	Biting midge	0	0	0	0	0	0	2	0
DIPTERA	Simuliidae	*Simulium*	Black fly	1	2	0	0	0	0	0	0
DIPTERA	Tipulidae	*Dicranota*	Cranefly	2	0	1	0	0	0	0	0
DIPTERA	Tipulidae	*Molophilus*	Cranefly	0	0	0	0	1	0	0	0
DIPTERA	Tipulidae	*Hexatoma*	Cranefly	0	1	0	0	0	0	2	2
DIPTERA	Tipulidae	*Ulomorpha*	Cranefly	0	1	1	0	0	0	2	0
DIPTERA	Tipulidae	*Pseudolimnophila*	Cranefly	0	0	5	0	0	0	15	0
DIPTERA	Tipulidae	*Tipula*	Cranefly	0	0	0	1	0	0	0	0
DIPTERA	Dixidae	*Dixella*		0	0	1	0	1	0	0	0

Biological Assessment

Water Chemistry: Designated uses (and their associated protection and regulations) have not been defined for intermittent streams; thus we used state regulatory criteria defined for coldwater fisheries to evaluate the water chemistry results (PADEP 2003). Temperature and pH were all within the range necessary to support aquatic life and did not differ between erosional and depositional habitats. Temperatures in mid- to late-May cannot exceed 14.4 °C; all values ranged from 11.0 – 11.5 °C. Water pH ranged from 6.06 – 6.81 (criteria for protection of aquatic life is 6.0 – 9.0 inclusive). Water quality standards have not been established for specific conductivity, primarily because this measurement is not directly correlated with aquatic health. However, it does tend to remain relatively constant under normal circumstances, making it a good indicator of sources of pollution. Areas with more groundwater input also have higher conductivity. Overall specific conductivity levels were low (typical range 1.5 – 2.5 µmhos/cm), even for plots 74E and 183D, which had substantially higher levels (60.2 and 47.7 µmhos/cm, respectively). This may indicate more groundwater input at these locations. However, a more likely explanation, given the low readings, is that the majority of flow was the result of recent rainstorms (rain lowers conductivity) and the plots with higher conductivity probably had more standing water with higher concentrations of dissolved solids.

Biological Diversity: Diversity indices can be useful for understanding community structure and the distribution of organisms within that community. Species diversity incorporates both richness (number of species present) and evenness (all species in relatively equal proportions). Higher diversity generally implies a more complex and healthier community. Shannon's Diversity (H') is a common theory-based index that measures the 'uncertainty' of a taxon selected at random from the community. It is calculated from the formula

$$H' = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

where: H' = the Shannon Diversity Index
P_i = fraction of the entire population made up of species i
S = number of species encountered
Σ = sum from species 1 to species S.

Values usually fall between 1.5 and 3.5, with lower values indicating less diversity. For example, a community with only one species would have an $H' = 0$. If the species are evenly distributed the value of H' is high. Another useful diversity measure is Whittaker's beta diversity, which is calculated by dividing the mean alpha diversity (plot level) by gamma diversity (site level) and subtracting by 1 (Peck 2010). Beta diversity provides a measure of species turnover and describes the heterogeneity in the community. High species turnover (usually around 4) implies that there is little to no overlap of species between plots. Table 4 shows the estimated Shannon diversity (H') and Whitaker's beta diversity or species turnover. Both diversity values were relatively moderate, suggesting intermediate levels of species diversity, evenness, and heterogeneity. This is not surprising considering the small size of the stream and limitations of the habitat.

Biological Integrity: Indices of biotic integrity describe the condition of the community via a suite of metrics that represent community structure, pollution tolerance, functional feeding groups, habitat occurrences, and life history strategies. In order to determine or 'score' the condition of a particular stream with regard to these metrics, a reference condition needs to be established. This can be accomplished in multiple ways but the preferred method by most is to define a regional reference condition for each metric based on least disturbed reference streams of similar size within a comparable geographic and geologic setting. The metric values for the stream in question are then compared to the range of metric values from the reference set and scored accordingly.

Although there are many types of macroinvertebrate biotic indices to choose from, none have been developed for intermittent streams. Since intermittent streams tend to have depressed richness values, applying indices developed for larger streams often results in erroneous assessments of impairment. One suggestion to overcome this is to apply a correction factor of 1.5 to richness metrics (Bode et al. 2002).

We used the Macroinvertebrate Biotic Integrity Index (MBII) developed by the U. S. Environmental Protection Agency's (USEPA) Environmental Monitoring and Assessment Program (EMAP) to estimate the biological condition of the benthic community at Shale Hills (Klemm et al. 2003). This index uses data collected from 574 wadeable stream reaches in the Mid-Atlantic Highlands Region to define floor and ceiling values of the reference condition for each metric. The final MBII score is the sum total of the metric scores standardized to a 0 – 100 scale with 0 representing worst condition and 100 best condition. Three general condition categories are expressed (good, fair, and poor); however, the real value is in the individual metrics scores and overall score. Table 3 displays the metrics used in the index, along with their description and expected direction of response to anthropogenic stress. Although the number of Ephemeroptera and Plecoptera collected fell near the lower ends of the reference range, Trichoptera richness exceeded the maximum value. These results are not surprising, considering caddisflies demonstrate more diverse strategies for surviving in temporary environments than mayflies and stoneflies. Low collector-filterer richness was also expected, since these organisms often rely on current velocities to move fine particles across their filtering apparatuses, something that is usually lacking in small intermittent streams. These metrics (except collector-filterer richness) scored much higher when the correction factor was applied. The top five dominant taxa represented approximately 76% of the total individuals collected at the site—much higher than the reference maximum. However, intermittent headwater streams are often dominated by a few taxa, primarily since those adapted for such conditions thrive in the absence of more competitive species requiring perennial flow. The raw MBII score was 47.8 which corresponds roughly to ‘fair’ condition. After accounting for the limitations placed on intermittent flows, the modified MBII score indicated ‘good’ condition for the stream community. Given the surrounding forest cover and apparent lack of stressors, we would expect this condition rating.

Table 3. Macroinvertebrate Biotic Integrity Index metric descriptions and their directions of response with increasing human disturbance (from Klemm et al. 2003).

Metric	Description	Response
Ephemeroptera Richness	Number of Ephemeroptera (mayfly) taxa	Decrease
Plecoptera Richness	Number of Plecoptera (stonefly) taxa	Decrease
Trichoptera Richness	Number of Trichoptera (caddisfly) taxa	Decrease
Collector-filterer Richness	Number of taxa with a collecting or filter-feeding strategy	Decrease
% Non-insect Individuals	Percent of individuals that are not insects	Increase
MTI (Macroinvertebrate Tolerance Index)	$\Sigma ip_i t_i$, where p_i is the proportion of individuals in taxon *I* and t_i is the pollution tolerance value (PTV) for general pollution	Increase
% 5 Dominant Taxa	Percentage of individuals in the five numerically dominant taxa	Increase

Table 4. Summary metrics and final MBII scores for Shale Hills sampling event (May 22, 2012). The modified MBII score accounts for expected depressed richness values in intermittent streams by applying a correction factor of 1.5 to the richness metrics.

Metric	Value	Raw Score	Modified Score
Shannon's Diversity (H')	2.32		
Whitaker's (Beta) Diversity	2.0		
Ephemeroptera Richness	5	1.3	5.9
Plecoptera Richness	4	3.4	9.9
Trichoptera Richness	4	10	10
Collector-filterer Richness	2	0	0
% Non-insect Individuals	0.064 (6.4%)	7.6	7.6
MTI (Macroinvertebrate Tolerance Index)	3.91	10	10
% 5 Dominant Taxa	0.7598 (76.0%)	1.2	1.2
MBII score		47.8	
MBII modified score			63.7

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