Bioassessment of Spout Run
Clarke Co, Virginia

Final Report

Submitted to

Office of Planning
County of Clarke
Berryville, VA

By

R. Christian Jones
Professor
Environmental Science and Policy

Ryan Hansen
Graduate Assistant

George Mason University
Fairfax, VA 22030

August 30, 2002

I. Introduction and Literature Review

Spout Run in Clarke County, Virginia is the subject of a watershed restoration project to mitigate nonpoint source pollution impacts in an agricultural landscape. Spout Run is formed by the confluence of Roseville Run and Page Brook. Fecal coliform bacteria have been detected in 40% of the wells sampled in Clarke County in the past 10 years, with beef cattle having been identified as the primary source (Hagedorn 1999). Furthermore, Spout Run is the county's only trout stream. To address these problems, the Clarke County Office of Natural Resources initiated a project to encourage construction of fences alongside Spout Run to exclude cattle and allow regrowth of riparian vegetation.

Excluding cattle from streams via the installation of fences along the stream reduces bank erosion and streambed disturbance which can hinder vegetative stability and increase sediment resuspension. However, there are questions as to the extent to which fencing allows for stream recovery and the time period over which any recovery will occur. In addition, fencing alone may not result in restoration of water quality and physical habitat if other Best Management Practices (BMPs), such as off-stream watering tanks, are not also utilized. There are also issues regarding the optimal characteristics of stream buffers, such as the distance between the fence and the stream bank and the type of vegetation (i.e. woody versus herbaceous) which should be present in the buffer zone between the stream and the fence. Given that stream fencing has significant costs, information on how to maximize its effectiveness in protecting water quality is valuable to natural resource managers in areas where animal grazing is an important land use.

Cattle with unrestricted access to streams may have deleterious or undesirable impacts on stream biota in several ways. Suspended sediment levels may be enhanced through erosion directly from the banks and/or from adjacent pasture. Suspended sediments may interfere with respiration and feeding of stream invertebrates (Lemly 1982) and fish (Gardner 1981). Deposited fine sediments may provide a poor substrate for many invertebrates and eliminate fish nesting areas. Enhanced levels of nutrients such as nitrogen and phosphorus reach these streams from manure deposited directly in the stream and/or on the adjacent pasture. Although less important in flowing waters than in lakes and ponds, nitrogen and phosphorus can stimulate the growth of nuisance algae which can alter stream food webs. Manure can also be a source of ammonia, which can be toxic to fish and benthic macroinvertebrates at high pH. The grazing and trampling action of cattle prevents the establishment of woody vegetation, eliminating the shading effect of trees. As a result, water temperatures may increase. Temperature is a critical factor controlling the life cycles of many aquatic organisms, and elevated stream temperatures can result in the elimination of cold-water animals such as stonefly nymphs and trout (Vannote and Sweeney 1980).

Knowing the potential for livestock with unrestricted access to streams to impact freshwater organisms, it should not be surprising to find that many studies to date indicate substantial degradation of the fauna of streams in watersheds with substantial land used as cattle pasture. A study in the piedmont region of Maryland found that the lack of fencing around stream channels, along with a lack of other BMPs, resulted in sediment and nutrient pollution from dairy operations (Shirmohammadi et al. 1997).

This study was designed to use benthic invertebrates and physical stream habitat to assess stream conditions and monitor the response to riparian zone fencing. The overall objective of the study is to provide county resource managers with information on the effectiveness of fencing as a best management practice (BMP) in improving water quality in Clarke County. This report is the third and final to cover the watershed of Spout Run (Jones et al. 2002 a, b).

II. Study Sites

Sites were selected to determine the status of Spout Run and to ascertain the effectiveness of livestock fencing as a means for improving stream quality. Ideally, in a study attempting to determine the degree to which a stream or streams have been impacted by non-point source pollution, a reference station located in a relatively undisturbed watershed is selected in order to obtain information on the biological condition of a stream which is minimally impacted by human activities, but which shares the same natural influences as the study streams (e.g., stream order, climate, geology, etc.). An attempt was made to locate such a reference stream for this study, but examination of appropriate 7.5 minute scale topographic maps of the surrounding area did not reveal any such streams. As with the Page Brook and Roseville Run studies, a site on Page Brook at Rt. 617 was used as the reference site (Jones et al. 2002 a, b). This site exhibited good habitat characteristics and a biological community with high integrity during the Page Brook samplings For the current study of Spout Run, four sites were selected that were relatively evenly dispersed along its roughly 5.5 km length (Figure 1). Each of these sites was visited in each of the following four seasons: Fall 1999, Spring 2000, Fall 2000, Spring 2001. Table 1 indicates the names, location, and sampling dates at each station. On each of the sampling runs except Fall 1999, duplicate benthic samples were collected at two randomly chosen stations for quality control purposes and to obtain some measure of sample variability. Also, as part of an MS thesis by the junior author of this report, the original group of Page Brook stations was sampled on the 2000 and 2001 sampling trips. This data is included in the report as ancillary information.

III. Methods

A modification of EPA Rapid Bioassessment Protocol (RBP) II was used as the basic tool for macroinvertebrate bioassessment (Plafkin et al. 1989). RBP II utilizes semiquantitative field collections in riffle/run and leaf litter habitats to determine the values of eight metrics which characterize the status of the benthic macroinvertebrate community. The protocol allows for the modification of metrics and the use of alternative metrics depending on regional conditions. Previous work has indicated that the scrapers/filter collector metric was very variable and not particularly indicative of degraded conditions (Jones and Kelso 1994). Furthermore, the occurrence of these two groups was sporadic in our samples. Thus, we deleted this metric. We used Sorensen's index for community similarity. The ratio shredders/total number could not be used as coarse particulate organic matter (CPOM) was not available at many sites. The seven metrics that we utilized in this study are shown in Table 2.

Macroinvertebrate communities were sampled at each site using a 44 cm x 22 cm kick net. The 0.5 mm mesh net was held to the bottom facing upstream and the substrate was disturbed for 1 m directly upstream from the net for one minute. Larger stones were also wiped clean manually when deemed necessary. Contents of the net were placed in a shallow pan. The net was inspected to remove adhering animals. Large stones and leaves were rinsed and discarded. Crayfish (Cambaridae) were enumerated and returned to the water. Other obvious animals were picked directly into the sample jar. The remaining sample was collected by pouring the contents of the pan through a 0.5 mm sieve. This material was also transferred to the sample jar. The sample was preserved with formalin. Samples were collected from two locations at each station, a rapidly flowing riffle and a less rapid run, and composited into a single jar.

In the lab samples were rinsed with tap water through a 0.5 mm sieve to remove formalin and placed into a 35 cm x 40 cm pan marked with 5 cm x 5 cm squares. The pan was then shaken to distribute the sample evenly over the entire surface of the pan. Using a random number table, squares were selected for organism removal until a target number of 200 organisms was achieved. The pan was also scanned for large and/or rare taxa which were added to the picked subsample. All organisms were picked from the selected squares. Obvious large and unusual specimens were also added to the picked sample. Cambaridae numbers were added to the count. The remaining sample was returned to the sample jar and represerved with alcohol/glycerine. Samples containing less than 100 animals were reported, but RBP metrics were not calculated. The selected organisms were sorted into ethanol-glycerine, identified to family and enumerated. Oligochaetes were not identified to family and were counted as a single taxon in all calculations. Taxonomic references included Merritt and Cummins (1996), McCafferty (1983), and Pennak (1978).

Macroinvertebrate rating was calculated following the guidance of the EPA bioassessment manual. In order to determine the values of certain metrics, it was necessary to assign biotic index values to each family (Hilsenhoff 1982). Since an external reference site unimpacted by agricultural activity with similar natural watershed characteristics was not available for sampling, the sampling event (i.e. station/date combination) in the Spout Run watershed which most consistently had scores on each metric ranking at or near the top of all samples was selected as the reference sample. As stated above this site was Page Brook at Rt. 617 (Jones et al. 2002 a). The raw scores of all samples were then expressed relative to the score of the reference sample. Metric scoring criteria used were those cited for RBP II (Fig. 6.3-4, Plafkin et al. 1989). EPT/Isopods was scored using the same criteria as EPT/Chironomids. Criteria for Sorenson's Index were: 0 for values less than 0.55, 3 for values between 0.55 and 0.75, and 6 for values greater than 0.75.

Relationships among sites were also explored using box plots created using SYSTAT for Windows. For a given category of samples a box plot depicts the spread of the middle half of the values as a box. A horizontal line within the box denotes the median. Whiskers (bracketed lines) extend to the edges of the data. Outliers are denoted by circles.

Habitat assessment was conducted using the methods outlined in the revised EPA bioassessment (Barbour et al. 1999). At each site the Physical Characterization/Water Quality and Habitat Assessment (High Gradient) Field Data Sheets were filled out, normally during the macroinvertebrate sampling. This information was used to construct a rating based on the criteria in the habitat assessment portion of the document.

IV. Results

Macroinvertebrates

Spout Run Samples

A total 4,963 macrobenthic invertebrates were identified and enumerated in 22 samples from the four stations on Spout Run. The midge family Chironomidae was the most abundant group comprising 30.4% of all specimens. The caddisfly family Hydropsychidae was the second most abundant with 21.2% of all individuals followed by the isopod Asellidae at 14.0% and then the Elmidae (riffle beetles) at 10.2% Other groups comprising over 1% of macrobenthos included the dipteran families Simulidae (blackflies) and Tipulidae (craneflies), the caddisfly family Polycentropidae, four mayfly families, the oligochaetes (aquatic worms), and the Cambaridae (crayfish). Number of individuals of each macroinvertebrate family found in each sample are contained in Appendix B. Relative abundance of each taxa is found in Appendix C.

Box plots were used to examine trends among sampling times by pooling data from all stations. The major non-insect taxa (Figure 2) included isopods (Asellidae), crayfish (Cambaridae), aquatic worms (Oligochaeta), and flatworms (Planariidae). Isopods were by far the most abundant noninsect group with median densities hovering around 10% on all sampling dates. Median crayfish densities were 1-2% of total abundance during 2000, but were less common in 2001. In 1999 crayfish numbers were not recorded. Oligochaetes were consistently found in small numbers, with medians generally about 1-2% of total except in 2001 when fewer were found. Gastropods were found in many samples, but were especially common in selected samples in 1999 and 2001 comprising up to 6% of total abundance.

Dominant insect taxa (Figure 3) were two-winged flies (Diptera), caddisflies (Trichoptera), mayflies (Ephemeroptera), and beetles (Coleoptera). Diptera were an important part of the community with median densities of 20-30% of total individuals in 1999-2000 increasing to over 50% in 2001. Tripchoptera were well represented on all dates with median values of 15-30%. Median Coleoptera levels were about 5% in 2000 and 2001, but were nearly 20% in 1999. Ephemeroptera were consistently observed on all sampled dates at 5-12% of the community.

Spatial trends were also examined using box plots. A strong dichotomy was observed in the occurrence of Asellidae with 20-30% dominance observed at the upper two sites, Powhatan School (1-Pow) and Squire (2-Squ), while median densities at the lower two sites was less than 2% (Figure 4). Crayfish did not exhibit a consistent longitudinal pattern. Oligochaetes were found at a median density of about 1-2% at all stations. Gastropods showed little longitudinal pattern with medians of less than 0.5% at all stations.

Diptera densities were a mirror image of those observed for Asellidae (Figure 5). Median densities were about 20% at the two upstream sites compared to 35-65% at the two downstream sites. Trichoptera showed a general increasing pattern moving downstream from about 15% at SR-P to nearly 40% at SR-621. Coleptera exhibited a bimodal pattern being very abundant at SR-P (median of 25%), dropping to about 7% at SR-S and nearly 0 at SR-HC before rebounding to about 7% at SR-621. Ephemeroptera were lowest at SR-P (4%) and substantially higher (10-12%) at the downstream sites.

A stacked bar plot of average relative abundance of the major taxa showed that while the major taxa remained similar throughout the study reach, Diptera exhibited a marked increase in relative abundance and Asellidae declined abruptly between SR-S and SR-HC (Figure 6). At SR-P and SR-S, there was a relatively even distribution of individuals among the five major taxa. The SR-HC and SR-621 the balance shifted toward Diptera with Trichoptera making some gains at SR-621. Since Asellidae is considered to be a more tolerant group than either Chironomidae (the dominant Diptera family) or Hydropsychidae (the dominant Trichoptera family), the shift at the two downstream stations could be interpreted as an improvement in biotic integrity. However, this shift does indicate a higher dominance by the most numerous taxa which is often associated with lower biotic integrity. Also, the family Chironomidae contains a variety of genera whose tolerance varies over a broad range.

Some metrics exhibited trends through time, but there were no clear overall temporal trends (Figure 7). Taxa richness was clearly higher in the second two trips (13-14) than in the first two (11-12). Family biotic index appeared to increase through fall 2000 and then decline. EPT/Chironomid abundance declined steadily during the sample period and percent dominance rose, both indicators of lower integrity. On the other hand EPT index appeared to rise suggesting higher integrity. EPT/isopod abundance and Sorensen's index were variable. The net result was a composite overall Biological Condition Index score that was fairly consistent with median varying from 23-26 or 55-60% of reference conditions.

The metrics were also fairly consistent spatially (Figure 8). Median taxa richness varied from 12-13. Family biotic index did decline between the two upper sites and the two lower sites indicating improved integrity. This was probably due to the shift from Asellidae to Chironomidae. EPT/Chironomids bounced around a little as chironomids and trichoptera (the main EPT group) varied in relative abundance from station to station. Percent dominance was slightly higher at downstream sites as chironomids became more dominant. EPT index did not change much, but EPT/isopod abundance increased downstream as isopods disappeared. The composite overall Biological Condition Index exhibited a zigzag pattern moving downstream with highest median value at SR-S and SR-621 of over 60% of reference and values between 50 and 55% at the other two sites.

Table 3 shows the metric values, metric scores, aggregate BCI, and impairment class for each sample collected in the study. As noted above the differences among stations and dates were relatively minor and all values were in the "Moderate Impairment" range.

B. Page Brook Resampling

As indicated earlier, previously sampled Page Brook stations upstream from Spout Run were resampled as part of a master's thesis project on Spout Run. The longitudinal pattern in noninsect taxa resulting from combining the Page Brook and Spout Run samples from 2000-2001 is shown in Figure 9. Asellidae was highest in the upstream Page Brook stations, declined in mid Page Run, increased again at the end of Page Run and then declined down the length of Spout Run. Cambaridae was variable with sporadic sites having medians of 2% or more, but most being less than 1%. Oligochaeta exhibited a marked peak at PB-M and declined steadily through the rest of Page Brook, remaining generally low in Spout Run. Gastropods were generally quite low except for a large percentage at SD.

Diptera exhibited a general rise in importance moving downstream in Page Brook and then Spout Run going from less than 5% in upper Page Brook to 40-60% at stations near the mouth of Spout Run (Figure 10). Major increases in diptera occured at PB-M and SR-HC. Trichoptera remained of low importance (median less than 5%) throughout Page Brook, but increased substantially in upper Spout Run (median about 15%) and continued increasing down the length of Page Brook (median almost 40%). Coleoptera was generally less than 5% in Page Brook and generally more than 5% in Spout Run. PB-M and PB-617 were exceptionally high in Coleoptera in Page Brook and PB-HC was exceptionally low in Spout Run. Ephemeroptera followed a similar pattern as Coleoptera with higher values in Spout Run matched only at PB-M and PB-617 in Page Brook.

Metrics showed some clear spatial patterns (Figure 11). Taxa richness exhibited a consistent increase moving down Page Brook from a median of 6 to about 12. The only exception to this was PB-M which was about 16. Taxa richness remained high and rather constant through the length of Spout Run. Family biotic index exhibited an overall decline from upper Page Brook through lower Spout Run from a value of nearly 8 (pure Asellidae) to below 5. Some lower values were observed at selected Page Brook stations: PB-M and PB-SD. EPT/Chironomid was generally highest in lower Page Brook and Spout Run despite the increase in chironomids. Percent dominance showed a general decline from values of 90-100 in upper Page Brook to about 40% in Spout Run. EPT index was substantially higher in Spout Run and selected Page Brook sites, again PB-M and PB-617. EPT/isopod abundance was much greater at the two lower Spout Run sites than anywhere else. Sorensen's index exhibited a consistent rise downstream in Page Brook and then leveled off in Spout Run. The overall BCI scores were substantially higher in Spout Run than in Page Brook. Selected Page Brook sites (PB-M, PB-SD, and PB-617) were intermediate.

C. Spout Run Habitat

Results of habitat analysis using the standard EPA habitat protocol are shown in Tables 4-7. Pasture was the dominant surrounding land use resulting in local erosion varying from slight to heavy (Table 4). Land use at the three upstream sites was field pasturage whereas at the downstream site forest was found along the stream with one residence nearby. There was some evidence of local NPS sources and moderate local erosion. The stream was generally 3-9 m wide with depths of 0.5 to 1 m. No channelization was found and no dams were present. At all sites the stream channel was mostly shaded.

Water quality measurements indicated that Spout Run was generally well-oxygenated with slightly basic pH and high alkalinity and hardness (Table 5). Differences in water quality were generally more pronounced between sampling dates than between sample sites. pH was highest and turbidity lowest in October. Turbidity was consistently lowest at the station farthest downstream.

Sand and cobble were generally the dominant particle sizes encountered (Table 6). At the farthest downstream station, silt was a very important component. Cobble and gravel were consistenly important at the two middle stations.

The quantitative habitat index suggested by Barbour et al. (1999) was employed at each site (Table 7). In general sites scored between 50 and 68 % of possible. The farthest downstream site tended to score slightly lower than the other sites with particularly low subscores for embeddedness and sediment deposition.

V. Discussion

The results of this study indicate that the biological communities in Spout Run were in better condition and exhibited higher integrity than those upstream in Page Brook and Roseville Run that were the subject of past reports (Jones et al. 2002a,b). Nonetheless they were moderately impaired with nonpoint sources and habitat disturbance in the form of livestock grazing being the principal stressor observed in the watershed.

To further assess the impact of habitat degradation a correlation was done between habitat score and Biological Condition Index score using the combined Page Brook-Spout Run data set. It is important to note that all of the field and lab work done to arrive at these scores was conducted by one person (R. Hansen). This decreases variability and lessens bias resulting in a more valid correlation than if multiple workers had been involved. A scatterplot showing the relationship between the two variables in shown in Figure 12. Note that there is a clear pattern in the data moving from lower left to upper right indicating a positive relationship: as habitat score rises, so does Biological Condition Index. The correlation coefficient of this relationship is 0.459 (n=36) which is highly significant. The cluster of points on the left side of the graph are from two sites: SD on Page Brook and 621 on Spout Run. These two sites had unusually low habitat scores given their BCI score. When these two stations were removed and the correlation coefficient recalculated, the correlation coefficient increased to 0.669 (n=30).

The relationship between habitat and biological condition was further examined by graphing both longitudinally (moving from upstream to downstream) (Figure 13). Again there is a general relationship between BCI and EPA habitat. Both increase on Page Brook through PB@M. Both drop at PB@SU and generally rise through PB@617. The Spout Run stations generally show relatively high values for both BCI and habitat. PB@SD and SR@621 were unexpectedly low in habitat.

The macroinvertebrate community at Spout Runs sites was relatively uniform being cominated by chironomids, caddisflies, and beetles with isopods an important presence at the upper two sites. This was in contrast to Page Brook where isopods were often over half of the community and sometimes over 90%. On the other hand, caddisflies were relatively rare in Page Brook, but made up 15-40% of the community in Spout Run. Beetles and mayflies were consistently common in Spout Run and found only a selected sites in Page Brook. The community in Spout Run was consistently characterized by less tolerant taxa than that in Page Brook as revealed by family biotic index. Thus, it is clear that the biological integrity of Spout Run is substantially higher than that in Page Brook. Since Spout Run is downstream from both Page Brook and Roseville Run, our study suggests that a natural recovery of biological integrity is occuring in the system as stress from cattle grazing and trampling decreases in the lower reaches of the watershed.

VI. Conclusions

The Spout Run watershed is a landscape whose vegetative cover has been extensively modified for agriculture. However, the immediate environs of Spout Run did not have the same intensity of grazing pressure that was observed upstream in Page Brook and Roseville Run. The results of this study indicate that the biological communities in Spout Run were in better condition and exhibited higher integrity than those upstream in Page Brook and Roseville Run that were the subject of past reports. Thus, the stream seemed to exhibit a partial recovery as the immediacy of impacts was reduced. Nonetheless they were moderately impaired with nonpoint sources and habitat disturbance in the form of livestock grazing being the principal stressor observed in the watershed.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. 2nd Ed. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Gardner, M.B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Transactions of the American Fisheries Society 110: 446-450.

Hagedorn, C. 1999. Biochemical and DNA patterns in the fecal streptococci for source tracking fecal contamination in water. Draft Report submitted to Office of Planning, County of Clarke, VA.

Hilsenhoff, W.L. 1982. Using a biotic index to evaluate water quality in streams. Technical Bulletin 132. Wisconsin Department of Natural Resources. Madison, WI.

Jones, R.C. and D.P. Kelso. 1994. Bioassessment of Nonpoint Source Impacts in Three Northern Virginia Watersheds. Final Report submitted to U.S. Environmental Protection Agency

Region 3.

Jones, R.C., L. Astin, and K. Rowland. 2002. Bioassessment of Page Brook. Final Report submitted to Office of Planning. Clarke County, Virginia.

Jones, R.C., L. Astin, and K. Rowland. 2002. Bioassessment of Page Brook. Final Report submitted to Office of Planning. Clarke County, Virginia.

Lemly, D.A. 1982. Modification of benthic insect communities in polluted streams: combined effects of sedimentation and nutrient enrichment. Hydrobiologia 87: 229-245.

McCafferty, W.P. 1981. Aquatic Entomology. The Fisherman's Illustrated Guide to Insects and their Relatives. Boston: Jones and Bartlett. 448 pp.

Merritt, R.W. and K.W. Cummins (eds.). 1996. An Introduction to the Aquatic Insects of North America. 3rd edition. Kendall/Hunt Publishing Co. Dubuque, IA.

Pennak, R.W. 1978. Freshwater Invertebrates of the United States. 2nd ed. John Wiley and Sons. New York.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Stream and Rivers: Benthic Macroinvertebrates and Fish. U.S. Environmental Protection Agency. Office of Water. EPA/44/4-89-001.

Shirmohammadi, A., K.S. Yoon, and W.L. Magette. 1997. Water quality in mixed land-use watershed - piedmont region of Maryland. Transactions of the American Society of Agricultural Engineers 40: 1563-1572.

Vannote, R.L. and B.W. Sweeney. 1980. Geographic analysis of thermal equilibria: A conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities. American Naturalist 115: 667-695.

Appendix A

Duplicate Sampling on Spout Run

On each of the last three sampling runs two sites were sampled in duplicate. These duplicates were used to establish variability due to small scale natural variation and lab analytical variation. A pooled measure of the standard deviation was calculated using for each parameter. This in turn was used to calculate the coefficient of variation (CV) which is the standard deviation expressed as a percentage of the mean. Results are shown in Table A-1.

There were rather large differences in CV values among the raw metrics. FBI showed the lowest CV while EPT/Chironomid abundance was the greatest. Looking at the normalized metric scores, EPT/Chironomid abundance again had a high CV, but was exceeded by EPT index and Sorensen's index. Note that Taxa Richness and Family Biotic Index had 0% CV. This was because there was no difference among the duplicates. Interestingly there was no difference among any of the samples for these two metrics: all samples scored 3 for Taxa Richness and 6 for FBI. The total IBI scores had a CV of 15.6% which translated into an IBI % possible of 8.99. Assuming triplicate samples and a normal distribution then two IBI scores would have to differ by 22.3 units on the % of reference scale to be significantly different.

Table 1.
Sample Locations
Spout Run Study

Sample ID	Location			Fall '99	Spr '00	Fall '00	Spr '01
SR-Pow	Spout Run at Powhatan School	Abrev.?		1	1	2	1
SR-Squ	Spout Run at Squire property	"	1	1	2	2	
SR-HC	Spout Run at Hope Center	"		1	2	1	2
SR-621	Spout Run at Rt. 621	"		1	2	1	1

Numbers indicate number of benthic samples collected

Table 2
Metrics Used in the Spout Run Study

Taxa Richness (TR)	-the number of taxa found in a given sample (high values indicate good water quality and habitat)
Family Biotic Index (FBI)	-the average tolerance value of individuals in a sample (low values indicate good water quality and habitat)
EPT/Chironomid Abundance (ept/chir, e/c)	-the number of individuals belonging to the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) divided by the number of individuals belonging to the Dipteran family Chironomidae (midges) (high values indicate good water quality and habitat)
Percent Dominance (% dom, %d)	-the percentage of individuals in a sample represented by the most abundant taxon (low values indicate good water quality and habitat)
EPT Index (EPT I)	-the number of taxa (in this case families) found in a sample belonging to the orders Ephemeroptera, Plecoptera, and Trichoptera (high values indicate good water quality and habitat)
EPT/Isopod abundance (ept/iso, e/i)	-the number of individuals belonging to the insect orders Ephemeroptera, Plecoptera, and Trichoptera divided by the number of individuals belonging to the crustacean order Isopoda (high values indicate good water quality and habitat).
Sorensen's Index of Community Similarity (Sor)	-a measure of who closely the family composition of a sample matches that of the reference sample (high values indicate good water quality and habitat).

Table 3 - Metrics and Biological Condition Index Calculation - Spout Run Study

		Metric Value---------->							Metric % of Ref---------->							Metric Score							Total	BCI (%	Impair-
Station	Date	TaxaR	FBI	ept/chi	%DOM	EPTI	ept/iso	Soren	TaxaR	FBI	ept/chi	%DOM	EPTI	ept/iso	Soren	TaxaR	FBI	ept/chi	%DOM	EPTI	ept/iso	Soren	BCI	of Ref)	ment
PB-SH	31-Jul-00	3	7.996	undef	99.81	0	0.000	0.240	13.64	71.03	undef	99.81	0.00	0.00	0.240	0	3	6	0	0	0	0	9	21.43	SEV
PB-TR	19-Jul-00	10	7.697	4.143	87.53	3	0.083	0.438	45.45	73.79	96.80	87.53	42.86	6.40	0.438	3	3	6	0	0	0	0	12	28.57	MOD
PB-OB	19-Jul-00	11	7.906	1.000	93.12	2	0.009	0.485	50.00	71.84	23.36	93.12	28.57	0.66	0.485	3	3	0	0	0	0	0	6	14.29	SEV
PB-M	19-Jul-00	16	6.936	1.750	60.58	4	0.240	0.579	72.73	81.89	40.89	60.58	57.14	18.58	0.579	3	3	3	0	0	0	3	12	28.57	SEV
PB-SU	24-Jul-00	9	6.346	0.073	54.87	2	0.209	0.452	40.91	89.50	1.70	54.87	28.57	16.22	0.452	3	6	0	0	0	0	0	9	21.43	SEV
PB-SD	31-Jul-00	10	6.359	0.000	50.37	0	0.000	0.375	45.45	89.33	0.00	50.37	0.00	0.00	0.375	3	6	0	0	0	0	0	9	21.43	SEV
PB-RR	24-Jul-00	14	7.813	0.250	83.38	3	0.013	0.556	63.64	72.70	5.84	83.38	42.86	1.01	0.556	3	6	0	0	0	0	3	12	28.57	SEV
PB-617	24-Jul-00	12	7.000	2.000	67.37	4	0.176	0.588	54.55	81.14	46.73	67.37	57.14	13.65	0.588	3	6	3	0	0	0	3	15	35.71	MOD
PB-SH	02-Oct-00	7	7.982	ERR	93.53	1	0.002	0.276	31.82	71.16	ERR	93.53	14.29	0.17	0.276	0	3	6	0	0	0	0	9	21.43	SEV
PB-TR	02-Oct-00	6	7.957	ERR	95.22	1	0.004	0.429	27.27	71.38	ERR	95.22	14.29	0.28	0.429	0	3	6	0	0	0	0	9	21.43	SEV
PB-OB	02-Oct-00	10	7.885	0.125	87.54	1	0.004	0.438	45.45	72.03	2.92	87.54	14.29	0.29	0.438	3	3	0	0	0	0	0	6	14.29	SEV
PB-M	02-Oct-00	18	5.750	0.952	22.30	4	0.645	0.550	81.82	98.78	22.25	22.30	57.14	50.01	0.550	6	6	0	6	0	3	0	21	50.00	MOD
PB-SU	03-Oct-00	9	7.432	0.286	40.93	1	0.062	0.323	40.91	76.43	6.68	40.93	14.29	4.80	0.323	3	3	0	3	0	0	0	9	21.43	SEV
PB-SD	03-Oct-00	12	4.684	0.667	43.33	1	0.500	0.471	54.55	121.26	15.58	43.33	14.29	38.76	0.471	3	6	0	3	0	3	0	15	35.71	MOD
PB-RR	03-Oct-00	11	7.670	0.400	78.51	2	0.022	0.545	50.00	74.05	9.35	78.51	28.57	1.73	0.545	3	3	0	0	0	0	3	9	21.43	SEV
PB-617	03-Oct-00	15	7.284	1.667	54.86	4	0.071	0.595	68.18	77.98	38.94	54.86	57.14	5.50	0.595	3	3	3	0	0	0	3	12	28.57	MOD
PB-SH	10-May-01	6	7.925	0.000	89.96	0	0.000	0.286	27.27	71.67	0.00	89.96	0.00	0.00	0.286	0	3	0	0	0	0	0	3	7.14	SEV
PB-TR	10-May-01	9	6.877	0.039	43.59	2	0.029	0.387	40.91	82.60	0.92	43.59	28.57	2.28	0.387	3	3	0	3	0	0	0	9	21.43	SEV
PB-OB	10-May-01	9	7.123	0.324	61.54	2	0.083	0.452	40.91	79.75	7.58	61.54	28.57	6.46	0.452	3	3	0	0	0	0	0	6	14.29	SEV
PB-M	10-May-01	17	5.377	0.123	50.00	6	1.667	0.513	77.27	105.64	2.87	50.00	85.71	129.20	0.513	3	6	0	3	3	6	0	21	50.00	MOD
PB-SU	09-May-01	9	7.593	0.136	56.50	2	0.022	0.516	40.91	74.81	3.19	56.50	28.57	1.67	0.516	3	3	0	0	0	0	0	6	14.29	SEV
PB-SD	09-May-01	5	6.000	0.000	68.12	0	undef	0.222	22.73	94.67	0.00	68.12	0.00	undef	0.222	0	6	0	0	0	6	0	12	28.57	MOD
PB-RR	09-May-01	12	6.200	0.098	57.64	4	0.317	0.588	54.55	91.61	2.30	57.64	57.14	24.58	0.588	3	6	0	0	0	0	3	12	28.57	SEV
PB-617	09-May-01	12	6.181	0.168	63.00	4	0.533	0.588	54.55	91.90	3.92	63.00	57.14	41.34	0.588	3	6	0	0	0	3	3	15	35.71	MOD
SR-P	05-Nov-99	13	5.129	1.542	40.00	4	0.902	0.457	59.09	110.74	36.02	40.00	57.14	69.96	0.457	3	6	3	3	0	6	0	21	50.00	MOD
SR-S	05-Nov-99	11	5.330	2.850	29.17	4	0.905	0.485	50.00	106.56	66.59	29.17	57.14	70.14	0.485	3	6	3	6	0	6	0	24	57.14	MOD
SR-HC	05-Nov-99	10	4.606	2.269	27.42	3	59.000	0.438	45.45	123.31	53.02	27.42	42.86	4573.6	0.438	3	6	3	6	0	6	0	24	57.14	MOD
SR-621	05-Nov-99	11	4.388	2.113	39.01	5	56.000	0.606	50.00	129.44	49.37	39.01	71.43	4341.0	0.606	3	6	3	3	3	6	3	27	64.29	MOD
SR-P	28-Jun-00	12	5.321	2.387	31.02	5	1.396	0.529	54.55	106.75	55.77	31.02	71.43	108.23	0.529	3	6	3	3	3	6	0	24	57.14	MOD
SR-S	28-Jun-00	13	5.900	2.585	36.75	5	0.955	0.629	59.09	96.27	60.41	36.75	71.43	74.03	0.629	3	6	3	3	3	6	3	27	64.29	MOD
SR-HC	28-Jun-00	10.5	5.027	0.477	52.777	4.5	10.437	0.464	47.72	113.15	11.14	52.78	64.28	809.11	0.464	3	6	0	0	0	6	0	15	35.71	MOD
SR-621	21-Jun-00	11.5	4.852	2.388	38.402	5.5	undef	0.564	52.27	117.12	55.78	38.40	78.57	undef	0.564	3	6	3	3	3	6	3	27	64.29	MOD
SR-P	09-Oct-00	14.5	5.722	1.563	35.047	4	0.52	0.576	65.91	99.35	36.51	35.05	57.14	40.25	0.576	3	6	3	3	0	0	3	18	42.86	MOD
SR-S	09-Oct-00	12.5	5.533	1.694	26.482	4.5	1.24	0.580	56.82	102.66	39.59	26.48	64.28	95.84	0.580	3	6	3	6	0	6	3	27	64.29	MOD
SR-HC	09-Oct-00	14	5.649	0.106	76.67	5	2.429	0.556	63.64	100.56	2.47	76.67	71.43	188.26	0.556	3	6	0	0	3	6	3	21	50.00	MOD
SR-621	09-Oct-00	16	4.726	1.297	33.79	6	48.000	0.526	72.73	120.18	30.31	33.79	85.71	3720.9	0.526	3	6	3	3	3	6	0	24	57.14	MOD
SR-P	15-May-01	13	5.773	0.455	38.94	5	1.053	0.514	59.09	98.40	10.62	38.94	71.43	81.60	0.514	3	6	0	3	3	6	0	21	50.00	MOD
SR-S	15-May-01	14.5	5.053	1.031	38.527	8	2.72	0.547	65.91	112.64	24.08	38.53	114.28	211.11	0.547	3	6	0	3	6	6	0	24	57.14	MOD
SR-HC	15-May-01	12.5	4.849	0.956	47.089	6.5	undef	0.521	56.82	117.23	22.33	47.09	92.86	undef	0.521	3	6	0	3	6	6	0	24	57.14	MOD
SR-621	15-May-01	12	5.333	0.442	50.67	5	16.667	0.471	54.55	106.50	10.34	50.67	71.43	1292.0	0.471	3	6	0	0	3	6	0	18	42.86	MOD

Impairment categories: NOT = non-impaired, MOD = moderately impaired, SEV = severely impaired. undef = either isopods or chironomids were not present leading to 0 in the denominator

Table 4
Habitat Evaluation. General Information
Spout Run

Station	Date	Land Use	Local NPS Sources	Local Erosion	Stream Width(m)	Stream Depth(m)	Channelized	Dam	Canopy Cover
SR-P	28-Jun-00	Field	Some	Moderate	6	1	N	N	Mostly shaded
SR-S	28-Jun-00	Field	Some	Moderate	9	1.5	N	N	Mostly shaded
SR-HC	28-Jun-00	Field	Some	Moderate	5	0.5	N	N	Mostly shaded
SR-621	28-Jun-00	Forest/Res	Some	Moderate	9	0.5	N	N	Mostly shaded
SR-P	09-Oct-00	Field	Some	Moderate	5	1	N	N	Mostly shaded
SR-S	09-Oct-00	Field	Some	Moderate	6	0.5	N	N	Mostly shaded
SR-HC	09-Oct-00	Field	Some	Moderate	5	0.5	N	N	Mostly shaded
SR-621	09-Oct-00	Forest/Res	Some	Moderate	6	1	N	N	Mostly shaded
SR-P	15-May-01	Field	Some	Moderate	3	0.7	N	N	Mostly shaded
SR-S	15-May-01	Field	Some	Moderate	4	0.5	N	N	Mostly shaded
SR-HC	15-May-01	Field	Some	Moderate	3	0.5	N	N	Mostly shaded
SR-621	15-May-01	Forest/Res	Some	Moderate	4	1	N	N	Mostly shaded

Table 5
Habitat Evaluation. Water Quality
Spout Run

Station	Date	Temp (oC)	DO (mg/L)	DO (%sat)	pH	Alkalinity (mgCaCO3/L)	Hardness (mgCaCO3/L)	Conductivity (umho)	Conductivity (umho@25oC)	Turbidity (NTU)
SR-P	28-Jun-00	–	–	–	8.08	260	274	–	–	14.9
SR-S	28-Jun-00	–	–	–	8.00	256	278	–	–	10.3
SR-HC	28-Jun-00	–	–	–	7.91	258	250	–	–	11.1
SR-621	28-Jun-00	–	–	–	8.04	252	270	–	–	4.1
SR-P	09-Oct-00	9.6	9.38	82.6	8.51	243	273	396	578	5.2
SR-S	09-Oct-00	9.9	10.83	96.0	8.71	247	277	395	574	3.2
SR-HC	09-Oct-00	9.7	11.5	101.5	8.71	232	268	380	554	9.4
SR-621	09-Oct-00	9.9	10.67	94.6	8.70	236	272	380	551	3.1
SR-P	15-May-01	11.5	9.32	85.8	7.90	–	–	434	606	23.6
SR-S	15-May-01	12.5	10.57	99.6	8.12	–	–	437	595	16.6
SR-HC	15-May-01	13.5	11.13	107.3	8.22	–	–	435	578	11.6
SR-621	15-May-01	13.4	10.47	100.7	8.18	–	–	438	583	5.5

Table 6
Habitat Evaluation. Substrate
Roseville Run

			Percent of Total Area						
Station	Date	Black Stones	Bedrock	Boulder	Cobble	Gravel	Sand	Silt	Clay
SR-P	28-Jun-00	No	2	5	5	10	39	39	0
SR-S	28-Jun-00	No	10	20	30	20	10	10	0
SR-HC	28-Jun-00	No	10	15	20	20	20	15	0
SR-621	28-Jun-00	No	2	5	5	5	40	40	3
SR-P	09-Oct-00	No	10	15	15	25	25	10	0
SR-S	09-Oct-00	No	5	10	25	20	25	10	5
SR-HC	09-Oct-00	No	5	15	15	15	40	5	5
SR-621	09-Oct-00	No	5	10	15	15	15	40	0
SR-P	15-May-01	No	5	15	15	15	40	5	5
SR-S	15-May-01	No	5	15	25	25	25	5	0
SR-HC	15-May-01	No	10	20	40	20	10	0	0
SR-621	15-May-01	No	0	5	5	5	25	60	0

Table 7
Habitat Evaluation. EPA Quantitative Habitat Scoring
Spout Run

Station	Date	Substrate & Cover	Embedded-ness	Vel/Dep Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Sinuosity	Bank Stability	Vegetative Protection	Riparian Width	Overall Score	% of Possible
SR-P	28-Jun-00	9	13	16	15	13	18	17	5	8	5	119	59.5
SR-S	28-Jun-00	8	15	13	8	13	14	16	6	5	2	100	50
SR-HC	28-Jun-00	9	15	16	10	16	18	13	5	7	3	112	56
SR-621	28-Jun-00	8	8	18	8	18	16	13	4	7	5	105	52.5
SR-P	09-Oct-00	16	16	17	11	20	17	12	7	9	7	132	66
SR-S	09-Oct-00	16	16	13	14	18	15	13	6	8	6	125	62.5
SR-HC	09-Oct-00	17	16	14	16	18	18	16	7	7	6	135	67.5
SR-621	09-Oct-00	11	10	12	5	18	16	14	2	4	3	95	47.5
SR-P	15-May-01	15	16	10	17	18	17	11	6	8	7	125	62.5
SR-S	15-May-01	17	18	18	17	18	16	14	4	7	6	135	67.5
SR-HC	15-May-01	15	18	19	16	17	18	15	5	5	6	134	67
SR-621	15-May-01	2	2	13	2	15	15	13	0	4	2	68	34

Table A-1
Standard Deviations and Coefficients of Variation
Derived from Duplicate Samples

Parameter	Standard Deviation	Coefficient of Variation
Raw Metric Scores		
Taxa Richness	2.27	17.9%
Family Biotic Index	0.216	4.2%
EPT/Chironomid Abundance*	1.30	66.9%
%Dominance	15.6	47.1%
EPT Index	1.41	25.7%
EPT/Isopod Abundance*	14.3	26.1%
Sorensen's Index	0.0523	9.7%
Nomalized Metric Scores (0-6 basis)		
Taxa Richness	0	0%
Family Biotic Index	0	0%
EPT/Chironomid Abundance	1.22	61.2%
% Dominance	1.22	40.8%
EPT Index	2.29	83.3%
EPT/Isopods Abundance	0.87	15.1%
Sorensen's Index	1.50	85.7%
IBI Total Score	3.77	15.6%
IBI (% of Possible)	8.99	15.6%

*Standard deviation calculations for these parameters were based on 4 pairs of duplicates due to undefined values (division by 0) for some samples.

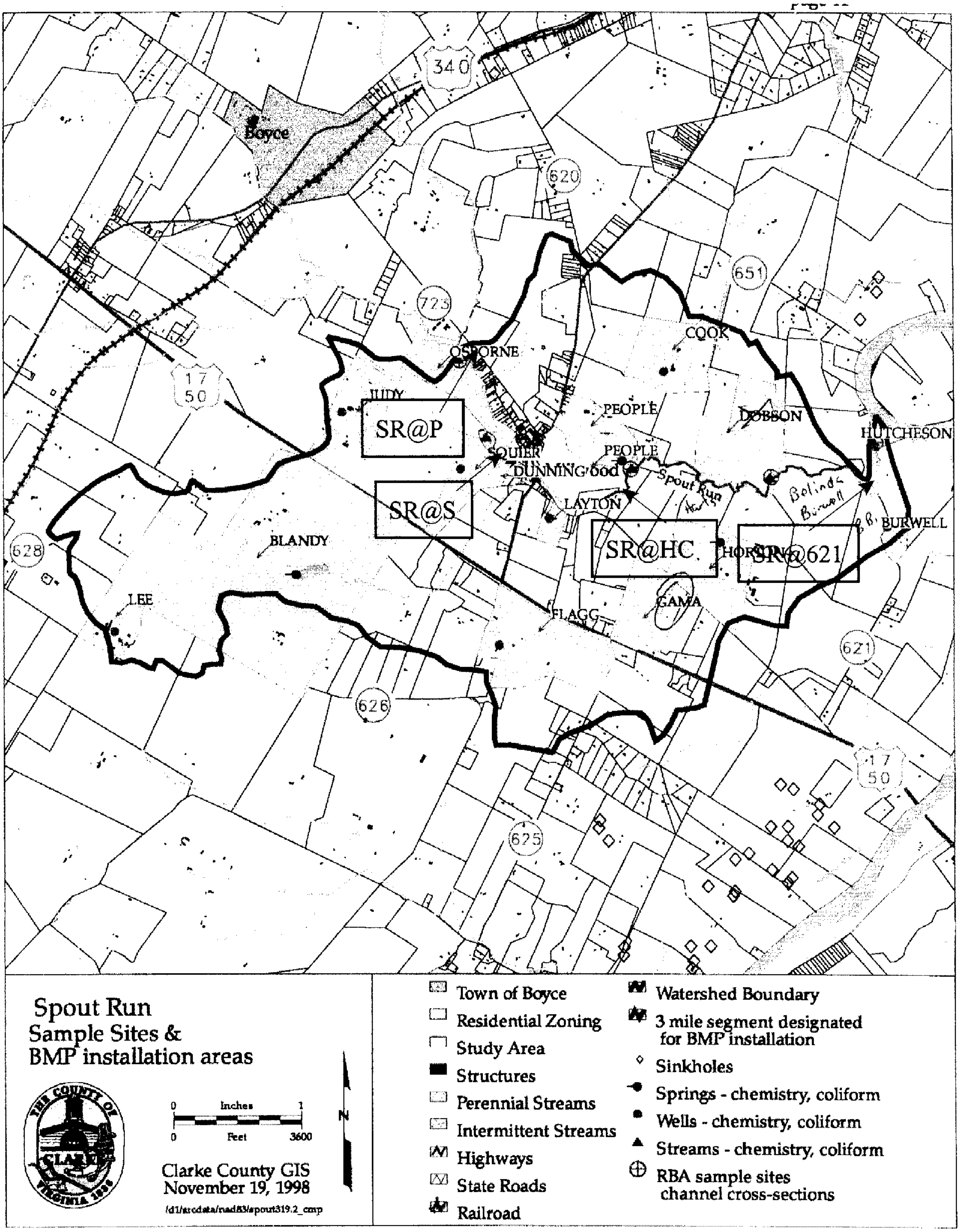

Figure 1. Map of the Study Area showing sampling sites

Spout Run Data

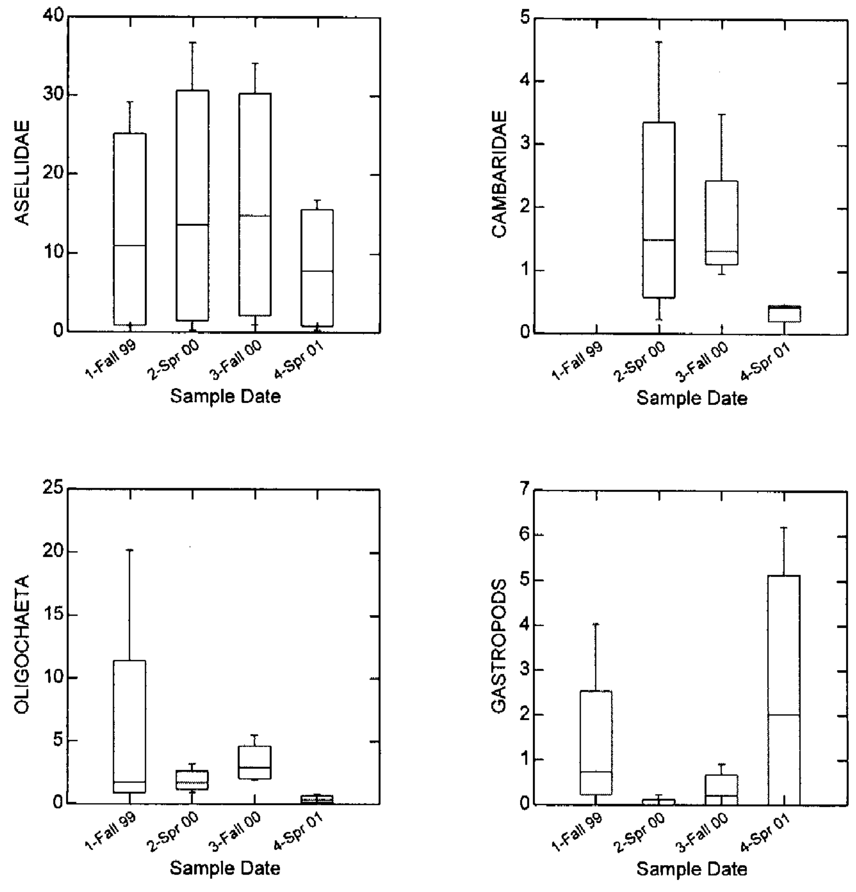

Figure 2. Major non-insect taxa as percentage of total individuals. Trends by sampling date pooling data from all sites. Asellidae (isopods). Cambaridae(crayfish). Oligochaeta (aquatic earthworms), Gastropoda (snails).

Spout Run Data

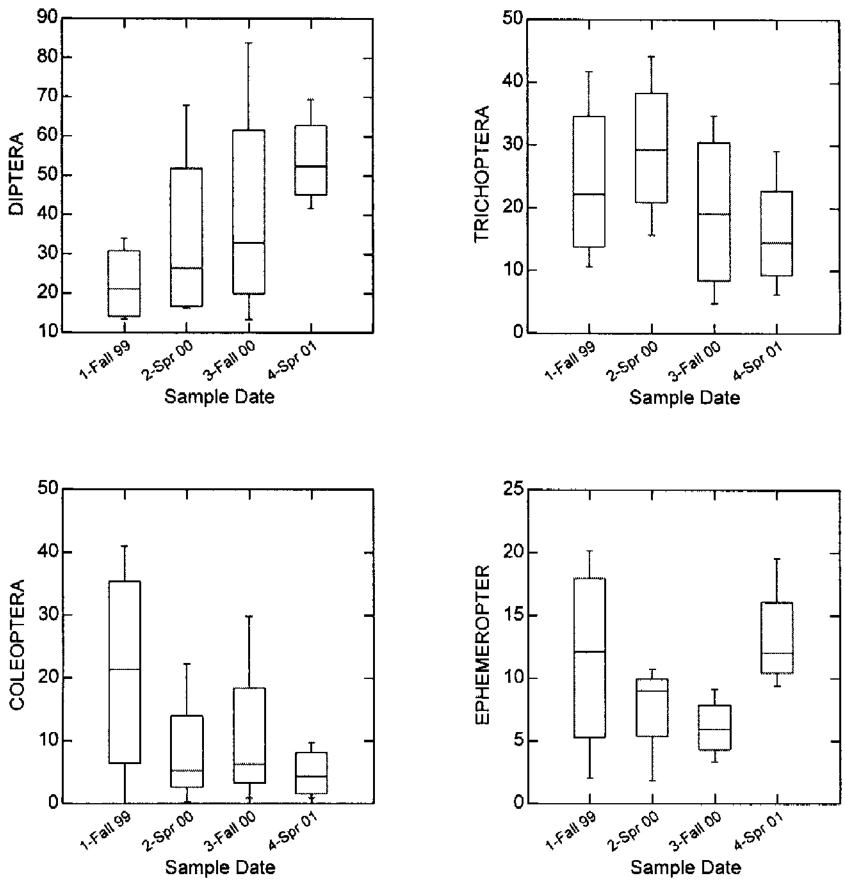

Figure 3. Major insect taxa as a percentage of total individuals. Trends by sampling date pooling data from all sites. Diptera (two-winged flies). Trichoptera (caddisflies). Coleoptera (beetles). Ephemeroptera (mayflies).

Spout Run Data

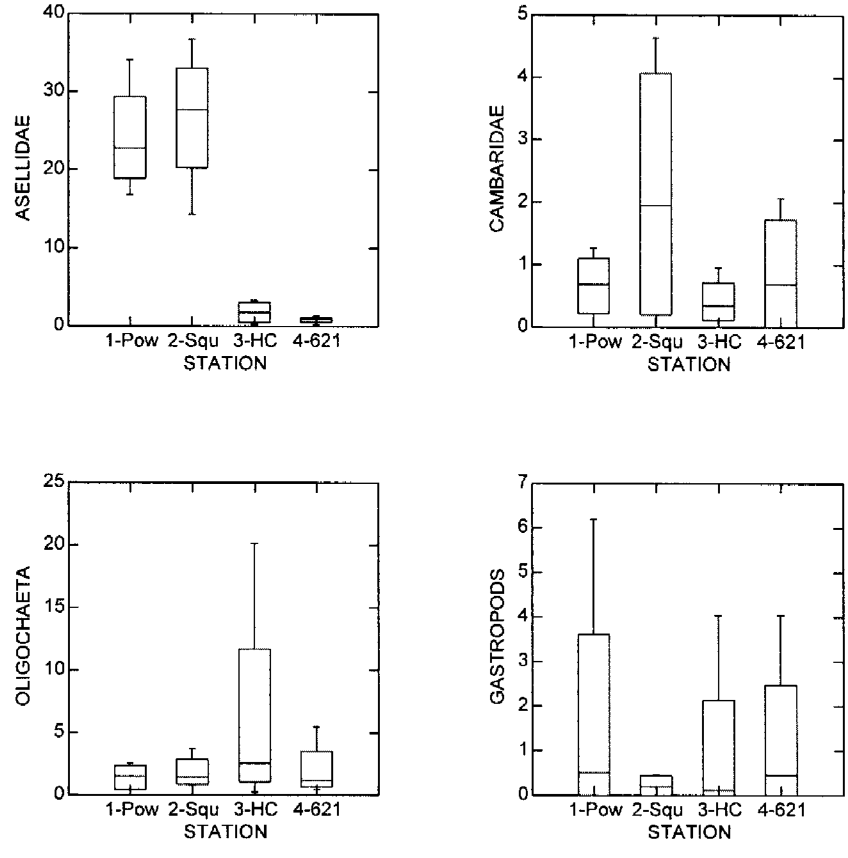

Figure 4. Major non-insect taxa as percentage of total individuals. Trends by sample site pooling data from all dates. Asellidae (isopods). Cambaridae(crayfish). Oligochaeta (aquatic earthworms), Gastropoda (snails).

Spout Run Data

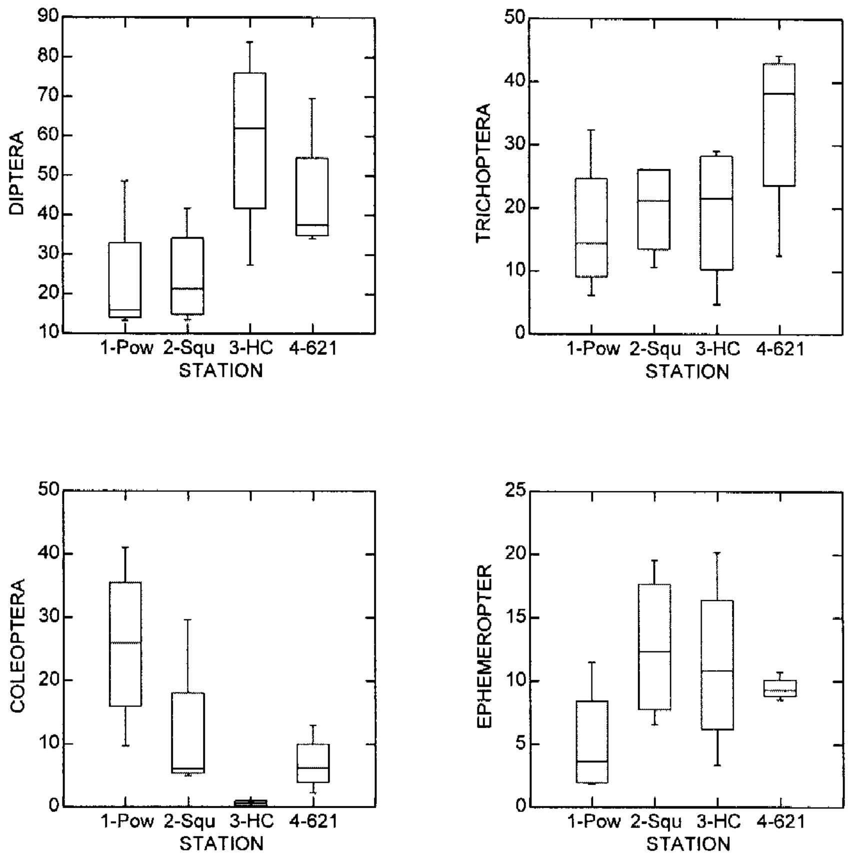

Figure 5. Major insect taxa as a percentage of total individuals. Trends by sample site pooling data from all dates. Diptera (two-winged flies). Trichoptera (caddisflies). Coleoptera (beetles). Ephemeroptera (mayflies).

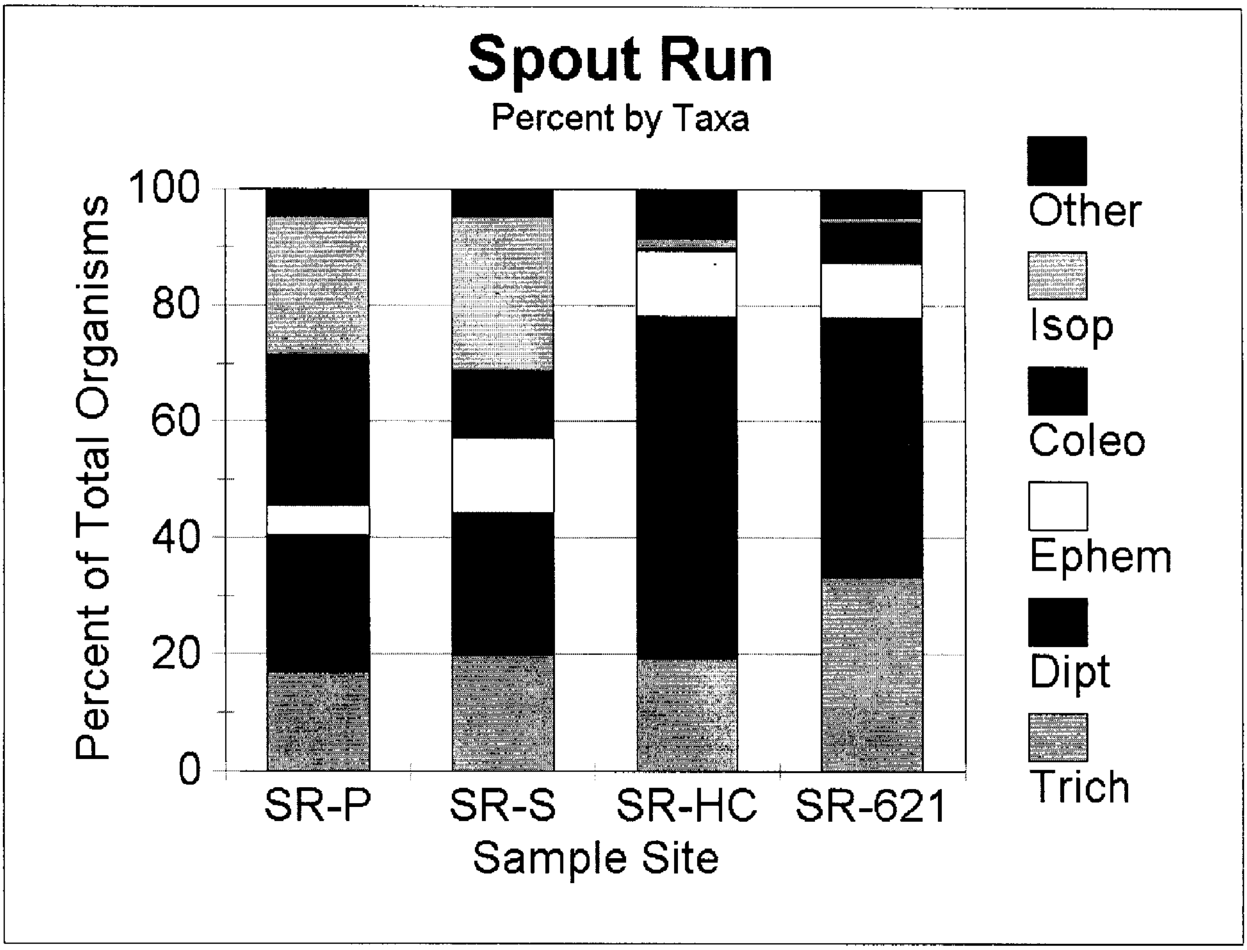

Figure 6. Relative abundance by major taxa. Average over all sample dates.

Spout Run Stations

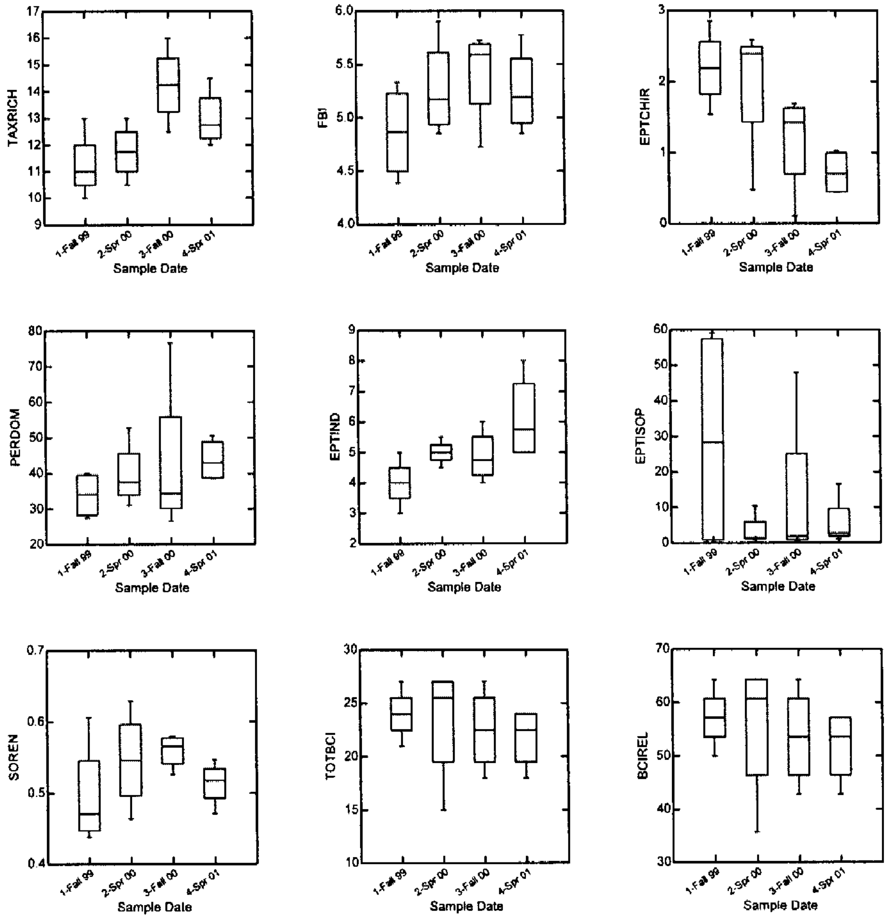

Figure 7. Metric values. Trends by sampling date pooling data from all sites. TAXARICH=taxa richness, FBI=family biotic index, EPTCHIR=EPT/Chironomid abundance, PERDOM=percent dominance, EPTIND=EPT index, EPTISOP=EPT/Isopod abundance, SOREN=Sorensen's index of community similarity, TOTBCI=Biological Condition Index Score (out of 42), BCIREL=BCI as a percentage of reference BCI.

Spout Run Stations

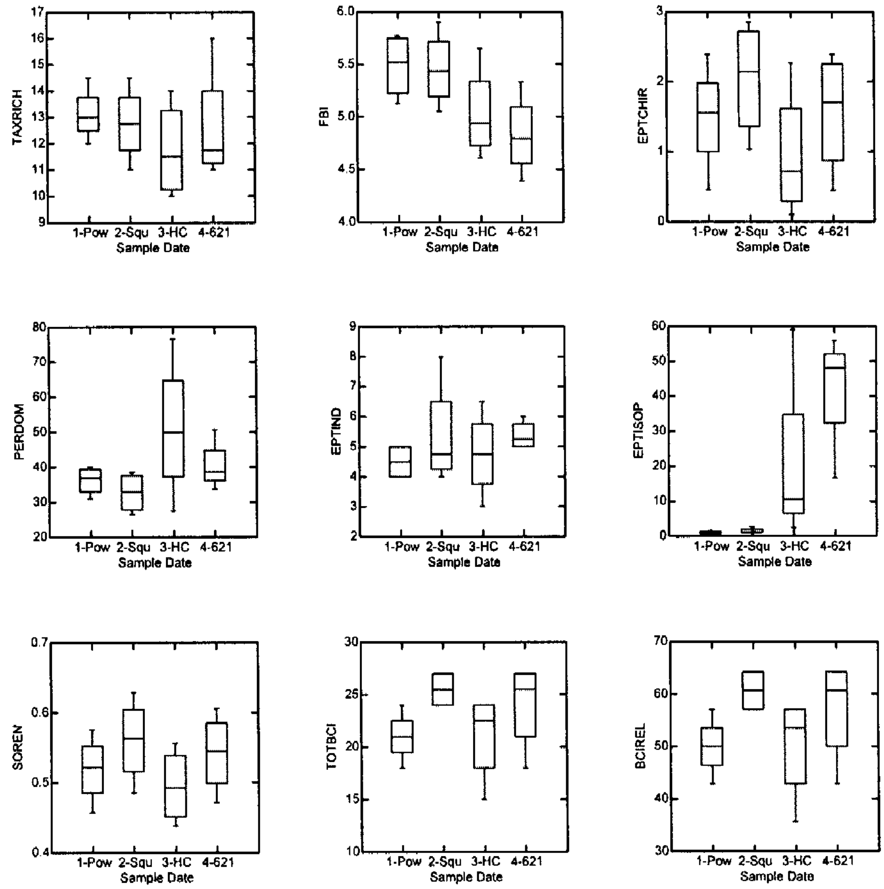

Figure 8. Metric values. Trends by sampling date pooling data from all sites. TAXARICH=taxa richness, FBI=family biotic index, EPTCHIR=EPT/Chironomid abundance, PERDOM=percent dominance, EPTIND=EPT index, EPTISOP=EPT/Isopod abundance, SOREN=Sorensen's index of community similarity, TOTBCI=Biological Condition Index Score (out of 42), BCIREL=BCI as a percentage of reference BCI.

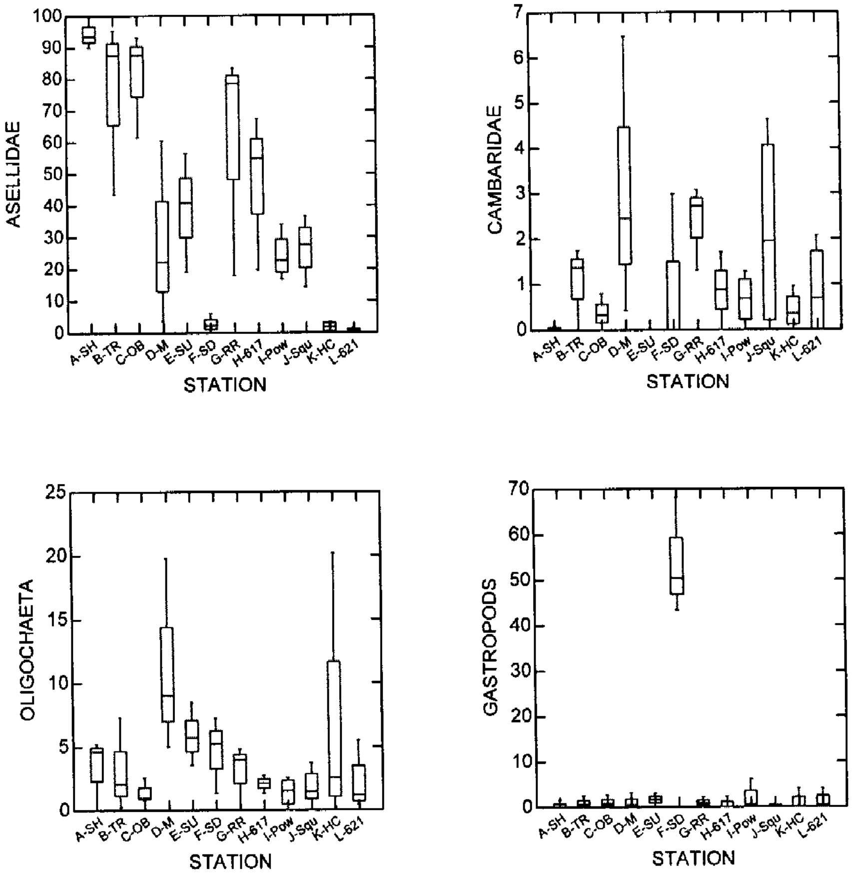

Figure 9. Combined Page Branch-Spout Run dataset for 1999-2001. Major non-insect taxa as percentage of total individuals. Trends by sample site pooling data from all dates. Asellidae (isopods). Cambaridae(crayfish). Oligochaeta (aquatic earthworms), Gastropoda (snails).

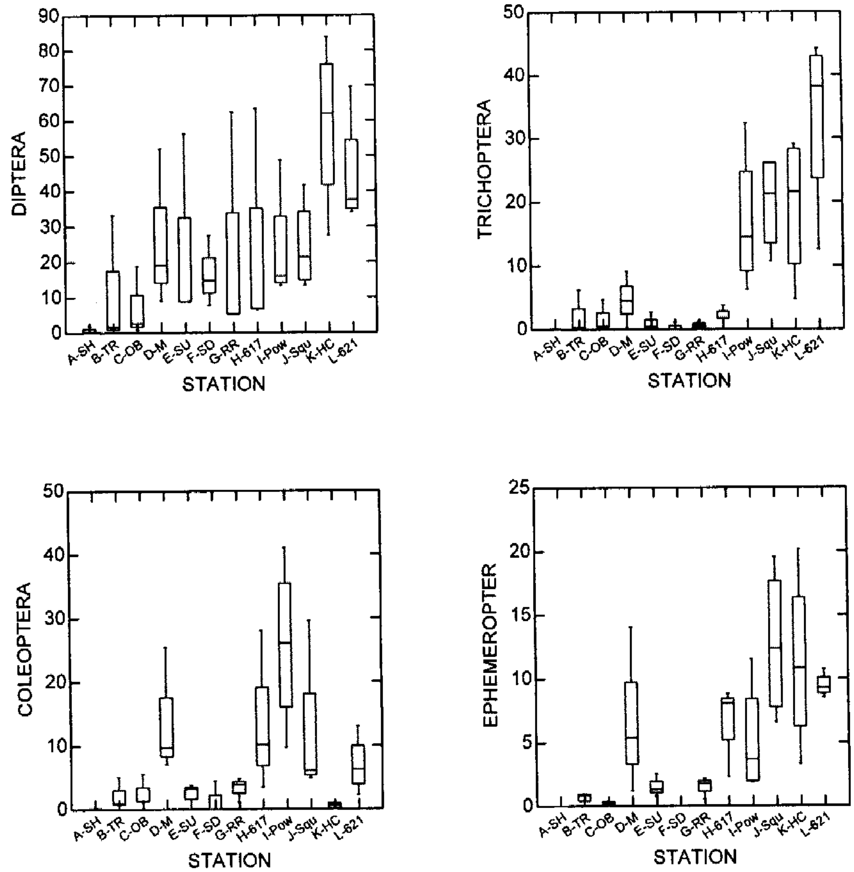

Figure 10. Combined Page Branch-Spout Run dataset for 1999-2001. Major insect taxa as a percentage of total individuals. Trends by sample site pooling data from all dates. Diptera (two-winged flies). Trichoptera (caddisflies). Coleoptera (beetles). Ephemeroptera (mayflies).

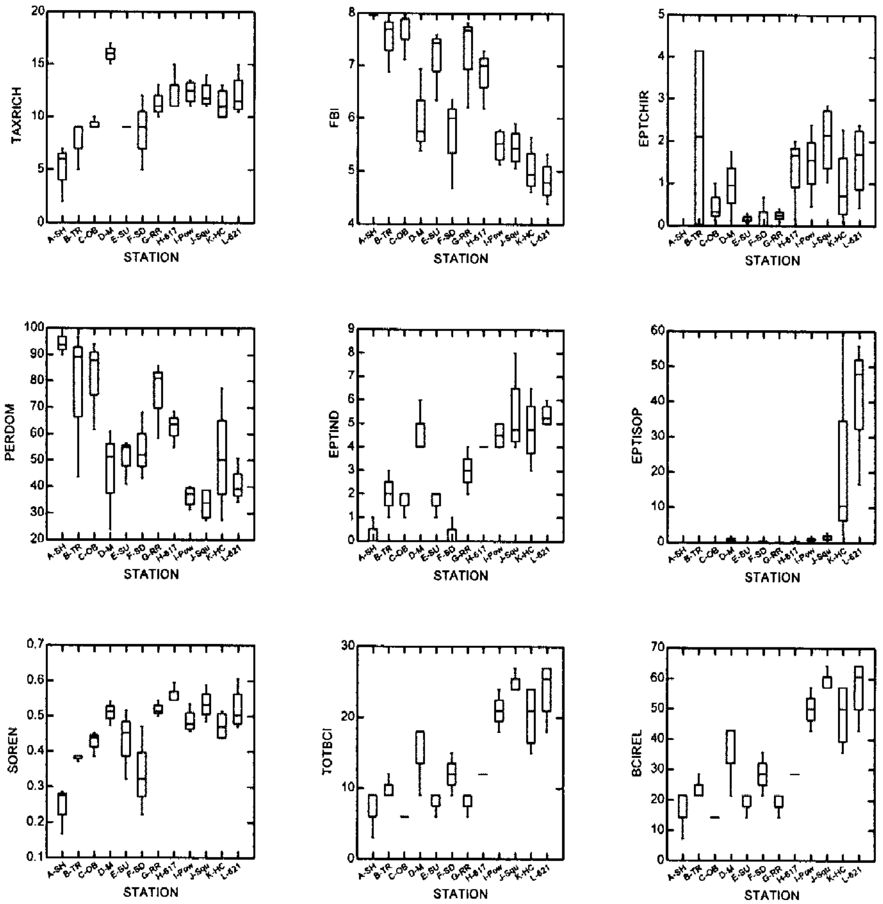

Figure 11. Combined Page Brook-Spout Run dataset for 1999-2001. Metric values. Trends by sampling date pooling data from all sites. TAXARICH=taxa richness, FBI=family biotic index, EPTCHIR=EPT/Chironomid abundance, PERDOM=percent dominance, EPTIND=EPT index, EPTISOP=EPT/Isopod abundance, SOREN=Sorensen's index of community similarity, TOTBCI=Biological Condition Index Score (out of 42), BCIREL=BCI as a percentage of reference BCI.

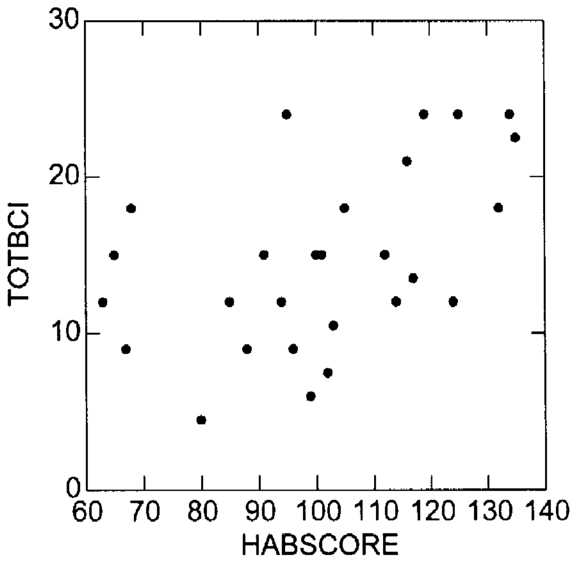

Figure 12. Correlation between Biological Condition Index Score (out of 42) and EPA Quantitative Habitat Score (out of 200). Combined Page Brook-Spout Run data 2000-2001.

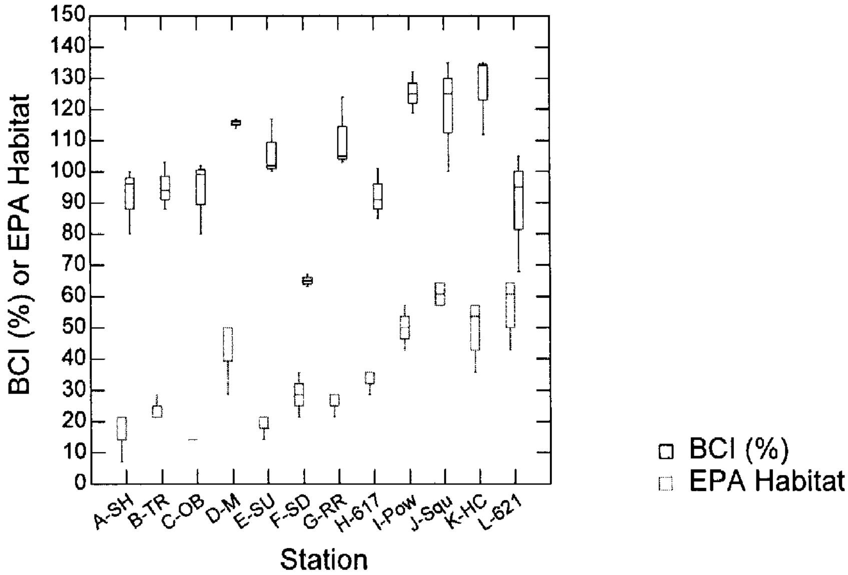

Figure13. Longitudinal Pattern in Biological Condition Index Score (% of Reference) and EPA Quantitative Habitat Score (out of 200). Combined Page Brook-Spout Run data 2000-2001. Lower box at each site is BCI score and upper box is EPA Habitat score