A COMPARISON OF CONTEMPORARY AND HISTORICAL BIOLOGICAL ASSESSMENT OF COAL MINING EFFECTS ON AQUATIC MACROINVERTEBRATE STREAM COMMUNITIES IN SCOTT, CAMPBELL, AND ANDERSON COUNTIES, EASTERN TENNESSEE

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Amandа Lockwood Whitley

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To the Graduate Council:

I am submitting herewith a thesis written by Amanda Lockwood Whitley entitled "A comparison of Contemporary and Historical Biological Assessment of Coal Mining Effects on Aquatic Macroinvertebrate Stream Communities in Scott, Campbell, and Anderson County, Easter Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biology.

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We have read this Thesis

And recommend its acceptance:

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DEDICATION

This thesis is dedicated to my husband Pete Whitley, without his support and constant love I would have never been able to complete this. I love you very much and am very lucky to have such a great friend.

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ABSTRACT

Surface mining of coal has been practiced in the New River watershed of East Tennessee since the 1940s. This study examines the effects of surface mining coal on stream macroinvertebrate communities using contemporary Tennessee Department of Environment and Conservation (TDEC) protocols ("modified SQKICK") and compares this method to methods employing quantitative Surber sampling used in studies conducted from 1978-1986. Habitat assessment was conducted on all sampled streams and abiotic factors including water temperature, dissolved oxygen, pH, total dissolved solids, and alkalinity were also measured. Surber samplers sample a more precisely defined area of stream substrate, ~.1 m^2, and therefore provide an estimate of macroinvertebrate density. The TDEC modified SQKicknet protocol requires collection of macroinvertebrates using D-frame kicknets from four separate riffles. The 1981 studies collected 8 paired surber samples (16 Surber samples total) from several riffles. The metric values obtained from the kicknet samples were compared to those obtained from the Surber samples collected in 2008. The metric values obtained from the Surber samples collected in 2008 were also compared to metric values obtained from Surber samples collected in 1981.

Habitat assessment classified streams from "not impaired" to "moderately impaired." Embeddedness and substrate instability were the main factors related to lower habitat assessment classifications. Water quality parameters measured indicated elevated pH, alkalinity, total suspended solids and specific conductivity in streams with recent mining in there watersheds. Metric values obtained from kicknets were similar to those obtained from Surber samples collected in 2008. Bioassessment classifications of the

SQkicknet samples varied from "not impaired" to "moderately impaired." Bioassessment of the paired Surber samples collected in 2008 classified the streams from "not impaired" to "moderately impaired," and did not differ greatly from the kicknets. Bioassessment of Surber samples collected in 1981 were classified from "not impaired" to "severely impaired" depending on the extent of mining disturbance in there watershed at that time. Given that little reclamation of mine sites was practiced prior to 1978, the generally better bioassessment classifications of 2008 Surber samples compared to 1981 Surber samples indicates reclamation of mined streams helps recovery; however, habitat assessments and water chemistry indicate there are still measurable mining effects.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER I

INTRODUCTION

A Brief History of Biomonitoring techniques and their relevance to this study

Current methods of aquatic macroinvertebrate sampling and biological monitoring of streams have changed over the years. However, many streams have been monitored extensively for time frames that encompass the changes in monitoring techniques. Thus, biological monitoring results obtained with older methods are hard to compare to those obtained with contemporary methods. One purpose of this study is to demonstrate that biological data collected with one sampling method, i.e., Surber samplers, from the 1970-80's can be used as those specified by current State of Tennessee bioassessment protocols, i.e., D-nets and kick nets, to obtain valid bioassessment classifications.

Coal mining is the principle anthropogenic factor impairing streams in the area of this study. Biological, chemical, and physical monitoring of streams in this area has been performed since at least the mid-1970. Coal mining practices and regulations have evolved continuously since then to the present, a trend expected to continue into the future. However, given that regulations and mining have varied at the same time as methods used to evaluate impacts on streams, it is difficult, if not impossible to assess the efficacy of new regulations and mining practices unless earlier monitoring techniques can be shown to yield similar results to contemporary techniques. The ability to use data collected by one method with valid comparability to data collected by a different method is a concept sometimes referred to as "transportability" (Wu and Legg, in press).

Documenting the "transportability" of data collected by earlier methods to those collected by contemporary methods will allow a review of the long-term impacts of surface mining coal on streams by assessing streams with data collected recently and performing the same assessment using data collected in the past. This will also allow an evaluation of the efficacy of contemporary mining regulation and mining reclamation practices.

A Brief History of Mining Regulation in the U.S.

Prior to 1967 there was no regulation of mining. Strip mining regulation began in Tennessee in 1974 where regulations and rules on how to process coal were outlined (State of Tennessee, 2009). Federal regulation of surface mining began in 1977 with passage of the Surface Mining Control and Reclamation Act (SMCRA). This act has had numerous amendments, the most recent in 1993. SMCRA requires that miners must include in their permit request a plan describing how the area will be reclaimed back to pre-mining conditions (US Code, 2009).

Since the 1990's, mountaintop removal (MR) has become a common method of coal extraction in southern Appalachia. Mountaintop removal mining is a surface mining technique that removes the entire mountain top to reach successive layers of coal. First, the forests are clearcut and removed. Then, the part of the mountain above the highest elevation coal seam is blasted with explosives and removed, usually by depositing it into adjacent hollows and valleys, i.e., valley fills (US EPA, 2005; OSM, 2007). Then, the exposed coal is scooped up and sent to market. The process is repeated to expose successive layers of coal until the cost of removing the mountain exceeds the value of the remaining coal seams. The volume of unconsolidated spoil always exceeds the original volume of the removed portion of consolidated mountain because solid rock is blasted into a mix of particle sizes with voids between them. Thus MR mining, and to a lesser extent, contour surface mining cannot be practiced without valley fills because there is more spoil than can be piled back on top of the mountain. In contour surface mining, fills are much smaller, are usually limited to "heads of hollows," and rarely bury permanent streams. Streams in the filled valleys are permanently destroyed and their downstream reaches impaired by the huge disturbance to the ecosystem. Mountaintop removal mining is not common in the area of this study, but unless curtailed by new, more stringent regulation of mine waste deposition in streams, it is quite possible that the practice will expand in the study area.

A Brief History of Mining in the New River Watershed

Coal strip mining has been practiced in east Tennessee since the 1940's (Vaughan et al., 1978). Strip mining, also referred to as surface mining, is the practice of removing overlying layers of rock and soil (i.e., "stripping") to reach the underlying mineral, in this case coal, without tunneling into the ground. Surface mining creates large volumes of unstable soil and rock that can be easily eroded (Leist et al., 1982). Large quantities of sediment washing into streams impair aquatic ecosystems and increase flooding. Reclamation with silt retention basins was one of the practices implemented to mitigate these problems (May et al., 1981). If proper treatment of the spoil is not done, costs of remediation, such as dredging waterway to remove sediment or destruction of wildlife and recreational uses is increased (May et al., 1981). Proper treatment can be described in many ways. The Surface Mining Control and Reclamation Act of 1977 (SMCRA) requires that multiple requirements be met before approval of mining (US Code, 2009). This includes considering current land use and how the land will be used after mining practices (US Code, 2009). The US Geological Survey indicates that proper spoil treatment requires analysis of the hydrology of the area potentially impacted by mining and that measures be taken to control mining damage by the permitee (May et al., 1981).

Coal consumption increased 1.4% in 2007 over 2006, mostly from combustion in coal fired power plants to produce electricity. In the states Tennessee, Kentucky, Alabama, and Arkansas coal production for power has decreased by 0.7 percent with natural gas taking up some slack. However, in all other regions coal consumption has risen (US DOE, 2009). This increase in coal consumption has raised environmental concerns that coal producing regions of the U.S., such as eastern Tennessee, will be adversely impacted by increased mining to satisfy this demand.

The area of interest for this study spans portions of Scott, Anderson, Morgan, and Campbell counties and has historically been a center of coal mining activity in Tennessee (Figure 1.1). These four counties have a combined total of two active underground and four surface mines that produced 849 thousand short tons of coal in 2007 (US DOE, 2009).

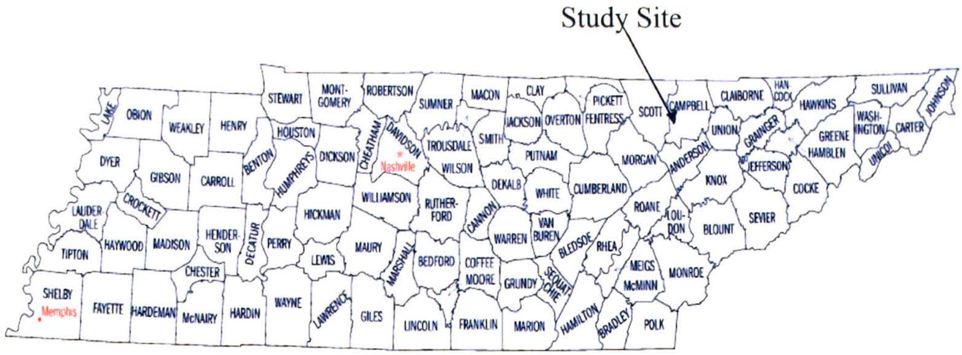


Figure 1.1. Map of Tennessee showing location of Scott, Anderson, Morgan, and Campbell County. Map adapted from http://quickfacts.census.gov/qfd/maps/tennessee_map.html

Geology and Ecology of the New River Watershed

The study area is the Cumberland Mountains, Southwestern Appalachian Ecoregion (US EPA, 2007). This ecoregion is characterized by mixed hardwoods and shortleaf pine forests with steep slopes and deep ravines (US EPA, 2007). The terrain is very rugged and the slope of the area averages 14° (Leist et al., 1982). Soils of this region are derived from sandstone, siltstones, and shale (Schiller,1986; Leist et al., 1982; Gaydos et al.; 1982). Yearly rainfall was 55 inches in the surrounding area with July and March having the most rainfall (Leist et al., 1982).

Coal beds in this area vary in thickness but are extremely long and found beneath a layer of clay. Soils of this area are well drained, stony and loamy with moderate to high potential for erosion. Soils are low in fertility and soil depth ranges from shallow to deep (Gaydos et al., 1982).

Rainfall data collected in Oneida County, Tennessee for the months of June and July of 2008 were 3.14 inches in June and 8.16 inches in July. Total yearly rainfall for Oneida was 49.1 inches. Individual watersheds could have received considerably more or less than this amount given that much of the precipitation at this time of year occurs as scattered showers. The average temperature was 22°C and 23°C in June and July, respectively (NOAA, 2009). Land cover in the New River Watershed includes mining, pasture, row crop agriculture, developed areas, and forest (USGS, 2009). Forest is the largest type of land cover lost due to mining activities (USGS, 2009).

The New River watershed is 382 square miles in portions of Morgan, Campbell, Scott, and Anderson counties in Tennessee. Figure 1.2 is a Google Earth map of the New River watershed illustrating the sampling sites and mined areas. All streams in this study were studied previously in 1978-1986 (Minear, et al., 1976; Vaughan, et al., 1978; Vaughan, 1979; Tolbert and Vaughan, 1980; Schiller, 1989; Dickens et al., 1989). The two streams not mined in these previous studies, Crabapple and Lowe Creeks, remain unmined and served as references streams in this study (Fig. 1.3a). Crabapple and Bruce Creek feed into Louse Creek which is a second order stream (Fig. 1.3b).

Bill's Branch and Green Branch both had recent mining activity in 2006 (Fig. 1.3c and 1.3d). Sugarcamp Creek had some mining impacts during the time of our study and had good flow compared to some of the streams we sampled in June (Fig 1.4 a.). Ursery Creek and Indian Fork were located in close proximity to each other and had impacts other than mining. Ursery Creek had an all terrain vehicles (ATV) road through it (Fig. 1.4 b.). Indian Fork had a road right along it along with housing; many of the residents mowed the lawn to the bank of the stream (Fig. 1.4 c.).

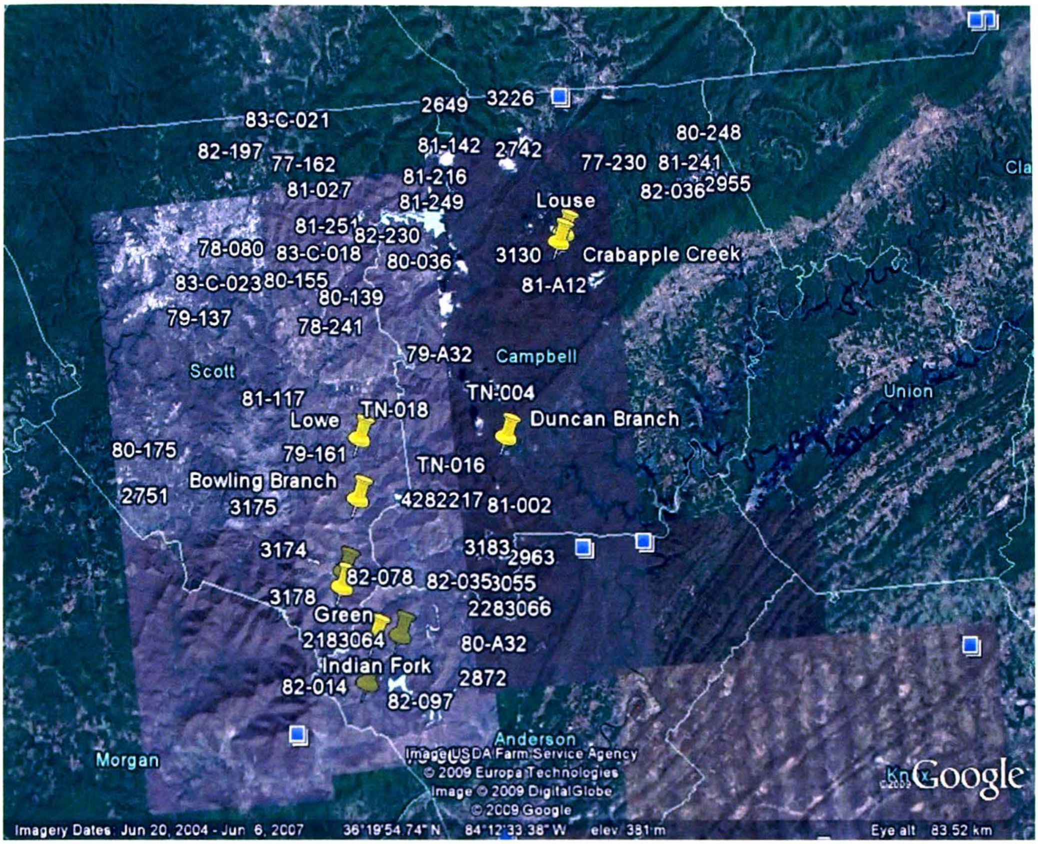
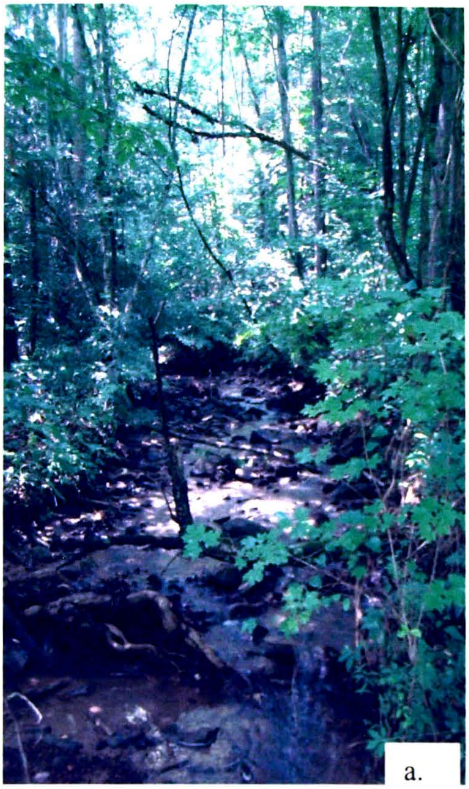


Figure 1.2 Google Earth image of sampling sites and mining that occurred in the watershed since SMCRA was enacted.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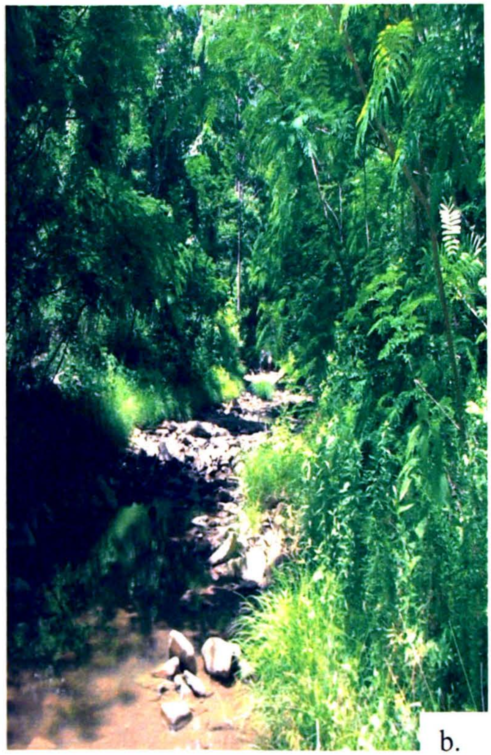
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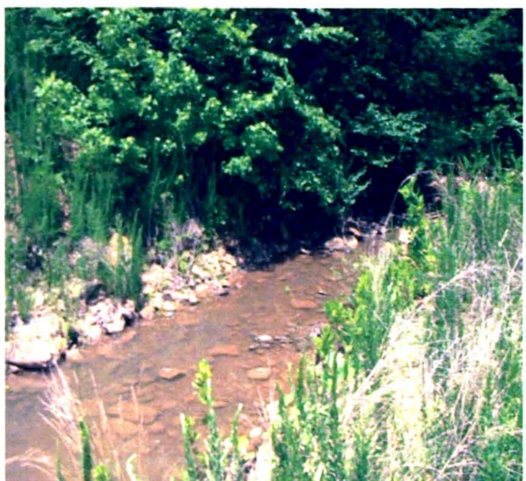
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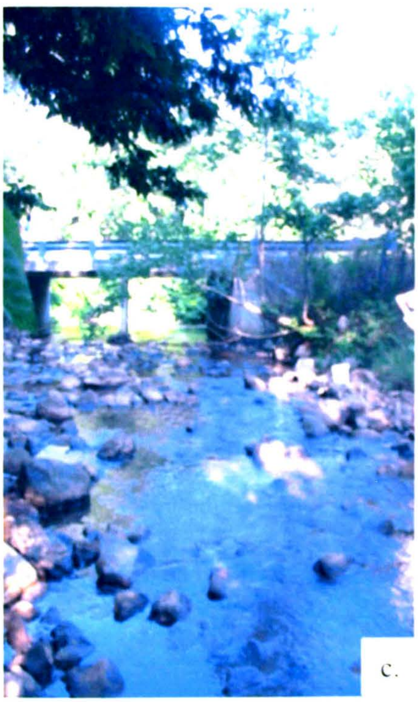
Figure 1.3a-d. a. Crabapple Creek, Campbell Co, Tennessee. b. Louse Creek, Campbell Co., Tennessee. c. Bill's Branch, Scott Co., Tennessee. d. Green Branch, Scott Co, Tennessee.

Figure 1.4 a-c. a. Sugarcamp Creek, Anderson Co, Tennessee. b. Ursery Creek, Anderson Co, Tennessee. c. Indian Fork, Anderson Co, Tennessee.



A Brief Refresher on pH and Alkalinity

This study used many different abiotic factors in addition to macroinvertebrates for demonstrating the health of a stream. In order to understand the importance of these factors it is important to know the difference between pH and alkalinity which was measured in previous studies as well as ours. The pH is the representation of hydrogen ion concentration represented on a logarithmic scale of 0 – 14. If H^+ ion concentration exceeds OH^- ion concentration, then pH is < 7 and the water is acidic; conversely if OH^- anion concentration exceeds H^+ ion concentration then pH > 7 and the water is basic.

Alkalinity is a measure of the buffering capacity of water, i.e., the ability to resist a change in pH when an acid or base is added. Alkalinity of stream water in the study area is primarily due to dissolved $CaCO_3$ resulting from the weathering of limestone, leading to high carbonate levels (Cole, 1979). Alkalinity can be measured by titration with acid. In our study area, streams naturally have low alkalinity and little buffering capability (May et al, 1982). Surface mining of coal increases stream alkalinity because it disturbs calcium carbonate-bearing rocks and the weathering of this rock increases the concentration of calcium carbonate and other acid buffering ions in receiving streams. Generally streams in the southern Appalachians do not become acidic from surface mining of coal as long as sulfur-bearing rocks are not abundant in the mine site (Pond et al., 2008). Calcium, iron, and magnesium levels fluctuated seasonally and unpredictably in some of the mined streams.

Previous Research in the Study Area

There have been several previous studies of mining effects on streams of the New River watershed (Table 1.1). Minear et al., (1976) studied six streams including Indian Fork, Anderson Creek, Lowe Branch, Bill's Branch, Bowling Branch, and Green Branch and described the physical and chemical effects of contour coal mining on streams including changes in temperature, pH, turbidity, and mineral content. They compared their findings to those reported from other studies in similar areas such as Kentucky and West Virginia. The results showed that pH varied throughout the year and could become acidic in some of the mined streams such as Indian Fork; this stream was red with iron oxide contributing to a low pH already. This study also found that pH levels in undisturbed streams were often below 6.0. Suspended solids were higher in streams that were mined. They did not look at specific conductivity; however, given the high concentrations of metals and suspended solids they observed, it is probable that specific conductivity would have also fluctuated proportionately, but would have been high.

Vaughan et al. (1978) studied the fish, insects, and diatoms of 24 streams in the New River watershed of eastern Tennessee, including the two reference streams of this study, Lowe and Crabapple Creeks, which remain undisturbed by mining to the present as far as we can tell. Most of the other streams had more than 10% of their watershed drainage area disturbed by mining at the time of Vaughan's study. In this study, the Shannon-Weaver Diversity Index was used as the measurer of stream health. Insect diversity declined sharply in streams 4-6 years after mining had stopped. Diversity returned to premining levels after a 20-year period of no disturbance, but Ephemeroptera diversity never fully recovered to premining levels. Thus, surface mining of coal appears to cause very long-term changes in the taxonomic structure of these streams. Fish diversity declined during the 4-6 year post-mining period, and never recovered in some of the New River Watershed streams. Diatoms never recovered in any of the streams and the authors attributed this to repopulation problems.

Vaughan, (1979) studied the fish and diatoms in four streams in the New River watershed. Lowe Branch was the undisturbed reference stream and Indian Fork, Bill's Branch and Green Branch were the mining-disturbed streams included in the study. The Shannon-Weaver Species Diversity index and taxonomic richness were the two metrics used to measure stream impairment. The diatom community of the stream with no mining disturbance had higher diversity and taxa richness than the mined streams. The fish community exhibited similar results with significantly higher diversity in the unmined stream compared to the mined streams.

Tolbert and Vaughan (1980) studied four streams in the New River watershed comparing an unmined stream, Lowe Branch, to three mined streams with five years to recover Bill's Branch, Green Branch, and Indian Fork. It also compared streams Ursery Creek with 6-10 years of recovery, Sugarcamp Creek with 16-20 years of recovery, and Duncan Creek with 21-25 years of recovery. The Shannon-Weaver Diversity Index was the biometric used to estimate stream recovery. The aquatic insect community of the undisturbed stream was dominated by Ephemeroptera, while Trichoptera dominated in streams disturbed by mining activities. They found that total abundance went down during mining and was reduced up to 20 years after mining, but eventually recovered. They also found that the number of different taxa did not significantly vary any time after mining.

Schiller (1986) studied Bruce and Crabapple Creeks in the New River watershed in Campbell County, Tennessee. Crabapple Creek was undisturbed by mining and served as a reference stream. Bruce Creek had not been mined since 1968 and then only a small surface area was disturbed (less than 5%). Both Crabapple and Bruce Creek watersheds are completely or almost completely forested. Schiller's study showed that the macroarthropod (insects and crustacea) community of Crabapple Creek had a higher biomass and abundance than Bruce Creek. He also studied the particulate organic matter dynamics in mined and unmined streams, along with secondary productivity of macroinvertebrates. For the purpose of this study we will focus on the results of the community diversity. The study also showed that the collector/gatherer functional feeding group was reduced in Bruce Creek, which he attributed to the increased amount of silt in this stream.

Dickens (1989) studied the chemical and hydrological changes in streams mined before and after the changes in mine reclamation mandated by SMCRA. The objective of the study was to see if there was an improvement in stream water quality after SMCRA was implemented. Water chemistry data was collected using automated sampling and periodically sampling was collected in the field by researchers. Lowe Branch was the reference stream while Anderson Branch, Bowling Branch, Bill's Branch, Green Branch, and Indian Fork were mined streams. The research results showed that pH in the disturbed area was increased, but slowly recovered over time. Dickens (1989) concluded that recovery will depend on a streams ability to flush out minerals and how much surface area of the watershed was disturbed by mining

Table 1.1. Previous research on the mined and unmined streams in this study.

Authors	Streams Studied	Brief Summary
Minear et al., 1976	Bowling Branch, Bill's Branch, Green Branch, Indian Fork, and Lowe Branch.	Analysis of chemical and mineral content in water.
Vaughan et al., 1978	24 streams including: Sugar Camp Creek, Louse Creek, Bowling Branch, Duncan Branch, Ursery Creek, Green Branch, Indian Fork, and Lowe Branch	Surveyed aquatic insect, fish, and diatom diversity.
Vaughan, 1979	Bill's Branch, Green Branch, Indian Fork, and Lowe Branch.	Analysis of fish and diatom diversity.
Tolbert and Vaughan, 1980	Bill's Branch, Green Branch, Indian Fork, and Lowe Branch	Surveyed Aquatic insect diversity and abundance
Schiller, 1986	Bruce Hallow and Crabapple	Aquatic insect diversity, POM[a], and secondary productivity.
Dickens et al, 1989	Bowling Branch, Bill's Branch, Ursery Branch, Green Branch, Indian Fork, and Lowe Branch.	Survey of chemical and mineral fluctuations.

[a] Particulate Organic Matter

Objectives of this study

The primary objective of this study was to revisit and conduct bioassessments on a subset of 11 previously studied streams chosen based upon their subsequent mining history to provide the following treatment effects:

- Streams in previous studies that were unmined reference streams that remained unmined to the present.
- Streams in previous studies that were unmined reference streams that have since been mined.
- Streams in previous studies that had been mined but have not been mined since.
- Streams in previous studies that had been mined and have been mined further since.

A subsidiary objective of this study is to compare bioassessments of the study streams using contemporary State of Tennessee sampling protocols to bioassessments of the same streams using the sampling protocol employed in the earlier studies. This provided a "calibration" of contemporary methods with earlier methods, unlocking a vast storehouse of existing biological data with limited usefulness, because it cannot be compared to contemporary data.

CHAPTER II

METHODS

Mining history

Mining history was determined using Geographical Information Systems (GIS). A map was developed with data collected from the State of Tennessee data base found at http://www.tngis.org/. Digital elevation models (DEM) were downloaded and then used as a layer. Shape files of mined sites were obtained from the Office of Surface Mining (OSM), Knoxville. These polygons had attribute tables of the history of mining and were used to determine mining activity and if it had been reclaimed yet. Another layer was put on the map for points that were taken at each sampling site during sampling. All latitude and longitude points were taken with a Garmin Rino 120 GPS, and then the data were entered in an Excel file to be imported for a map layer.

Habitat Assessment

The State of Tennessee protocol requires a habitat assessment to be completed for each stream (TDEC, 2006). This form is reproduced in Appendix A. The habitat assessments consist of observing and quantifying several habitat metrics considered reflecting the amount of disturbance in the reach of the stream sampled. Metrics such as riparian vegetation, canopy cover, bank and substrate stability and embeddedness, the mix of habitat types in the form of riffle-run-pool distribution, large woody debris, etc, and hydrological balance were all scored and then summed into a multimetric habitat score analogous to the multimetric bioassessment protocol described below. Habitat assessments were completed for all the sampled streams. The habitat assessment was only completed once for each stream even though some of the streams were sampled twice because no change in the habitat occurred between the June and July sample collections.

Abiotic Analysis

Total dissolved solids, oxygen content, temperature, specific conductance, and pH were measured using an YSI 650 MDS. Alkalinity was measured with a LaMotte kit model WAT-DR; titrations were performed in the field. All measures of water chemistry were completed before biological samples were collected to prevent macroinvertebrate sampling from affecting these results. All data were recorded in a field notebook on site.

Sample Collection, Processing, and Analysis

Two methods of sampling macroinvertebrates were used: State of Tennessee standard operating procedures for modified semi-quantitative single habitat kick (SQKICK) macroinvertebrate sampling (TDEC 2006), and quantitative Surber sampling as was often used in earlier studies of these streams (Schiller 1986). The Tennessee water quality assessment protocol for small headwater streams consists of the following steps:

1. A 500 micron-mesh D frame net was used to collect macroinvertebrates from riffles. The net was placed in a riffle downstream from the person collecting the sample. The substrate in front of the net was disturbed to a depth of about 10 cm. All large rocks are scrubbed with a brush and then placed outside the net. Four

different riffles were sampled. Nets were examined and any macroinvertebrates clinging to the net are picked off with forceps and included in the sample. Successive samples were collected from downstream to upstream to prevent interference between samples. The four kick net samples were composited into a single large sample. Collected macroinvertebrates was placed into labeled jars and preserved in 10% formalin in the field. Upon return to the lab, the formalin was replaced with 80% ethanol as the sample preservative.

2. Macroinvertebrate samples are distributed into a gridded pan (28-2 inch squares) to reduce the sample to two hundred randomly selected macroinvertebrates, i.e., a "200 pick." This was achieved by completely removing all macroinvertebrates from randomly selected grid squares. Because it was unlikely that a total of exactly 200 macroinvertebrates will occur upon removal of all macroinvertebrates from the last square picked, a tolerance of ± 20% is accepted, thus the size of the sample can vary between 160 – 240 (200 ± 40).
3. The 200 ± 40 organisms were identified to genus or the lowest possible taxonomic designation (Merrit et al., 2008).
4. The taxonomic composition of the processed sample was used to calculate a macroinvertebrate index based on the 7 biometrics described in Table 2.1.

Table 2.1 The biometrics used in the Tennessee Macroinvertebrate Index SQKICK samples (TDEC, 2006).

Metric	**Definition**
EPT (Ephemeroptera, Plecoptera, Trichoptera) Richness	Sum of Ephemeroptera, Plecoptera, and Trichoptera taxa.
TR (Taxa Richness)	Sum of all taxa
%OC (Percent oligochaetes and chironomids)	%OC = {(total number of Oligochaeta + Chironomidae)/(total number of individuals in the subsample)}X100
%EPT (EPT Abundance)	%EPT = {(Sum of Ephemeroptera, Plecoptera, Trichoptera count)/ (total number of individuals in the subsample)}X100
NCBI (North Carolina Biotic Index)	NCBI = Sum of $x_i\, t_i /n$ x_i = number of individuals within a taxon t_i = tolerance value of a taxon (found in Appendix C of TDEQ, 2006) n = total number of individuals in the subsample.
%NUTOL (Percent Nutrient tolerant organisms)	%NUTOL = {(Total number of *Chuematopsyche, Lirceus, Physella, Baetis, Psephenus, Stenelmis, Simulium, Elimia, Oligochaeta, Polypedilum, Rheotanytarsus, Stenacron, Criotopus, and Chironomus*)/ (total individuals in the sample)} X100
%Clingers (Percent contribution of organisms that build fixed retreats or have adaptations to attach to surfaces in flowing water)	%Clingers = {(total of clinger individuals)/(total individuals in the sample)}X100

The calculated biometric values are assigned a score of 0, 2, 4, or 6. These given scores will vary based on the ecoregion reference condition. The ecoregion reference condition is the biometric scores for each metric empirically determined from samples of least disturbed reference streams in that ecoregion published in the Quality System Standard Operating Procedure Manual (TDEC 2006). The higher the score, the more similar the study stream is to the least disturbed reference condition for streams in that ecoregion. The metrics Taxa richness (TR), Ephemeroptera, Plecoptera, and Tricoptera richness (EPT), Ephemeroptera, Plecoptera, and Tricoptera abundance (%EPT), and percent of taxa that build fixed retreats or have adaption to attach to surface (%Clingers) decrease in value as impairment increases, percent oligocheaes and chironominds (%OC), percent nutrient tolerant organisms (%NUTOL), and North Carolina Biotic Index (NCBI) increase in value as impairment increases. For example an EPT score of 6 indicates there are as many taxa of these pollution intolerant insect orders in the study stream as are expected to be found in least disturbed reference streams of that ecoregion, indicating good water quality. A low EPT score of 0 or 2 demonstrates that these taxa are not well represented in the stream relative to least disturbed reference streams in the ecoregion, indicating poor water quality. The proportion of oligochaetes and chironomids in a sample increases as water quality declines. So the %OC metric is scored so that a score of 6 indicates the stream has a low abundance of oligochaetes and chironomids relative to the abundance of other taxa in the sample as would be expected in a least disturbed stream in the ecoregion. Conversely, a low metric score for %OC indicates that individuals of these taxa are abundant relative to individuals of other taxa, a condition not expected in least disturbed streams of the ecoregion, indicating impaired water quality. Thus, each biometric represents a hypothesis regarding water quality. The value of some biometrics, (e.g. TR, EPT, %EPT, and % Clingers) is hypothesized to increase in good water quality and decrease in poor water quality, while the value of other biometrics, (e.g. %OC, %NUTOL, and NCBI), is hypothesized to decrease in good water quality and increase in poor water quality. These hypotheses have been formulated based on empirical observation of how they respond to known levels of impairment in streams. The biometric scores are used to adjust all of the metrics to the same scale and weight them equally. For example, the TR metric can easily exceed a value of 50, while the NCBI metric ranges between 0 to 10. Scoring them from 0-6 based on how closely the values of each metric approach the values expected for least disturbed streams in the ecoregion weights them equally.

However, a bioassessment is not based on a single metric, but on a multimetric, the sum of the seven metric scores referred to as the "Macroinvertebrate Index." Thus a bioassessment is a test of the hypothesis of how similar a study stream is in the aggregate (a sum of biometrics) to the least disturbed reference streams of the ecoregion. Since there are 7 metrics that are scored between 0 to 6, the Macroinvertebrate Index can range from 0 to 42 with 0 representing the hypothetical most impaired condition and 42 the least impaired condition. The bioassessment assigns a classification of impairment as nonimpaired, slightly impaired, moderately impaired, or severely impaired, based on bioecoregion specific ranges of the Macroinvertebrate Index.

Surber samplers with 500 micron-mesh nets were used to collect macroinvertebrates from riffles as described in previous studies (Vaughan et al., 1978;

Vaughan, 1979; Tolbert and Vaughan, 1980; Schiller, 1989). Eight pairs of Surber samples were collected for each stream a total of 16 samples. Surber samplers were placed in a flowing riffle and the 0.1 m^2 area upstream of the sampler net was disturbed to a depth of 10 cm. All rocks were scrubbed with a brush and placed outside of the Surber sample area. Macroinvertebrates collected in each Surber sample were placed into separate containers and preserved in 10% formalin. The paired samples were designated as "a" or "b", respectively. Thus, the first of the 8 paired Surber samples were labeled "1a" and "1b", the second "2a" and "2b", and so on until 8 paired samples were collected. In the previous studies of these streams the paired Surber samples were combined into a composited sample, but we processed each Surber separately for the following reasons. First, we were interested to see how many macroinvertebrates were typically collected in individual Surber samples. Second, we were interested to see how many individual Surber samples would typically need to be composited to achieve a "200 pick." Third, we anticipated that other previous studies may have collected individual Surber samples and we wished to preserve the option of comparing our samples to those. Surber samples were collected from the downstream to upstream direction to avoid interference between samples. The formalin used to preserve samples in the field was replaced with 80% ethanol upon return to the lab and all macroinvertebrates were picked out of the sample. All macroinvertebrates in each Surber sample were identified to the lowest taxonomic level possible.

The methods for collecting the samples in D-frame kicknets and Surber samplers do not differ except for the size of the area sampled and the amount of sample compositing. Paired Surber samples were composited and then bioassessment was performed according to the State of Tennessee protocol. This was also done for Surber sample data collected in 1981 allowing us to evaluate long term changes in water quality.

Statistical Analysis

Bartlett's Regression Method was applied to the Surber samples and the SQ kicknet samples in an attempt to test the "transportability" of the Surber and D-frame kicknet samples. If a given metric has a similar value when obtained from a D-net sample and a Surber sample from streams sampled at the same time and location over a wide range of stream conditions, a significant linear regression should result. Perfect transportability of the data would be indicated by a regression line with a slope of 1 and a 0 intercept. In ordinary linear regression the independent variable is fixed, and the error in the dependent variable is unknown. Bartlett's Regression Method was developed to test for linear relationships between two variables when the error in the independent variable is not known, i.e. both variables have unknown error rates (Legg, 1986). In the Bartlett method you must choose which variable will be dependent and which will be independent. This allows some flexibility in applying the method because generally it is easier to achieve a significant result when the independent variable spans a wider range of values. Both the Surber scores and the SQ kicknet scores were examined as the independent variable in attempting to achieve a significant result.

For testing the probability of reaching the "200 pick" of Surber samples with two or three combined Surbers, Excel was used. This was done by adding all of the samples together in all possible arrangements of our samples and then using those numbers to determine the percentage of reaching 160. For example, Sugarcamp Creek, first Surber sample for is 1a, yielded 110 total individuals, so in our simulation the first row would have 110 + 110 = 220. Then the next Surber sample for Sugarcamp Creek had 158 total individuals so the next row would be 158 + 110 = 268. This was repeated for every one of our possible combinations of our 16 samples per stream. This creates 256 combinations for two combined Surber samples. For doing the three combined Surbers the same process is done but added to the combined Surbers. For example the first row was 110 now we take the first addition from the combined Surbers which was 220: 110 + 220 = 330 for the first row. This process was repeated for three combined Surbers for a combination of 4,496. If the probability of 100% within three combined Surber samples, Minitab was used to reproduce our sample one million times. Using this program it was possible to simulate sampling one million different times from the sixteen Surber samples. This showed the probability of reaching 160 total macroinvertebrates. After each simulation the simulations were combined this was applied to four combined Surbers. When the fraction of samples was less than 160 individuals the probability to reach the "200 pick" was derived.

CHAPTER III

RESULTS

Mining Activity

Lowe Branch and Crabapple Creek have never been disturbed by mining in their watersheds. Louse Creek, Bruce Hollow and Bowling Branch have had only small levels of disturbance from mining, all prior to SMCRA. No mining occurred in Bill's Branch watershed since before 1978 upstream from the sampled reach; however mining occurred in 2004 downstream from the sampled reach. Parts of Duncan Branch watershed was mined in 2006, and parts of Sugarcamp Creek watershed during 1983, Indian Fork watershed in 2006, and in the Green Branch watershed in 2007. Ursery Creek had a very large area of mine disturbance in its watershed during 2006. The mine in the Ursery Creek watershed is over 700 acres. All pre-1978 mining activity should have been reclaimed as required by SMCRA by the time the 2008 samples were collected. The GIS map (Fig. 3.1) was used to interpret mining activity. Mining activity from previous studies before SMCRA and from current data is summarized in Table 3.1. Because SMCRA was not enacted until that date, OSM does not have good records of mining activity before 1978. We relied on estimates published in earlier studies to determine mining history prior to 1978.

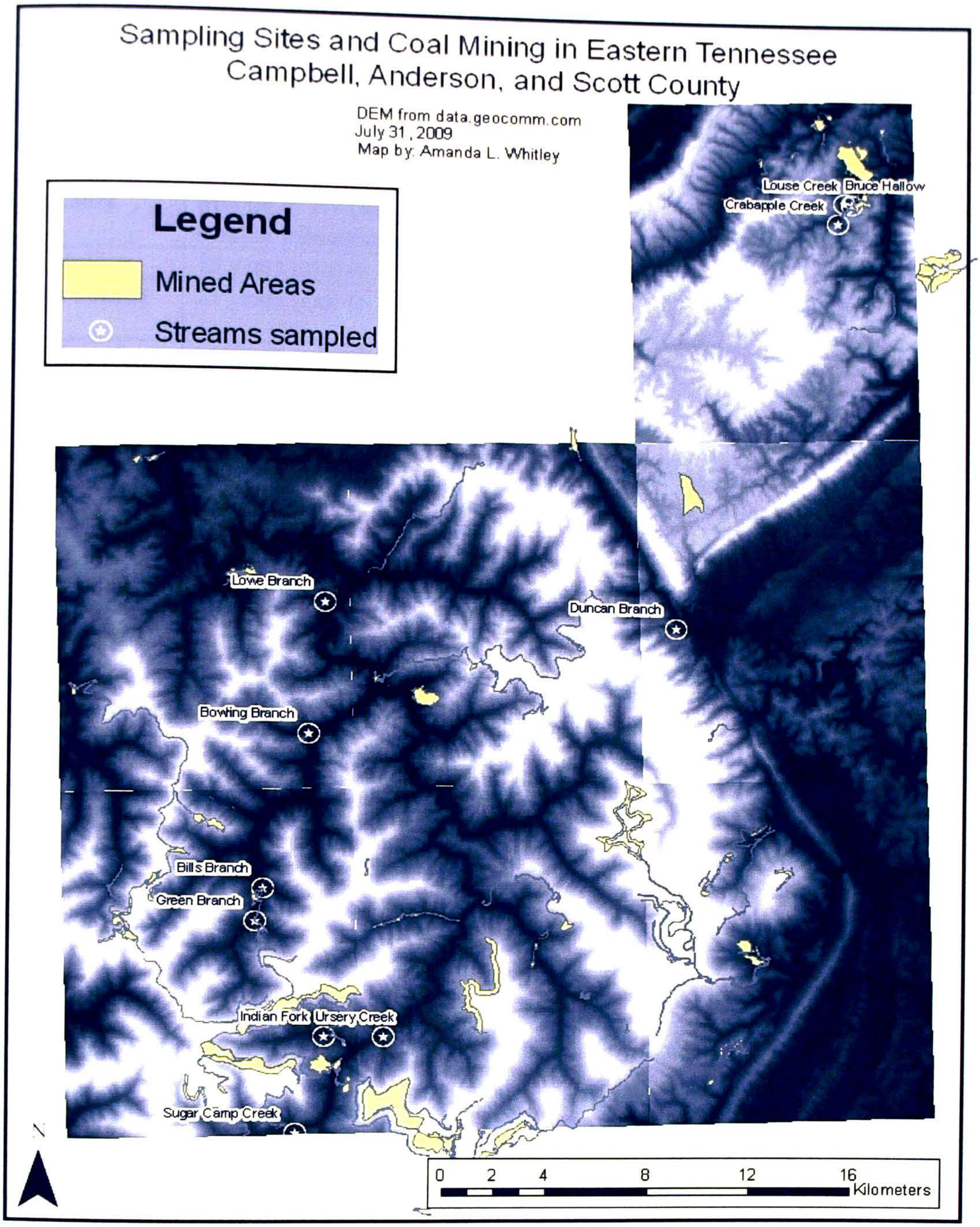


Figure 3.1. Digital Elevation Model of study site in Campbell, Anderson, and Scott County, Tennessee. Study sites are depicted by stars with circles and surface mining sites are indicated by yellow polygons.

Table 3.1. Mining history of New River watershed of Anderson, Scott, and Campbell County, Tennessee as of July 2009.

Stream	**Mining History**	**Data Collected From**
Sugarcamp Creek	1950 and 1983	Tolbert and Vaughn and GIS map* (1980)
Louse Creek	Mining in 1981and Probable, but of smaller tributaries not named on permits.	GIS map*
Bruce Hollow	15 years prior to 1980	Schiller (1986)
Duncan Branch	25 years prior to 1980 and mined in 2006	Schiller (1986) and GIS map*
Green Branch	1972-75 and 2007	Schiller (1986), Minear and Tschantz. (1976), and Dickens et al. (1989, GIS map*.
Ursery Creek	2006	GIS map
Indian Fork	1950-1972 and 2006	Minear and Tschantz. (1976), and Dickens et al. (1989), GIS map*.
Bowling Branch	1976-1978	Minear and Tschantz. (1976), and Dickens et al. (1989).
Bill's Branch	1974-75	Dickens et al. (1989), Minear and Tschantz (1976), and GIS map*.
Crabapple Creek	No mining	Schiller (1986) and GIS map*.
Lowe Creek	No mining	Schiller (1986), Dickens et al (1989) and GIS map*.

*Refers to fig. 3.1.

Habitat Assessments

Habitat assessments were conducted only once for each stream on the first date they were sampled. Habitat assessments varied from "not impaired" to "severely impaired" (Table 3.2). The reference streams, Crabapple and Lowe Creeks, along with Bruce Hollow, had habitat assessments of "not impaired." Sugarcamp Creek, Louse Creek, Bill's Branch, Ursery Creek, and Bowling Branch all had habitat assessments of "moderately impaired." Indian Fork was the only stream with habitat assessed as "severely impaired."

Table 3.2. Habitat Assessment Scores for 11 streams studied in the New River Watershed in East Tennessee.

Stream	**Habitat Assessment**	**Date**
Sugarcamp Creek	Moderately Impaired	6/17/2008
Louse Creek	Moderately Impaired	6/18/2008
Bruce Hollow	Not Impaired	6/18/2008
Bills Branch	Moderately Impaired	6/19/2008
Ursery Creek	Moderately Impaired	6/19/2008
Indian Fork	Severely Impaired	6/18/2008
Bowling Branch	Moderately Impaired	7/23/2008
Duncan Branch	Moderately Impaired	6/18/2008
Green Branch	Moderately Impaired	6/19/2008
*Lowe Branch	Not impaired	7/22/2008
*Crabapple Creek	Not Impaired	7/23/2008

* Indicates reference streams

Abiotic Results

Water temperature varied among all streams ranging from15.5 C° to 19.9 C°. Sugarcamp and Louse Creeks had higher temperatures than many of the other streams (fig. 3.2). All streams except Lowe Branch and Crabapple Creek were sampled in June. Lowe Branch and Crabapple were sampled in July because they had insufficient flow to sample in June. Bruce Hollow and Bowling Branch were sampled in both June and July and, are referenced as 1 and 2, respectively in all figures and tables. The water temperature of these two streams increased approximately 3 C° in July compared to June; the temperatures recorded for Lowe and Crabapple Creeks which were only sampled in July are quite similar to those of Bowling Branch and Bruce Hollow sampled in July. Thus, by extrapolation, it is likely they would have been comparable to the temperatures of most of the other streams in June had they been sampled then.

Specific conductance was highest in Sugarcamp Creek at 0.840 mS/cm (Fig. 3.3). Indian Fork and Ursery Creek were also high compared to the other streams at 0.793 mS/cm and 0.568 mS/cm. Bruce Hollow had the lowest reading for specific conductance at 0.005 mS/cm.

Ursery Creek and Indian Fork also had higher total dissolved solids with 0.369 g/L and 0.516 g/L (Fig. 3.4). Crabapple Creek has the lowest value at 0.022 g/L.

Louse Creek had the highest percent of dissolved oxygen at 98.5% (Fig. 3.5). Crabapple Creek and Bruce Hollow in the June sampling had the lowest percentage of dissolved oxygen at 87.4 % and 86.5 %.

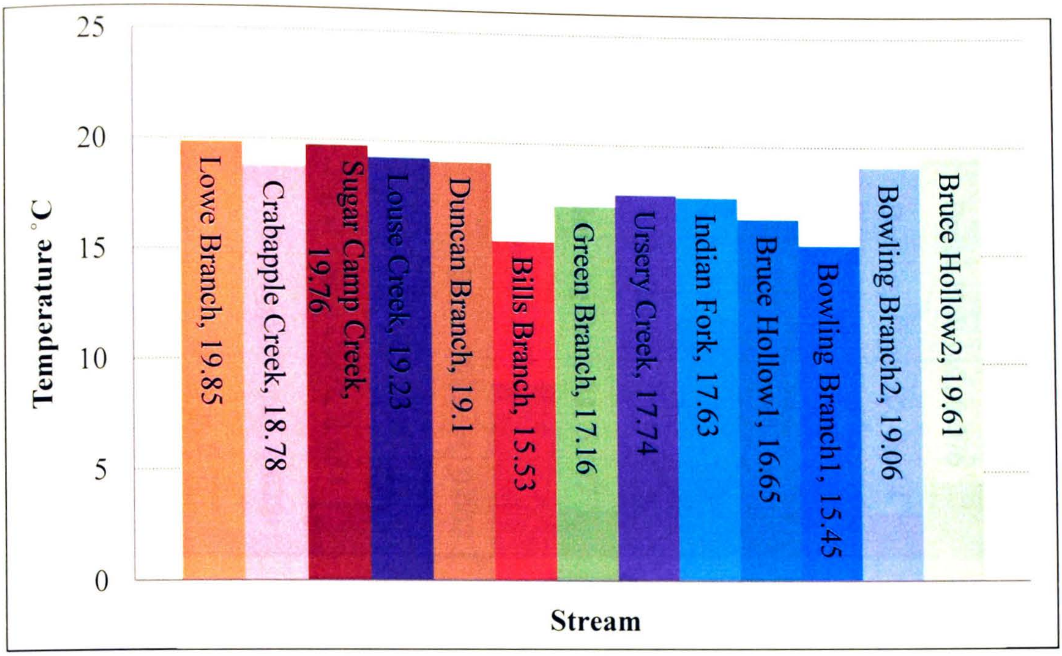


Figure 3.2. Temperature of stream water for 11 streams sampled in Scott, Anderson, Campbell counties, Tennessee.

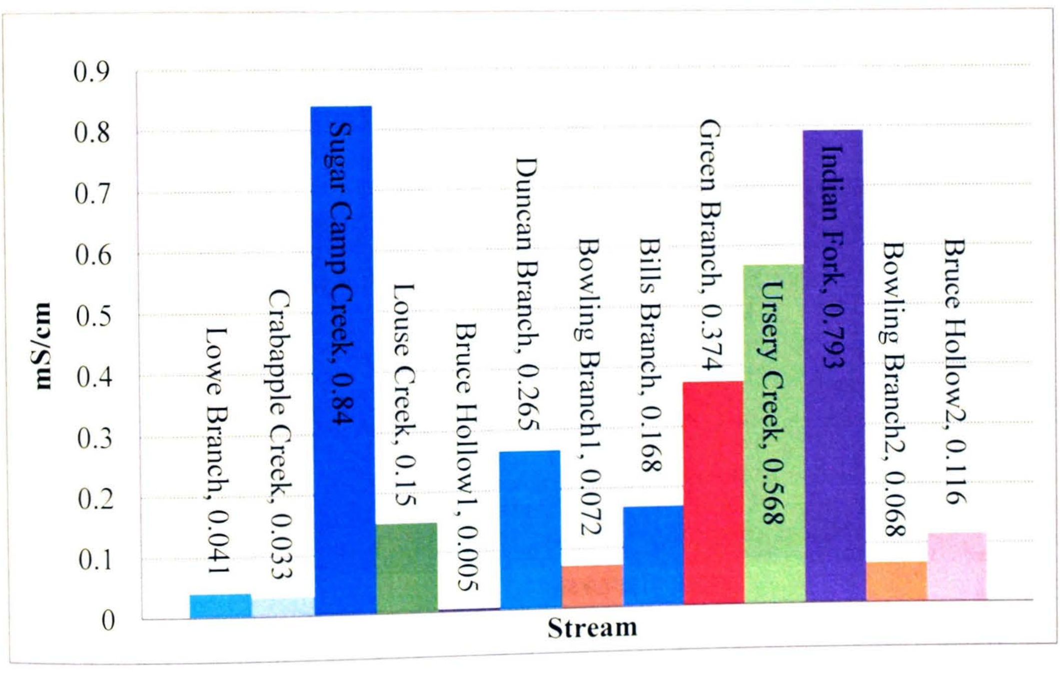


Figure 3.3 Specific conductivity of stream water for 11 streams sampled in Scott, Anderson, Campbell counties, Tennessee.

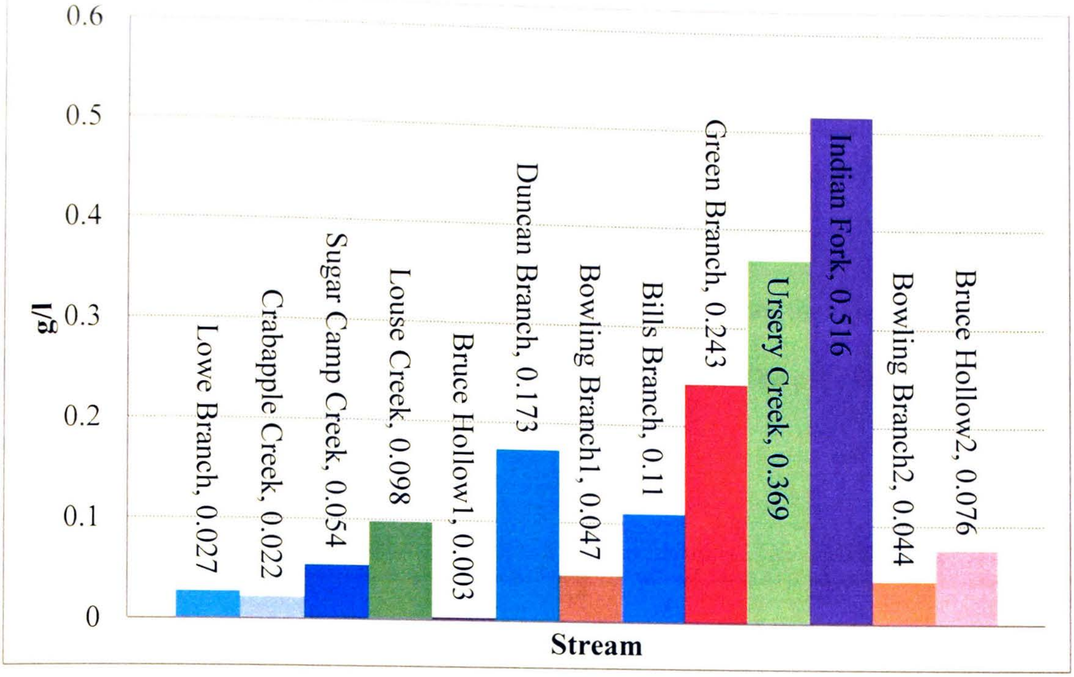


Figure 3.4. Total dissolved solids of stream water for 11 streams sampled in Scott, Anderson, Campbell counties, Tennessee.

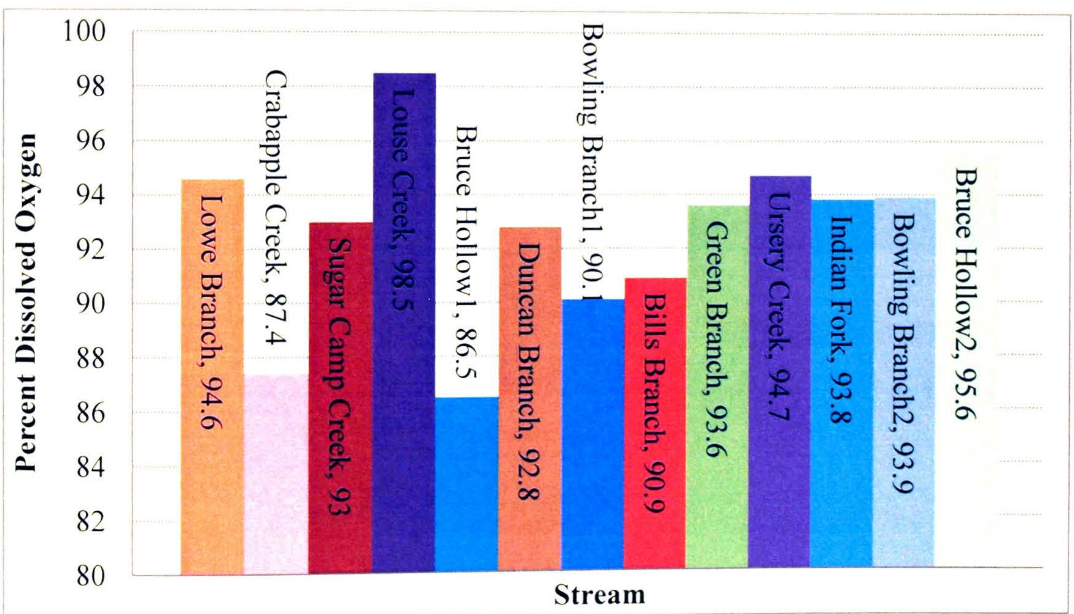


Figure 3.5. Percent of dissolved oxygen of stream water for 11 streams sampled in Scott, Anderson, Campbell counties, Tennessee.

Indian Fork and Ursery Creek had much higher levels of alkalinity. Indian Fork had an alkalinity of 100 ppm and Ursery Creek was 116 ppm (Fig 3.6). The lowest value was for Lowe Branch and Crabapple Creek at 12 ppm for both. Alkalinity data were not collected for Bill's Branch.

Ursery Branch and Indian Fork also had higher pH values than the other streams. Ursery had a pH of 8.01 while Indian Fork had a pH of 7.98. The pH of the other streams ranged 6.76 to 7.39 (Figure 3.7).

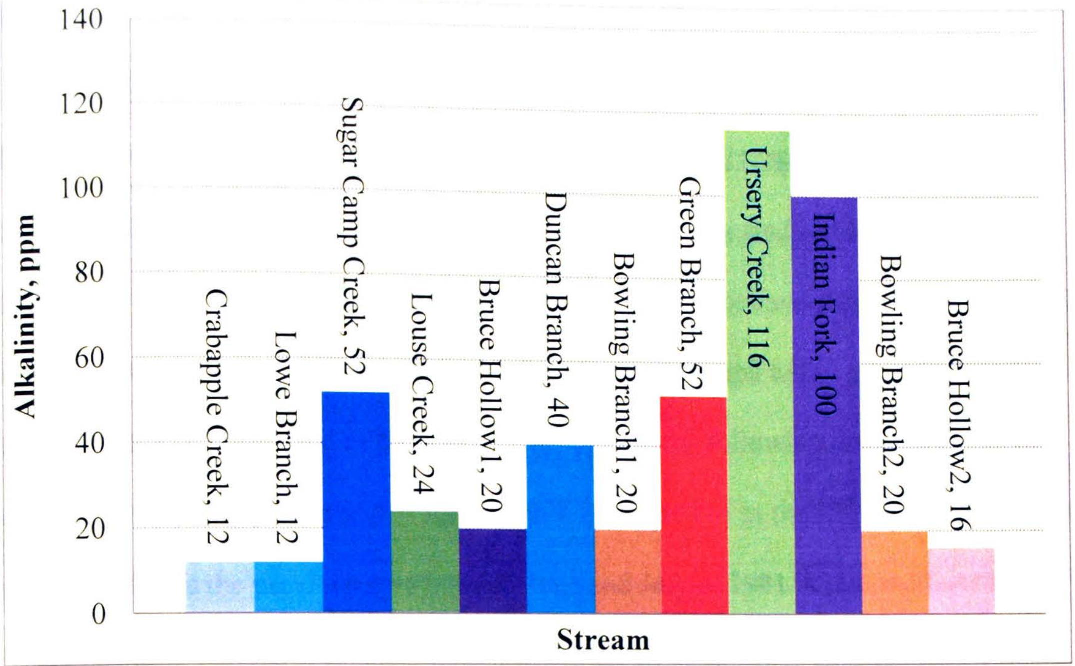


Figure 3.6. Alkalinity of stream water for 11 streams sampled in Scott, Anderson, Campbell counties, Tennessee.

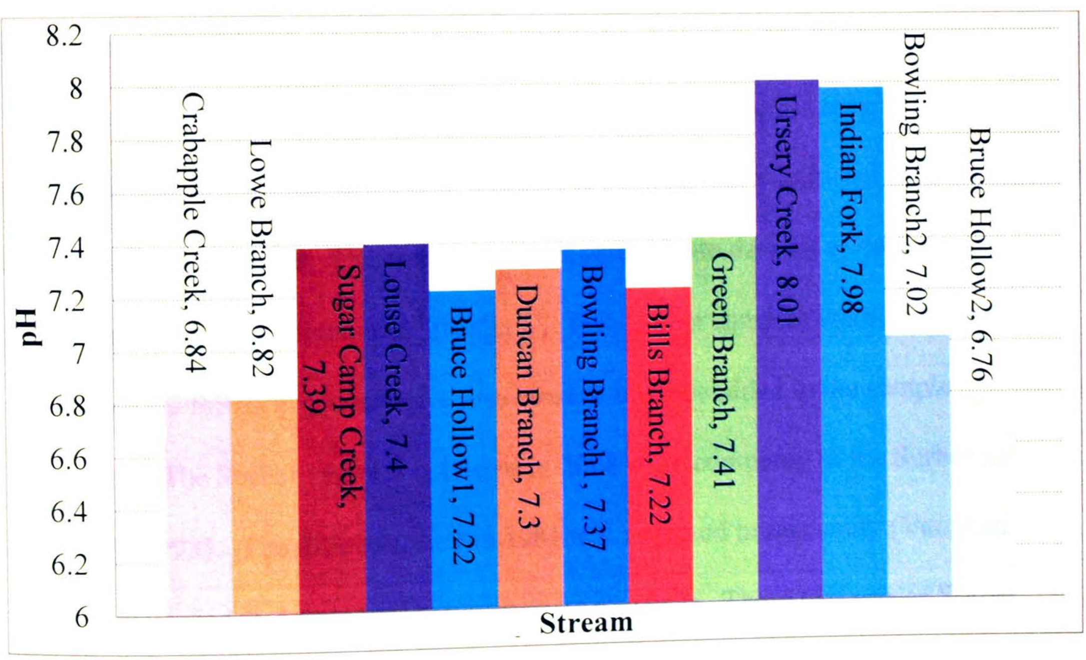


Figure 3.7. pH of stream water for 11 streams sampled in Scott, Anderson, Campbell counties, Tennessee.

Biological Data

Biological data in this study consists of macroinvertebrate samples collected using D-frame nets as specified in the state of Tennessee protocol (TDEC, 2006), and using Surber samplers in the same manner as described in previous studies of these streams (Vaughan, 1979; Vaughan et al., 1982; Schiller, 1986). Macroinvertebrate data collected in 1981 (Vaughan et al., 1982) are also analyzed and compared to the macroinvertebrate data collected and analyzed in this study. Throughout the following discussion, the data collected in this study in June and July of 2008 is referred to as the "2008" data; while the data collected in the previous study during June and July of 1981 is referred to as the "1981" data.

The complete macroinvertebrate data set collected using kicknets is presented in Appendix B. Common taxa collected were *Baetis*, *Paraleptophlebia*, *Leuctra*, *Cheumatopsyche*, *Psephenus*, *Microvelia*, and Chironomidae. Much of the taxonomic variation among samples was due to differences in the Chironomid taxa. Kicknets were collected from all 11 streams studied, but Surber samples were collected from a subset of only six of these streams. The complete macroinvertebrate data set collected using Surber samplers is presented in Appendix C. Two Surber samples were lost from Louse Creek because formalin preservative was accidentally not added to the sample containers in the field. The Surber samples collected in 2008 were compared to the Surber samples collected in 1981. The data collected in 1981 and analyzed in this study (Vaughan et al., 1982) is presented in Appendix D (Vaughan, et al. 1982). These two sets of Surber sample data were compared to ascertain possible differences due to continued recovery from mining impacts prior to previous studies or additional degradation due to mining impacts since the previous studies. Also, since the same streams draining unmined watersheds were sampled in both studies, other non-mining impacts, such as enrichment from atmospheric nitrogen deposition or global warming, might be detected. Surber samples from both studies were collected in June and July to minimize possible differences in the macroinvertebrate communities from seasonal effects.

SQ Kicknet Data Results

Table 3.3 presents the metric values for the SQ kicknet samples for the 11 streams studied in the New River Watershed. Note kicknet samples were collected from two streams, Bruce Creek and Bowling Branch, on two separate dates, June 18 and July 23. The two reference streams had too little flow to sample in June and when they were sampled in July, two of the streams that were sampled in June were sampled again as a temporal reference. Data differed from the two sampling dates in June and July except for %Clingers. This difference was varied and shows no trend between the two sampling dates (Table 3.3).

Table 3.3. Metric Scores of kicknets samples for 11 streams in the New River Watershed of Scott, Campbell, and Anderson counties, Tennessee.

Stream	TR	EPT Richness	%EPT	%OC	NCBI	%NUTOL	%Clingers
Sugarcamp Creek	25	14	63	25	3.19	30	36
Louse Creek	28	15	41	40	5.29	44	44
Bruce Hollow 6/18	30	10	47	15	4.12	38	43
Duncan Branch	34	14	52	27	3.54	44	60
Bowling Branch 6/18	36	13	40	44	4.43	35	29
Bill's Branch	27	14	57	16	3.47	35	50
Green Branch	25	13	53	36	3.46	49	57
Ursery Creek	24	9	53	34	3.02	39	53
Indian Fork	20	7	32	26	3.21	55	66
Lowe Creek	30	14	35	19	4.25	34	40
Bowling 7/23	27	7	45	32	3.36	34	26
Crabapple Creek	23	11	43	19	2.89	35	49
Bruce Hollow 7/23	32	13	33	35	4.38	48	33
Mean	**28**	**12**	**46**	**28**	**4**	**40**	**45**

SQ kicknet Data Compared to Surber Sampler data

The means of metric scores for the 16 individual Surber samples collected in each of the six streams sampled with Surber samplers is presented in Table 3.4. The mean metric scores for the six streams is also presented in this table along with the P-value for the Mann Whitney U tests comparing the metric means from the Surber samples to the metric means from the kicknet samples. Only the mean value of EPT taxa richness obtained from Surber samplers was significantly different from that obtained with kicknets. Generally, similar taxa were collected in the Surber nets compared to the kicknets, but mayflies in the genera *Epeorus* and *Baetis*, and the stonefly genus *Suwallia* were more abundant in the Surber samples than in the kicknet samples.

Table 3.4. Mean Metric Scores for 16 individual Surber samples collected in each of 6 streams of the New River Watershed along with the mean metric value of the six streams. P values for the Mann-Whitney U test if the mean metric score of samples collected with Surber nets differ from the mean metric score of samples collected with kicknets.

Biometrics	**Lowe**	**Louse**	**Green**	**Sugarcamp**	**Crabapple**	**Bill's**	**Mean**	**P-value, Mann Whitney U**
Taxa Richness	19	27	23	20	26	23	**23**	$P \geq 0.05$
EPT Richness	6	11	10	10	9	11	**9**	$P \leq 0.01$
% EPT	22	47	53	51	41	43	**43**	$P \geq 0.05$
% OC	46	32	26	31	33	37	**34**	$P \geq 0.05$
NCBI	4	4	3	3	3	4	**3.42**	$P \geq 0.05$
% NUTOL	54	22	36	35	23	40	**35**	$P \geq 0.05$
% Clingers	24	44	64	45	46	37	**43**	$P \geq 0.05$

Taxa Richness of the 16 Surber samples ranged from a low of 6 in one of the Lowe Creek Surber samples to 41 in one of the Crabapple Creek Surber samples. Mean Taxa Richness of 16 Surber samples collected in each stream ranged from 19-27 and averaged 26.33 in the six streams. Mean Taxa Richness of the 16 Surber samples was usually lower than the Taxa Richness of the composited kicknet samples was 28, (fig. 3.8), but this difference was not statistically significant. The lone exception was Crabapple Creek in which the mean Taxa Richness of the 16 Surber samples was 26, higher then Taxa Richness of the four composited kicknets, 23.

The mean EPT taxa richness was consistently higher in the SQ kicknet samples, ($x = 14$, compared to the mean of the 16 Surber samples, 9 (Fig. 3.9). This difference was significant $P = 0.01$.

The mean %EPT of the Surber samples, ($\overline{x} = 43\%$), was less than in the SQ kicknet samples, ($x = 48\%$), but this difference was not significantly different (Fig. 3.10).

In the mean %OC Surber sample was ($x = 34\%$), was higher than the SQ kicknet samples ($x = 26\%$) (Fig. 3.11). However, the %OC did not differ significantly between the two sampling method.

Mean of NCBI score of the Surber samples was 3.42, slightly less than 3.76, the mean NCBI score kicknet samples. This was not a statistically significant difference (Fig. 3.12)

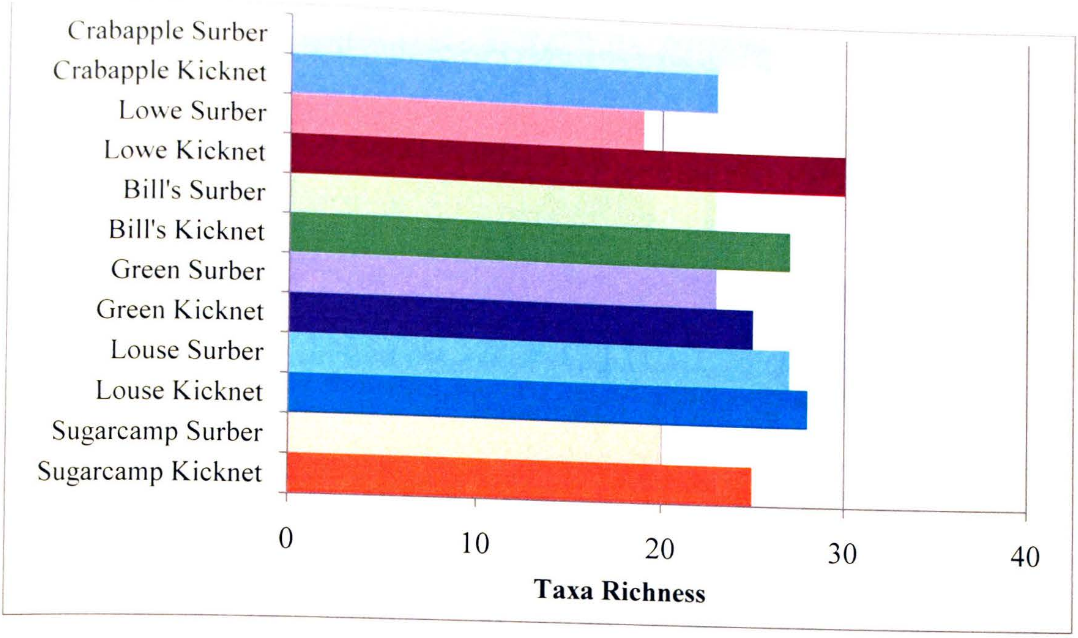


Figure 3.8. Mean taxa richness of 16 Surber samples compared to taxa richness of the SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

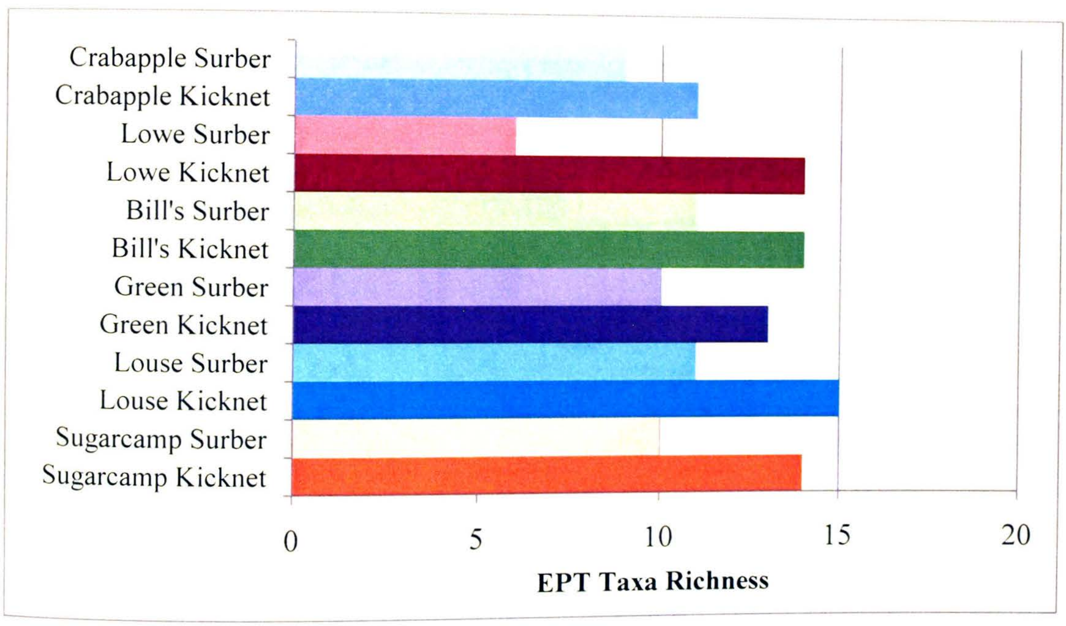


Figure 3.9. Mean EPT taxa richness of 16 Surber samples compared to EPT taxa richness of the SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

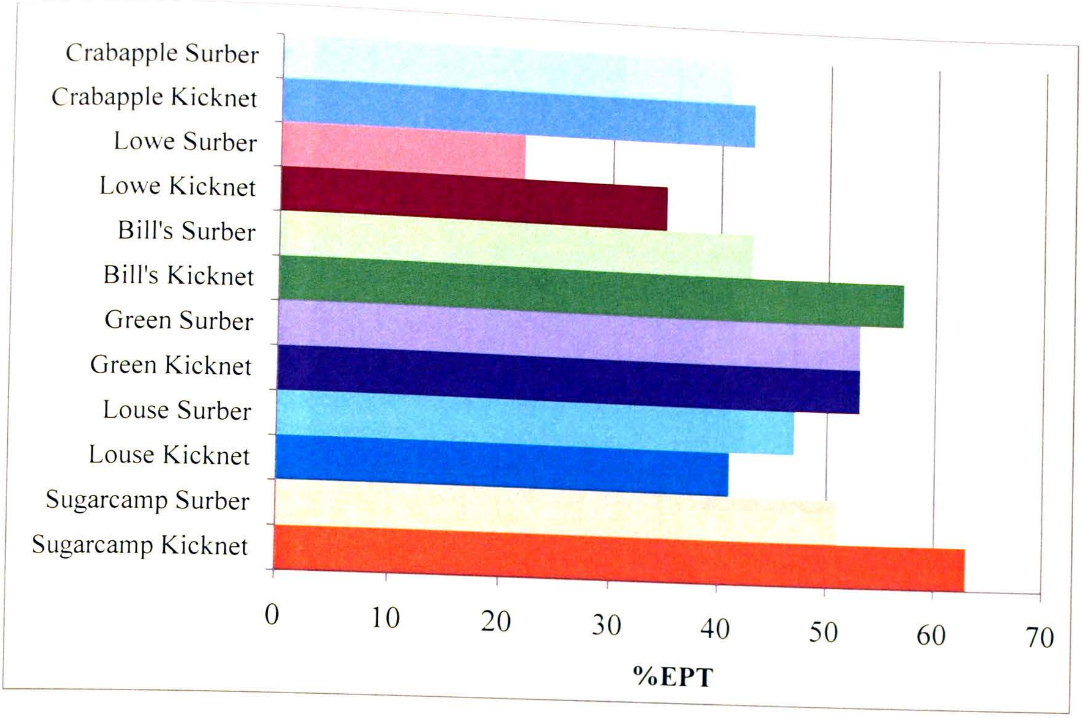


Figure 3.10. Mean %EPT of 16 Surber samples compared to %EPT of the SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

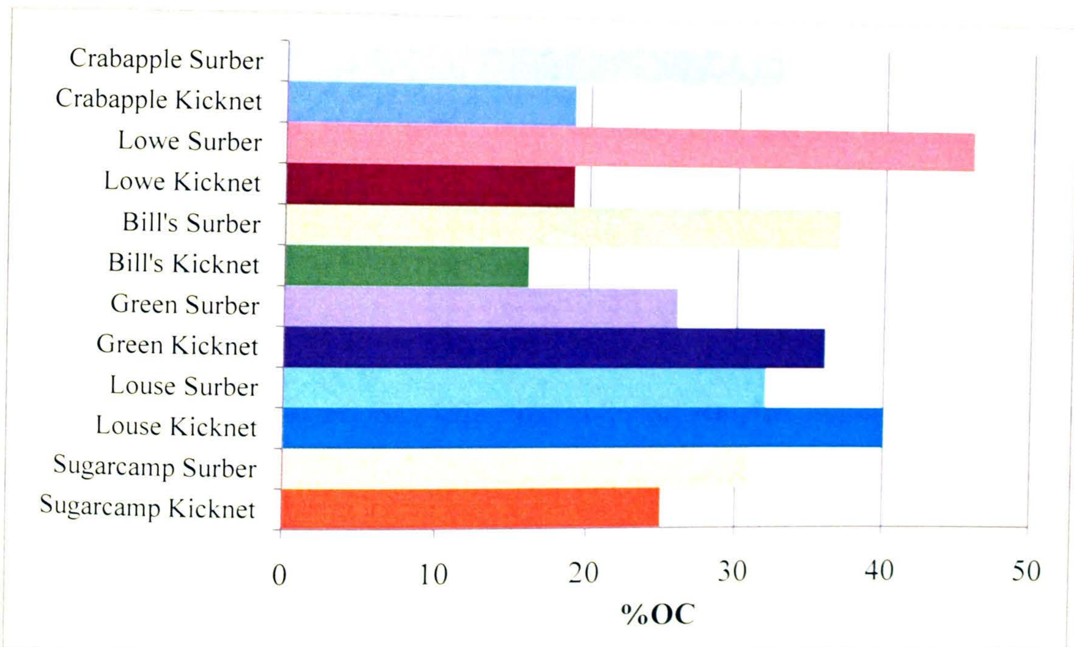


Figure 3.11. Mean %OC of 16 Surber samples compared to %OC of the SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

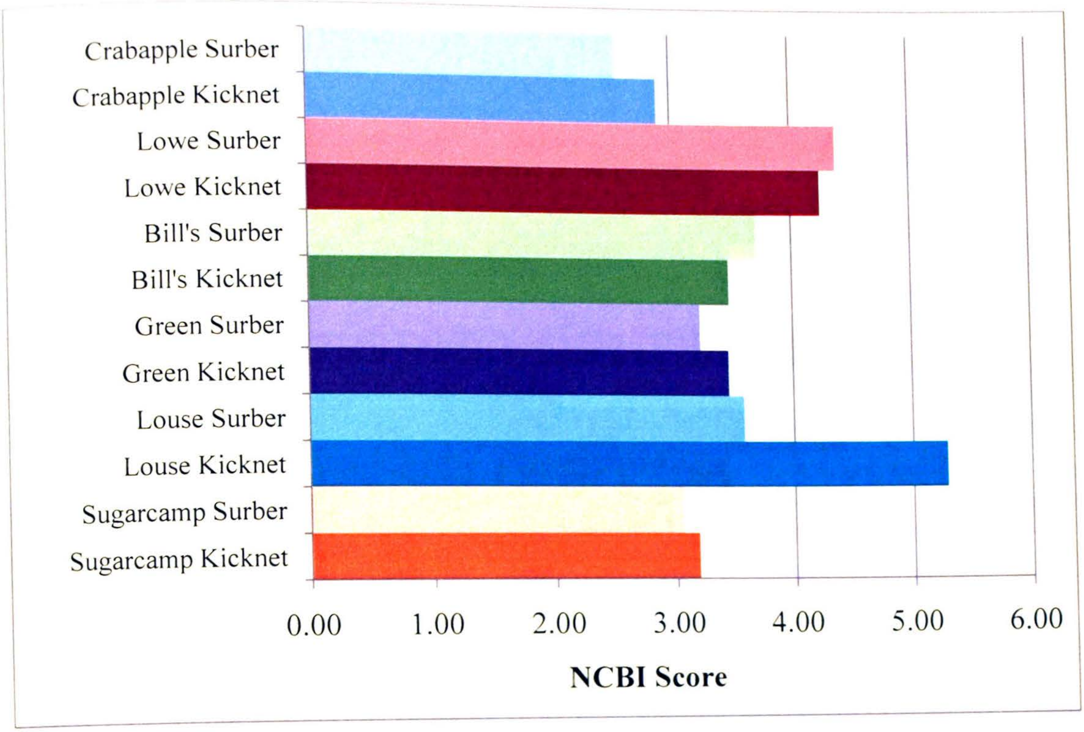


Figure 3.12. Mean NCBI scores of 16 Surber samples compared to NCBI Score of SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

Mean %NUTOL score in the Surber samples, 35%, was less than that in the kicknet samples, 38%, but this was not a statistically significant difference. There was considerable difference in %NUTOL scores between Surber samples and kicknet samples, but no pattern to these differences (Fig 3.13).

The mean %Clingers was 43% score in Surber samples, slightly lower than that in the kicknet samples of 46%. This difference was not statistically significant (Fig. 3.14).

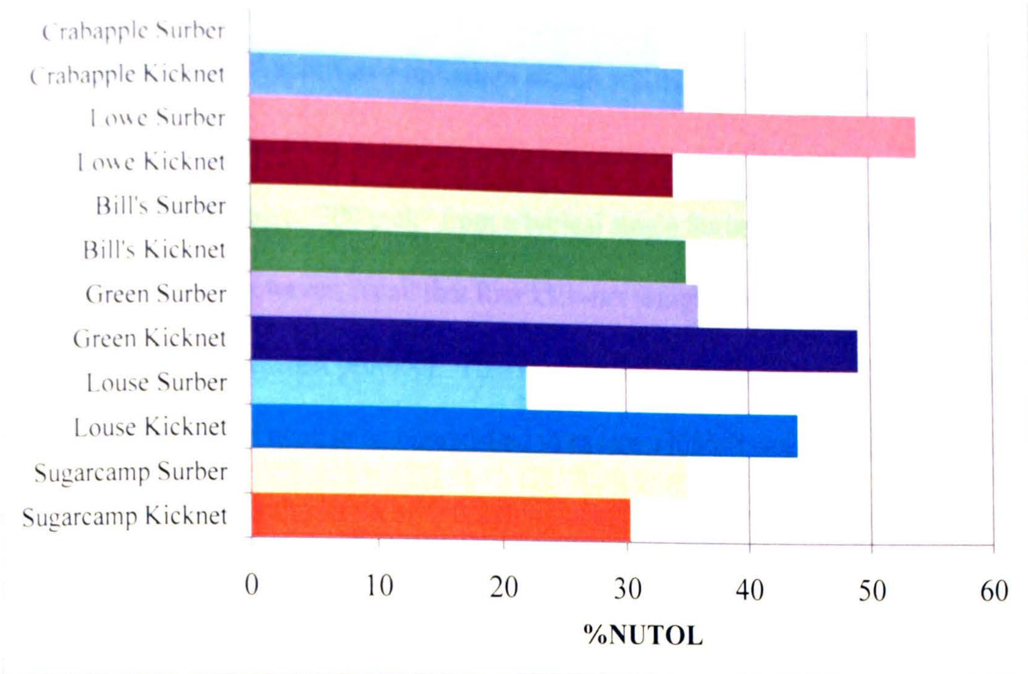


Figure 3.13. Mean %NUTOL score of 16 Surber samples compared to %NUTOL score of SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

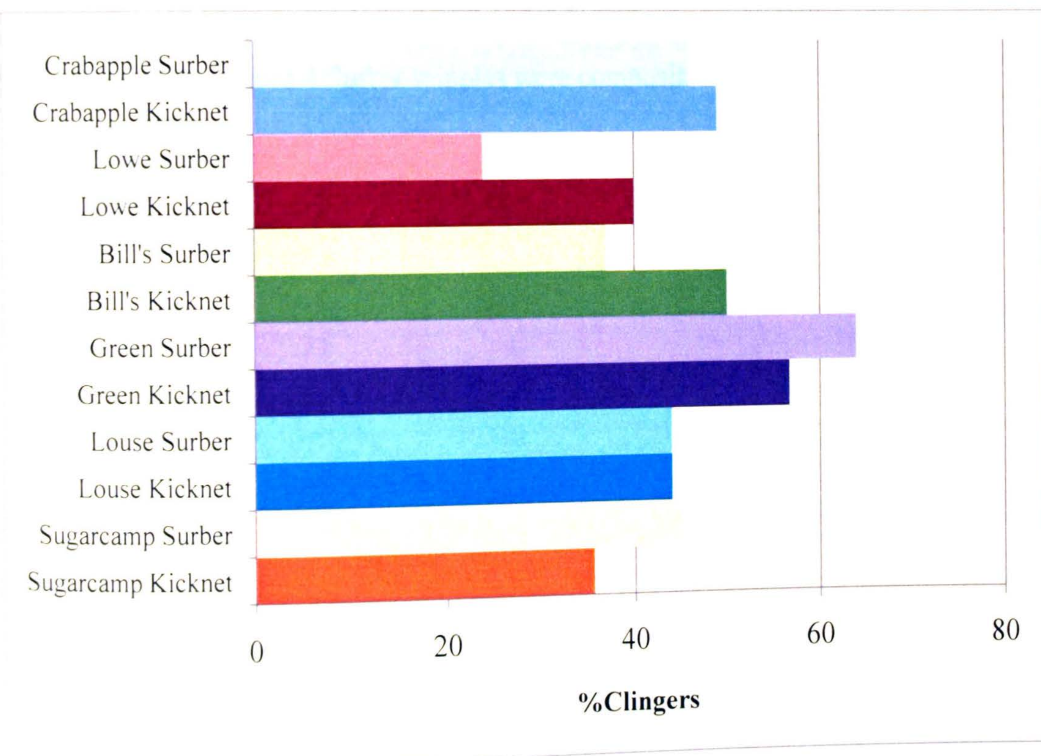


Figure 3.14. Mean %Clingers score of 16 Surber samples compared to the %Clingers score of the SQ kicknet sample for Scott, Campbell, and Anderson counties, Tennessee.

The Number of Surbers Required for Bioassessment

TDEC protocol specifies a minimum of 200 ± 20% macroinvertebrates be collected in a sample in order to proceed with bioassessment of that sample. The probability of obtaining a "200 pick" from a typical single Surber sample in these streams is low (Table 3.5). However, recall that four kick-net samples are composited in the TDEC modified SQ-kicknet protocol. This leads to the logical question of how many Surber samples would need to be composited to assure a high reasonable probability of achieving the 200 pick threshold of 160 individuals. By simulating one million random samples from the 2008 data sets it was determined that compositing three Surber samples provided a "200 pick" over 95% of the time. Only Green Branch and Lowe Branch did not approach a 100% probability of achieving a 200 pick when three Surber samples were composited. All streams achieved a near 100% probability of collecting 160 macroinvertebrates when 4 Surber samples were composited (Fig. 3.15).

Table 3.5. Average number of macroinvertebrates collected in Surber samples in each stream.

Stream	Average Number of Macroinvertebrates Collected	Date
Lowe Creek	94	7/22/2008
Crabapple Creek	235	7/23/2008
Louse Creek	242	6/18/2008
Green Branch	232	6/19/2008
Sugarcamp Creek	122	6/17/2008
Bill's Creek	192	6/19/2008

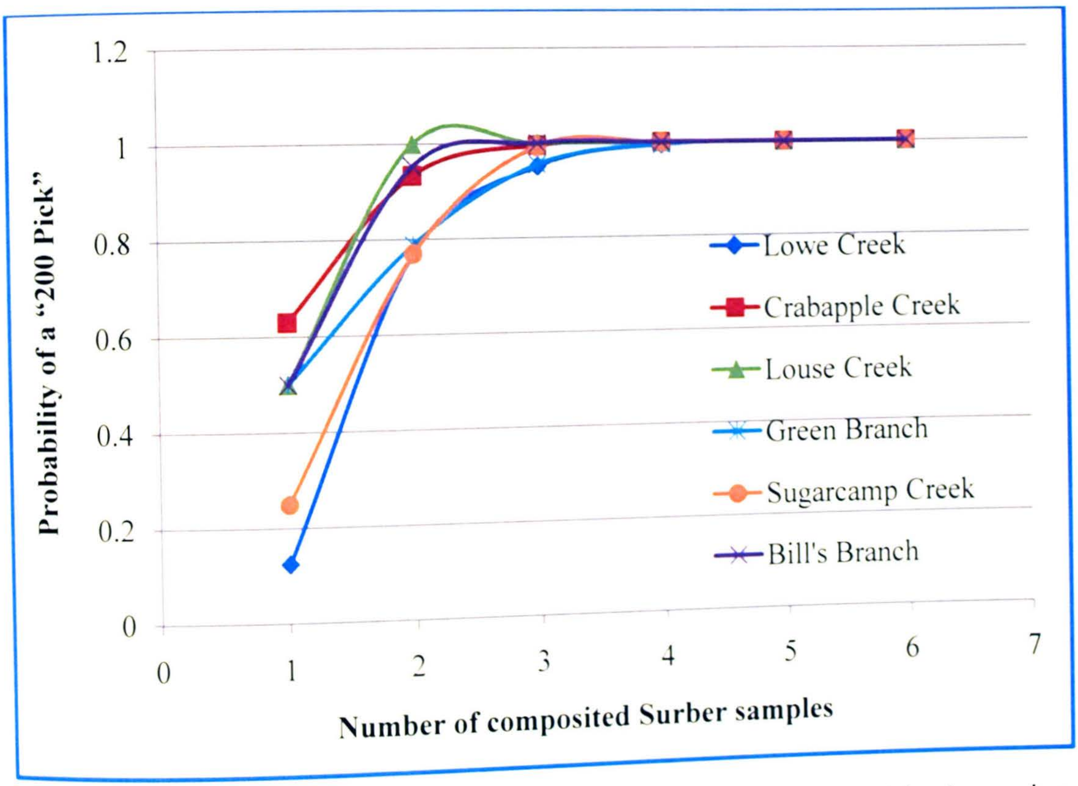


Figure 3.15. Probability of Reaching 160 Macroinvertebrates by compositing increasing numbers of Surber samples.

Comparison of Paired Surber Samples to Kicknet Samples

Given that compositing only two Surber samples achieves a "200 pick" much of the time (Fig. 3.16), and that it was necessary to composite individuals Surber samples into paired Surber samples in order to compare 2008 data to data collected in 1981, it is potentially informative to compare paired Surber samples to kicknet samples to assess the effect of doubling the area of substrate sampled per Surber and/or increasing the number of macroinvertebrates collected in the Surber samples. Table 3.6 compares mean metric values of eight paired Surber samples to the kicknet metric values. Although the mean metric values of the paired Surber samples differed somewhat from the mean values of the individual Surber samples, this resulted in only a small difference compared to the kicknet samples. When mean metric values of individual Surber samples were compared to kicknet samples, only EPT taxa richness was significantly different between Surber samples and kicknet samples (Table 3.4). When mean metric values of paired Surber samples are compared to mean metric values of kicknet samples, only Taxa Richness was significantly different between the two sampling devices.

Table 3.6. Mean Metric Scores for 8 paired Surber samples collected in each of 6 streams of the New River Watershed along with the mean metric value of the six streams. P values for the Mann-Whitney U test if the mean metric score of samples collected with Surber nets differ from the mean metric score of samples collected with kicknets.

Stream	TR	EPT	%EPT	%OC	NCBI	% NUTOL	% Clinger
Lowe Surber	29	10	21	47	4.5	54	23
Crabapple Surber	37	13	41	33	2.52	21	45
Louse Surber	34	14	50	30	3.01	19	45
Green Surber	36	16	53	32	3.51	35	59
Sugarcamp Surber	28	14	55	30	2.94	32	43
Bill's Surber	33	16	43	39	3.64	40	37
Mean Surber	**32.9**	**13.7**	**44**	**35**	**3.35**	**34**	**42**
Lowe Kicknet	30	14	35	19	4.25	34	40
Crabapple Kicknet	23	11	43	19	2.89	35	49
Louse Kicknet	28	15	41	40	5.29	44	44
Green Kicknet	25	13	53	36	3.46	49	57
Sugarcamp Kicknet	25	14	63	25	3.9	30	36
Bill's Kicknet	27	14	57	16	3.47	35	50
Mean Kicknet	**26**	**14**	**49**	**26**	**3.74**	**38**	**46**
Mann Whitney U	**$P \leq 0.01$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**

Comparison of 2008 Surber Samples to 1981 Suber Samples

Two surber samples were composited and referred to as "paired Surber" samples when they were collected in the previous studies of these streams, including the 1981 data included here (Vaughan et al., 1982). Thus, the 16 Surber samples collected in this study were "composited" into 8 paired Surber samples to allow comparison of the two data sets. Comparison of the Surber samples in this study to those collected in 1981 reveals more macroinvertebrates were collected in the 2008 samples (Fig. 3.15). For example, Sugarcamp Creek paired Surber samples averaged only 11 macroinvertebrates in 1981 but averaged 243 macroinvertebrates in 2008. Table 3.7 compares mean number of macroinvertebrates collected in paired Surber samples in 1981 compared to the mean number of macroinvertebrates collected in 2008. Only Lowe Creek paired Surber samples collected in 2008 failed to reach a sufficient number of macroinvertebrates to constitute a "200 pick" (= 200±40 macroinvertebrates), whereas, in 1981, only paired Surber samples collected in Louse Creek captured enough macroinvertebrates to constitute a "200 pick."

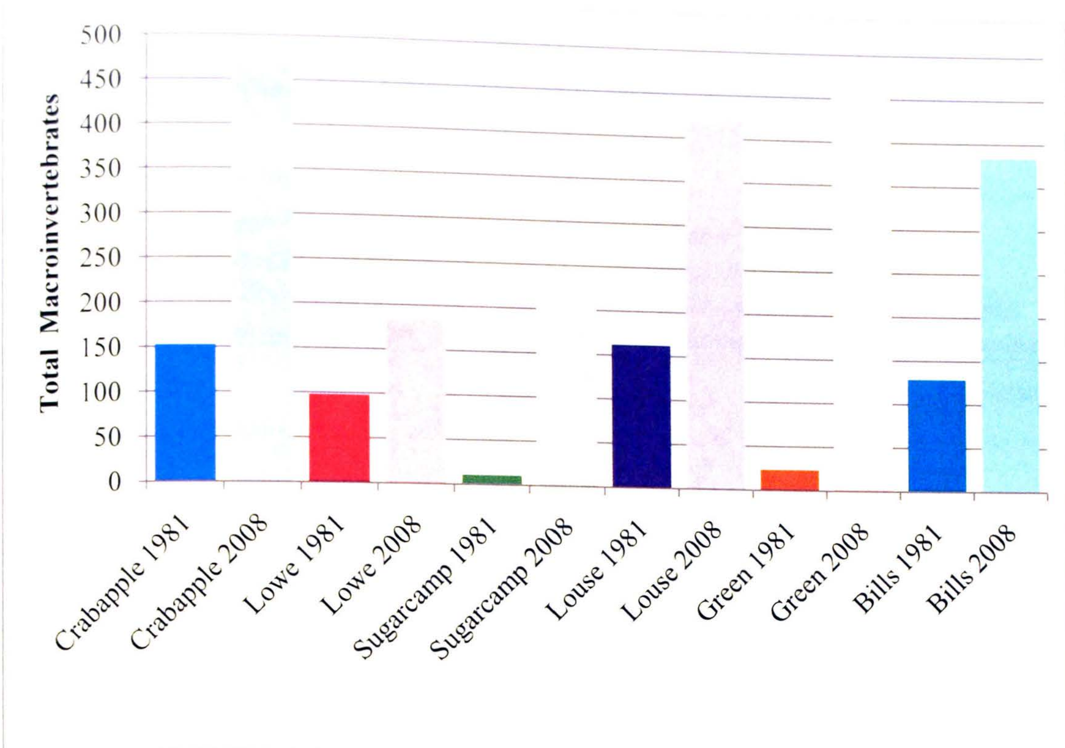


Figure 3.16. Total macroinvertebrates collected in eight paired Surber samples (a paired Surber sample = 2 composited Surber samples) in 1981 and in 2008 in the watershed of Scott, Anderson,and Campbell counties, Tennessee.

Table 3.7. Mean number of macroinvertbrates collected in paired Surber samples in 1981 compared to 2008. Mean abundance values differed significantly (Mann Whitney U, P≤ 0.01)

Stream	Mean Number of Macroinvertebrates Collected in 1981 Surber samples	Date Sampled	Mean Number of Macroinvertebrates Collected in 2008 Surber samples	Date Sampled
Lowe Creek	98	6/24/1981	184	7/22/2008
Crabapple Creek	152	7/14/1981	469	7/23/2008
Louse Creek	162	6/09/1981	420	6/18/2008
Green Branch	24	6/24/1981	466	6/19/2008
Sugarcamp Creek	11	6/30/1981	243	6/17/2008
Bill's Creek	129	6/24/1981	384	6/19/2008
Mean	**96**		**361**	

Table 3.8 compares mean metric scores of paired Surber samples collected in 1981 to mean metric scores of paired Surber samples collected in 2008. Despite the fact that the 1981 samples collected considerably fewer macroinvertebrates, the mean metric values of the two sets of data only differed significantly in Taxa Richness and EPT Taxa Richness.

Table 3.8. Mean metric values of paired Surber samples for 6 streams collected in 1981 and 2008 in the New River Watershed along with the mean metric score of the six streams. P values for the Mann-Whitney U test if the mean metric score of samples collected with Surber nets differ from the mean metric score of samples collected with kicknets.

Stream	**TR**	**EPT**	**%EPT**	**%OC**	**NCBI**	**%NUTOL**	**%Clingers**
Lowe 1981	15	10	65	15	2.7	28	62
Crabapple 1981	18	11	66	21	3.34	29	52
Louse 1981	18	12	50	9	4.91	45	32
Green 1981	6	5	82	14	5.11	43	42
Sugarcamp 1981	3	0	2	65	5.09	65	2
Bill's 1981	17	12	92	3	2.97	5	46
Mean 1981	**13**	**8**	**59**	**21**	**3.52**	**36**	**39**
Lowe 2008	29	10	21	47	4.5	54	23
Crabapple 2008	37	13	41	33	2.52	21	45
Louse 2008	34	14	50	30	3.01	19	45
Green 2008	36	16	53	32	3.51	35	59
Sugarcamp 2008	28	14	55	30	2.94	32	43
Bill's 2008	33	16	43	39	3.64	40	37
Mean 2008	**33**	**14**	**44**	**35**	**3.74**	**34**	**42**
Mann Whitney U	**$P \leq 0.01$**	**$P \leq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**	**$P \geq 0.05$**

Bioassessment of SQ Kicknet and Surber Samples

The TDEC modified SQ Kicknet Protocol classified Sugarcamp Creek, Duncan Branch, Bill's Branch, Green Branch, Bowling Branch (2), and Crabapple Creeks as "not impaired." All other streams including one of the reference streams, Lowe Creek, were classified as "slightly impaired" using the TDEC modified SQ Kicknet Protocol (Table 3.9).

The 16 Surber samples were processed separately and a bioassessment was performed on each of the separately processed Surber samples. This resulted in more than a single bioassessment classification for each stream sampled with Surber samplers. Bioassessment classifications ranged from "not impaired" to "moderately impaired." Not all Surber samples had the minimum 160 macroinvertebrates to constitute a "200 pick" as required by the TDEC modified SQ kick protocol. Bioassessments of the 16 Surber samples from each stream are presented in Table 3.10.

Table 3.9. Bioassessment classifications of the streams using the TDEC modified SQ kicknet protocol.

Stream	Bioassessment Score	Date
Sugarcamp Creek	Not Impaired	6/17/2008
Louse Creek	Slightly Impaired	6/18/2008
Bills Branch	Not Impaired	6/19/2008
Ursery Creek	Slightly Impaired	6/19/2008
Indian Fork	Slightly Impaired	6/18/2008
Duncan Branch	Not Impaired	6/18/2008
Green Branch	Not Impaired	6/19/2008
Bruce Hollow	Slightly Impaired	6/18/2008
Bruce Hollow	Slightly Impaired	7/23/2008
Bowling Branch	Slightly Impaired	6/19/2008
Bowling Branch	Not Impaired	7/23/2008
*Lowe Branch	Slightly Impaired	7/22/2008
*Crabapple Creek	Not Impaired	7/23/2008

*Reference streams

Table 3.10. Bioassessment classifications of each of the 16 Surber samples collected from six streams in the New River Watershed, Tennessee.

Stream	Not Impaired	Slightly Impaired	Moderately Impaired
Lowe Creek	1	5*	10
Crabapple Creek	6*	10	1
Louse Creek	5	9*	0
Green Branch	9*	7	0
Bill's Branch	3*	12	1
Sugarcamp Creek	8*	8	0

*indicates Bioassessment classification obtained from modified SQ kicknet protocol.

The 16 Surber samples collected from each stream were composited into eight paired Surber samples from each stream in order to compare bioassessments of data collected in 2007 to data collected in 1981. Bioassessment of the 2007 paired Surber samples are summarized in Table 3.11.

Table 3.11 Bioassessment classifications of eight paired Surber samples collected in 1981 and 2008 in six streams in the New River Watershed, Tennessee.

Stream	Not Impaired	Slightly Impaired	Moderately Impaired	Severely Impaired
Lowe 1981	7	1		0
Lowe 2008	1	4*	3	0
Crabapple 1981	6	2	0	0
Crabapple 2008	6*	1	1	0
Louse 1981	0	8	0	0
Louse 2008	6	2*	0	0
Green 1981	0	7	1	0
Green 2008	7*	1	0	0
Bill's 1981	8	0	0	0
Bill's 2008	5*	3	0	0
Sugarcamp 1981	0	0	6	2
Sugarcamp 2008	5*	3	0	0

*indicates Bioassessment classification obtained from modified SQ kicknet protocol.

Surber samples were used to collect macroinvertebrates in both 1981 and 2008. However Surber samples in 1981 were paired in the field when collected with a total of 8 collected samples; whereas the samples in 2008 were kept separate yielding 16 samples (Appendix C and D) (Vaughan, et al. 1982). Bioassessment classifications using individual Surber samples most often classified streams as slightly impaired, but more than one classification resulted from different Surber samples in all streams except Bill's Branch. Classifications for each paired Surber sample ranged from "moderately impaired" to "not impaired" in both Crabapple Creek and Lowe Branch. The range of multimetric scores obtained from paired Surber samples in each stream and how this compares to the multimetric score obtained from the modified SQ kick protocol (Fig. 3.17). Louse Creek kicknet multimetric scores did not fall within the limits of the Surber results. Lowe and Green Branch kicknet scores fell outside the box on either side. Crabapple Creek and Bill's Branch fell were right on the median line of the eight Surbers sampled.

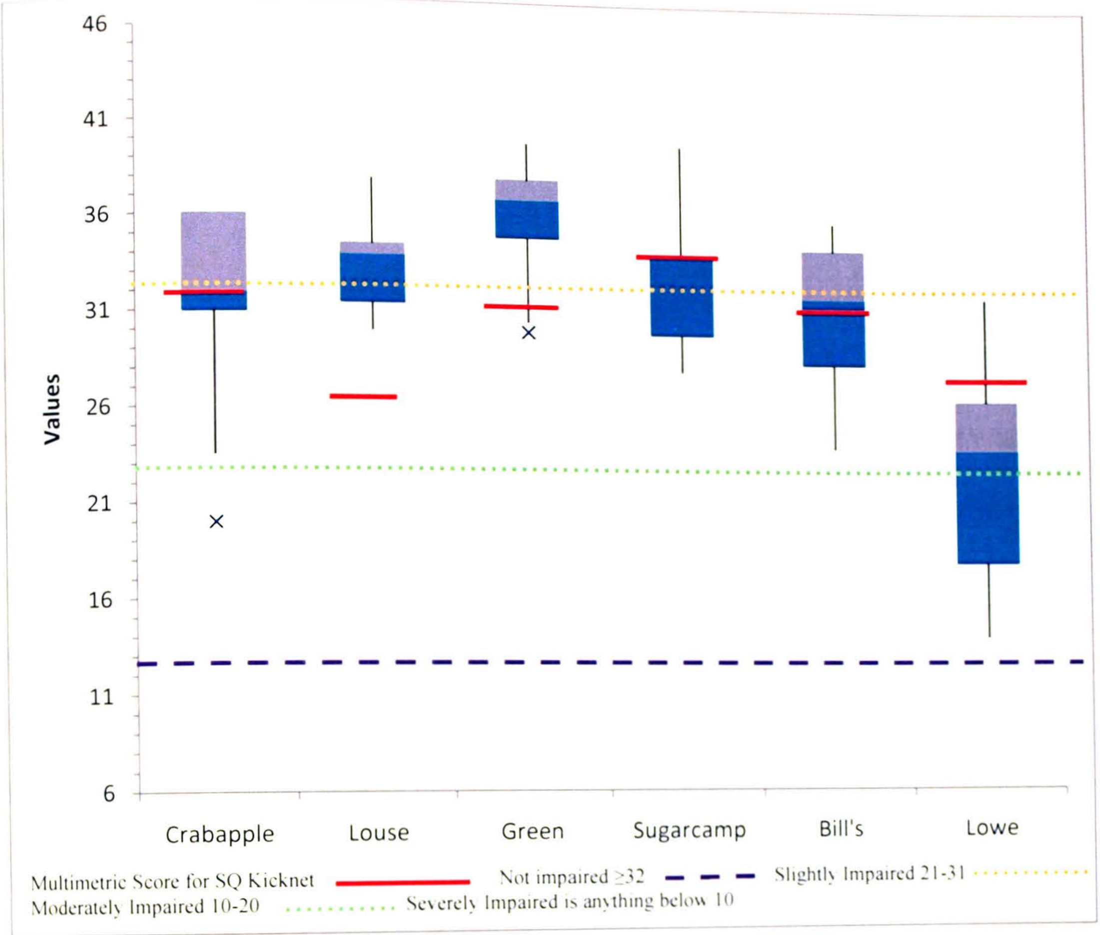


Figure 3.17. Box plots of Multimetric Scores for 8 paired Surber samples. Multimetric scores obtained from the modified SQ kick protocol are indicated by the red bar.

CHAPTER IV

DISCUSSION

Mining Activity

Lowe Branch and Crabapple Creek have never been mined. Bruce Hollow had relatively small areas of mining disturbance over 35 years ago (Schiller, 1986). The watersheds of Bill's Branch and Bowling Branch have not been mined for over thirty years. Ursery Creek, Green Branch, Indian Fork and Duncan Branch were all recently mined and reclaimed (GIS Map, 2008). Louse Creek had mining in some of its tributary stream watersheds in the 1980's (Dickens, 1988). Mining history is difficult to track before 1978 when SMCRA was enacted because no permitting system was in place. Before SMCRA, mining permits were not tracked in a GIS system as they are now, so it is difficult to accurately estimate the exact dates and extent of mining in stream watersheds prior to 1978 when SMCRA was passed.

Habitat Assessment

Habitat assessment can be important for interpreting bioassessments when effects on the stream are the result of local alterations of the riparian zone of the sampled reach or are the result of upstream watershed disturbance that alters variables measured in the habitat assessment, such as embeddedness. It can assist in characterization of streams for accurate comparison by factoring in measurable habitat differences between streams (Barbour et al., 1999). Comparisons between streams, or between assessments of the same stream over time, can be done by the use of a standard habitat assessment protocol.

The habitat assessment is performed at the time of macroinvertebrate sampling. Each time a habitat assessment is performed many physical characteristics of the stream and its immediate riparian corridor are observed and scored providing an accurate description of the physical habitat condition of the stream reach.

Habitat assessment protocols were not developed until the mid 1980's and so were not conducted on these streams in previous studies, but it is likely that had habitat assessments been conducted in the previous studies, they would not have significantly differed from those obtained in this study. This is because earlier studies reported similar habitat impairments as observed in this study such as embeddedness and sedimentation even though these were not formally quantified in the previous studies. Riparian and other criteria scored in the habitat assessment have not changed judging from the mature state of the forest canopy observed in most sampling reaches. The main physical property of the stream habitat scored in the habitat assessment directly affected by mining is embeddedness caused by erosion of large quantities of fine particles of rock created when large areas of the watershed are disturbed to extract coal. Substrate stability can also be directly affected if large amounts of fine sediment and gravel are eroded from the mine areas and transported downstream. Mining activity alters hydrology and increases flows and flashiness which can exacerbate erosion of fine particles into the stream that cause embeddedness and substrate instability.

Generally, lower habitat assessment scores of streams in this study resulted from embeddedness of the substrate. Most of the streams draining mined watersheds had some degree of embeddedness. Many of the sampled stream reaches had paved and unpaved roads beside them, but most of these probably do not continue very far upstream. Habitat assessment classified both reference streams as well as Bruce Hollow "not impaired." Both reference streams, as well as many of the previously mined streams, had extensive native vegetation such as alder, hemlocks, and rhododendron along their stream banks, and a complete forest canopy. Habitat assessment classified all the other streams except Indian Fork Creek as "moderately impaired." Duncan Branch had a mechanic's garage with many parked vehicles downstream from the sample reach, which in and of itself does not affect the habitat assessment, but indicates the more developed location of this stream reach compared to most of the other streams. Ursery Creek had large amounts of sediment in the stream. Indian Fork Creek was classified as having "severely impaired" habitat, reflecting low scores for its riparian condition due to a paved road along one stream bank and little vegetated buffer on the other bank because of residential clearing in addition to some embeddedness. Indian Fork is unusual compared to the mostly smaller streams in this study which are usually completely forested. Somewhat larger streams such as Indian Creek generally have lower gradients and larger flood plains more suitable for the building of roads and residences. These details can be hard to quantify without the use of a standardized habitat assessment protocol that documents habitat impairment at the time of sampling (Barbour et al., 1999).

Unfortunately these habitat assessments can also be misleading. None of the stream sites had mining activity within the sampled reach or even visible from the sampled reach. Mining activity occurs well upstream of the forested sample reaches, often at elevations in the watershed above any permanently flowing water, and the main signature of this activity on the habitat assessment is embeddedness and instability of stream substrates caused by erosion of fine particles into the flowing reaches of the stream during storm runoff. However, within the sampled reach the riparian zones are often in excellent condition, there is a high diversity of substrate size classes, and a good mix of riffles, runs, and pools, resulting in fairly high habitat assessment scores for most streams, despite considerable impairment from past mining activity at higher elevations in the watershed.

Physical and Chemical Properties of Streams

Water temperature variation among streams at the time of sampling may reflect different stream sizes as well as time of day and sample date effects. Louse Creek and Indian Fork Creek are at least 3rd order streams, while most of the streams are 1st order. Larger streams often have higher temperatures because a smaller portion of their flow is derived from cooler ground water flow. One contributing factor to higher temperatures measured in July could have been the heavy rains immediately before the July sampling which reduced the portion of ground water flow in these streams during the storm runoff. The June sampling was during a prolonged dry period and stream flows then would have been more groundwater dominated at that time. Indeed, some streams were almost dry, with too little water flow to sample in June. This difference in predominant stream flow source can affect stream water temperature (Thorp and Covich, 2001). Of course, stream water temperature increases as the summer progresses as illustrated in Bruce Hollow by comparing the June record at 16.65 C° to July, at 19.61 C°, (fig. 3.2).

Specific conductivity of stream water increases after mining disturbance (Dickens et al., 1989; Pond et al., 2008; Bradfield, 1986). The measurement of specific conductance is often used to monitor the impact of mining on stream water (Bradfield, 1986). Indian Fork had the highest specific conductance score of 0.793 mS/cm. In addition to upstream mining disturbance, there is a road running along this stream, and a number of houses upstream from the sampled reach. All of these could contribute to the high specific conductivity of this stream. Ursery Creek had the next highest specific conductivity at 0.568 mS/cm as well as a large amount of embedded cobble and abundant sediment, all of which may have resulted from current mining activity in its watershed. Bruce Hollow had the lowest recorded specific conductivity of 0.005 mS/cm during the first sample event in June, but a considerably higher level of 0.116 mS/cm during the second sampling event in July. The low water level at the time of June sampling may explain this result. Bradfield,(1986) reported specific conductivity in Crabapple Branch at 0.02 mS/cm, Bowling Branch at 0.056 mS/cm, Bill's Branch at 0.160 mS/cm, and Green Branch, 0.360 mS/cm for the month of March 1983. These readings are lower than the values measured in these streams of our study. Pond et al. (2008) reported decreases in multimetric index scores when specific conductance levels were greater than 0.5 mS/cm, only three of our streams reached this level at the time of sampling, Indian Fork (0.793 mS/cm), Ursery Creek (0.568 mS/cm), and Sugarcamp Creek (0.840 mS/cm).

Total dissolved solids (TDS) are an important measure of the amount of inorganic and organic compounds dissolved in the water column. Total dissolved solids have been shown to be significantly higher in streams disturbed by mining (Dickens et al., 1989; US EPA, 2005). Indian Fork had the highest TDS at 0.516 g/L. This was considerably higher than the 0.052 g/L mean reported in a previous study after mining disturbance in Indian Fork (Dickens et al, 1989). Minear and Tschantz, (1976) measured huge seasonal fluctuations in suspended solids, with highest levels in the June/July time period. Indian Fork reached 0.35 g/L while Green Branch reached 0.4 g/L the authors noted that these high levels occurred after a storm event (Minear and Tschantz, 1976). Minear and Tschantz (1976) found TDS levels to consistently exceed the State of Tennessee maximal allowable level of 0.1 g/L at that time. The current federal standard is not to exceed 0.5 g/L (TDEC, 2008) which was at least sometimes exceeded. Total dissolved solids in Ursery Creek, Green Branch, Duncan Branch, and Indian Fork all exceeded 0.1 g/L in this study, but were well within the current Federal standard. However, all the streams except Lowe Branch were sampled during very low flow conditions when dissolved solids are expected to be low. All of the streams except the reference streams, Crabapple and Lowe Creek, and Bruce Hollow, Bowling and Duncan Branches were near recently reclaimed mining activity. This suggests that the reclamation requirements of SMCRA may not be correcting the high dissolved solids loads caused by surface mine disturbance in these watersheds.

Dissolved oxygen (D.O.) is an important factor determining the distribution of macroinvertebrates (Connolly et al., 2004). At levels of 20% to 10% saturation of D.O. there is an increase in some Chironomids and a decrease in most other taxa (Connolly et al., 2004). Higher levels of oxygen have been shown to positively affect macroinvertebrate abundance (Connolly et al., 2004; Bednarek and Hart, 2005; Love et al., 2008). Dissolved oxygen levels exceeded 80% in all the streams we sampled and should not have been a factor effecting the bioassessment.

Alkalinity levels were highest in Ursery Creek and Indian Fork at 116 mg/L and 100 mg/L, respectively. Previous studies found that after mining there was an increase in alkalinity for streams found in the different geological areas, (Dickens et al., 1989). Another study reported fluctuations of alkalinity in Indian Fork that the authors attributed to abandoned surface mines including large auger mining holes (Minear and Tschantz, 1976). Dickens et al., (1986) showed that alkalinity increased after five years of no mining disturbance. Alkalinity of Green Branch increased to 52 mg/L from the highest level of 35 mg/L reported by Minear and Tschantz (1976). Bowling Branch had slightly higher levels than previous studies, but was still fairly low at both times of sampling (Minear and Tschantz, 1976; Dickens et al., 1989). The low alkalinity we measured in Lowe Creek is consistent with measurements in previous studies which never exceeded 10 mg/L (Minear and Tschantz, 1976). In this study the alkalinity of Bruce Creek, 20 and 16 mg/L for June and July, respectively, and Crabapple Creek at 12 mg/L measured, was slightly lower than the 19.4 mg/L and 19.6 mg/L, respectively, reported by Schiller (1986).

Stream pH is dependent of the geology of the area. Limestone found in the area has the ability to naturally buffer streams. Streams in this study area undisturbed by mining often have pH values slightly on the acidic side, 6 to 6.5 su. Coal deposits, or adjacent rocks, will sometimes contain iron pyrite which when exposed to oxygen by mining undergoes a chemical reaction creating and increasing the amount of sulfuric acid (US EPA, 2005). However, iron pyrite is relatively rare in the coal deposits of the New River Watershed. More often, the disturbance of carbonate minerals by mining in this region causes an increased pH and alkalinity of stream water. The pH levels for most of the streams studied were near the neutral range. Ursery Creek and Indian Fork were the only streams with high pH values of 8.01 and 7.89, respectively. Minear and Tschantz

(1976) reported pH values as low as 5 su for Indian Fork indicating that some acid rumoff may have been affecting this stream then. Schiller (1986) reported a pH of 7.2 for Crabapple Creek and 7.1 for Bruce Hollow in June of 1980.

Bartlett's Regression Method, a Test of Data Transportability

Bartlett's Regression Method was used to regress the metric scores obtained from the kicknet samples against the metric scores obtained from the Surber samples to test for "transportability" of the data between sampling equipment, i.e. Surber nets versus kicknets. Bartlett's Regression Method applies to data sets such as in this analysis where the error of both variables is unknown. In traditional linear regression the error of the independent variable is controlled because it is "fixed" at predetermined levels. In this data set, both the independent and the dependent variable are random variables. This method of testing for transportability of metric data was recently applied to macroinvertebrate data collected with Surber samplers and kicknets in two Wyoming streams (Wu and Legg, in press). In this method, a significant linear relationship between the metric values obtained from macroinvertebrate samples collected with one device and the metric values obtained from macroinvertebrate samples collected with a different device indicates an analysis using data collected with either device will yield similar results. A significant regression with a slope of "1" and a y-intercept of "0" indicates identical metric scores would be obtained with either collecting device, i.e. complete transportability. However, no significant results were obtained when applying Bartlett's regression method to the data collected in this study, probably because of the small number of samples and the limited range of metric values in this data. Recall, in the modified SQ kick net protocol, the four kick net samples collected in each stream were composited into a single kicknet sample, resulting in a total of only six SQ kicknet samples. Even though metric values were obtained from each of the 16 Surber samples collected in each stream, the mean of the 16 metric scores was used in the regression to equalize the number of observations of the two variables in the analysis. Thus, despite the fact that hundreds of individual samples were collected, the compositing of kicknets required by TDEC protocol resulted in the reduction of these many samples to a sample size of six.

Metrics Values Obtained from SQ Kicknet and Surber Samples

In most cases taxa richness was higher for SQ kicknets, but Crabapple Creek and Lowe Branch Surber samples had slightly higher taxa richness. We would expect that the taxa richness to be slightly larger in the kicknets samples since they sample slightly more area than Surber samplers and richness metrics tend to increase with increase in area sampled. EPT taxa richness was always higher in SQ kicknet samples. Some of the streams such as Louse and Sugarcamp Creeks had four more EPT taxa in kicknet samples compared to Surber samplers. Average %EPT scores were higher in Surber samples for Louse Creek than from SQ kicknet samples. Green Branch had the same %EPT in Surber samples as in kicknets, even though it had three more EPT taxa in kicknet samples. Average %OC scores were usually higher in Surber sample than in the kicknet samples. This suggests Surber samplers may be somewhat more efficient at capturing these small, wormlike macroinvertebrates compared to kicknets. Lowe Creek Surber samples had %OC scores twice as high as kicknet scores. It should be noted that this stream was sample during a storm event and before that this stream was so dry that it could not be sampled. This may be a reason for such high numbers in such tolerant taxa. Most of the NCBI scores were similar for both sampling devices, except in Louse Creek, where its NCBI score for the SQ kicknet samples was 5.29 and the average of the Surber samples was 3.01. One reason the NCBI score may have been lower in Surber samples in Louse Creek is that at least one, and often more than one, *Dicranota,* which has a low pollution tolerance value of zero, was collected in most of the Surber samples, but not in the SQ kicknet sample. There was no pattern for %NUTOL. All but two streams had higher %Clingers scores from kicknet samples than from Surber samples. Lowe Branch had %Clingers scores almost twice as high for SQ kicknet samples than from Surber samples. This may be due to sampling Lowe Creek immediately after a storm event when stream flow was fairly fast for the size of the stream. The fast stream flow may have amplified the tendency to collect more clingers in kicknets than with Surbers. Surber sampling is much more rigorous than SQ kicknet sampling in that a more defined, but smaller area of the stream substrate, is carefully processed compared to kick net samples, so the higher metric scores for kick nets may seem surprising. However, each Surber samples about 1/10th the approximately 1 m^2 of substrate area sampled by the kicknets; thus, the comparable, and in some cases higher, scores of the Surber samples suggests they are a more efficient sampling device.

Bioassessment of modified SQ Kicknet samples

Bioassessment of the modified SQ kicknet samples yielded classifications that were somewhat surprising, as there were no scores below "slightly impaired." These streams were sampled during a severe drought. Lowe and Crabapple were so low in June that they could not be sampled until after a major rain storm in July. In fact, Lowe Creek was sampled while the storm was still occurring and its flow was still high and very much in the "flash" phase of its hydrograph. Crabapple Creek was sampled the next day and rain showers were still occurring in its watershed, yet its flow had only increased to levels barely adequate to allow sampling of macroinvertebrates. The drought conditions preceding and during sampling may have caused the low reference stream bioassessment scores. Churchel and Batzer (2006) showed that streams consisting of gravel substrates and were dried from drought conditions had recovery in 15 days after a significant rainfall. Communities of macroinvertebrates for the first three months were similar, but over a year community composition changed (Churchel and Batzer, 2006). This could indicate why the Ephemeroptera populations were so low in our study; perhaps the Ephemeroptera population had not yet recovered? In another study of headwaters in Appalachia, Angradi et al. (2001) found that abundance of Ephemeroptera was highest in the spring and lowest in the fall. Since the reference streams were sampled a month later in the summer it is expected they would have lower abundance and diversity of mayflies than if sampled in May or April. Thus, both the delay in sampling as well as the very low flow levels of the reference streams prior to sampling probably reduced their macroinvertebrate multimetric scores.

Sugarcamp Creek, Bill's Branch, Bowling Branch (2), Duncan Branch, and Green Branch were classified as "not impaired." These bioassessments based on SQ kicknet samples would be hard to compare to previous studies where macroinvertebrates were sampled with Surber samplers without the analysis of metric values and bioassessments using both sampling devices reported here. Some of these sites have not been mined for over 40 years and may have recovered to premining condition, but this needed to be confirmed by comparing bioassessments of Surber samples, using the same sampling method used in earlier studies. However community structure does not appear to be the same in our samples compared to the earlier studies. Vaughan et al. (1978) reported that community structure for some orders such as the Ephemeroptera, which was usually dominated the species prior to mining, had not recovered even 20 years after mining disturbance. Given that Lowe Branch is a reference stream never disturbed by mining, it seems that the very low water levels for months prior to sampling coupled with the high water flows during sampling resulted in a very atypical sample. The %Ephem values in kicknet samples were slightly higher, but nowhere near the 70% Ephemeroptera reported for some reference streams by Vaughan et al. (1978). All the other streams had %Ephem values greater than 40%, but none had a value above 55%. However, %Ephem in paired Surber samples collected in 2008 was only 21%.This could indicate that many of the stream communities have still not fully recovered to premining conditions.

Bruce Creek and Bowling Branch were sampled both in June and July. Bruce Creek was classified as "slightly impaired" on both sampling dates. The June bioassessment classified Bowling Branch as "slightly impaired" while the July bioassessment classified it as "not impaired," although borderline. Love et al. (2008) showed that if insect abundance was high it would decrease the effect of extinction of a local population after a severe drought. In addition they discovered that burrowing species survived droughts and after 15 days of recovery began developing different patterns of community structure (Love et al., 2008). Bowling Branch may be an example of community structure recovering from drought after several days of rainfall in the month of July.

Louse and Ursery Creeks are larger than most of the other streams studied and both were flowing when sampled in June. Bioassessment classified both as "slightly impaired." Ursery Creek had a lot of embeddedness, a common effect of increased sediment in streams affected by coal mining. Most watersheds in the region experience considerable recreational ATV traffic which also could contribute to this condition.

Bioassessment for SQ Kicknet and Surber Samples

Bioassessment classifications of individual Surber samples were not consistently similar to those of kick nets. Many individual Surber samples were classified as more impaired than the bioassessment of the SQ kicknet samples. This would be expected since Surber samplers sampled a smaller area than the modified SQ kicknet samples, and thus, collected fewer macroinvertebrates and fewer taxa. The average number of insects collected per Surber sample in this study was 181. The lowest average number of macroinvertebrates sampled was 94 in Lowe Branch. Many of the Surber samples collected in 2008 did contain over 160 macroinvertebrates, the minimum number allowed in the modified SQ kick protocol, but sometimes yielded bioassessment classifications that differed from the SQ kick. Compositing individual Surber samples into paired Surber samples captured more macroinvertebrates than paired Surber samples collected in 1981 (Fig. 3.8). All of the streams in 2008 had higher abundance of individuals than the Surber samples from 1981.

Comparing Surber sampler bioassessment results from this study to those from 1981, there is some indication of improvement in water quality for some of the streams. Louse Creek, Green Branch, and Sugarcamp Creek Surber samples all have better bioassessment classification than they did in 1981. These three streams have scores in the range of "not impaired" to "slightly impaired." The results from 1981 were in the range of "slightly impaired" to "severely impaired." Lowe Branch has declined compared to 1981, but this may have been due to sampling during a storm following a prolonged severe drought. Bioassessment of Crabapple Creek and Bill's Branch was unchanged compared to1981. This result for Crabapple Creek seems to confirm the validity of applying contemporary assessment protocols to data from earlier studies. Similarly, the result for Bill's Branch seems to confirm the conclusions of earlier researchers that surface mined streams do not completely recover from mining disturbance for decades (Vaughan, et al., 1979; Schiller, 1986). However, multimetric scores on which these bioassessment classifications were made may have been lower than might have been obtained if the streams had been sampled earlier in the summer, especially considering the prolonged severe drought prior to sampling.

Individual Surber samples collected in this study often did not contain the 160-240 (200±20%) macroinvertebrates required by the TDEC modified SQ-kick Protocol, but two composited Surber samples, (i.e., paired Surber samples) usually contained the required minimum 160 macroinvertebrates. The probability of obtaining a "200 pick" as increasing numbers of individual Surber samples are composited is illustrated in Figure 3.15. Note that the probability of collecting a minimum "200 pick" when compositing two Surber samples is as low as 70 % for Green Branch, Sugarcamp Creek, and Lowe

Branch. However, when compositing three Surber samples, the probability of obtaining a 200 pick was 95% or more for Green and Lowe branch, and approached 100% for most streams. The low abundance of macroinvertebrates in Lowe Branch may reflect the fact that it was sampled in the midst of a summer spate at rather high flow, but may have been almost dry for some time immediately prior to this. Since the probability of collecting a "200 pick" is essentially 100% when four Surber samples are composited, using Surber samplers would be comparable to the four composited kicknet samples in effort.

However, for unknown reasons, abundance of macroinvertebrates in the 1981 Surber sample data was generally much lower than in this study. Thus, the probability of reaching over "200 pick" for some streams would have required compositing more of the 1981 Surber samples. For example, Sugarcamp Creek averaged only 11 macroinvertebrates per paired Surber sample in 1981. To collect a "200 pick" with these samples would require compositing at least 16 paired Surber samples (i.e., collecting 32 individual Surber samples). However, this stream was extremely impaired at the time and the kick net samples also would have failed to collect a "200 pick." Samples collected in 1981 were of streams mined prior to implementation of SMCRA and so usually no reclamation was practiced after mining. This may indicate why samples were so small.

The box plot diagram (Fig. 3.17) demonstrated that in half of the streams paired Surber multimetric scores were not similar to SQ kicknet scores. Further, there was no consistency in the range of Surber multimetric scores relative to the SQ kicknet scores within streams. The SQ kicknet score in Louse Creek was below the range of Surber multimetric scores. The SQ kicknet multimetric score in three of the streams, Crabapple

Creek, Bill's Branch, and Sugarcamp Creek, were the same as the median multimetric score of the Surber samples, and the SQ kicknet multimetric score in two of the streams. While Louse Creek and Green Branch, were above the median multimetric score of the Surber samples. This may indicate that there is little difference in bioassessment using Surber samplers compared to kicknets.

Conclusions

Habitat assessments showed that all streams with mining had some habitat impacts with assessment classifications ranging from "moderately impaired" to "severely impaired." Usery Creek had a lot of embeddiness from previous mining and clearly had not recovered yet even after reclamation. Indian Fork was "severely impaired" and had been mined in 2006. This may indicated that although streams are reclaimed there are still habitat impairment years after mining. It appears that current mining reclamation is helping to mitigate the negative effects of mining as indicated by macroinvertebrate bioassessment scores. The streams that were recently mined and reclaimed had scores of either "not impaired" or "slightly impaired." In previous studies, mine impacted streams were not reclaimed and had much lower taxa richness and bioassessment classifications relative to reference streams whereas the recently mined and reclaimed streams of this study which differed much less from reference streams. For example, Surber samples collected from Sugarcamp Creek in 1981collected an average of less than 11 macroinvertebrates, whereas paired Surbers collected in 2008 collected an average of 243 macroinvertebrates. Similarly, Green Branch paired Surbers collected an average of 24 macroinvertebrates in 1981 compared to an average of 466 individuals per paired Surber sample collected in 2008.

However, water chemistry data suggest that reclamation is not preventing significant chemical changes to stream water. Green Branch had high alkalinity, while Ursery Creek and Indian Fork had high pH's and high specific conductivity. This may in time have an effect on macroinvertebrate communities. Further data needs to be gathered to monitor the amount of runoff from mining. Minear and Tschantz (1976) showed large fluctuations in storm runoff during long-term monitoring. Most streams in this study were sampled during low flow conditions when suspended solids are low and most stream flow is from groundwater that may not have been carrying chemical constituents that would be present in runoff from mine disturbed areas during storm events. Chemical data sampling during large rain events is necessary to ascertain the effectiveness of reclamation in preventing polluted runoff from mine areas. The high pH, alkalinity, and conductivity measured is recently mined and reclaimed streams suggest that further monitoring is needed to assess the effectiveness of mining reclamation to mitigate water chemistry impacts. Surber sampling is used in many previous studies of streams in this region, and we have shown that the State of Tennessee Protocol can be applied to macroinvertebrates collected with Surber samplers to conduct bioassessment. In addition, we have shown that four Surber samples will yield the "200 pick" for the State of Tennessee protocol. In fact our data showed that with two to three combined Surber samples you will reach the "200 pick." Applying these metrics to Surber sampling methods will allow past data to be updated to the State of Tennessee Protocol, thus allowing current stream bioassessment data to be compared to past data on mined streams.

Unfortunately we were unable to use the Bartlett's Regression Model to independently confirm the "transportability" Surber or kicknet data in the TDEC bioassessment protocol. Additional samples need to be collected to obtain an adequate sample size to apply Bartlett's Regression Method. One way to achieve this larger sample size would be to analyze the four SQ kicknets collected in the TDEC protocol separately before they are composited.

This study did not compare bioassessments performed on increasing numbers of composited Surber samples to bioassessments performed on the four composited SQ kicknets collected in the TDEC protocol. This study simply assessed the number of Surber samples needed to collect sufficient numbers of macroinvertebrates to perform a bioassessment. Rarely would more than four Surber samples (2 paired Surber samples) have been needed to collect enough macroinvertebrates for a bioassessment. It would be worthwhile performing this analysis, but that effort exceeds the time resources available. It is interesting to note that while the bioassessments obtained from individual and from paired Surber samples were not always identical to those obtained from the kicknet samples, they were generally similar; this is despite the fact that the Surbers sampled a much smaller area of stream substrate than the kicknets. This suggests that the Surbers are a somewhat more efficient sampling device and require no more effort to use than the kicknets in these small streams.

This study supports that a year or two after mining and reclamation, macroinvertebrate bioassessment classifications are in the good range, but mining mobilizes many materials that will continue to work their way into streams for an extended amount of time. Long term studies are needed to assess if any negative effects on macroinvertebrate stream communities. Continuation of this study will monitor any changes in stream health and give a correlation between Surber samples and the current Tennessee protocol.

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APPENDIX A

Habitat assessment sheets used in the field for 2008, in the New River Watershed, Tennessee

HABITAT ASSESSMENT DATA SHEET- HIGH GRADIENT STREAMS (BACK)

Station ID________________ Date________________

Habitat Parameter	Optimal	Subeptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present	Channelization may be extensive; embankments or shoring structures, present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5-7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >35
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60 % of bank in reach has areas of erosion. high erosion potential during floods	Unstable; many eroded area; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
SCORE___(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE___(RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protective (score each bank) Note: determine left or right side by facing downstream	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height
SCORE___(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE___(RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone > 18 meters; human activities (i.e. parking lots, roadbeds, clear-cuts, lawns or crops) have not impacted zone	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE___(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE___(RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

TOTAL SCORE ____________

HABITAT ASSESSMENT DATA SHEET- HIGH GRADIENT STREAMS (FRONT)

STREAM NAME			
STATION #		LOCATION	
LAT	LONG	ECOREGION	
WBID/HUC		WATERSHED GROUP	
FORM COMPLETED BY		INVESTIGATORS	
		DATE_____ TIME_____ AM PM	

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient)	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the from of newfall, but not yet prepared for colonization (may rate at high end of scale)	20-40% mix of stable habitat; availability less than desirable; substrate frequently disturbed or removed	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 76% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow) (Slow is <0.3m/s deep is >0.5m)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low)	Dominated by 1 velocity/depth regime (usually slow-deep)
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low – gradient streams) of the bottom affected by sediment deposition	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed	Water fills >75% of the available channel; or 25 % of channel substrate is exposed.	Waters fills 25-75 % of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

APPENDIX B

SQ Kicknet taxa list for Indian Fork, Louse Creek, Duncan Branch, Sugarcamp Creek, Ursery Creek, Green Branch, Bowling Branch(June and July), Bill's Branch, Crabapple Creek, Bruce Creek (June and July), and Lowe Creek, in Scott, Campbell, and Anderson counties, Tennessee.

New River Watershed kicknet samples

TAXA	Sugarcamp	Louse	Bruce Hollow 6/18	Duncan	Bowling 6/19	Bills	Green	Ursery	Indian	Lowe	Bowling 7/23	Crabapple	Bruce 7/23
ANNELIDA			2										
Branchiobdella													1
HIRUDINEA								5					
OLIGOCHAETA	2	11	4	6	38	7	13		3	15	18	5	10
NEMATODA				1	1				1	1	1		
TURBELLARIA												3	
DECAPODA								1			2		
Cambaridae		1			3	3	1		1	4			
HYDRACARINA			2	1							1		
MEGALOPTERA													
Nigronia		10	4	3	1					6			
Sialis										1			1
PLECOPTERA	2	1											
Chloroperlidae						5					3	9	
Suwallia					1		12						9
Peltoperlidae													
Tallaperla												1	
Viehoperla										2			
Perlidae							1						
Acroneuria	1		1	3			1				2		3
Attaneuria			1									3	
Hansonperla							3						7
Perlinella	3	3				6				7			
Leuctra	22	11	53	35	32	20	82	60	8	20	31	26	16
Perlodidae													
Malirekus					2								
Remenus								4					
EPHEMEROPTERA												1	
Baetidae		2								3		1	
Baetis	3			3	8	19		4			5		1
Centroptilum		1			2	5				1			
Diphetor hageni	3				1				2				
Paracloeodes	4												
Procloeon							1						
Caenidae													
Caenis		1											
Ephemeridae													
Ephemera		1										1	4
Ephemerellidae					1					1			
Drunella longicornis	1	1		1		1			1				

Heptageniidae		1	1		2	3							
Epeorus		2		2	2			9	34	1			
Heptagenia		3		3		10					2		
Leucrocuta												1	
Maccaffertium						1				15	9	23	
Stenacron				10									
Stenonema	18	37			5	4	13						2
Leptophlebiidae					1							9	
Paraleptophlebia	49	4	9	2	25	14	1	2		3	39	5	10
LEPIDOPTERA								1					
ODONATA													
Gomphidae													
Dromogomphus													
Gomphus				3			5						
Lanthus					1				2		1	7	4
Progomphus								1					
TRICHOPTERA													
Glossosomatidae							1						
Glossosoma	1			4		1	1		5				1
Hydropsychidae													
Hydropsychidae Pupae								1					
Cheumatopsyche	6	6	7	14	4	5	23	9	10				2
Hydropsyche	3	7	16	18				1	1	1		1	13
Limnephilidae													
Pychopsyche										1			
Odontoceridae	1												
Psilotreta			7										
Philopotamidae													
Chimarra		1											
Dolophilodes			1	1									
Wormaldia						2							
Polycentropodae							1	1					
Cernotina				1									
Polycentropus	1		3	1			2			1			1
Phryganeidae													
Oligostomis										1			
Uenoidae													
Neophlax										1			1
HEMIPTERA													
Veliidae													
Husseyella			1										
Microvelia	3	7	1		5	2	3	1	2		4		1
Rhagovelia			1			2	1				1		1
COLEOPTERA													
Dryopidae													
Helichus	2				2					3			
Dytiscidae				1									
Celina													1

Hydroporus								1					
Elmidae													
Elmidae Larvae					1	2							
Ancyronyx			1										
Dubiraphia		1											
Optioservus		9	4	2		1			10			9	4
Oulimnius										1		6	
Stenelmis					1					1	2	7	1
Hydraenidae								1					
Ochthebius					1								
Psephenidae													
Psephenus	9	5	3	18	11	29	16	2	57	27	13	23	7
Ectopria			1		2					1		7	10
Scirtidae													
Cyphon					1								
Staphylinidae													
Stenus												1	
DIPTERA									1				
Larvae											4		
Pupae											1		
Athericidae													
Atherix								1	1				
Ceratopogonidae													
Atrichopogon	2					2			1				
Culicoides				1									
Monohelea											2		
Probezzia	1		3							1			
Chironimidae	40	66	17	28	22	19	79	56	35	14	37	29	55
Conchapelopia	1												
Constempellina												1	
Larsia	4												
Neozavrelia					1								
Orthocladinae			9	2	26				12	2	1		8
Orthocladius					1								
Paratanytarsus				1									
Rheopelopia				1									
Stempellinalla				1									
Tanypodinae		3	2	9	7	2	4	2		1	3		1
Tanytarsus				1									
Zavreiella				2							6		1
Dixidae													
Meringodixa			1										
Empididae													
Chelifera					1				3				
Clinocera													1
Hemerodromia		2				3	1				1		
Metachela				1	1		1						
Neoplasta	4						3						

Simuliidae													
Prosimullium								4					
Tabanidae			1										
Tipulidae		1						1	1				
Anotcha		1											
Cryptolabis											1		
Dactylolabis					1								
Dicranota								1					2
Erioptera					1								
Hexatoma	2		4	1	2		1	1		9	13	5	8
Leptotarsus								1					
Pedicia			1										
Pseudolmnophllia						2				21			
Tipula		1				1							
AMPHIPODA													
Talitridae											1		
Hyalella azteca													
ISOPODA													
Lirceus			49	6									28

APPENDIX C

Individual Surber sample taxa list for 2008; for Sugarcamp Creek, Crabapple Creek, Lowe Creek, Green Branch, Louse Creek, and Bill's Creek in Scott, Campbell, Anderson counties, Tennessee.

New River Watershed Lowe Surber samples																
TAXA	**Lowe Surber 1a**	**Lowe Surber 1b**	**Lowe Surber 2a**	**Lowe Surber 2b**	**Lowe Surber 3a**	**Lowe Surber 3b**	**Lowe Surber 4a**	**Lowe Surber 4b**	**Lowe Surber 5a**	**Lowe Surber 5b**	**Lowe Surber 6a**	**Lowe Surber 6b**	**Lowe Surber 7a**	**Lowe Surber 7b**	**Lowe Surber 8a**	**Lowe Surber 8b**
ANNELIDA			1													
OLIGOCHAETA	7	30	24	4	3	38	24	24	12	8	6	2	3	4	7	1
NEMATODA			3			2		1	1							
TURBELLARIA		5	2								1	1				1
DECAPODA																
Cambaridae	3	1			1		2		1	3		1		1	3	2
Palaemoniidae																
HYDRACARINA			1	1		2					2	1				
MEGALOPTERA																
Corydalidae																
Nigronia	5	6		1	1	1	3	1		19	4			1	2	
Sialis	1				4	3										
Harlomillsia																
PLECOPTERA																
Chloroperlidae																1
Alloperla																
Suwallia	6		1	6	2					1						
Peltoperlidae																
Peltoperla	1															
Viehoperla		1														
Perlidae																
Acroneuria	6			1												
Beloneuria																
Hansonperla		3	1		4					4		1				

Isoperla		6			1											
Leuctridae																
Leuctra	9	1	7	10	7	5	5	3	2	14	4	1			1	
EPHEMEROPTERA																
Baetidae					2			1						1		1
Acentrella										1						
Acerpenna					6		3					1				
Baetis	4	9		2		2			3		2		1	8	1	1
Plauditus		1														
Caenidae																
Caenis					2		2	1		1						
Ephemeridae					4	1										
Ephemera			4													
Ephemerellidae			2													
Heptageniidae							1				1	1				2
Heptagenia			1		1					1						
Leucrocuta																
Maccaffertium		4	8		6	3	5		2	7	1					
Stenacron			3			1										
Stenonema	11			6												
Leptophlebiidae		1														
Habrophlebiodes	4										1					
Leptophlebia																
Paraleptophlebia	2		7	5	4	3	3	1		9						
LEPIDOPTERA																
Cambridae								1								
Nymphaliella	1															
ODONATA																
Gomphidae																
Gomphus				1												
TRICHOPTERA			1					1						1		1
Goeridae																

Goera				1												
Hydropsychidae					1					2		1		1		
Cheumatopsyche	14										2			2		
Hydropsyche		5													1	
Philopotamidae																
Chimarra											1					
Dolophilodes	8	1														
Polycentropodae							2									
Polycentropus			2	2												
HEMIPTERA								1				1				
COLEOPTERA								1								
Dryopidae																
Helichus					1			1	1		2				1	
Elmidae																
Macronychus																
Optioservus			3		2		1	3		3		1		1		1
Ordobrevia											2					
Oulimnius	3									6	2				1	
Stenelmis	5	14		1	1			3				1		1		
Helaphoridae																
Helophorus								1								
Hydraenidae																
Enicocerus					1											1
Hydrophilidae																
Laccobius								1								
Psephenidae																
Psephenus	8	8	2	11	18	13	12	6	4	1	1	1	8	3	11	4
Ectopria			2		2	1	1	1	2		1				1	1
Staphylinidae			1									1				
DIPTERA															15	
Ceratopogonidae		1	3	4	1	2	3							3		
Alluaudomyia																1

94

Atrichopogon			3			1							1			
Bezzia						1		1	1	2	1	1				
Culicoides			3			1										
Probezzia					1			1								
Chironimidae	4	1	51	8	30	54	35	57	20	35	42	12	13	31	29	7
Endotribelus											1					
Rheotanytarsus						5			7							
Saetheria																2
Orthocladinae	2			3	4			1			1					
Parakiefteriella																
Parametriocnemus																1
Tanypodinae		3	3		1	1			1						2	2
Paramerina				1					1							
Telmatopelopia																1
Tanytarsus			4		3		2			1	1					1
Empididae								2								
Neoplasta								2								
Simuliidae														1		
Tipulidae	1				1	4										
Hexatoma	7	6	6	2	2	9	7	13		3	5		2	1	4	
Pseudolmnophllia			17	5		9		17			3				2	
Tipula			1			1				1				1	1	
AMPHIPODA																
Crangonyx		1														
Biometrics																
Taxa Richness	22	21	28	20	30	24	17	23	14	20	23	15	6	15	15	18
EPT Richness	10	10	10	8	12	6	7	4	3	9	7	5	1	4	3	4
% EPT	58	30	22	44	34	9	19	5	12	33	14	18	4	21	4	19
% OC	11.6	31.5	49.1	21.3	35.0	60.1	55.0	56.2	70.7	36.1	58.6	50.0	57.1	57.4	46.3	46.9
NCBI	3.79	5.26	4.15	2.76	3.79	5.28	5.23	4.66	5.45	4.05	4.51	4.18	4.70	4.66	3.83	3.90
% NUTOL	33.9	49.1	47.9	32.0	44.4	65.0	64.0	61.6	62.1	36.1	58.6	57.1	85.7	67.2	57.3	37.5
% Clingers	63.4	27.8	12.6	50.7	29.9	12.3	19.8	11.6	15.5	23.0	16.1	21.4	28.6	14.8	19.5	25.0

Taxa Richness	4	2	4	2	4	4	2	4	2	2	4	2	0	2	2	2
EPT Richness	4	4	4	2	4	2	2	0	0	2	2	2	0	0	0	0
% EPT	4	2	2	4	2	0	0	0	0	2	0	0	0	2	0	0
% OC	6	6	4	6	4	2	4	2	2	4	2	4	2	2	4	4
NCBI	4	4	4	6	4	4	4	4	4	4	4	4	4	4	4	4
% NUTOL	6	4	4	6	4	2	2	2	2	6	2	4	0	2	4	4
% Clingers	6	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4
multimetric score	34	26	26	28	26	18	18	16	14	24	18	20	10	16	18	18
Bioassessment	not impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	moderately impaired	moderately impaired	moderately impaired	moderately impaired	slightly impaired	moderately impaired	moderately impaired	moderately impaired	moderately impaired	moderately impaired	moderately impaired

New River Watershed Louse Surber samples

TAXA	Louse Surber 1a	Louse Surber 1b	Louse Surber 2a	Louse Surber 2b	Louse Surber 3a	Louse Surber 3b	Louse Surber 4a	Louse Surber 4b	Louse Surber 5a	Louse Surber 5b	Louse Surber 6a	Louse Surber 6b	Louse Surber 7a	Louse Surber 7b	Louse Surber 8a	Louse Surber 8b
PLANARIA						1			1							
OLIGOCHAETA	1	3	6	14	6	7	2	5	4	5			1		2	4
NEMATODA					2				1	1						
TURBELLARIA					1											
DECAPODA																
Cambaridae				1			1	1			1		1			
HYDRACARINA			2			1					1					3
MEGALOPTERA																
Corydalidae																
Nigronia	4	3	78	6	4		4	6	9	1	6		12		2	3
Sialis							1								1	1
PLECOPTERA																
Perlidae																
Acroneuria			2					1			1		7			1
Beloneuria					2		3									
Hansonperla	1	1	23	2	6	1	1	3	7	2	1				2	2
Leuctridae																
Leuctra	16	15	51	28	14	12	32	25	19	24	10		15		18	31
EPHEMEROPTERA																
Ameletidae																
Ameletus				2												
Baetidae																
Acerpenna							1									
Baetis	16	14	39	17	27	6	22	6	2	4	2		7		2	8
Falleon								1					1			

Ephemera				2	1		3		1		1				1	
Ephemerellidae																
Ephemeralla	2															
Drunella longicornis			3		1						1		2			
Seratella			1													
Heptageniidae																
Epeorus	12	5	13	2	4	2	7	4					4			
Heptagenia			1		18		1									
Maccaffertium					7					3	5		2		2	
Stenacron															1	
Stenonema	17	6	65	43		21	58	42	13	38	18		36		24	23
Isonychiidae																
Isonychia	3		18		4	2		2					9			
Leptophlebiidae				1												
Paraleptophlebia	4	5	17		8	5	21	15	2	16	2		5		12	3
ODONATA																
Aeshnidae																
Boyeria											1					
Gomphidae		1	1							1						
Dromogomphus																
Gomphus															2	
Lanthus			2		4		2	2			2		1			5
TRICHOPTERA													2			
Glossosomatidae																
Glossosoma			2								1					
Hydropsychidae																
Cheumatopsyche	16	6	67	31	19	4	12	7		1			19		2	3
Hydropsyche	1		39		1	3					15					
Hydroptilidae																
Orthotrichia				1	1		2									
Odontoceridae																
Psilotreta					1		4									

Philopotamidae		1														
Dolophilodes											1		1			1
Polycentropodae				3							1					
Cyrnellus											1					
Polycentropus							1				1					3
HEMIPTERA																
Veliidae																
Microvelia		15		1	1	3	7	3		2	1		1		1	8
Rhagovelia		4		1	4	1	2			1						
COLEOPTERA										1						
Dryopidae																
Helichus					2		1	1								
Elmidae																
Optioservus	14	13	49	17	39	1	18	1	3	3	2		1			
Oulimnius	1		2				1									
Stenelmis	1	1		1		1		1							1	3
Psephenidae																
Psephenus	9	5	21	29	12	14	34	6	5		2				1	6
Ectopria											1					
Staphylinidae										1	1					1
DIPTERA																
Athericidae																
Atherix	1															
Ceratopogonidae																
Atrichopogon		1														
Bezzia															1	
Dashelea							2									
Probezzia			2		1	2	1						1			15
Chironimidae	48	28	149		2	56	8	57	16	24						
Chironominae	2			116	104		16						48		21	53
Brillia						1										
Conchapelopia	3			3		1	3		2	1					1	

Constempellina	5			1												
Genus 12			1													
Neozavrelia				1												
Rheotanytarsus													1			1
Subletta						1										
Orthocladinae	6	17	50	9	55	11	45	4	2							
Orthocladius															4	
Parakiefteriella	1															
Paratanytarsus			1													
Procladius			2	1												
Stempellinalla			7		2		4	1								
Tanypodinae	12	7	11	8	9	9		6		9			5		1	8
Tanytarsus					1	1										1
Zavreiella										1						
Empididae																
Hemerodromia	1		9	2			2									
Metachela								1								
Neoplasta			2					1								1
Simuliidae													1			
Tipulidae																
Anotcha	3			16											3	
Cryptolabis																
Dactylolabis																
Dicranota	2	1	3	2	5	9	10	12	3	2	2		14			1
Erioptera																
Heldon																
Hexatoma	1		4	4		1		1								
Leptotarsus				1												
Pedicia		1														
Pseudolmnophllia			1													1
ISOPODA																
Lirceus								2		2			5			10

Biometrics																
Taxa Richness	28	22	35	31	33	27	34	28	16	21	26	0	25	0	22	27
EPT Richness	10	8	14	11	15	9	14	10	6	7	15	0	12	0	9	9
% EPT	43	35	46	36	31	32	51	49	49	62	75	####	54	###	61	38
% OC	38.4	35.9	30.5	41.8	48.6	49.2	23.5	33.6	26.7	28.0	0.0	####	27.2	###	27.6	33.5
NCBI	3.41	3.90	4.01	4.13	4.02	3.79	3.44	3.42	3.16	2.95	3.08	####	3.56	###	3.37	3.93
% NUTOL	36.9	28.1	32.7	20.5	10.6	46.3	16.9	35.9	27.8	22.4	2.5	####	12.4	###	6.7	13.0
% Clingers	44.3	34.0	42.3	46.4	30.4	32.8	50.6	40.6	44.4	46.2	66.7	####	42.6	###	47.6	43.0
METRIC SCORE																
Taxa Richness	4	4	6	4	6	4	6	4	2	2	4	0	4	0	4	4
EPT Richness	4	2	4	4	4	2	4	4	2	2	4	0	4	0	2	2
% EPT	4	2	4	2	2	2	4	4	4	6	6	####	4	###	6	2
% OC	4	4	6	4	4	4	6	4	6	6	6	####	6	###	6	4
NCBI	6	4	4	4	4	4	6	6	6	6	6	####	6	###	6	4
% NUTOL	6	6	6	6	6	4	6	6	6	6	6	####	6	###	6	6
% Clingers	2	4	2	2	4	4	2	2	2	2	6	####	2	###	2	2
multimetric score	30	26	32	26	30	24	34	30	28	30	38	####	32	###	32	24
Bioassessment	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	not impaired	slightly impaired	slightly impaired	slightly impaired	not impaired	#DIV/0!	slightly impaired	#DIV/0!	slightly impaired	slightly impaired

New River Watershed Green Surber samples

TAXA	Green Surber 1a	Green Surber 1b	Green Surber 2a	Green Surber 2b	Green Surber 3a	Green Surber 3b	Green Surber 4a	Green Surber 4b	Green Surber 5a	Green Surber 5b	Green Surber 6a	Green Surber 6b	Green Surber 7a	Green Surber 7b	Green Surber 8a	Green Surber 8b
OLIGOCHAETA	23		63	2	54	12	16	8	2	25	121	1	21	1	85	
NEMATODA			1			1		1		5					2	
DECAPODA								1				1	2			
Cambaridae	1		1		2		1				1				2	
HYDRACARINA													1			
MEGALOPTERA																
Corydalidae																
Nigronia	4		5	1	2	2				3	1		1	1		
Sialis				1						1						
PLECOPTERA			4		2						2					
Chloroperlidae													12			
Suwallia	12		10	5	23		8			18	24	2		4	52	
Tallaperla											1					
Perlidae																
Acroneuria				1			1		1	2		2				2
Beloneuria	2					1	4				8					
Hansonperla			6	1	3			2		2		1		1	5	
Isoperla		1	1													
Leuctridae																
Leuctra	133	8	130	25	84	21	51	15	4	180	125	46	91	11	296	21
Nemouridaae																
Amphinemura															1	
EPHEMEROPTERA															6	
Baetidae														2		
Acentrella	4										1					

Baetis	2		3		5			3		4			2			
Centroptilum											2					
Procloeon	2					1	6				1		14			
Psuedocentroptiloides															3	
Psuedocleon															2	
Ephemerellidae																
Drunella longicornis	1	1			1		2			1	2	1				
Heptageniidae		1		1			2			12	3	5				
Epeorus			3	3	1		5		1	5	35		6		22	2
Heptagenia	2						1						4	1	3	
Maccaffertium			11	1												
Stenacron							1									
Stenonema	10			3	13		14		1	16	10		4	2	15	2
Isonychiidae																
Isonychia			1													
Leptophlebiidae													1			
Paraleptophlebia			1				1								2	1
ODONATA																
Aeshnidae																
Aeshna															1	
Boyeria	1		1				1			1						
Gomphidae																
Lanthus					2					1			1			
Stylogomphus	1															
TRICHOPTERA													1		1	
Glossosomatidae																
Glossosoma	2		4	3	3	2	2		3		2	1			3	1
Hydropsychidae																
Cheumatopsyche	28		15	3	12	2	29		1	11	5	5	1		6	5
Hydropsyche	4		26		7					1	2				13	1
Hydroptilidae															3	
Odontoceridae																

Psilotreta					1											
Philopotamidae					1											
Chimarra	1					1										
Dolophilodes	1		2												2	
Polycentropodae						1		1			1			1		
Polycentropus			2								2	2			2	
Rhyacophlidae							1									
Rhyacophila			1				1									
HEMIPTERA			1													
Microvelia	2		6	1	5	4		7	3	1	2		1	1	3	
Rhagovelia			1	2		1		1								
COLEOPTERA																
Dytiscidae																
Hydroporus														1		
Elmidae																
Optioservus		1				1	1									
Hydraenidae																
Ochthebius			1													
Psephenidae																
Psephenus	47	7	46	10	6	4	13	46	11	10	19	16	10	3	24	5
Ectopria			1		1		1	1		8	1	1			1	
Staphylinidae													2			
DIPTERA							1									
Ceratopogonidae			1		2			1			1					
Atrichopogon	1									1					1	
Monohelea				1	2											
Probezzia	1															
Chironimidae	38		19	6	44	2	11	9	5	72	75	10	35	7	151	3
Cryptochironmus	1				1											
Eukiefferiella											1					
Diamesa							1									
Hayesomyia	1															

Rheotanytarsus	2						2			3	1					
Orthocladinae	11		40		28	1	6	7		59	63	1	8	5	2	4
Orthocladius															7	
Parametriocnemus			1		2			1		1					1	
Plhudsonial	3		4		7					5		1				
Rheopelopia											2					
Stempellina																2
Stempellinalla	1		2	2	1		1			2	2		1		1	
Tanypodinae											1		2	1	7	
Tanytarsus											1				2	
Empididae																
Clinocera	2		1		2			1								
Hemerodromia					2		1	4							2	
Metachela	2		1		3					12			2			
Neoplasta													1		6	
Syrphidae						1										
Simuliidae																
Heldon							1			1	1					
Simulium															2	
Cyclorrhaphous pupae		1														
Tipulidae	7						2			6	1					
Dicranota													3		3	
Hexatoma														1		
Leptotarsus										1						
Pedicia										1						
Biometrics																
Taxa Richness	33	7	33	19	30	17	30	17	10	32	33	16	24	16	34	12
EPT Richness	14	4	15	10	12	7	16	4	6	11	16	9	9	7	16	8
% EPT	58	55	53	64	48	50	69	19	34	54	43	68	60	51	58	71
% OC	22.7	0.0	31.0	13.9	42.5	25.9	19.7	22.9	21.9	35.5	51.3	13.5	29.5	32.6	34.6	18.4
NCBI	3.15	1.50	3.81	2.59	4.15	3.98	3.60	3.65	3.37	3.29	4.49	2.11	3.12	3.31	3.15	2.34
% NUTOL	38.5	35.0	34.4	29.2	36.0	34.5	37.2	57.8	59.4	25.1	42.3	33.3	29.5	25.6	35.9	26.5

% Clingers	69.4	90.0	57.9	75.0	47.8	56.9	72.9	58.7	68.8	56.1	46.2	84.4	56.4	51.2	59.3	79.6
METRIC SCORE																
Taxa Richness	6	0	6	2	4	2	4	2	0	6	6	2	4	2	6	2
EPT Richness	4	0	4	4	4	2	6	0	2	4	6	2	2	2	6	2
% EPT	4	4	4	6	4	4	6	0	2	4	4	6	6	4	4	6
% OC	6	6	6	6	4	6	6	6	6	4	4	6	6	6	4	6
NCBI	6	6	4	6	4	4	6	6	6	6	4	6	6	6	6	6
% NUTOL	4	6	6	6	6	6	6	4	2	6	4	6	6	6	6	6
% Clingers	6	6	6	6	2	6	6	6	6	6	2	6	6	2	6	6
multimetric score	36	28	36	36	28	30	40	24	24	36	30	34	36	28	38	34
Bioassessment	not impaired	slightly impaired	not impaired	not impaired	slightly impaired	slightly impaired	not impaired	slightly impaired	slightly impaired	not impaired	slightly impaired	not impaired	not impaired	slightly impaired	not impaired	not impaired

New River Watershed Sugarcamp Surber samples

TAXA	Sugarcamp Surber 1a	Sugarcamp Surber 1b	Sugarcamp Surber 2a	Sugarcamp Surber 2b	Sugarcamp Surber 3a	Sugarcamp Surber 3b	Sugarcamp Surber 4a	SugarcampSurber 4b	Sugarcamp Surber 5a	Sugarcamp Surber 5b	Sugarcamp Surber 6a	Sugarcamp Surber 6b	Sugarcamp Surber 7a	Sugarcamp Surber 7b	Sugarcamp Surber 8a	Sugarcamp Surber 8b
OLIGOCHAETA	2	4	1	1	1	1		7	2	2	1	5	3		2	1
NEMATODA	1														1	1
HYDRACARINA		1														
MEGALOPTERA																
Corydalidae																
Nigronia	3	6										1	1	2	1	
PLECOPTERA	1															
Chloroperlidae																
Peltoperlidae																
Tallaperla													1			
Perlidae												1				
Acroneuria								1				1		2	1	
Hansonperla	1		1			1	1		2					5	1	2
Isoperla								2								
Perlinella													1			
Leuctridae																
Leuctra	5	29	2	13	6	10	4	59	19	6	3	25	5	61	19	4
EPHEMEROPTERA																
Baetidae							1	3								
Acentrella			9													
Baetis	2	3			7	10		25	5		1	8	2	4	8	2
Centroptilum			1													

Falleon														5		
Ephemerellidae																
Drunella longicornis		4	3		4	1	1	6	1	2	1	1		5	5	
Heptageniidae	2															
Epeorus		7	10	1	12	23		16	2	2		3	8	6	19	
Heptagenia	3	3							16			4	7	2		1
Stenacron					1											
Stenonema	2		4				1	6		3	3	4		7	6	2
Leptophlebiidae																
Paraleptophlebia	31	38	5	8	1	15	3	40	17	10	9	49	7	30	38	10
ODONATA																
Gomphidae																
Gomphus															1	
Lanthus			1	1						1				1	2	
TRICHOPTERA																
Glossosomatidae														2		
Glossosoma		3	14		2	4	2	10				2		7	1	
Goeridae																
Goerita	1															
Hydropsychidae								1								
Cheumatopsyche					1	3		10	2		7	3	2	8	8	1
Hydropsyche		6	7					6		1				10	9	1
Potamyia														1		
Hydroptilidae						1										
Ithytrichia					1											
Odontoceridae																
Psilotreta			1													
Philopotamidae			2													
Dolophilodes			3			2		1						5		
Polycentropodae																
Polycentropus		2								1	1	1		2	4	1
HEMIPTERA																

Veliidae																
Microvelia		1	1						1						2	
Rhagovelia					1			1				1	1		1	2
COLEOPTERA																
Dytiscidae																
Heterostemuta																1
Ochthebius								2								
Psephenidae																
Psephenus		15	13	10	11	6	20	14	7	14	9	10	12	7	8	6
Ectopria	1		1					1				1				1
DIPTERA																
Ceratopogonidae			1													
Bezzia									1							
Dashelea						1										
Forcipomyia								1		1						
Probezzia				1		1		3								
Chironimidae	42	19	6	22	8	13	5	34	46	22	12	47	14	18	43	10
Brillia		5		4								2				
Cardioclodius				2												
Hudsonimyia								1								1
Hydrobaenus														4	2	
Labrundinia											1					
Orthocladinae	8		13	12	4	7		48	7	5	6	6	4	17		2
Orthocladius															2	
Parakiefteriella								1								1
Plhudsonial								1								
Stempellinalla					1		1	1			2	1				
Tanypodinae		6		2			3	4				2	1	2		
Tanytarsus			1							1						
Thienemannimyia												1				
Dixidae																
Dixa															1	

Empididae									1						1	
Clinocera										1						
Hemerodromia						1										
Metachela								1			1					
Neoplasta	2	2						1				2				
Simuliidae																
Prosimullium								2								
Tipulidae																
Anotcha												1				
Dicranota															1	
Heldon															1	
Hexatoma	3	4	1	2	2		1	2	1	6	3	2	2	2	3	1
Pedicia						1										
Ulmorpha						1										
Biometrics																
Taxa Richness	16	19	23	13	16	19	12	32	16	16	15	26	16	25	28	20
EPT Richness	8	9	13	3	9	10	7	14	8	7	7	12	8	17	12	9
% EPT	44	60	61	28	56	69	30	60	49	32	42	55	46	75	62	47
% OC	47.3	21.5	20.8	54.4	22.2	20.6	20.9	31.2	42.3	38.5	36.7	34.8	31.0	19.1	25.7	29.4
NCBI	3.53	2.49	2.95	3.52	2.91	2.67	2.33	3.20	3.30	3.46	3.89	3.03	3.26	2.43	2.96	3.10
% NUTOL	40.0	24.1	19.8	41.8	34.9	22.5	58.1	20.9	43.8	48.7	48.3	35.3	43.7	15.3	31.9	35.3
% Clingers	12.7	43.7	58.4	30.4	58.7	48.0	65.1	42.8	36.2	38.5	40.0	31.0	50.7	57.7	41.9	70.6
METRIC SCORE																
Taxa Richness	2	2	4	2	2	2	2	6	2	2	2	4	2	4	4	2
EPT Richness	2	2	4	0	2	4	2	4	2	2	2	4	2	6	4	2
% EPT	4	6	6	2	4	6	2	4	4	2	4	4	4	6	6	4
% OC	4	6	6	4	6	6	6	6	4	4	4	4	6	6	6	6
NCBI	6	6	6	6	6	6	6	6	6	6	4	6	6	6	6	6
% NUTOL	4	6	6	4	6	6	4	6	4	4	4	6	4	6	6	6
% Clingers	4	2	6	4	6	2	6	2	2	2	2	4	2	6	2	6
multimetric score	26	30	38	22	32	32	28	34	24	22	22	32	26	40	34	32

Bioassessment	slightly impaired	slightly impaired	not impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	not impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	not impaired	not impaired	slightly impaired

New River Watershed Crabapple Surber samples																
TAXA	**Crabapple Surber 1a**	**Crabapple Surber 1b**	**Crabapple Surber 2a**	**Crabapple Surber 2b**	**Crabapple Surber 3a**	**CrabappleSurber 3b**	**Crabapple Surber 4a**	**CrabappleSurber 4b**	**Crabapple Surber 5a**	**CrabappleSurber 5b**	**Crabapple Surber 6a**	**Crabapple Surber 6b**	**Crabapple Surber 7a**	**Crabapple Surber 7b**	**Crabapple Surber 8a**	**Crabapple Surber 8b**
OLIGOCHAETA	5	27	5	1	21	28	12	4	3	4	3	3	18	9	10	
NEMATODA		5			2	4	5	3		1	2		5	5	1	
TURBELLARIA	3	3			14	1	2	8	4	1			2	13	1	
DECAPODA																
Cambaridae	1		1		3	1	3	2			1		1		4	
Palaemoniidae																
HYDRACARINA						1		2			1	1	2		1	1
MEGALOPTERA																
Corydalidae																
Nigronia		1			1		4		1				2	22		1
Sialis													2		1	
PLECOPTERA																
Chloroperlidae																
Alloperla															6	
Utaperla				1												
Peltoperlidae																
Peltoperla	8								8							
Viehoperla		3				2		1								
Perlidae																
Acroneuria	3					1	2		1				2	1	2	
Beloneuria		1														
Hansonperla	12	5			14		4	3	12	8		9	9	10	18	6
Leuctridae																

Leuctra	81	138	11	1	69	33	44	16	22	14	37	18	81	157	35	31
Pteronarcyidae																
Pteronarcella					1											
EPHEMEROPTERA					4								3	5		2
Baetidae	1							1		1	1		1	1		1
Baetis		1				2									1	5
Ephemeridae															2	2
Ephemera															1	
Ephemerellidae		1														
Eurylophella				3								1				
Heptageniidae	3				3						1	1	15	5	4	
Epeorus																
Heptagenia								3		2						1
Leucrocuta															5	
Maccaffertium		3														
Stenacron	1															
Stenonema	5	11	2	1	1	3	5	5						8	8	7
Leptophlebiidae												4			20	
Paraleptophlebia	7	83				13	20	13	1	3	1		21	118	4	43
ODONATA																
Gomphidae																
Gomphus	8															
Lanthus		1					4		1				2	4		1
Stylogomphus															20	
TRICHOPTERA						2								1		
Agapetus														2		
Glossosoma		1											2			1
Goeridae																
Goera	3				1											
Hydropsychidae																
Hydropsychidae Pupae							3									
Cheumatopsyche	22	1			10				1		1		1			

Hydropsyche		14				34	1	9	19	7	1		1	9	17	15
Hydroptilidae																
Lepidostomatidae																
Lepidostoma															2	
Limnephilidae																
Pychopsyche														1	1	
Odontoceridae																
Psilotreta											1		1			2
Polycentropodae										1	1			8		
Polycentropus		2			1			1								
Pschomyiidae																
Lype		7										3			1	
Rhyacophlidae					1											
HEMIPTERA																
Veliidae																
Microvelia		2			1		3	1					2	3	1	
Rhagovelia			1												1	
COLEOPTERA																1
Curculionidae							1									
Dryopidae																
Helichus		8					2									
Elmidae																
Lara															1	
Macronychus																
Optioservus	6	1				7	9	8	5	4	7		1	12		11
Ordobrevia																
Oulimnius	6	1			1		3	3	2		1			1	9	4
Stenelmis	4	11	1	1	4	4	11	4	2		1		1	3	6	5
Hydraenidae																
Ochthebius								1								
Hydrophilidae												1				
Ptilodachtylidae																

Anchytarsus					1											
Psephenidae																
Psephenus	15	9	12	1	14	1	2	20	6	10	9	14	26	12	11	13
Ectopria	6		3		3	1	4	7		3	5	2	6	33	9	7
DIPTERA								2								
Ceratopogonidae																
Bezzia	2	2										1			4	
Ceratopogon																1
Culicoides								1						3		
Probezzia		3				1			1	1	3		8	3		2
Stilobezzia													1			
Chironimidae	2	2		16	1	137									2	49
Chironominae	28	112	8		44		34	30	16	11	27	10	192	128	101	
Brillia		2														
Conchapelopia		2														
Nanocladius		1														
Orthocladinae	1	49	1		2	4	6		4	3	3	1	5		2	7
Stempellinalla		1				3	4	4								
Tanypodinae	2	17	1	3	1	6	1				1	5	7	9	1	1
Macropelopia						1										
Zavreiella													3	2		
Culcidae								1						1		
Dixidae														2		
Dixa		2					2			2			1			
Empididae											1					
Empididae pupae																
Hemerodromia								1	1							
Metachela			2			1										
Neoplasta		6				4								1	1	
Stratiomyidae																

Nemotelus										5						
Tipulidae	1												3			
Cryptolabis						1										
Dicranota								1	2					1		
Hexatoma	7	15			8	2	8	7		10	5	2	4	5	15	1
Leptotarsus					1											
Molophilus		2														
Ormosia		1	1													
Pseudolmnophllia	2													2		
Rhabdomastix									2							
Tipula							1			1	1		1		3	
Ulmorpha																1
ISOPODA																
Lirceus	1	2	1		3								2	2	1	
Biometrics																
Taxa Richness	29	41	14	9	27	26	28	28	21	20	24	16	34	35	39	26
EPT Richness	11	14	2	4	9	7	7	9	7	7	8	6	10	12	16	11
% EPT	59	48	26	21	44	30	40	32	56	39	38	47	31	53	38	51
% OC	15.4	38.1	30.0	71.4	30.0	60.1	28.5	23.5	20.2	19.6	29.6	25.0	51.8	24.5	34.8	25.7
NCBI	2.33	2.24	3.17	4.04	2.49	4.38	2.47	2.25	2.52	2.76	1.94	1.98	1.56	1.54	2.26	2.89
% NUTOL	20.3	9.3	38.0	67.9	23.0	57.0	12.5	17.3	10.5	15.2	12.2	22.4	11.1	4.3	9.0	30.2
% Clingers	66.3	37.2	58.0	25.0	47.8	28.9	43.0	47.5	57.9	44.6	55.7	51.3	31.3	41.6	33.9	61.3
METRIC SCORE																
Taxa Richness	4	6	2	0	4	4	4	4	2	2	4	2	6	6	6	4
EPT Richness	4	4	0	0	2	2	2	2	2	2	2	2	4	4	6	4
% EPT	4	4	2	2	4	2	2	2	4	2	2	4	2	4	2	4
% OC	6	4	6	2	6	2	6	6	6	6	6	6	4	6	4	6
NCBI	6	6	6	4	6	4	6	6	6	6	6	6	6	6	6	6
% NUTOL	6	6	4	2	6	4	6	6	6	6	6	6	6	6	6	6
% Clingers	6	2	6	4	2	4	2	2	6	2	6	2	4	2	4	6
multimetric score	36	32	26	14	30	22	28	28	32	26	32	28	32	34	34	36

Bioassessment
not impaired
slightly impaired
slightly impaired
moderately impaired
slightly impaired
slightly impaired
slightly impaired
slightly impaired
slightly impaired
slightly impaired
slightly impaired
slightly impaired
slightly impaired
not impaired
not impaired
not impaired

New River Watershed Bill's Surber samples

TAXA	Bill's Surber 1a	Bill's Surber 1b	Bill's Surber 2a	Bill's Surber 2b	Bill's Surber 3a	Bill's Surber 3b	Bill's Surber 4a	Bill's Surber 4b	Bill's Surber 5a	Bill's Surber 5b	Bill's Surber 6a	Bill's Surber 6b	Bill's Surber 7a	Bill's Surber 7b	Bill's Surber 8a	Bill's Surber 8b
OLIGOCHAETA	17	60	31	33	2	7	10	5	28	14	23	7	4	30	25	8
NEMATODA	1	2		3	2											
DECAPODA	1						4	1	1			1		2		
HYDRACARINA				1			2									
MEGALOPTERA																
Corydalidae																
Nigronia	1	5	2	1				2		3	1				6	
PLECOPTERA																
Chloroperlidae	2							1	2				3			
Suwallia		13		7		10	5			4	11	4		5	25	
Perlidae							1								1	
Acroneuria								1	1		1					
Beloneuria											3					
Hansonperla	3	6		1			4	4		2		2		4		
Isoperla	3							2		1						
Leuctridae																
Leuctra	15	91	5	22	6	11	36	23	25	53	35	10	10	19	97	6
EPHEMEROPTERA																1
Baetidae											2				7	1
Acentrella	1	3														
Acerpenna																
Baetis	20	47	15	5		1					21		1			2
Centroptilum				1	1				1							
Heterocleon		3														
Falleon				23	4		9	6	13	10		4	1	5		

Polycentropodae											1					
Cernotina									2			2			1	
Polycentropus											1					
HEMIPTERA																
Veliidae																
Microvelia		3	2	1	1	2	5	1	29	8	3	1		1	2	
Rhagovelia	2				2											
COLEOPTERA																
Dryopidae																
Helichus			1							2						
Dytiscidae																
Heterostemuta																
Hydroporus									1							
Elmidae																
Optioservus										1						
Ordobrevia			1													
Stenelmis	3	7			2	1	1	1			1					
Hydraenidae																
Enicocerus																
Ochthebius														1		
Psephenidae																
Psephenus	2	16	1		12	16	10	27	14	33	67	8	8	45	1	12
Ectopria			1						1	1		1		1	2	1
DIPTERA													1			
Ceratopogonidae				2												
Atrichopogon				1												
Bezzia		1	3								1					
Monohelea				1			1							2	1	1
Probezzia									1	2		1	1			
Stilobezzia																1
Chironimidae	5	30	3	69	13	48	25	25	35	58	86	28	25	72	55	6
Orthocladinae	7	25	3	48	6	11	2	1	31	9	29				24	4

Procloeon			1								1					
Caenidae							1									
Ephemeridae																
Ephemera									1							
Ephemerellidae																
Drunella longicornis										1						
Heptageniidae				6	9		4								3	2
Epeorus	10	56	2	4			1	1	7	3					2	
Heptagenia	4	2	3	2		6	3	4		1	10	9	2	8	3	5
Maccaffertium	5	9	1				6	4	5	9		6		7		
Stenonema			1			5					7					
Leptophlebiidae															2	
Paraleptophlebia	7	37	1	6	7	14	20	9	17	17	30	5	9	12	10	3
ODONATA																
Aeshnidae																
Aeshna			1				1					1				1
Cordulegastidae																
Codulegaster			1													
Gomphidae										1				2		
Gomphus											1					
Lanthus					1						3					
TRICHOPTERA	2									2			3			
Glossosomatidae								1		4					3	
Glossosoma		1	2						3	5			5		3	
Goeridae														1		2
Goerita											1					
Hydropsychidae	1	5		1			3		1	2	1		3	1	10	
Cheumatopsyche			3				1	2	2	7		1	2			
Ceratopsyche								1								
Hydropsyche							1									
Philopotamidae																
Dolophilodes		1						2							1	

Parakiefteriella			1			1										
Stempellinalla			1				2									
Tanypodinae		10		19		1	5	2	6	8	9	2	6		14	
Telmatopelopia	1															
Tanytarsus					1		1									
Zavreiella				3												
Dixidae																
Dixa		2	1	1	1				2							
Meringodixa																
Empididae															2	
Hemerodromia	1	2							1					1		
Metachela		6		28		3	1	2	3	2	1				2	
Neoplasta	2	3	7													
Simuliidae									2							
Tipulidae				4							1					
Dicranota									1							
Hexatoma					1			2			3	1	1	6	1	3
Pseudolmnophllia																3
Tipula							1									
Biometrics																
Taxa Richness	23	27	26	26	17	15	29	25	28	27	28	19	15	20	26	17
EPT Richness	11	13	10	11	5	6	14	14	13	14	14	9	9	9	14	7
% EPT	63	61	36	27	38	34	57	47	34	46	35	46	46	28	55	34
% OC	25.9	28.0	41.5	58.7	31.0	49.6	27.1	25.4	42.4	33.8	41.5	39.4	41.2	45.3	38.9	29.0
NCBI	3.94	3.50	6.20	4.60	3.50	3.77	2.82	2.84	4.26	3.13	3.62	3.46	2.81	4.00	3.02	3.85
% NUTOL	23.3	25.3	40.4	34.8	40.8	52.6	28.3	46.2	33.5	42.6	50.0	46.8	45.9	65.3	26.7	41.9
% Clingers	31.9	43.0	20.2	14.3	40.8	35.8	39.8	48.5	24.6	44.5	39.3	35.1	38.8	35.1	49.8	53.2
METRIC SCORE																
Taxa Richness	4	4	4	4	2	2	4	4	4	4	4	2	2	2	4	2
EPT Richness	4	4	4	4	2	2	4	4	4	4	4	2	2	2	4	2
% EPT	6	6	2	2	2	2	4	4	2	4	2	4	4	2	4	2

% OC	6	6	4	2	6	4	6	6	4	4	4	4	4	4	4	6
NCBI	4	6	2	4	6	6	6	6	4	6	6	6	6	4	6	4
% NUTOL	6	6	4	6	4	4	6	4	6	4	4	4	4	2	6	4
% Clingers	4	2	4	4	2	2	2	2	4	2	2	4	2	4	2	6
multimetric score	34	34	24	26	24	22	32	30	28	28	26	26	24	20	30	26
Bioassessment	not impaired	not impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	moderately impaired	slightly impaired	slightly impaired

APPENDIX D

Paired Surber Samples for 1981 from Vaughan, G. L., L. Minter, and J. Schiller (1982). In Scott, Anderson, and Campbell counties, Tennessee.

New River Watershed Lowe 1981 Surber samples

TAXA	Lowe 1	Lowe 2	Lowe 3	Lowe 4	Lowe 5	Lowe 6	Lowe 7	Lowe 8
MEGALOPTERA								
Corydalidae								
Nigronia	1		6	1		1	1	4
Sialis	1							1
PLECOPTERA								
Chloroperlidae								
Sweltsa	1	14	15	9		10	17	3
Peltoperlidae								
Peltoperla		1	1		2		1	2
Perlidae								
Acroneuria	30	29	16	18	8	23	32	16
Leuctridae								
Leuctra	4	4	1	3	1		1	
Perlodidae								
Malirekus			3	2		2		
Nemouridaae								
Amphinemura						1		
EPHEMEROPTERA								
Baetidae								
Baetis	8	10	6	10	1	1	6	1
Centroptilum	4	2	1	1	4	1	1	2
Ephemerellidae								
Ephemeralla		7	2	1	1	6	4	1
Heptageniidae								
Heptagenia	6		2	1	4	1	2	3
Stenonema	22	9	7	10	8	18	15	2
Leptophlebiidae								
Habrophlebiodes	1		1	1				
Leptophlebia								
Paraleptophlebia	2	3	4	5	3	1	6	9
ODONATA								
TRICHOPTERA								
Hydropsychidae								
Symphitopsyche								1
Rhyacophlidae								
Rhyacophila					1			

Uenoidae								
Neophlax				1				
COLEOPTERA								
Elmidae								
Optioservus			1		1	1		
Psephenidae								
Psephenus	8	33	14	26	12	9	2	2
DIPTERA		1	1	1				
Ceratopogonidae			1					
Chironimidae	4	18	13	11	9	14	46	8
Dixidae			2					
Tipulidae								
Hexatoma	2	7	8	5			2	1
Tipula	1		2	2	1			
Biometrics								
Taxa Richness	15	12	20	17	14	13	15	15
EPT Richness	9	9	12	12	10	10	10	10
% EPT	82	57	55	57	59	72	62	71
% OC	4.2	13.0	12.1	10.2	16.1	15.7	33.6	14.3
NCBI	2.83	2.44	2.59	2.62	3.12	2.36	2.88	2.73
% NUTOL	12.6	37.0	25.2	34.3	37.5	25.8	35.0	17.9
% Clingers	74.7	65.2	53.3	63.0	66.1	69.7	51.8	50.0
METRIC SCORE								
Taxa Richness	2	2	2	2	2	2	2	2
EPT Richness	2	2	4	4	4	4	4	4
% EPT	6	4	4	4	4	6	6	6
% OC	6	6	6	6	6	6	4	6
NCBI	6	6	6	6	6	6	6	6
% NUTOL	6	6	6	6	4	6	6	6
% Clingers	6	6	6	6	6	6	2	2
multimetric score	34	32	34	34	32	36	30	32
Bioassessment	not impaired	slightly impaired	not impaired	not impaired	slightly impaired	not impaired	slightly impaired	slightly impaired

New River Watershed Louse 1981 Surber samples

TAXA	Louse 1	Louse 2	Louse 3	Louse 4	Louse 5	Louse 6	Louse 7	Louse 8
PLECOPTERA								
Chloroperlidae						1	2	1
Peltoperlidae								
Peltoperla	2			1	28	11	4	
Perlidae								
Acroneuria		3	7	17	10	22	10	13
Isoperla					2			
Leuctridae								
Leuctra	4	3	1		5	4	3	1
Perlodidae	7	1	5	1	4		1	
Malirekus						2		
Nemouridaae								
Amphinemura	2				3			
EPHEMEROPTERA								
Baetidae								
Baetis	9		6	4	8	8	9	2
Centroptilum		30	26	14	6		2	5
Psuedocleon	7		5	2	1	10	6	
Ephemeridae								
Ephemera		3	2	14				
Ephemerellidae								
Eurylophella				1				
Ephemeralla	2		3	2	3	5	3	6
Heptageniidae	1	5	8	7	11		1	
Heptagenia	5	18	12	5	17	11	9	5
Stenacron				4	3			
Stenonema		5	4	6	4	1	2	
Leptophlebiidae					1			
Habrophlebiodes			1					
Paraleptophlebia	1							
ODONATA								
Aeshnidae								
Boyeria			1					
Gomphidae								1
Lanthus			1					
Progomphus								

TRICHOPTERA								
Hydropsychidae							1	
Hydropsychidae Pupae								
Cheumatopsyche	1				1	1	2	
Diplectrona					1	1		
Symphitopsyche						2		
Lepidostomatidae								
Lepidostoma		1			3			
COLEOPTERA								
Dryopidae								
Helichus		1			1			
Elmidae								
Optioservus					4	6	11	3
Stenelmis			1				2	
Psephenidae								
Psephenus				1			1	2
Ectopria					2			2
DIPTERA								
Ceratopogonidae			1	1			1	
Bezzia							1	
Chironimidae	2	9	26	19	29	7	10	6
Empididae		1						
Simuliidae					1	1	1	
Tabanidae				1				
Tipulidae								
Dicranota						1	2	3
Hexatoma					3	3		
Polymera			1					
Pseudolmnophllia							2	
Biometrics								
Taxa Richness	12	13	19	18	24	19	24	14
EPT Richness	11	9	12	13	18	13	14	7
% EPT	59	58	50	60	25	38	50	59
% OC	2.9	7.6	16.1	14.7	6.5	3.4	9.0	10.7
NCBI	4.81	5.41	5.28	4.42	6.36	5.59	4.28	3.10
% NUTOL	42.0	39.8	47.8	41.1	73.5	57.2	36.0	25.0
% Clingers	29.0	30.5	23.6	33.3	20.7	28.4	45.0	48.2
METRIC SCORE								
Taxa Richness	2	2	2	2	4	2	4	2
EPT Richness	4	2	4	4	6	4	4	2
% EPT	4	4	4	6	2	2	4	4

% OC	6	6	6	6	6	6	6	6
NCBI	4	4	4	4	2	4	6	6
% NUTOL	4	4	4	4	2	4	4	6
% Clingers	4	4	4	4	4	4	6	6
multimetric score	28	26	28	30	26	26	2	2
							30	28
Bioassessment	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired

New River Watershed Crabapple 1981 Surber samples

TAXA	Crabapple 1	Crabapple2	Crabapple 3	Crabapple 4	Crabapple 5	Crabapple 6	Crabapple 7	Crabapple 8
MEGALOPTERA								
Corydalidae								
Nigronia	2							
Sialis					1			
PLECOPTERA								
Chloroperlidae								
Sweltsa	2	3	5	1	10	7		
Peltoperlidae								
Peltoperla	2			1				
Perlidae								
Acroneuria	24	5	20	13	32	12	9	2
Leuctridae								
Leuctra	28	8	14	7	6	15	5	2
Perlodidae								
Malirekus		1	2					
EPHEMEROPTERA								
Baetidae								
Baetis	8	6	23	22	42	1	1	
Centroptilum	52	12		11	3	7	6	14
Psuedocleon	1							
Ephemeridae								
Ephemera		2	1		1		5	6
Ephemerellidae								
Eurylophella		1						
Ephemeralla				1				
Heptageniidae								
Heptagenia	9	7	8	9	5	11	31	
Stenacron	1	2						
Stenonema	94	25	23	37	12	8	13	4
Leptophlebiidae								
Paraleptophlebia	5	4	13	5	7	1	4	
ODONATA								
Gomphidae								
Gomphus			1	2		1	2	
TRICHOPTERA								
Glossosomatidae								

Glossosoma					3			
Hydropsychidae								
Cheumatopsyche	6		1		1			
Symphitopsyche		2	2					
Lepidostomatidae								
Lepidostoma	1		1					
Philopotamidae								1
Wormaldia			1		1			
Polycentropodae								
Polycentropus						1		
HEMIPTERA								
Gerridae								
Gerris						1	1	
Veliidae								
Microvelia		1			1			
COLEOPTERA								
Dytiscidae								
Hydroporus						1		
Elmidae								
Dubiraphia					1			
Optioservus	1		4		3	1	1	2
Stenelmis	1	1	3	1	1	2		
Psephenidae								
Psephenus	6	24	7	12	2	1	8	5
Ectopria		1	1	1	1		2	
DIPTERA								
Blephariceridae	2							
Ceratopogonidae	1		3					2
Atrichopogon					1			
Bezzia						1		
Chironimidae	111	11	32	10	3	37	21	33
Tanypodinae	3							
Dixidae			2	3	3			
Tipulidae								
Dicranota					1	1		
Hexatoma	1		3	1	2	1	1	
Biometrics								
Taxa Richness	22	18	22	17	24	18	14	10
EPT Richness	13	13	13	10	12	9	8	6
% EPT	65	67	67	78	86	57	67	41
% OC	31.6	9.5	18.7	7.3	2.1	33.6	19.1	46.5

NCBI	3.93	3.23	2.89	3.34	2.82	3.26	3.11	4.15
% NUTOL	34.6	32.8	25.1	16.8	4.9	36.4	26.4	53.5
% Clingers	48.2	66.4	50.9	59.9	54.5	52.7	62.7	21.1
METRIC SCORE								
Taxa Richness	4	2	4	2	4	2	2	0
EPT Richness	4	4	4	4	4	2	2	2
% EPT	6	6	6	6	6	4	6	4
% OC	6	6	6	6	6	4	6	4
NCBI	4	6	6	6	6	6	6	4
% NUTOL	6	6	6	6	6	6	6	4
% Clingers	2	6	2	6	6	2	6	4
multimetric score	32	36	34	36	38	26	34	22
Bioassessment	slightly impaired	not impaired	not impaired	not impaired	not impaired	slightly impaired	not impaired	slightly impaired

New River Watershed Sugarcamp 1981 Surber samples								
TAXA	**Sugarcamp 1**	**Sugarcamp 2**	**Sugarcamp 3**	**Sugarcamp 4**	**Sugarcamp 5**	**Sugarcamp 6**	**Sugarcamp 7**	**Sugarcamp 8**
MEGALOPTERA								
Corydalidae								
Nigronia								
Sialis	1	1		2	1	1	2	1
PLECOPTERA								
Peltoperlidae								
Peltoperla			1	1				
HEMIPTERA								
Veliidae								
Microvelia					1	1		
DIPTERA								
Ceratopogonidae								
Bezzia						2		
Chironimidae	17	8	13	10	1	13	2	1
Dolichopodidae							1	
Tipulidae								
Dicranota		2	2			1		
Biometrics								
Taxa Richness	2	3	3	3	3	5	3	2
EPT Richness	0	0	1	1	0	0	0	0
% EPT	0	0	6	8	0	0	0	0
% OC	94.4	72.7	81.3	76.9	33.3	72.2	40.0	50.0
NCBI	4.99	4.19	4.21	5.16	6.01	4.91	6.21	5.06
% NUTOL	94.4	72.7	81.3	76.9	33.3	72.2	40.0	50.0
% Clingers	0.0	0.0	6.3	7.7	0.0	0.0	0.0	0.0

METRIC SCORE								
Taxa Richness	0	0	0	0	0	0	0	
EPT Richness	0	0	0	0	0	0	0	0
% EPT	0	0	0	0	0	0	0	0
% OC	0	2	0	2	6	2	0	0
NCBI	4	4	4	4	2	4	4	4
% NUTOL	0	2	0	2	6	2	2	4
% Clingers	4	4	4	4	4	4	4	4
multimetric score	8	12	8	12	18	12	14	16
Bioassessment	severely impaired	moderately impaired	severely impaired	moderately impaired	moderately impaired	moderately impaired	moderately impaired	moderately impaired

New River Watershed Green 1981 Surber samples

TAXA	Green 1	Green 2	Green 3	Green 4	Green 5	Green 6	Green 7	Green 8
PLECOPTERA								
Chloroperlidae	2		1					
Perlidae								6
Acroneuria		4	2	1	1	1		
Leuctridae								
Leuctra				1				
Perlodidae								
Malirekus	1				1	1		4
EPHEMEROPTERA								
Baetidae								
Baetis	2				5	3	3	1
Centroptilum	7	5	7	2		6	7	10
TRICHOPTERA								
Hydropsychidae								
Cheumatopsyche	1	3		3	16	9	17	14
Symphitopsyche					3		2	3
HEMIPTERA								
Veliidae								
Rhagovelia								1
COLEOPTERA								
Psephenidae								
Psephenus		1				1		
Ectopria				1				
DIPTERA								
Chironimidae	1	5	1	2	4	6	3	3
Chironominae								
Dolichopodidae			1					
Biometrics								
Taxa Richness	6	5	5	6	7	8	5	9
EPT Richness	5	3	3	4	6	6	4	7
% EPT	93	67	83	70	88	76	91	91
% OC	7.1	27.8	8.3	20.0	12.5	20.7	9.4	6.7
NCBI	4.92	4.68	5.14	4.79	5.26	5.36	5.88	4.83
% NUTOL	14.3	50.0	8.3	50.0	62.5	55.2	62.5	37.8
% Clingers	21.4	44.4	25.0	60.0	53.1	37.9	53.1	44.4
METRIC SCORE								
Taxa Richness	0	0	0	0	0	0	0	0

EPT Richness	2	0	0	0	2	2	0	2
% EPT	6	6	6	6	6	6	6	6
% OC	6	6	6	6	6	6	6	6
NCBI	4	4	4	4	4	4	2	4
% NUTOL	6	4	6	4	2	4	2	4
% Clingers	4	2	4	6	2	2	2	2
multimetric score	28	22	26	26	22	24	18	24
Bioassessment	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	slightly impaired	moderately impaired	slightly impaired

New River Watershed Bill's 1981 Surber samples

TAXA	Bill's 1	Bill's 2	Bill's 3	Bill's 4	Bill's 5	Bill's 6	Bill's 7	Bill's 8
MEGALOPTERA								
Corydalidae								
Nigronia	3	2		1				
PLECOPTERA								
Chloroperlidae								
Sweltsa	1	10	6	8	6	1	2	5
Peltoperlidae								
Peltoperla	1		1	2	3			
Perlidae								
Acroneuria	1	6	6	2	10	3	4	1
Leuctridae								
Leuctra	46	32	41	38	28	9	9	12
Perlodidae								
Malirekus	3		9	25	9	1	6	4
EPHEMEROPTERA								
Ameletidae								
Ameletus								1
Baetidae								
Baetis	23	27	49	83	45	29	37	32
Centroptilum	6	23	8		2		12	2
Psuedocleon			2	2	1			
Ephemerellidae								
Ephemeralla			1	2				
Heptageniidae								
Epeorus			2	4	2	3	1	
Heptagenia	15	61	13	9	13	7	9	4
Stenonema	7	6	2	3	4		1	1
Leptophlebiidae								
Habrophlebiodes		2		1	3	1		
Paraleptophlebia					2			
ODONATA								
Gomphidae								
Gomphus	1	1	1			1		
TRICHOPTERA								
Hydropsychidae								
Hydropsychidae Pupae								
Cheumatopsyche						1		

Symphitopsyche	5	2	4	9	2	2	5	1
Diplectrona		1		1	3			1
Philopotamidae								
Wormaldia	1			1		2		
COLEOPTERA								
Psephenidae								
Psephenus	1	1	13	4	1	2	1	
DIPTERA								
Ceratopogonidae								
Bezzia					1			
Chironimidae	2	4	1	6	1	3	4	3
Tanypodinae					2	1		1
Dolichopodidae		1						
Tipulidae								
Dicranota				1			1	
Hexatoma	1	1	1	1				1
Tipula	1					2		
Biometrics								
Taxa Richness	17	16	17	20	19	16	13	14
EPT Richness	11	10	13	15	15	11	10	11
% EPT	92	94	90	94	96	87	93	93
% OC	1.7	2.2	0.6	3.0	2.2	5.9	4.3	5.8
NCBI	2.64	3.01	2.76	2.85	2.60	3.23	3.64	3.08
% NUTOL	2.5	2.8	8.8	4.9	1.4	8.8	5.4	4.3
% Clingers	61.9	65.0	52.5	35.5	50.7	41.2	29.3	34.8
METRIC SCORE								
Taxa Richness	2	2	2	2	2	2	2	2
EPT Richness	4	4	4	4	4	4	4	4
% EPT	6	6	6	6	6	6	6	6
% OC	6	6	6	6	6	6	6	6
NCBI	6	6	6	6	6	6	6	6
% NUTOL	6	6	6	6	6	6	6	6
% Clingers	6	6	2	4	2	2	4	4
multimetric score	36	36	32	34	32	32	34	34
Bioassessment	not impaired	not impaired	slightly impaired	not impaired	slightly impaired	slightly impaired	not impaired	not impaired