FISH SURVEY IN SEVERAL TRIBUTARIES OF THE SULPHUR FORK CREEK AND RED RIVER WATERSHEDS IN MONTGOMERY AND ROBERTSON COUNTY, TENNESSEE

GREGORY KEITH HARRIS

To the Graduate Council:

I am submitting herewith a thesis written by Gregory Keith Harris entitled "Fish Survey in Several Tributaries of the Sulphur Fork Creek and Red River Watersheds in Robertson and Montgomery Counties, Tennessee." I 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 Biological Sciences.

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Date March 23, 2006

Fish Survey in Several Tributaries of the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson County, Tennessee

A Thesis

Presented for the

Master of Science

Degree

Austin Peay State University

Gregory Keith Harris

March 2006

DEDICATION

This thesis is dedicated to my parents
Lyle and Brenda Harris
who have given me love and support
throughout the years and the encouragement
needed to bring me to this point in my life.

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ACKNOWLEDGMENTS

I thank my major professor, Dr. Mack T. Finley for his guidance and encouragement during this project. I would also like to thank all committee members, Drs. Steve Hamilton, Joe Schiller, and Jeff Lebkuecher, for their comments and assistance during this project. Funding for this project was provided by the Environmental Protection Agency's Non-Point Source Program 319 through the Tennessee Department of Agriculture and The Center for Field Biology, Austin Peay State University. I also thank all those who assisted in the collection of field data and especially Mr. Robert Brinkman whose help went above and beyond the call of duty. Finally I would thank my family who gave me love and understanding during my quest for my master's degree.

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ABSTRACT

Nonpoint source pollution is the primary source of pollution in the Sulphur Fork Creek and Red River Watersheds. Siltation, unrestricted livestock access, and the depletion of vegetation from riparian zones are some of the major factors affecting these watersheds while urbanization and residential development continue to increase. The purpose of this study was to inventory the fish of the tributaries of the Sulphur Fork Creek and Red River Watersheds, use the fish fauna inventory to calculate a multi-metric score (Index of Biotic Integrity) to make water quality assessments, determine if multi-metric scores differ significantly depending on stream reach sampled, and to establish baseline data for future studies.

Sampling was conducted by electrofishing three 100-meter stream reaches in each tributary. A total of 24 reaches were sampled. Collected fish were identified to species in the field and voucher specimens of each species were preserved in 10% formalin. Fish that could not be identified in the field were preserved in 10% formalin and identified in the lab. Eight families comprising 30 species of fish were collected in this study.

The mean metric scores of the stream reaches did not

show any significant differences based on their Index of Biotic Integrity scores (Appendix D) calculated for each stream reach. Also, mean metric scores were not significantly different among Upper, Middle, or Lower stream reach within each stream. Further studies are needed to assess the effects of increasing residential and urban development in this watershed.

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SECTION 1-INTRODUCTION

Why the Concern About Water Quality?

Clean water is essential to sustain life on Earth. Without natural clean water sources there would be no practical means for procuring clean drinking water, no clean water to support aquatic life, and no clean water for recreational purposes.

In 1972 congress passed and President Richard Nixon signed into law the Clean Water Act and directed the United States Environmental Protection Agency (EPA) to manage the nation's water supplies. The objective of this act was to reduce the discharge of pollutants into our waterways in order to achieve water quality safe for fishing and recreation.

Since passage of the Clean Water Act, focus has been placed on non-biological factors such as the physical and chemical properties with the assumption that biological integrity would improve as well. Studies have shown that biological and ecological integrity continues to decline (Karr et al., 1986).

Types of Water Systems

Freshwater systems can be divided into two broad habitat types. The first type is lentic, which are still waters such as ponds, lakes, and marshes. The second type of aquatic habitat is lotic, or flowing waters such as rivers, streams, and their tributaries. This research effort involved several tributaries of the Sulphur Fork Creek watershed (SFCW) in Robertson county, Tennessee including two reference streams that are tributaries of the lower Red River Watershed (RRW) in Montgomery and Robertson counties, Tennessee.

Previous Surveys of the Fish Fauna in this Watershed

Kinsey (1998) surveyed the fish fauna of five stream reaches in Miller Creek (Appendix A1). The Tennessee Wildlife Resource Agency (TWRA) has surveyed fishes in Sulphur Fork Creek, Red River, and Carr Creek in 1997, 2000, and 2001, respectively (Appendix A2, A3, and A4). Woodruff (1971) surveyed fish in Passenger Creek, a tributary of Red River as part of a larger study of the ichthyofauna of northern Montgomery County, Tennessee (Appendix A5).

Nonpoint Source Pollution in the SFCW and RRW

Hirschi et al. (1997) defines nonpoint source pollution as pollution that cannot be traced to a specific origin. Nonpoint source (NPS) pollution is the primary cause of water quality impairment in the SFCW (Tennessee Department of Environment and Conservation, 2002).

Sedimentation in the SFCW and RRW

The primary pollutant affecting these watersheds is sediment. Sedimentation occurs when sediment input to the stream exceeds the stream's capacity to remove it. Sedimentation destroys microhabitat for fish and benthic macroinvertebrates (Tennessee Department of Environment and Conservation, 2002) and clogs the interstitial spaces of the substrate, a condition referred to as embeddedness. Sedimentation can be attributed to several factors but one major problem is the loss of riparian vegetation. The loss of riparian vegetation can be traced to various activities such as urban development, logging, and poor farming practices, including unrestricted livestock access to streams and tilling land too close to streams. Conventional farming techniques, which involve intensive soil tillage, lead to topsoil erosion.

Armour et al. (1991) found that grazing affects water quality by trampling and destabilizing streambanks leading to bank erosion, stream siltation, increased water turbidity, and embeddedness. Since many streams in the study area do not have sufficient vegetated riparian zones, eroded soil is transported in runoff directly into streams. The resulting turbidity and sediment decrease the photosynthetic ability of primary producers (Flynt et al., 2001). The removal of riparian vegetation also reduces shading of streams, which increases water temperature and diurnal temperature fluctuations (Wohl and Carline, 1996). Increased water temperature reduces its dissolved oxygen concentration, which is essential for a healthy fish and macroinvertebrate fauna (Barbour et al., 1999).

Fecal Bacteria in the SFCW and RRW

Previous research has shown that fecal coliform bacteria levels in these watersheds are above the EPA's and State of Tennessee's acceptable recreational use limits of 126 colony-forming units per 100 mL of water (Dailey et al., 1998). Bacterial pollution is partly attributed to livestock defecating directly into the streams in addition to runoff from pastures. Hirschi et al. (1998) state that large amounts of manure are carried into the streams from adjacent pastures and feedlots by storm runoff. Removal of riparian vegetation, which normally filters cattle waste from runoff during heavy rains, increases manure entry into streams.

Fish as Indicators of Water Quality

Water quality in the SFCW and RRW tributaries was assessed using the fish fauna. Karr (1981), Karr et al. (1986), and Shearer and Berry (2002) used fish community composition to assess water quality. Bartenhagen et al. (2005) lists the following advantages and disadvantages of using fish as water quality indicators.

Advantages of using fish to assess Water Quality

- Fish are good indicators of long-term effects and habitat conditions.
- Fish assemblages constitute a wide range of trophic levels; toxic substances tend to biomagnify, and thus fish community structure reflects community health.
- Fish are consumed by humans which makes contamination studies important.
- Fish are relatively easy to collect and identify.
- Environmental requirements, life history information and distribution are well known for most species.

Disadvantages to using fish to assess Water Quality

-Motility and migration cause difficulty in pinpointing a pollutant as the cause of abnormalities in individuals or a population.

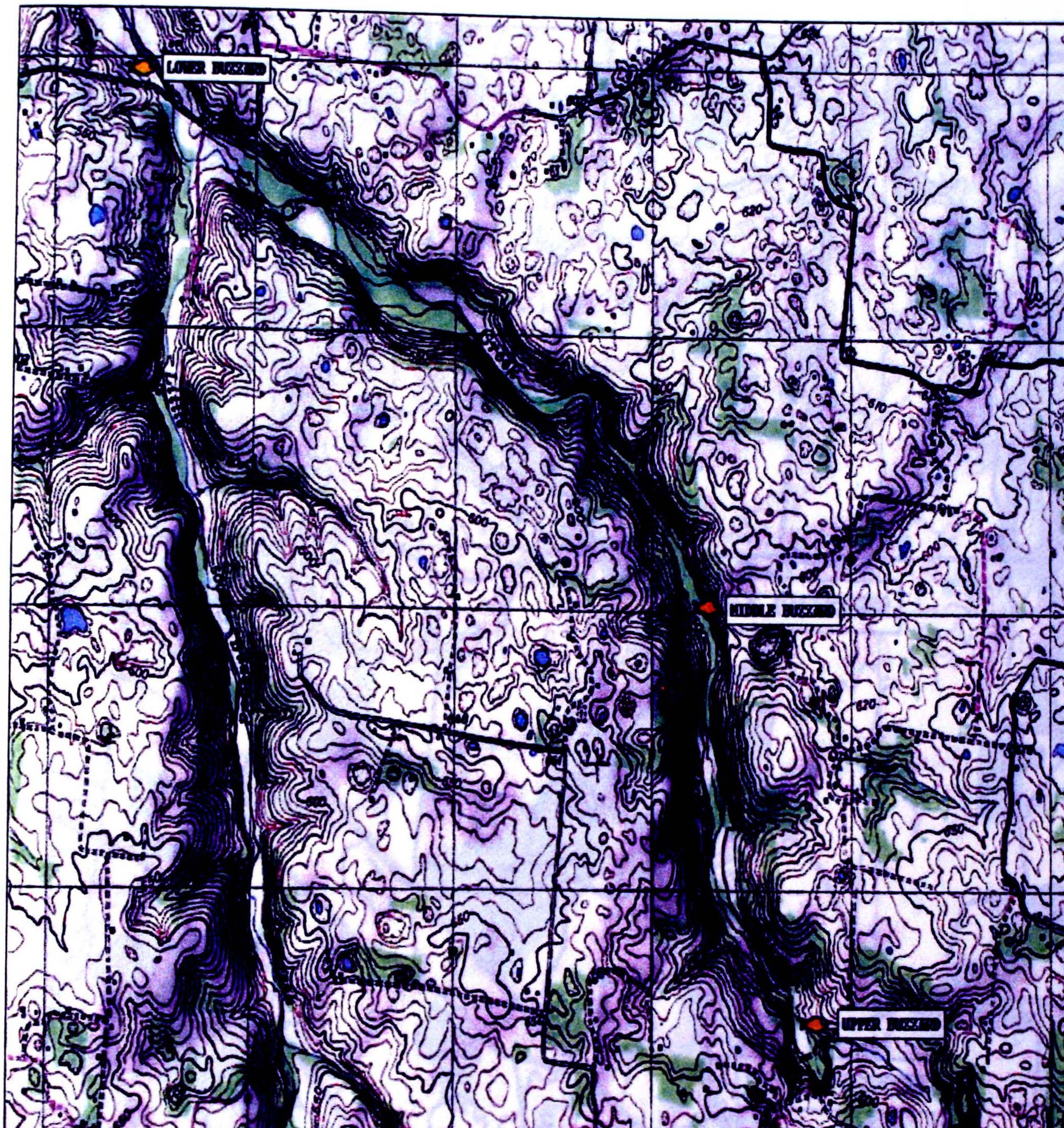
-Monitoring only certain fish species will miss changes in the benthic community or in other species in the community that over time will affect the fish species.

-Fish are not as sensitive as their food (macroinvertebrates) to pollution and monitoring of fish may not reflect severe changes in the invertebrate community.

-An assessment of fish alone will not ensure "ecosystem health."

Site Localities

Water quality of six tributaries of the SFCW and two tributaries of the RRW were evaluated using fish data. The two tributaries sampled in the RRW were Buzzard and Passenger creeks (Figures 1 and 2 respectively) in Robertson and Montgomery counties, respectively. These streams were selected because they are ecoregion reference streams for the Pennyroyal Karst Plain (71e) in the study area. The criteria for being a reference stream is based on macroinvertebrate fauna, water chemistry, and habitat assessment scores. There have been no fish assessments by the State in either of these tributaries. Ecoregion streams are to be used as the reference condition and the



Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 miles
0 1 2 3 4 5 km
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Figure 1: Map of stream reaches at Buzzard Creek in Robertson County, Tennessee.

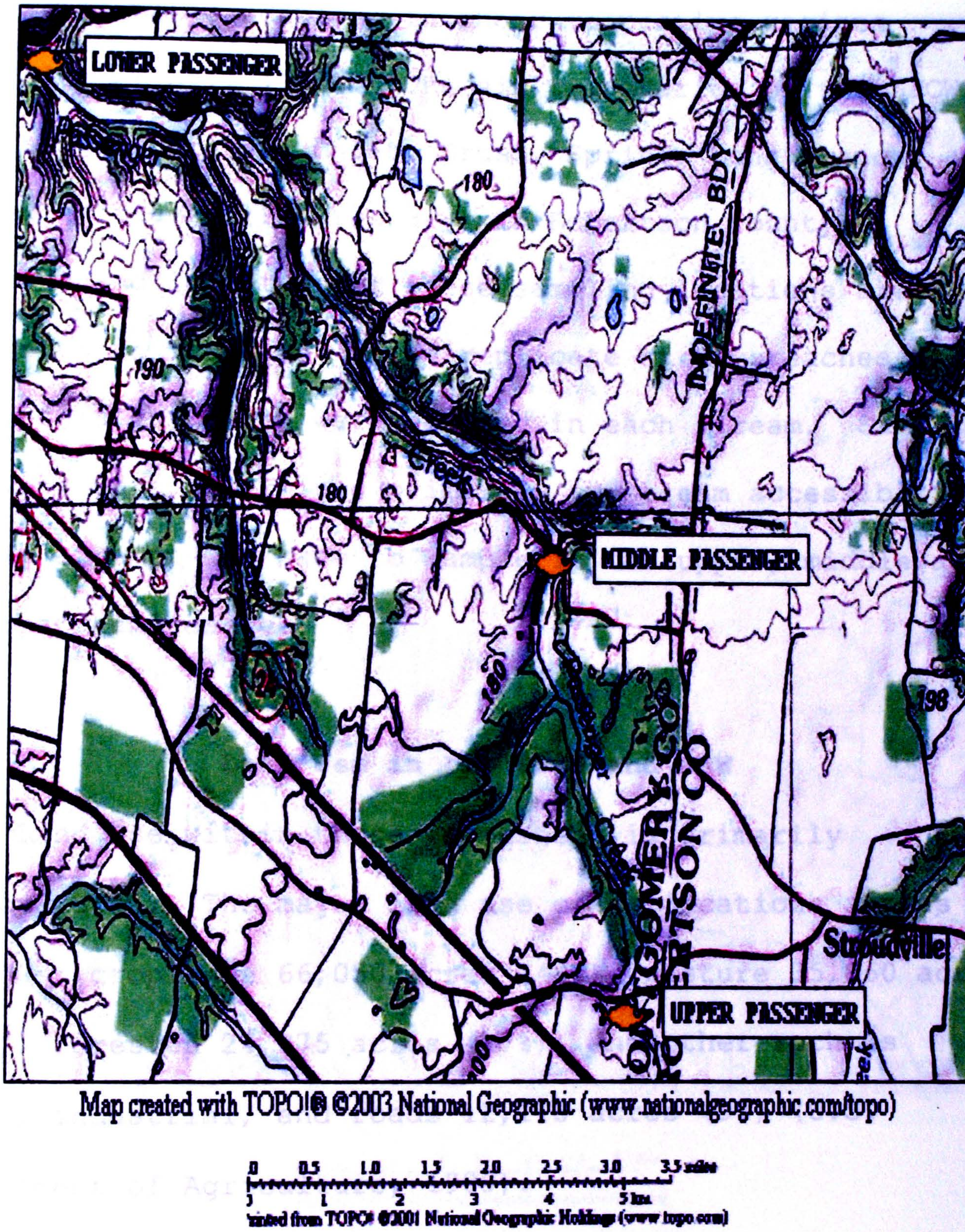


Figure 2: Map of stream reaches at Passenger Creek in Montgomery County, Tennessee.

best available conditions in their respective regions (Griffith et al., 1997). The six tributaries of the SFCW sampled were Miller, Caleb, Brush, Spring, Long Branch, and Beaverdam creeks (Figures 3-8) in Robertson county. Latitude and longitude of these sampling locations are presented in Table 1. Three replicate stream reaches of 100 meters in length were sampled in each stream. Sampling stations were determined primarily by stream accessibility, but an attempt was made to sample in the upper, middle and lower stream reaches.

Land Use in the SFCW and RRW

Land use within these watersheds is primarily agricultural. The major land use classifications are as follows: croplands 66,050 acres (48%), pasture 35,860 acres (26%), forested 24,075 acres (17%), and other such as urban, industrial, and roads 12,115 acres (9%) (U.S. Department of Agriculture, 1989).

Significance of Study

This study will describe the fish fauna of small streams in the SFCW and RRW and provide valuable baseline data to assess pollution trends and future proposed habitat

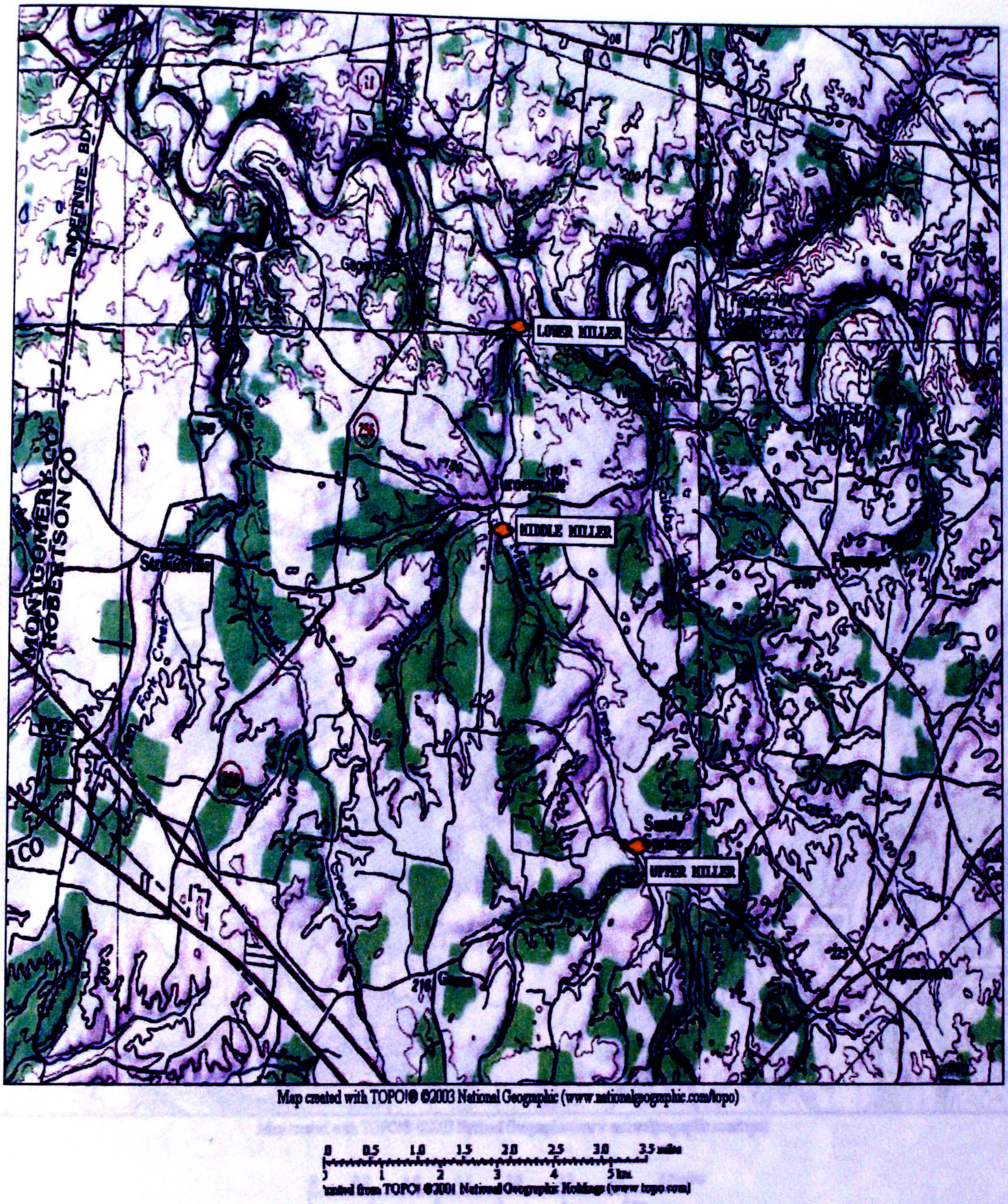


Figure 3: Map of stream reaches at Miller Creek in Robertson County, Tennessee.

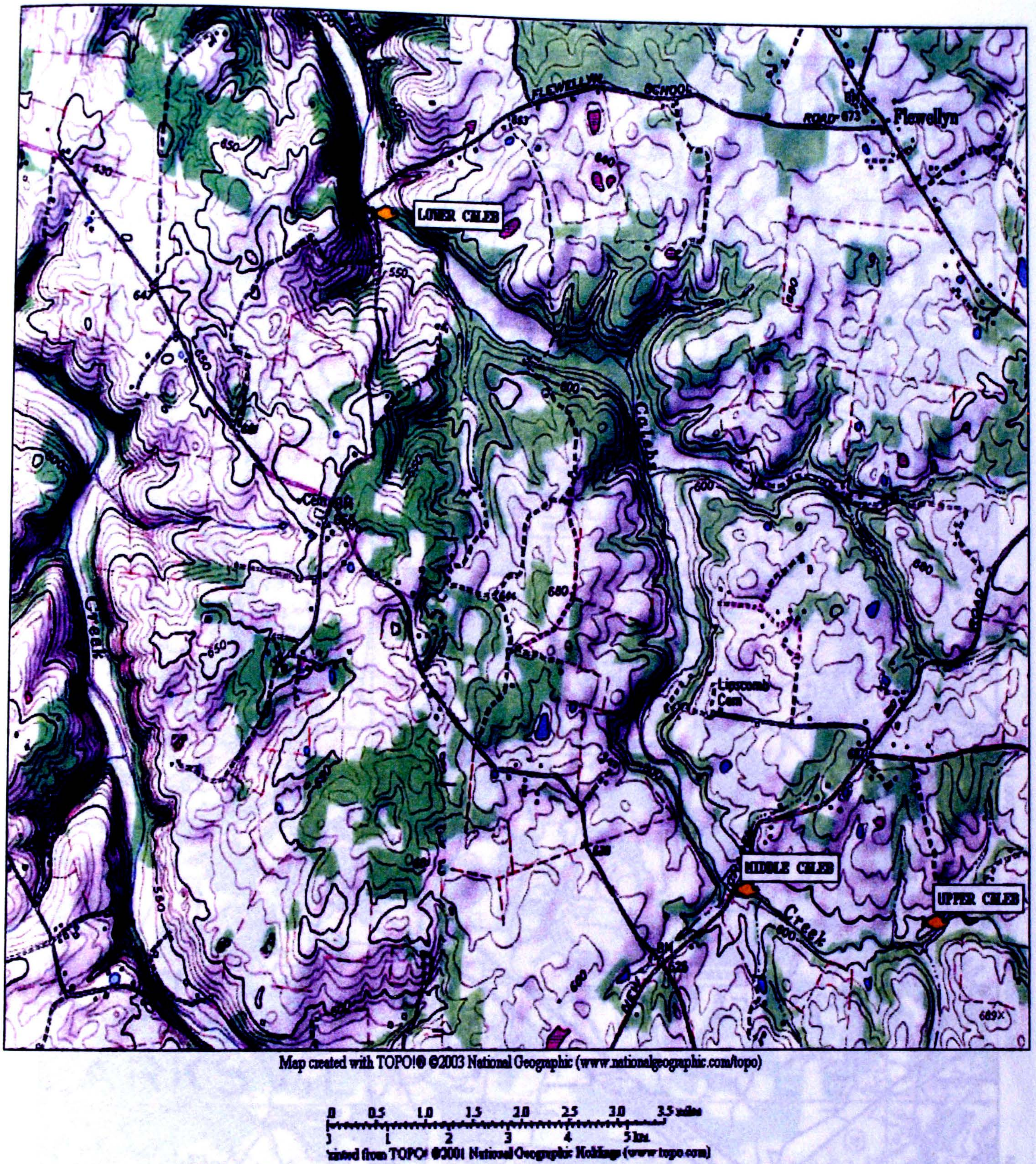


Figure 4: Map of stream reaches at Caleb Creek in Robertson County, Tennessee.

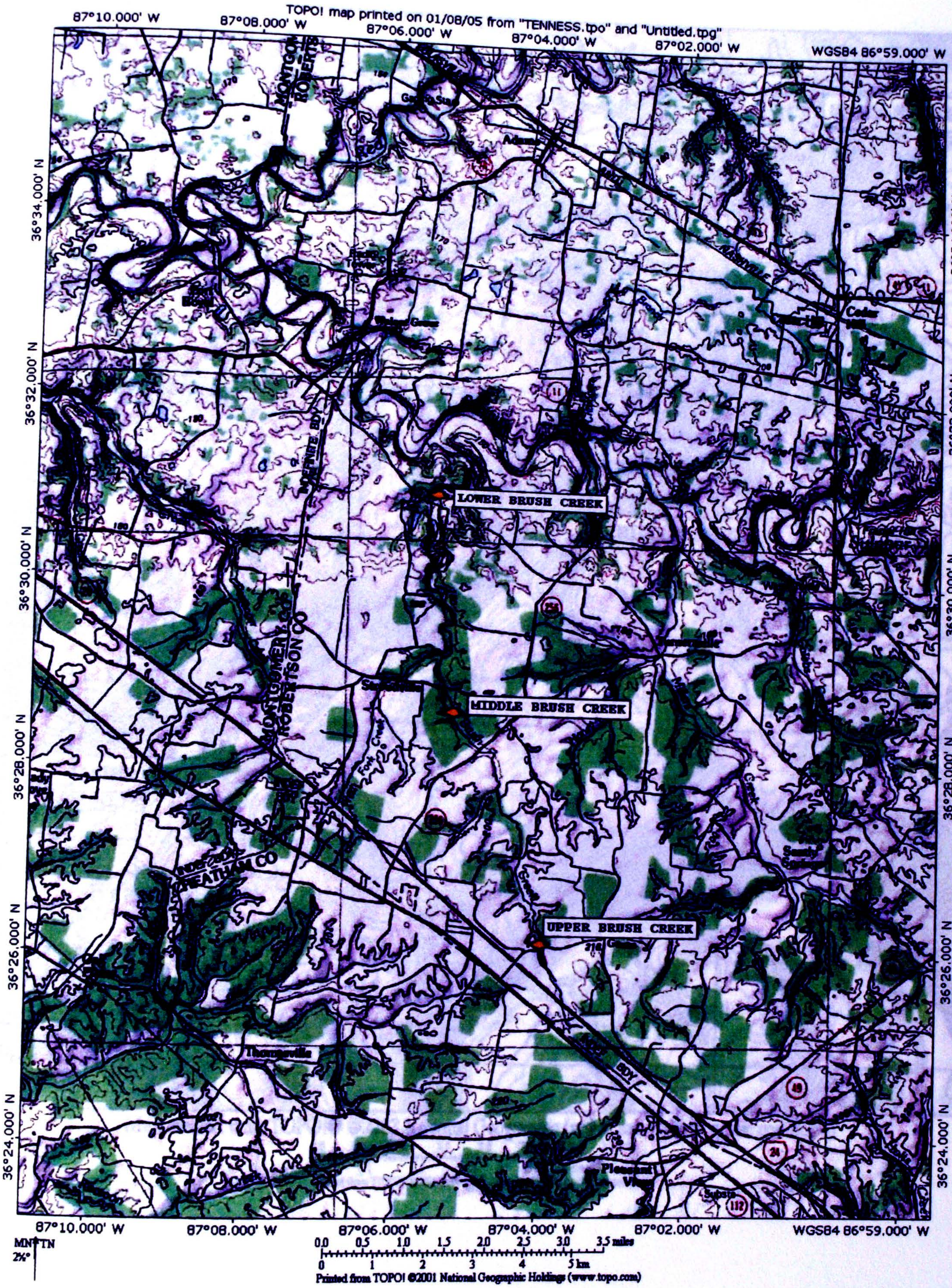
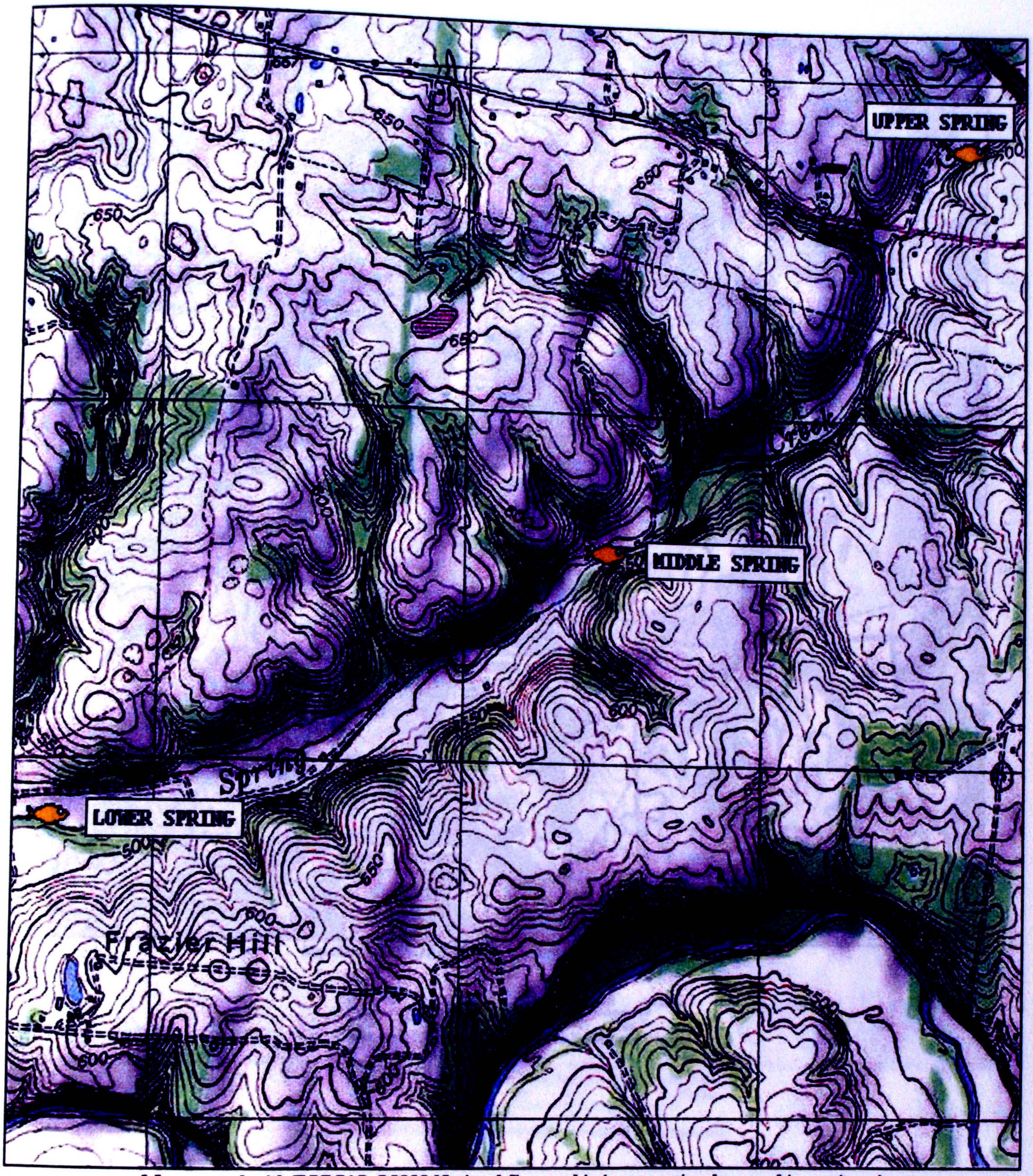


Figure 5-Map of stream reaches at Brush Creek in Robertson County, Tennessee.



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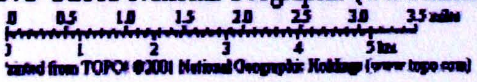

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Figure 6: Map of stream reaches at Spring Creek in Robertson County, Tennessee.

Figure 7: Map of stream reaches at Longbranch Creek in Robertson County, Tennessee.

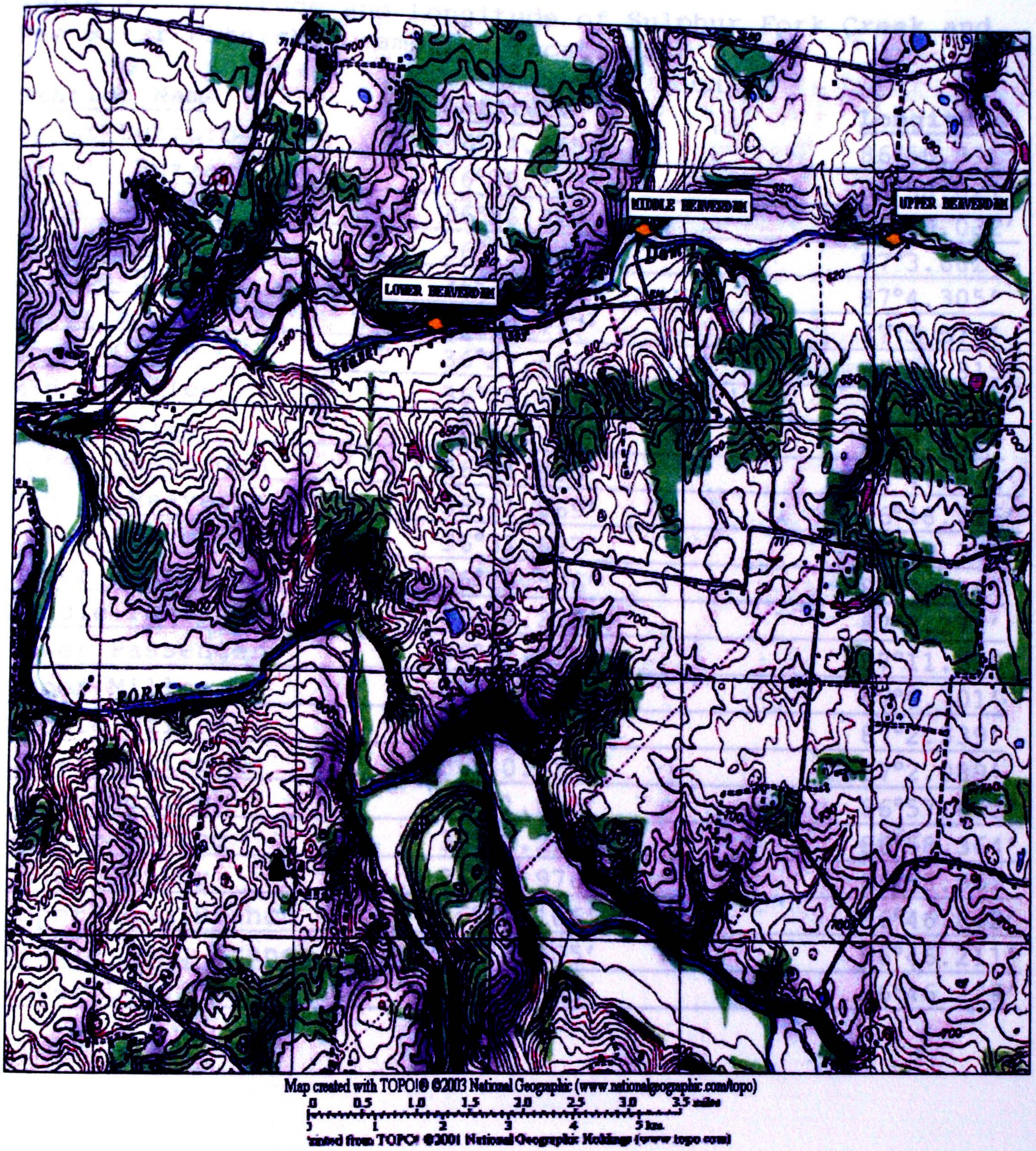


Figure 8: Map of stream reaches at Beaverdam Creek in Robertson County, Tennessee.

Table 1: Latitude and Longitude of Sulphur Fork Creek and Red River Watershed sampling locations.

Station Name	**Latitude**	**Longitude**
Upper Buzzard	36°34.565′	86°56.891′
Middle Buzzard	36°35.755′	86°58.021′
Lower Buzzard	36°36.329′	86°59.032′
Upper Brush	36°25.597′	87°3.682′
Middle Brush	36°27.004′	87°4.305′
Lower Brush	36°30.777′	87°5.578′
Upper Caleb	36°27.633′	86°59.315′
Middle Caleb	36°28.656′	87°0.186′
Lower Caleb	36°29.767′	87°0.441′
Upper Beaverdam	36°31.895′	86°47.845′
Middle Beaverdam	36°31.869′	86°48.726′
Lower Beaverdam	36°31.697′	86°49.359′
Upper Passenger	36°28.576′	87°7.814′
Middle Passenger	36°30.239′	87°8.272′
Lower Passenger	36°32.022′	87°11.630′
Upper Miller	36°26.979′	87°0.701′
Middle Miller	36°29.191′	87°2.339′
Lower Miller	36°30.521′	87°2.089′
Upper Spring	36°31.913′	86°57.602′
Middle Spring	36°31.294′	86°58.364′
Lower Spring	36°30.976′	86°58.962′
Upper Long Branch	36°26.106′	86°46.842′
Middle Long Branch	36°26.505′	86°46.211′
Lower Long Branch	36°27.883′	86°46.229′

restorations in these watersheds. Other than the work performed by TWRA and other graduate students of Austin Peay State University in a few of these sampled tributaries, there is little reliable information describing the fish communities in these small tributaries. This study will also compare differences among the fish assemblages of upper, middle, and lower stream reaches to assess the variability in bioassessment scores within streams.

SECTION 2-MATERIALS AND METHODS

Habitat Assessment

Habitat assessment was performed in each reach of each tributary according to EPA guidelines (Barbour et al., 1999). Habitat assessments measure the instream and out of stream habitat, fluvial morphology, and stream dynamics (see Figures 9 and 10). Habitat assessments were performed by walking the length of each sampling reach and estimating the appropriate habitat metric scores per the criteria set forth for each metric. The habitat assessments were performed because previous studies (Raven et al., 1998) have shown that there is a strong correlation between taxonomic richness and habitat score. The EPA as well as the State of Tennessee suggests performing habitat assessments prior to any biological sampling.

Fish Sampling

Fish were sampled in each stream by electrofishing. Klemm et al. (1993) state electrofishing is an efficient capture method that can be used to obtain reliable information on fish abundance, length-weight relationships, and age and growth of fish in most streams of order 6 or

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION
STATION #________ RIVERMILE________	STREAM CLASS
LAT ________ LONG ________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE ______ TIME ______ AM PM — REASON FOR SURVEY

Parameters to be evaluated in sampling reach

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 form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; 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 0
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 75% 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 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	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 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% 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% 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 0
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.	Water 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 0

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition - Form 2 A-7

Figure 9-Front page of Habitat Assessment form used to assess the sampling stations in the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson counties, Tennessee.

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	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 0
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 to 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 >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
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 areas; "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 Protection (score each bank)	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 ________

A-8 *Appendix A-1: Habitat Assessment and Physicochemical Characterization Field Data Sheets - Form 2*

Figure 10-Back page of Habitat Assessment form used to assess the sampling stations in the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson counties, Tennessee.

less. Prior to sampling, block seines were placed at the upstream and downstream ends of each 100-meter stream reach to prevent fish from entering or leaving a sampling reach and also to net any fish that may have escaped downstream during the collection process. Fish were stunned using a Smith-Root™ 15-C POW electrofishing backpack shocker. Electrofishing proceeded from downstream to upstream of each reach. Two to four assistants followed the electroshocking unit to net stunned fish. Captured fish were held in perforated buckets that allowed constant water flow to reduce mortality. When possible, fish were identified to species in the field and species counts were recorded (Appendix B). Fish that could not be identified in the field as well as specimens retained as voucher specimens were euthanized using Finquel™ and then preserved in 10% formalin (Etnier and Starnes, 1993). All individuals in the stream wore waders and insulated gloves to reduce the risk of injury. Stream reaches were fished from downstream to upstream to avoid collecting fish previously collected that might drift downstream into the next sample reach.

Fish species counts were used to calculate an Index of Biotic Integrity (IBI) score (Appendix C) for each stream reach (Karr, 1981). The IBI used was developed specifically for the Tennessee Valley region (Tennessee Valley Authority, 1999). A list of the metrics used to calculate the IBI are presented in Table 2. These metrics were selected based on previous work performed by TVA in setting up the IBI protocol for bioassessment in the state of Tennessee. Metric scores were calibrated to stream drainage area as suggested by TVA (Appendix D). Metrics were scored as 5,3,1, or 0 as determined by their position on these TVA metric-scoring graphs. All the drainage areas of the tributaries in this study were less than 100 square miles (USGS, 1996). All statistical tests were performed using JMP-IN™ 4.0. All IBI stream reach mean metric scores were tested for normality and transformed as needed to meet the assumptions of MANOVA (Multiple Analysis of Variance). All data that did not meet the normality assumption was analyzed using non-parametric variance analysis.

Table 2: Metrics used to assess water quality in the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson Counties, Tennessee

1. Number of native species
2. Number of native darter species
3. Number of native sunfish species
4. Number of intolerant species
5. Percentage of fish as tolerant species
6. Percentage of fish as omnivores and stoneroller species
7. Percentage of fish as insectivores
8. Percentage of fish as piscivores

SECTION 3-RESULTS AND DISCUSSION

Descriptive Statistical Analysis

Thirty fish species in eight families were collected from the eight streams in the Sulphur Fork and Red River watersheds (Appendix B). A mean of 6.75 families and 14.13 species were collected per stream. Figure 11 shows the number of species collected per stream. The range is from 11 in Spring Creek to 17 in both Passenger and Beaverdam creeks. The 30 species collected were classified as belonging to feeding groups as defined by Etnier and Starnes (1993): 53.3% insectivores, 6.7% generalist feeders, 6.7% herbivores, 3.3% omnivores, 3.3% filter feeders, and 20% unknown feeding guild.

Inferential Statistical Analysis

A correlation analysis was performed in this study (Figure 12) to test the hypothesis that taxa richness is correlated with habitat assessment score of the stream reach (Raven et al., 1998). The Spearman-rank value for this test was 0.191469. Since this value is less than the critical value of 0.738 (Ambrose and Ambrose, 1995), the null hypothesis that there is no significant correlation

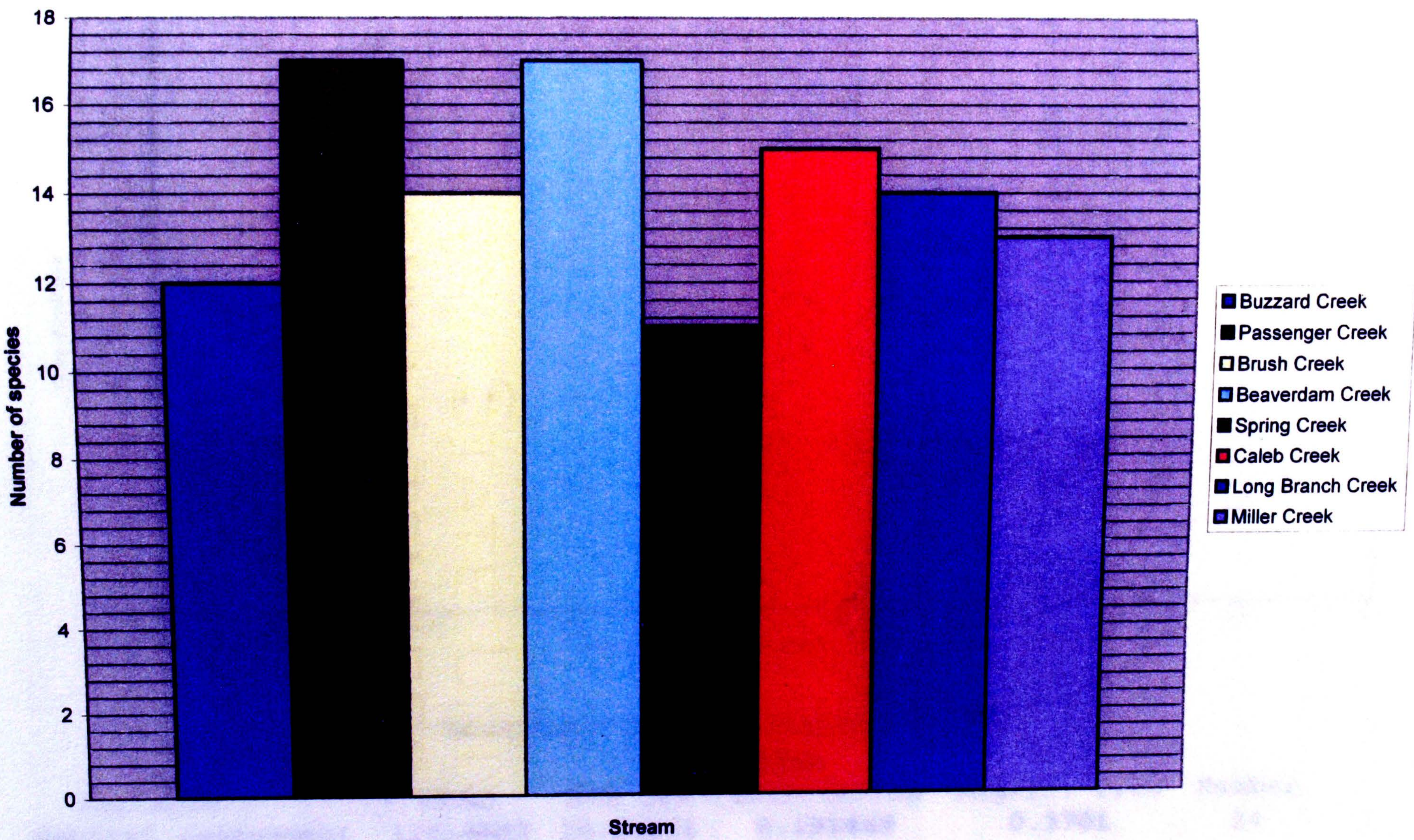
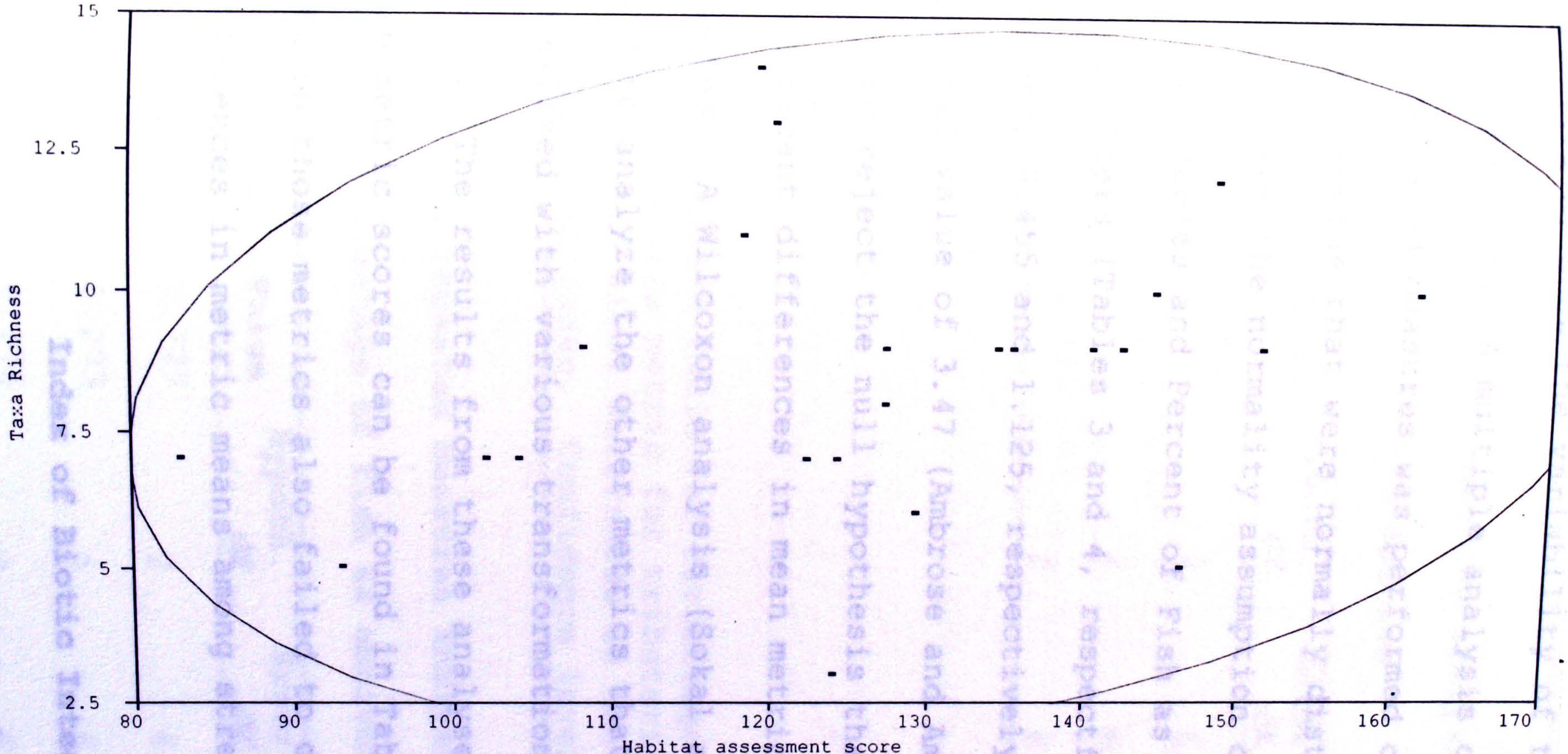


Figure 11: Species richness in tributaries of the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson counties, Tennessee.



Bivariate Normal Ellipse P=0.950

Correlation

Variable	Mean	Std Dev	Correlation	Signif. Prob	Number
Habitat assessment	126.9583	19.26808	**0.191469**	**0.3701**	24
Taxa Richness	8.333333	2.632021			

Figure 12: Correlation between taxa richness and habitat assessment score of stream reaches. Confidence error for analysis set at 95%.

between habitat score and taxa richness is accepted.

Mean error plots of metric scores by stream reach (Appendix E) show the variability of the means among the stream reaches. A multiple analysis of variance (MANOVA) with repeated measures was performed on stream reach mean metrics scores that were normally distributed. Only two metrics met the normality assumption of MANOVA: Number of Native Species and Percent of Fish as Omnivores and Stonerollers (Tables 3 and 4, respectfully). The resulting F-tests, 0.455 and 1.125, respectively are less than the critical value of 3.47 (Ambrose and Ambrose, 1995), thus we fail to reject the null hypothesis that there are no significant differences in mean metric scores among stream reaches. A Wilcoxon analysis (Sokal and Rohlf, 1994) was used to analyze the other metrics that could not be normalized with various transformations (log and square root). The results from these analyses of the stream reach mean metric scores can be found in Table 5. The Wilcoxon test on those metrics also failed to detect significant differences in metric means among stream reaches.

Index of Biotic Integrity

The IBI was first developed by James Karr (1981) and

Table 3: MANOVA table for Number of Native Species metric for tributaries of the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson Counties, Tennessee. Confidence level is ∝=95%.

Multivariate repeated measures analysis

Test of: **Number of Native Species**

Statistic	Value	Hypoth. df	Error df	F	P
Wilks' Lambda	0.868	2	6	0.455	0.655
Pillai Trace	0.132	2	6	0.455	0.655
H-L Trace	0.152	2	6	0.455	0.655

Table 4: MANOVA table for Percentage of fish as omnivores and stonerollers metric for tributaries of the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson Counties, Tennessee. Confidence level is ∝=95%.

Multivariate repeated measures analysis

Test of: **Percentage of fish as omnivores and stonerollers**

Statistic	Value	Hypoth. df	Error df	F	P
Wilks' Lambda	0.727	2	6	1.125	0.385
Pillai Trace	0.273	2	6	1.125	0.385
H-L Trace	0.375	2	6	1.125	0.385

Table 5-Results from the Wilcoxon test performed on the metric raw data from the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson Counties, Tennessee.

Metric	Wilcoxon P value*
Number of Darter Species	0.9559
Number of Native Sunfish Species	0.6635
Number of Intolerant Species	0.6023
Percentage of Fish as Tolerant Species	0.0662
Percentage of Fish as Insectivores	0.5812
Percentage of Fish as Piscivores	0.3768
Multimetric Scores	0.4562

* P values greater than 0.05 are not significant at the 95% confidence level.

used as a means of assessing stream health by looking at different aspects of the fish community in a particular stream. The IBI incorporates zoogeographic, ecosystem, community, and population aspects of the fish assemblages into a single ecologically-based index (Barbour et al., 1999). The Tennessee Valley Authority has modified and calibrated Karr's original IBI along with setting the expectation values (what you should find in a healthy Tennessee stream) so that the metrics used are suitable for Tennessee streams. In Table 6, the total score derived from summing the eight metric sub-scores for each stream reach is presented along with a qualitative assessment of each reach based on the multi-metric score of each stream reach.

Discussion of IBI Results

The range of the multi-metric scores in the assessment ranged from 28 (Upper Caleb) to 14 (Upper Passenger). Forty-two percent of the stream reaches fell in the excellent range while 46% of the stream reaches fell in the good category. Eighty-eight percent of the stream reaches were in the top 50% of the assessment categories. Although these streams have various pollutants entering them, they

Table 6: List of stream reaches and their respective multimetric score.

STREAM NAME	MULTIMETRIC SCORE[1]	ASSESSMENT
Upper Beaverdam	16	Good
Middle Beaverdam	20	Good
Lower Beaverdam	20	Good
Upper Brush	22	Excellent
Middle Brush	18	Good
Lower Brush	16	Good
Upper Buzzard	16	Good
Middle Buzzard	22	Excellent
Lower Buzzard	20	Good
Upper Caleb	28	Excellent
Middle Caleb	20	Good
Lower Caleb	22	Excellent
Upper Longbranch	18	Good
Middle Longbranch	24	Excellent
Lower Longbranch	22	Excellent
Upper Miller	20	Good
Middle Miller	26	Excellent
Lower Miller	18	Good
Upper Passenger	14	Fair
Middle Passenger	16	Good
Lower Passenger	22	Excellent
Upper Spring	22	Excellent
Middle Spring	20	Good
Lower Spring	24	Excellent

[2]**Scoring Criteria:**
Excellent: 22-28
Good: 15-21
Fair: 8-14
Poor: 0-7

[1]Multimetric score is composite score derived from adding up all 8 metrics for each stream reach.

[2]Scoring Criteria derived from setting the top score as the reference condition and then getting percentiles from how the other locations compare to the reference condition (Barbour et al., 1999).

continue to maintain a relatively healthy fish fauna based on IBI scores.

Relationship of this Study with Previous Studies

In the study performed by Kinsey (1998), she found many more species in Miller Creek than this study found. This may be because she sampled more frequently and had more sampling stations in this stream. The current study only sampled at three locations and each location was only sampled once.

Woodruff's study (1971) only had Passenger Creek in common with this study. His study focused on streams of northern Montgomery County. His study found 21 families and 70 species in his collective survey (Woodruff, 1971). TWRA has not studied any of these tributaries to this author's knowledge.

SECTION 4-CONCLUSIONS

Neither MANOVA nor Wilcoxon's test detected significant differences in mean metric scores among stream reach (upper, middle, lower). Similarly, the IBI assessments did not significantly differ among stream reaches within streams. This is not surprising considering the stream reaches share similar in-stream and out-of-stream habitats and also share similar land use. Stream reach data was combined and a single IBI score calculated for each stream. This also resulted in no significant differences in stream mean metric scores (Table 5). Since sampling had to be done where access was permissible, this limited the selection of where sampling could be performed. In theory the sampling should have occurred at random points along each stream's upper, middle, and lower reaches. Given the variation in the IBI scores among stream reaches the EPA protocol of three stream reaches giving a representation of the fish fauna of a given stream fails. Adding more stream reaches would give a better representation of the fish community in a stream. The Kinsey study (1998) and the Woodruff study (1971) resulted in a greater number of fish species than this study. I would speculate that if the stream reaches in this study would have been sampled multiple times the number of species would have been higher.

The Future of This Watershed

The ongoing stream restoration projects in this watershed are necessary along with environmental education programs. Implementation of no-till farming, watering stations for livestock, cattle exclusion from riparian zones and creeks, and general protection and restoration of riparian zones will positively impact the water quality in this watershed. In addition to several grassroots organizations, such as the Red River Watershed Association, several federal and state government agencies are providing support for habitat improvements in this watershed. Some of these agencies are the U.S. Natural Resources Conservation Service, the Tennessee Department of Agriculture, the Tennessee Department of Environment and Conservation, and the University of Tennessee Extension Service.

Additional fisheries research is needed in this watershed to detect changes in fish diversity and numbers compared to this study. Fish surveys of additional streams not studied in this project would provide a more complete assessment of water quality in this watershed. Studies should also be done in areas of riparian restoration to document its benefits on stream fish fauna.

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APPENDIX A

Table A1: Fish taxa collected by Kinsey (1998) in Miller Creek in Robertson County, Tennessee.

Fish Species Name	**Number Collected**
Hypentilum nigricans	2
Ambloblites rupestris	4
Lepomis cyanellus	2
Lepomis macrochirus	8
Lepomis megalotis	1
Micropterus dolomieu	1
Micropterus salmoides	3
Cottus carolinae	48
Campostoma anomalum	94
Hybopsis amblops	15
Luxilus chrysocephalus	93
Lythrurus ardens	212
Phoxinus erythrogaster	70
Pimephales notatus	59
Rhynichthys atratulus	71
Semotilus atromaculatus	37
Cyprinella galactura	8
Fundulus catenatus	66
Fundulus olivaceus	1
Etheostoma caeruleum	16
Etheostoma flabellare	13
Etheostoma flavum	38
Etheostoma rufilineatum	30
Etheostoma simoterum	11
Etheostoma squamiceps	25
Gambusia affinis	2

Table A2: Fish taxa collected by TWRA (1997) in Sulphur Fork Creek in Robertson County, Tennessee.

Campostoma anomalum	*Cottus carolinae*
Ctenopharyngodon idella	*Ambloplites rupestris*
Cyprinella galactura	*Lepomis cyanellus*
Cyrpinus carpio	*Lepomis gulosus*
Luxilus chrysocephalus	*Lepomis macrochirus*
Lythrurus ardens	*Lepomis megalotis*
Pimephales notatus	*Micropterus puncatus*
Hypentelium nigricans	*Micropterus salmoides*
Moxostoma duquesnei	*Etheostoma blenniodes*
Moxostoma erythrurum	*Etheostoma flavum*
Fundulus catenatus	*Etheostoma spectabile*

Table A3: Fish taxa collected by TWRA (2000) from the Red River in Robertson County, Tennessee.

Lepisosteus osseus	*Pylodictus olivaris*
Anguilla rostrata	*Fundulus olivaceous*
Campostoma anomalum	*Cottus carolinae*
Ctenopharyngodon idella	*Morone mississippiensis*
Cyprinella spiloptera	*Ambloplites rupestris*
Cyprinella whipplei	*Lepomis cyanellus*
Cyprinus carpio	*Lepomis macrochirus*
Erimystax dissimilis	*Lepomis megalotis*
Hybopsis amblops	*Lepomis microlophus*
Luxilus chrysocephalus	*Micropterus dolomieu*
Lythrurus ardens	*Micropterus punctatus*
Nocomis effuses	*Micropterus salmoides*
Notropis atherinoides	*Etheostoma blennioides*
Pimephales notatus	*Etheostoma caeruleum*
Carpiodes carpio	*Etheostoma rufilineatum*
Hypentelium nigricans	*Etheostoma simoterum*
Ictiobus bubalus	*Etheostoma spectibile*
Moxostoma carinatum	*Etheostoma tippecanoe*
Moxostoma duquesnei	*Etheostoma zonale*
Moxostoma erythrurum	*Percina caprodes*
Ictalurus punctatus	*Percina maculata*

Table A4: Fish taxa collected by TWRA (2001) at Carr Creek in Robertson County, Tennessee.

Campostoma anomalum	*Cottus carolinae*
Cyprinella galactura	*Ambloplites rupestris*
Hybopsis amblops	*Lepomis cyanellus*
Luxilus chrysocephalus	*Lepomis gulosus*
Lythurus ardens	*Lepomis macrochirus*
Pimephales notatus	*Lepomis megalotis*
Hypentelium nigricans	*Micropterus dolomieu*
Moxostoma spp.	*Micropterus punctatus*
Ameiurus melas	*Etheostoma blenniodes*
Ameiurus natalis	*Etheostoma caeruleum*
Fundulus catenatus	*Etheostoma rufilineatum*
Fundulus olivaceous	*Etheostoma simoterum*

Table A5: Fish taxa collected by Woodruff (1971) at Passenger Creek in Montgomery County, Tennessee.

Scientific Name	Common Name
Campostoma anomalum	Central Stoneroller
Notropis chrysocephalus	Striped Shiner
Semotilus atromaculatus	Creek Chub
Hypentelium nigricans	Northern Hogsucker
Noturus exilis	Slender Madtom
Lepomis cyanellus	Green Sunfish
Lepomis macrochirus	Bluegill

APPENDIX B

Table B1: Fish Collected by species in the tributaries of the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson Counties, Tennessee.

Common Name	Genus	Species	Buzzard	Passenger	Brush	Beaverdam	Longbranch	Caleb	Miller	Spring
Least brook lamprey	*Lampetra*	*aepyptera*	1	0	0	0	0	0	0	0
Central Stoneroller	*Campostoma*	*anomalum*	14	56	224	132	102	61	9	17
Whitetail Shiner	*Cyprinella*	*galactura*	0	1	23	15	0	17	0	0
Striped Shiner	*Luxilus*	*chrysocephalus*	24	29	17	43	9	23	0	11
Silverband Shiner	*Notropis*	*schumardi*	0	0	0	0	0	0	1	0
Rosefin Shiner	*Lythrurus*	*ardens*	1	17	0	3	1	0	8	33
Bigeye Shiner	*Notropis*	*boops*	0	0	3	0	0	0	0	0
Bluntnose Minnow	*Pimephales*	*notatus*	0	11	8	1	5	9	0	0
Southern Redbelly Dace	*Phoxinus*	*erythrogaster*	25	0	0	0	0	32	0	41
Blacknose Dace	*Rhinichthys*	*atratulus*	6	17	14	7	0	18	1	19
Creek Chub	*Semotilus*	*atromaculatus*	0	0	0	10	0	0	0	1
Northern Hogsucker	*Hypentelium*	*nigricans*	1	0	0	0	2	0	0	0
Golden Redhorse	*Moxostoma*	*erythrurum*	0	1	0	0	0	0	0	0
Slender Madtom	*Noturus*	*exilis*	0	2	0	2	1	0	1	0
Northern Studfish	*Fundulus*	*catenatus*	0	1	53	2	3	5	1	2
Blackspotted Topminnow	*Fundulus*	*olivaceus*	0	1	0	0	0	1	0	0
Blackstriped Topminnow	*Fundulus*	*notatus*	0	0	0	1	0	0	0	0
Banded Sculpin	*Cottus*	*carolinae*	50	48	15	20	0	28	11	39
Bluegill	*Lepomis*	*macrochirus*	0	1	45	17	4	1	1	2
Rock Bass	*Ambloplites*	*rupestris*	2	2	0	0	4	1	2	0
Spotted Bass	*Micropterus*	*punctulatus*	0	0	2	1	0	0	0	0
Dollar Sunfish	*Lepomis*	*marginatus*	0	0	0	0	0	1	0	0
Spotted Sunfish	*Lepomis*	*punctulatus*	0	0	1	0	0	0	0	0

Table B1 continued

Common Name	Genus	Species	Buzzard	Passenger	Brush	Beaverdam	Longbranch	Caleb	Miller	Spring
Longear Sunfish	*Lepomis*	*megalotus*	0	0	0	9	3	0	1	0
Green Sunfish	*Lepomis*	*cyanellus*	0	0	0	0	0	1	0	0
Snubnose Darter	*Etheostoma*	*simoterum*	12	22	20	3	14	17	1	13
Greenside Darter	Etheostoma	blennioides	1	2	0	5	1	0	0	0
Redline Darter	Etheostoma	rufilineatum	0	5	3	4	5	8	0	0
Rainbow Darter	Etheostoma	caeruleum	1	4	1	4	4	0	4	1
Striped Darter	Etheostoma	virgatum	0	0	0	0	0	0	1	0

APPENDIX C

TABLE C1: Metric Calculations for the tributaries of the Sulphur Fork Creek and Red River Watersheds in Montgomery and Robertson Counties, Tennessee.

Sampling Location	# Native Species	# Native Darter Species	# Native Sunfish Species (less *Micropterus sp.*)	# of Intolerant Species	% of Fish as Tolerant Species	% of Fish as Omnivores and Stoneroller Species	% of Fish as Insectivores	% of Fish as Piscivores	IBI Totals
Upper Beaverdam	13(3)	3(3)	2(1)	1(1)	8(5)	59(1)	12(1)	0(1)	16
Middle Beaverdam	11(1)	3(3)	0(1)	2(3)	0(5)	23(3)	34(3)	2(1)	20
Lower Beaverdam	7(1)	2(1)	2(1)	1(1)	0(5)	10(5)	90(5)	0(1)	20
Upper Brush	9(3)	2(1)	2(1)	1(1)	1(5)	29(3)	63(5)	2(3)	22
Middle Brush	9(3)	1(1)	1(1)	2(3)	27(3)	16(5)	16(1)	0(1)	18
Lower Brush	9(3)	2(1)	0(1)	2(3)	1(5)	67(1)	21(1)	0(1)	16
Upper Buzzard	5(1)	1(1)	0(1)	0(1)	23(3)	0(5)	45(3)	0(1)	16
Middle Buzzard	9(3)	5(3)	0(1)	0(1)	2(5)	22(5)	11(1)	2(3)	22
Lower Buzzard	6(3)	1(1)	0(1)	1(3)	0(5)	0(5)	88(5)	2(3)	20
Upper Caleb	14(5)	2(3)	2(3)	1(1)	5(5)	42(3)	16(1)	0(1)	28
Middle Caleb	8(3)	1(1)	1(1)	0(1)	10(5)	26(3)	44(5)	0(1)	20
Lower Caleb	9(3)	2(3)	0(1)	1(1)	13(5)	15(5)	32(3)	0(1)	22
Upper Longbranch	7(3)	2(3)	1(1)	1(1)	0(5)	78(1)	5(1)	2(3)	18
Middle Longbranch	10(3)	2(3)	2(3)	3(5)	11(5)	51(1)	30(3)	0(1)	24
Lower Longbranch	7(3)	3(3)	0(1)	0(1)	0(5)	41(3)	12(1)	12(5)	22
Upper Miller	5(1)	1(1)	0(1)	1(1)	6(5)	6(5)	88(5)	0(1)	20

TABLE C1 continued

Sampling Location	# Native Species	# Native Darter Species	# Native Sunfish Species (less *Micropterus sp.*)	# of Intolerant Species	% of Fish as Tolerant Species	% of Fish as Omnivores and Stoneroller Species	% of Fish as Insectivores	% of Fish as Piscivores	IBI Totals
Middle Miller	9(3)	3(3)	1(1)	1(1)	0(5)	11(5)	37(3)	5(5)	**26**
Lower Miller	5(1)	0(1)	1(1)	2(3)	0(5)	60(1)	20(1)	10(5)	**18**
Upper Passenger	9(1)	2(1)	0(1)	1(1)	22(3)	39(3)	38(3)	0(1)	**14**
Middle Passenger	10(1)	2(1)	1(1)	0(1)	10(5)	37(3)	35(3)	0(1)	**16**
Lower Passenger	12(3)	4(3)	1(1)	1(1)	2(5)	13(5)	75(5)	4(5)	**22**
Upper Spring	7(3)	2(3)	0(1)	0(1)	19(5)	14(5)	22(3)	0(1)	**22**
Middle Spring	3(1)	1(1)	0(1)	0(1)	3(5)	0(5)	72(5)	0(1)	**20**
Lower Spring	7(3)	2(3)	0(1)	1(1)	0(5)	7(5)	82(5)	0(1)	**24**

APPENDIX D

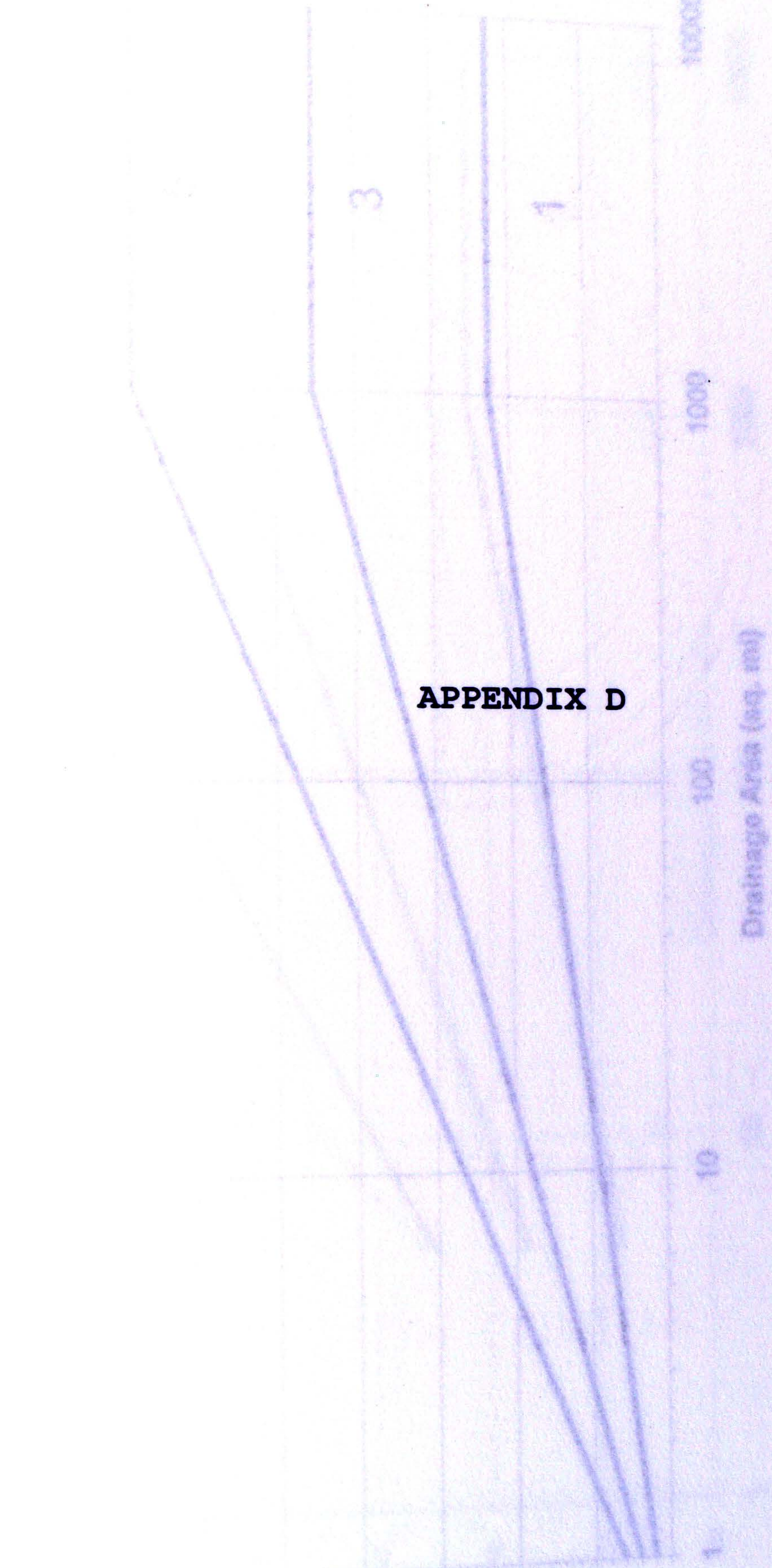

Figure D1: Graph used to determine metric score value for Number of native species based on number of native species and Drainage area.

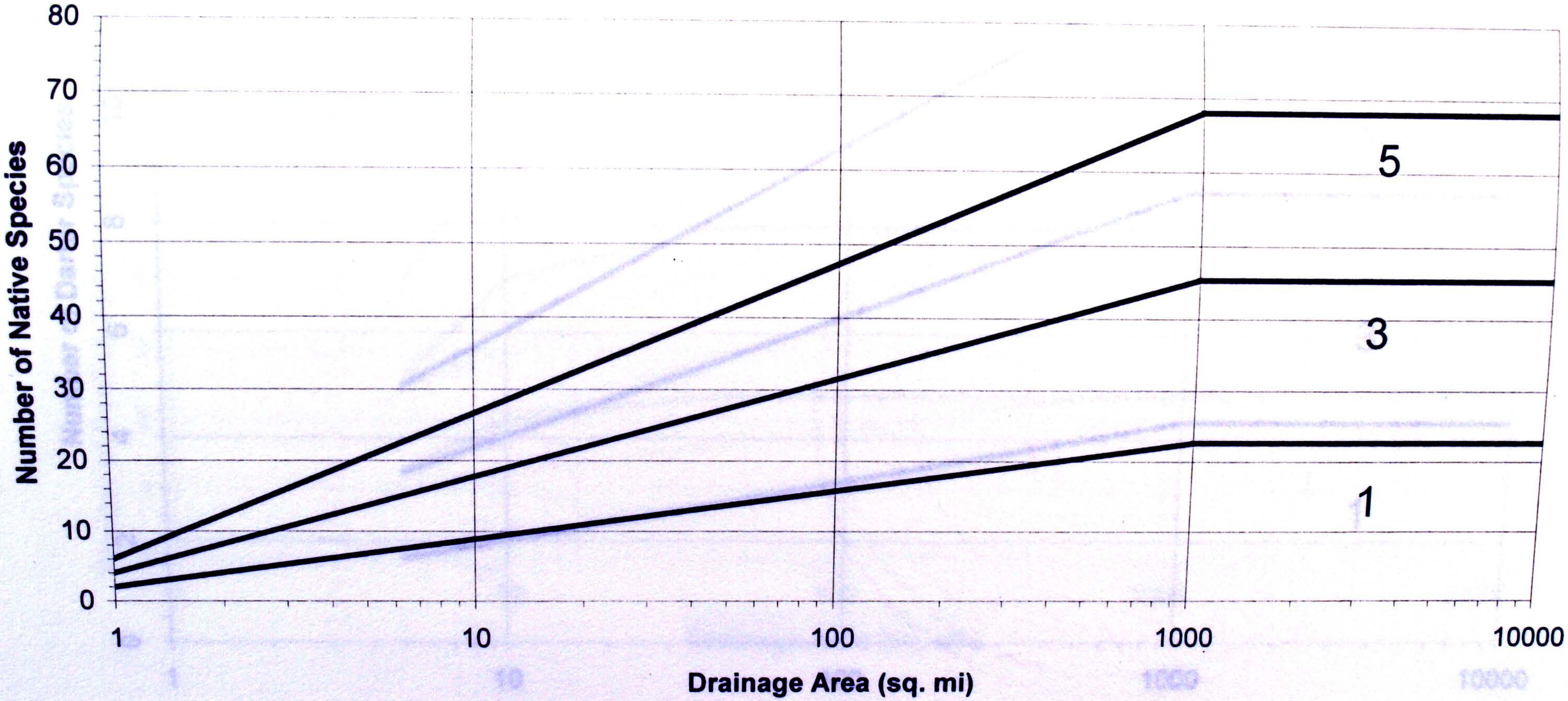

Figure D1: Graph used to determine metric score value for Number of native species based on number of native species and Drainage area.

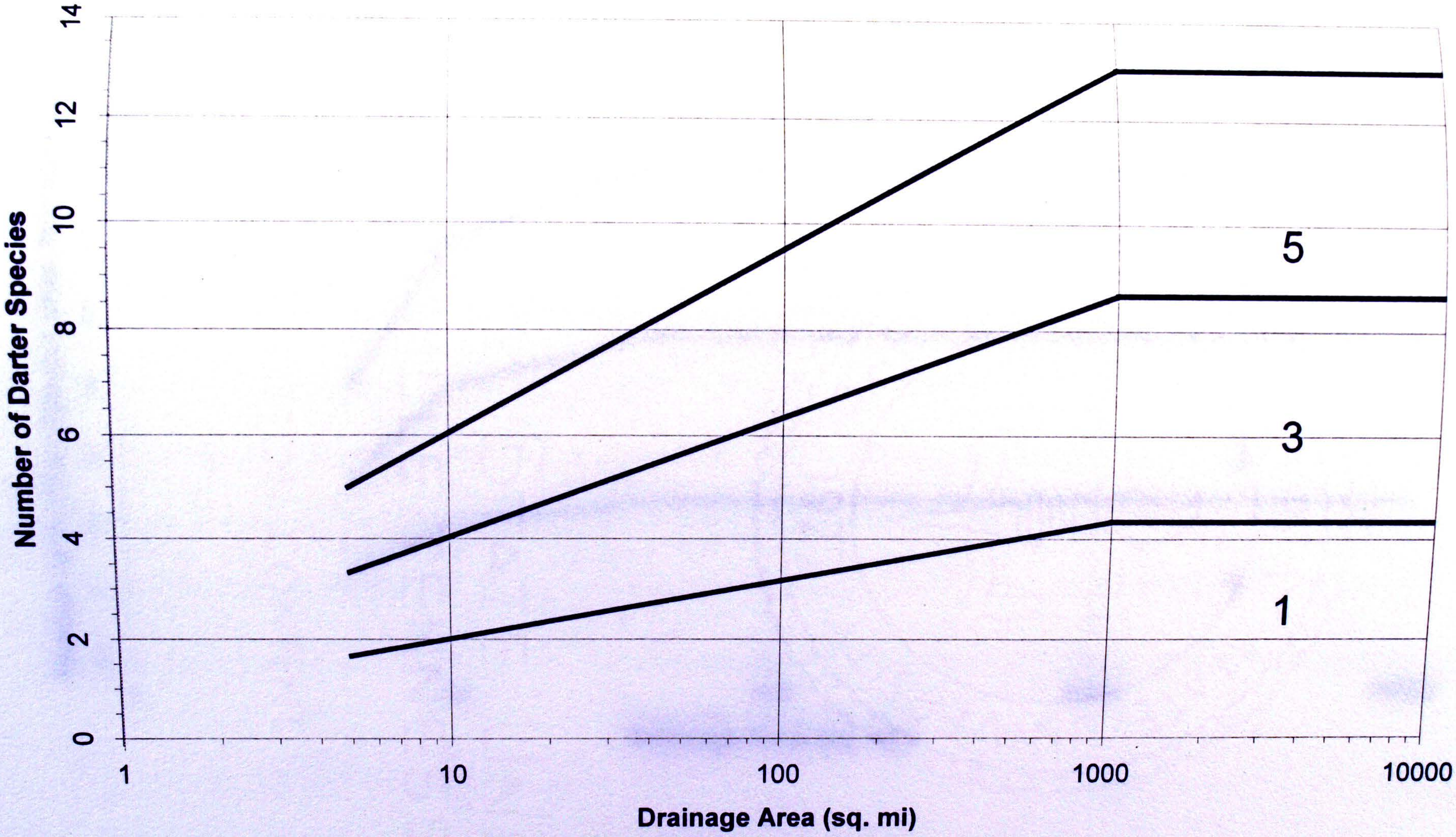

Figure D2: Graph used to determine metric score for Number of Darter species based upon drainage area and number of darter species.

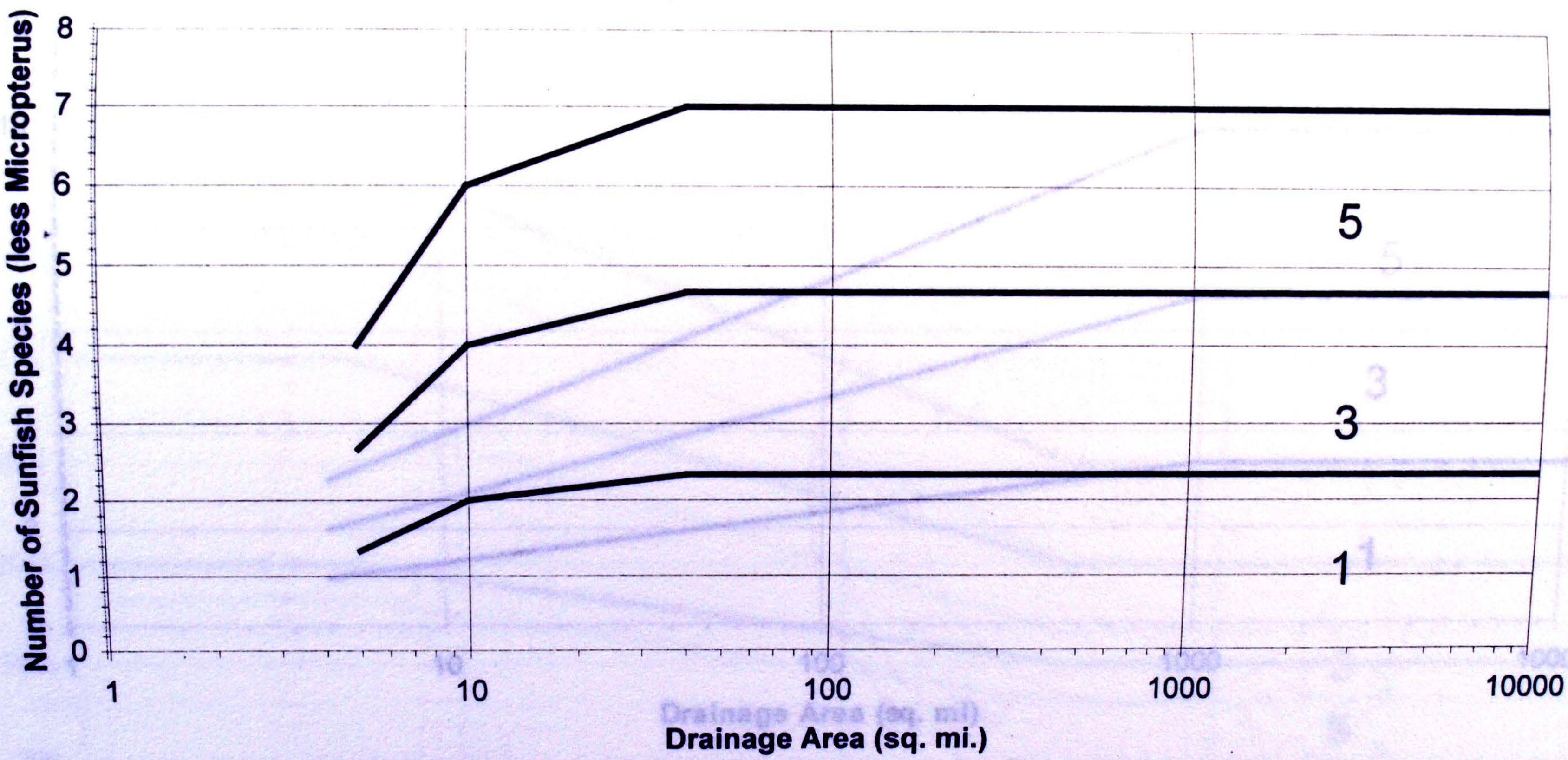

Figure D3: Graph used to determine metric score for Number of Sunfish Species (less *Micropterus*) based on Drainage area and Number of Sunfish species.

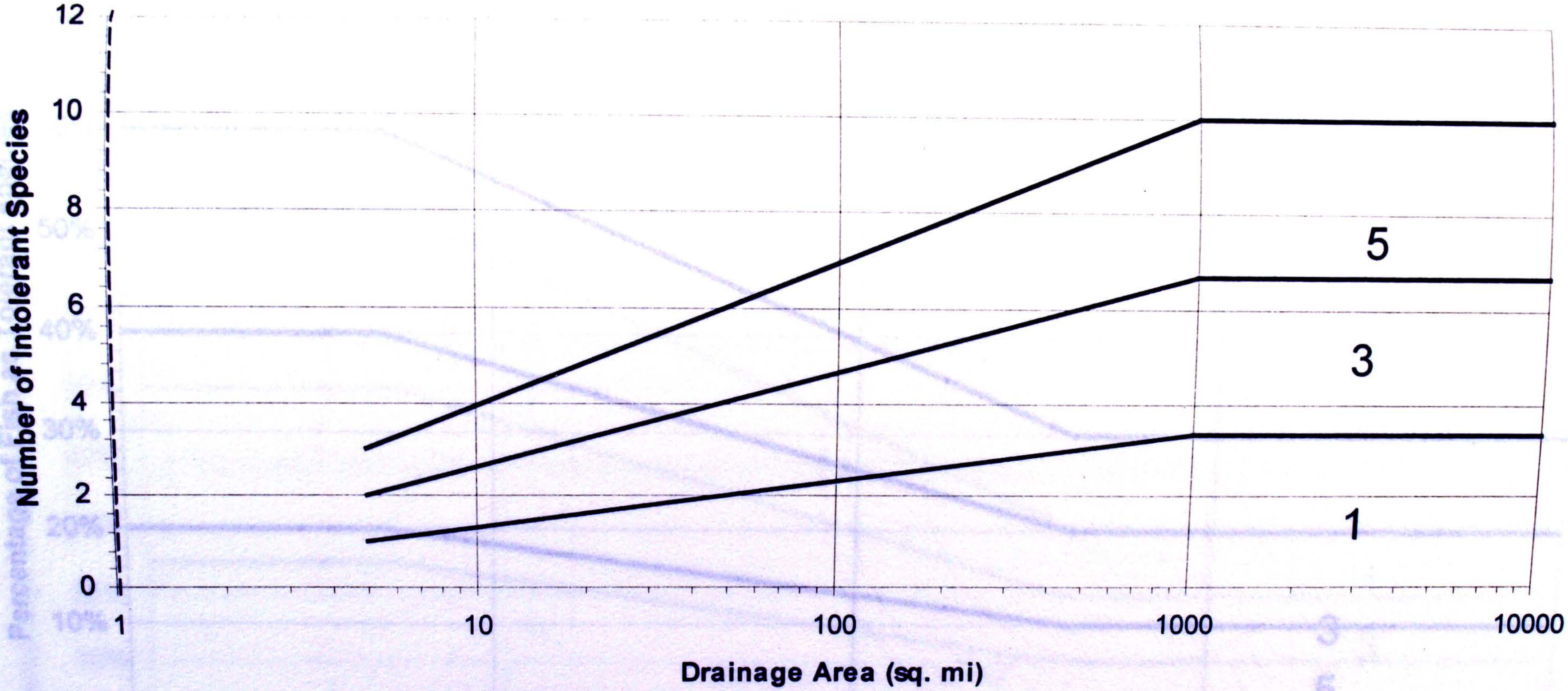

Figure D4: Graph used to determine the metric score for Number of Intolerant Species based on Drainage area and Number of intolerant species.

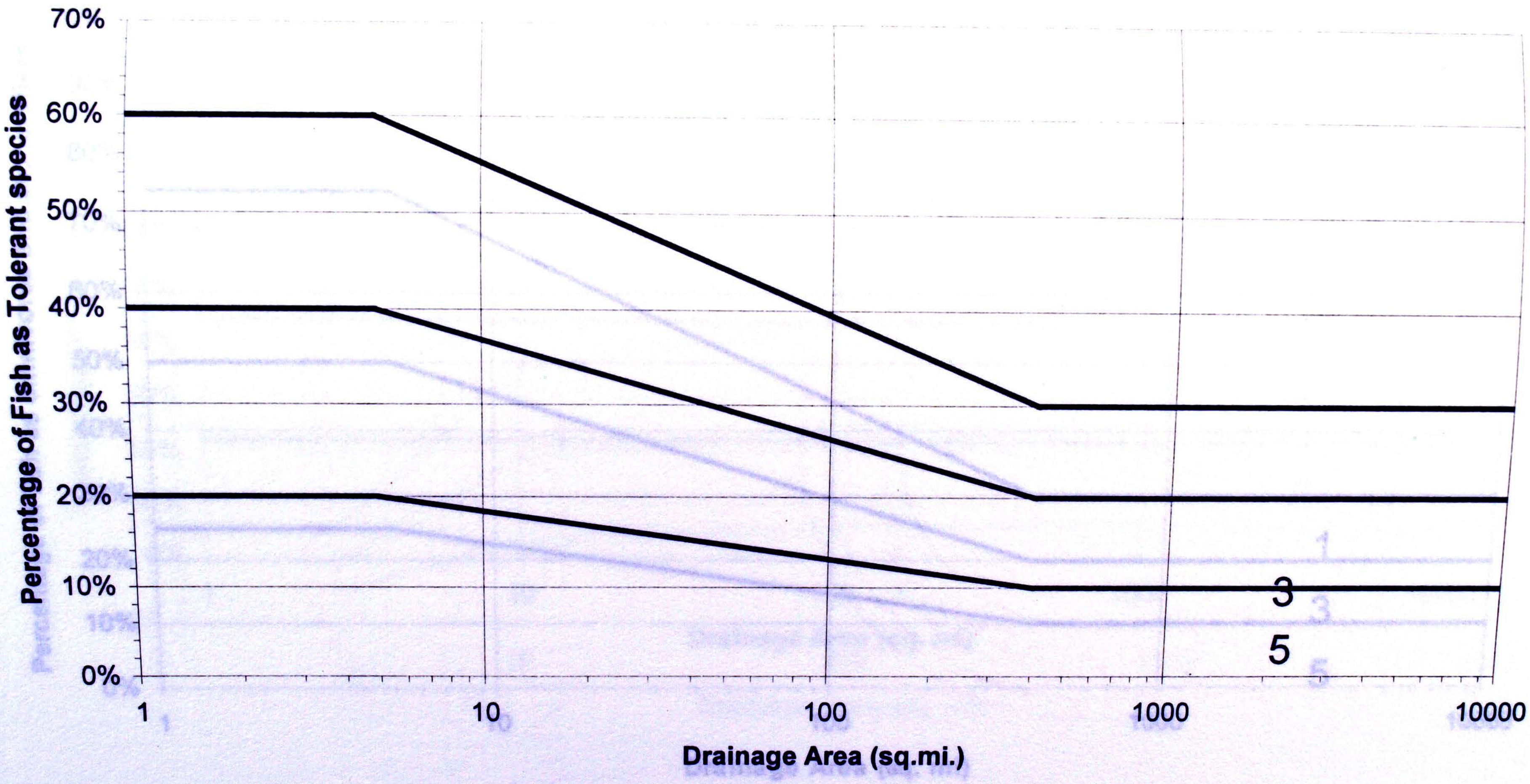

Figure D5: Graph used to determine metric score for Percent tolerant species based upon Drainage area and percentage of fish that were pollution tolerant.

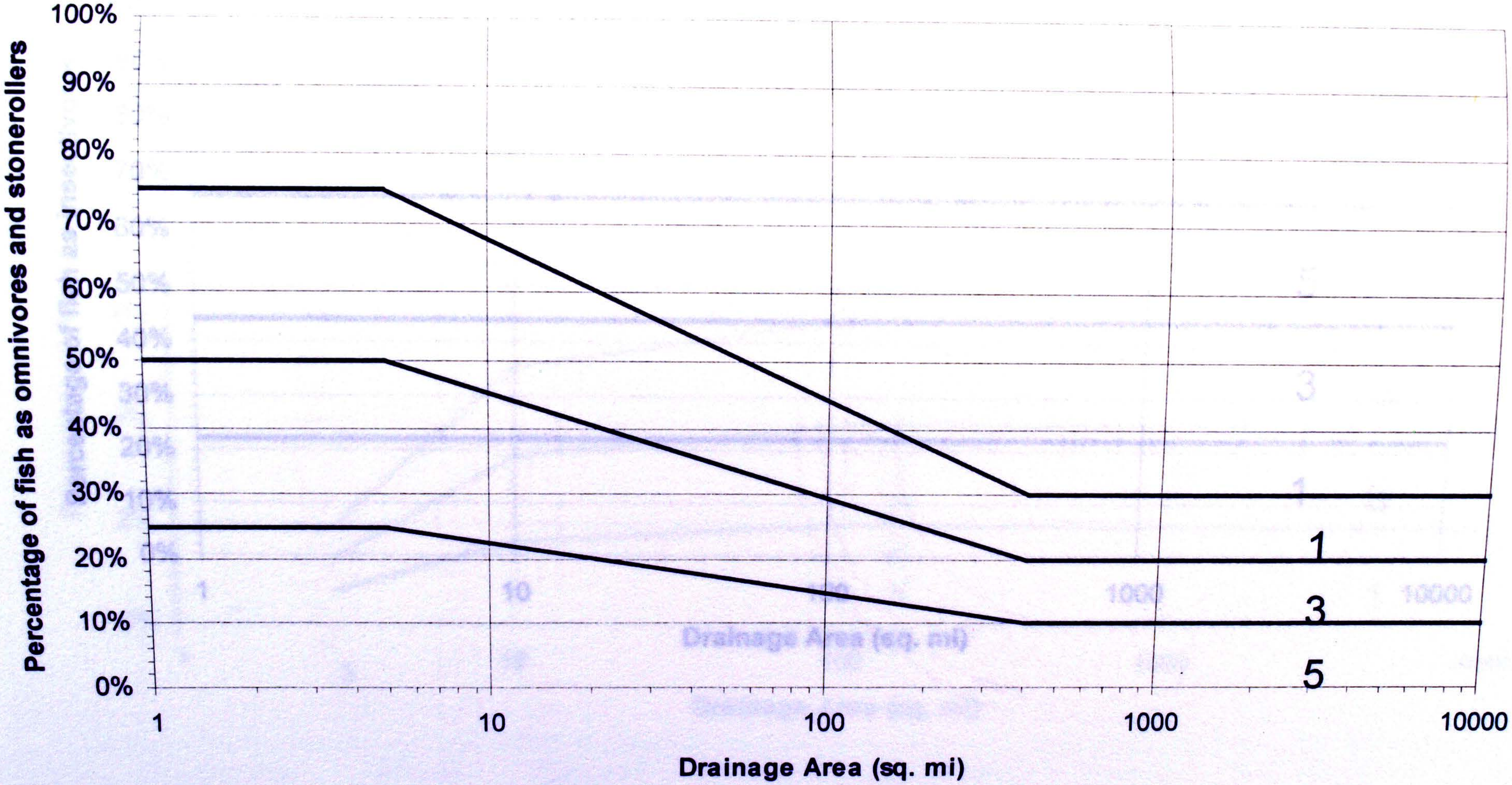

Figure D6: Graph used to determine metric score for Percent fish as omnivore and stoneroller species based upon Drainage area and percentage of fish as omnivores and stoneroller species.

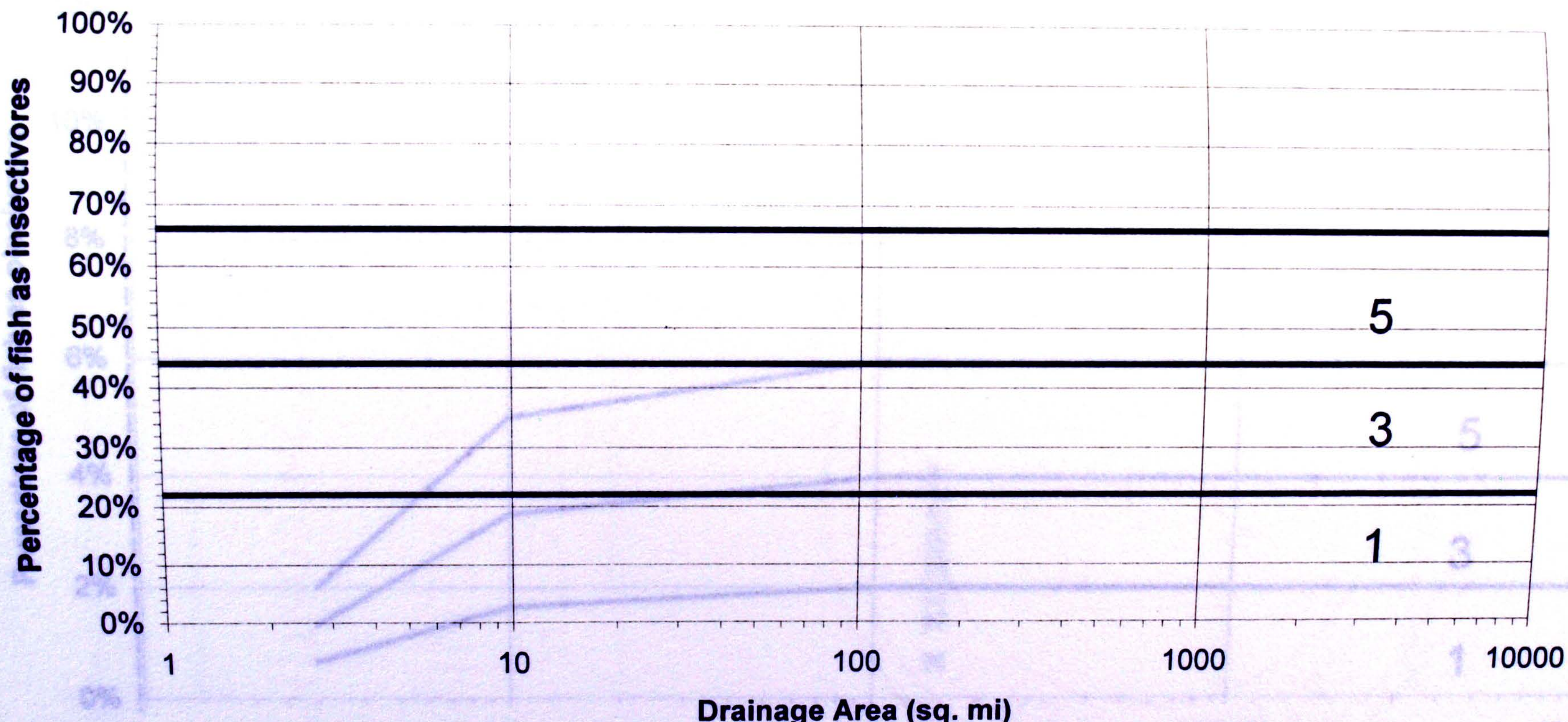

Figure D7: Graph used to determine metric score for percentage of fish as insectivores based upon Drainage area and percentage of fish as insectivores.

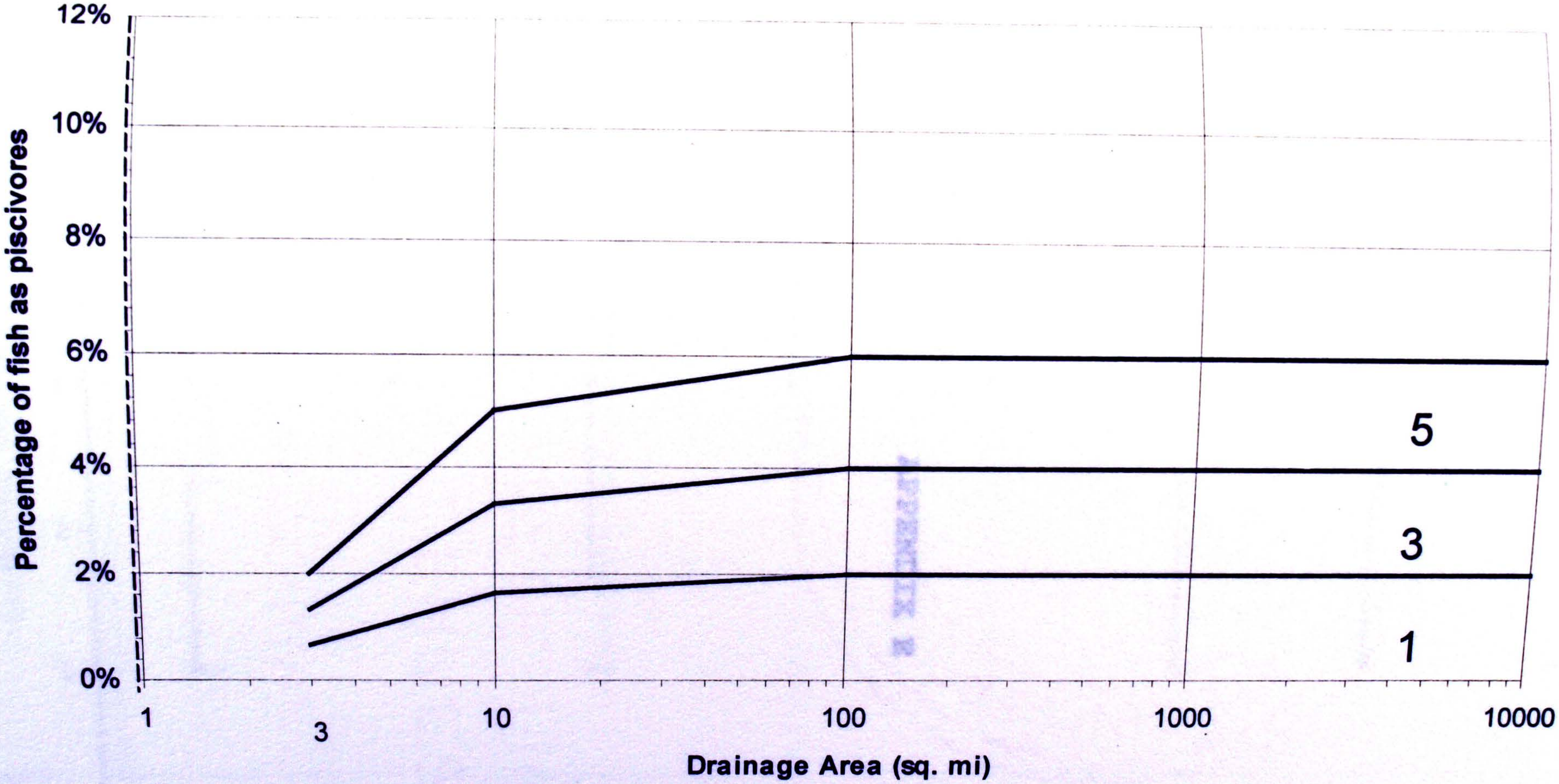

Figure D8: Graph used to determine the metric score for percentage of fish as piscivores based upon Drainage area and percentage of fish as piscivores.

APPENDIX E

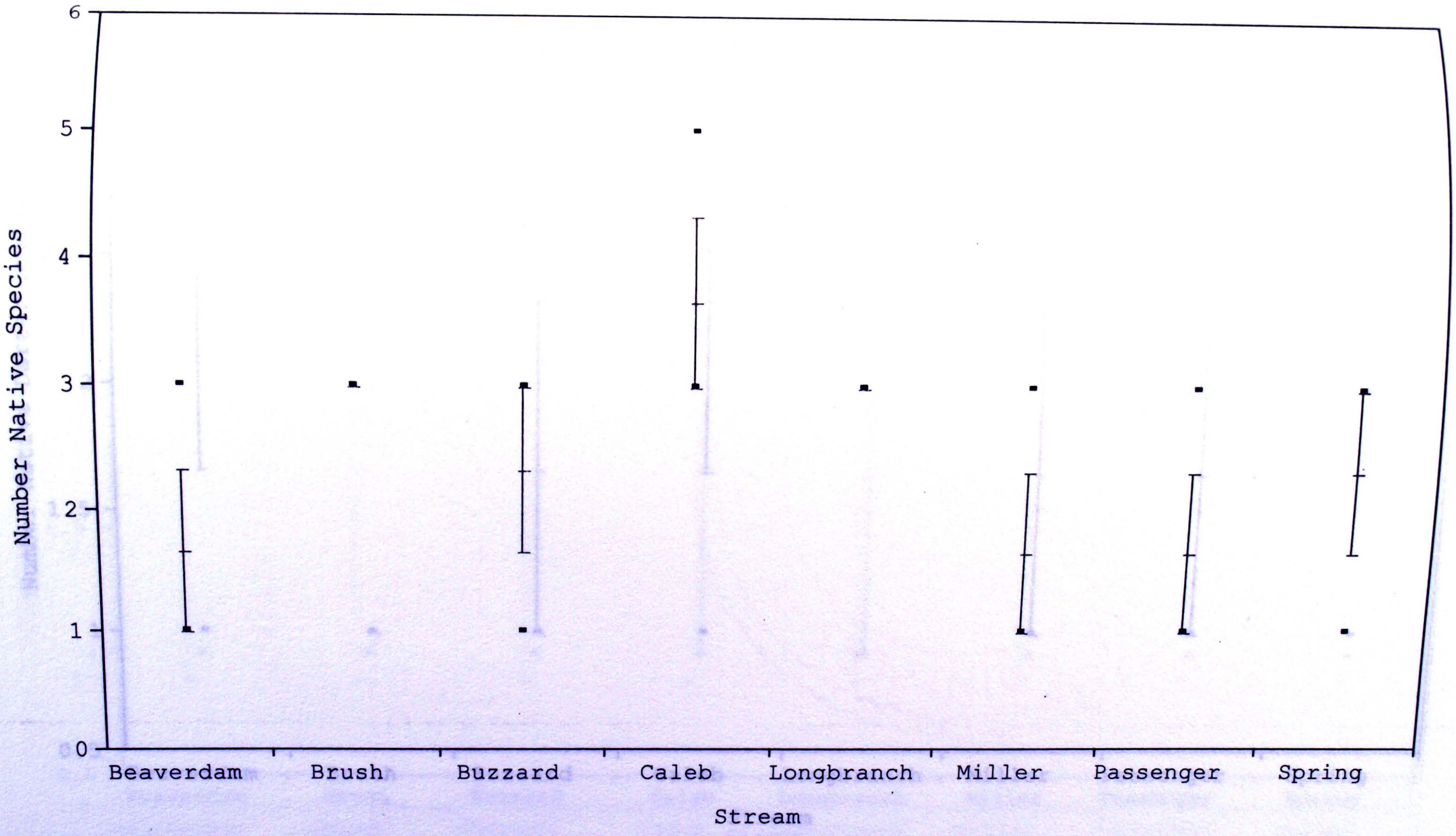

Figure E1: Graph of Number of Native Species metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

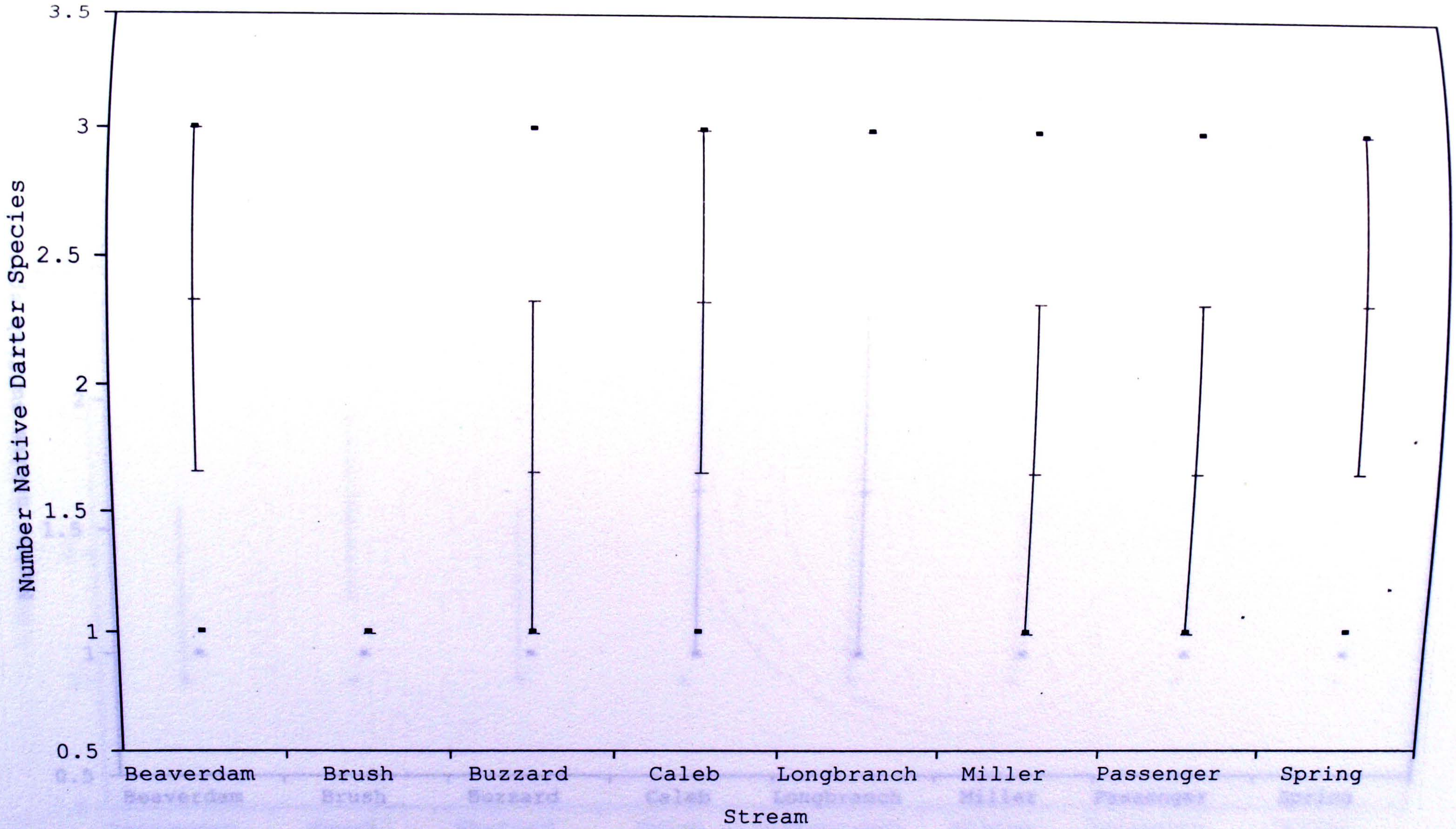

Figure E2: Graph of Number of Native Darter Species metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

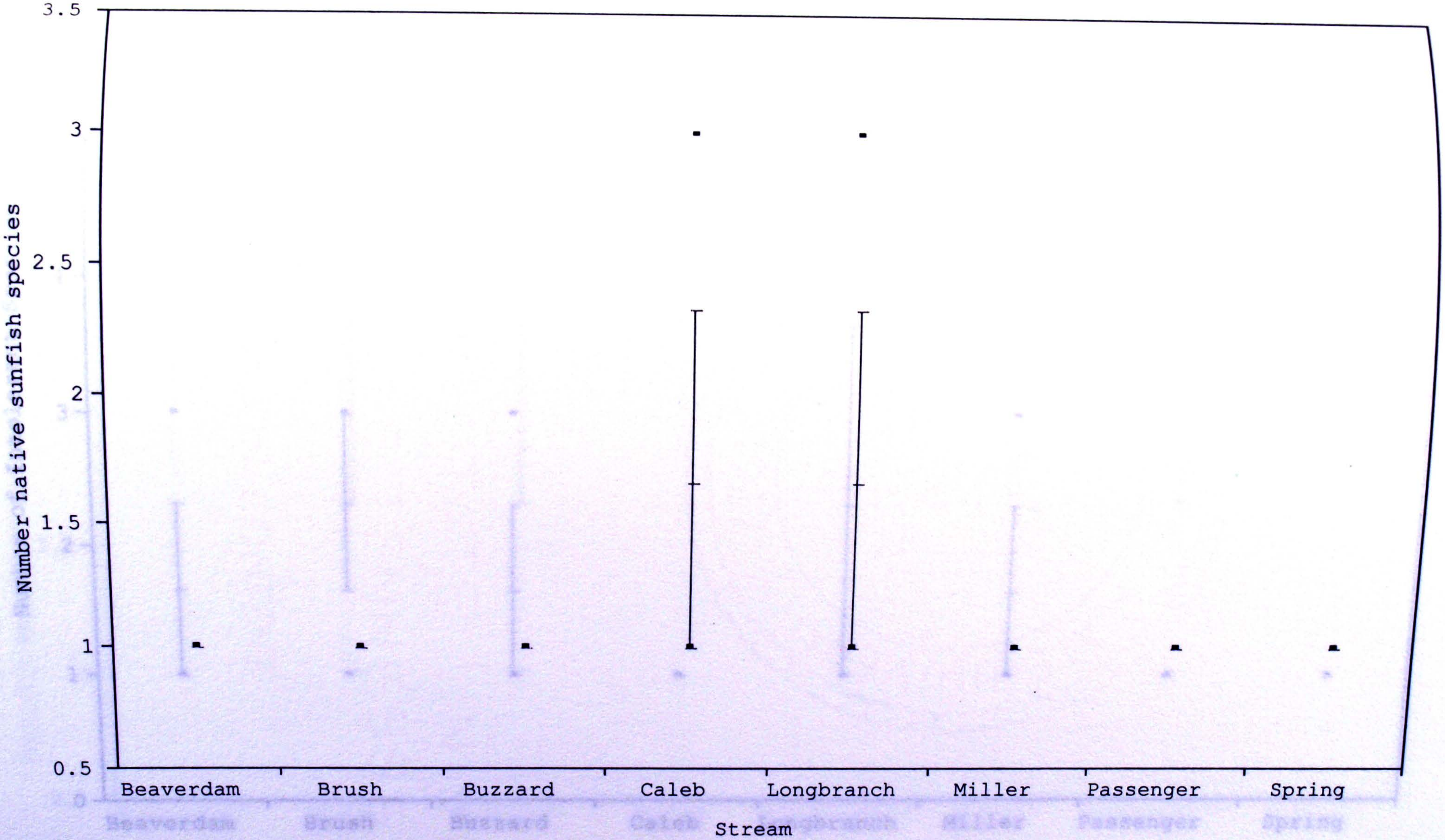

Figure E3: Graph of Number of Native Sunfish Species metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

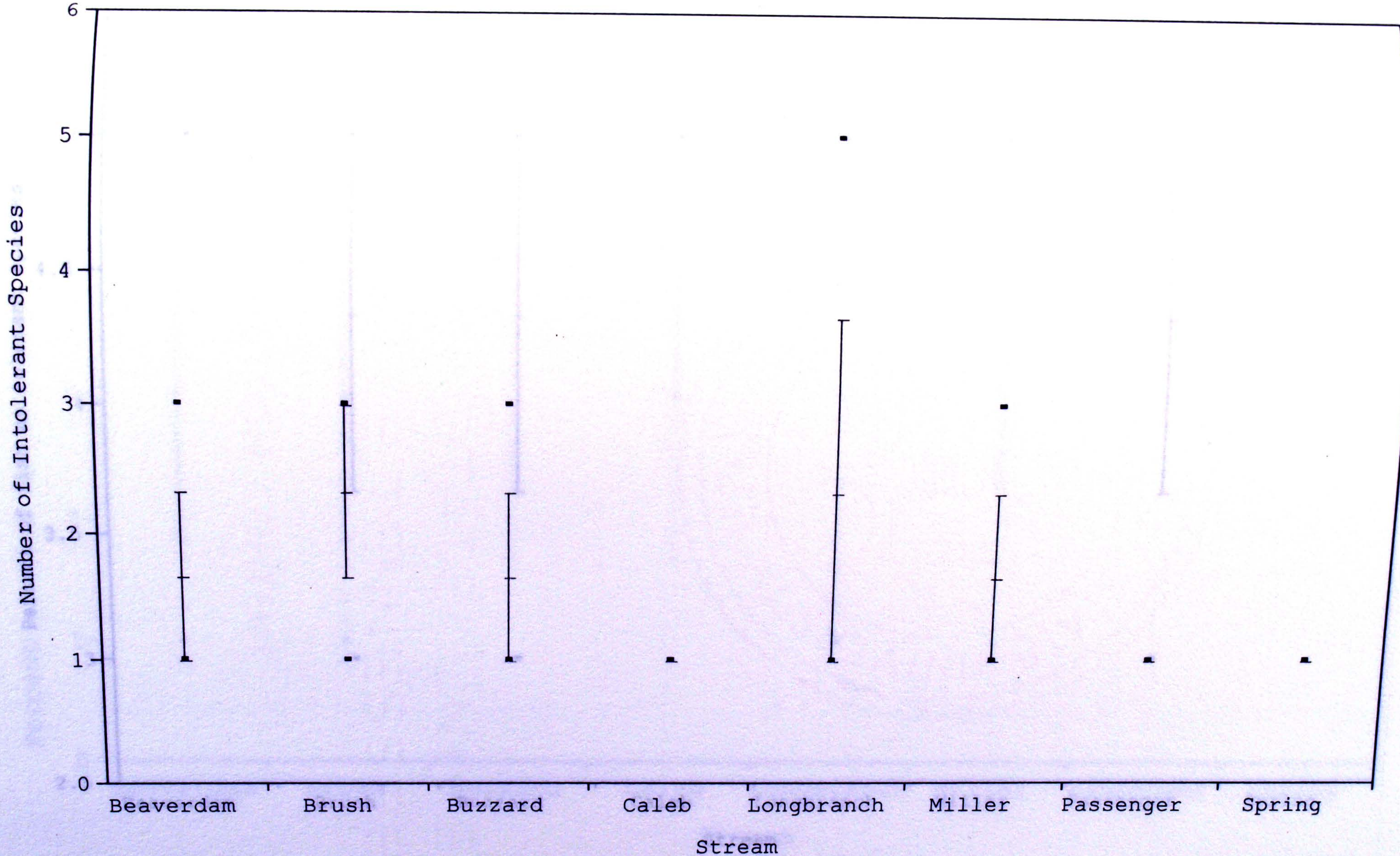

Figure E4: Graph of Number of Intolerant Species metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

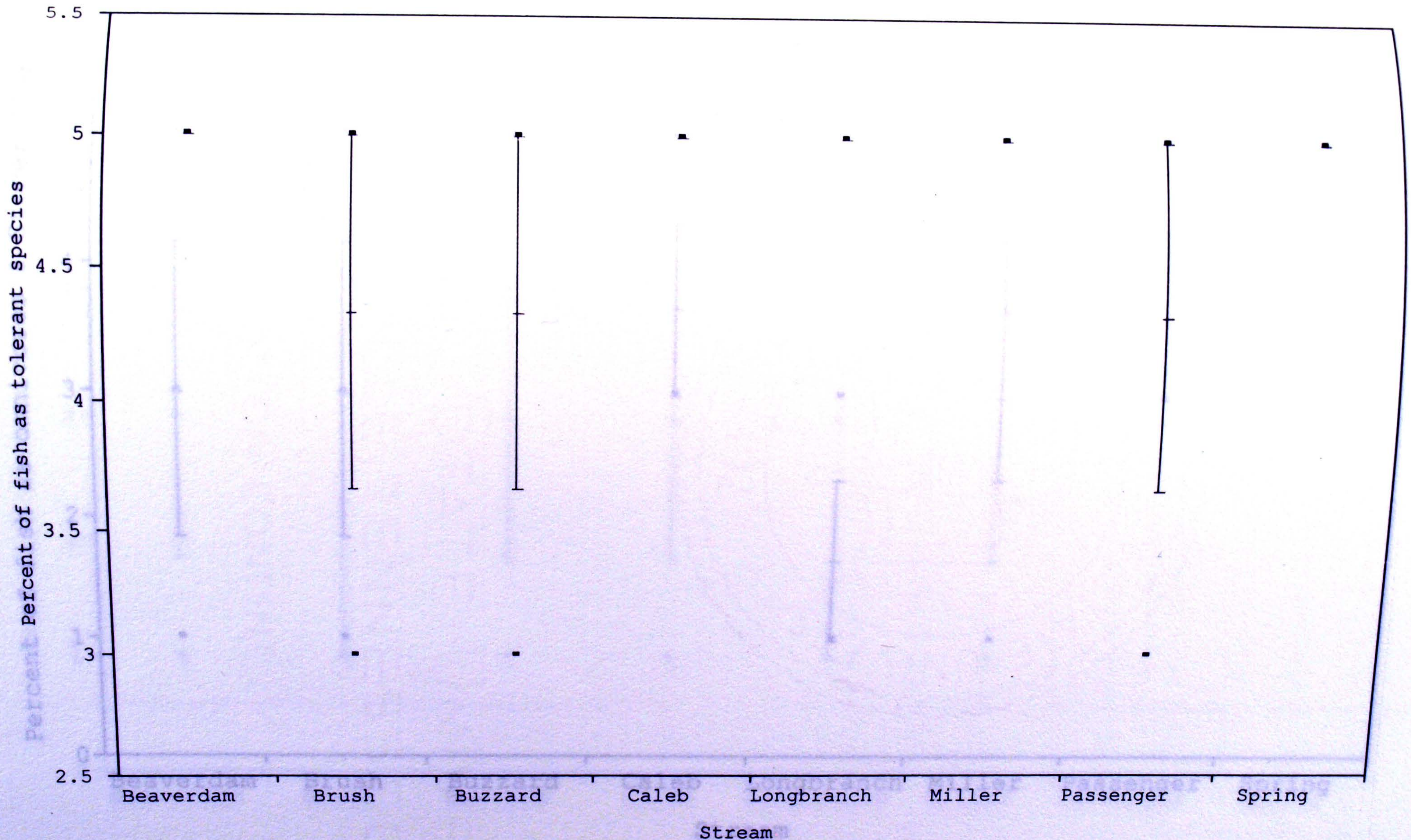

Figure E5: Graph of Percent of Fish as Tolerant Species metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

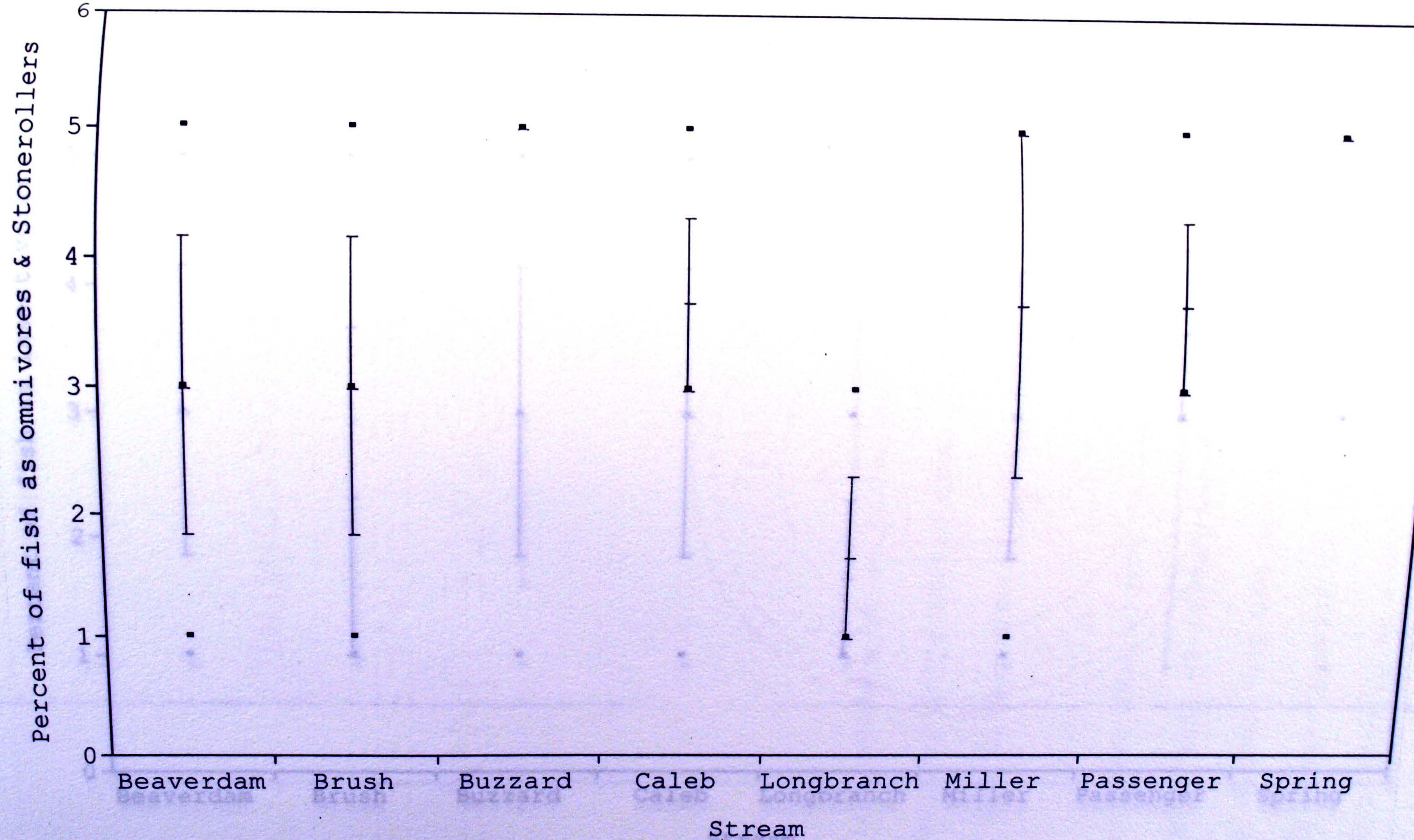

Figure E6: Graph of Percent of Fish as Omnivores and Stoneroller Species metric score for the sampled tributaries. The error bars are the 95% confidence errors for the means.

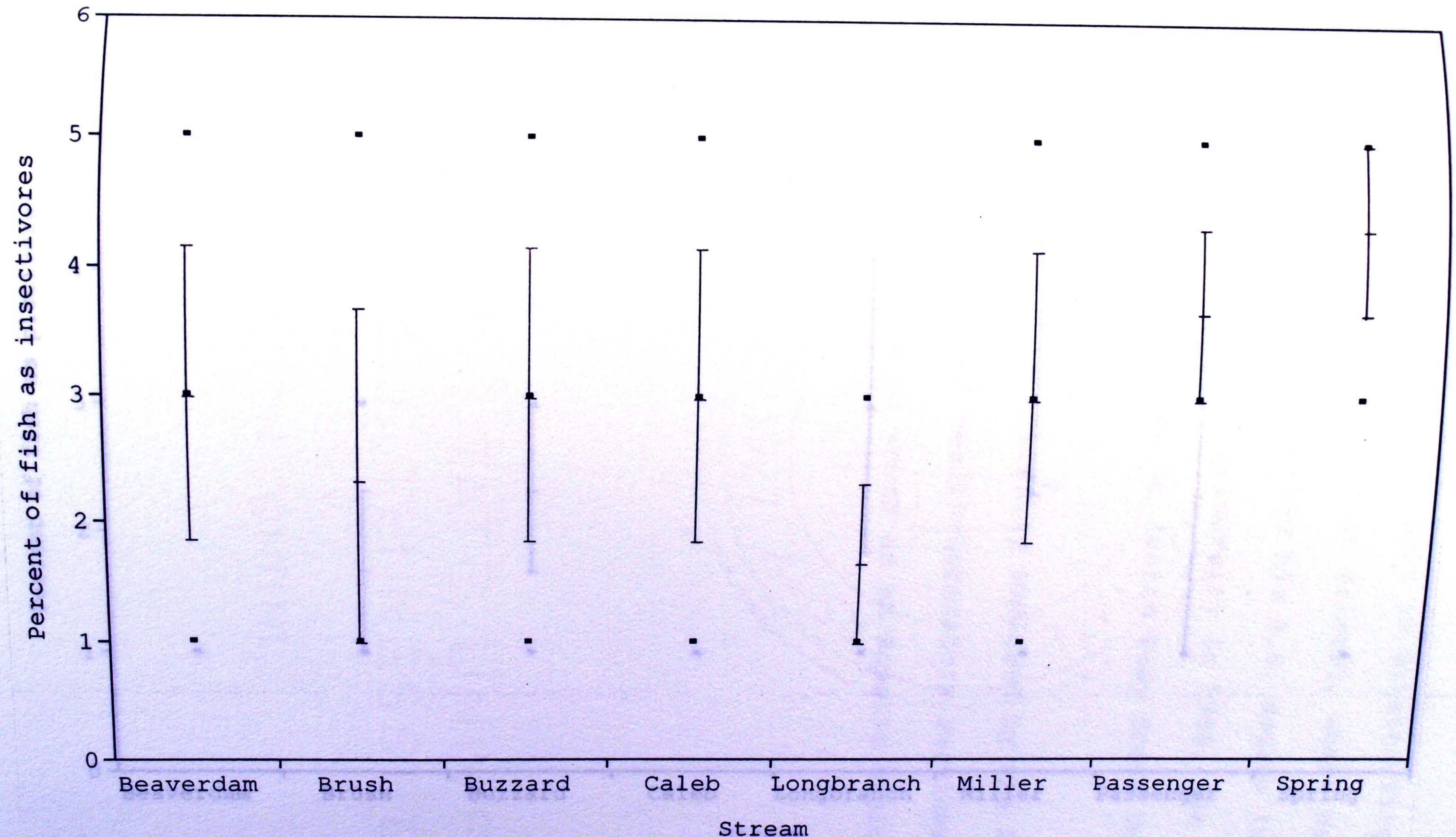

Figure E7: Graph of Percent of Fish as Insectivores metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

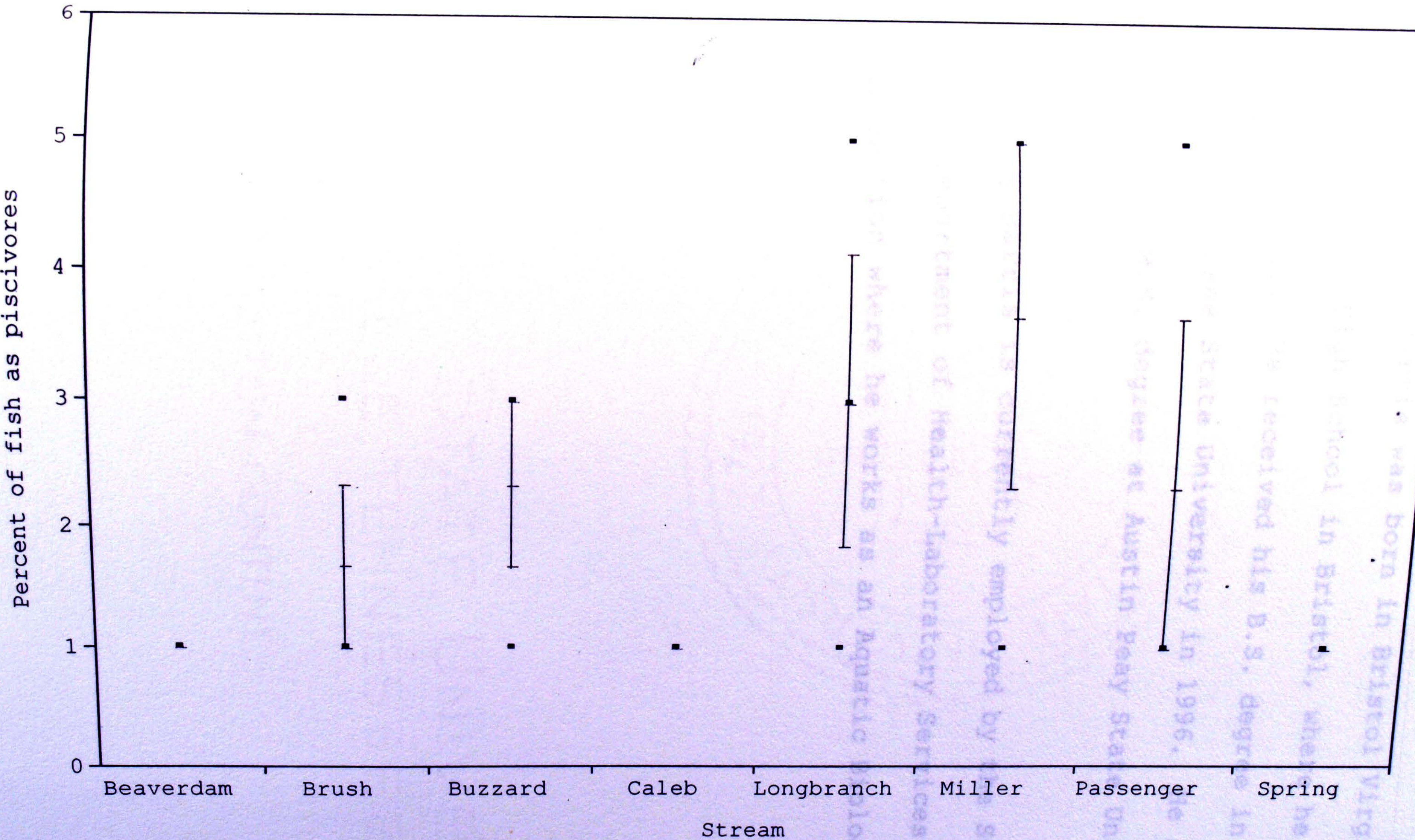

Figure E8: Graph of Percent of Fish as Piscivores metric scores for the sampled tributaries. The error bars are the 95% confidence errors for the means.

VITA

Gregory Keith Harris was born in Bristol Virginia. He attended Virginia High School in Bristol, where he graduated in 1991. He received his B.S. degree in biology from East Tennessee State University in 1996. He started working on his M.S. degree at Austin Peay State University in 1999.

Gregory Harris is currently employed by the State of Tennessee-Department of Health-Laboratory Services-Aquatic Biology Section where he works as an Aquatic Biologist III.