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I am submitting herewith a thesis written by Barry D. Hart entitled "An Evaluation of Five Aquatic Sampling Methods Useable in an Appalachian Mountain Stream, Great Smoky Mountains National Park, Sevier County, Tennessee." I have examined the final paper 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 Ecology and Evolutionary Biology.

David A. Etnier, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Provost and Dean of Graduate Studies

An Evaluation of Five Aquatic Sampling Methods Useable in an Appalachian Mountain Stream, Great Smoky Mountains National Park, Sevier County, Tennessee

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ABSTRACT

Five aquatic sampling methods were examined and evaluated for potential use in a future quantitative study in Mannis Branch, Great Smoky Mountains National Park, Sevier County, Tennessee. The methods examined were rock, kick, artificial substrate, leaf pack, and drift sampling. A primary focus of the study was to examine the variability among samples and sample units and to explore analytical and data manipulation tools for preparing sample data for analyses. Total counts and in many cases counts of functional feeding guilds (e.g., scrapers, collectors, predators, and shredders) were analyzed.

Samples were tested for normality and equal variances prior to statistical significance tests and appropriate transformations applied to non-normal and heteroscedastic sample counts. Two transformations were routinely used and compared where sample data required manipulation, log (x + 1) and Box-Cox power transformation. Primarily parametric (e.g., one-way ANOVA) and, secondarily, nonparametric analyses (e.g., Kruskal-Wallis rank sums test) were performed to provide preliminary assessment of the variability and differences among sampling sites. Where one-way ANOVA and Kruskal-Wallis tests detected significant differences, multiple comparisons tests typically detected one or more sites downstream of a natural barrier (i.e., a waterfall) as having higher benthic macroinvertebrate counts relative to other sampling sites.

An assessment is made for each method's continued use for quantitative purposes

in Mannis Branch and is based on required sample sizes, time and effort involved in collecting and processing samples, and effectiveness for sampling the benthic fauna.

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CHAPTER I

INTRODUCTION

An underlying theme in ecology is the search for patterns and processes that influence the composition and structure of biotic communities (Begon et al., 1990; Hart, 1992). Several factors have been implicated as contributing to the function and structure of natural communities. Environmental perturbations and disturbance (Fisher, 1983; Ward and Stanford, 1983; McElravy et al., 1989; Feminella and Resh, 1990), life history trajectories and natural variability (Peckarsky, 1984), habitat heterogeneity (Reice, 1983; Diehl, 1992), competition (Peckarsky and Dodson, 1980), and predator-prey interactions (Reice, 1983) are a few factors that strongly affect the distribution and abundance of organisms. Of these, predation is often viewed as a major controlling force that influences community structure and may shape the evolution of some animal communities (Peckarsky, 1984).

The effects of predation on the structure and composition of natural communities are complex and variable. Peckarsky (1984) presents several plausible outcomes of predator-prey interactions. 1) Predation may reduce the density of individuals throughout the community. 2) Predatory selectivity may reduce some individuals of a given species, size class, or sex thus, creating shifts in the relative abundances, size distribution, and sex ratios of affected species within the community. 3) Prey diversity within the community may be reduced should the numbers of vulnerable, rare species be reduced to non-viable status. 4) Prey diversity may increase should predatory impacts selectively reduce the

numbers of dominant competitors, thereby, allowing inferior competitors to occupy habitats where they were formerly excluded and/or to allow new species to colonize the affected habitats. The influences of predation upon a prey community, however, are not always clear (Colinvaux, 1973).

Previous studies that have examined predator-prey interactions in aquatic systems have produced different results. Paine (1966) demonstrated dramatic changes in community composition and structure after the removal of a keystone predator, *Pisaster*, in a rocky intertidal marine community. Brooks and Dodson (1965) discovered that the presence of a planktivorous fish, *Alosa*, in New England lakes eliminated large-sized plankton, thus altering the size distribution and composition of the plankton assemblage. Conversely, Allan (1982) found no differences in drift and benthic densities or composition of invertebrates after a trout reduction experiment in a Colorado stream. Likewise, Reice (1983) found no apparent direct effects on the density and species richness and diversity of the benthic community in an experiment involving the exclusion of large vertebrate predators. Reice further suggested that invertebrate predators in the third-order North Carolina stream he investigated far outnumbered the density of vertebrate predators and that the former might have a greater impact on invertebrate prey than did large vertebrate predators (i.e., fish and salamanders).

Clearly, the above examples are taken from very different aquatic systems and employ different sampling methodologies. Still, why do predators seem to have extraordinary influences in some communities and not in others? Allan (1982) suggested that stream invertebrates are highly adapted to the presence of fish and that changes in predation pressure do not alter the prey community. Williams and Feltmate (1992)

warned that such conclusions may be erroneous due to the limitations of study design, which may ultimately fail to take into account life history strategies and many response variables of prey-species to predator density and presence. In their discussion of predatory impacts of fish on benthic communities, Williams and Feltmate used examples from Sih (1987), Schofield et al. (1988), Gilliam et al. (1989), Schlosser and Ebel (1989), and Feltmate and Williams (1991) to suggest that fish can have calculable effects on the density and size distribution of stream insects. In each of these study examples, certain macroinvertebrate prey species exhibited density, size, and/or condition reduction in the presence of predatory fish. It should be noted, however, that the studies that Williams and Feltmate used in their argument were conducted in manipulated environments, either in artificial streams or under enclosure/exclosure field experiments. In their closing arguments, Williams and Feltmate (1992) suggested that by investigating sections of a stream (under natural conditions) with and without predatory fish (e.g., above and below waterfalls), life history strategies that prey-species have evolved to avoid predation could be effectively investigated. Taking this position one step further, a stream exhibiting these characteristics may be ideal for examining direct predatory impacts upon benthic invertebrate densities and prey-species diversity.

Background

Mannis Branch, a small, second order stream in the Great Smoky Mountains National Park (GSMNP), possesses unique characteristics that may provide an ideal model for investigating questions related to predator-prey interactions in lotic environments. Like many small streams in the GSMNP, waterfalls are present on Mannis

Branch, with two being widely separated and high enough to be an effective barrier to upstream fish dispersal. The presence of natural barriers (e.g.., waterfalls) to fish dispersal provides an ideal "field laboratory" for studying benthic invertebrate interactions under fishless conditions as well as in the presence of fish.

In an effort to restore native southeastern brook trout (*Salvelinus fontinalis*) populations back into formerly occupied habitat, fisheries biologists of the GSMNP conducted fish surveys in Mannis Branch during the summer of 1996. Fish sampling was conducted immediately above the downstream-most waterfall and continued upstream for approximately 1200 m. This effort carried the survey approximately 300 m above the uppermost waterfall. Two species of fish were collected during that survey. *Rhinichthys obtusus* was found within the first 250 m of the survey and a total of 541 rainbow trout (*Oncorhynchus mykiss*) was collected and permanently removed from the stream section between the two waterfalls. Only a single rainbow trout was found above the upper-most waterfall. In October 1996, 105 brook trout representing all age classes were released into the stream section between the two waterfalls in an effort to establish brook trout into this portion of Mannis Branch (Steve Moore, personal communication). The area above the upper-most waterfall was believed to remain fish-free.

The two conditions where one section supports fish and an adjacent section of the same stream is fishless provide an exceptional opportunity to simultaneously examine the benthos of these two areas. This scenario also allows certain physical factors to remain nearly constant between the two stream sections (e.g., pH, conductivity, water temperature, etc.). This reduces some of the multivariate challenges many researchers face when exploring causative factors between different stream systems. Yet, designing a

sampling program to explore the influence of predatory fish on the benthic community remains a formidable task.

Sampling Challenges

The literature is replete with numerous methods for sampling benthic communities (see Hynes, 1970; Merritt et al., 1996) and along with these, a complex array of sampling considerations should be addressed during the design of a particular study (Williams and Feltmate, 1992). Prior to the outset of a benthic study, the project's objectives and desired results should dictate the choice of collection device(s), the selection of sampling site(s), sampling frequency, number of sampling units to collect, and the types of analytical procedures to perform (Green, 1979; Resh, 1979; Allan, 1984; Merritt et al., 1996). A common problem encountered in benthic studies is the high sampling variability of the number of individuals collected among replicate units. One or more factors may contribute to sampling variability including the choice and use (or misuse) of a sampling device(s), biological features of the study group (e.g., the propensity of a species to aggregate), habitat heterogeneity, and investigator error due to field collection and sorting procedures (Resh, 1979). High sampling variability often requires an inordinate number of units and samples to be collected during a study (Usinger, 1956), particularly if the objective is to detect small changes or differences occurring in the target population. Furthermore, data collected may require mathematical manipulation (e.g., data transformation) before certain statistical tests can be applied (Allan, 1984; Williams and Feltmate, 1992). To address these and, potentially, many more complications during the design of a sampling program, Green (1979) recommends

that a pilot study of the target population be conducted first to guide the design of the final study.

Various methods have been used to examine or test for potential pressures that carnivorous fish exert on the stream benthos. The most commonly used methods involve the collection of stream drift and/or fixed-area samplers such as the Hess and Surber samplers to test for effects between stream sections where the densities of predatory fish have been manipulated (Allan, 1982; Feltmate and Williams, 1991; Forrester, 1994). However, the precision of using fixed-area samplers has seriously been questioned due to the large variability typically found among samples (e.g., Usinger, 1956; Allan, 1982). Rather than relying on standard sampling devices, I attempt to evaluate five sampling methods for potential use in a future quantitative study in Mannis Branch. Some of the methods I examine are unorthodox compared to those typically used in quantitative assessments and studies. The methods being evaluated are individual stone, kick, tile, leaf pack, and drift sampling. Of the five, tile (Flannagan and Rosenberg, 1982; Rosenberg and Resh, 1982; Lamberti and Resh, 1985) and drift sampling (Elliott, 1970; Allan, 1982; Allan and Russek, 1985) have been used intensively in quantitative studies. Quantitative sampling of individual stones has been addressed (Scrimgeour et al., 1993) but their use for estimating benthic densities is under represented. Kick sampling is often used in semi-quantitative studies (Morgan and Egglishaw, 1965; Hynes, 1970; Merritt and Cummins, 1996) and leaf packs are often used to examine ecological and life history factors involving trophic relationships (e.g., Benfield et al., 1977; Benfield and Webster, 1985; Benfield, 1996). However, the use of all five for estimating benthic densities and testing hypotheses is infrequently employed.

Closely associated with each method is a broad range of analytical challenges. A common theme among aquatic ecologists is the understanding of the inherent variability of aquatic collections. Finding the appropriate methods and analytical tools for preparing such varied data for subsequent analyses and interpretation is of paramount importance. This study uses basic exploratory techniques (primarily parametric) as an attempt to understand the variable nature of aquatic samples relative to each method evaluated and for preparing sample data for the most important step; analysis and interpretation.

Objectives

The objectives of this study are to evaluate rock, kick, artificial substrate, leaf pack, and drift sampling methods for potential use in a more rigorous study to test for differences in the benthic community between a stream section that supports a top predator, brook trout, and a section where trout are absent in Mannis Branch. For this pilot study, the assessment of each method involves:

1. Exploring possibilities for analyzing or preparing the data for statistical analyses and hypothesis testing.
2. Providing preliminary tests for significance between the two treatments/conditions (i.e., trout present versus trout absent).
3. Providing estimates or suggestions for sample size.
4. Providing recommendations for improving sample collection and experimental design.
5. Providing an assessment of the effort and time involved.

CHAPTER II

STUDY AREA

Mannis Branch is a second order tributary to Little River in the Great Smoky Mountains National Park, Sevier County, TN. The stream enters Little River at approximately River Mile 47 and has a north flowing aspect. The Mannis Branch watershed drains an area of approximately 3.2 km^2 (measured by delineating the catchment ridgelines that separate Mannis Branch and adjoining watersheds using Maptech, Terrain Navigator 2001 software). Elevation of the watershed ranges from 580 m at the Little River confluence to 1220 m on Meigs Mountain.

Though extensively logged in the early 1900s, the area drained by Mannis Branch now supports an undisturbed, maturing second growth forest. The canopy is relatively dense (ocular estimate of ≥ 70% canopy density) and is principally comprised of tuliptree (*Liriodendron tulipifera*), eastern hemlock (*Tsuga canadensis*), yellow buckeye (*Aesculus octandra*), red maple (*Acer rubrum*), various oaks (*Quercus* spp.), American beech (*Fagus grandifolia*), and birch (*Betula* spp.). The understory vegetation is comprised of immature canopy species as well as dogwood (*Cornus florida*), silverbell (*Halesia carolina*), witch-hazel (*Hamamelis virginiana*), Fraser magnolia (*Magnolia fraseri*), mountain laurel (*Kalmia latifolia*), rosebay rhododendron (*Rhododendron maximum*), and dog hobble (*Leucothoe fontanesiana*). In many areas along Mannis Branch, the riparian vegetation occurs as dense thickets of *Rhododendron maximum*, forming a dense "subcanopy" over the stream surface.

The geomorphology of Mannis Branch is strongly influenced by the underlying geological formation. Elkmont Sandstone is the principal substrata of the study area (Moore, 1988). Erosive and weathering forces of this formation in the watershed have contributed to several characteristics of Mannis Branch. A broad range of substrates occurs throughout the stream's course including bedrock, large and small boulders, cobble, gravel, and sand. Several stream reaches are notably sinuous, with some portions of the branch flowing through complex braids (typically boulder-strewn areas with embedded woody debris). However, the typical profile of the stream is a low gradient, pool/riffle sequence with riffle areas dominating.

Two waterfalls are prominent features of Mannis Branch, and the location and separation of both create an ideal condition for this study. Approximately 30 m upstream of the mouth of Mannis Branch is the highest waterfall on the stream (hereafter referred to as "lower boundary waterfall"), which is about 15 m in height. Approximately 860 m upstream of the lower boundary waterfall is a second waterfall (hereafter referred to as "upper boundary waterfall") about 2 m in height (Figure 1). Both waterfalls are considered to be significant barriers to upstream fish dispersal (Steve Moore, personal communication).

The stream section between the lower boundary and upper boundary waterfalls is typically 2 to 4 m wide with no direct tributaries contributing to stream flow. Beginning at the upper boundary falls and proceeding upstream for approximately 200 m, stream size and flow are comparable to the section between the two falls. However, 200 m upstream of the upper boundary falls a minor tributary, which may become intermittent during dry periods, lightly contributes to stream flow. An additional 200 m above the

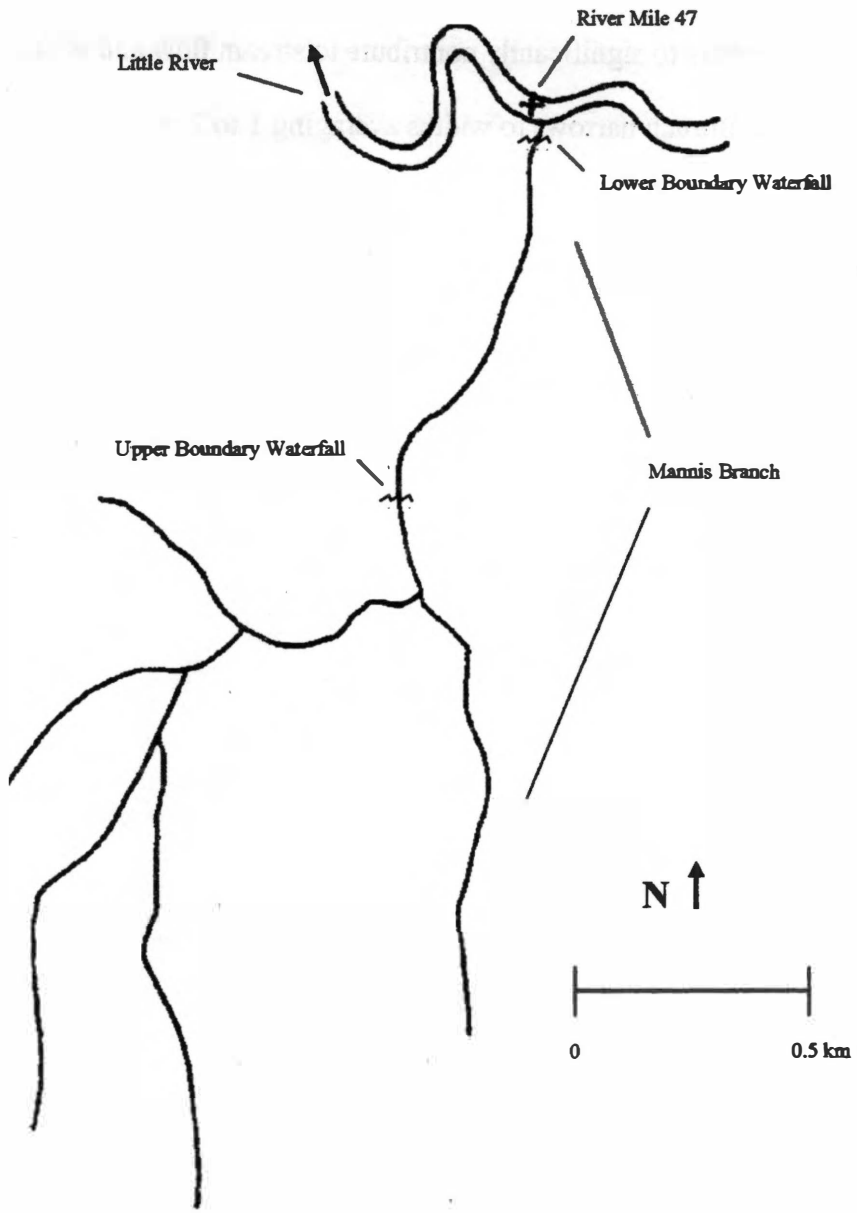


Figure 1. Mannis Branch, position of physical features (i.e., waterfalls) and relation to Little River, Great Smoky Mountains National Park, Sevier County, Tennessee.

confluence of the minor tributary, a larger tributary enters the main stem of Mannis Branch, which appears to significantly contribute to stream flow and width. Upstream of this point, Mannis Branch narrows to widths averaging 1 to 2 m.

CHAPTER III

MATERIALS AND METHODS

Five aquatic sampling methods and techniques were examined and refined over the course of this study. The methods evaluated include rock, kick, artificial substrate, leaf pack, and drift sampling. Physical measurements such as stream and air temperature (taken 1 m above stream surface; $\pm 0.05^0$ C), water depth, stream width, water velocity and/or discharge were collected during the majority of sampling sessions. Discharge and water velocity were measured with a Teledyne-Gurley Pygmy Current Meter following the methodology given in Gore (1996) and Newbury (1996).

Rock Sampling

Four sites were selected for rock sampling in Mannis Branch. Two sites were selected in the section upstream of the upper boundary waterfall (MB-S1 and MB-S2), and two sites were selected downstream of the upper boundary waterfall (MB-S3 and MB-S4; see Figure 2). Attempts were made to select sites that supported similar widths, substrate composition, habitat characteristics, and gradient. The length of each site was determined by habitat similarity and the number of plausible sampling units that could be extracted throughout a given stream reach. The number of sampling sites above the upper boundary falls was restricted to two primarily due to habitat limitations. Sampling sites were not extended above the first major tributary to Mannis due to marked differences in stream size. An equal number of sampling sites (i.e., two) was chosen for

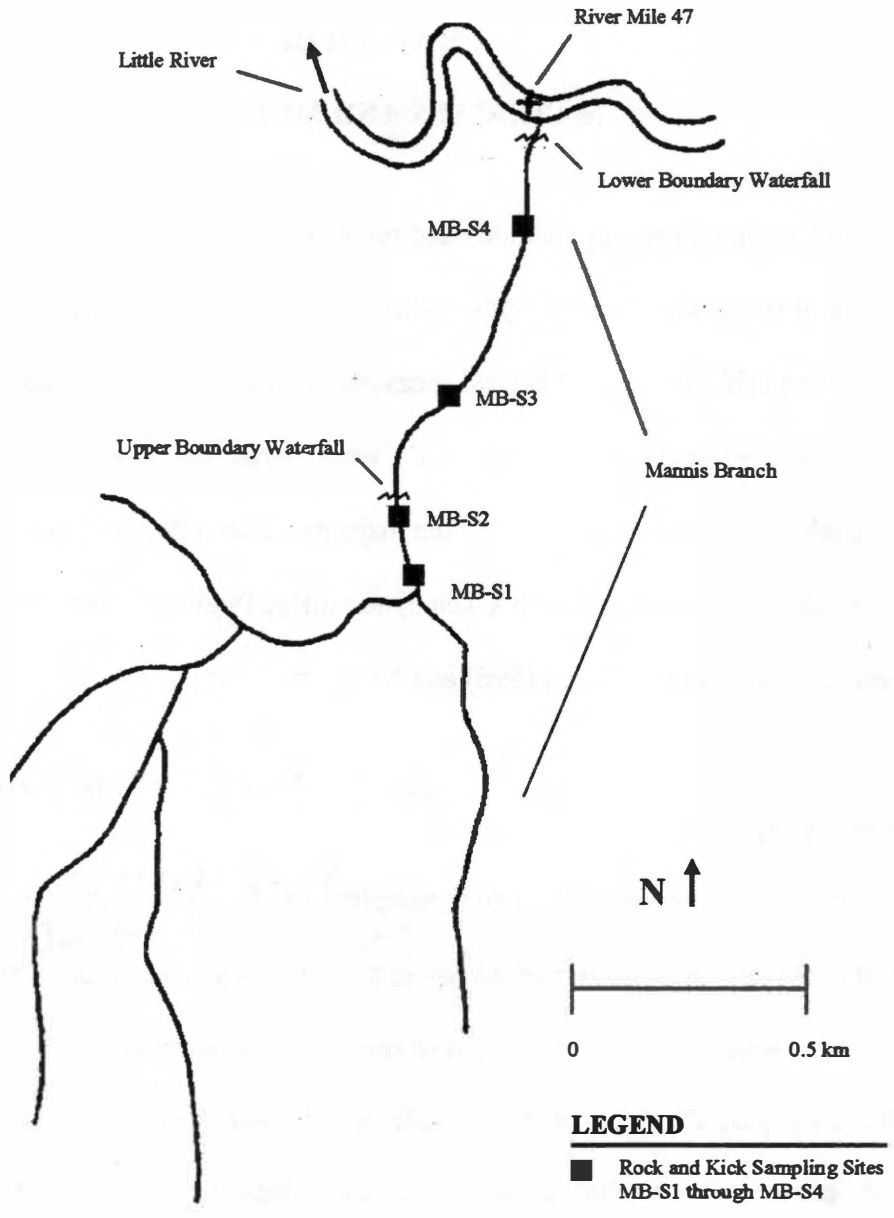


Figure 2. Rock and kick sampling sites on Mannis Branch and relation to Little River, Great Smoky Mountains National Park, Sevier County, Tennessee.

the reach between the lower and upper boundary waterfalls for comparison. The minimum distance between sampling sites was set at 100 m to minimize impacts created from sampling activities at upstream sites.

The upstream-most site (i.e., MB-S1) is located approximately 180 m above the upper barrier waterfall (Figure 2). The site begins at the head of a riffle just below a pool-riffle sequence and ends approximately 50 m upstream at the head of a pool. Habitat throughout the reach is dominated by riffles/runs of moderate depth (10-20 cm) with interspersed complex pocket pools formed behind channel obstructions (typically boulders). Substrate composition is primarily cobble (15 to 30 cm) and small boulders (30 to 60 cm) with embedded gravel (0.2 to 7.5 cm) and fines (less than 0.2 cm; substrate classification sizes from Overton et al., 1993). Stream width at MB-S1 in late August 1998 (assuming base flow) averaged 2.2 m.

The second sampling site (MB-S2) begins approximately 65 m above the upper boundary falls. The beginning of this site is at the end of a riffle/run and ends 35 m upstream at the head of a large pool (maximum pool width is 5.5 m). Habitat within this site is dominated by riffles/runs with interspersed boulder-formed pocket pools. Average stream width of MB-S2 in August 1998 was 2.9 m.

The third sampling site (MB-S3) is located within 150 m downstream of the upper boundary falls. The site begins at the tail of a large pool (maximum pool width is 5 m) and proceeds upstream for 35 m. Riffles/runs and complex substrates (i.e., wide range of substrate sizes) dominate within this site. MB-S3 had an average width of 2.9 m in August 1996 and a length of 35 m.

The fourth sampling site (MB-S4) begins approximately 320 m upstream of the lower boundary falls. This site is similar to the other three sites in that the major habitat types are riffles and runs. The average width of MB-S4 is 2.9 m and it is approximately 45 m long.

Rock samples were primarily collected during late winter to mid summer in 1997 and late winter and early spring in 1998. From a pool of six separate samples, four are included for analysis and evaluation. The four samples analyzed herein were chosen because of comparable sampling techniques and sample sizes taken during this period. These include samples from June and July 1997 and February and April 1998. The primary difference between the 1997 and 1998 samples involve the approach and sampling strategy that was taken for rock (sampling unit) selection.

Sampling protocol in June and July 1997 involved collecting a sample size of six cobbles in each of the four sampling sites. Rocks were arbitrarily chosen from undisturbed riffle areas, usually at the tail of a pool. Riffle areas were chosen for sampling over other habitat types due to: 1) the relative ease of rock extraction (water depths are shallow); 2) consistent flows that wash fleeing insects into a downstream net; 3) expected greater abundance of benthic macroinvertebrates (Allan, 1995); 4) an attempt to regulate environmental variability among sampling units (i.e., sampling from a single habitat was thought to reduce broad fluctuations in the number of individuals collected among rocks). Riffle areas where rocks were extracted generally had stream depths of 14 to 19 cm and water velocities from 0.2 to 0.4 m/s.

Each rock unit was carefully approached downstream of its position, removed from the stream bottom and placed into a hand-held screen (mesh size 0.8 x 1.2 mm),

which was positioned immediately below the sampled stone. The dimensions of the screen (61 x 61 cm) were sufficient to capture fleeing individuals in the water column. Each rock was then transferred to a plastic pail. The surface of the hand-held screen was then rinsed into the pail to remove invertebrates that dislodged into the screen upon stone removal. Sampled rocks were thoroughly washed by hand and picked clean of all macroinvertebrates. Contents of the pail were poured through a fine meshed sieve (256 *u*m) and then backwashed into a plastic container with 70% isopropyl alcohol for preservation. A number unique to each sampled stone was recorded and the corresponding sample labeled accordingly. Samples were transported to the laboratory for sorting.

Following the removal and preservation of macroinvertebrates from each rock unit, surface area of the corresponding stone was determined. This procedure provided a density estimate of macoinvertebrates per rock area. Calculating surface area for each sampled stone was accomplished by carefully and completely wrapping each rock with aluminum foil and trimming all excess foil from around a rock's edges. Each fitted piece of aluminum foil was then assigned the same field number as the associated preservative and carried back to the laboratory and weighed. The weight of each foil was then compared to a reference piece of foil with known weight (10.35g) and area (2432 cm^2). Surface area for each sampled stone was calculated by taking the ratio of the weight of the sampled foil and reference piece and multiplying by the area of the reference foil.

The protocol for collecting rock samples in 1998 was identical to the procedures established in 1997 with the exception of the selection strategy for extracting rocks from the stream. Rock samples collected in February and April 1998 were randomly chosen

within each of the four sampling sites rather than relying on investigator discretion. At each site, all possible riffle areas for collecting samples were assigned a two-digit number (typically 01 – 14 or greater) throughout the length of each site. A pseudorandom numbers table from Salvia (1990) was used to select the riffle where rocks were sampled. Rocks within a riffle were randomly chosen by visually overlaying a numbered grid of the area to be sampled and using a pseudorandom numbers table to select cells of the imaginary grid for sampling. In instances where a selected cell was in close proximity (<1 m) to a previously sampled area, it was discarded and a new one selected. This was done to help ensure independence of the individual sampling units. Implementing these procedures reduced investigator bias for selecting sampling units and met assumptions critical for validating certain statistical tests (Green, 1979; Hurlbert, 1984; Sokal and Rohlf, 1995); a critical process that was lacking in the 1997 samples.

Kick Sampling

Kick samples were taken concurrently with rock samples and within the same sampling sites (i.e., MB-S1 through MB-S4; Figure 2). Similar to rock sampling, kicks were conducted within a single habitat type, riffles. Each sampling unit was taken in areas with comparable flow velocity (typically 0.3 to 0.7 m/s) and depth (9 to 21 cm). Substrate sizes where kicks were generally taken ranged from large gravel to large cobble.

Methodology for kick sampling involved the placement of a large mesh (0.8 x 1.2 mm), hand-held screen (61 x 61 cm nylon screen fastened to wooden handles) downstream of the area sampled followed by vigorously disturbing the substrate by

kicking and rolling rocks (see Hynes, 1970) over a timed interval of 30 seconds. Initially, kicks were being conducted over a period of 60 seconds but this length of sampling time was later deemed counterproductive due to the volume of debris collected into the screen. It was discovered that as substrate material increased on the surface of the screen, small eddies were created directly in front of the net causing some of the material (including dislodged animals) to be washed around the screen. This would likely contribute to an underestimation of macroinvertebrate abundance per kick effort.

Riffle areas where samples were collected in June and July 1997 were arbitrarily chosen based on habitat similarities alone. Catch per unit effort (i.e., per 30 second kick interval) was the standard method and unit for measuring abundance. However, the area of substrate being disturbed varied between kicks. To implement uniformity over all sampling units (i.e., 30-second kicks) and to meet certain assumptions for statistical analyses, the procedures for selecting and colleting individual kick units were altered for the February and April 1998 samples. Within each sampling site, all potential kick areas (riffles) were assigned a two-digit number throughout the respective site's length. Six kick units (or corresponding riffle areas) were then selected for sampling from a pseudorandom numbers table (Salvia, 1990). Once a unit was randomly chosen, a metal frame of 0.16 m^2 was placed over the substrate and immediately in front of the hand-held screen. Kicking and substrate disturbance was carried out within the confines of the metal frame. This strategy created consistency and standardization among sampling units, reduced sampling error, and allowed for a more reasonable density estimate of macroinvertebrates per unit area of substrate over a sampling effort of 30 seconds.

Following the collection of a kick, the contents on the screen were washed into a plastic pan. The kick net was carefully examined and all macroinvertabrates still clinging to the screen were removed and included in the sample. The contents of the pan were then sieved (mesh size, 256 *u*m) and backwashed into a plastic bag with 70% isopropyl alcohol as preservative. Each sample was given a unique number and transported to the laboratory for sorting.

Artificial Substrates

Artificial substrates were used in this study to evaluate whether a rock-like substance with standard dimensions could be used in Mannis Branch to effectively sample the stream benthos. Ideally, using a standard substrate type with known area would provide density estimates of macroinvertebrates colonizing the substrates and would reduce variability from among sampling units (Lamberti and Resh, 1985). Should portions of the benthic community use the substrates in sufficient numbers, then artificial substrates may possibly be used to further examine and compare invertebrate densities between the upper section of Mannis Branch where fish are absent and the lower section of the stream where fish are present.

The substrates that were examined in this study are factory cut, unglazed quarry tiles. The dimensions of each tile are 15.24 x 15.24 x 1.27 cm for a total surface area of 542 cm^2. A 0.64 cm diameter hole was drilled through each tile for anchoring the substrates to the stream bed. Anchoring was achieved by driving a 30.5 cm galvanized spike into the substrate approximately 27 cm deep. Braided nylon twine was tied to the

head of each buried spike and attached to a cotter key that was secured in the drilled hole of each tile.

Tiles were placed in the stream on two occasions using different placement strategies in each period and allowed to incubate over a given period of time. The first incubation period spanned 44 days from 13 May to substrate removal on 25 June 1998. The second period spanned 81 days from 23 August until removal on 11 November 1998. The reason for this disparity between incubation periods reflects an attempt to find a suitable incubation time for macroinvertebrates to colonize the substrates.

During the first incubation period, four sites were chosen to introduce the tiles. Two sites were selected upstream of the upper boundary waterfall and, likewise, two sites were chosen downstream of the waterfall. (The four sites were near the rock and kick sampling sites. Figure 2 should be consulted for general placement localities.) Attempts were made to select sites that had similar depths, habitat types, and stream velocity. All "tile sites" had stream depths between 16 and 17 cm, velocities of 0.25 to 0.33 m/s, and were in riffles below mid-stream pools (measurements taken on 13 May 1998). Stream shading was extensive at each site due to the mature forest canopy and overhanging *Rhododendron maximum* at streamside. At each site, nine tiles were placed in a 3 x 3 grid with each tile having a separation distance of at least 7 cm between nearby tiles. At the end of the incubation period, each tile was removed separately by lifting the tile and placing it in a D-frame net (mesh, 800 *u*m) followed by severing the anchoring twine. Tiles were separately washed in a plastic pan and thoroughly cleaned of all attached macroinvertebrates. The contents from tile washing were sieved (mesh 256 um) and then backwashed into a plastic bag with 70% isopropyl alcohol.

After carefully reviewing the grid strategy for tile sampling, it was discovered that this physical arrangement of artificial substrates actually represented a strong case of pseudoreplication within sites (see Hurlbert, 1984). First, a potential source of error involves the close spatial arrangement of the substrates in which one tile could conceivably have an undetectable effect on nearby tiles (e.g., one nearby tile may be preferred by invertebrates over an adjacent tile or may create a repulsive effect among other tiles). Thus, individual tiles within each site likely lacked independence and could not be used as true replicates. Replication in this design occurred at the site level (Hurlbert, 1984). Second, the grid design greatly limits the utility of this method for comparing macroinvertebrate densities when using inferential statistics for testing whether the presence or absence of trout has an effect on animals colonizing the tiles. By using the grid design, any and all detectable differences between tile sites are limited to just those four small plots on the stream and to those plots alone. It was realized that generalizations of detectable differences could not be made system or stream-wide without expanding the sampling design. As a result, the spatial arrangement of tiles was dramatically altered during the second incubation period of August through November.

The design of the August – November sampling period centered on the stream reach. In this context, reaches are defined as stream segments that have a high degree of habitat similarity, which primarily consisted of three consecutive pool/riffle sequences. Within each reach, riffle areas of similar depth (14 to 21 cm), substrate composition (cobble and embedded gravel), and velocities (0.2 to 0.3 m/s) were selected for tile placement (measurements taken on 23 August). The placement of individual tiles within a riffle was randomly selected by numbering all possible spots a tile could be placed and

using a pseudorandom numbers table (Salvia, 1990) to determine tile placement. To ensure that sampling units (tiles) were independent of one another, tiles were anchored (see procedure above) singularly in a riffle and replicated over five separate riffles per reach. Individual tiles were separated by at least 5 m. Three separate reaches were replicated in the section above the upper boundary waterfall and three reaches were replicated below the waterfall. In all, 15 tiles were placed in the section above the waterfall and 15 below with five tiles per reach and three reaches per section. In this design, tiles in a single habitat unit are replicated within a reach and reaches are replicated per treatment (i.e., trout absent vs. trout present). Tiles were removed from the stream and processed in the same manner as for the May – June period.

Leaf Packs

Leaf packs were used in this study to evaluate yet another method for sampling the stream benthos. A leaf pack or sampling unit consisted of a standard weight (20 g) of thoroughly dried sugar maple (*Acer saccharum*) leaves placed into large mesh (4 mm) nylon bags. Leaf packs were placed singularly in riffle areas of comparable depths and velocity. Packs were generally placed along stream margins and anchored by tying braided twine to the mesh bag and to nearby tree trunks or roots along the stream bank. Leaf packs were not placed in mid-stream riffles for fear of losing bags during storm events. Twelve individual leaf packs were placed in the section upstream of the upper boundary falls and twelve placed below the upper boundary falls for a total of 24 packs (see Figure 3 for placement localities). Bags were separated from one another by at least 1 m and allowed to incubate for four weeks prior to removal (e.g., see Dobson, 1991).

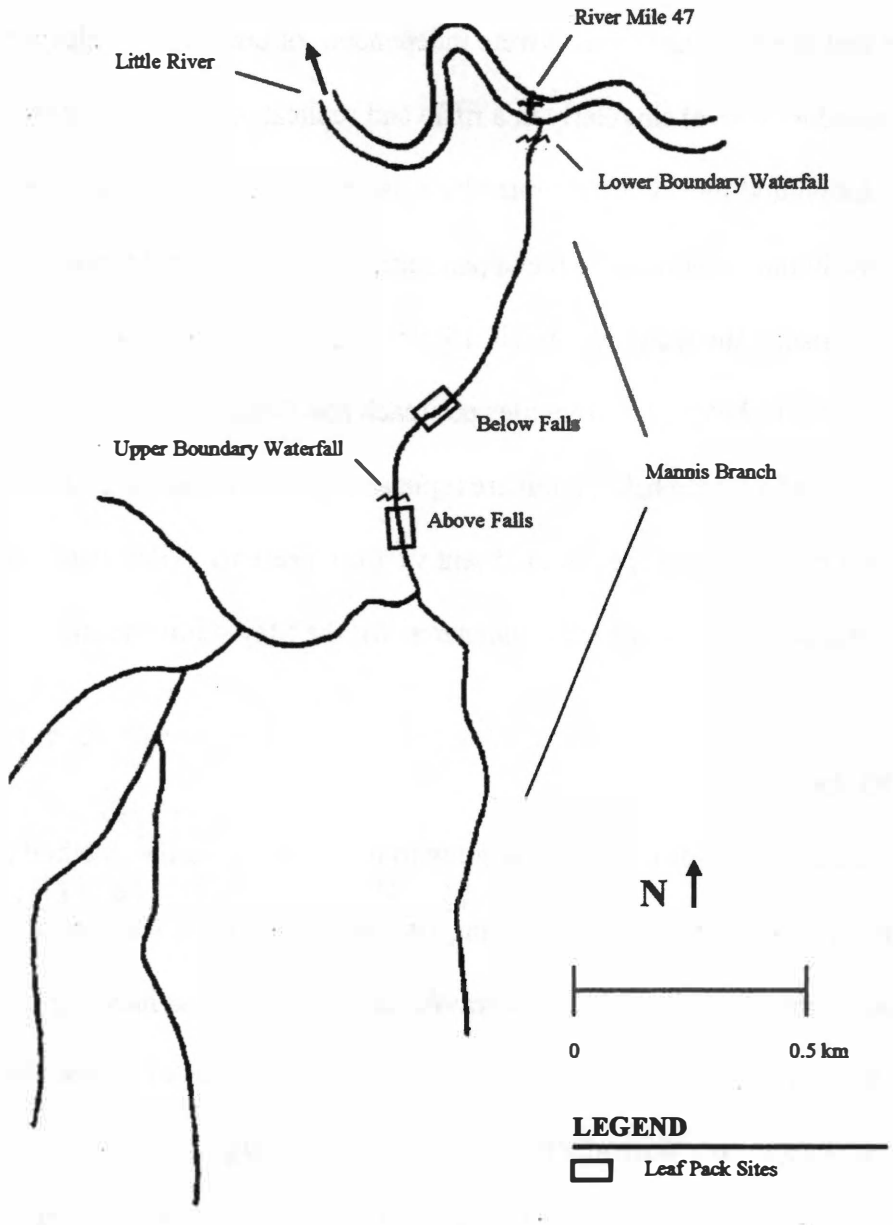


Figure 3. Leaf pack sampling sites on Mannis Branch and relation to Little River, Great Smoky Mountains National Park, Sevier County, Tennessee.

During removal, each pack was lifted from the substrate and placed into a D-ring net that was positioned immediately downstream of the bag. The anchoring twine was then severed and the pack placed into a plastic bag and transported to the laboratory. Leaf packs were processed by dumping all remaining leaves per pack in a plastic pan followed by washing each leaf to remove macroinvertebrates from the sample. Individuals collected during this process were then transferred to 70% isopropyl alcohol for later sorting and identification.

Three separate leaf sampling periods were conducted in 1998, but data from only a single period was found to be useable for discussion and analysis (see Chapter IV). This single sample was incubated for 29 days beginning on 19 February and removed from the stream on 19 March 1998.

Drift

Stream drift was collected at two widely separated sites on Mannis Branch; one above and one below the upper boundary waterfall (Figure 4). Drift samples were collected on 26-27 April, 28-29 June, and 17-18 November 1998. A single drift net was placed at each site with both being ran simultaneously for comparing drift density per site. Sampling at both sites occurred in a mid-channel riffle immediately downstream of a pool. Channel and habitat characteristics were similar at both sites. Standard drift nets were used with each having a net mouth of 30 x 46 cm, 363 *u*m mesh, and were 1 m long. Samples were collected by placing drift nets perpendicular to stream flow and allowed to remain in the water column at hourly intervals. Care was taken to avoid placing the bottom rim of the net flush against the substrate. Each time a net was placed in the

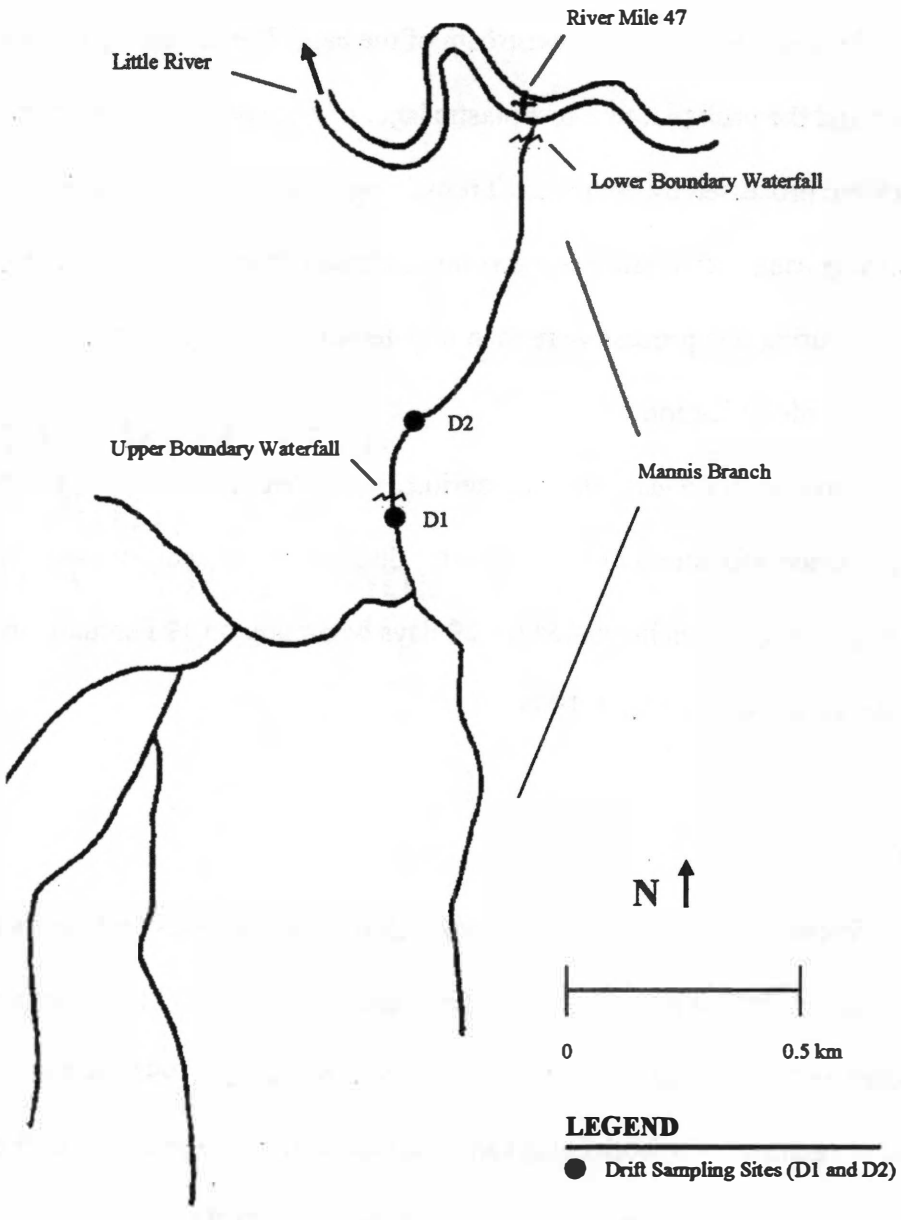


Figure 4. Drift sampling sites on Mannis Branch and relation to Little River, Great Smoky Mountains National Park, Sevier County, Tennessee.

stream, a 4 to 6 cm gap was left between the bottom of the net and the substrate. Elliott (1970) and Allan and Russek (1984) suggested this procedure to avoid capturing crawling animals as this could conceivably overestimate drift density.

A density estimate of organisms drifting into a net was calculated as number of individuals captured per volume of water filtered. This required measuring discharge passing through the net per sampling interval. Net discharge was calculated by taking triplicate velocity measurements across the width of the net with a Teledyne-Gurly Pygmy flow meter and multiplying the velocity estimate by the product of water depth and net width. Discharge at the mouth of the net was measured immediately following net placement and just prior to net removal per sampling interval. Both discharge measurements were then averaged to estimate volume filtered over the one-hour sampling period. At the end of the sampling interval, drift nets were removed from the stream and all contents washed into a detachable bucket at the base of each net. Drift contents were then backwashed into plastic bags with 70% isopropyl alcohol and transported to the laboratory for processing.

Previous studies (e.g., Waters, 1962; Elliott, 1970; Brittain and Eikeland, 1988) that have examined drift phenomenon have demonstrated marked increases in the numbers of drifting invertebrates approximately one-hour after sunset, one-hour before sunrise, and at various intervals during the night over a 24-hour sampling period. These studies also showed that the numbers of benthic macroinvertebrates drifting during the day were notably less within the same 24-hour period. Based on these well-established findings, a sampling regime was devised that centered on collecting drift one-hour before and one-hour after sunrise and one-hour before and one-hour after sunset over a 24-hour

period. Within this period, two diurnal and two nocturnal samples were evenly distributed over those respective cycles. This amounted to four diurnal (sunrise to sunset) and four nocturnal (sunset to sunrise) samples collected per site for a total of 16 drift samples collected over a 24-hour period. Sunset and sunrise times were recorded from local media and are expressed as Eastern Standard Time (EST) or Eastern Daylight Savings Time (EDT) depending on the season sampling took place. All times are written according to the international convention following the suggestions of Herman (1986). The labor involved and the amount of detritus filtered into the nets within one-hour of sampling prohibited collecting drift over longer periods and at more frequent intervals.

Although drift was collected during various intervals in 1997, drift from 26-27 April, 28-29 June, and 17-18 November 1998 are selected for evaluation and discussion. Drift collected during these three periods followed identical sampling strategies and was consistently processed. These samples were collected within four days of the New Moon phase of the lunar cycle to avoid potential depressant effects of moonlight on drift behavior of benthic macroinvertebrates (Anderson, 1966).

Laboratory Methods and Data Tabulation

Samples collected in the field were transported to the laboratory for sorting, identification, and enumeration. Samples were sorted in their entirety under a dissecting microscope. Sorted contents (i.e., benthic macroinvertebrates) were identified to the lowest taxon possible. Specimens of the Chironomidae and Simuliidae were identified to family, only. Non-insect groups such as Oligochaeta, Harpactacoidea, and Hydracarina were not taken to a lower taxon. In many cases, early instars of well documented insect

families and/or individuals damaged during sample collection could not be identified to the lowest taxon possible and were taken to the next highest taxonomic unit (e.g., genus or family). Brigham et al. (1982) and Merritt and Cummins (1996) were the primary references used for identifications. Supplementary keys for particular insect orders, families, genera, and/or species groups were also consulted (e.g., Flint, 1962; Allen and Edmunds, 1965; Bednarik and McCafferty, 1979; Wojtowicz, 1982; Parker and Wiggins, 1987; Stewart and Stark, 1988).

On occasion, adults of Ephemeroptera, Plecoptera, and Trichoptera were captured while collecting rock, kick, and drift samples. Methods used for capturing adults varied from using aerial sweep nets during daylight hours to light trapping while drift sampling. Adults were collected to provide qualitative information only.

Following identification, insect taxa were grouped and enumerated into four functional feeding groups based on their respective foraging strategies: scrapers, shredders, collectors (gatherers), and predators (see Merritt and Cummins, 1996). This provided an additional measure for assessing a method's utility; one that does not rely solely on total catch per unit alone. Additionally, certain sampling methods examined in this study actually target particular trophic groups. For example, sampling rocks and artificial substrates actually favors sampling for organisms that graze or scrape the surface of substrates for food (Lamberti and Resh, 1985; Lamberti and Feminella, 1996). Likewise, examining leaf packs favors sampling for shredders (Benfield and Webster, 1985; Benfield, 1996); organisms that shred and ingest leaf material (Allan, 1995). It was believed that by examining additional facets of the ecological relationships of the organisms themselves, patterns might emerge from the data that could contribute in the

assessment of a method's utility.

Prior to statistical analysis, raw data from rock and drift samples were corrected to compensate for variability among rock sizes and net discharge, respectively. Rock sizes or surface area varied substantially from rock to rock. To compensate for this variability, density estimates were standardized to 1000 cm^2 by dividing the number of invertebrates collected by the respective rock's surface area and multiplying this ratio by 1000. Similarly, drift density was standardized to numbers drifting per 100 m^3 of water filtered by dividing the number of invertebrates collected per net-hour by the amount of flow filtered through the net per hour and multiplying this ratio by 100 (Allan and Russek, 1985).

Statistical Analyses

A central goal of this study was to evaluate the utility of five sampling methods for use in a future study to determine whether the presence of a top predator, brook trout, exerts detectable impacts on the benthic community of Mannis Branch. The very nature of this problem demands the use of powerful analytical tools to detect or test for small changes in benthic densities and/or species composition (Allan, 1982; Allan, 1984). Thus, the type of statistical analyses used for exploring this problem is critical and of central importance for providing answers to this question.

The foundation of the question, "will trout affect the numbers of the prey community (i.e., benthic macroinvertebrates)," is rooted in traditional hypothesis testing. In this case, the null hypothesis (H_0) and an alternative hypothesis (H_A) are stated as:

H_0: the presence of trout will not affect the numbers of benthic invertebrates.

H_A: the presence of trout will affect the numbers of benthic invertebrates.

Two approaches for testing the null hypothesis involve parametric and nonparametric analyses. It is generally held that parametric statistics are more powerful or efficient than nonparametric analyses and should be applied over the latter when certain assumptions of the data are met (Elliott, 1977; Potvin and Roff, 1993; Zar, 1999). Based on the long history and utility of parametric statistics for hypothesis testing, data collected from the evaluated sampling methods were manipulated for use in and analyzed by standard parametric techniques.

For parametric statistics to apply and test results validated, data should be: 1) independent within and among samples; 2) normally distributed; 3) homoscedastic or have equal variances in a set of samples; 4) additive (Elliott, 1977; Sokal and Rohlf, 1995; Underwood, 1997). The fourth assumption (i.e., additivity or summation assumption) is primarily intended to estimate the magnitudes of effects of experimental treatments and is not relevant to examining the differences among populations (Underwood, 1997) as applied in this study. The first three assumptions, however, are critical to the use of parametric statistics in this study and are relied upon repeatedly for examining the majority of samples collected.

Two principal statistical tests were applied to all samples. These involved testing for normality and homogeneity of variances at a significance level of $P < 0.05$. The Shapiro-Wilk W Test was used for testing normality. This test was followed by four separate tests (i.e., the O'Brien, Brown-Forsythe, Levene, and Bartlett) for examining homogeneity of variances. The O'Brien, Brown-Forsythe, and Levene tests examines the equality of group variances by performing an analysis of variance (ANOVA) on a new

response variable that is constructed to measure spread in each group (SAS, 1995). Bartlett's test is similar to the likelihood ratio test (Sokal and Rohlf, 1995) and is valid only under normality (SAS, 1995). Where tests suggested that the data were normally distributed and of equal variances, a one-way ANOVA was performed to test for differences of benthic densities between sites. Where significant differences were detected, individual pairwise comparisons of group means using Student's *t* tests were performed, followed by multiple comparisons among group (i.e., sampling sites) means using the Tukey-Kramer honestly significant difference (HSD) test. Multiple comparison tests examined the differences of mean density or abundance of invertebrates between sampling sites and provided information on where differences occurred.

When tests for normality and/or homogeneity of variances showed significant differences (i.e., data were not normally distributed and/or variances unequal), variance-stabilizing transformations were carried out over the data set and then reanalyzed. It has become commonplace among field biologists and ecologists that most data sets involving species counts from field collections are rarely normally distributed and often show dependency of the variance on the mean, thus invalidating parametric analyses (Elliott, 1977; Allan, 1984; Potvin and Roff, 1993). Several transformation techniques are practiced and utilized based on the distribution of the raw data to be analyzed (Elliott, 1977; Allan, 1984). One of the most commonly used transformations in field studies where the data are highly clumped is the log (x + 1) transformation (Allan, 1984). This transformation is often used in aquatic studies (e.g., Allan, 1982; Gilliam et al., 1989; Scrimgeour et al., 1993; Forrester, 1994) and is the recommended choice where the values of sample variances far exceed their respective means (Elliott, 1977). Sample

means and variances were examined for rock and kick samples and based on these results and the suggestions of Elliott (1977), log (x + 1) transformation was applied to the data sets and retested for normality and equal variances. A second transformation technique was applied to the data sets for comparison. The statistical software (i.e., JMP; SAS, 1997) used for the analyses supports the Box-Cox Power Transformation model. This transformation technique estimates the best fit of the data to normality by raising the response to some power by following an iterative procedure (SAS, 1995; Sokal and Rohlf, 1995). In those instances where log (x + 1) transformation of the data failed to meet normality and/or homogeneity of variances, the Box-Cox transformation was used for performing ANOVA and means comparison tests.

Occasionally, transformation techniques fail to normalize biological and ecological data. When this assumption critical to parametric analysis is not met, distribution-free or nonparametric methods are used. The Kruskal-Wallis rank sums test is a widely used method to test for differences based on ranked observations from the smallest to the largest value (Zar, 1999). The calculated statistics are based on summation of the ranks per sample (Potvin and Roff, 1993). The Kruskal-Wallis test was typically the last resort for analysis where transformations failed to normalize samples. If significance was detected from the Kruskal-Wallis method, the Nemenyi multiple comparisons test for differences in rank sums (Zar, 1999) was performed.

After initial tests were performed on total numbers of invertebrates collected, the statistical procedures and tests described above were carried out on numbers of invertebrates per functional group. For rock sampling, only scrapers were analyzed. For kick sampling, analyses were conducted on scrapers, predators, shredders, and non-

chironomid – simuliid collectors. Concerning the latter, chironomids and simuliids often occurred at such large and widely fluctuating numbers that their presence in the data "masked" the presence of other collectors such as hydropsychid caddisflies.

In studies that utilize statistical methods for testing hypotheses, an estimate of the required or recommended sample size for detecting significant differences within a prescribed accuracy range from the mean is critical (Green, 1979). In this limited study, sample sizes are extraordinarily low and likely contribute to a lack of normality and unequal variances. Using the small number of samples collected, required sample sizes were calculated by using the equation from Eckblad (1991). The equation that Eckblad suggests for sample size determination is

$$N \approx \frac{(t\text{-value})^2 \text{ (sample variance)}}{(\text{accuracy x sample mean})^2}$$

where N is the required sample size; *t*-value is from a *t*-distribution at a significance level of $P < 0.05$, with degrees of freedom equal to the denominator for determining sample variance; accuracy is the desired estimate of the mean relative to the mean's true value. To increase the probability for detecting small changes in benthic numbers, accuracy should be held within a close range of the mean (Green, 1979). Accuracy estimates of within 10 to 20% of the mean were used in calculating most required sample sizes. Required sample sizes were calculated based on sample statistics from raw data.

For drift sampling, only a single net at each site was deployed, thus there are no replicate samples for statistical analyses. However, drift density (number of individuals drifting through a net per hour per 100 m^3) calculated at both sites is plotted to visually

examine drift relationships between the two stream sections and diurnal and nocturnal samples were pooled to test for differences between the two drift sites.

CHAPTER IV

RESULTS AND DISCUSSION

Overall, 132 taxa representing two phyla, four classes, and nine orders were identified in this study (see Appendix, Table A-1). Of this estimate, the majority are Insecta. The orders Ephemeroptera, Plecoptera, and Trichoptera together comprise approximately 70% of total taxa. Genera and/or families that are "place-holders" for early instars are not counted or included in the estimate of 132. For many taxa, early larval stages are impossible to identify to species or to the lowest taxonomic unit. Species with larval descriptions not yet published or known were identified to genus and are included in the estimate above. It is important to note that the above count by far underestimates the total number of invertebrate species occurring in Mannis Branch. With the exception of *Cambarus bartonii*, all non-insect taxa were identified to genus, order, or class and were not taken to the lowest taxonomic unit. Of the class Insecta, Chironomidae, Simuliidae, and Tabanidae were identified to family only.

Appendix, Table A-1 provides a summary of the sampling methods evaluated and the taxa collected per method. Also provided is qualitative information on adult insects collected from Mannis Branch. Identifications of adults helped to confirm larval identifications and also provided additional information on species occurring in the stream where the respective immature stages are unidentifiable to species or where aquatic sampling failed to detect occurrences. The summary of methods used in this study provides a crude measure for comparing the efficacy of each sampling method for

collecting a particular taxon, taxonomic group, and/or trophic group. By ranking the order of importance (based on the number of taxa collected alone) of each method, kick sampling collected more taxa followed by drift, rock, leaf pack, and tile sampling.

Rock Sampling

Rock sampling was conducted in June and July 1997 and February and April 1998. Physical measurements taken during these sampling periods are summarized in Table 1. In addition to seasonal temperature variation, stream discharge was greater during the February and April sampling period compared to the June and July samples. This is also representative of seasonal variability as precipitation tends to be greater during late winter and spring.

A quick review of the raw data for rock sampling reveals that few taxa appear regularly and at consistent numbers across all units and within each sampling site (Appendix, Table A-2 through Table A-5). Among those that do are Baetidae, Heptageniidae (particularly *Epeorus* spp.), and Ephemerellidae, most of which belong to a single functional feeding group, scrapers. Depending on the season of collection, other taxa such as glossosomatid caddisflies appear somewhat consistently across samples (e.g., Appendix, Table A-2). However, consistently high numbers of any one particular taxon occurring across all sampling units per sampling period are absent. The sporadic appearance of most taxa in the data set limits the use of particular species for statistical analyses. Therefore, total numbers per sampling unit as well as numbers of a trophic guild (i.e., scrapers) are used for evaluating the rock sampling method.

Table 1. Selected physical measurements taken at rock and kick sampling areas per collection on Mannis Branch. Measurements were averaged over all combined sampling sites.

Sampling Period	Temperature Range (^{0}C)		Average Width (m)	Average Depth (m)	Discharge (m^3/minute)
	Air	Water			
June 1997	14.0 – 17.5	13.0 – 14.0	3.0	0.19	3.44
July 1997	16.5 – 21.0	15.0 – 16.5	3.2	0.17	5.12
February 1998	1.5 – 15.0	6.5 – 8.5	3.4	0.19	8.57
April 1998	10.5 – 24.0	9.0 – 14.0	3.6	0.20	9.48

Raw data from all rock samples (Appendix, Table A-2 through Table A-5) are corrected for the high variability of cobble surface area and standardized to 1000 cm^2 per sampling unit. The corrected data for each period are examined and explored for determining the appropriate data transformation followed by preliminary analyses and significance tests.

The Shapiro-Wilk W Test for normality indicates that the June 1997 sample is normally distributed (Table 2a). However, the probability statistic calculated from the W-test value is somewhat low. Based on the probability values for all other samples, it is concluded that the only rock sample with a normal distribution is the June sample. The July sample departed from normality marginally (Table 2b), but the February and April samples are far from normal (Table 2c and 2d, respectively). Histograms and quantile box plots for each sample indicate areas in the data that likely contribute to non-normality (Figures 5 and 6). In all cases, even for the June sample but only slightly, the data are positively skewed. This is suggested by position of the quantile box plots above the frequency distributions in Figures 5 and 6. For each sample, the median (vertical line in the quantile box plots) is less than the sample mean and the concentration of the counts (i.e., number of individuals per sampling unit) are located at one end of the distribution. The only box plot that is centered over the distribution is the June 1997 sample (Figure 5a). One additional aspect of the data that may have contributed to a non-normal distribution is the presence of outliers (Figure 6a and 6b). For the February and April samples, each has one sampling unit with a large number of individuals in the sample. The large count from February occurred in sampling site MB-S1 where one cobble measuring 921 cm^2 had 268 individuals (Appendix, Table A-4). The large count from

Table 2. Test for normality of all rock samples (counts corrected for rock surface area) using the Shapiro-Wilk W Test. Data tested at the significance level of $P < 0.05$. (NS = not significant, data normally distributed; S = significant, data is not normally distributed.)

a) June 1997

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
53.9039	23.2407	4.7440	24	0.9304	0.1015	NS

b) July 1997

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
40.6165	22.4841	4.5895	24	0.9143	0.0434	S

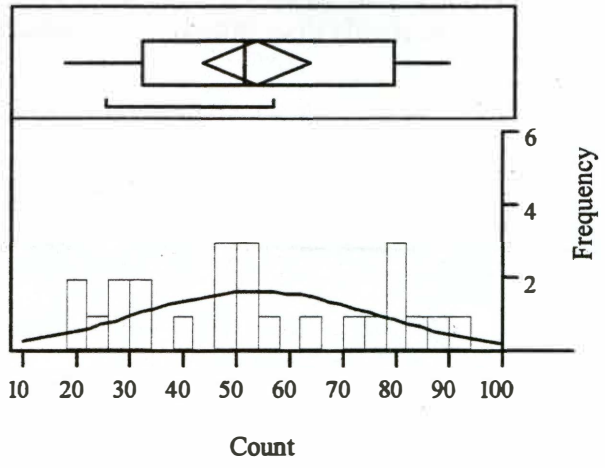
c) February 1998

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
108.9754	56.8245	11.5992	24	0.8946	0.0155	S

d) April 1998

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
145.8568	81.6468	16.6661	24	0.8411	0.0011	S

a) June 1997



b) July 1997

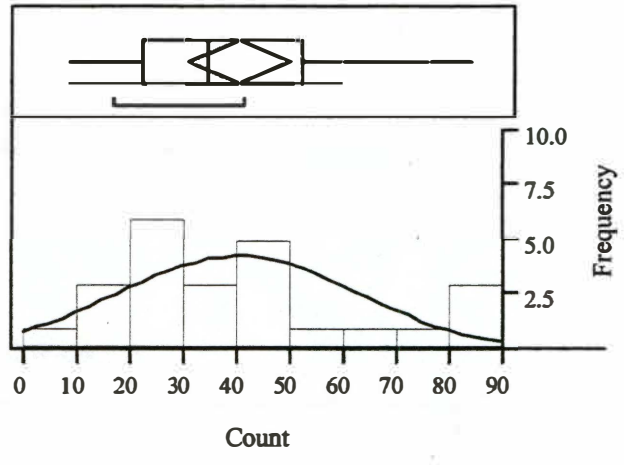
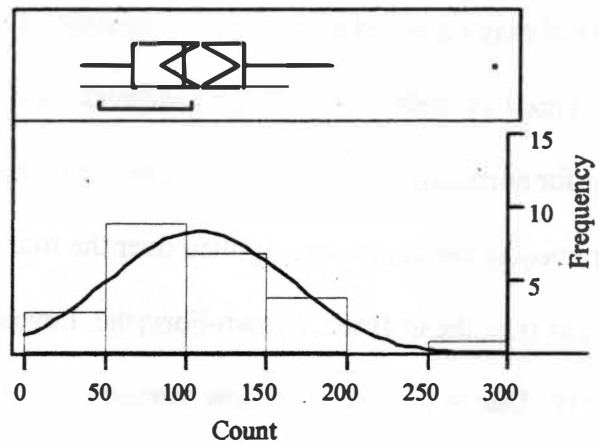


Figure 5. Histogram with normal curve superimposed and quantile box plot of corrected rock sampling data from June (a) and July (b) 1997. Quantile box plot shows median (vertical line within box), means diamond inside box (expresses sample mean and 95% confidence intervals), and the 25th and 75th quantiles (ends of box). Whiskers (lines extending out from the box) represent outermost data points within quartile range data. The bracket underlying the quantile box represents the greatest concentration (i.e., 50%) of the counts.

a) February 1998



b) April 1998

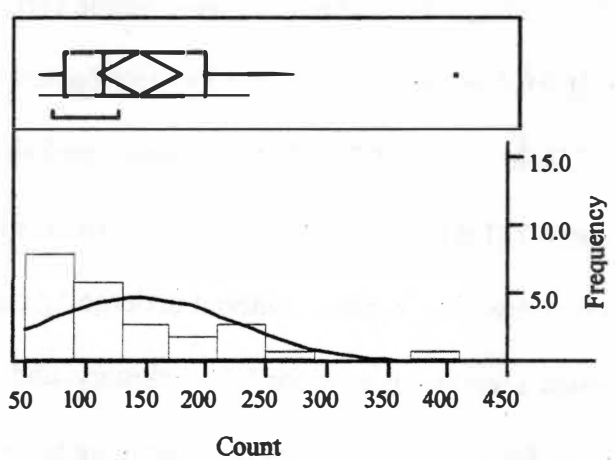


Figure 6. Histogram with normal curve superimposed and quantile box plot of corrected rock sampling data from February (a) and April (b). Quantile box plot shows median (vertical line within box), means diamond inside box (expresses sample mean and 95% confidence intervals), and the 25th and 75th quantiles (ends of box). Whiskers (lines extending out from the box) represent outermost data points within quartile range. The bracket underlying the quantile box represents the greatest concentration at 50% of the counts.

April occurred in sampling site MB-S4 where one cobble measuring 1314 cm^2 had 534 individuals (Appendix, Table A-5). The latter had an extraordinarily high count of *Acentrella* sp. cf. *ampla* and may represent a transcription mistake. Based on the preceding tests, data from the July, February, and April samples require transformation.

Although the test for normality suggests that three of the four samples require transformation, tests for unequal variances were applied over the four samples to examine if any of four variance tests (i.e., the O'Brien, Brown-Forsythe, Levene, and Bartlett) detected heteroscedasticity. Due to the extremely low sample sizes, it was anticipated that unequal variances would be detected. Surprisingly, out of sixteen test trials, not a single test detected heteroscedasticity in the samples (Table 3). This is likely due to the equally large variances in each sample. Had one or more sample variances been exceedingly large or small relative to the other variances, heterogeneity would have likely been detected (see Underwood, 1997). The significance probability values were quite high for the June sample (Table 3a), and based on the normality test results, this sample can be analyzed by parametric methods without undergoing transformation. It should be noted that Bartlett's test is not valid for July, February, and April samples because rock sampling data from those months were found to be non-normal. Bartlett's test is applicable for normally distributed data, only (SAS, 1995). Based on the results from the other three tests, it appears that variances are equal for all samples. Without prior knowledge of the normality tests, one may assume that the data for July, February, and April is valid for parametric analysis. However, applying methods such as ANOVA would have invalidated test results and would have likely contributed to inaccurate conclusions concerning the data (Sokal and Rohlf, 1995; Zar, 1999).

Table 3. Sample statistics (mean, standard deviation, and standard error) and tests for equal variances of all kick samples using the O'Brien, Brown-Forsythe, Levene, and Bartlett tests ($P < 0.05$). (DF = degrees of freedom in the numerator; DF Den = degrees of freedom in the denominator; NS = not significant, i.e., equal variances.)

a) June 1997

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	56.167	22.706	9.270	O'Brien	0.149	3	20	0.929	NS
MB-S2	6	35.576	23.129	9.442	Brown-Forsythe	0.115	3	20	0.950	NS
MB-S3	6	54.378	21.117	8.621	Levene	0.089	3	20	0.965	NS
MB-S4	6	69.495	16.939	6.916	Bartlett	0.174	3	-	0.914	NS

b) July 1997

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	38.388	17.460	7.128	O'Brien	1.308	3	20	0.299	NS
MB-S2	6	58.898	26.181	10.688	Brown-Forsythe	1.705	3	20	0.198	NS
MB-S3	6	30.634	14.094	5.754	Levene	2.056	3	20	0.138	NS
MB-S4	6	34.545	23.784	9.710	Bartlett	0.701	3	-	0.552	NS

c) February 1998

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	145.138	75.944	31.004	O'Brien	0.953	3	20	0.434	NS
MB-S2	6	125.205	56.152	22.924	Brown-Forsythe	0.790	3	20	0.514	NS
MB-S3	6	95.975	33.554	13.698	Levene	1.388	3	20	0.275	NS
MB-S4	6	69.283	28.324	11.563	Bartlett	1.834	3	-	0.139	NS

d) April 1998

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	165.472	73.329	29.936	O'Brien	0.934	3	20	0.443	NS
MB-S2	6	101.404	37.132	15.159	Brown-Forsythe	0.669	3	20	0.581	NS
MB-S3	6	138.467	71.033	28.999	Levene	1.830	3	20	0.174	NS
MB-S4	6	178.085	121.318	49.528	Bartlett	1.931	3	-	0.122	NS

The relationship of the sample means and their variances was investigated further for all rock samples. Sample means were plotted against sample variances on a log/log scale (Figure 7) to examine the mean – variance relationship. Means and associated standard deviations for each sample are given in Table 3. Variances were calculated by squaring the standard deviations. Figure 7 reveals the dependency of sample variances on sample means ($r^2 = 0.697$, $P < 0.0001$ at $P < 0.05$); that is, as means increase so do the variances. Elliott (1977) suggested that when dependency of the variance – mean relationship is apparent, data should be transformed if parametric methods are to be applied. When variances are much greater than their means, log (x + 1) transformation is the preferred technique for removing this relationship.

Data from the July, February, and April rock samples were log (x + 1) transformed and re-tested for normality and homogeneity of variances. Following transformation, normality was achieved for two samples, July and April (Table 4a and 4c). Log transformation did not normalize the February sample (Table 4b), which may partially be explained by the one outlier from MB-S1. The results from the four tests for homoscedasticity on the log transformed data were different than expected. February, the sample that lacked normality, had the highest test probability values suggesting that the variances are convincingly equal (Table 5b). The two data sets that had low significant probability values for all variance tests were the two samples that tested normal in the Shapiro-Wilk test, July and April (Table 5a and 5b). In fact, Levene's test for the July sample had a probability value at $P = 0.051$, which was too close to the significance level of $P < 0.05$ to accept for equal variances in the July data set. These perplexing results suggest that either the sample size is too low or a different transformation is required.

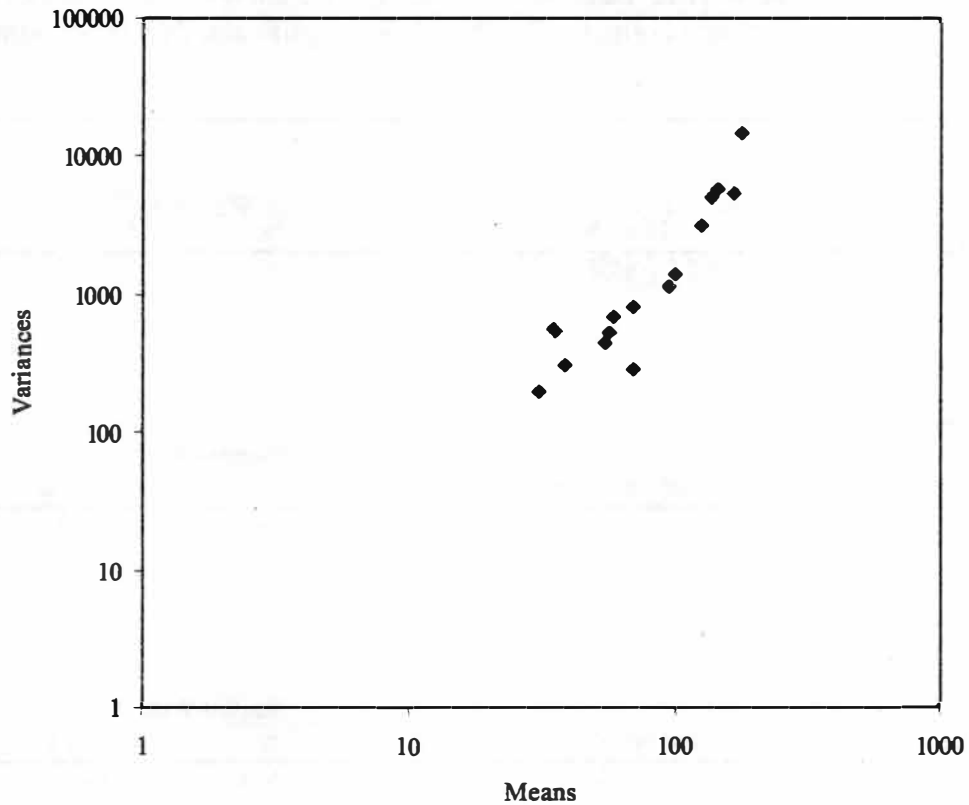


Figure 7. Relationship between the means and variances of all rock samples ($r^2 = 0.697$, $P < 0.0001$, at $P < 0.05$). Values are plotted on a log/log scale.

Table 4. Test for normality on log (x + 1) transformed totals of July (a), February (b), and April (c) rock samples (counts corrected for rock surface area) using the Shapiro-Wilk W Test. Data tested at the significance level of $P < 0.05$. (NS = not significant, data normally distributed; S = significant, data is not normally distributed.)

a) July 1997

				Shapiro-Wilk W Test		
Mean	Std Dev	Std Err Mean	N	W	Prob < W	
6.276	2.213	0.452	24	0.953	0.322	NS

b) February 1998

				Shapiro-Wilk W Test		
Mean	Std Dev	Std Err Mean	N	W	Prob < W	
11.828	3.627	0.740	24	0.912	0.043	S

c) April 1998

				Shapiro-Wilk W Test		
Mean	Std Dev	Std Err Mean	N	W	Prob < W	
14.120	3.790	0.774	24	0.954	0.341	NS

Table 5. Tests for equal variances of log (x + 1) transformed rock samples from July (a), February (b), and April (c). Significance level at $P < 0.05$. Note that sample statistics are in log transformed values and not backtransformed to original values. (DF = degrees of freedom in the numerator; DF Den = degrees of freedom in the denominator; NS = not significant, i.e., equal variances; S = significant for unequal variances.)

a) July 1997

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	6.620	1.907	0.779	O'Brien	2.454	3	20	0.093	NS
MB-S2	6	6.147	1.451	0.592	Brown-Forsythe	2.396	3	20	0.099	NS
MB-S3	6	6.009	2.141	0.874	Levene	3.081	3	20	0.051	S
MB-S4	6	6.328	3.456	1.411	Bartlett	1.275	3	-	0.281	NS

b) February 1998

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	14.562	4.433	1.810	O'Brien	0.478	3	20	0.702	NS
MB-S2	6	11.620	3.600	1.470	Brown-Forsythe	0.139	3	20	0.936	NS
MB-S3	6	11.011	2.825	1.153	Levene	0.288	3	20	0.833	NS
MB-S4	6	10.185	2.731	1.115	Bartlett	0.488	3	-	0.690	NS

c) April 1998

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	16.332	5.558	2.269	O'Brien	2.393	3	20	0.099	NS
MB-S2	6	12.818	1.491	0.609	Brown-Forsythe	1.808	3	20	0.178	NS
MB-S3	6	13.009	3.120	1.274	Levene	2.191	3	20	0.121	NS
MB-S4	6	14.320	3.714	1.516	Bartlett	2.264	3	-	0.079	NS

The statistical program JMP (SAS Institute Inc., 1997) supports the data transformation model, Box-Cox Power Transformation. This model fits data to normality based on a family of power transformations, which are defined by the log-likelihood function (SAS, 1995; Sokal and Rohlf, 1995). Rock samples from all four periods were reanalyzed after applying the Box-Cox transformation over the data sets. The Shapiro-Wilk test indicates that normality was achieved over all samples (Table 6).

Homogeneity of variances was also tested on the Box-Cox transformed counts. All tests suggest or confirm equal variances across all samples (Table 7). Based on test results for normality and equal variances, it appears that the Box-Cox transformation provides the most appropriate transformation for rock sampling data and has prepared the July, February, and April data sets for the next step, parametric analyses.

One-way ANOVA was performed on all samples using Box-Cox transformed counts. Two of the four samples, June and February, have significance probability values very near the test value of $P < 0.05$ (Table 8a and 8c). Both samples suggest slight differences among sites for the two sampling periods. To determine which sampling sites may have contributed to this suspected difference, means of the samples for each site were compared using a pairwise comparison test (Student's *t* test) and the Tukey-Kramer honestly significant difference (HSD) test. For the June sample, differences in means were detected for sampling sites MB-S2 and MB-S4 in both comparison tests (Table 9a) with MB-S4 having the higher mean density of 69.5 individuals per 1000 cm^2 of rock surface area (calculated from raw data and corrected for area). For the February sample, the Student's *t* test detected a significant difference of group means between the sites upstream of the upper boundary waterfall (i.e., MB-S1 and MB-S2) and one site, MB-S4,

Table 6. Test for normality on Box-Cox transformed rock samples using the Shapiro-Wilk W Test. Data tested at the significance level of $P < 0.05$. (NS = not significant, data normally distributed; S = significant, data is not normally distributed.)

a) June 1997

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
76.298	22.932	4.681	24	0.936	0.139	NS

b) July 1997

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
89.400	20.363	4.157	24	0.968	0.624	NS

c) February 1998

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
441.887	48.583	9.917	24	0.986	0.972	NS

d) April 1998

Mean	Std Dev	Std Err Mean	N	Shapiro-Wilk W Test W	Shapiro-Wilk W Test Prob < W	
3735.69	61.369	12.527	24	0.965	0.559	NS

Table 7. Sample statistics and tests for equal variances of Box-Cox transformed rock samples using the O'Brien, Brown-Forsythe, Levene, and Bartlett tests ($P < 0.05$). Note that sample statistics are in the Box-Cox transformation values and not backtransformed to original statistics. (DF = degrees of freedom in the numerator; DF Den = degrees of freedom in the denominator; NS = not significant, i.e., equal variances.)

a) June 1997

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	78.891	22.034	8.995	O'Brien	0.258	3	20	0.855	NS
MB-S2	6	57.015	23.578	9.626	Brown-Forsythe	0.155	3	20	0.925	NS
MB-S3	6	77.440	20.111	8.210	Levene	0.134	3	20	0.939	NS
MB-S4	6	91.849	15.069	6.152	Bartlett	0.324	3	-	0.808	NS

b) July 1997

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	89.396	15.741	15.741	O'Brien	1.419	3	20	0.267	NS
MB-S2	6	104.596	19.054	19.054	Brown-Forsythe	1.358	3	20	0.284	NS
MB-S3	6	81.742	14.684	14.684	Levene	1.619	3	20	0.217	NS
MB-S4	6	81.867	25.797	25.797	Bartlett	0.623	3	-	0.600	NS

c) February 1998

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	472.529	43.051	17.575	O'Brien	0.376	3	20	0.771	NS
MB-S2	6	456.633	51.969	21.216	Brown-Forsythe	0.354	3	20	0.787	NS
MB-S3	6	436.042	34.987	14.283	Levene	0.423	3	20	0.738	NS
MB-S4	6	402.345	42.124	17.197	Bartlett	0.240	3	-	0.868	NS

d) April 1998

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	3752.69	71.544	29.208	O'Brien	0.447	3	20	0.722	NS
MB-S2	6	3699.44	50.560	20.641	Brown-Forsythe	0.151	3	20	0.928	NS
MB-S3	6	3736.12	53.513	21.847	Levene	0.657	3	20	0.588	NS
MB-S4	6	3754.53	66.608	27.193	Bartlett	0.257	3	-	0.857	NS

Table 8. One-way ANOVA on Box-Cox transformed rock sample counts for June (a), July (b), February (c), and April (d) samples. Significance level set at $P = 0.05$.

a) June 1997

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	3730.112	1243.37	2.9729	0.056	NS?
Within Sites	20	8364.622	418.23			
Total	23	12094.733	525.86			

b) July 1997

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	2077.853	692.618	1.857	0.1694	NS
Within Sites	20	7459.656	372.983			
Total	23	9537.509	414.674			

c) February 1998

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	16524.450	5508.15	2.917	0.059	NS?
Within Sites	20	37763.101	1888.16			
Total	23	54287.551	2360.33			

d) April 1998

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	11746.314	3915.44	1.046	0.394	NS
Within Sites	20	74875.938	3743.80			
Total	23	86622.253	3766.18			

Table 9. Means comparisons using Student's *t* and Tukey-Kramer HSD of the Box-Cox transformed rock samples for June (a) and February (b). Comparisons are made at the site level (i.e., MB-S1 through MB-S4). Values are the absolute difference in the means minus the least significant difference. Positive values show pairs that are significantly different and further indicated by an "*".

a) June 1997

Student's *t* test

	MB-S4	MB-S1	MB-S3	MB-S2
MB-S4	-24.629	-11.671	-10.221	10.205*
MB-S1	-11.671	-24.629	-23.179	-2.754
MB-S3	-10.221	-23.179	-24.629	-4.204
MB-S2	10.205*	-2.754	-4.204	-24.629

Tukey-Kramer HSD

	MB-S4	MB-S1	MB-S3	MB-S2
MB-S4	-33.048	-20.090	-18.639	1.786*
MB-S1	-20.090	-33.048	-23.179	-11.172
MB-S3	-18.639	-23.179	-33.048	-12.623
MB-S2	1.786*	-11.172	-12.623	-33.048

b) February 1998

Student's *t* test

	MB-S1	MB-S2	MB-S3	MB-S4
MB-S1	-52.331	-36.435	-15.845	17.852*
MB-S2	-36.435	-52.331	-31.741	1.956*
MB-S3	-15.845	-31.741	-52.331	-18.634
MB-S4	17.852*	1.956*	-18.634	-52.331

Tukey-Kramer HSD

	MB-S1	MB-S2	MB-S3	MB-S4
MB-S1	-70.219	-54.322	-33.732	-0.0347
MB-S2	-54.322	-70.219	-49.628	-15.931
MB-S3	-33.732	-49.628	-70.219	-36.521
MB-S4	-0.0347	-15.931	-36.521	-70.219

below the upper boundary waterfall. Unlike the June sample, MB-S4 has the lowest counts for February. However, Tukey-Kramer's test failed to detect these differences. It is premature to draw conclusions on cause and effects (e.g., the presence of trout versus the absence of trout) that may be occurring in the sampling sites based on these limited data and test results. The conservative route at this juncture is to assume that these detected differences in the pairwise Student's *t* test are more likely an artifact of the analytical method coupled with a small sample size and high variability among sampling units.

One statistic concerning the effectiveness of these tests is the extremely low power that was detected. The ANOVA test on the Box-Cox transformed data for June and February has a power estimate of 0.61 and 0.60 respectively. Therefore, the likelihood of committing a Type II error is approximately 40% (i.e., failing to detect significance when in fact group means are significantly different). In this situation, it is highly probable that a Type II error was committed, at least for June. Had the critical test value of $P < 0.05$ been set at a more liberal level (e.g., $P < 0.10$), significance would have been detected and power would have increased to 0.74. However, the probability for committing a Type I error (i.e., detecting significance when there is no significant difference) increases (Eberhardt and Thomas, 1991). Power for July and April are much lower than that determined for June and February, 0.41 and 0.24 respectively. Zar (1999) gives equations for estimating the required sample size for a one-way ANOVA with the aim of increasing power. Based on the calculated test statistics and "effect size" of the transformed counts, an increase in sample size to 12 rocks per site would have increased the power of the test to nearly 0.94 for both the June and February samples.

Approximately 20 rocks per site are required to increase the power to 0.95 for the July sample and 30 rocks per site to increase the power of the April sample to 0.92. It should be noted that if the initial sample size was 12, 20, or 30 rocks per site, a completely different set of sample statistics and parameters would have been calculated and thus, a new estimate of power which may or may not have been satisfactory for the test. Regardless, the above power estimates emphasize the need for exceedingly large sample sizes for testing hypotheses.

Rock sampling data were briefly examined to see if using counts of functional groups provides a better fit of the data and analytical models than by using total numbers alone. Since the majority of rock samples contained individuals of the "scraper" trophic guild, counts of this functional group were examined. Appendix, Table A-1 was consulted for selecting taxa that at some point during their larval development graze or scrape the surface of stones for food. Once scraper taxa were selected, counts were enumerated and tabulated to provide a new set of rock sampling data for analysis. Tests identical to those used for total numbers were applied to the "scraper data". However, test results were only briefly examined and were not analyzed as intensively as for total counts. A summary of the test results for scrapers follow.

Of the four samples, original scraper counts of July and February are normally distributed ($P = 0.135$ and $P = 0.246$, respectively) and homoscedastic ($P = 0.452$ and $P = 0.993$, respectively). However, a significant departure from normality was detected for the June and April counts ($P = 0.003$ and 0.010, respectively; $P < 0.05$). Both log (x + 1) and Box-Cox transformations were applied to the scraper counts for June and April and compared. Results of the Shapiro-Wilk test suggests that the Box-Cox transformation

provides the best fit for both June and April scraper counts ($P = 0.532$ and $P = 0.203$ respectively) and has equal variances ($P = 0.705$ and $P = 0.588$, respectively).

A one-way ANOVA was performed on the scraper data for all rock samples. Test results indicated no significant differences among the sites for July, February, or April (Table 10b, 10c, and 10d respectively). However, a significant difference was detected on the Box-Cox transformed June counts (Table 10a). Multiple means comparisons using Tukey-Kramer and the pairwise Student's *t* test were performed over the data set to locate where the differences occurred. Significance was detected in the Student's *t* test of four pairwise comparisons: sites MB-S1 versus MB-S2; MB-S1 versus MB-S4; MB-S2 versus MB-S3; and MB-S2 versus MB-S4. The more conservative (see SAS, 1995) Tukey-Kramer HSD detected significance in only two means comparisons; sites MB-S2 versus MB-S3 and MB-S2 versus MB-S4. The detection of significance is primarily due to the very low counts of scrapers across all sampling units (rocks) in site MB-S2 (mean = 9.3, ± 2.9). Site MB-S4 had the greatest counts of scraping organisms for June 1997 (mean = 29.7, ± 11.8). For June, scrapers were most abundant in the section of Mannis supporting trout but had the lowest counts in an area where trout are absent.

Critical to this study with long-range goals to test for small differences in benthic densities is the estimation of required sample size. Equations from Eckblad (1991) are used to estimate sample sizes with different accuracy estimates. Ideally, a sample size that is accurate within 10% of the true mean is preferred as such a narrow variance about the mean is more apt to detect small differences between sampling sites. Required or suggested sample sizes were calculated for each sampling period using total counts (n = 24) and sampling units within sites. Sample size estimate for the June 1997 sample

Table 10. One-way ANOVA on untransformed (July-b and February-c) and Box-Cox transformed (June-a and April-d) rock sample counts of scrapers only. Significance level set at $P = 0.05$.

a) June 1997

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	1121.673	373.891	8.841	0.0006	S
Within Sites	20	845.835	42.292			
Total	23	1967.508	85.544			

b) July 1997

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	21.867	7.289	0.129	0.942	NS
Within Sites	20	1130.592	56.530			
Total	23	1152.459	50.107			

c) February 1998

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	1503.775	501.258	1.243	0.321	NS
Within Sites	20	8068.331	403.417			
Total	23	9572.105	416.178			

d) April 1998

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	2216.754	738.918	2.4421	0.094	NS
Within Sites	20	6051.515	302.576			
Total	23	8268.269	359.490			

within ± 10% of the true mean is approximately 80 units or rocks (at $P = 0.05$, a t-value of 2.069, df = 23, sample mean of 53.904, and variance of 540.144). Based on the sample statistics for all 24 rocks (over all sites combined), accuracy for the June sample is estimated at 18%, which is extraordinary for aquatic data. However, this estimate completely overlooks sample sizes within groups or sites. Breaking this estimate down to detecting differences among sites with a sample size of only six rocks, the accuracy for the June sample per site is 42%, 68%, 41%, and 26% for MB-S1 through MB-S4, respectively. To lower accuracy within 10% of the projected true mean would require 108, 280, 100, and 39 individual rocks per site. At an accuracy of 10% within the true mean, the July data suggests that a sample size of 131 units is needed. This has an overall accuracy estimate of 23% within the true mean. Again, this is all sampling units pooled. The accuracy estimates are much higher when breaking this down to the site level, which are 48%, 47%, 48%, and 72% for sites MB-S1 through MB-S4, respectively. Sample sizes required to lower these estimates to within 10% of the true means respective to each sampling site are 137, 131, 140, and 313 rocks or units. The February and April samples have similar sample size requirements. It is apparent that the required sample sizes, based on these pilot data, cannot reasonably be collected. However, a realistic sample size may be achieved if accuracy within 20% of the true mean is accepted. It may be possible to detect moderate changes in the benthos at this accuracy level.

Average sample size was calculated at the 20% accuracy level for each sampling site per sampling period or month. At such a small sample size of six units per site, the variances are exceedingly large, thus resulting in a large and often unrealistic required sample size. The average sample size required at 20% accuracy is 33 (± 26 SD), 45 (± 22

SD), 31 (± 11 SD), and 44 (± 24 SD) per June, July, February, and April, respectively. If rock sampling is to be used for testing hypotheses, a minimum sample size of 30 to 45 rocks per site may be acceptable. If four sampling stations or sites are maintained for subsequent studies, this would entail collecting at least 120 sampling units per sample. It should be noted that the above estimates are quite coarse and only provide a rough idea of the effort required for continued use of this method. Because of the use of the *t*-value in the equation for estimating sample size, an underlying assumption is that the estimate comes from normally distributed data. With the exception of June, prior analyses have proven that this is not the case. Nevertheless, some idea of the sampling effort required for hypothesis testing is suggested.

One final assessment for rock sampling must be addressed. This relates to the time and effort that must be expended per sampling event. On average, it took approximately 30 minutes to choose the precise sampling area for extracting only six rocks based on a stratified (by habitat type), randomized design. This included the numerical assignment of plausible sample spots throughout a sampling site and choosing rock units from a pseudorandom numbers table (February and April samples only). Once a stone was removed, it took approximately 35 minutes to process a single unit. Processing included rock washing, foil wrapping and trimming, and contents preserved with notes recorded. In the laboratory, sorting, enumerating, and tabulating each unit took from two to four hours excluding foil weighing, data recording, and statistical analyses. Effort involved increases dramatically with increased sample sizes.

Kick Sampling

Kick samples were taken concurrently with and at the same sampling stations or sites as rocks. An examination of the four samples reveals that the numbers of macroinvertebrates per kick vary highly between sampling units within sites and among sites for each sampling period (Appendix, Tables A-6 to A-9). Although measures were implemented to control some environmental variability (i.e., units were collected within a single habitat type and under similar conditions), spatial variability of the organisms themselves (e.g., clumping or aggregations) is an inherent ecological and biological phenomenon that cannot be controlled, thus rendering statistical evaluations and hypothesis testing a challenging task (Resh, 1979). The data from each sampling period is explored to assess the utility of kick sampling for testing hypotheses in Mannis Branch.

Raw data totals from kick samples were examined and tested for normality and equal variances to determine if the assumptions for parametric analyses were met. Analyses for significance testing were performed on those samples meeting the required assumptions. The Shapiro-Wilk W test on the June 1997 kick sample, which consisted of only five sampling units or kicks per site, revealed that the data are normally distributed ($P = 0.212$, n = 20 at $P < 0.05$). The four tests for homogeneity of variances (i.e., the O'Brien, Brown-Forsythe, Levene, and Bartlett tests) each had high significance probability values (Table 11a) suggesting that the variances are equal in the June sample. Thus, the June sample meets the normality and equal variances assumption for parametric analysis to be validated.

A one-way ANOVA was carried out on the June sample to test for differences among group means and a significant difference was detected with a power estimate (i.e.,

Table 11. Sample statistics (means, standard deviation, and standard error) and tests for equal variances of June (a), July (b), February (c), and April (d) kick samples using the O'Brien, Brown-Forsythe, Levene, and Bartlett tests ($P < 0.05$). ("*" refers to untransformed, raw data; "**" log (x+1) transformed data; "***" refers to untransformed, raw data with outlier removed; DF = degrees of freedom in the numerator; DF Den = degrees of freedom in the denominator; NS = not significant, i.e., equal variances; S = significant.)

a) June 1997*

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	5	135.200	71.409	31.935	O'Brien	0.217	3	16	0.884	NS
MB-S2	5	177.000	62.901	28.130	Brown-Forsythe	0.049	3	16	0.985	NS
MB-S3	5	135.000	61.964	27.711	Levene	0.169	3	16	0.916	NS
MB-S4	5	298.400	88.931	39.771	Bartlett	0.215	3	-	0.886	NS

b) July 1997**

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	12.213	3.214	1.312	O'Brien	1.298	3	20	0.303	NS
MB-S2	6	15.837	6.974	2.847	Brown-Forsythe	1.585	3	20	0.224	NS
MB-S3	6	14.376	2.564	1.047	Levene	1.562	3	20	0.230	NS
MB-S4	6	16.144	4.525	1.847	Bartlett	1.771	3	-	0.150	NS

c) February 1998***

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	5	96.200	30.384	13.588	O'Brien	0.992	3	19	0.418	NS
MB-S2	6	187.833	52.765	21.541	Brown-Forsythe	0.657	3	19	0.589	NS
MB-S3	6	100.000	34.153	13.943	Levene	1.626	3	19	0.217	NS
MB-S4	6	209.167	56.803	23.190	Bartlett	0.771	3	-	0.510	NS

d) April 1998*

Site	N	Mean	Std Dev	Std Err	Test	F	DF	DF Den	Prob>F	
MB-S1	6	137.333	83.711	34.175	O'Brien	0.554	3	20	0.651	NS
MB-S2	6	117.333	56.990	23.266	Brown-Forsythe	0.588	3	20	0.630	NS
MB-S3	6	215.167	55.586	22.693	Levene	0.610	3	20	0.616	NS
MB-S4	6	223.500	80.714	32.951	Bartlett	0.435	3	-	0.728	NS

$1 - \beta$) of 0.84 (Table 12a). To examine where the differences occur, an unplanned pairwise comparison of the means using the Student's *t* test followed by multiple means comparison of Tukey-Kramer HSD was performed. The Student's *t* test detected differences in means in three pairwise comparisons. These differences occur between sampling sites MB-S1 versus MB-S4; MB-S2 versus MB-S4; and MB-S3 versus MB-S4. However, the Tukey-Kramer HSD test detected differences between only two pairwise comparisons: MB-S1 versus MB-S4 and between MB-S3 versus MB-S4. The sample statistics for June (Table 11a) indicate that the mean for site MB-S4 is more than two times that for sites MB-S1 and MB-S3. Appendix, Table A-6 show consistently high counts for each kick unit at MB-S4 with one kick having a total count at least 1.5 times that of any count in the sample. There is no explanation at this juncture why this site had a greater number of macroinvertebrates per sampling unit other than kicks were taken in productive riffles. For this one site, chironomids accounted for 26% of the collections alone and one mayfly species, *Ephemerella rossi*, accounted for 18% of the total.

The test for normality on the July kick sample suggests that the data are not normally distributed ($P = 0.027$, n = 24 at $P < 0.05$) and a transformation is needed prior to testing by parametric methods. The Shapiro-Wilk test also detected a significant departure from normality on the February kick sample. The probability significance value ($P = 0.0001$) was far below the test level of $P < 0.05$.

The April kick sample is normally distributed and has a high significance probability value of $P = 0.863$. The sample also tested for equal variances, and in all four tests, the significance probability values were relatively high (Table 11d). Since the April sample is normally distributed and has equal variances, a one-way ANOVA was

Table 12. One-way ANOVA on kick samples for June (a), July (b), February (c), and April (d). Significance level set at $P < 0.05$. ("*"refers to untransformed, raw data; "**" refers to log (x+1) transformed sample; "***" refers to untransformed, raw data, with outlier removed.)

a) June 1997*

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	89478.80	29826.30	5.735	0.007	S
Within Sites	16	83216.00	5201.00			
Total	19	172694.80	9089.2			

b) July 1997**

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	57.931	19.310	0.898	0.460	NS
Within Sites	20	430.102	21.505			
Total	23	188.033	21.219			

c) February 1998***

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	59057.186	19685.7	9.450	0.0005	S
Within Sites	19	39578.467	2083.1			
Total	22	98635.652	4483.4			

d) April 1998*

Source of Variation	DF	SS	MS	F Ratio	Prob > F	
Among Sites	3	52192.33	17397.4	3.504	0.034	S
Within Sites	20	99299.00	4964.9			
Total	23	151491.33	6586.6			

performed to test for differences among sample means. A significant difference was detected (power of test = 0.692) among group means (Table 12d). To determine which group differed significantly, the Student's *t* test for individual pairwise comparisons and the Tukey-Kramer HSD were both performed. The Student's *t* test indicated a significant difference between three pairs of group means. This difference occurred between sampling sites MB-S1 versus MB-S4; MB-S2 versus MB-S4; and MB-S2 versus MB-S3. The more conservative Tukey-Kramer test failed to detect significant differences among group (i.e., sampling site) means. Because a conflict occurs between the two comparison tests, the more conservative route (i.e., the Tukey-Kramer test) is usually opted. However, a visual examination of the April kick sample reveals that a larger number of macroinvertebrates were collected from the two lower sites supporting trout (i.e., MB-S3 and MB-S4) as opposed to the fish-free, upper sites (MB-S1 and MB-S2; Appendix, Table A-9). Furthermore, power analysis of the test reveals that the probability of committing a Type II error (i.e., failing to detect significance when there is a significant difference) is 0.31. Based on the significant test value of $P = 0.034$ (Table 12d) and the high probability of committing a Type II error, Tukey-Kramer's test suggesting that significance is not occurring between sampling sites is rejected and the Student's *t* pairwise results that differences occur accepted.

The log (x + 1) transformation was applied to the non-normal July and February kick samples based on Elliott's (1977) suggestion for the type of transformation to apply when the sample variance far exceeds the mean. The log transformation of the July data was successful toward achieving normality ($P = 0.165$, n = 24 at $P < 0.05$). The log transformed July data was then tested for homogeneity of variances, and all tests failed to

detect heteroscedasticity (Table 11b). The assumptions for parametric analyses have now been met, and a one-way ANOVA was performed to test for differences among group means. Significant differences among the groups or sites was not detected (Table 12b) however, power of the test was extremely low (0.21).

Log (x + 1) transformation of the February counts failed to normalize the data ($P = 0.027$, n = 24 at $P < 0.05$). After applying the Box-Cox power transformation, normality was detected ($P = 0.266$, n = 24 at $P < 0.05$). Tests for equal variances were then performed on the latter to complete the assumptions requirement for parametric analyses. The various tests had conflicting results. Both O'Brien's and the Brown-Forsythe tests suggested that the variances were equal ($P = 0.283$ and $P = 0.386$, respectively). However, Levene's test had a probability significance value ($P = 0.085$) near the significant level of $P < 0.05$, and Bartlett's test was marginal for significance at $P = 0.051$. Based on these results, parametric analysis is approached with caution. An ANOVA on the Box-Cox transformed February sample detected significance among group means ($P = 0.014$ at $P < 0.05$, power = 0.70). Tukey-Kramer comparisons test detected significance between sites MB-S3 and MB-S4, only. Examination of raw data (Appendix, Table A-8) as well as sample statistics reveals that sampling site MB-S4 had the higher counts overall.

Because of the conflicting tests for equal variances on the Box-Cox transformed data for February, a commonly used nonparametric method, the Kruskal-Wallis test, was applied (Potvin and Roff, 1993). This test is a distribution-free method and does not assume normality, however, the test does assume that the variances are equal (Potvin and Roff, 1993) or at least somewhat homogeneous (Zar, 1999). The original untransformed

and non-normal February counts were tested using the Kruskal-Wallis method and a significant difference was detected ($X^2 = 10.084$, df = 3, $P = 0.018$ at $P < 0.05$). To locate where the difference occurs in the data set, a nonparametric method, the Nemenyi rank sums test (Zar, 1999), was used for multiple comparisons. Nemenyi's test detected a significant difference between one comparison, sites MB-S3 and MB-S4 ($q = 3.81$, critical value of $q_{0.05, \infty, 4} = 3.63$ at $P = 0.05$ and k = 4), an identical result to that of the parametric Tukey-Kramer test on the Box-Cox transformed data.

Raw data from the February sample was explored one step further to locate or pinpoint which sampling unit was creating different results among the tests for equal variances. An extraordinarily high count for one kick unit at site MB-S1 ($X_2 = 549$ individuals) is indicated in Appendix, Table A-8. By removing this single unit, a new pattern arises across the data set during analysis. Tests for normality revealed that the untransformed, original counts with X_2 removed is marginal for normality ($P = 0.055$ at $P < 0.05$) and has equal variances ($P = 0.217$ for Levene's test to 0.589 for the Brown-Forsythe test). Applying parametric analyses under these new conditions were met with surprising results. A significant difference was detected in a one-way ANOVA with extraordinary power (power = 0.98; Table 12c), and means comparisons (both Student's *t* and Tukey-Kramer) revealed that significantly different counts were detected between sites MB-S1 versus MB-S2; MB-S1 versus MB-S4; MB-S2 versus MB-S3; and MB-S3 versus MB-S4. Relating this information to the presence/absence of trout, it suggests that sites within each section of Mannis Branch differed as much as between sections (i.e., in stream areas with and without trout) for this particular sample.

The above analyses of the February kick sample emphasize the importance for

recognizing outliers. Where a single large count exists in the data, differences can occur in the analyses that may lead to erroneous conclusions. Parametric analysis in this case was causing conflicting results. The single large count in MB-S1 was actually creating a "masking effect" over the data set and inhibiting the detection of significantly different groups. In this particular case, nonparametric methods appear to be the best approach for analysis where the outlier remained in the data set (see Potvin and Roff, 1993). Furthermore, it is not always the best practice to remove outliers from biological data sets for often times such aberrant counts are providing additional information about the spatial distribution and ecological/biological clues of the target population (Green, 1979).

Kick samples generally contained large numbers of benthic macroinvertebrates representing several different species and higher taxonomic groups (Appendix, Table A-1). However, only a few species appeared regularly in all samples (see Appendix, Tables A-6 through A-9). Trophic groups or guilds of aquatic insects were examined in a manner similar to that for rock sampling. The principal difference in kick sampling is that all four guilds appeared in sufficient numbers and regularity for analysis. Some of the more commonly occurring taxa represented in the scraper guild are the Ephemerellidae (e.g., *Ephemerella rossi* and early instars of *Ephemerella* and occasionally *Drunella*), Heptageniidae (e.g., *Epeorus* sp. cf. *dispar*, *E.* sp. cf. *pleuralis*, and occasionally *Rhithrogena* spp.), Glossosomatidae (e.g., *Agapetus minutus* and *Glossosoma nigrior*), and Elmidae (e.g., *Optioservus* spp. and *Oulimnius latiusculus*). Invertebrate predators appeared in kick samples more sporadically but were represented by commonly occurring families such as Perlidae and Perlodidae and to a lesser extent Chloroperlidae, Gomphidae, and Rhyacophilidae. Shredders were primarily represented

by Leptophlebiidae (*Paraleptophlebia adoptiva/mollis*), Leuctridae (*Leuctra* sp.), Nemouridae (*Amphinemura* spp.), Peltoperlidae (primarily *Tallaperla* sp.), Lepidostomatidae (*Lepidostoma* sp.) and occasionally by Limnephilidae (*Pycnopsyche* spp.) and Tipulidae (*Tipula abdominalis*). Collectors were represented by large counts of Chironomidae and occasionally of Simuliidae. Some of the larger and more conspicuous members of collectors that appeared regularly in kick samples were Arctopsychidae (*Parapsyche cardis*), Hydropsychidae (*Ceratopsyche* spp. and *Diplectrona modesta*), and Philopotamidae (*Dolophilodes distinctus* and *Wormaldia* sp.).

Many taxa occurring in Mannis Branch have more than one feeding strategy at some point in their life histories based on Merritt and Cummins (1996). This made the segregation of taxa into separate guilds for statistical analyses difficult. The principal deciding factor for segregating taxa into a guild relied upon the primary feeding strategy that best represented the species in question. This may not have been the most appropriate method but it seemingly allowed for detailed focus on the respective functional groups without recounting a taxon that was previously analyzed in a separate functional group.

Prior to testing for differences of individual guilds between sampling sites, tests for normality and homogeneity of variances were run to validate the assumptions for parametric analyses. If raw data of a guild were found to depart from a normal distribution or variances were heterogeneous, the log (x + 1) or Box-Cox power transformations were applied to the data set and retested for normality and homogeneity of variances. Parametric analyses were performed once the data met the assumptions of normality and equal variances. In those instances where transformations failed to fit the

data to a normal distribution, the original (untransformed) counts of a guild were analyzed by nonparametric methods using the Kruskal-Wallis rank sums test.

In the June sample, scrapers accounted for approximately 48% of the total number of macroinvertebrates collected followed by collectors at 30%, predators at 14%, and shredders at 4%. (To reiterate, once a particular taxon was categorized by a functional type, it was not included for analysis into a second guild though its life history may warrant such an inclusion.) The raw counts of scrapers were found to be normally distributed ($P = 0.289$ at $P < 0.05$) and with equal variances (test probabilities ranging from $P = 0.829$ to $P = 0.798$ for four tests). A one-way ANOVA detected a significant difference among group means (Table 13a). The Tukey-Kramer multiple comparison test detected the difference as occurring between sampling sites MB-S1 and MB-S4 with the latter having the higher number of scrapers. For collectors, it was felt that the broad range of counts for chironomids and simuliids would mask differences that may be occurring for other members of the guild such as hydropsychid caddisflies. Therefore, counts of these small and highly abundant collectors (i.e., chironomids and simuliids) were removed prior to analysis. Collectors (primarily hydropsychid caddisfies) were found to be non-normally distributed ($P = 0.008$) but had equal variances (range of test probabilities for three tests, $P = 0.827$ to 0.957). As a result, the distribution-free Kruskal-Wallis test was performed, which failed to detect significance between sampling sites. Appropriate tests applied on the June counts of invertebrate predators and shredders failed to detect significant differences between sampling sites (Table 13a).

For the July kick sample, collectors (chironomids and simuliids included) comprised the majority of the sample, accounting for approximately 46% of the total

Table 13. Summary of tests and test results on trophic guilds (scrapers, predators, non-chironomid / simuliid collectors, and shredders) from kick samples collected in June 1997 (a), July 1997 (b), February 1998 (c), and April 1998 (d) in Mannis Branch. All tests are at $P < 0.05$. ("*" refers to Box-Cox transformed data; S = significant; NS = not significant; NS? = questionable significance)

a) June 1997

Guild	Type of Test	DF	Test Value	Prob > Test	
Scrapers	ANOVA	3, 16	F = 4.223	0.022	S
Predators	ANOVA	3, 16	F = 2.294	0.117	NS
Collectors	Kruskal-Wallis	3	$X^2 = 3.045$	0.385	NS
Shredders	Kruskal-Wallis	3	$X^2 = 3.996$	0.262	NS

b) July 1997

Guild	Type of Test	DF	Test Value	Prob > Test	
Scrapers	ANOVA	3, 20	F = 0.524	0.671	NS
Predators	ANOVA*	3, 20	F = 1.517	0.241	NS
Collectors	Kruskal-Wallis	3	$X^2 = 8.227$	0.042	S
Shredders	Kruskal-Wallis	3	$X^2 = 0.185$	0.980	NS

c) February 1998

Guild	Type of Test	DF	Test Value	Prob > Test	
Scrapers	Kruskal-Wallis	3	$X^2 = 11.165$	0.011	S
Predators	Kruskal-Wallis	3	$X^2 = 7.680$	0.053	NS?
Collectors	Kruskal-Wallis	3	$X^2 = 2.348$	0.504	NS
Shredders	ANOVA*	3, 20	F = 1.890	0.164	NS

d) April 1998

Guild	Type of Test	DF	Test Value	Prob > Test	
Scrapers	ANOVA	3, 20	F = 3.004	0.055	NS?
Predators	ANOVA*	3, 20	F = 3.538	0.033	S
Collectors	Kruskal-Wallis	3	$X^2 = 6.313$	0.097	NS
Shredders	Kruskal-Wallis	3	$X^2 = 1.856$	0.603	NS

number followed by scapers at 31%, predators at 14%, and shredders at 4% (Appendix, Table A-7). Collectors other than chironomids and simuliids (e.g., hydropsychid caddisflies) accounted for approximately 14% of the sample. Table 13b gives a summary of the tests performed and test results on each of the guilds. The only guild in which a statistically significant difference ($P = 0.042$ at $P < 0.05$) was detected among group means is collectors (non-chironomid - simuliids). A Nemenyi multiple comparisons test was performed on the Kruskal-Wallis derived rank sums to locate the difference. A significant difference was detected between sampling sites MB-S3 and MB-S4, the two sites below the upper boundary falls. As indicated by the multiple comparisons test, MB-S4 is the site with the greatest numbers of non-chironomid - simuliid collectors.

For the February 1998 sample, scrapers comprised the majority of the sample accounting for approximately 44% of the total numbers collected followed by collectors (including chironomids and simuliids) at 34% of the total, predators at 9%, and shredders at 7% (Appendix, Table A-8). Collectors other than chironomids and simuliids comprised approximately 7% of the sample. Of the analyses conducted on all trophic groups from this sample, a statistically significant difference was detected only for scrapers (Table 13c). Because of a non-normal distribution (Shapiro-Wilk test, $P = 0.014$ at $P = 0.05$), the distribution-free Kruskal-Wallis procedure was performed on the scraper data in which significance between rank sums of the sampling sites was detected. The Nemenyi multiple comparisons test detected the difference ($q = 4.041$, critical value of $q_{0.05, \infty, 4} = 3.633$) as occurring between sites MB-S3 and MB-S4 with the latter having the higher number of scrapers (Appendix, Table A-8).

The April 1998 sample has proportionally more scrapers than any other guild at

approximately 74% of the total number followed by collectors (including chironomids and simuliids) at 15%, predators at 6%, and shredders at 3%. Of the number of collectors alone, approximately 22% are non-dipteran taxa (primarily hydropsychid caddisflies). Following analyses, a statistically significant difference was detected on the counts for a single trophic guild, invertebrate predators (Table 13d). A one-way ANOVA on Box-Cox transformed counts of predators detected significance among group means (P = 0.033 at $P = 0.05$). The Student's t pairwise comparison test detected differences between sites upstream of the upper boundary falls (i.e., MB-S1 and MB-S2) from the sites downstream of the falls (i.e., MB-S3 and MB-S4). Both of the sampling sites downstream of the upper boundary waterfall had greater numbers (hence, higher means) of predators than the sites upstream of the falls.

Overall, these preliminary tests suggest that where significance is detected, the sites in the section supporting brook trout generally have higher densities of benthic macroinvertebrates compared to the fish-free section. However, sample sizes are extremely low and highly variable and should not be used in this study for establishing inferences.

The utility of the kick sampling method is addressed further through sample size and accuracy estimation using the formulae from Eckblad (1991). Estimated sample sizes from the June kick sample are based on a preliminary sampling size of five kicks per site for a total of 20 kicks or units overall. If the intended accuracy estimate is 10% within the true mean, a sample size of 115 kicks or units is required based on the sample statistics of all kicks combined for June (i.e., sample mean of 186.400, variance of 9089.143, and t-value of 2.093 at df = 19 and $P = 0.05$). Based on the sample statistics of

all kicks combined for June, an accuracy estimate of 24% within the true mean is calculated. However, statistically significant differences are being tested at the site level, which involves a much lower sample size and greater variances. Using the sample statistics for each sampling site in June, accuracy of the kicks are estimated at 49%, 33%, 43%, and 28% for sites MB-S1, MB-S2, MB-S3, and MB-S4, respectively. To lower the accuracy to within 10% of the true mean would require sample sizes of 122, 55, 92, and 39 kicks respective to each site. If the observed variances are truly representative of the variability at this site, then an increase in sample size to 15 kicks per site would lower the accuracy estimates to approximately 17% to 29% within the true mean and 24 kicks per site to within 13% to 22% of the mean.

Required sample sizes and accuracy estimates were calculated for each of the remaining samples (i.e., July, February, and April) per sampling site. Sample statistics for each site were used to derive sample sizes and accuracy estimates (Eckblad, 1991). (Table 11c and 11d provide sample statistics for original untransformed data. Sample statistics for July 1997, Table 11b, must be back-transformed prior to sample calculations.) Accuracy estimates respective to each sampling site for July, February, and April are comparable to those calculated for June and range from 27 to 69% with an average of 41% (± 13.6% SD, n = 12). By increasing the sample size per site to 15 kicks, accuracy increases to a range of 14 to 36% with an average accuracy estimate of 22% (± 0.07 SD, n = 12). A sample size of 24 kicks per site yields accuracy estimates ranging from 11 to 28% with an average estimate of 16% (± 0.06 SD, n = 12). For this method to be useful in hypothesis testing, particularly as a means to detect subtle changes in the stream benthos, a sample size of at least 24 kicks per site is recommended. It is unlikely

that this sample size will be accurate within 10% of the mean but it is one that is more reasonable to obtain and will likely be accurate within 20% of the true mean.

One final assessment for this method is the time and effort required for collecting kick samples. On average, it took 30 to 40 minutes to randomly select sampling units throughout a sampling site. Each kick required approximately 10 to 15 minutes to process in the field. However, laboratory time involving the sorting, identification of, and enumerating individuals from each kick unit required four to ten hours of effort. This estimate does not include data entry and statistical evaluation.

Artificial Substrates

Unglazed quarry tiles of standard size were submerged and anchored in Mannis Branch during two prescribed incubation periods. Two different sampling designs were used respective to each period and are compared and evaluated.

The first incubation period spanned 44 days from 13 May to 25 June 1998. The design for tile sampling during the May – June period followed a study by Lamberti and Resh (1985) in which they examined the efficacy of tile sampling compared to using natural substrates, rocks. This design is based on a grid layout where a prescribed number of tiles are placed in a uniform fashion within a single habitat type (e.g., pool or riffle) that has similar environmental conditions throughout the sampling site (i.e., constant depth and velocity at tile placement). For the first trial, nine individual tiles were placed in each of four sites in Mannis Branch. For future reference, tile sites of the first trial period are identified as T1 and T2 for the sites upstream of the upper boundary waterfall and T3 and T4 for sites downstream of the waterfall.

During this limited incubation period, some success was met as measured by macroinvertebrates colonizing the substrates; at least 40 taxa were collected (Appendix, Table A-1, A-10, and A-11). However, the vast majority of invertebrates occurred very sporadically in the sample. Some taxa are represented by a single occurrence. Additionally, the predominance of early instars resulted in less precise taxonomic identification. Very few individuals were late instars and thus, identified to species. A large number of the individuals collected could only be identified to genus or in many cases to family. Chironomidae comprised the majority of each tile. In all, chironomids accounted for 85% of the total number of macroinvertebrates collected across all four sampling sites. In the upper-most sampling site alone (i.e., T1), 93% of all invertebrates collected were chironomids. Other than midges, hydropsychid caddisflies were the only taxonomic group that appeared regularly in the sample.

By segregating taxa into functional groups, it was anticipated that scrapers would comprise a large percentage of invertebrates utilizing the substrates. However, collectors (apart from chironomids) were found to occur in greater numbers (compare "Trophic Group" category of Appendix, Table A-1 with individual counts in Table A-10 and A-11). Of the scrapers and non-chironomid collectors, scrapers accounted for 44% and non-chironomid collectors 56%. Taxa representative of the scraper guild were Baetidae, Ephemerellidae, Heptageniidae, Glossosomatidae, Goeridae, Odontoceridae, and Elmidae. Non-chironomid collectors occurring in the samples were largely represented by hydropsychid caddisflies.

Exploratory analyses were conducted on this sample to examine which analytical methods are most appropriate to test for significant differences between the four sampling

sites. (Because the sampling universe for the grid design is restricted to just four small plots in Mannis Branch, generalizations or inferences of cause and effect are not applicable system-wide.) The data were manipulated in several different ways to determine whether sampling for a particular trophic group was more usable than using total numbers collected alone.

Total numbers from Appendix, Table A-10 and A-11 were first tested for normality. The Shapiro-Wilk test detected a significant departure from normality over the counts ($P = 0.0001$, n = 36, at $P < 0.05$). Both the log (x + 1) and Box-Cox transformations were applied to the sample to examine whether the data could be fitted to a normal distribution and which transformation, if any, provided the best fit. The Shapiro-Wilk test for normality failed to detect a significant departure from a normal distribution in both the log transformed counts ($P = 0.293$, n = 36 at $P < 0.05$) and the Box-Cox transformed counts ($P = 0.157$, n = 36 at $P < 0.05$). Upon comparing the significance probability values for both transformations, the log transformation appears to have a better fit to a normal distribution. Both transformations were determined to have equal variances based on the results of four tests for homoscedasticity (probability values ranging from $P = 0.130$, Levene's test to $P = 0.292$, Brown-Forsythe on Box-Cox transformed counts; $P = 0.189$, Brown-Forsythe test to $P = 0.537$, Bartlett's test on log transformed counts).

A one-way ANOVA was performed on both transformed counts and the results compared. A statistically significant difference was detected for the log transformed data ($P = 0.007$ at $P < 0.05$). The Tukey-Kramer HSD test detected significance as occurring between the upstream-most tile site (i.e., T1) and the downstream-most site (i.e., T4).

Based on the means of the log transformed data, T4 had a greater mean and higher count overall than T1. However, this result was not corroborated by the Box-Cox transformed counts. A one-way ANOVA on the latter failed to detect significance among tile sites ($P = 0.393$ at $P < 0.05$). Sample statistics from the Box-Cox transformation revealed that means of all sites were within 2% of one another. One final analysis was applied to help determine which test results were accurate. Since the original counts were non-normal but variances "somewhat equal" (Zar, 1999), the distribution-free Kruskal-Wallis test was used to help resolve this disparity. The Kruskal-Wallis test failed to detect differences in rank sums between the sites ($X^2 = 3.649$, df = 3, $P = 0.302$ at $P < 0.05$) and corroborates the results from the Box-Cox transformed counts. It is concluded that the log transformation in this instance is not the appropriate transformation to apply across the data set and would have led to erroneous conclusions had it been the sole approach for manipulating the data. This further emphasizes the fact that care must be taken when relying on a particular data manipulation or analytical approach for hypothesis testing. Where multiple approaches or analytical options exist, they should be applied and compared (Elliott, 1977; Allan and Russek, 1985).

The sheer number of chironomids in the data set completely "swamps" the presence and distribution of other taxa. Tile data from the May - June sample was re-analyzed after removing chironomid counts to examine the distribution of other taxa. The original data with chironomids removed tested for normality ($P = 0.119$ at $P < 0.05$) and has equal variances ($P = 0.3129$ to $P = 0.360$ for O'Brien's and Bartlett's test, respectively). A one-way ANOVA on the original, untransformed counts detected a statistically significant difference among group means ($P = 0.028$, at $P < 0.05$; power =

0.55). The Tukey-Kramer multiple comparisons test detected significance between tile sites T1 and T4 with the latter having the larger mean and higher counts.

The raw data from Appendix, Table A-10 and A-11 show that very few mayflies and scrapers in general occur in T1 whereas these are more abundant in T4. The need for statistically analyzing scrapers is not warranted in this case because only three individuals were collected in site T1 and 10 in site T2. Comparatively, 67 individuals were collected in site T3 and 54 in T4.

Collectors, other than chironomids, are examined as well. The majority of the individuals comprising this group are early instars of the Hydropsychidae. Total numbers collected of this group ranged from 16 at tile sampling site T3 to 76 individuals at site T2. Since data comprising this group is non-normally distributed ($P = 0.0001$ at $P < 0.05$) but have equal variances ($P = 0.287$ to $P = 0.363$), the Kruskal-Wallis test was used. Test results detected a significant difference occurring among group means ($P = 0.026$ at $P < 0.05$). The Tukey-Kramer test detected significant differences occurring between sites T2 and T3 as suggested from the disparate counts given above.

Developing a cause-and-effect relationship is premature and unfounded based on this single sample. However, an interesting observance is that tiles from the two sites upstream of the upper boundary waterfall had very few scrapers but appeared to support a larger number of non-chironomid collectors (e.g., hydropsychid caddisflies) relative to the sites downstream of the waterfall. Conversely, scrapers appeared in greater numbers in the two sites downstream of the waterfall where the number of non-chironomid collectors was significantly lower (especially at site T3 where statistical significance was detected).

A final assessment of the May – June sampling design must be addressed. One critical assumption for parametric analyses to be valid may have been violated due to the grid design. Tiles were separated by only a few centimeters and under these conditions, it cannot be confirmed that each tile was independent of one another. Furthermore, tiles within each of the four sites are not true replicates though a mean and related sample statistics are derived (see Hurlbert, 1984, for a thorough discussion and discourse on this critical topic). This design greatly limits the utility of this method for testing differences between the stream sections above and below the upper boundary waterfall. As a result, a different sampling design was examined during the second sampling cycle of artificial substrates.

The sampling design for the second phase of tile sampling utilized the habitat type or riffle area as the object for replicating. Rather than using small plots for collecting samples, replicates were randomly taken at the stream unit or reach. In the following analyses, stream reach represents a physical unit in which five tiles were randomly distributed and stratified by habitat type (i.e., riffle). From the perspective of treatment effects (i.e., fish present vs. fish absent), reaches are replicated respective to stream section. That is, three reaches were sampled in each section of the stream with the upper boundary waterfall as a natural barrier for treatment separation. (For reference, the three sampling sites or "reaches" upstream of the upper boundary waterfall are indicated by UR1 through UR3 and "reaches" downstream of the upper boundary waterfall are indicated by LR1 through LR3.)

The second sampling or incubation interval spanned 81 days from 23 August to 11 November 1998. It was thought that by increasing the incubation period, biological

conditions on the surface of the tiles (e.g., an increase in periphyton and bacterial communities; Lamberti and Resh, 1985) might create an environment that would favor an increase in individuals, late instars, and/or additional taxa to colonize the tiles. However, an increase in incubation time did not result in these desired conditions. Overall, approximately 31 taxa were identified. Chironomids were again the most commonly collected organism, accounting for 81% of all animals appearing in the sample (Appendix, Table A-12). Additionally, the majority of individuals were very early instars and assignable only to family in some cases. Apart from chironomids, no single taxon appeared regularly in the sample, although scrapers as a group regularly occurred and are collectively the second most commonly occurring invertebrate group (i.e., second to collectors with chironomids included). One perplexing aspect of this sample compared to the May – June sample is the absence of hydropsychid caddisflies, important collectors in the earlier sample. However, the differences in taxa colonizing the substrates are likely an artifact of temporal dynamics of the organisms themselves (Resh, 1979).

Total counts of the sample were normalized and equal variances achieved through the Box-Cox transformation. One-way ANOVA was applied to the transformed counts and a significant difference was detected among group means ($P = 0.0208$, power = 0.55, at $P < 0.05$). A Student's t pairwise comparison test detected differences between four reaches: UR1 versus LR3, UR1 versus LR2, UR3 versus LR3, and UR3 versus LR2. Therefore, two sampling reaches above the upper boundary waterfall differed from two reaches below the waterfall. Appendix, Table A-12 indicates that the two lower most (i.e., downstream-most) reaches have greater counts compared to all other reaches. However, the high counts for both reaches primarily come from three tiles that had high

chironomid abundances ($X_2 = 204$ and $X_5 = 152$ in LR2 and $X_2 = 293$ in LR3).

The high chironomid counts again "masked" the presence of other taxa in the sample. Resultantly, the sample was re-analyzed with chironomids removed. The untransformed original counts were tested for normality and a significant departure from a normal distribution was detected ($P = 0.0001$ at $P < 0.05$). However, three methods for transforming the data (i.e., log, square root, and Box-Cox) failed to normalize the non-chironomid counts. Upon close examination of the data, comparatively large counts of early instars of Ephemerellidae were enumerated from two tiles in reach LR2 (i.e., $X_2 = 26$ and $X_5 = 32$) and one from reach LR3 ($X_2 = 37$). These three sampling units were creating a strong positive skewness in the distribution of the data and were the primary cause for a non-normal distribution and unequal variances. The data were reanalyzed with the three outliers removed and the original untransformed counts tested marginal for normality ($P = 0.045$). Rather than relying on parametric analysis in this instance, the distribution-free Kruskal-Wallis test was applied and failed to detect significant differences among rank sums of the six reaches with the outliers removed ($X^2 = 6.956$, df = 5, $P = 0.224$ at $P < 0.05$). The nonparametric test was applied a second time on the original counts with outliers present and the results were similar, no significant differences among rank sums were detected ($X^2 = 7.981$, df = 5, $P = 0.157$ at $P < 0.05$).

Of the trophic groups occupying tiles, scrapers occupied the majority of the substrates and had the highest non-chironomid numbers in two reaches below the upper boundary waterfall. Previously mentioned, ephemerellids contributed to high counts and sample statistics in reaches LR2 and LR3. Due to skewness and non-normality of the scraper counts, nonparametric methods were chosen to examine scraper numbers. The

significance probability value from the Kruskal-Wallis test indicated a marginal significant difference among stream reaches for the untransformed scraper numbers (X^2 = 10.849, df = 5, P = 0.055 at $P < 0.05$). The Nemenyi multiple comparisons test for rank sums indicated a marginal difference (test value q = 4.191, at critical value of $q_{0.05, \infty, 6}$ = 4.030) between the lowest reach, LR3, and one reach upstream of the upper boundary waterfall, UR3. The reach with the highest count of scrapers is LR3 with UR3 having the lowest count. By removing the ephemerellid outliers, no significant difference is detected by the tests.

The utility of tile sampling in Mannis Branch is questionable. Lamberti and Resh's (1985) supposition that introduced substrates accurately represent macroinvertebrate density and species composition of natural rocks appear not to apply in Mannis Branch. Although statistical comparisons between unglazed quarry tiles and natural rocks are not assessed here, broad comparisons and generalizations can be made by contrasting the data from rock sampling (Appendix, Table A-2 to Table A-5) with the results from tile sampling (Appendix, Table A-10 to Table A-12). One plausible reason for the difficulty in using this method in Mannis Branch is that very little sunlight reaches the stream's surface. Throughout the stream's course, a mature and dense overstory filters sunlight, which may inhibit a suitable and abundant periphyton community to develop on the tiles within a narrow time frame (Rosenberg and Resh, 1982). Therefore, conditions for creating potential foraging opportunities for various consumers ranging from scrapers or grazers to predators are lacking on recently introduced tiles. Should the tiles be allowed to incubate longer than the periods used in this trial, different results may occur.

Leaf Packs

Mesh bags containing leaves of a single tree species, sugar maple (*Acer saccharum*), and of standard weight (i.e., 20 g) were examined in this study to evaluate the method's utility for deriving density estimates of colonizing macroinvertebrates. Leaf packs were standardized for weight and leaf species to create a constant substrate in an attempt to control variability between sample packs. The placement of leaf packs was consistently in shallow riffle areas, typically along stream margins as another attempt to control potential environmental variability. In all, 24 packs were placed in Mannis Branch, 12 upstream and 12 downstream of the upper boundary waterfall. Leaf packs were incubated in the stream for approximately four weeks.

Three separate sampling or incubation periods were attempted in Mannis Branch. The first was incubated for 29 days beginning on 19 February to removal on 19 March 1998. The second incubation spanned 27 days from 7 June to 3 July 1998 and the third for 26 days from 17 October to 11 November 1998. The June – July and October – November samples underwent unexpected and unanticipated environmental perturbations. Prior to leaf pack placement in early June, sustained rains over the preceding weeks had elevated stream flow and unwittingly, leaf packs were placed in riffle areas of shallow depth (approximately 8 to 14 cm) along the stream margin. During the incubation period, very little precipitation fell and accordingly, stream flows decreased markedly. Upon leaf pack retrieval on 3 July, 16 of the 24 leaf packs were sitting on dry cobble away from the stream's edge. The contents of those bags were primarily of terrestrial origin and semi-aquatic Collembola and are not considered further in this study. Leaf packs of the October – November period were incubating during the

height of autumnal leaf fall. Upon retrieval of the packs on 11 November, well over 80% of the bags were hidden beneath volumes of fallen deciduous leaves and because of this, two sources of error occurred during the sampling process. Retrieval of each mesh bag led to the collection of individuals inhabiting the mass of leaves that had fallen or lodged against the sample unit. Also, leaves that were amassed over or against the bags had to be removed prior to retrieving the packs. This created disturbances in the immediate area of the leaf packs and likely dislodged colonizing macroinvertebrates. These sampling errors resulted in collections that were not truly representative of each unit or leaf pack. Because of the wide fluctuations of individuals per bag, this sample is not considered further. Thus, the only sample that provides a consistent and useable measure for examining density of colonizing macroinvertebrates per leaf pack is the February – March sample.

The general design of the layout for the February – March sample has limitations. A single site was selected upstream and downstream of the upper boundary waterfall for sampling and is therefore pseudoreplicated (Hurlbert, 1984). However, this limited evaluation of leaf pack sampling examines the taxa collected and analytical challenges of using this method for density estimates and hypothesis testing.

Approximately 53 taxa were collected in the February – March sample. Included in this estimate are taxa representing six families of Ephemeroptera, seven families of Plecoptera, and ten families of Trichoptera (Appendix, Table A-13). Taxa occurring in at least 75% of all leaf packs are *Ameletus cryptostimulus*, early instars of Ephemerellidae, *Paraleptophlebia adoptiva/mollis*, *Amphinemura* sp., *Tallaperala* sp., *Isoperla* sp. and early instars of Perlodidae, *Lepidostoma* sp., and Chironomidae. Of these, the genera

Paraleptophlebia, *Amphinemura*, *Tallaperla*, and *Lepidostoma* are principally shredders (Unzicker and Carlson, 1982; Unzicker et al., 1982; Stewart and Stark, 1988; Stewart and Harper, 1996) and together with the number of early instars of Leptophlebiidae and Peltoperlidae, comprise approximately 32% of the total number of macroinvertebrates collected from all leaf packs. Additional shredders collected in the sample but present in low numbers are *Pteronarcys* sp., *Pycnopsyche* spp., and *Tipula abdominalis* (see Cummins and Klug, 1979; Unzicker and Carlson, 1982; and Stewart and Stark, 1988 for trophic information). Several taxa occurring in the sample may function as shredders at some point in their life histories but undergo trophic shifts at various developmental stages (Stewart and Stark, 1988). For instance, the consistent presence of *Isoperla* sp. cf. *similis* and high number of early instars of Ephemerellidae and Perlodidae may represent occurrences whereby these organisms are functioning as shredders or collectors rather than as predators for *Isoperla* and Perlodidae or as scrapers for Ephemerellidae (confer with Appendix, Table A-1, "Trophic Group" designations). Therefore, the interpretation of the numbers representing a trophic guild should be viewed as an approximation or a generalization for this study.

In spite of the numbers of shredders appearing in the February – March sample, Chironomidae alone accounted for 33% of all invertebrates collected. Additional species possibly functioning as collectors in the leaf packs are Baetidae and Heptageniidae both of which have other functional roles such as scrapers (Unzicker and Carlson, 1982).

Total numbers collected were examined for normality and equal variances and the appropriate data transformation explored. The Shapiro-Wilk test for normality detected a significant departure from a normal distribution ($P = 0.008$ at $P < 0.05$) of the raw data.

Likewise, the null hypothesis that variances are equal is rejected in four applied tests (P = 0.022, 0.024, 0.006, and 0.009 for the O'Brien, Brown-Forsythe, Levene, and Bartlett tests, respectively). Examination of the raw data reveals that the counts are highly variable and skewed due to the high counts of some of the units (e.g., $X_{10} = 470$ and $X_{11} = 469$ in the site above the upper falls; Appendix, Table A-13). To normalize the data and remove heteroscedasticity, the log (x + 1) transformation and the Box-Cox power transformation are applied to the original counts and compared. Log transformation of the values was successful in making the distribution more normal ($P = 0.372$ at $P < 0.05$) and for removing heteroscedasticity ($P = 0.083$, 0.133, 0.127, and 0.118 for the O'Brien, Brown-Forsythe, Levene, and Bartlett tests, respectively). The Box-Cox transformed data provided the best fit of the data for normality ($P = 0.720$ at $P < 0.05$) but failed to remove unequal variances ($P = 0.023$, 0.043, 0.043, and 0.054 at $P < 0.05$ for the four respective variance tests above). Therefore, the log transformed procedure provided the best transformation for preparing the data for parametric analysis.

Because there are only two sites to compare, the Student's t test is applied. The Student's t failed to detect a significant difference between the two sites using the log transformed counts (t =-0.91; df = 22; $P = 0.377$ at $P < 0.05$). It was anticipated that the large counts of chironomids may be masking differences occurring in the data set. Log transformed counts were re-examined with Chironomidae removed. Resultantly, the Student's t failed to detect significance between the sites using total counts with midges removed (t = -0.813, df = 22, $P = 0.425$ at $P < 0.05$).

The principal functional feeding group in the leaf packs is shredders and because of their importance to this sampling method taxa representative of the guild are analyzed.

Taxa included in the analysis are *Lirceus* sp., Leptophlebiidae, Leuctridae, Peltoperlidae, Pteronarcyidae, Lepidostomatidae, Limnephilidae, and *Tipula abdominalis*. Log transformation of the shredder counts both normalized the data ($P = 0.118$ at $P < 0.05$) and removed heteroscedasticity ($P = 0.301$, 0.445, 0.487, and 0.434 at $P < 0.05$ for the O'Brien, Brown-Forsythe, Levene, and Bartlett tests, respectively). Student's t test on the log transformed counts failed to detect a significant difference between the two sampling sites ($t = -1.104$ df = 22, $P = 0.2815$ at $P = 0.05$).

A final statistical test was performed on the remaining taxa after Chironomidae and shredders were removed. This particular subset is primarily constituted of collectors and/or taxa possessing two or more functional roles (e.g., scrapers – collectors or collectors – predators, etc.). Taxa contributing to the majority of the counts in this analysis are Ephemerellidae (36%) and Perlodidae (24%). Raw, untransformed counts of this group are normally distributed ($P = 0.314$ at $P < 0.05$) and are marginal for equal variances (range of probability values from $P = 0.078$ for the Levene test to $P = 0.125$ for O'Brien's test). Student's t test applied to the raw counts of this subgroup failed to detect significance between the two sampling sites ($t = 0.362$, df = 22, $P = 0.721$ at $P < 0.05$).

It is difficult and premature to predict or calculate the required sample size based on this limited sample. However, an approximate number of mesh bags required for deriving density estimates within a narrow range of the true mean may be projected. Applying the sample statistics to the equation in Eckblad (1991), the accuracy estimate over all 24 bags is within 26% of the true mean (mean = 190.5, variance = 13239.391, N = 24, $t = 2.069$, df = 23 at $P = 0.05$). Accuracy estimates for the two respective sampling sites are 42% for the site upstream of the upper boundary waterfall and 25% for the area

downstream of the waterfall. This disparity is primarily due to a large invertebrate count for three sample units above the waterfall (Appendix, Table A-13). To lower these estimates to within 10% of the true mean will require a sample size of 209 and 76 leaf packs respective to each site. However, by accepting an accuracy estimate of 20% within the true mean, a sample size of 52 and 19 packs are required. This estimate does not improve by segregating the counts into functional groups either. Using the counts of shredders alone at an accuracy level of 20% of the mean, 84 leaf packs are required for the upper site and 75 are required for the lower site.

A limitation of these sample size estimates is that they are derived from a single sample taken in late winter and may not be representative of other seasons. It is possible that summer or early autumn sampling (prior to leaf fall) may have less variable collections and may be the preferred time of year for employing this method.

A final assessment of this method relates to the effort involved in processing the samples. The time required for placing and securing mesh bags in the stream generally takes 10 minutes per bag and retrieval time is comparable. However, processing a leaf pack in the laboratory often takes 30 minutes or more per bag as each leaf must be thoroughly washed to remove living invertebrates. Once the contents are preserved, sorting, enumerating, and identifying each sample pack often requires two to four hours.

Drift Sampling

Drift samples were collected over a 24-hour period in April, June, and November 1998. Drift from these periods are selected for evaluation due to the consistency of sampling methodology, non-storm events, and sample processing for each of the three

periods. The standard unit of measurement used for evaluating or comparing drift samples is the number of individuals collected over a one-hour sampling interval per 100 m^3 of flow filtered through the drift net (Allan and Russek, 1985). All samples are standardized to 100 m^3 due to the high variability of flow per hourly sample. One critical limitation to this method is that only a single drift net was used per site or stream section (i.e., upstream and downstream of the upper boundary waterfall). Due to the labor involved, replicate nets per section were not used. Therefore, drift density estimates from a single net per section are compared for generalized differences.

Drift was collected on 26-27 April 1998 during the New Moon phase of the lunar cycle to avoid potential depressant effects of moonlight on stream drift (Anderson, 1966). Air temperatures taken 1 m above the stream's surface ranged from 10.5^{0}C at night to 23^{0}C during the day. Stream temperatures ranged from 11^{0}C at night to 13^{0}C during the day. Hourly samples were carefully scheduled to concentrate sampling efforts on the hours preceding and following sunrise and sunset. Sunrise times for 26 and 27 April were 0649 and 0648 (EDT), respectively. Sunset occurred at 2018 and 2019 (EDT) respectively for the two dates.

Mean discharge per net-hour for the April sample was relatively high and likely contributed to the large numbers of invertebrates collected per sample (Appendix, Table A-14). The drift site downstream of the upper boundary waterfall (D2) on average filtered 1.8 times more water per hour than the site upstream of the waterfall (D1). However, D1 had a higher drift density in practically every hourly sample (Figure 8).

The drift pattern of Figure 8 is very similar to other studies that have examined the drift phenomenon (e.g., Waters, 1962; Waters, 1965; Elliott, 1970; Müller, 1974).

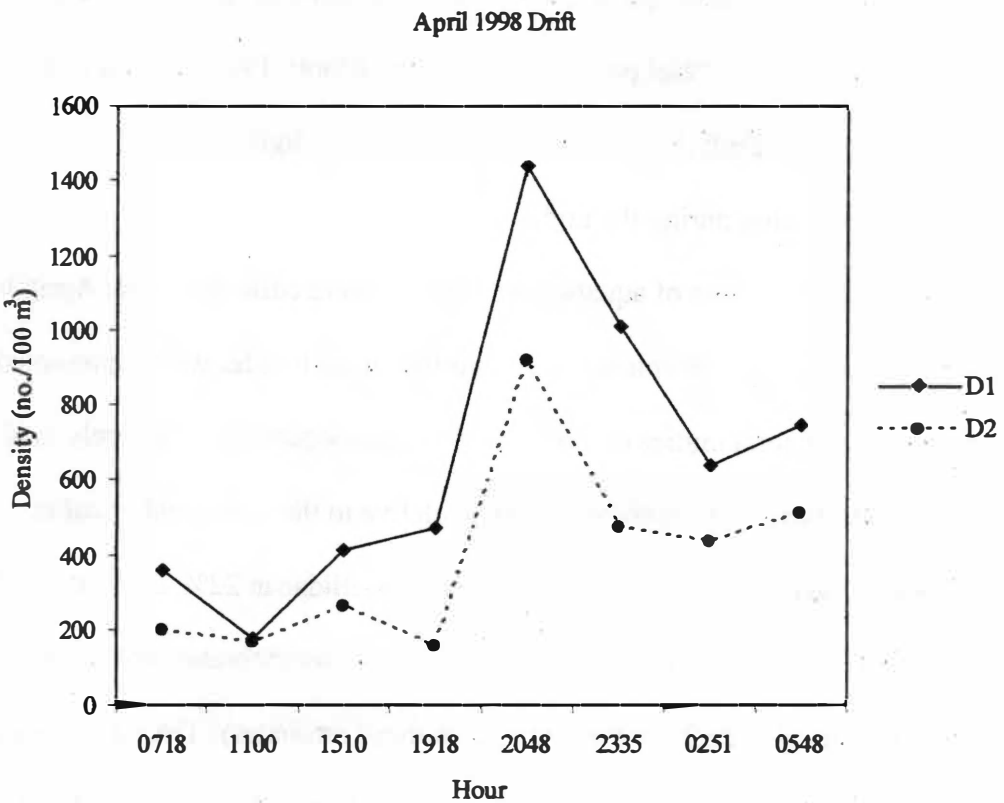


Figure 8. Hourly drift samples taken from two sites (D1 and D2) on Mannis Branch, 26-27 April 1998. Each hour represents the beginning of an hourly sample (EDT). Sunrise times were 0649 and 0648 for 26 and 27 April, respectively. Sunset times were 2018 and 2019 for 26 and 27 April, respectively. Site D1 is upstream of the upper boundary waterfall and site D2 is downstream of the waterfall.

There is a sharp and abrupt increase in drift density for both sites in the hour before and immediately after sunset followed by a slow decline throughout the night. Just prior to sunrise, a second increase, although at a lower rate, in drifting invertebrates occurred. Based on this single sample, "diel periodicity" of drift (Elliott, 1970) is occurring in both sites in Mannis Branch. Drift densities occurring during daylight hours are generally lower than those occurring during the night.

Approximately 77 taxa of aquatic invertebrates were collected in the April drift. Of the Ephemeroptera and Plecoptera, seven families of each order were represented in the sample along with ten families of Trichoptera. Taxa occurring consistently in all hourly samples and having the highest densities relative to the total number collected were the families Baetidae, Peltoperlidae, and Ephemerellidae at 22%, 20%, and 13%, respectively for a total contribution of 55% of all aquatic invertebrates (terrestrial invertebrates appearing in drift are not included in these estimates). Drift densities for each of the three families are compared between sites (D1 and D2) per diurnal and nocturnal periods (Figure 9). For each family, there appears to be a definite drift pattern between sites and between day and night. A slightly greater number of individuals were in stream drift for both diurnal and nocturnal periods at site D1 compared to D2. Similar to what was noted for total drift, greater numbers respective to these three families entered drift during the night compared to daylight hours. For April, a diel periodicity of some taxa is suggested for Mannis Branch.

The four hourly samples of diurnal and nocturnal drift were pooled and tested for significant differences between drift sites per diel period. Tests were conducted on total counts and on drift densities of the three most abundant families; Baetidae,

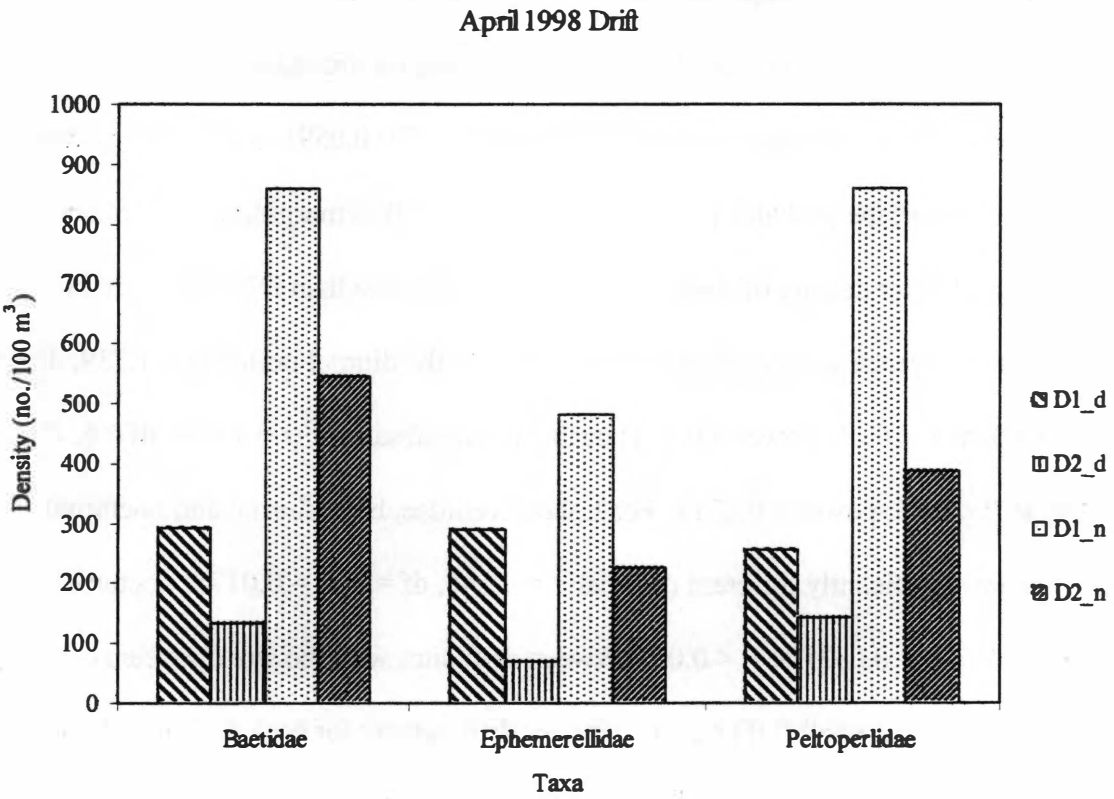


Figure 9. Drift densities of the three most abundant families of invertebrates (Baetidae, Ephemerellidae, and Peltoperlidae) in the 26-27 April 1998 drift sample. Density estimates are determined for daytime drift at each site (D1_d and D2_d) and nocturnal drift per site (D1_n and D2_n).

Ephemerellidae, and Peltoperlidae. After confirmation of normality and equal variances, the Student's *t* test was performed on total counts in the nocturnal samples respective to each drift site, and a significant difference was not detected ($t = 1.778$, df = 6, $P = 0.1256$ at $P < 0.05$; power = 0.323). Similarly, tests conducted on diurnal drift were not significantly different between sites ($t = 2.325$, df = 6, $P = 0.0591$ at $P < 0.05$; power = 0.497). However, the probability test value of $P = 0.0591$ is marginally significant with D1 having a higher density of daytime drifting invertebrates than D2. For Baetidae, no significant difference was detected between sites for the diurnal period ($t = 1.739$, df = 6, $P = 0.1328$ at $P < 0.05$; power = 0.311) or the nocturnal sample ($t = 1.445$, df = 6, $P = 0.199$; at $P < 0.05$; power = 0.231). For Ephemerellidae, both diurnal and nocturnal samples are significantly different (diurnal: $t = 3.248$, df = 6, $P = 0.0175$; nocturnal: $t = 2.754$, df = 6, $P = 0.0331$ at $P < 0.05$) between drift sites with the site upstream of the upper boundary waterfall (D1) having a higher drift density for both diel periods. Drift density of Peltoperlidae was significantly different for day drift ($t = 2.933$, df = 6, $P = 0.026$ at $P < 0.05$) but not for night drift ($t = 1.602$, df = 6, $P = 0.1603$ at $P < 0.05$). Drift site D1 had a significantly higher density of diurnal drifting Peltoperlidae than did site D2.

Forrester (1994) examined drift behavior of *Baetis* in the presence and absence of brook trout in a second-order stream in New Hampshire and discovered differences in the mayfly's propensity to drift under the two conditions. He observed a general pattern in which *Baetis* drifted at higher densities and rates in the presence of charr than in the predator's absence. For this single sample, that pattern is not detected in the statistical analyses of the pooled diurnal and nocturnal drift. Furthermore, by comparing general

drift densities (Figure 9), other than significance tests, it appears that baetids drifted in slightly greater numbers in the site with no trout (D1) than in the section with trout (D2). It must be emphasized that this is a general observation and is not backed by testable results. However, the general differences in drift between the two sites for Baetidae, Ephemerellidae, and Peltoperlidae may warrant further study.

Drift was collected on 28-29 June 1998, approximately four days following the New Moon phase of the lunar cycle. Air temperatures taken 1 m above the stream's surface ranged from 19.5^{0}C at night to 23.5^{0}C during the day. Stream temperatures remained constant at 18^{0}C for both night and day. Sampling schedule was identical to April in that hourly samples were taken during the hours preceding and following sunrise and sunset with two additional samples collected over the respective diel periods. Sunrise for 28 and 29 June was 0622, and sunset occurred at 2056 (EDT).

Stream flow was much lower during the June sample compared to April (Appendix, Table A-15). The average hourly flow filtered through the drift nets per site was approximately 36.7 m^3 for the upper site (D1) and 46.7 m^3 for the downstream site (D2); a difference of almost three times less than the April sample.

A pattern similar to the April drift is suggested by the increase in the density of drifting insects in the nocturnal samples (Figure 10). Drift densities remained at a consistent level for both sites until approximately one hour before sunset when aquatic invertebrate numbers began to increase. Drift occurring at D1 increased slightly more than two times that for the morning and mid-afternoon hours and remained elevated throughout the night and early morning hours. The abrupt increase in drift density at D2 is attributed to a single taxon that was collected during the hour following sunset. This

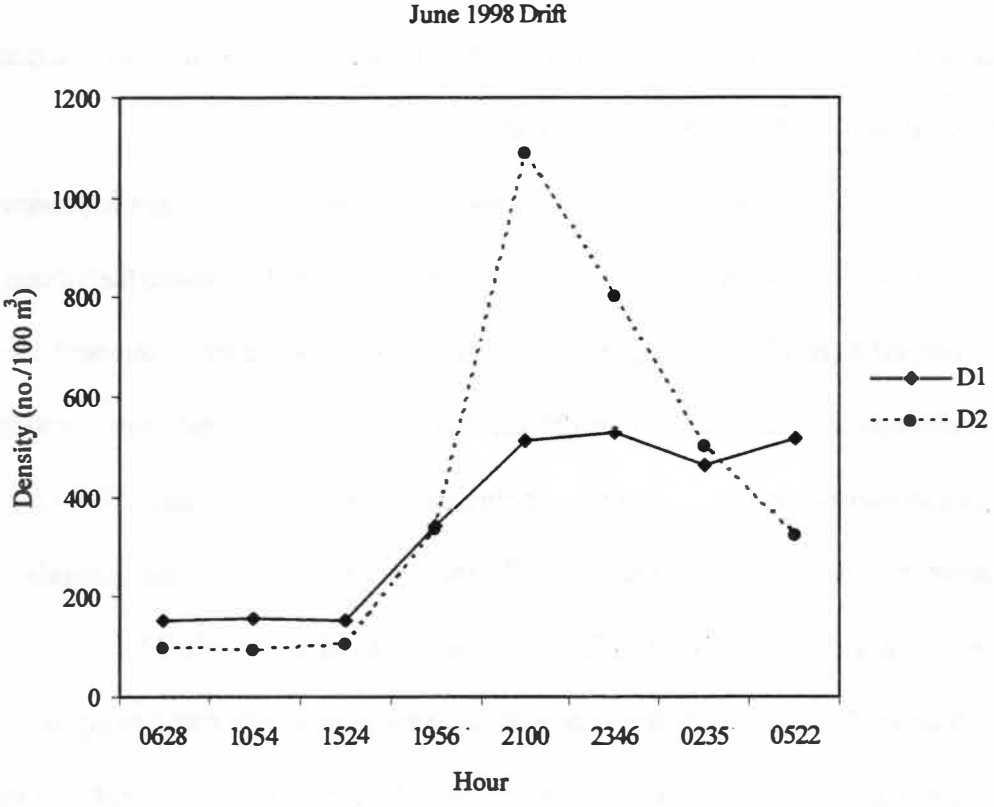


Figure 10. Hourly drift samples taken from two sites on Mannis Branch, 28-29 June 1998. Each hour represents the beginning of an hourly sample (EDT). Sunrise times were 0622 and 0622 for 28 and 29 June, respectively. Sunset times were 2056 and 2056 for 28 and 29 June, respectively. Site D1 is upstream of the upper boundary waterfall and site D2 is downstream of the waterfall.

single sample consisted of 273 individuals of *Tallaperla* sp. (Appendix, Table A-15). Converting this count to the standard volume of 100 m^3 translates to a density of 666 individuals, which accounted for 61% of all individuals in this one-hour sample. No other taxon occurring in this sample drifted in such high numbers. Other studies that have recorded high numbers of drifting insects over a given sampling interval have attributed such occurrences to upstream disturbances such as a large animal crossing a stream (e.g., O'Hop and Wallace, 1983). In such a situation, it would seem that a marked increase would occur in multiple taxa rather than in a single taxon as in this case. Applying this observation to the presence of a top predator, trout, it seems highly unlikely that fish presence would cause *Tallaperla* alone to drift in such high numbers. However, it is not clear how peltoperlid stoneflies behave in the presence of trout. It may be that trout presence increases a propensity in peltoperlids to drift under low light conditions for predator avoidance. This is often one explanation given for the phenomenon of benthic macroinvertebrates drifting in greater numbers at night (Allan, 1978).

Overall, 55 taxa were collected in the June sample with the majority representing five families of Ephemeroptera, six familes of Plecoptera, and nine families of Trichoptera. Very few taxa were collected consistently and at high densities. Many species appeared infrequently with a few being represented by a single occurrence. Ephemerellidae, one of the most common and abundant mayfly families of the April drift, appeared sporadically in the June drift and accounted for approximately 1% of the total number. Three families of insects comprised over 71% of the total number of individuals in June. Peltoperlidae accounted for 44% of the total numbers collected followed by Baetidae at 20% and Elmidae at 7%.

Drift densities for each of the three families above are compared between sites D1 and D2 per diurnal and nocturnal periods (Figure 11). Density of diurnal drift at both sites was very similar for Elmidae (t = -0.086, df = 6, P = 0.9341 at $P < 0.05$). For Peltoperlidae, day drift between the two sites was not significantly different (t = 0.601, df = 6, P = 0.5697 at $P < 0.05$). Baetidae density, however, was significantly greater in the diurnal drift at D1 than at D2 (t = 2.849, df = 6, P = 0.0292 at $P < 0.05$). Tests on the nocturnal drift indicated no significant difference between D1 and D2 for Baetidae (t = 0.198, df = 6, P = 0.8493 at $P < 0.05$), Elmidae (t = 0.707, df = 6, P = 0.5060 at $P <$ 0.05), or for Peltoperlidae (t = -1.429, df = 6, P = 0.2030 at $P < 0.05$). Though significance was not statistically detected for the night drift of Peltoperlidae, the extraordinary density estimate for a single one-hour period is of note (Figures 10 and 11; Appendix, Table A-15).

For a final evaluation of drift for the June period, total numbers from the four hourly samples of diurnal and nocturnal drift were pooled and tested for significant differences between drift sites per diel period. The distribution-free Kruskal-Wallis was performed on day drift between the two sites and no significant differences were detected (X^2 = 2.1084, df = 1, P = 0.1465 at $P < 0.05$). The Student's t failed to detect significance of the log (x + 1) transformed nocturnal counts (t = -0.942, df = 6, P = 0.382 at $P < 0.05$).

For November, drift was collected two nights prior to the New Moon phase on the 17th and 18th. Air temperature ranged from 2.5^{0}C at night to 12.0^{0}C during the day. Stream temperature varied from 9.0^{0}C at night to 11.5^{0}C during the day. Sunrise times for 17 and 18 November were 0712 and 0713, and sunset occurred at 1728 and 1727

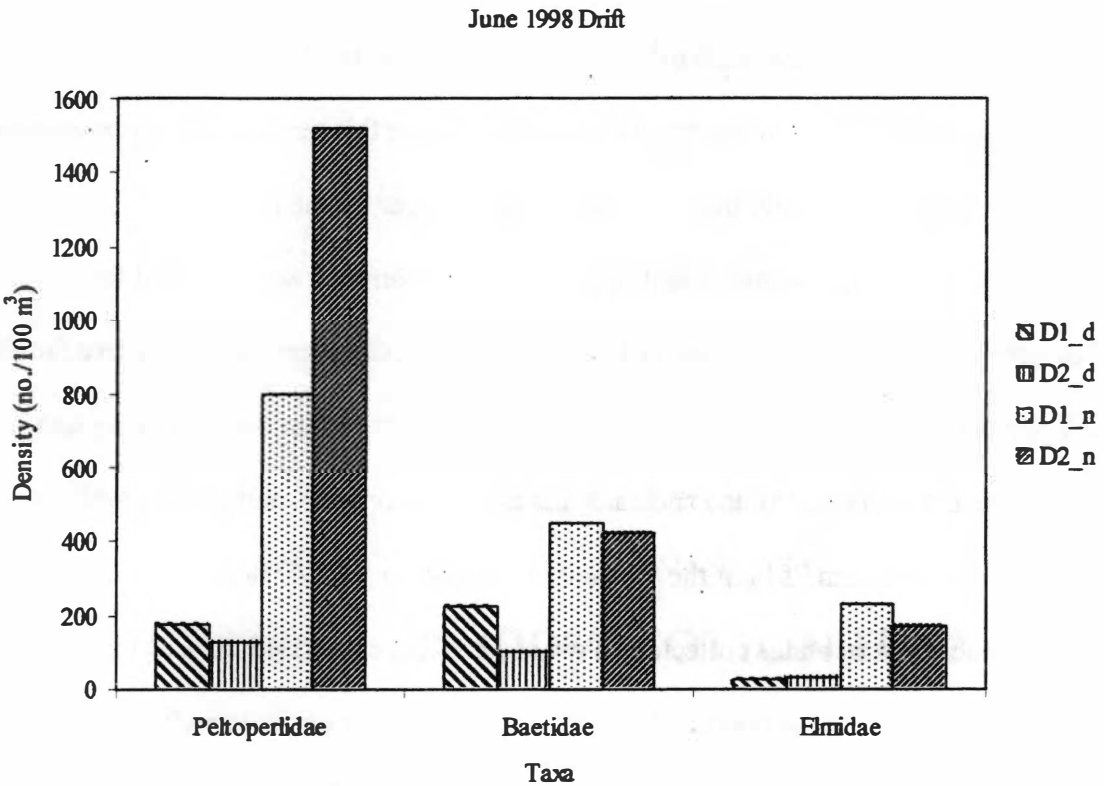


Figure 11. Drift densities of the three most abundant families of invertebrates (Peltoperlidae, Baetidae, and Elmidae) in the 28-29 June 1998 drift sample. Density estimates are determined for daytime drift at each site (D1_d and D2_d) and nocturnal drift per site (D1_n and D2_n).

(EST) respectively.

Stream flows during the November collection were the lowest of the three samples (Appendix, Table A-15). The average hourly flow filtered through the drift nets per site was approximately 22.0 m^3 for the upper site (D1) and 16.3 m^3 for the downstream site (D2). The extremely low flows during this period may not be unusual because autumn is typically the driest season of the year for the region.

The lowest taxonomic count of the three drift samples was recorded for November. Overall, 40 taxa were collected with 78% being represented by five families of Ephemeroptera, seven families of Plecoptera, and eleven families of Trichoptera. Only three taxa, Chironomidae and early instars of *Epeorus* sp. and Ephemerellidae, appeared in more than 75% of the 16 samples, accounting for 47% of the total number of aquatic macroinvertebrates collected. Two species that comprised 20% of total drift but appeared primarily in the nocturnal samples were *Ameletus cryptostimulus* and *Paracapnia angulata* (Figure 12). Additional taxa that exhibited a propensity for drifting at night were *Paraleptophlebia adoptiva/mollis*, early instars of Perlodidae, and *Dixa* sp., collectively comprising 10% of the total count.

Comparatively, the drift site in the section of Mannis Branch that supports brook trout (i.e., D2) had the highest drift density over the 24-hour period (Figure 13) but oddly, the lowest flow filtered through the drift net. The overall pattern of drift for November is similar to the preceding samples in that higher numbers of aquatic invertebrates entered drift during the night with the greatest increase over any given period occurring around sunset. However, the sharp increase in drift density for the mid-morning sample at site D2 is unlike any other sample examined in this study. In the sample collected from

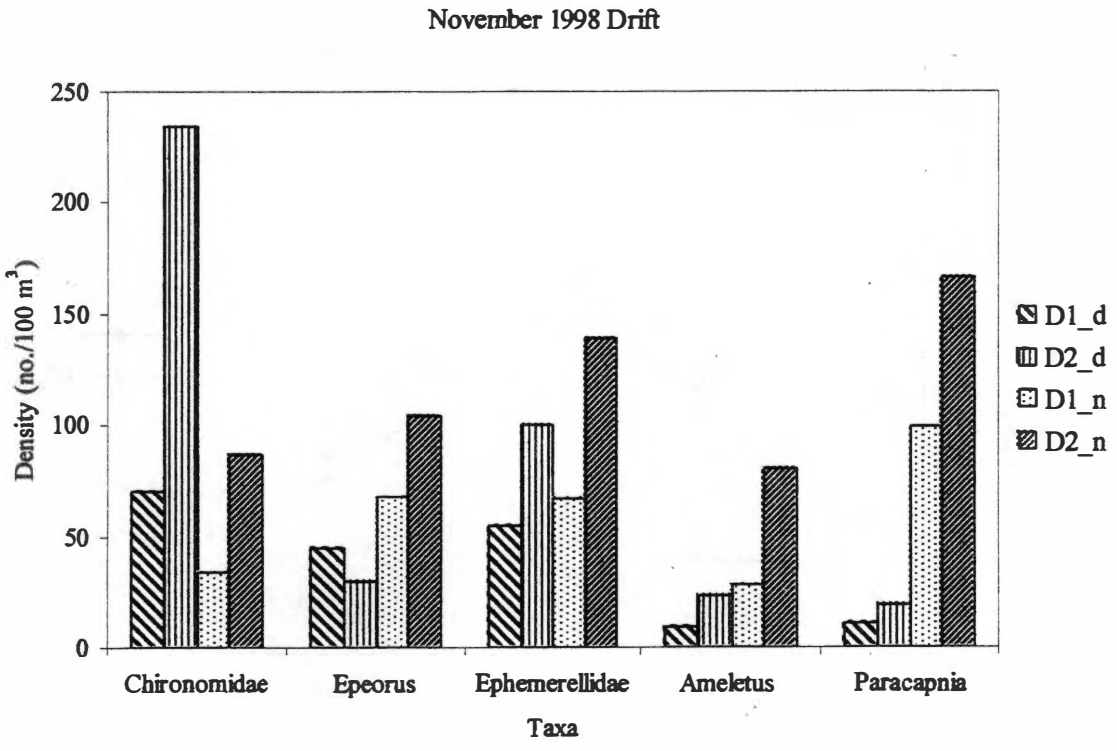


Figure 12. Drift densities of the five most abundant taxa in the 17-18 November 1998 drift sample. Density estimates are determined for daytime drift at each site (D1_d and D2_d) and nocturnal drift per site (D1_n and D2_n).

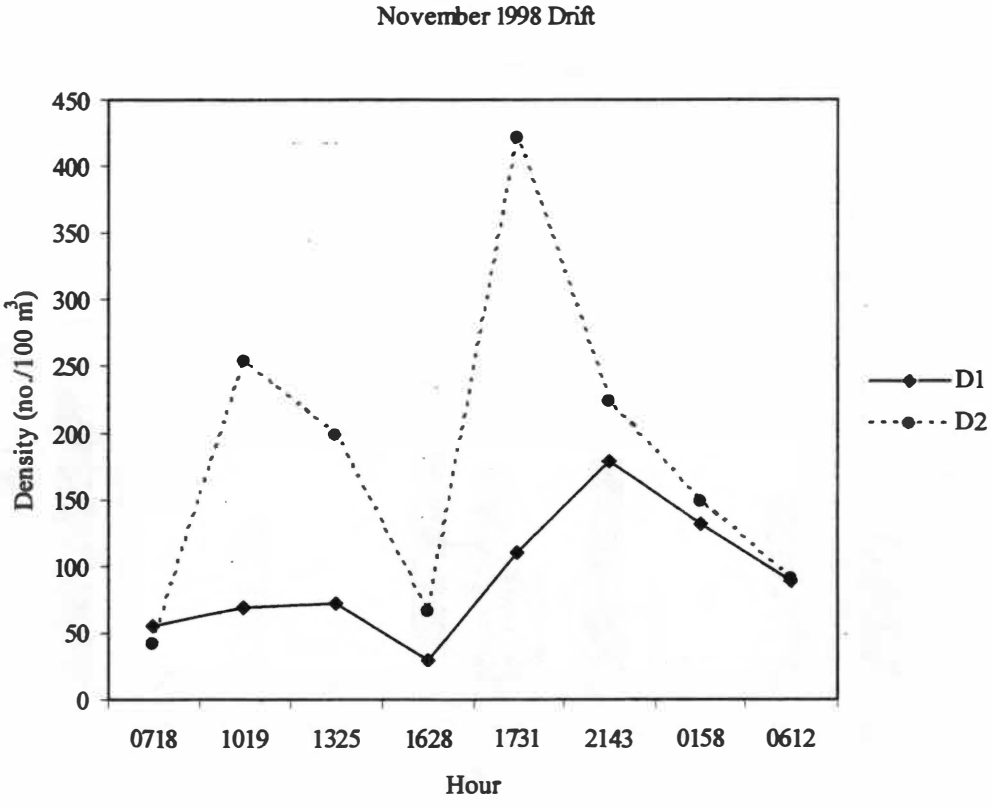


Figure 13. Hourly drift samples taken from two sites on Mannis Branch, 17-18 November 1998. Each hour represents the beginning of an hourly sample (EST). Sunrise times were 0712 and 0713 for 17 and 18 November, respectively. Sunset times were 1728 and 1727 for 17 and 18 November, respectively. Site D1 is upstream of the upper boundary waterfall and site D2 is downstream of the waterfall.

1019-1119, Chironomidae comprised 37% of the total number collected. Additionally, 16 taxa entered drift for this one-hour period (i.e., hour 1019-1119; Appendix, Table A-16), the most for any diurnal sample during November. There is no clear explanation for this increase in the number of taxa entering the drift or for the high drift density. The second sudden increase in drift density at D2 occurred near sunset (Figure 13) when 20 taxa entered drift. Approximately 70% of the sample collected at sunset was comprised of five taxa: *Paracapnia angulata* at 18%, *Epeorus* spp. and early instars of Ephemerellidae both at 15%, Chironomidae at 13%, and *Ameletus cryptostimulus* at 9%.

Total numbers as well as the most commonly occurring taxa in the four hourly samples of diurnal and nocturnal drift were pooled and tested for significant differences between sites. Total counts were log (x +1) transformed to fit a normal distribution ($P = 0.149$) and to achieve equal variances ($P = 0.500$, O'Brien's test at $P < 0.05$). The Student's t test detected no significant differences between sites of the diurnal drift ($t = -1.407$, $df = 6$, $P = 0.209$ at $P < 0.05$; power = 0.221) or for nocturnal drift ($t = -1.407$, $df = 6$, $P = 0.668$ at $P < 0.05$; power = 0.067). Likewise, no significant differences were detected for log (x + 1) transformed counts of early instars of Ephemerellidae for both diurnal ($t = -0.775$, $df = 6$, $P = 0.468$ at $P < 0.05$; power = 0.101) and nocturnal samples ($t = -1.617$, $df = 6$, $P = 0.157$ at $P < 0.05$; power = 0.276). The distribution-free Kruskal-Wallis test was performed on the original, untransformed counts of *Epeorus* sp. and no significant difference was detected between sites for the diurnal or nocturnal samples (test statistics for both samples are $X 2 = 0.333$, $df = 1$, $P = 0.564$). Due to the infrequent diurnal collection of *Paracapnia angulata* and *Ameletus cryptostimulus*, counts from the nocturnal samples alone were examined for significance for the two species. The

Kruskal-Wallis test detected no significant differences between the two sites for both species ($X^2 = 0.333$, df = 1, $P = 0.564$ at $P < 0.05$). Other than Chironomidae, all other taxa occurred so sporadically that tests for significance could not be applied.

Several taxa that were prominent in the April and/or June samples (e.g., Baetidae and Peltoperlidae) occurred in very low numbers for the November sample. Conversely, taxa that were present in low numbers or absent in the preceding samples appeared more frequently in November as in the case for *Paracapnia angulata*. This is a direct response of temporal changes occurring in the benthos. Many taxa that were common or appeared as early or late instars in the April and June samples have emerged as adults by autumn. These seasonal shifts are very important to note and understand while sampling for cause and effect relationships. It is of paramount importance for the investigator to become familiar with the life histories of the target population (Resh, 1979); in this case the aquatic macroinvertebrates of Mannis Branch. By doing so, the temptation to project and declare apparent cause and effect processes, such as predatory impacts, may be judiciously applied with the assistance of statistical analyses.

A final evaluation of the drift sampling method is the time and effort involved for processing samples. Often, drift nets become clogged with detritus and coarse debris. This renders sample sorting particularly laborious and time consuming. For this reason, many researchers resort to subsampling each individual drift sample with subsamples often taken from 25 to 75% of the total sample volume (Allan, 1982; Allan, 1985). This saves a tremendous amount of time when processing samples (Barbour and Gerritsen, 1996). However, the trade offs are that rare taxa are likely to be missed or overlooked and some errors may be made when extrapolating a proportion of the sample to total

numbers per sample volume. For this reason, drift samples were processed in their entirety during this study. Samples collected during periods of high flow that collected much detritus (e.g., April drift) took 12 to 20 hours to sort, identify, and catalog a single, hourly sample. Thus, time and effort must be considered during the planning stages for using drift as a sampling method.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Data Transformations and Preliminary Analyses

The purpose of this study was to examine and evaluate five aquatic sampling methods for potential use in a future quantitative study in Mannis Branch. The primary approach taken in this study was to examine the characteristics of the data collected by each method and to explore plausible procedures for preparing the samples for significance tests. This was viewed with great importance as the underlying purpose for the next stage of this study is to test the null hypothesis that a top predator does not exert a detectable influence on the benthic community in Mannis Branch. It was felt that by finding and employing the most appropriate tools for preparing the data for statistical evaluation and then applying preliminary tests, helpful insights may be provided toward avoiding potential pitfalls and mistakes that may ultimately weaken the final analyses and the interpretation of results.

It is generally held that parametric methods are preferred over nonparametric techniques for testing hypotheses because the latter performs less powerful tests due to fewer assumptions about the data (Elliott, 1977; Green, 1979). The use of parametric techniques (e.g., ANOVA) requires that certain assumptions concerning the data are met. Two assumptions critical to the preparation of data for parametric analyses are that sample data are normally distributed and have equal variances. However, species counts from field studies, especially where sample sizes are low and highly variable, rarely meet

these assumptions (Green, 1979; Allan, 1984; Potvin and Roff, 1993). A commonly used tool to overcome this problem is transformation of the sample data, which changes the scale of the original measurements to fit a normal distribution and removes the dependency of the variance on the mean (Green, 1979; Allan, 1984). In this pilot study, log (x + 1) and the Box-Cox power transformations (the latter using an iterative model in the statistical program JMP) were two commonly used procedures for transforming sample counts to meet these assumptions where tests for normality (i.e., the Shapiro-Wilk test) and equal variances (i.e., the O'Brien, Brown-Forsythe, Levene, and Bartlett tests) detected significant departures. Generally, both techniques were successful in transforming the species counts to a normal distribution and removing variance – mean dependency. In several instances, data sets that were transformed by both procedures were tested by one-way ANOVA and test results compared. Where comparisons of the two procedures were made, test results were often very similar. Occasionally, both transformations failed to meet the assumptions for parametric analysis. This typically occurred where large outliers were present in the data. The Kruskal-Wallis rank sums method was used in these instances and was found to be a reliable test. Where significance was detected during preliminary tests and analyses, multiple comparisons tests (i.e., the Student's *t* and Tukey-Kramer HSD for parametric analysis and Nemenyi test for non-parametric analysis) were used to identify the sampling sites where significance was detected. Overall, the data transformation techniques and analytical methods used in this pilot study were found to be valuable tools for preparing sample counts and testing for significant differences among sampling sites. Their use, however, must be judiciously applied. The decision for using a particular method for hypothesis

testing should ultimately depend upon the characteristics of the data to be tested (Green, 1979).

Sampling Methods

The argument has been made that individual stones are valid sampling units because density estimates can be derived from known surface areas (provided these have been measured) and rocks are a biological unit of habitat for many benthic species (Scrimgeour et al., 1993). For this study, individual stones were the primary sampling unit for one sampling method. Although all stones sampled were within a single size class (i.e., cobbles as defined by Overton et al., 1993), a high degree of variability occurred for both surface area of the individual stones and number of macroinvertebrates collected per unit (i.e., rock). This variability coupled with low sample size led to large variances, non-normal data, unequal variances, and extremely low power for most analyses. Much of the biological variability is likely due to the non-random spatial distribution of the organisms utilizing this substrate (Resh, 1979), but may also be attributed to the sampling method as well (Scrimgeour et al., 1993). Additional contributions to sampling variability may be attributed to the method of stone removal. For instance, when a stone is removed off the stream bottom, individuals occupying adjacent stones may become dislodged and included in the sample. Controlling this form of sampling error is extremely difficult if not impossible.

Because of the low sample size, low power, and high variability, all preliminary significance tests including scraper guild analysis cannot be used to draw inferences for rock sampling. Nevertheless, rocks are considered as valid biological units in this study

and warrant future use. Though not without inherent sampling difficulties, the information gained during this study does present a rough estimate of the minimum required sample sizes for hypothesis tests and also provides biological information on the taxa utilizing cobbles in Mannis Branch. The suggested sample sizes as calculated from sample statistics, may create logistic problems and much effort would be required for efficient sample processing. The primary problems to consider while using this method for statistical analyses are variability due to sampling error, time it takes to calculate rock surface area, and effort involved in collecting appropriate sample sizes.

Two approaches were used in kick sampling. The June and July 1997 samples were collected by using a catch per unit effort methodology whereby effort was measured in 30-second time intervals. Under this approach, the actual area of substrate sampled varied slightly between sampling units. It was thought that this lack of consistency of sampled area was introducing added components of error and variability. An attempt to control and reduce this inconsistency between sampling units was implemented in the February and April samples by confining kick activity to within a 0.16 m^2 frame. However, accuracy or precision estimates within a 95% confidence interval about sample means were equally large for all samples. Thus, kick sampling was very similar to rock sampling in that a high degree of variability persists among all samples. The future use of this method for hypothesis testing should likely be weighed by the effort involved for sampling collection and processing. Based on these limited data, a minimum sample size per sampling site should be approximately 24 individual kicks. Even then, it is not guaranteed that precision will be high enough for detecting small differences among treatments (i.e., between an area supporting trout versus a fish-free stream section). Time

and effort one is willing to expend as well as sampling logistics should be the final criteria for including or rejecting this method during the next phase of the study. One final problem associated with this method is that a broad range of substrate sizes are actually included in each sample; no two rocks within a confined sampling area will have the same dimensions. Substrate heterogeneity is seldom considered during fixed-area and semi-quantitative (such as kicks) sampling methods and certainly contributes to high variability among units (Resh, 1979).

Lamberti and Resh's (1985) claim that artificial substrates (in this case, standard sized tiles) suffice as a substitute for natural rocks was not corroborated in this pilot study. Ideally, tiles of uniform size should reduce the variability among individual units. However, the invertebrates colonizing the tiles in this study did not appear comparable to those on natural substrates (i.e., rocks) and variability was still a factor. One critical factor that was very different in tile sampling from rock sampling is the size class of invertebrates colonizing the tiles and slight differences in species composition. Though diversity indices were not calculated and compared, the presence of large numbers of chironomids found among tiles are not comparable to what occurred in the rock samples. Much of the disparity of tile sampling compared to rock sampling may lie in the stream environment of Mannis Branch. This second-order stream has a very high shade component and sunlight rarely reaches the stream surface during periods of leaf growth of the canopy above. This factor alone may explain the paucity of late instars of taxa other than some collectors such as chironomids. Furthermore, tiles may not have incubated for long enough periods for a fauna similar to those of stones to colonize these substrates. As a result, tile sampling should not be considered in the next phase of the

study in order to concentrate sampling efforts toward more useable methods.

Pre-weighed leaf packs containing specific species of leaves are often used in trophic and leaf-breakdown or processing studies (e.g., Benfield and Webster, 1985; Benfield, 1996). Their use as a means for estimating density or abundance was not successful in this study; primarily due to faulty placement of leaf packs in the stream environment and inappropriate season for sampling. The one sample that was evaluated had characteristics similar to the other methods; high variability between units or leaf packs. Again, time and effort for sample processing may be the most appropriate factor for the method's continued use as a means to calculate density. It may be that leaf-breakdown studies are the most appropriate use for this method. However, making a final judgment for discarding or using the method in the next phase of this study is unfounded based on this single sample.

Sampling stream drift has a long and informative history (Waters, 1962; Anderson, 1966; Elliott, 1970; Allan, 1978; Allan, 1982; Brittain and Eikeland, 1988). Using this method for investigating predator-prey relationships has also provided valuable information (Allan, 1978; Forrester, 1994). Though the overall design of collecting drift had limitations in this study, interesting patterns emerged in the drift between the section of Mannis Branch that supports trout and the section that does not. However, the one limitation that restricts drawing inferences based on this limited survey is that drift nets or sites were not replicated between the two stream sections. Thus, the only information generated is what occurred in the stream drift at the two sampling sites per sample period. If it is possible to expend the effort to include replication, then this method should receive priority during the next stage of the study. Because the presence

of trout has been linked to the drift behavior of some late instars of mayflies and potentially other taxa (Forrester, 1994), measuring head capsule width as a method for assessing instar stage should be considered.

Based on the sampling experiences of each method evaluated, a priority ranking of the methods to be considered for the next phase of this study is as follows: drift, rock, kick, leaf pack, and tile sampling. In retrospect, the methods that are most likely to provide the greatest amount of information for time and effort expended are drift and rock sampling.

Sampling Considerations and Experimental Design

Concerning methodologies, a limitation of this study is that only five aquatic sampling methods were evaluated. Many more are discussed in the vast literary base devoted to this subject. It is possible that more appropriate sampling devices for examining the potential effects a top vertebrate predator exerts on the benthic community are in use and well known. However, these are unknown to me.

A final consideration of this study is equally one of the most important; sampling and analytical design. The limitations of the methods used to collect samples have been addressed. However, there were limitations of experimental design that must be addressed as well. For all samples collected, regardless of sampling method, the individual units must be independent of one another. To ensure that this critical assumption is met, units should be randomly selected within a given habitat type (i.e., stratified random selection) to the extent that collecting one unit does not impact or influence the fauna associated with another sampling unit. To violate independence,

severe consequences may surface during the final analysis and may lead to inflated Type I or Type II errors depending on whether there is a positive or negative correlation among the sampling units (Underwood, 1997). It is believed that the selection of individual rocks and kick samples in February and April 1998 as well as tile placement during the second tile sampling session best represented the assumption of independence.

Another limitation of this study was the number of sampling sites established in the section supporting trout versus the area with trout absent. For rock and kick sampling, the minimum number of sites possible (i.e., two per stream section) was established. While this design is better than using a single site per section (and hence, pseudoreplication), an additional site for each section may contribute to a better understanding of the variability between stream sections. However, the time and effort involved for collecting and processing the appropriate number of sampling units per site may override the possibility for adding sites per stream section during the next phase of the study.

The preliminary analyses performed on the samples collected were kept simple for this pilot study. The one-way ANOVAs performed on all samples were carried out to examine the differences and sampling challenges occurring among the sampling stations or sites. General statements or references to fish presence versus fish absence were made only where significance between sampling sites was detected in any given analysis. The larger problem driving this preliminary examination (i.e., predatory effects of trout) was not taken to the appropriate degree of investigation. The significance tests (i.e., both parametric and nonparametric) applied to these limited data are oversimplified and do not represent the most appropriate design for the next, rigorous stage of this study; that is, to

test for differences in the stream benthos between natural, unmanipulated sections of Mannis Branch that support predatory fish and an area that is fish-free. The sampling design and hence, analytical framework that best represents the problem to be investigated is more complex than the simple design applied to this pilot study.

An important aspect of the problem (or hypothesis) to be tested is to view the investigation in a hierarchical framework. At the top level, there exists, for all practical purposes, a fixed-effect. One natural, unmanipulated section in Mannis Branch supports predatory fish while an adjacent, unmanipulated section upstream remains fish-free. At the next, subordinate level are the sampling sites within each treatment (i.e., fish presence versus fish absence). Although the sampling sites are chosen based on similar physical characteristics (e.g., stream width, gradient, substrate composition, habitat type, etc.), the units (whether they are individual rocks, kicks, leaf packs, etc.) are randomly chosen plus the biological elements collected per unit are not manipulated by investigator induced treatments but rather, represent random effects. Therefore, the overall design for testing the Null Hypothesis that brook trout do not exert a detectable effect on the stream benthos in Mannis Branch is best represented by a mixed model nested ANOVA. The test statistics and calculations derived from this design are different than what is typically represented in most aquatic studies. Many investigators never mention the actual design of their experiments and rarely perform their analyses using what typically occurs in the natural world; random effects (Williams and Feltmate, 1992). Sokal and Rohlf (1995) present equations and offer a good discussion of random versus fixed effects and should be used as a basic template for conducting significance or hypothesis tests during the next phase of this study. Naturally, all data should be tested and examined prior to the final

analysis to ensure certain assumptions have been met. If data transformation techniques are unreliable for meeting the assumptions of an ANOVA, then distribution-free tests should be considered and applied (Potvin and Roff, 1993).

Critical to the successful completion of a sampling program or biological investigation is an accurate assessment of the time and costs that will be required (Green, 1979). In a complex environment such as Mannis Branch, the variability between sampling units is often enormous. Resultantly, large sample sizes are required for detecting subtle differences between sampling sites and/or treatment effects. To meet the demand for collecting large sample sizes, ample monetary resources must be available to compensate for the time and efforts of staff collecting and processing the samples. Otherwise, resorting to small sample sizes to offset financial costs may ultimately lead to disappointing results and wasted investment.

The complex substrates and apparent clumping pattern of the benthic community (based on the variability between sampling units) in Mannis Branch presents many sampling challenges. The complex environment coupled with the need for large sample sizes is problematic for an investigator to adequately test the potential impacts brook trout exert on the benthic fauna. Furthermore, investigator impact upon the benthic community could be severe if large sample sizes are collected repeatedly within a single site in a single season. Based on the results of this pilot study and the realization that required sample sizes may not be physically possible to collect, the next phase of the study may not be feasible. Should the study continue, the experimental design and a cost-benefit assessment must be thoroughly planned and wisely implemented.

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Table A-1. List of taxa identified from Mannis Branch, sampling methods in which they appeared, and known or suggested feeding relationships of recognized taxa. Species and/or genera (insects only) represented under "Adults" refer to qualitative sampling from aerial sweep netting and light trapping. Trophic group refers to four general feeding categories of Insecta, where known; information abstracted from Merritt and Cummins (1996). (*Trophic group categories: C = collectors and gatherers; P = predators; Scr = scrapers and grazers; Shr = shredders. Where two or more categories per taxa are indicated, the first represents the primary feeding strategy followed by secondary and tertiary strategies.)

TAXA	Rock	Kick	Tile	Leaf Pack	Drift	Adults	Trophic Group*
Annelida							
Oligochaeta	X	X	X	X	X		
Arthropoda							
Crustacea							
Copepoda							
Harpactacoidea	X	X	X		X		Scr
Isopoda							
Lirceus sp.	X	X	X	X	X		Shr, C
Decapoda							
Cambaridae							
Cambarus bartonii		X					P, C, Shr
Cambarus sp. (juveniles)	X	X			X		
Arachnoidea							
Hydracarina	X	X	X		X		
Insecta							
Ephemeroptera							
Ameletidae							
Ameletus cryptostimulus	X	X	X	X	X		Scr
Baetidae							
Acentrella sp. cf. *ampla*	X	X	X	X	X		C
Baetis sp. (early instars)	X	X	X	X	X		C, Scr
Baetis sp. cf. *brunneicolor*	X	X			X		C, Scr
Baetis tricaudatus	X	X	X		X		C, Scr
Ephemerellidae							
Drunella sp. (early instars)	X	X	X				Scr
Drunella tuberculata	X	X			X		Scr
Ephemerella catawba	X	X		X	X		C, Scr
Ephemerella hispida	X	X			X		C, Scr
Ephemerella rossi	X	X			X		C, Scr
Ephemerella sp. (early instars)	X	X	X	X	X		C, Scr
Ephemerella sp. 1 (like *catawba*		X		X	X		C, Scr
but with 5 tarsal claw denticles)							
Eurylophella funeralis				X	X		C
Serratella deficiens					X		C

Table A-1. Continued.

TAXA	Rock	Kick	Tile	Leaf Pack	Drift	Adults	Trophic Group*
Ephemeroptera (continued)							
Ephemeridae							
Ephemera guttulata		X				X	C, P
Ephemera sp. (early instars)		X			X		C, P
Heptageniidae							
Cinygmula subaequalis	X	X		X	X		Scr, C
Epeorus sp. cf. *dispar*	X	X	X	X	X		C, Scr
Epeorus sp. cf. *pleuralis*	X	X		X	X		C, Scr
Heptagenia julia	X	X			X		Scr, C
Leucrocuta thetis	X	X	X	X	X		Scr, C
Rhithrogena amica		X					C, Scr
Rhithrogena fuscifrons	X	X			X		C, Scr
Stenacron interpunctatum/carolina					X		C, Scr
Stenacron sp. (early instars)	X						C, Scr
Stenacron sp. cf. *pallidum*		X					C, Scr
Stenonema meririvulanum	X	X		X	X		Scr, C
Stenonema ithaca/modestum	X	X	X		X		Scr, C
Stenonema pudicum	X	X			X		Scr, C
Isonychiidae							
Isonychia sp.	X	X	X		X		C, P
Leptophlebiidae							
Habrophlebia vibrans			X		X		C, Shr (?)
Paraleptophlebia adoptiva/mollis	X	X		X	X		C, Shr
Odonata							
Cordulegastridae							
Cordulegaster erronea	X	X			X		P
Gomphidae							
Lanthus vernalis		X		X	X		P
Plecoptera							
Capniidae							
Allocapnia sp.						X	Shr
Paracapnia angulata			X		X		Shr (?)
Chloroperlidae							
Alloperla sp.						X	P
Haploperla brevis					X		P
Rasvena terna		X					P (?)
Sweltsa mediana						X	P
Sweltsa sp. (nymphs)	X	X	X	X	X		P
Leuctridae							
Leuctra ferruginea						X	Shr
Leuctra sp. (nymphs)	X	X	X	X	X	X	Shr
Paraleuctra sara						X	Shr
Nemouridae							
Amphinemura appalachia	X	X		X	X	X	Shr, C
Amphinemura delosa/nigrita (larvae)	X	X			X		Shr, C

Table A-1. Continued.

TAXA	Rock	Kick	Tile	Leaf Pack	Drift	Adults	Trophic Group*
Plecoptera (continued)							
Nemouridae (continued)							
Amphinemura nigrita						X	Shr, C
Amphinemura sp. (early instars)	X	X	X	X	X		Shr, C
Soyedina sp.						X	Shr
Peltoperlidae							
Tallaperla anna						X	Shr
Tallaperla maria						X	Shr
Tallaperla sp.	X	X	X	X	X		Shr
Viehoperla ada		X				X	Shr (?)
Perlidae							
Acroneuria abnormis	X	X			X		P
Beloneuria georgiana/stewarti	X					X	P (?)
Eccoptura xanthenes	X	X	X	X	X		P
Hansonoperla appalachia		X					P (?)
Paragnetina immarginata		X					P
Perlesta sp. cf. *frisoni*	X	X	X		X		P
Perlodidae							
Diploperla duplicate				X			P
Isoperla holochlora	X	X			X		P, C
Isoperla sp. (early instars)	X	X		X	X	X	P, C
Isoperla sp. cf. *similis*		X		X			P,C
Malerikus hastatus		X					P (?)
Malerikus /Yugus	X	X					P (?)
Remenus bilobatus	X	X		X	X		P (?)
Yugus arinus		X					P (?)
Yugus bulbosus		X			X		P (?)
Pteronarcyidae							
Pteronarcys scotti (adults)						X	Shr, P, Scr
Pteronarcys sp. (early instars)	X	X		X	X		Shr, P, Scr
Pteronarcys sp. cf. *scotti* (nymphs)		X					Shr, P, Scr
Heteroptera							
Gerridae							
Aquarius remigis					X	X	P
Veliidae							
Rhagovelia obesa					X		P
Trichoptera							
Apataniidae							
Apatania sp.		X					Scr, C
Arctopsychidae							
Arctopsyche irrorata		X			X		C
Parapsyche cardis	X	X		X	X		C
Brachycentridae							
Brachycentrus sp. (early instars)		X					C, Scr
Micrasema burksi		X		X			Shr, C

Table A-1. Continued.

TAXA	Rock	Kick	Tile	Leaf Pack	Drift	Adults	Trophic Group*
Trichoptera (continued)							
Glossosomatidae							
Agapetus minutus	X	X	X	X	X	X	Scr, C
Glossosoma nigrior	X	X	X		X		Scr
Goeridae							
Goera calcarata					X		Scr
Goera sp. (early instars)	X	X					Scr
Goerita semata			X				Scr
Hydropsychidae							
Ceratopsyche macleodi	X	X				X	C
Ceratopsyche slossonae	X					X	C
Ceratopsyche sp. (early instars)	X	X	X				C
Diplectrona modesta	X	X		X	X	X	C
Hydroptilidae							
Mayatrichia ayama					X		Scr
Lepidostomatidae							
Lepidostoma sp.	X	X	X	X	X		Shr
Limnephilidae							
Pycnopsyche flavata	X			X	X		Shr
Pycnopsyche guttifer group		X		X			Shr
Pycnopsyche sonso	X	X		X			Shr
Odontoceridae							
Pseudogoera singularis						X	P
Psilotreta frontalis		X		X			Scr, C
Psilotreta rossi	X	X					Scr, C
Psilotreta sp. (early instars)	X	X	X				Scr, C
Philopotamidae							
Dolophilodes distinctus	X	X			X	X	C
Wormaldia moesta						X	C
Wormaldia sp. (larvae)	X	X		X	X		C
Polycentropodidae							
Nyctiophylax sp.	X	X	X		X		P, C, Shr
Polycentropus sp.	X	X	X		X	X	P, C, Shr
Psychomyiidae							
Lype diversa	X	X			X	X	Scr
Rhyacophilidae							
Rhyacophila appalachia/nigrita	X	X		X		X	P
Rhyacophila atrata	X	X					P
Rhyacophila carolina	X	X		X	X	X	P
Rhyacophila fenestra/ledra		X					P
Rhyacophila fuscula	X	X	X	X	X		P
Rhyacophila glaberrima				X	X	X	P
Rhyacophila minor	X	X		X	X		P
Rhyacophila torva						X	P

Table A-1. Continued.

TAXA	Rock	Kick	Tile	Leaf Pack	Drift	Adults	Trophic Group*
Trichoptera (continued)							
Sericostomatidae							
Fattigia pele		X			X		Shr (?)
Uenoidae							
Neophylax consimilis	X						Scr
Neophylax mitchelli	X	X		X	X		Scr
Neophylax ornatus	X	X			X		Scr
Neophylax sp. (early instars)	X	X	X	X	X		Scr
Coleoptera							
Dryopidae							
Helichus basalis					X	X	Scr, C (?)
Elmidae							
Optioservus immunis	X	X			X	X	Scr, C
Optioservus ovalis	X	X			X	X	Scr, C
Optioservus sp. (larvae)	X	X	X	X	X		Scr, C
Oulimnius latiusculus (adults)	X	X		X	X	X	Scr, C (?)
Oulimnius latiusculus (larvae)	X	X			X		Scr, C (?)
Promoresia tardella (adult)					X	X	Scr, C (?)
Promoresia sp. (larvae)		X			X		Scr, C (?)
Stenelmis sp. (adults)					X	X	Scr, C
Eubriidae							
Ectopria sp.	X	X	X		X		Scr
Hydraenidae							
Hydraena sp. (adults)					X	X	?
Psephenidae							
Psephenus herricki		X					Scr
Diptera							
Blephariceridae							
Blepharicera sp.	X	X			X		Scr
Ceratopogonidae							
Palpomyia complex	X	X	X	X	X		P, C
Chironomidae	X	X	X	X	X		C, P
Dixidae							
Dixa sp.		X	X	X	X		C
Empididae							
Chelifera sp.	X	X	X		X		P, C (?)
Clinocera sp.		X					P, C (?)
Dolichocephala sp.		X					P, C (?)
Hemerodromia sp.	X	X	X				P, C
Roederiodes sp.				X			P, C (?)
Nymphomyiidae							
Nymphomyia sp.	X				X		Scr, C
Simuliidae	X	X	X	X	X		C
Tabanidae			X				P

Table A-1. Continued.

TAXA	Rock	Kick	Tile	Leaf Pack	Drift	Adults	Trophic Group*
Diptera (continued)							
Tipulidae							
Antocha sp.	X	X			X		C
Dicranota sp.	X	X	X	X	X		P
Hexatoma sp.	X	X	X		X		P
Molophilus sp.		X					?
Pseudolimnophila sp.		X					?
Tipula abdominalis	X	X		X			Shr
Tipula sp. 1	X	X					?
Tipulidae sp. cf. *Pedicia*		X					?

Table A-2. Rock samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, June 1997. Surface area of each sampled rock in cm^2.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	1104	1833	987	975	1422	1363	599	963	1433	893	658	564	869	987	728	576	1034	1292	700	637	597	961	684	775
TAXA																								
Annelida																								
Oligochaeta																				1				1
Arthropoda																								
Crustacea																								
Copepoda																								
Harpacticoidea							1										1							
Arachnoidea																								
Hydracarina		1			3	1	2	3	2	2	1		1	2	1	1	6		3			12		
Insecta																								
Ephemeroptera																								
Baetidae																								
Acentrella sp. cf. *ampla*		3	1	2														2	5	7	1	4		
Baetidae sp. (early/damaged instars)	1	2			1	1							1											
Baetis sp. (early/damaged instars)															1		1							
Baetis sp. cf. *brunneicolor*														1				1						
Baetis tricaudatus	1	8	4		5			1	1	2									6			4		
Ephemerellidae																								
Drunella sp. (early instars)																		2	1			1		
Ephemerella rossi		8	3	2	5	5		3	1	1				1				1	1	2	5			2
Ephemerellidae sp. (early instars)								1																
Heptageniidae																								
Epeorus sp. cf. *dispar*	2	12	5	2	3	4	2	1	1	1	1			3	1			2	2	3	5	2	2	
Epeorus sp. (early instars)		4			1					1	2			2				1	1	2	1	3		1
Heptageniidae sp. (early instars)	2														1			2						
Leucrocuta sp. (early instars)											1						2							
Leucrocuta thetis	1						1	1									1	1						
Rhithrogena fuscifrons						1															1			
Stenonema modestum/ithaca															1									
Stenonema pudicum														1										

Table A-2. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	1104	1833	987	975	1422	1363	599	963	1433	893	658	564	869	987	728	576	1034	1292	700	637	597	961	684	775
TAXA																								
Ephemeroptera (continued)																								
Heptageniidae (continued)																								
Stenonema sp. (early instars)								1													1			1
Leptophlebiidae																								
Paraleptophlebia adoptia/mollis	1			1				1															1	
Plecoptera																								
Leuctridae																								
Leuctra sp.	5		1	2	1			1			1		2											
Nemouridae																								
Amphinemura delosa/nigrita					1																			
Peltoperlidae																								
Peltoperlidae sp. (early instars)		5			4								1											
Tallaperla sp.		2						1																
Perlidae																								
Acroneuria abnormis					1						1			1							1			
Acroneuria sp. (early instars)	2			1	4			1				1	1											2
Perlidae sp. (early/damaged instars)	4	10	1	1	3	2	2	5	1	4		1	1	4				1	1	2	2	1		2
Perlodidae																								
Perlodidae sp. (early instars)		1																						
Trichoptera																								
Arctopsychidae																								
Parapsyche cardis		1			1																			
Glossosomatidae																								
Agapetus minutus	3		2	2	1		1	5	5		4	3	5	36	6	4	9	10	1	1	7	3	7	6
Glossosoma nigrior	2	5	5		3	9			1				1					5		6	11	4	1	
Glossosomatidae sp. (early instars)																								3
Hydropsychidae																								
Diplectrona modesta	5	1		1	3	1		3						4							1		1	1
Hydropsychidae sp. (early instars)								1											8	5	1	21	4	3

Table A-2. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	1104	1833	987	975	1422	1363	599	963	1433	893	658	564	869	987	728	576	1034	1292	700	637	597	961	684	775
TAXA																								
Trichoptera (continued)																								
Lepidostomatidae																								
Lepidostoma sp.					1				1				3					1	1		6			1
Limnephilidae																								
Pycnopsyche flavata																	2							
Pycnopsyche sonso								1																
Philopotamidae																								
Dolophilodes distinctus		2																						
Polycentropodidae																								
Nyctiophylax sp.													1											
Polycentropodidae sp. (early instars)					1						1							3						
Polycentropus sp.	1					1																		
Rhyacophilidae																								
Rhyacophila appalachia/nigrita																					1			
Rhyacophila carolina		1		1																				
Rhyacophila fuscula																			1					
Rhyacophila sp. (early instars)																						1		
Uenoidae																								
Neophylax mitchelli		1				1				1								2						
Neophylax ornatus		1				1																		
Neophylax sp. (early instars)						1												1	2	4		5	10	3
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)						1							1			6								
Optioservus ovalis				1																				
Optioservus sp. (larvae)	1					6						1				1								
Oulimnius latiusculus (adults)																								
Oulimnius latiusculus (larvae)	2			1					1			1				1				1				

Table A-2. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	1104	1833	987	975	1422	1363	599	963	1433	893	658	564	869	987	728	576	1034	1292	700	637	597	961	684	775
TAXA																								
Coleoptera (continued)																								
Eubriidae																								
Ectopria sp.	1												3							1		2		
Diptera																								
Ceratopogonidae																								
Palpomyia complex					1					1														
Chironomidae	6	70	29	7	68	41	3	44	11	15	10	8	28	34	8	14	27	31	3	13	5	19	22	9
Empididae																								
Chelifera sp.					2											1				1		1		
Empididae sp.													1											
Hemerodromia sp.	1	10		1	2	1		4		1		1	3									2	1	1
Nymphomyiidae																								
Nymphomyia sp.		2	1			1			1															
Simuliidae													1											
Tipulidae																								
Antocha sp.					1													1						
Dicranota sp.	1																							
TOTAL SPECIMENS	42	150	52	25	116	78	12	78	26	29	22	16	54	89	19	28	49	67	36	49	49	85	49	36

Table A-3. Rock samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, July 1997. Surface area of each sampled rock in cm^2.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	902	1123	874	552	928	674	884	1208	658	1022	698	855	1210	985	919	1008	1116	790	1217	945	623	949	1455	677
TAXA																								
Annelida																								
Oligochaeta					1															1				
Arthropoda																								
Crustacea																								
Isopoda																								
Lirceus sp.							1		1															
Arachnoidea																								
Hydracarina					3						3	2				2			2		1			1
Insecta																								
Ephemeroptera																								
Baetidae																								
Acentrella sp. cf. *ampla*	18	4	4	2	3			1			1		11	2			4	7	2		3			
Baetidae sp. (early/damaged instars)	1				1			1								1								
Baetis sp. (early/damaged instars)							2	2		3	4													
Baetis sp. cf. *brunneicolor*								1		1											1			
Baetis tricaudatus	6	5	2	1	1	1				1	2						1		3					
Ephemerellidae																								
Drunella tuberculata						1										3			4	1		2		
Ephemerella sp. (early instars)													1				1						1	
Heptageniidae																								
Epeorus sp. cf. *dispar*	9	5	4	2	1	3		1					2	1				1	3			1	2	
Epeorus sp. (early instars)	2	3	1			1							5	2				1	1	3		5		1
Heptagenia julia	1																	1					1	
Heptagenia sp. (early instars)															1									
Heptageniidae sp. (early instars)							1		1		2				1						1			
Leucrocuta sp. (early instars)										1		1		1	1			2					2	
Leucrocuta thetis								8			3	3												
Rhithrogena fuscifrons																					1		1	
Stenacron sp. (early instars)									2	1														

Table A-3. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	902	1123	874	552	928	674	884	1208	658	1022	698	855	1210	985	919	1008	1116	790	1217	945	623	949	1455	677
TAXA																								
Ephemeroptera (continued)																								
Heptageniidae (continued)																								
Stenonema meririvulanum															1									
Stenonema pudicum							1																	
Stenonema sp. (early instars)																							2	
Isoncyiidae																								
Isonychia sp.		1																						
Leptophlebiidae																								
Paraleptophlebia adoptiva/mollis														1					2	4			1	
Odonata																								
Cordulegastridae																								
Cordulegaster erronea								1																
Plecoptera																								
Chloroperlidae																								
Sweltsa sp.													1											
Leuctridae																								
Leuctra sp.															1				1	3	2			
Nemouridae																								
Amphinemura sp. (early instars)	1				2					2														
Peltoperlidae																								
Peltoperlidae sp. (early instars)	3	1		1																				
Perlidae																								
Acroneuria abnormis			2										1	1										
Acroneuria sp. (early instars)								1					1				3	2		1			2	
Beloneuria georgiana/stewarti																							1	
Eccoptura xanthenes							1																	
Perlesta sp. cf. *frisoni*										1												1		
Perlidae sp. (early/damaged instars)			2				2			4	1	1	2						1		1	2		
Perlodidae																								
Perlodidae sp. (early instars)		1																						

Table A-3. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	902	1123	874	552	928	674	884	1208	658	1022	698	855	1210	985	919	1008	1116	790	1217	945	623	949	1455	677
TAXA																								
Trichoptera																								
Arctopsychidae																								
Parapsyche cardis		1	3	2	6					2		1	5	1	1	2	3	1	2	1	1	1		
Glossosomatidae																								
Agapetus minutus											1								1					
Glossosoma nigrior	1	3			1		1						14	1	6	1	1	5	5	2	13			
Glossosomatidae sp. (pupae)													2		4	1	1	2	2					
Goeridae																								
Goera sp.												1							1	1				
Hydropsychidae																								
Ceratopsyche macleodi																						6	1	
Ceratopsyche sp. (early instars)													2		2	3		4	11	6	7			
Diplectrona modesta		3	3	2									1						1		1			
Hydropsychidae sp. (early instars)	1				2	1	5			1			1	2		1			1				1	
Odontoceridae																								
Psilotreta sp. (early instars)					1					1														
Philopotamidae																								
Dolophilodes distinctus	1		2										1							1				
Wormaldia sp.																			1					
Polycentropodidae																								
Polycentropodidae sp. (early instars)	1				1						1	1												
Polycentropus sp.										1	1													
Psychomyiidae																								
Lype diversa					1																			
Rhyacophilidae																								
Rhyacophila carolina							1						1											
Rhyacophila fuscula					1								1									1		
Rhyacophila minor							2													1				
Rhyacophila sp. (early instars)		1						1									2			1	1			

Table A-3. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	902	1123	874	552	928	674	884	1208	658	1022	698	855	1210	985	919	1008	1116	790	1217	945	623	949	1455	677
TAXA																								
Trichoptera (continued)																								
Uenoidae																								
Neophylax sp. (early instars)													1						1		1			
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)			1		7					2	1	2				1								
Optioservus ovalis																					1			
Optioservus sp. (larvae)					2				1		1				1	1								
Oulimnius latiusculus (adults)				2	1	1			1		1	1			1				1	2	2			
Eubriidae																								
Ectopria sp.		2				1			2	1		1	2	3					2				1	
Diptera																								
Ceratopogonidae																								
Palpomyia complex						1																		
Chironomidae	3	7	8		9	3	12	42	8	63	34	54	5	7	4	6	3	6	8	10	7	2	5	4
Empididae																								
Chelifera sp.										1		1							1					
Hemerodromia sp.									1															
Simuliidae	13			2									4	1				1						
Tipulidae																								
Dicranota sp.								1																
Hexatoma sp.																			1				1	
Tipula sp.					1								1							1	1			
TOTAL SPECIMENS	61	37	32	14	45	13	29	60	17	86	56	69	65	23	24	22	19	33	58	39	45	21	22	6

Table A-4. Rock samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, February 1998. Surface area of each sampled rock in cm^2.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	815	921	508	515	634	830	679	383	360	585	773	439	479	451	771	526	578	757	698	731	942	482	884	834
TAXA																								
Annelida																								
Oligochaeta	1		1		1		3		1					1					2		1	2		1
Arthropoda																								
Crustacea																								
Isopoda																								
Lirceus sp.						1																		
Arachnoidea																								
Hydracarina		4		1	2	4					7		7	3	9			3			3	1	5	1
Insecta																								
Ephemeroptera																								
Ameletidae																								
Ameletus cryptostimulus						1	1							1							2			
Baetidae																								
Acentrella sp. cf. *ampla*		5																						
Baetidae sp. (early/damaged instars)					3	2	1	2		1	4	2	7	4	7	1		4			3	1	4	
Baetis tricaudatus	1				1		1		1	1					1					1				
Ephemerellidae																								
Ephemerella Catawba		2																						
Ephemerella sp. 1 (similar to									1							1								
catawba but with 5 tarsal claw																								
denticles)																								
Ephemerella hispida		2			1					3	4													
Ephemerella rossi		1																						
Ephemerella sp. (early instars)	4	45	4	7	13	24	2	10	6	5	24	2	1	2	12	3	6	16	1	6	12	7	17	7
Ephemerellidae sp. (early instars)											1				3			1					1	
Heptageniidae																								
Cinygmula subaequalis	1								1							1	1	3		1	1		1	2
Epeorus sp. cf. *dispar*	10	4	2		3		4		2	4					1			1			4			

Table A-4. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	815	921	508	515	634	830	679	383	360	585	773	439	479	451	771	526	578	757	698	731	942	482	884	834
TAXA																								
Ephemeroptera (continued)																								
Heptageniidae (continued)																								
Epeorus sp. cf. *pleuralis*	23	9	6	8	12	6	8	9	10	14	9	6	2	5	5	3	1	6	2	7	2	5	5	2
Epeorus sp. (early instars)	15	11	10	3	6	5		9	2	10	8	3	6	4	22	8	5	17		3	14	6	14	2
Leucrocuta thetis								1									1	4	1	2	10	1	4	
Rhithrogena amica																	1			3				1
Rhithrogena sp. (early instars)				1															1	2				
Stenonema meririvulanum					1																		1	
Stenonema pudicum																					1			
Stenonema sp. cf. *integrum*																					1			
Stenonema sp. cf. *terminatum*																		2						
Stenonema sp. (early instars)																		1			2		3	
Leptophlebiidae																								
Paraleptophlebia adoptiva/mollis		9	1			2			1							1		2	4		4	6	12	2
Plecoptera																								
Leuctridae																								
Leuctra sp.												1										1		
Nemouridae																								
Amphinemura sp. (early instars)	1	1	1			4			1		1						1					2		
Peltoperlidae																								
Peltoperlidae sp. (early instars)		7	1			1		5		2	2									1				
Tallaperla sp.	2	6				1																		
Perlidae																								
Acroneuria abnormis				1						1	2	2		1	1	1	1			1			1	
Acroneuria sp. (early instar)																	1							
Perlidae sp. (early/damaged instars)				1		1														1	2			
Perlodidae																								
Isoperla sp. (early instars)		4						1																
Malerikus/Yugus (early instars)	1						1																	
Perlodidae sp. (early instars)				1		1		1			3						1				1			

Table A-4. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	815	921	508	515	634	830	679	383	360	585	773	439	479	451	771	526	578	757	698	731	942	482	884	834
TAXA																								
Plecoptera (continued)																								
Pteronarcyidae																								
Pteronarcys sp. (early instars)	1	1					2		2					1								1	1	
Trichoptera																								
Arctopsychidae																								
Parapsyche cardis		12	1	2	7	2		2		5	8													
Brachycentridae																								
Micrasema burksi		1																						
Glossosomatidae																								
Glossosoma nigrior					1										1									
Hydropsychidae																								
Ceratopsyche macleodi								1			2		1							1				
Diplectrona modesta		11	12	2	1	6	1	1	1		3	2	3	1	2	1	2	4		1				
Lepidostomatidae																								
Lepidostoma sp.		2		1		1	1								2		2			1			1	
Limnephilidae																								
Pycnopsyche gentilis		1																						
Philopotamidae																								
Dolophilodes distinctus		2																						
Wormaldia sp.				1																				
Polycentropodidae																								
Nyctiophylax sp.																					5			
Polycentropus sp.																								2
Rhyacophilidae																								
Rhyacophila appalachia/nigrita						1			2		1													
Rhyacophila carolina		4																			1			
Rhyacophila fuscula					2				1		2			1							1			
Rhyacophila sp. (early instars)	1	1	1			1					2													

Table A-4. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	815	921	508	515	634	830	679	383	360	585	773	439	479	451	771	526	578	757	698	731	942	482	884	834
TAXA																								
Trichoptera (continued)																								
Uenoidae																								
Neophylax mitchelli															1									
Neophylax ornatus					1																1			
Neophylax sp. (early instars)		2									2						1	1						1
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)						2																1		1
Optioservus immunis		1																1						
Optioservus sp. (larvae)					1	2					1				2		1	2	3	1	1	1		4
Oulimnius latiusculus (adults)					3														1		1			
Eubriidae																								
Ectopria sp.		2	1	1							1		1										1	
Psephenidae																								
Psephenus herricki																			1					
Diptera																								
Blephariceridae																								
Blepharicera sp.	1																							
Ceratopogonidae																								
Palpomyia complex							1																	
Chironomidae	10	82	12	8	31	17	4	22	14	17	54	3	12	11	27	8	10	23	3	5	14	3	14	13
Dixidae																								
Dixa sp.																			2		1			
Empididae																								
Chelifera sp.		3	1					2			2			3	1			3				1	1	
Dolichocephala sp.																		1						
Hemerodromia sp.	1	5	6	2	2	3							3	5	1	1		8				2	1	
Nymphomyiidae																								
Nymphomyia sp.					1																			
Simuliidae	11	28	6	1	6		2		8	3	4	13			1								4	

Table A-4. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	815	921	508	515	634	830	679	383	360	585	773	439	479	451	771	526	578	757	698	731	942	482	884	834
TAXA																								
Diptera (continued)																								
Tipulidae																								
Antocha sp.					1										1		1	1						
Dicranota sp.																			1					
Hexatoma sp.			1												1				1					
Tipulidae sp. (early instars)						1																		
TOTAL SPECIMENS	84	268	67	42	100	89	32	66	54	66	148	34	43	43	101	30	37	105	25	37	88	41	92	39

Table A-5. Rock samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, April 1998. Surface area of each sampled rock in cm^2.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	693	764	414	999	555	435	646	740	451	670	632	519	407	475	498	658	773	705	977	1085	1005	1314	1052	764
TAXA																								
Annelida																								
Oligochaeta											1							1	1			3		
Arthropoda																								
Crustacea																								
Isopoda																								
Lirceus sp.			1																				1	
Arachnoidea																								
Hydracarina	6	8	2	7							3						2	1			3	8		
Insecta																								
Ephemeroptera																								
Ameletidae																								
Ameletus cryptostimulus					1					1												1		1
Baetidae																								
Acentrella sp. cf. *ampla*	1	3	1	3			5	5		4	4	3	30	5	8	10	11	8	23	20	36	226	38	94
Baetidae sp. (early/damaged instars)	9	2	1	8	1	2					1	2	1		2				4	9	14	26	9	5
Baetis sp. (early/damaged instars)	1							1		3	2								4	1	4	9		
Baetis sp. cf. *brunneicolor*											1										1			
Baetis tricaudatus	7	15	5	18	2		2	7	1	4	3	5	11	4	3	8	1	9	5		3	5	3	2
Ephemerellidae																								
Ephemerella catawba							1												1	2	1	5		
Ephemerella hispida		2			1		1												2					
Ephemerella rossi	18	25	5	35	7	6	4	5	3	1	10	1							13	5	17	13	10	12
Ephemerella sp. (early instars)	9	31	9	7	5	3	11	12	9		3	5	17	17	9	17	15	12	5	1	1	20	12	5
Ephemerella sp. 1 (like *ctawba* but	1		1	1												1								
with 5 tarsal claw denticles)																								
Heptageniidae																								
Cinygmula subaequalis	1		3		2	3	1	1	1	1		1	4		2	1	2	5			12	1	1	5
Epeorus sp. cf. *dispar*	2	1	1				2		1	1		1			3	7	8	3	2	1	12		7	

Table A-5. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	693	764	414	999	555	435	646	740	451	670	632	519	407	475	498	658	773	705	977	1085	1005	1314	1052	764
TAXA																								
Ephemeroptera (continued)																								
Heptageniidae (continued)																								
Epeorus sp. cf. *pleuralis*	2	1		6	4			5		5	2	5	1		4	2	2	14	23	2		5	5	
Epeorus sp. (early instars)				8		3	2	2		4	3			1	2	4	1	2	9	1	5		1	1
Heptageniidae sp. (early instars)																			1					1
Leucrocuta thetis	1	1		1			4		2	6		2									1			
Rhithrogena fuscifrons																	1			1			1	
Rhithrogena sp. (early instars)					1																		1	
Stenacron sp. (early instars)																							1	
Stenonema meririvulanum								2								1								
Stenonema sp. (early instars)								1	1				1								1	1		
Leptophlebiidae																								
Paraleptophlebia adoptiva/mollis	1	1	1						1				1		1	4	1	2	1			4	1	
Odonata																								
Gomphidae																								
Lanthus vernalis													1											
Plecoptera																								
Chloroperlidae																								
Chloroperlidae sp. (early instars)			1							1			1					1						1
Sweltsa sp.																	1							
Leuctridae																								
Leuctra sp.							1		1							1	1		1			2		
Nemouridae																								
Amphinemura appalachia	1	1														1			3					
Amphinemura sp. (early instars)	1						1					1												
Peltoperlidae																								
Peltoperlidae sp. (early instars)	7	24	6	11			1	6	1		3		3		2	1						3		
Tallaperla sp.																		1						

Table A-5. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	693	764	414	999	555	435	646	740	451	670	632	519	407	475	498	658	773	705	977	1085	1005	1314	1052	764
TAXA																								
Plecoptera (continued)																								
Perlidae																								
Acroneuria abnormis										1									2				1	
Acroneuria sp. (early instar)																		1						
Eccoptura xanthenes																			1					
Perlidae sp. (early/damaged instars)			1	2			1					2				2					1		1	1
Perlodidae																								
Isoperla holochlora								1											1					
Isoperla sp. (early instars)		2											1						1					
Malerikus hastatus														1										
Perlodidae sp. (early instars)		3	1																					
Remenus bilobatus									1										1					
Pteronarcyidae																								
Pteronarcys sp. (early instars)			1				1																	
Trichoptera																								
Arctopsychidae																								
Parapsyche cardis								2							1									
Glossosomatidae																								
Agapetus minutus		3	1	1	2	1					1		2		2		3			1				2
Glossosoma nigrior		1			1		2	1																
Hydropsychidae																								
Ceratopsyche macleodi																		1					1	
Diplectrona modesta	4	2	2	3			1	2	2		1	1	3		2	2	1	4	4		1		2	
Odontoceridae																								
Psilotreta rossi																			1					
Psilotreta sp. (early instars)																						1		
Philopotamidae																								
Dolophilodes distinctus																			2					
Wormaldia sp.														2		1								

Table A-5. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	693	764	414	999	555	435	646	740	451	670	632	519	407	475	498	658	773	705	977	1085	1005	1314	1052	764
TAXA																								
Trichoptera (continued)																								
Polycentropodidae																								
Nyctiophylax sp.			4	1												4					1	1	2	1
Polycentropodidae sp. (early instars)																1						3		
Polycentropus sp.				1				1													1	1		1
Rhyacophilidae																								
Rhyacophila appalachia/nigrita				1																				
Rhyacophila atrata																				1		1		
Rhyacophila carolina																					1			
Rhyacophila fuscula		3	1							1	1												1	1
Rhyacophila sp. (early instars)			1				1																	
Uenoidae																								
Neophylax consimilis																						1		
Neophylax mitchelli	1		1	2		1	1	1	1	2		1	2										1	1
Neophylax ornatus		6	2			2						2				2								
Neophylax sp. (early instars)		3	3	2	3	1	4	1		2	5	2				1	2							
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)			1	1					3						1		1	1	1	4		10	1	2
Optioservus sp. (larvae)			4			3	1	1		1		1		1			1	1		4		7	5	1
Oulimnius latiusculus (adults)		1	4					2	2								1		1					
Oulimnius latiusculus (larvae)		2	2		1					2	1							2		2		1		
Eubriidae																								
Ectopria sp.		1		2			1				1													
Diptera																								
Ceratopogonidae																								
Palpomyia complex	1																			1				
Chironomidae	37	33	23	76	10	6	18	17	9	2	60	3	31	6	11	28	9	16	10	23	25	157	5	27

Table A-5. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Rock Surface Area (cm^2)	693	764	414	999	555	435	646	740	451	670	632	519	407	475	498	658	773	705	977	1085	1005	1314	1052	764
TAXA																								
Diptera																								
Empididae																								
Chelifera sp.		2		3				1			1											2		
Clinocera sp.																						4		
Hemerodromia sp.	9	4	2	5		1		1							1	2								
Nymphomyiidae																								
Nymphomyia sp.	1	1		1																				
Simuliidae	1											2		4		1		1	1			2		
Tipulidae																								
Antocha sp.		1		2			1									1				1	1	11		
Dicranota sp.					1										1									
Hexatoma sp.													1											
Tipula abdominalis									1															
TOTAL SPECIMENS	122	183	91	208	42	32	68	78	40	42	107	40	111	41	55	103	64	86	124	80	142	534	111	164

Table A-6. Kick samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, June 1997.

Sampling Site	MB-S1					MB-S2					MB-S3					MB-S4				
Sampling Units (Kicks) Per Site	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																				
Nematoda	1											1								
Annelida																				
Oligochaeta	5	2	2	2	4	5		2	4	4	2	3	1	8	1	4	4	7	2	6
Arthropoda																				
Crustacea																				
Copepoda																				
Harpacticoidea																				1
Isopoda																				
Lirceus sp.	1					1		2	6		2									1
Decapoda																				
Cambaridae																				
Cambarus bartonii										1										
Cambarus sp. (juveniles)					2	1	1		1	2		1		1			2			
Arachnoidea																				
Hydracarina	1		2			1	1	1	2			1				1	1	1	1	2
Insecta																				
Ephemeroptera																				
Ameletidae																				
Ameletus cryptostimulus									1											
Baetidae																				
Acentrella sp. cf. *ampla*			1		3				2			1				1				
Baetidae sp. (early/damaged instars)			1		1							1		1			1		1	1
Baetis sp. (early/damaged instars)						1				1	1						1			
Baetis sp. cf. *brunneicolor*																			4	6
Baetis tricaudatus		3	2		2	5	3	2		1		1	2			2	2	1	1	
Ephemerellidae																				
Drunella sp. (early/damaged instars)			1		1						1						11	1	3	3
Ephemerella catawba			1			1	12			1			1			2		2		
Ephemerella rossi	19	8	28	50	35	34	62	43	114	17	40	56	3	47	40	79	98	60	19	19
Ephemerella sp. (early instars)						1	1										1			

Table A-6. Continued.

Sampling Site	MB-S1					MB-S2					MB-S3					MB-S4				
Sampling Units (Kicks) Per Site	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																				
Ephemeroptera (continued)																				
Ephemeridae																				
Ephemera guttulata										3										
Heptageniidae																				
Cinygmula subaequalis												1						1		
Epeorus sp. cf. *dispar*	1	3	12	7	5	6	2	5	2	1	3	4	10	4		1	9	9	2	5
Epeorus sp. cf. *pleuralis*				1		2							1			1	1	2		
Epeorus sp. (early instars)	2							1	1	1	1	2		1	1	2	3	2		1
Heptagenia julia											1									
Heptageniidae sp. (early instars)										1		1		1			8		2	1
Leucrocuta sp. (early instars)																				3
Leucrocuta thetis	1						1	3		4										
Rhithrogena fuscifrons		1		3	2	2	1	1	1		5	7	3	7	4	10	4	12	19	6
Stenacron sp. (early instars)	1																			
Stenacron sp. cf. *pallidum*																			1	
Stenonema meritivulanum				1	4	2		3	1	2								1	1	
Stenonema modestum/ithaca															1	1	6		3	
Stenonema sp. (early instars)			1						1	2		3		6	1	2	2	5	1	1
Leptophlebiidae																				
Leptophlebiidae sp. (damaged instars)	3				16	1	6	3	3	1	1	3		4	2		8		5	2
Paraleptophlebia adoptiva/mollis					1			1		1				1		3	5	4		1
Odonata																				
Gomphidae																				
Lanthus vernalis	3						1	7	1	3	1	1					3	1	1	2
Plecoptera																				
Chloroperlidae																				
Chloroperlidae sp. (early instars)																	1	1		
Leuctridae																				
Leuctra sp.	3	1			10			2	1			2				2	8	1	1	1

Table A-6. Continued.

Sampling Site	MB-S1					MB-S2					MB-S3					MB-S4				
Sampling Units (Kicks) Per Site	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																				
Plecoptera (continued)																				
Nemouridae																				
Amphinemura appalachia				1	1				1											
Amphinemura delosa/nigrita									1											
Amphinemura sp. (early instars)								1												
Peltoperlidae																				
Peltoperlidae sp. (early instars)							1										2			
Tallaperla sp.			1		8			3	3								2	1		
Perlidae																				
Acroneurla abnormis		2				1	3		4	2		2	1	2	1	4	8	3	1	1
Acroneuria sp. (early instars)	1	1		1	5	5	2	13	12	4	1	10		1	1		6	3	4	3
Eccoptura xanthenes		8															1	1		
Paragnetina immarginata												1								
Perlesta sp. cf. *frisoni*	3		1	9	7	2		9	4		3	3		1	1	2	9	3	3	9
Perlidae sp. (early/damaged instars)	1				4	1	2						2	1			1			
Perlodidae																				
Isoperla holochlora			1		1		2													
Isoperla sp. (early instars)	1																			
Malerikus hastatus			1	1		1														
Malerikus/Yugus (early instars)																	1			
Remenus bilobatus					1				4									1		
Yugus bulbosus									2					3		1				
Pteronarcyidae																				
Pteronarcys sp. cf. *scotti*														1	1	1	1	2		
Pteronarcys sp. (early instars)														1			3			
Trichoptera																				
Arctopsychidae																				
Parapsyche cardis			1																	
Glossosomatidae																				
Agapetus minutus	5	2	4	4	2	1	3	6	6	3	14	13	2	5	2	7	22	9	6	7

Table A-6. Continued.

Sampling Site	MB-S1					MB-S2					MB-S3					MB-S4				
Sampling Units (Kicks) Per Site	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																				
Trichoptera (continued)																				
Glossosomatidae (continued)																				
Glossosoma nigrior	1	2	3	13	4		5		3	2	3	4	1	10	4	8	4	11	4	10
Hydropsychidae																				
Diplectrona modesta	14	3	3	18	29	7	29	34	30	12	9	26	1	7	2	5	33	9		4
Hydropsychidae sp. (early instars)							2											2		
Lepidostomatidae																				
Lepidostoma sp.				1	2		1										2	1		
Limnephilidae																				
Pycnopsyche sonso																			1	
Odontoceridae																				
Psilotreta frontalis																				5
Psilotreta sp. (early instars)								1							1					
Philopotamidae																				
Dolophilodes distinctus					3				1		1			1		1	2	1		
Wormaldia sp.																	1	1		
Polycentropodidae																				
Polycentropodidae sp. (early instars)			1	2	1					1						1	4			
Polycentropus sp.				1						1	1	1					1	2	2	1
Rhyacophilidae																				
Rhyacophila appalachia/nigrita	1				1				1		1		1	1			2			
Rhyacophila atrata																				3
Rhyacophila carolina			1					1	2								1			
Rhyacophila fenestralledra							1													
Rhyacophila fuscula			1	1	1		1		1			1			2	2	1	1	1	
Rhyacophila sp. (early instars)					1													1		
Uenoidae																				
Neophylax mitchelli	1		2	1	1	1	1	1	1		1									
Neophylax ornatus		1							1											

Table A-6. Continued.

Sampling Site	MB-S1					MB-S2					MB-S3					MB-S4				
Sampling Units (Kicks) Per Site	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																				
Trichoptera (continued)																				
Uenoidae (continued)																				
Neophylax sp. (early instars)																	2			4
Coleoptera																				
Elmidae																				
Elmidae sp. (early/damaged instars)	1						1	1	2		1	1			1		11	5	19	2
Optioservus immunis									3					1			1			
Optioservus ovalis	1		3								4					2	2		3	
Optioservus sp. (larvae)		3	6	3	2	10	2	2	10	8	1	4		9	16	3	2	5	13	15
Oulimnius latiusculus (adults)	1		3	2	5		2		1	2	1			1		2	2	7	2	2
Oulimnius latiusculus (larvae)	2	2	2	2	1			4	1	2						1	3	3	4	3
Promoresia sp. (larvae)	2		5		3				2	1		1			1			1	2	1
Eubriidae																				
Ectopria sp.			1			1		2	2	2		2					5			1
Diptera																				
Blephariceridae																				
Blepharicera sp.								1												
Ceratopogonidae																				
Palpomyia complex		1			7	1			1	2	3	2					5	2	3	1
Chironomidae	32	6	20	14	64	24	29	21	30	20	20	29	5	44	45	55	93	71	93	70
Empididae																				
Chelifera sp.	1						2										1			2
Dolichocephala sp.																	1			
Empididae sp. (early/damaged instars)																	1			
Hemerodromia sp.				1	1												1			1
Simuliidae		4	2	1	1	7	2		1			1	3	4			4	4		
Tipulidae																				
Antocha sp.							1													
Dicranota sp.				1	4	1			1	1				1						

Table A-6. Continued.

Sampling Site	MB-S1					MB-S2					MB-S3					MB-S4				
Sampling Units (Kicks) Per Site	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																				
Diptera (continued)																				
Tipulidae (continued)																				
Hexatoma sp.	5	2	1		2		1		2	1		1			4	2	7	7	6	9
Tipula abdominalis					1	1		2	1			1								1
Tipulidae sp. (early/damaged larvae)		1		1	1	4	1		1	5	5	2		7	3	15	23	31	29	40
TOTAL SPECIMENS	114	56	114	142	250	131	185	178	276	115	127	194	37	182	135	223	450	299	263	257

Table A-7. Kick samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, July 1997.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks) Per Site	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Nematoda		1																				1		
Annelida																								
Oligochaeta		2			4	1	1	2		1	6	2	2		1			3		2	2	3	2	1
Arthropoda																								
Crustacea																								
Isopoda																								
Lirceus sp.								1		1	4	2								1				
Decapoda																								
Cambaridae																								
Cambarus sp. (juveniles)								1		1		1		2	1		2							
Arachnoidea																								
Hydracarina		2			1	1					1											2	1	1
Insecta																								
Ephemeroptera																								
Baetidae																								
Acentrella sp. cf. *ampla*					1				2					1		2				1				2
Baetidae sp. (early/damaged instars)			1						1															
Baetis sp. (early/damaged instars)											1				2									
Baetis sp. cf. *brunneicolor*																	1							
Baetis tricaudatus		1	2	2	1			2	1	2				1										
Ephemerellidae																								
Drunella tuberculata		5	2	1	2	2			5				9	4	2	1	2	2	5	1	1	9	1	5
Ephemerella catawba																			1					3
Ephemerella sp. (early instars)											1													
Ephemerellidae sp. (early instars)										1														
Ephemeridae																								
Ephemera guttulata										1	7	4												
Heptageniidae																								
Epeorus sp. cf. *dispar*	2	10	32	15	6	4	1	7	11	7	3	2	4	11		8	4	1	4	1	8	1	1	11
Epeorus sp. (early instars)																				1				

Table A-7. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks) Per Site	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Ephemeroptera (continued)																								
Heptageniidae (continued)																								
Heptagenia julia				1												2	3					3		
Heptagenia sp. (early instars)							1				3			2	1					5	3		2	2
Heptageniidae sp. (early instars)		1					1		1			1	1					1						2
Leucrocuta sp. (early instars)					1	1				1	1	3			1						1	3		
Leucrocuta thetis	1											1												
Rhithrogena fuscifrons		1	1	1			1	1	1				7	1	1	3	5	2	4	5	4	2	4	
Stenacron sp. (early instars)											1			1										
Stenonema meritvulanum	1	1					1	1		6	1													
Stenonema modestum/ithaca																	1							
Stenonema pudicum												1										4		
Stenonema sp. (early instars)						1				1			3			1	2		1		1			1
Isonychildae																								
Isonychia sp.										1	1						1	1						
Leptophlebiidae																								
Leptophlebiidae sp. (damaged instars)			1	1	1		3				3	2		4		3	1	1			1	1		
Paraleptophlebia adoptiva/mollis							1			1														
Odonata																								
Cordulegastridae																								
Cordulegaster erronea										1														
Gomphidae																								
Lanthus vernalis					3	1				2	5	5		2	1					1		2		
Plecoptera																								
Chloroperlidae																								
Rasvena terna	1																							
Sweltsa sp.																1								
Leuctridae																								
Leuctra sp.	1	2	1	1	2					2	3	1	1		3		1		1	5		3	1	

Table A-7. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks) Per Site	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Plecoptera (continued)																								
Nemouridae																								
Amphinemura sp. (early instars)	1				1						1									1				2
Peltoperlidae																								
Tallaperla sp.	1	4	1		7			1			3			3		2				1	1			1
Perlidae																								
Acroneuria abnormis	2			2	3			2	3				5	7		1				5	6	1		10
Acroneuria sp. (early instars)						2		1	5	6	13	5	4	6	4		2	1	2				1	
Eccoptura xanthenes										2	1	1		2										
Perlesta sp. cf. *frisoni*		3	1	1		1	2		1	2		1	5	1	2		2	1		1	3	3		
Perlidae sp. (early/damaged instars)			1	1	2	1			1	1	6	1	1				1			2				1
Perlodidae																								
Isoperla sp. (early instars)								1																
Malerikus hastatus			1													2	1							
Malerikus/Yugus (early instars)														1						2	1			1
Perlodidae sp. (early instars)					2																			
Pteronarcyidae																								
Pteronarcys sp. cf. *scotti*														1			1							
Pteronarcys sp. (early instars)																				1				
Trichoptera																								
Arctopsychidae																								
Arctopsyche irrorata																			2					2
Arctopsychidae sp. (early instars)																							2	1
Parapsyche cardis	1	5	3	5	11	6	2	11	4	3	6	1	3	3	1	2	1	3	1		5	1		4
Brachycentridae																								
Brachycentrus sp. (early instars)				1																				
Glossosomatidae																								
Agapetus minutus																		2	1			1	3	
Glossosoma nigrior		2	2	5	6	5	3	2	6		9	2	11	2	2	5	13	10	3	16	6	13	3	
Glossosomatidae sp. (damaged instars)			2			1			1		1				1		2			1		2	1	

Table A-7. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks) Per Site	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Trichoptera (continued)																								
Goeridae																								
Goera sp.													3		1	1	1			1	2	9	4	
Hydropsychidae																								
Ceratopsyche macleodi													2	2			3		13	8	6	13	10	11
Ceratopsyche sp. (early instars)		1		1						1			1	2	4	5	2	2		8				
Diplectrona modesta	3	10	1	5	11	3	2		4	6	15	2	2	3			1	1	1	2	2	6		7
Hydropsychidae sp. (early instars)	4		2	4	7	3	2	1	3	3	7	5	1		1		4			1		2		
Lepidostomatidae																								
Lepidostoma sp.					1						2						1							
Odontoceridae																								
Psilotreta frontalis										1			1								4	2		
Psilotreta sp. (early instars)											2									1				
Philopotamidae																								
Dolophilodes distinctus														1							1			2
Wormaldia sp.									1															
Polycentropodidae																								
Nyctiophylax sp.																1								
Psychomyiidae																								
Lype diversa											2													
Rhyacophilidae																								
Rhyacophila appalachia/nigrita										1		2												
Rhyacophila atrata																						1	1	
Rhyacophila carolina																					1			
Rhyacophila fuscula		2				2	1	4	4	1	4		1	2	1	1	2		2					4
Rhyacophila minor					1						1													
Rhyacophila sp. (early instars)		1			1					1	4	1			3	1	1			2			1	1
Sericostomatidae																								
Fattigia pele												1												

Table A-7. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks) Per Site	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Trichoptera (continued)																								
Uenoidae																								
Neophylax ornatus																		1						
Neophylax sp. (early instars)		1									1	5						3						
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)		1		2		1	1	1		2	2		4		3	1				1		3		
Optioservus immunis		2		1		3							1				1					2		1
Optioservus ovalis		1	1			1			1			1	1					1	4	1		4	2	
Optioservus sp. (larvae)		4	5	1	3	2	1	1	1	2	6	7	1		2	1	2	3		1		2	7	4
Oulimnius latiusculus (adults)		1	1	1	2	1			1	5	2	1			2	2		3	1	1	1	9		1
Oulimnius latiusculus (larvae)			1			2	1		1	1	4	2					1			1		3	2	
Promoresia sp. (larvae)				1	1							1												
Eubriidae																								
Ectopria sp.	2			2	1	4	1		1	4	10	1					1	3	2					3
Diptera																								
Blephariceridae																								
Blepharicera sp.								1											1					
Ceratopogonidae																								
Atrichopogon sp.									1															
Palpomyia complex	1				2					1	2	1	2			2		1		3		1	2	1
Chironomidae	11	13	6	22	19	11		32	8	16	75	21	31	14	15	20	31	9	4	55	9	53	33	28
Dixidae																								
Dixa sp.																								1
Empididae																								
Chelifera sp.									1		6					1				2				2
Hemerodromia sp.	2	1																						
Simuliidae	1		2	1				120	4	1	10		3	44	2	2	3	1	3	5	5			59
Tipulidae																								
Antocha sp.				1																				

Table A-7. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks) Per Site	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Diptera (continued)																								
Tipulidae (continued)																								
Dicranota sp.				1		1					2		1									1	1	
Hexatoma sp.		2			3	2	2		1	2	3	6	4		1			1		7		4	1	1
Tipula abdominalis											2	1												
Tipula sp.														1										
Tipulidae sp. (early/damaged larvae)			1	2	1	1	1					4	4	5	4	1	5	2		3	4	7	8	2
Tipulidae sp cf. *Pedicia*										1														
TOTAL SPECIMENS	35	80	71	82	107	64	29	193	75	92	243	98	119	129	62	72	105	59	56	156	78	177	94	178

Table A-8. Kick samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, February 1998.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Nematoda								2																
Annelida																								
Oligochaeta	4	23	5		2	2	1	7		6		2	1	3	2	1	6	6	5	10	2	7	10	1
Arthropoda																								
Crustacea																								
Copepoda																								
Harpactacoidea		4														1						1	1	
Isopoda																								
Lirceus sp.		1	1		5	4	2	4	2	1	2				1			1						
Decapoda																								
Cambaridae																								
Cambarus bartonii	1	1																						
Cambarus sp. (juveniles)					1		2		1	1				1					1		1			1
Arachnoidea																								
Hydracarina		5	1		1			2	1		2		1	1					1	1		1	1	
Insecta																								
Ephemeroptera																								
Ameletidae																								
Ameletus cryptostimulus	1		8	10	3	1	8	1		8	2		7	2	1			5			2	4	5	1
Baetidae																								
Baetidae sp. (early/damaged instars)		4						1							1									
Baetis sp. (early/damaged instars)															1		1							
Baetis tricaudatus	1						1		1		3	1					1		2				1	
Ephemerellidae																								
Ephemerella catawba	1	1			1			11		1				1		2		1	1	3	2	11	4	3
Ephemerella hispida		1		1					1	3	1			5				1						
Ephemerella rossi		2																						
Ephemerella sp. (early instars)	6	50	11	15	7	2	3	7	9	3	11		1	8	1	4	12	3	21	12	8	17	18	8
Ephemerella sp. 1 (similar to *catawba*				1	4	1	8	2	4	5	7	2	8	1	2	4	12	10		10	3	11		12
but with 5 tarsal claw denticles)																								

Table A-8. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Ephemeroptera (continued)																								
Ephemerellidae (continued)																								
Ephemerellidae sp. (early instars)												10												
Ephemeridae																								
Ephemera sp. (early/damaged instars)									2		1													
Heptageniidae																								
Cinygmula subaequalis	2	8	2	3			10	3	3	1	6	5		3		3	3	7	2	6	15	10	3	5
Epeorus sp. cf. *dispar*		8	1		2		9	2	12	4	5	5	4	4	3		4	1		7	5	5	7	2
Epeorus sp. cf. *pleuralis*	11	47	5	11	29		17	14	48	15	58	26	7	10	25	6	17	4	36	6	14	10	15	23
Epeorus sp. (early instars)	1	1	1			3			1	1		3	3	5	5	1	2			3		1	1	2
Heptageniidae sp. (early instars)		1				6		1									1		1		1			
Leucrocuta thetis		4	1		1		5		3	2		1	1				2			2	7		10	3
Rhithrogena amica					2									1							3	4		1
Rhithrogena fuscifrons									1			1								1				1
Rhithrogena sp. (early instars)		1			1					1			6		1						2	5	2	4
Stenacron sp. (early instars)	2																							
Stenonema meritivulanum		1								1	1	1					1							
Stenonema modestum/ithaca																						1	4	
Stenonema sp. (early instars)							1		1	1		1		3			2	1	3	2	3		6	
Leptophlebiidae																								
Leptophlebiidae sp. (damaged instars)		12	1		3		1	3	2	5	10	4		1	1		7		1	4	7	6	18	4
Paraleptophlebia adoptiva/mollis	2	4																						
Odonata																								
Gomphidae																								
Lanthus vernalis	1				1	2					1						1			3	1			
Plecoptera																								
Chloroperlidae																								
Chloroperlidae sp. (early instars)		3							1		2							1				1		1
Rasvena terna															1									
Sweltsa sp.				1							1					1			2	1				

Table A-8. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Plecoptera (continued)																								
Leuctridae																								
Leuctra sp.		5						1	3	1		1		1					4		1			
Nemouridae																								
Amphinemura appalachia		6							2	2	3	1		1		1			7	3	2			
Amphinemura sp. (early instars)		9			1					2	1	1		1			1		2			1		
Peltoperlidae																								
Peltoperlidae sp. (early instars)		9																	2					
Tallaperla sp.	1	15		4	2	2			10	1	17	5	1			3			4			3	3	
Perlidae																								
Acroneuria abnormis	2	5		3			4			3	1	4	2	1	1		5		3	2			4	
Acroneuria sp. (early instars)							2	1	2	1			1				3			1				1
Eccoptura xanthenes					1				2		1													
Perlesta sp. cf. *frisoni*					1		3		1	2				2			1		1	1				1
Perlidae sp. (early/damaged instars)		2				3						1		1					1				3	
Perlodidae																								
Isoperla holochlora		1						1																
Isoperla sp. (early instars)		1						1			3	1	1						1			1		
Isoperla sp. cf. *similis*												1				1								
Malerikus hastatus					1	1			3		2										1	1		1
Malerikus/Yugus (early instars)	1	1	2	3	4		3		5	4	4	5	1	1	5	1	3	2	2	2	2	14	1	3
Perlodidae sp. (early instars)		1																	1					
Remenus bilobatus																			1					
Yugus arinus																			1	1	1	2		1
Yugus bulbosus		2																						
Pteronarcyidae																								
Pteronarcys sp. (early instars)		1							3		7						3		2	2	1	1		
Pteronarcys sp. cf. *scotti*									1	1									3				1	

Table A-8. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Trichoptera																								
Apataniidae																								
Apatania sp.																				1				
Arctopsychidae																								
Parapsyche cardis	1	2			1				6	1		1							2	1			1	
Brachycentridae																								
Micrasema burksi								1																
Glossosomatidae																								
Agapetus minutus																					1			
Glossosoma nigrior				1	1				1		1		1	2		1		2	1		2		1	
Hydropsychidae																								
Ceratopsyche macleodi									3	1	1						1		3	14	1	2	7	
Ceratopsyche slossonae																				1				
Diplectrona modesta	4	22	2	12	15		13	4	10	15	2	15	1	9	5	2	16	2	6	31	5	13	11	
Lepidostomatidae																								
Lepidostoma sp.	1	3			1			1					1	1	1		1	2	1	1		2	5	2
Limnephilidae																								
Pycnopsyche gentilis		1																						
Odontoceridae																								
Psilotreta rossi	1																							
Philopotamidae																								
Dolophilodes distinctus		3			2			1				4				1				1				
Wormaldia sp.		1								1		1					3							
Polycentropodidae																								
Polycentropus sp.	1																							
Psychomyiidae																								
Lype diversa		1									1						2							
Rhyacophilidae																								
Rhyacophila appalachia/nigrita		4							2											1		1	1	
Rhyacophila atrata		1																						1

Table A-8. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Trichoptera (continued)																								
Rhyacophilidae (continued)																								
Rhyacophila fuscula		1	1				1	1	2			2		1	1		1		2	2			1	
Rhyacophila glaberrima																			1					
Rhyacophila minora																			1	2		3	1	
Rhyacophila sp. (early instars)		2	1		1		1		1		3	1							1			2	1	
Sericostomatidae																								
Fattigia pele								1																
Uenoidae																								
Neophylax mitchelli		1		1			1					1							1	1		1		1
Neophylax ornatus		4	2	1	1			1		2	1	1	1	1				1	1	1			2	
Neophylax sp. (early instars)		6		3	2		1	2			2	1	2	1				2		2		2	3	
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)		4		1	2	4		1	1	3	1							1				1	1	1
Optioservus immunis		3	2	3	6	7		2		1	4								1	2			1	1
Optioservus ovalis			1	1			1	3	8	3	4	4			2		1		9	4		3	1	1
Optioservus sp. (larvae)		26	11	1	4	18	12	4	17	10	23	8	6	8	1	12	1	6	2	2	17	21	17	10
Oulimnius latiusculus (adults)		11	2	1		1	2	1	4	1	3	6		1		1			4	2		1		1
Oulimnius latiusculus (larvae)				2	3	2	3	2	5		2		1			2	1	3	2	2	2	3	1	3
Eubriidae																								
Ectopria sp.	1	1		1	1	1		2			3	1	1	3		1	1	1	1		1			
Diptera													1											
Blephariceridae																								
Blepharicera sp.											1													
Ceratopogonidae																								
Palpomyia complex		8	1	2	1	1		8	7	3	4						2	1	1	7		3	2	1
Chironomidae	25	178	19	15	29	8	29	43	64	41	26	27	11	33	18	15	43	20	96	76	50	36	112	27
Dixidae																								
Dixa sp.									1															

Table A-8. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Diptera (continued)																								
Empididae																								
Chelifera sp.		1										1							2	1			1	2
Hemerodromia sp.	1		1														1					1		
Simuliidae	3	16		1	1			1	1	1	13	4	1		1	4			27	4				2
Tipulidae																								
Antocha sp.									1	2				1										
Dicranota sp.		4							1			1						1	2		1		1	
Hexatoma sp.	1	3	1	2	2	1	2		1			2		1	1	4		4	7	1	3	5	2	5
Molophilus sp.								1											1					
Pseudolimnophila sp.													1											
Tipula abdominalis		1									2	1				1					2		3	
Tipulidae sp. (early/damaged instars)		1	3		1			1	1	1			1		1		2			1	2	2	2	1
TOTAL SPECIMENS	76	549	86	100	147	72	145	146	261	161	249	165	73	119	82	76	161	89	287	243	171	220	297	137

Table A-9. Kick samples of benthic macroinvertebrates collected at four sampling sites from Mannis Branch, April 1998.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Nematoda																								
Annelida																								
Oligochaeta			5	5	4	3	1	4	2		2	1	1		5	6	2	3			1	6	1	2
Arthropoda																								
Crustacea																								
Copepoda																								
Harpactacoidea																					1			
Isopoda																								
Lirceus sp.		1			1			3					9											
Decapoda																								
Cambaridae																								
Cambarus bartonii																					1			
Cambarus sp. (juveniles)		1	1	1	1	1					1		2			1	1						2	
Arachnoidea																								
Hydracarina	2																1							1
Insecta																								
Ephemeroptera																								
Ameletidae																								
Ameletus cryptostimulus			1					1						1		1							1	1
Baetidae																								
Acentrella sp. cf. *ampla*														1	1	1	1		1	1			5	
Baetidae sp. (early/damaged instars)														4							3	1	1	1
Baetis sp. (early/damaged instars)					6	1	3				1		7											
Baetis sp. cf. *brunneicolor*				1							1													
Baetis tricaudatus									2					5	6	14		1	3			3	5	2
Ephemerellidae																								
Ephemerella catawba					1	1		1								1					4	4	2	7
Ephemerella hispida							3				3		3			1								
Ephemerella rossi	3	5	42	23	52	27	1	29	12		8	17												
Ephemerella sp. (early instars)	5		10	5	44	14	25	15	1	5	48	18	120	79	42	65	69	28	53	49	101	78	69	113

Table A-9. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Ephemeroptera (continued)																								
Ephemerellidae (continued)																								
Ephemerella sp. 1 (similar to *catawba*			2		1		4	2				1	1	6		4		2	1		1		4	2
but with 5 tarsal claw denticles)																								
Ephemeridae																								
Ephemera sp. (early/damaged instars)														1			1							
Heptageniidae																								
Cinygmula subaequalis	2	4	10	9	18	10	11	24		2	5	8	16	8	17	29	5	4	8	12	5	8	7	20
Epeorus sp. cf. *dispar*				1		1			4	1	7	1		7	8	6	1	1			2	1	4	
Epeorus sp. cf. *pleuralis*		14	19	12	7	36	5	1	37	12	41	2	1	5	7	8	1	24	33	6	12	12	22	6
Epeorus sp. (early instars)	5		1		3		3	1	4		2		1	7	1	3	9		4		8	3		
Heptageniidae sp. (early instars)	3		2											2			2				1			
Leucrocuta sp.							1					1					3							
Leucrocuta thetis			1			1			1				1	3	1		1					1	1	
Rhithrogena amica																1								
Rhithrogena fuscifrons				2				4				4	1		14	12	1	6	3	2	2	5	5	12
Rhithrogena sp. (early instars)												1												
Stenonema meririvulanum						1																1		
Stenonema modestum/ithaca													1	1							5			
Stenonema sp. (early instars)									1		1		2	3		3	5	1			1	1	2	
Leptophlebiidae																								
Leptophlebiidae sp. (early instars)			1		3	2		1			2		2	4		1	3	2	2	1	4	8	13	
Odonata																								
Gomphidae																								
Lanthus vernalis								1	1			1					1			1		1		
Plecoptera																								
Chloroperlidae																								
Chloroperlidae sp. (early instars)					2								1			1	1				1	1		1
Sweltsa sp.									1							1					1	1		

Table A-9. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Plecoptera (continued)																								
Leuctridae																								
Leuctra sp.														1			1	1						
Nemouridae																								
Amphinemura appalachia						1							1	2								1	7	
Amphinemura sp. (early instars)													1									1		
Peltoperlidae																								
Peltoperlidae sp. (early instars)			3				1													1			4	
Tallaperla sp.	1				7		3		1		3	1											4	
Perlidae																								
Acroneuria abnormis	2								7		4	3		2		1		1	1				3	
Acroneuria sp. (early instars)						1	2	1					1				2		1		1	2	1	
Eccoptura xanthenes																1								
Hansonoperla appalachia														1										
Perlesta sp. cf. *frisoni*	1	1	1					2					1	1	1	2	1		2					1
Perlidae sp. (early/damaged instars)				1									4	2	1		2						2	1
Perlodidae																								
Isoperla holochlora											2	1												
Malerikus hastatus				2	1							1					1							
Malerikus/Yugus (early instars)	1	3		1			2	1	2				2	2	4			1	1	1		1		2
Perlodidae sp. (early instars)																							2	
Yugus arinus																							1	
Yugus bulbosus											2	1				2	1	2					6	
Pteronarcyidae																								
Pteronarcys sp. (early instars)																							2	
Pteronarcys sp. cf. *scotti*																			1					1
Trichoptera																								
Arctopsychidae																								
Parapsyche cardis		1			1						6												2	

Table A-9. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Trichoptera (continued)																								
Glossosomatidae																								
Agapetus minutus	1	11	3	2	27	3		2				5	4	19	34	28	17	13	1	1	2	8	3	11
Glossosoma nigrior			2		4	1					1			1		1	2							4
Glossosomatidae sp. (damaged instars)	1												1	1	4		5							
Hydropsychidae																								
Ceratopsyche macleodi																		2		2	4		3	1
Ceratopsyche sp. (early instars)																								1
Diplectrona modesta	3	3	1		1	4		1	4		6	4	4	7	7	6	2	2	2		7	5	21	3
Hydropsychidae sp. (early instars)																		1					1	
Lepidostomatidae																								
Lepidostoma sp.							3		1		1	1	1	2									1	1
Limnephilidae																								
Pycnopsyche guttifer group																					1			
Odontoceridae																								
Psilotreta frontalis																								2
Psilotreta sp.																					1			
Philopotamidae																								
Dolophilodes distinctus	1		1			1		1																
Wormaldia sp.								1									1							
Polycentropodidae																								
Nyctiophylax sp.							1																	
Polycentropus sp.			1														1							1
Psychomyiidae																								
Lype diversa									2															
Rhyacophilidae																								
Rhyacophila appalachia/nigrita	1																			1			1	3
Rhyacophila atrata																			1	1				
Rhyacophila fuscula				2		2			1					1			1	1	1	2	1	1	1	5

Table A-9. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Trichoptera (continued)																								
Rhyacophilidae (continued)																								
Rhyacophila minor				1							1											1	3	1
Rhyacophila sp. (early instars)	1	1															1			1			1	
Uenoidae																								
Neophylax mitchelli	2	1	3	6		1	1	13		1	3	9	5	3	2	3	2		1			4	1	11
Neophylax ornatus						2				1				1										
Neophylax sp. (early instars)	2	2	4	5	10		9	19			2	6	1	1	2	2	3			2	3	2	4	4
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)	2	3	2	2	8	1							5	2	3	1	1	1	2		4	4	4	6
Optioservus immunis		3	3	1	2	4							1			3								
Optioservus ovalis		4	1	1		1	6	2			1	1	2		1	2	1			4		1	2	5
Optioservus sp. (larvae)		13	12	4	25	9	16	13		2	3	11	18	8	15	38	5	2	12	24	22	7	15	20
Oulimnius latiusculus (adults)		1	3	1	1	1	1	1		1	1	2	2		1	2	1			1	2	3	3	5
Oulimnius latiusculus (larvae)			5	1	13	1		5			2	3	1	1	2	3	1		3		1		2	5
Eubriidae																								
Ectopria sp.		1	1				1			1				2								2	1	
Diptera																								
Blephariceridae																								
Blepharicera sp.																				1				
Ceratopogonidae																								
Palpomyia complex	1	1		1	2			2		1			5			1	2	2		1	1	1	1	2
Chironomidae	6	6	9	1	23	32	4	6	3		25	14	19	25	16	30	20	28	2	10	31	32	29	59
Empididae																								
Chelifera sp.			1																				1	1
Clinocera sp.																		1						1
Simuliidae				2	6	3			4		4		3		1		1		1				10	

Table A-9. Continued.

Sampling Site	MB-S1						MB-S2						MB-S3						MB-S4					
Sampling Units (Kicks)	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
TAXA																								
Diptera (continued)																								
Tipulidae																								
Antocha sp.			1	1							3	1	1										2	1
Dicranota sp.	1		1		3							1												2
Hexatoma sp.			1	1	1		2	2		1		1	6	3	2	1	6				4	4	1	1
Tipula abdominalis					1				1		2				1				1			1		
Tipulidae sp. (early/damaged instars)					1					1	1			2	1	1					1			2
TOTAL SPECIMENS	47	80	154	95	281	167	108	158	92	29	195	122	257	227	200	289	187	131	140	126	241	215	288	331

Table A-10. Tile samples of benthic macroinvertebrates collected at two sampling stations above the upper boundary falls on Mannis Branch, May - June 1998. (Data from sites T3 and T4 in Table A-11.)

Sampling Site	T1									T2								
Sampling Units (Individual Tiles)	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
TAXA																		
Annelida																		
Oligochaeta					1													
Arthropoda																		
Insecta																		
Ephemeroptera																		
Baetidae																		
Baetidae sp. (early/damaged instars)													1					
Baetis tricaudatus																1	1	
Ephemerellidae																		
Ephemerellidae sp. (early instars)								2						1				
Heptageniidae																		
Epeorus sp. (early instars)										1			1				1	
Heptageniidae sp. (early instars)																	1	1
Isonychiidae																		
Isonychia sp.													3					
Leptophlebiidae																		
Paraleptophlebia adoptiva/mollis														1	1			
Plecoptera																		
Leuctridae																		
Leuctra sp.														3	2			
Nemouridae																		
Amphinemura sp. (early/damaged instars)													1					
Peltoperlidae																		
Peltoperlidae sp. (early instars)								1									1	
Tallaperla sp.	2							1		2	1			2				
Perlidae																		
Eccoptura xanthenes															1			
Perlesta sp. cf. *frisoni*															1			
Perlidae sp. (early/damaged instars)	1		1		1	1				1	1	1	1	1		1		

Table A-10. Continued.

Sampling Site	T1									T2								
Sampling Units (Individual Tiles)	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
TAXA																		
Plecoptera (continued)																		
Perlodidae																		
Perlodidae sp. (early instars)						1				1								
Megaloptera																		
Corydalidae																		
Corydalidae sp. (early/damaged instars)		1																
Trichoptera																		
Hydropsychidae																		
Diplectrona modesta								1		3			2	1				
Hydropsychidae sp. (early instars)	6	1	2	5	5	1	17	2		9	12	4	18	4	5	4	3	8
Lepidostomatidae																		
Lepidostoma sp.					1									1				
Odontoceridae																		
Psilotreta sp. (early instars)					1													
Polycentropodidae																		
Polycentropodidae sp. (early instars)														8			4	6
Polycentropus sp.															1			
Rhyacophilidae																		
Rhyacophila fuscula							1											
Rhyacophila sp. (early instars)				2	1			1										
Coleoptera																		
Elmidae																		
Elmidae sp. (early instars)														1				
Diptera																		
Chironomidae	50	41	40	85	81	89	201	150	67	30	55	54	56	37	30	88	30	60
Empididae																		
Chelifera sp.							1			1								
Tabanidae													1					
TOTAL SPECIMENS	59	43	43	92	91	92	220	158	67	48	69	59	84	60	41	94	41	75

Table A-11. Tile samples of benthic macroinvertebrates collected at two sampling stations between the lower and upper boundary falls on Mannis Branch, May - June 1998. (Data from sites T1 and T2 in Table A-10.)

Sampling Site	T3									T4								
Sampling Units (Individual Tiles)	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
TAXA																		
Arthropoda																		
Crustacea																		
Copepoda																		
Harpactacoidea				1														
Isopoda																		
Lirceus sp.															1			
Arachnoidea																		
Hydracarina												2						
Insecta																		
Ephemeroptera																		
Baetidae																		
Acentrella sp. cf. *ampla*						1												
Baetidae sp. (early/damaged instars)	2				1	3		2	1				1	1				
Baetis sp. (early/damaged instars)			1	1	2	3	1	4	8	1			2		3	1		
Baetis tricaudatus			1															
Ephemerellidae																		
Drunella sp. (early instars)										2		2						
Ephemerellidae sp. (early instars)	7	6				1		1				5		1	1		2	1
Heptageniidae																		
Epeorus sp. (early instars)					1		1	1			1			4			1	
Heptageniidae sp. (early instars)	1					1	1	1	4	2		2	1					
Leucrocuta sp. (early instars)											7		2		1		1	
Leucrocuta thetis										6				1				
Stenonema ithaca/modestum				3				2										
Leptophlebiidae																		
Paraleptophlebia adoptiva/mollis	1																	
Plecoptera																		
Leuctridae																		
Leuctra sp.	1																	

Table A-11. Continued.

Sampling Site	T3									T4								
Sampling Units (Individual Tiles)	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
TAXA																		
Plecoptera (continued)																		
Nemouridae																		
Amphinemura sp. (early/damaged instars)																1		
Peltoperlidae																		
Tallaperla sp.	1								1		2		3					
Perlidae																		
Eccoptura xanthenes			1															
Perlesta sp. cf. *frisoni*	1	1								1								
Perlidae sp. (early/damaged instars)			1							2			1			1	2	
Trichoptera																		
Arctopsychidae																		
Arctopsyche irrorata										1				2				
Glossosomatidae																		
Agapetus minutus						1												
Glossosoma nigrior			1	1							1							
Goeridae																		
Goerita semata										1								
Hydropsychidae																		
Ceratopsyche sp. (early/damaged instars)										4				1			2	
Diplectrona modesta														1			1	
Hydropsychidae sp. (early instars)	2	1	1	1	1	1	5				2	6	1	3		3	4	2
Polycentropodidae																		
Nyctiophylax sp.														1				
Polycentropodidae sp. (early instars)										2	1	7		8	2	3		2
Rhyacophilidae																		
Rhyacophila fuscula										1								
Rhyacophila sp. (early instars)											1			1			2	
Coleoptera																		
Elmidae																		
Elmidae sp. (early instars)						1												

Table A-11. Continued.

Sampling Site	T3									T4								
Sampling Units (Individual Tiles)	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
TAXA																		
Coleoptera (continued)																		
Eubriidae																		
Ectopria sp.						1												
Diptera																		
Chironomidae	24	94	84	76	99	85	38	57	105	56	38	63	37	59	64	66	68	77
Dixidae																		
Dixa sp.											1	1						
Empididae																		
Chelifera sp.																	1	
Empididae sp. (early instars)					1													
Simuliidae						2			1								1	
Tabanidae			1						1									
TOTAL SPECIMENS	40	102	91	83	105	100	46	68	121	79	54	88	48	83	72	75	85	82

Table A-12. Tile samples of benthic macroinvertebrates collected from three replicate reaches upstream and three replicate reaches downstream of the upper boundary falls on Mannis Branch, August - November 1998. (UR = upper reaches; stream or habitat units in the section above the upper boundary falls. LR = lower reaches; stream or habitat units in the section between the lower and upper boundary falls)

Sampling Site (by Stream Reach)	UR1					UR2					UR3					LR1					LR2					LR3				
Sampling Units (Individual Tiles)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																														
Annelida																														
Oligochaeta											1			1			1			1		1		1	1				1	
Arthropoda																														
Crustacea																														
Copepoda																														
Harpactacoidea					1												1							1			2		1	1
Arachnoidea																														
Hydracarina		1																			1							1		
Insecta																														
Ephemeroptera																														
Ameletidae																														
Ameletus cryptostimulus			5	3					1	1			5				3	2	1	1		1		6	6		4	4	3	2
Baetidae																														
Baetidae sp. (early/damaged instars)											1																1			1
Ephemerellidae																														
Ephemerellidae sp. (early instars)				1			1		1	1							2				2	26		2	32	3	37	8	12	2
Heptageniidae																														
Epeorus sp. (early instars)		1		1					1	1			1				1					4			1		6		2	1
Heptageniidae sp. (early instars)		1	1															1									2			
Leucrocuta sp. (early instars)					1								1																	
Leucrocuta thetis	1							2								1	1							2	3					
Stenonema ithaca/modestum																		1				2								
Stenonema sp. (early instars)																										1				
Leptophlebiidae																														
Habrophlebia vibrans						1			1										1											
Paraleptophlebia adoptiva/mollis									1											1										

Table A-12. Continued.

Sampling Site (by Stream Reach)	UR1					UR2					UR3					LR1					LR2					LR3				
Sampling Units (Individual Tiles)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																														
Plecoptera																														
Capniidae																														
Capniidae sp. (early instars)																	1													1
Paracapnia angulata								2									1					3								
Chloroperlidae																														
Sweltsa sp.								1																						
Leuctridae																														
Leuctra sp.			2	1			1		1																					
Perlidae																														
Eccoptura xanthenes				1																										
Perlesta sp. cf. *frisoni*																	1													
Perlidae sp. (early instars)																						1								
Perlodidae																														
Perlodidae sp. (early instars)								1	1			2				1						1		2	2			1		
Pteronarcyidae																														
Pteronarcys sp. (early instars)						2	1																							
Trichoptera																														
Lepidostomatidae																														
Lepidostoma sp.	4		1			2	1	1	1					1				1		2		7							1	1
Limnephilidae																														
Limnephilidae sp. (early instars)									8	1		1		1				1	1	3		1				1		1		2
Odontoceridae																														
Psilotreta sp. (early instars)						1																								1
Polycentropodidae																														
Nyctiophylax sp.												3	1						2								2			
Polycentropodidae sp. (early instars)																		1		3					1			2	2	
Polycentropus sp.																			1					2						
Rhyacophilidae																														
Rhyacophila fuscula																											1	1		
Rhyacophila sp. (early instars)																						1					4	1		

Table A-12. Continued.

Sampling Site (by Stream Reach)	UR1					UR2					UR3					LR1					LR2					LR3				
Sampling Units (Individual Tiles)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
TAXA																														
Coleoptera																														
Elmidae																														
Elmidae sp. (early instars)			1			2	1	1			1											1								
Diptera																														
Ceratopogonidae																														
Palpomyia complex					1				1								1			1	1									1
Chironomidae	21	21	38	16	32	33	23	41	44	25	24	49	83	16	17	30	42	18	80	48	22	154	88	81	106	58	234	27	68	78
Dixidae																														
Dixa sp.						1																							1	
Empididae																														
Hemerodromia sp.																				1		1								
Tipulidae																														
Dicranota sp.					1																									
Hexatoma sp.					2	1		1																				1		
TOTAL SPECIMENS	26	24	48	23	38	43	28	50	61	29	27	55	91	19	17	32	55	25	86	61	26	204	88	97	152	63	293	47	91	91

Table A-13. Leaf pack samples of benthic macroinvertebrates collected upstream (above) and downstream (below) of upper boundary falls from Mannis Branch, 19 February to 19 March 1998.

Sampling Site	Above Upper Falls												Below Upper Falls											
Sampling Units (Leaf Packs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
TAXA																								
Annelida																								
Oligochaeta						1										2								
Arthropoda																								
Crustacea																								
Copepoda																								
Harpactacoidea																						1		
Isopoda																								
Lirceus sp.	1	1	7			3		1	2	1	3	1								1	1			
Decapoda																								
Cambaridae																								
Cambarus bartonii																			1					
Insecta																								
Ephemeroptera																								
Ameletidae																								
Ameletus cryptostimulus	1	1	5	1	3			3		2	24	60	14	7	3	13	2		18	2			7	3
Baetidae																								
Acentrella sp. cf.. *ampla*											2					1						1	1	
Baetidae sp. (early/damaged instars)								3		1		6	4		1	6								
Baetis sp. (early/damaged instars)		1						1	1	3	1	5					1		1			3	2	
Ephemerellidae																								
Ephemerella catawba																							2	2
Ephemerella sp. (early instars)		1						2							18		1				2	2		
Ephemerella sp. 1 (similar to *catawba*			1												5									1
but with 5 tarsal claw denticles)																								
Ephemerellidae sp. (early instars)				7	7	4	10	27	16	24	16	21			37	61	30	24	14	8	22	23	34	23
Eurylophella funeralis					1	6		3		4	7	6		2					4	2	2		2	
Eurylophella sp.									6															

Table A-13. Continued.

Sampling Site	Above Upper Falls												Below Upper Falls											
Sampling Units (Leaf Packs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
TAXA																								
Ephemeroptera (continued)																								
Ephemeridae																								
Ephemera sp. (early instars)	4	11	16										20	20										
Heptageniidae																								
Cinygmula subaequalis																								1
Epeorus sp. cf. *dispar*			2																					
Epeorus sp. cf. *pleuralis*							1			2				1								1		
Epeorus sp. (early instars)		1	2																				1	2
Leucrocuta thetis											1						1		1				1	
Stenonema meritvulanum			1								2	1					1							
Stenonema sp. (early instars)	1				1											1								
Leptophlebiidae																								
Leptophlebiidae sp. (early instars)	1			1	1	7	1		3						2	1	2		3		1			4
Paraleptophlebia adoptiva/mollis			10		1	5	3	8	12	30	27	6		2	1	1	3		2	2	8	32	4	48
Odonata																								
Gomphidae																								
Lanthus vernalis	1																						1	
Plecoptera																								
Chloroperlidae																								
Chloroperlidae sp. (early instars)				1			1	1	1	3	3	1							1	2			1	1
Sweltsa sp.											1													2
Leuctridae																								
Leuctra sp.	1	3	8			2	7	5	16	43	27	3							1	4	6	15	1	10
Nemouridae																								
Amphinemura appalachia		3					1	1	10	3					2	1	1	3		1				1
Amphinemura sp. (early instars)	5	7	9	3	5	21	16	19	22	77	61	9	2	3		4	4		5	9	21	39	29	31
Peltoperlidae																								
Peltoperlidae sp. (early instars)			6	4	7	1	6	4	10	14	4	2	1		7	8	1	1		2	2	1	4	7
Tallaperla sp.	4	12	27	7	8	12	73	25	24	65	25	11	7	4	12	15	2	10	10	28	58	28	13	26

Table A-13. Continued.

Sampling Site	Above Upper Falls												Below Upper Falls											
Sampling Units (Leaf Packs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
TAXA																								
Plecoptera (continued)																								
Perlidae																								
Eccoptura xanthenes											1													
Perlidae sp. (early/damaged instars)											2				2	1		2						
Perlodidae																								
Diploperla duplicate												1											1	
Isoperla sp. (early instars)											3													
Isoperla sp. cf. *similis*	8	1	4	4	3	8	5	4	2	21	6	6	1	7	3	6	9	9	4	8	6	7	17	8
Malerikus hastatus																				1				
Malerikus/Yugus (early instars)							1		1															
Perlodidae sp. (early instars)	2	4	13		3	2	10	15	6	15	6	10	2	2		12	3	1	3	3	7	9	1	6
Remenus bilobatus		1	1				2			3	2											1		2
Pteronarcyidae																								
Pteronarcys sp. (early instars)		1						1		2	1					1		1				1		3
Trichoptera																								
Arctopsychidae																								
Parapsyche cardis							1																	
Brachycentridae																								
Micrasema burksi																1								
Glossosomatidae																								
Glossosoma nigrior																							2	
Hydropsychidae																								
Diplectrona modesta			1			1		1	12	4	1		1		1						5			
Hydropsychidae sp. (early instars)																						8	1	2
Lepidostomatidae																								
Lepidostoma sp.	3	3	5	8	1	17	6	11	21	12	21	16	8	5	10	1	2	2	10	12	7	10	15	11
Limnephilidae																								
Limnephilidae sp.			1																					
Pycnopsyche flavata			1							3	2		4	3						1	2	2	6	

Table A-13. Continued.

Sampling Site	Above Upper Falls												Below Upper Falls											
Sampling Units (Leaf Packs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
TAXA																								
Trichoptera (continued)																								
Limnephilidae (continued)																								
Pycnopsyche guttifer group						2		1		1	7	2		4		1	1		1	1	3		1	1
Pycnopsyche sonso															3									
Odontoceridae																								
Psilotreta frontalis											1						1		1	1				
Philopotamidae																								
Wormaldia sp.							1																1	
Rhyacophilidae																								
Rhyacophila appalachia/nigrita						2	2	1		1												1		
Rhyacophila carolina																					1			
Rhyacophila fuscula																	1							
Rhyacophila glaberrima		1																						
Rhyacophila minora										1				2							1		1	
Rhyacophila sp. (early instars)					2		2		4	6	1						1							
Uenoidae																								
Neophylax mitchelli										1	1													
Neophylax sp. (early instars)			1					2			3	3	1			2							1	1
Coleoptera																								
Elmidae																								
Elmidae sp. (early/damaged instars)									1											1				1
Optioservus sp. (larvae)											1													
Oulimnius latiusculus (adults)								1												1				
Diptera																								
Ceratopogonidae																								
Palpomyia complex			1							3	1											1		
Chironomidae	19	41	37	34	24	88	25	165	119	121	205	133	12	30	18	33	85	28	70	21	31	88	69	23
Dixidae																								
Dixa sp.	2	1	4	1	9	13			3								5	8		2			2	

Table A-13. Continued.

Sampling Site	Above Upper Falls												Below Upper Falls											
Sampling Units (Leaf Packs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
TAXA																								
Diptera (continued)																								
Empididae																								
Roederiodes sp.																						1		1
Simuliidae		2	1							1		1								1		2		
Tipulidae																								
Dicranota sp.						1	1	1	2	2		1		1		1			1		2	2		1
Tipula abdominalis			1			1				1								1			3		1	1
TOTAL SPECIMENS	53	96	165	71	76	197	175	306	294	470	469	305	77	93	125	173	157	90	151	114	191	279	222	223

Table A-14. Hourly drift samples of benthic macroinvertebrates collected at two sampling stations; one upstream (D1) and one downstream (D2) of the upper boundary falls on Mannis Branch, 26-27 April 1998. Local sunrise time was 0649 and 0648 (EDT) for 26 and 27 April, respectively. Local sunset time was 2018 and 2019 (EDT) for 26 and 27 April, respectively.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718-0818		1100-1200		1510-1610		1918-2018		2048-2148		2335-0035		0251-0351		0548-0648	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	109.2	193.8	110.1	168.3	116.1	184.9	103.3	182.2	93.1	172.4	93.3	198.0	105.4	169.5	97.7	182.9
TAXA																
Annelida																
Oligochaeta			1							2			2			4
Arthropoda																
Crustacea																
Copepoda																
Harpactacoidea											2					
Isopoda																
Lirceus sp.	2		1				2								4	
Decapoda																
Cambaridae																
Cambarus sp. (juveniles)										4						
Arachnoidea																
Hydracarina	4	12	6	15	10	36	16	4	8	8	10			2		8
Insecta																
Ephemeroptera																
Ameletidae																
Ameletus cryptostimulus		2	3						6	2	2		2	2		
Baetidae																
Acentrella sp. cf. *ampla*	8	16		6	4	16	12	2	14	38	14	44	4	32	20	84
Baetidae sp. (early/damaged instars)	6	2	1	4		8	6		30	20	26	22	8	6	16	16
Baetis sp. (early/damaged instars)	50		13	3	32	14	38	30	102	152	56	100	48	56	58	88
Baetis sp. cf. *brunneicolor*	34	38	4	23	40	32	70		156	102	120	22	50	48	80	126
Baetis tricaudatus		34	1	4		10		6	8	20	2	2	6	2	4	2

Table A-14. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718-0818		1100-1200		1510-1610		1918-2018		2048-2148		2335-0035		0251-0351		0548-0648	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	109.2	193.8	110.1	168.3	116.1	184.9	103.3	182.2	93.1	172.4	93.3	198.0	105.4	169.5	97.7	182.9
TAXA																
Ephemeroptera (continued)																
Ephemerellidae																
Ephemerella catawba			1						2	20	2	8		12	2	
Ephemerella hispida							4		22	16	4	2		2	4	4
Ephemerella rossi				1			2			20						
Ephemerella sp. (early instars)	88	28	28	18	128	40	60	22	100	82	74	32	86	46	146	108
Ephemerella sp. cf. *crenula*							2									
Ephemerella sp. 1 (similar to *catawba*									2							
but with 5 tarsal claw denticles)																
Ephemerellidae sp. (early instars)		4	4	2		10			2	20	2	14	2	8		
Eurylophella funeralis			1	1				2	4	2	2	4	2	2		
Serratella deficiens	2												2		6	
Ephemeridae																
Ephemera sp.										2						
Heptageniidae																
Cinygmula subaequalis					2		2		10		2	2	6		2	2
Epeorus sp. cf. *dispar*	4		3	1	10	2	2		26	36	14	32	6	14		4
Epeorus sp. cf. *pleuralis*	14	6	3	1	4	2	8		6	72	8	30	10	16	18	48
Epeorus sp. (early instars)			1	2	2				6	8	2	4	6		6	2
Heptageniidae sp. (early instars)									2	2	4	2		4		
Leucrocuta sp. (early instars)										2				2		
Leucrocuta thetis					2				4		6		6		2	
Rhithrogena fuscifrons		2				2				2	4		2	2		
Stenacron interpunctatum/carolina											4					
Stenonema meritvulanum									4		4	4	4	2		
Stenonema ithaca/modestum												2				
Stenonema sp. (early/damaged instars)				1						4			2			2

Table A-14. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718-0818		1100-1200		1510-1610		1918-2018		2048-2148		2335-0035		0251-0351		0548-0648	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	109.2	193.8	110.1	168.3	116.1	184.9	103.3	182.2	93.1	172.4	93.3	198.0	105.4	169.5	97.7	182.9
TAXA																
Ephemeroptera (continued)																
Isonychiidae																
Isonychia sp.	2				6	2	2		20	12	8	4	16	6	18	6
Leptophlebiidae																
Habrophlebia vibrans									2			2				
Leptophlebiidae sp. (early/damaged instars)		2	1	3	6	10		4	42	114	14	70	14	36	6	20
Paraleptophlebia adoptiva/mollis	2	2	1	2		4	6		62	24	40	2	22	8	44	2
Odonata																
Cordulegastridae																
Cordulegaster erronea											2					
Gomphidae																
Lanthus vernalis	2															
Plecoptera																
Chloroperlidae																
Chloroperlidae sp. (early instars)	2							2			2			2		2
Haploperla brevis		2								2		6				
Leuctridae																
Leuctra sp.	6	4	4	4	2	10	4	8	32	62	22	20	22	24	32	24
Nemouridae																
Amphinemura appalachia	6	8	1	1		2			20	42	28	38	34	16	24	8
Amhpinemura delosa/nigrita	2	2	2	2	10	2	8	8	14	60	18	22	18	20	8	10
Amphinemura sp. (early/damaged instars)	2	2	2						6	2	4	18	4	2	6	
Peltoperlidae																
Peltoperlidae sp. (early instars)	70	54	53	58	64	84	92	62	382	262	174	156	126	128	110	112
Tallaperla sp.		2		2					8	18	10		6	8	6	6
Viehoperla ada										2						
Perlidae																
Eccoptura xanthenes										2						

Table A-14. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718-0818		1100-1200		1510-1610		1918-2018		2048-2148		2335-0035		0251-0351		0548-0648	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	109.2	193.8	110.1	168.3	116.1	184.9	103.3	182.2	93.1	172.4	93.3	198.0	105.4	169.5	97.7	182.9
TAXA																
Plecoptera (continued)																
Perlidae (continued)																
Perlesta sp. cf. *frisoni*									4					2	4	2
Perlidae sp. (early/damaged instars)				1	4				2	4	4	6	2	6	4	
Perlodidae																
Isoperla holochlora									18	8	18	22	4	4		6
Isoperla sp. (early instars)	4		1		4		4		14		4	4	16	4	6	6
Malerikus hastatus										14						
Malerikus/Yugus (early instars)												2				
Perlodidae sp. (early instars)	4	2	4	2		2	8		16	10	58	4	18	4		6
Remenus bilobatus									4	2			2	4	4	
Yugus bulbosus	2															
Pteronarcyidae																
Pteronarcys sp. (early instars)		2				2			2	2		2				2
Heteroptera																
Gerridae																
Aquarius remigis													2			
Trichoptera																
Glossosomatidae																
Agapetus minutus	10	2	2	1		4			4	2		6				2
Hydropsychidae																
Diplectrona modesta			3		6	2	6	2	4	28	30	30	18	20	2	4
Lepidostomatidae																
Lepidostoma sp.	2	14	2	3	14	8	4	10	20	32	12	24	12	10	4	16
Limnephilidae																
Limnephilidae sp.										2						
Pycnopsyche flavata			2													

Table A-14. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718-0818		1100-1200		1510-1610		1918-2018		2048-2148		2335-0035		0251-0351		0548-0648	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	109.2	193.8	110.1	168.3	116.1	184.9	103.3	182.2	93.1	172.4	93.3	198.0	105.4	169.5	97.7	182.9
TAXA																
Trichoptera (continued)																
Philopotamidae																
Dolophilodes distinctus		2	1			4	2		2	10	6	4	8	2		4
Philopotamidae sp. (early instars)	2										4					
Wormaldia sp.							4		2			4	2	2		2
Polycentropodidae																
Nyctiophylax sp.				1				2						2		4
Polycentropodidae sp. (early instars)									2							2
Polycentropus sp.	2															
Psychomyiidae																
Lype diversa	2	2	2		2		2									2
Rhyacophilidae																
Rhyacophila carolina											2	8	2			
Rhyacophila fuscula			1	2												2
Rhyacophila glaberrima									2		2					
Rhyacophila sp. (early instars)							2				6					
Sericostomatidae																
Fattigia pele					2											
Uenoidae																
Neophylax mitchelli					4								2			
Neophylax sp. (early instars)						2				2						
Coleoptera																
Elmidae																
Elmidae sp. (early instars)											2	2				
Optioservus immunis											4			2		2
Optioservus ovalis												4			2	
Optioservus sp. (larvae)		4	1		2	2		2	4			2	4		2	
Oulimnius latiusculus (adults)				1						2	14	8	6	4		

Table A-14. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718-0818		1100-1200		1510-1610		1918-2018		2048-2148		2335-0035		0251-0351		0548-0648	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	109.2	193.8	110.1	168.3	116.1	184.9	103.3	182.2	93.1	172.4	93.3	198.0	105.4	169.5	97.7	182.9
TAXA																
Elmidae (continued)																
Oulimnius latiusculus (larvae)								2		4		2				
Promoresia tardella (adults)							2			2						
Stenelmis sp.												4	2			
Eubriidae																
Ectopria sp.			1								2			2		
Hydraenidae																
Hydraena sp.										4		14		2		
Diptera																
Blephariceridae																
Blepharicera sp.	2									4		2				
Ceratopogonidae																
Palpomyia complex				1						2	4					
Chironomidae	38	74	20	57	48	84	66	36	70	52	58	18	32	104	44	106
Dixidae																
Dixa sp.		2	1	1				6		8		2	2			
Empididae																
Chelifera sp.					2			2								2
Hemerodromia sp.																2
Nymphomyiidae																
Nymphomyia sp.											2					
Simuliidae	16	52	17	59	72	88	48	68	68	146	24	98	24	48	34	66
Tipulidae																
Antocha sp.						4	6									
Dicranota sp.		2	1							2						
Hexatoma sp.										4	2			6		2
Tipulidae sp. (early/damaged instars)												4		2		
TOTAL SPECIMENS	390	380	194	283	482	488	490	280	1340	1584	944	940	674	738	728	928

Table A-15. Hourly drift samples of benthic macroinvertebrates collected at two sampling stations; one upstream (D1) and one downstream (D2) of the upper boundary falls on Mannis Branch, 28-29 June 1998. Local sunrise time was 0622 and sunset was 2056 (EDT).

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0628 - 0728		1054 - 1154		1524 - 1624		1956 - 2056		2100 - 2200		2346 - 0046		0235 - 0335		0522 - 0622	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	41.5	50.8	43.2	49.1	33.8	37.3	30.0	35.4	33.1	41.0	36.2	44.8	38.5	61.9	37.5	53.4
TAXA																
Annelida																
Oligochaeta							1							1		1
Arthropoda																
Crustacea																
Copepoda																
Harpactacoidea																1
Isopoda																
Lirceus sp.											1					
Decapoda																
Cambaridae																
Cambarus sp. (juveniles)											1					
Arachnoidea																
Hydracarina		1	3		2	1	2	15	1	1		2	2	1		3
Insecta																
Ephemeroptera																
Baetidae																
Acentrella sp. cf. *ampla*	9	3	6	5	12	6	15		16	33	12	32	20	17	53	37
Baetidae sp. (early/damaged instars)	1	1						1						2	1	6
Baetis sp. (early/damaged instars)	1		3		1	2				4		5		1		
Baetis sp. cf.. *brunneicolor*			1	2			1		5	7	5	1	3	5	2	7
Baetis tricaudatus	9	4	6	2	9		7	15	11	15	8	10	10	8	19	14
Ephemerellidae																
Drunella sp. (early instars)	1		2													
Ephemerella catawba		1					1					3		2		
Ephemerella sp. (early instars)									3	5		2			2	

Table A-15. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0628 - 0728		1054 - 1154		1524 - 1624		1956 - 2056		2100 - 2200		2346 - 0046		0235 - 0335		0522 - 0622	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	41.5	50.8	43.2	49.1	33.8	37.3	30.0	35.4	33.1	41.0	36.2	44.8	38.5	61.9	37.5	53.4
TAXA																
Ephemeroptera (continued)																
Ephemerellidae (continued)																
Ephemerellidae sp. (early instars)								3		1	5		2			
Eurylophella funeralis									1	2				1		
Heptageniidae																
Epeorus sp. cf. *dispar*	2						4	4		4		4	1	1	2	
Epeorus sp. cf. *pleuralis*											1					
Epeorus sp. (early instars)													1		1	
Heptagenia julia														1		
Heptageniidae sp. (early instars)					1			2		1		1		2		3
Leucrocuta sp. (early instars)				1			1									1
Leucrocuta thetis						1										
Rhithrogena fuscifrons										1		1				
Stenonema meririvulanum									1	1		1		1	1	
Isonychiidae																
Isonychia sp.					1				3	2	2	4	2	3	3	
Leptophlebiidae																
Leptophlebiidae sp. (early/damaged instars)									4	3	4	1	1	1	1	1
Paraleptophlebia adoptiva/mollis			1	1		1	2						1			
Odonata																
Gomphidae																
Lanthus vernalis														1		
Plecoptera																
Leuctridae																
Leuctra sp.		1	3			1	3	3	7	17	3	11	3	10	3	4
Nemouridae																
Amphinemura appalachia		1		1			1	1		1						
Amphinemura sp. (early/damaged instars)							1					2				

Table A-15. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0628 - 0728		1054 - 1154		1524 - 1624		1956 - 2056		2100 - 2200		2346 - 0046		0235 - 0335		0522 - 0622	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	41.5	50.8	43.2	49.1	33.8	37.3	30.0	35.4	33.1	41.0	36.2	44.8	38.5	61.9	37.5	53.4
TAXA																
Plecoptera (continued)																
Peltoperlidae																
Peltoperlidae sp. (early instars)						7										
Tallaperla sp.	19	9	20	12			25	23	68	273	81	213	82	183	59	43
Perlidae																
Acroneuria abnormis											1		1	1		
Acroneuria sp. (early instar)								1								
Perlesta sp. cf. *frisoni*					1		1		2	2	2		1	2		
Perlidae sp. (early/damaged instars)				1			1	2	2	4	3	4		3		1
Perlodidae																
Isoperla holochlora								2	1	3				3		
Malerikus/Yugus (early instars)														1		
Perlodidae sp. (early instars)			2		1		2	1	1	4	7	6	5	6		2
Pteronarcyidae																
Pteronarcys sp. (early instars)														2		
Heteroptera																
Gerridae																
Aquarius remigis				1							1	1				
Veliidae																
Rhagovelia obesa																1
Trichoptera																
Arctopsychidae																
Arctopsychidae sp. (early instars)		3		1										3		3
Arctopsyche irrorata											1					
Parapsyche cardis	10		4		4	2	8	1	1		1	4	12		10	1
Glossosomatidae																
Glossosoma nigrior										1						

Table A-15. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0628 - 0728		1054 - 1154		1524 - 1624		1956 - 2056		2100 - 2200		2346 - 0046		0235 - 0335		0522 - 0622	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	41.5	50.8	43.2	49.1	33.8	37.3	30.0	35.4	33.1	41.0	36.2	44.8	38.5	61.9	37.5	53.4
TAXA																
Trichoptera (continued)																
Hydropsychidae																
Ceratopsyche macleodi								1								
Ceratopsyche sp. (early/damaged instars)																1
Diplectrona modesta	1		2		1	1	3		1	1	2	1	1	3	1	
Hydropsychidae sp. (early instars)	1	3	1	4			2		2			1			4	4
Hydroptilidae																
Mayatrichia ayama														1		
Lepidostomatidae																
Lepidostoma sp.		1			1		1			2	1	1			3	1
Philopotamidae																
Dolophilodes distinctus	1	1						1		1	2	1			2	1
Wormaldia sp.															1	
Polycentropodidae																
Polycentropodidae sp. (early instars)					1											
Polycentropus sp.					1											
Psychomyiidae																
Lype diversa		1	1													1
Rhyacophilidae																
Rhyacophila carolina											1		1	1		
Rhyacophila fuscula				1				1	1				1		1	
Rhyacophila sp. (early instars)		1						1						1		
Coleoptera																
Dryopidae																
Helichus basalis												1				
Elmidae																
Elmidae sp. (early instars)				2			3							1		1
Optioservus immunis									3	1	2	1	4	6	3	1

Table A-15. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0628 - 0728		1054 - 1154		1524 - 1624		1956 - 2056		2100 - 2200		2346 - 0046		0235 - 0335		0522 - 0622	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	41.5	50.8	43.2	49.1	33.8	37.3	30.0	35.4	33.1	41.0	36.2	44.8	38.5	61.9	37.5	53.4
TAXA																
Coleoptera (continued)																
Elmidae (continued)																
Optioservus ovalis					2				1			1	1	1		
Optioservus sp. (larvae)							1		1		2			1		
Oulimnius latiusculus (adults)				1		1	2	4	7	10	28	26	16	6	1	3
Oulimnius latiusculus (larvae)							1		1				1			
Promoresia tardella (adult)				2		2			4	10	5	6	1	2	3	2
Promoresia sp. (larvae)		1														
Stenelmis sp.												1				
Eubriidae																
Ectopria sp.					1									1		
Diptera																
Blephariceridae																
Blepharicera sp.								1	1			1			1	
Chironomidae	3	10	8	5	7	7	5	13	6	6	3			10	5	15
Dixidae																
Dixa sp.	4	3	2	1	3	1	8	3	6	14	4	4	4	4	5	7
Simuliidae	2	4	2	3	3	6		21	8	16	1	6	2	9	7	5
Tipulidae																
Dicranota sp.											1					
TOTAL SPECIMENS	64	49	67	46	52	39	103	119	169	446	191	359	179	309	194	171

Table A-16. Hourly drift samples of benthic macroinvertebrates collected at two sampling stations; one upstream (D1) and one downstream (D2) of the upper boundary falls on Mannis Branch, 17-18 November 1998. Local sunrise time was 0712 and 0713 (EST) for 17 and 18 November, respectively. Local sunset time was 1728 and 1727 (EST) for 17 and 18 November, respectively.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718 - 0818		1019 - 1119		1325 - 1425		1628 - 1728		1731 - 1831		2143 - 2243		0158 - 0258		0612 - 0713	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	18.0	14.2	24.5	22.5	23.6	17.2	22.7	18.2	23.5	15.9	21.9	13.9	22.8	15.6	19.0	13.2
TAXA																
Annelida																
Oligochaeta				1		3						2			2	
Arthropoda																
Crustacea																
Copepoda																
Harpactacoidea	1															
Arachnoidea																
Hydracarina			1	4		1								1		1
Insecta																
Ephemeroptera																
Ameletidae																
Ameletus cryptostimulus			1	4			1	1		6	3	2	2	2	1	2
Baetidae																
Acentrella sp. cf. *ampla*				3				2								
Baetidae sp. (early/damaged instars)													1			
Baetis sp. (early/damaged instars)									1				1	1		
Ephemerellidae																
Ephemerellidae sp. (early instars)		1	6	11	4	1	3	7	2	10	5	4	1	5	6	2
Heptageniidae																
Epeorus sp. cf. *dispar*										1	1					
Epeorus sp. cf. *pleuralis*									1				1			
Epeorus sp. (early instars)	2	2	3	1	3	2	2		6	9	5	3	2	4	2	
Heptageniidae sp. (early instars)		1				1						1				
Leucrocuta thetis				1												

Table A-16. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718 - 0818		1019 - 1119		1325 - 1425		1628 - 1728		1731 - 1831		2143 - 2243		0158 - 0258		0612 - 0713	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	18.0	14.2	24.5	22.5	23.6	17.2	22.7	18.2	23.5	15.9	21.9	13.9	22.8	15.6	19.0	13.2
TAXA																
Ephemeroptera (continued)																
Heptageniidae (continued)																
Rhithrogena sp. (early instars)											1					
Stenonema meririvulanum										1	1					
Stenonema pudicum													1			
Stenonema sp. (early/damaged instars)				1										1		
Leptophlebiidae																
Habrophlebia vibrans				1												
Paraleptophlebia adoptiva/mollis				1					3	2	1	5	1	1		
Odonata																
Plecoptera																
Capniidae																
Capniidae sp. (early instars)										1						
Paracapnia angulata	2			3		1			6	12	6	9	8	4	2	
Chloroperlidae																
Sweltsa sp.													1			
Leuctridae																
Leuctra sp.										2	1					1
Nemouridae																
Amphinemura sp. (early/damaged instars)						1										
Peltoperlidae																
Peltoperlidae sp. (early instars)										1						
Perlidae																
Perlidae sp. (early/damaged instars)										3						
Perlodidae																
Perlodidae sp. (early instars)									1	2	3		2	2		2

Table A-16. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718 - 0818		1019 - 1119		1325 - 1425		1628 - 1728		1731 - 1831		2143 - 2243		0158 - 0258		0612 - 0713	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	18.0	14.2	24.5	22.5	23.6	17.2	22.7	18.2	23.5	15.9	21.9	13.9	22.8	15.6	19.0	13.2
TAXA																
Heteroptera																
Veliidae																
Rhagovelia obesa											1					
Trichoptera																
Arctopsychidae																
Parapsyche cardis												1				
Glossosomatidae																
Glossosoma nigrior										1						
Glossosomatidae sp. (damaged instars)	1			1											1	
Goeridae																
Goera calcarata				1												
Hydropsychidae																
Diplectrona modesta					1		1		3				1			
Lepidostomatidae																
Lepidostoma sp.		1				1				1	3			1		
Limnephilidae																
Limnephilidae sp.			1	1						1	1	1				
Philopotamidae																
Dolophilodes distinctus	1									1	1		1			
Polycentropodidae																
Nyctiophylax sp.								1								
Polycentropodidae sp. (early instars)	1										1					
Psychomyiidae																
Lype diversa				1												
Rhyacophilidae																
Rhyacophila fuscula													1			
Rhyacophila minor										1						

Table A-16. Continued.

Diurnal Period	Day Drift								Night Drift							
Sampling Time	0718 - 0818		1019 - 1119		1325 - 1425		1628 - 1728		1731 - 1831		2143 - 2243		0158 - 0258		0612 - 0713	
Sampling Stations	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Flow Filtered Through Net (m^3/hour)	18.0	14.2	24.5	22.5	23.6	17.2	22.7	18.2	23.5	15.9	21.9	13.9	22.8	15.6	19.0	13.2
TAXA																
Trichoptera (continued)																
Uenoidae																
Neophylax ornatus											1					
Colcoptera																
Elmidae																
Elmidae sp. (early instars)										1						
Optioservus immunis													2			
Optioservus ovalis											1					
Optioservus sp. (larvae)						1										
Diptera																
Chironomidae	2	1	5	21	9	22		1		9	3	2	1		3	2
Dixidae																
Dixa sp.									3	2		1	2	1		2
Simuliidae				1									1			
TOTAL SPECIMENS	10	6	17	57	17	34	7	12	26	67	39	31	30	23	17	12

VITA

Barry D. Hart was born in Clarksville, Tennessee on 11 August 1964 and raised in a rural setting near VanLeer, Tennessee. After graduating from Dickson County High School in 1982, he entered Austin Peay State University a year later in 1983. He earned a Bachelor of Science degree in Music, Piano Performance in 1988 and returned for a second major in Biology and a minor in Chemistry the following year. Barry's position as a Research Assistant for Austin Peay State University's Center for Field Biology led him to a temporary position with the U. S. Forest Service, Intermountain Research Station in Boise, Idaho. There he developed a fascination with stream ecology while working on a bull trout research project in the Boise River and Sawtooth Mountains. He expanded upon his interest in stream ecology as a graduate student at the University of Tennessee, Knoxville.

During the formal years of Barry's graduate education (1995 – 1998), he held an internship with the TVA Regional Heritage Program in Norris, Tennessee. This position eventually led to a professional career as a Terrestrial Zoologist/Ecologist with the Alabama Natural Heritage Program, The Nature Conservancy in 1999. Barry continues to work for the Alabama Natural Heritage Program and thrives upon exploring the Southeast's phenomenal aquatic and terrestrial biological diversity.

He and his family currently reside in Prattville, Alabama.

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