1992

# Examination of the benthic insect populations and surface substrate characteristics in two granitic streams in the Lolo National Forest MT

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## Recommended Citation

Ruetz, David Philip, "Examination of the benthic insect populations and surface substrate characteristics in two granitic streams in the Lolo National Forest MT" (1992). *Graduate Student Theses, Dissertations, & Professional Papers*. 7459.
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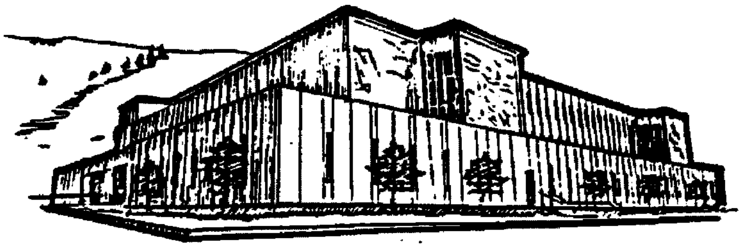

# AN EXAMINATION OF THE BENTHIC INSECT POPULATIONS AND SURFACE SUBSTRATE CHARACTERISTICS IN TWO GRANITIC STREAMS IN THE LOLO NATIONAL FOREST, MT.

by

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B.A., University of Wisconsin-Milwaukee, 1982

Presented in partial fulfillment of the requirements
for the degree of
Master of Science
University of Montana
1992

Approved by

Vicki Watson
Chairman, Board of Examiners

Dean, Graduate School

March 25, 1992
Date

4-71

Ruetz, David P., M. S., March 1992 Environmental Studies

An Examination of the Benthic Insect Populations and Surface Substrate Characteristics in Two Granitic Streams in the Lolo National Forest, MT. (43 pp.)

Director: Vicki Watson VW

Surface substrate characteristics and benthic insects were sampled during 1985 in two granitic streams in the Idaho Batholith Region of the Lolo National Forest in Montana. The purpose of the study was to determine whether surface substrate roughness, diversity and class size could be used as sensitive predictors of benthic insect density and diversity in such streams.

Four sample areas were established on each stream and spaced equidistantly from the stream mouth to the headwaters. Substrate variables in each stream were characterized by determining "substrate roughness", "substrate diversity", and "most common substrate class". Benthic insect communities were characterized by determining "density", "richness (genus)", and "order diversity".

A Kolmogorov-Smirnov two sample test was utilized in analyzing data between individual sites within a stream and for pooled data between streams. The Spearman Rank Correlation method was also applied to pooled data to test the association between surface substrate characteristics and benthic insect population parameters in each stream.

Tests for pooled data indicated that surface substrate roughness and diversity were substantially similar in both streams while most common substrate class, benthic insect density, richness (genus) and order diversity were significantly different. In addition, significant correlations existed between surface substrate roughness and diversity within each stream; however, no significant correlations were found between substrate characteristics and the benthic population parameters in either stream.

These results suggest that the surface substrate characteristics measured here are not sensitive predictors of the density and diversity of benthic insect populations in such streams. More intensive sampling or measuring other surface substrate characteristics might serve as indicators but may not be practical for routine monitoring.

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# INTRODUCTION

Many watersheds in the mountainous regions of the Western United States have been affected by accelerated rates of erosion and sedimentation due to the construction of logging roads and commercial timber harvest methods. In addition to increasing erosion and sedimentation, such activities can create major ecosystem alterations in a watershed by disturbing the normal nutrient cycle, changing water chemistry and thermal regimes, and altering hydrologic flow rates.

Kochenderfer and Aubertin (1975) found that in undisturbed watersheds maximum stormflow turbidities were an order of magnitude greater than the average for base flow, but in watersheds where commercial timber harvesting was practiced the ratio was two orders of magnitude. Increased discharge following deforestation can also cause accelerated channel erosion. Heede (1972) showed that large woody debris in stream channels reduces the number of gravel bars and bedload movement, and also that excessive debris from logging can create major disturbances in stream channels if the debris dams a stream and later fails in high flows.

Granitic watersheds can be particularly susceptible to higher rates of erosion and sedimentation because the granite decomposes into coarse sands that are easily eroded from steep, unstable slopes (Platts, 1975). In the Idaho

Batholith, a granitic area in the western United States where extensive logging has occurred, land-use disturbances have resulted in substantial depositions of fine sediment in many streams (Megahan, 1972). The construction and maintenance of roads for logging, recreation and mining has been a major source of fine sediment (Bjornn, et. al., 1977).

Changes in a stream's channel and substrate resulting from increased flow rates and sedimentation can cause corresponding changes in fish and benthic invertebrate populations. Sedimentation can reduce biological productivity in a watershed by covering or filling the stream bottom with sand, thereby decreasing the amount of habitat for benthic invertebrate colonization and fish habitat. Bjornn, et. al. (1977) found that in a natural stream riffle consisting of cobbles, benthic insects were 1.5 times more abundant in a plot cleaned of sediment, with mayflies and stoneflies 4 and 8 times more abundant respectively. Studies have also shown that sedimentation may reduce the survival of salmonid embryos by preventing them from successfully emerging as fry from redds (Hausle and Coble, 1976; Philips, et. al., 1975).

The physical characteristics of substrate material found on stream bottoms is of great biological significance to benthic invertebrate and fish populations (Cummins, 1966; Cummins and Lauf, 1969). The sizes and kinds of material determine the types of habitats available. Some researchers have suggested that benthic invertebrate abundance is related to substrate particle size (Hynes, 1970). Allan (1975) artificially constructed substrates of different particle sizes and complexities in a Colorado stream and found that species richness was increased in mixed substrates. Minshall (1977) found that the microdistribution of some benthic invertebrates varied with water velocity and substrate, with substrate size and surface area having the largest effect. Minshall (1977) also noted that substratum is a multi-factor variable, suggesting that components such as texture and degree of compaction (or extent of interstitial spaces) as well as particle size and surface area may act to regulate composition and abundance. Hart (1978) tested whether the sizes and shapes of individual rocks affected species abundance, richness, and diversity in a California stream and found that significantly higher species richness occurred on irregular shapes as opposed to smooth shapes.

Some studies have suggested that factors other than the physical characteristics of the substrate may have an effect on the distribution of benthic invertebrate populations. Current velocities may determine the microdistribution of certain invertebrates that depend on current flow for food delivery (Edington, 1968). The presence of plant detritus on substrates may also regulate the distribution of benthic invertebrates that depend on such detritus for food (Egglishaw, 1964; Reice, 1975). The rate of leaf litter composition has been shown to vary significantly among different substrata in woodland streams (Reice, 1974), and decomposing detritus on different substrata have different associations of benthic invertebrate species. (Reice, 1977).

Some researchers have suggested that measurements of the substrate can be used to estimate the productivity of streams (Rabeni and Minshall, 1977). Bjornn, et. al. (1977) state that certain substrate parameters (predominant substrate, level of cobble imbeddedness and size of sediments surrounding cobbles) are useful criteria for evaluating benthic insect habitat in Idaho Batholith streams. They conclude that cobbles imbedded in coarse sediments (eg. pebbles) generally support a richly diverse insect community.

This study examines relationships between benthic insect populations and surface substrate characteristics in two granitic streams in the Idaho Batholith region of the Lolo National Forest in Montana. The purpose of the study was to determine whether surface substrate roughness, diversity and class size can be used as sensitive predictors of benthic insect density and diversity in such streams.

The two streams selected for the study were Lee Creek and the North Fork of Granite Creek. Both streams are tributaries to Lolo Creek. Lolo Creek flows into the

Bitterroot River, and the Bitterroot River is a tributary to the Clark Fork River. The Lee Creek drainage has been the site of extensive logging and road construction and served in this study as an example of a disturbed watershed. At the time of this study logging and road building had not occurred in the North Fork of Granite Creek drainage; therefore, it could exemplify an undisturbed watershed. Lolo National Forest hydrologists conducted studies of sediment yield in these two streams during the late 1970's and early 1980's. Although the two drainages are similar in size, regressions of sediment yield on discharge for the Lee Creek drainage were significantly different from the North Fork Granite Creek drainage, suggesting that land-uses in Lee Creek may have had an impact on water quality (USFS, 1982). Lolo National Forest hydrologists have determined that the majority of sediment in Lee Creek is derived from unstabilized roads in the highly erosive soils of this drainage. Hence, it is thought that the two streams are expected to be different and present a wide variety of differences in substrate characteristics and benthic insect populations.

Though sediment yield has been determined in these two watersheds, no intensive examination of the substrate or benthic populations of these streams has been conducted. It is hoped that the results of this study will indicate whether the parameters measured here will be useful in assessing the effects of logging and road building in granitic drainages.

# DESCRIPTION OF THE STUDY SITES

Both study sites are located in the Idaho Batholith, a 16,000 square mile expanse of intrusive acid, igneous rock. Various granitic rocks comprise the Batholith; however, quartz monzonite prodominates. This granite decomposes into a coarse sand that is easily eroded from steep unstable slopes. (Bjornn, et. al. 1977).

Lee Creek: (USFS, 1987)

Lee Creek, is a second-order stream located approximately 8 miles east of the Montana-Idaho border. It is located at latitude 46°42'10", and longitude 114° 32'0", and is within the Boise Principal Meridian (sec. 18, T 11 N, R 23 W). The elevation of the watershed ranges from 4,213-6,450' feet above sea level. The drainage area is 3.9 square miles, and the length of the stream channel is approximately 3.6 miles. Lee Creek drainage receives an average precipitation of 52.0 inches per year.

Glacially scoured uplands of low to moderate relief occur at the headwaters of the basin. Moderately steep, residual slopelands (ave. 45%) and steep slopes occur at lower elevations. Glacial landforms, found in 9% of the basin, occur as troughwalls and valley trains in narrow valleys. The valley bottom is alluvial. Granite, gneiss and quartz monzonite underlie 76.3% of the drainage, and 11.5% consists

of Calcareous Belt meta-sediments. The remainder consists of Belt metasedimentary and undifferentiated materials.
The average stream flow of Lee Creek is 3.7 cfs/sq.mi. and sediment yield averages 134 lbs/day/sq.mi. Conductivity averages 41 mhos, and temperature averages 4.3 C.

Lee Creek drainage has been heavily disturbed by multiple land-uses (logging, road construction and use, recreation). In the 1940's an access logging road was constructed along its entire length, and in some sections the road passes within several meters of the stream channel. In several sections logging debris has accumulated in the stream channel and has resulted in the formation of dams and plunge pools. In other sections, coarse sand has completely filled the interstitial spaces of the substratum or has completely covered it.

North Fork Granite Creek: (USFS, 1987)

North Fork Granite Creek is a second-order stream located approximately 7 miles northwest of Lee Creek, and is a tributary to Lolo Creek. It is located at latitude 46° 44'0", and longitude 114°36'10", and is within the Boise Principal Meridian (sec. 3, T 11 N, R 22 W). Elevations of the watershed range from 4,720-7,260 feet above sea level. Its drainage area is 3.9 square miles and its stream channel length is 2.7 miles. The North Fork Granite Creek drainage averages 52.0 inches of precipitation per year.

Strongly frost-churned convex ridgetops and glacially scoured alpine cirques and headwalls form its headwaters. Rock outcrops are extensive on its steep slopes. Bedrock orientation controls slope complexity. Unstable slopes and rolling, hummocky, poorly drained terrain are found in association with these landtypes.

Granite, gneiss, and quartz monzonite constitute 80.8% of the geology of the North Fork drainage with the remaining 19.2% consisting of unconsolidated materials. The annual average stream flow in North Fork Granite Creek is 6.1 cfs/sq.mi, and the average sediment yield is 116 lbs/day/sq.mi. Conductivity averages 13 mhos, and temperature averages 3 C.

# METHODS

## Collection of Data:

Field data were collected in Lee Creek and North Fork Granite Creek during the months of March and April 1985. Four sample areas or "clusters" were established on each stream. Cluster 1 for each stream was situated at the stream mouth, and each subsequent cluster was spaced approximately one-half mile upstream of the preceding cluster. (See Figs. 1 and 2). Measurements of the surface substrate and samples of benthic invertebrates were taken every 4 feet within each cluster until a total of 20 substrate measurements and 20 invertebrate samples were obtained, i.e, the total length of each cluster equals 80 feet. Sample site selection across the stream width for each of the 20 samples within a site were chosen from random numbers.

A substrate profile meter fashioned after Medina (1984) was used to map surface substrate roughness at the 20 sample sites within each cluster. (See Fig. 3). The device allows the investigator to measure the substrate with minimum disturbance of the stream bottom. The meter was designed to fit into, and take measurements within, a Surber 0.1 sq. meter benthic invertebrate sampler that had been previously placed on the stream bottom in the sampled area.

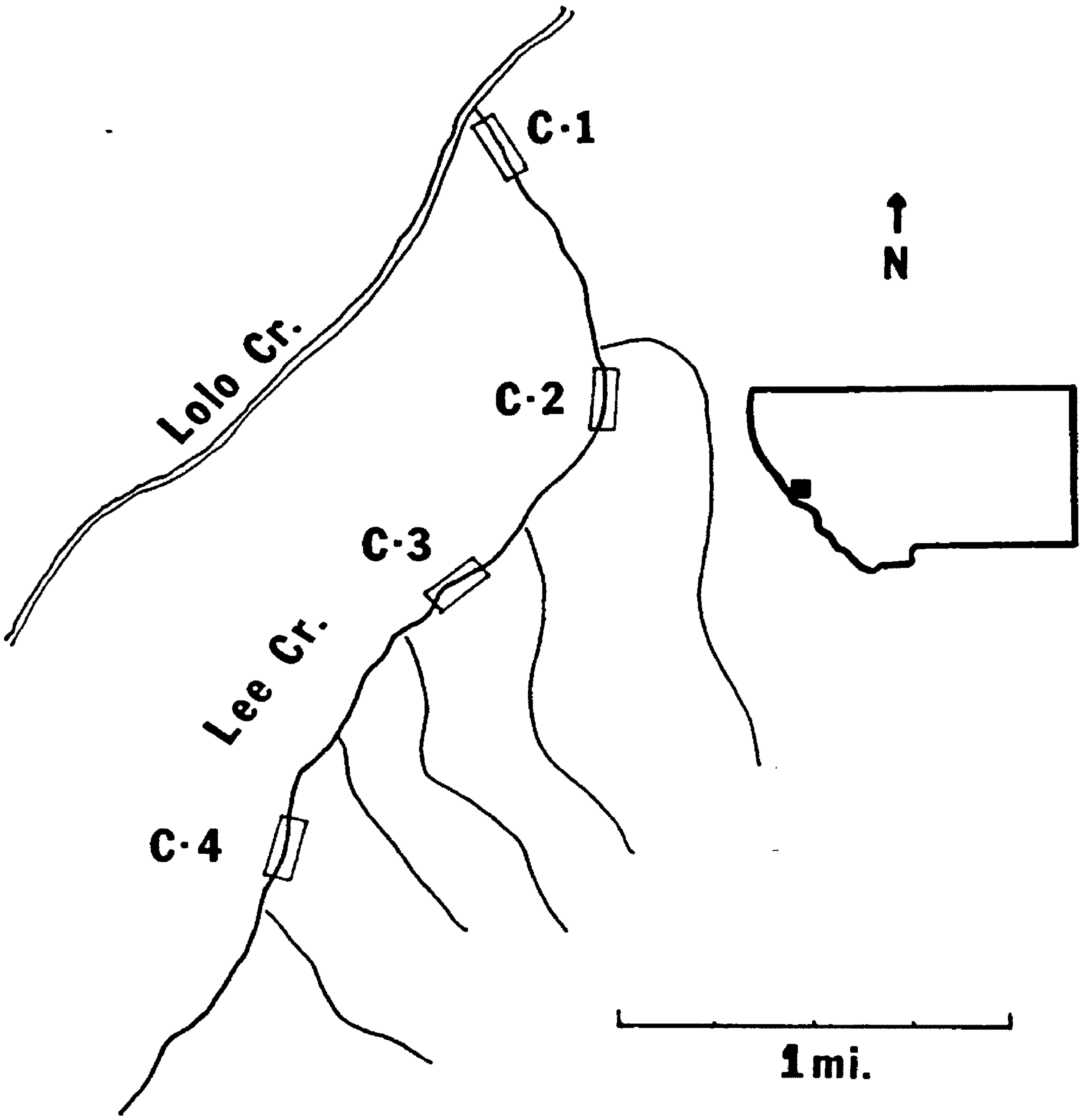

Figure 1. Lee Creek drainage and sample stations.

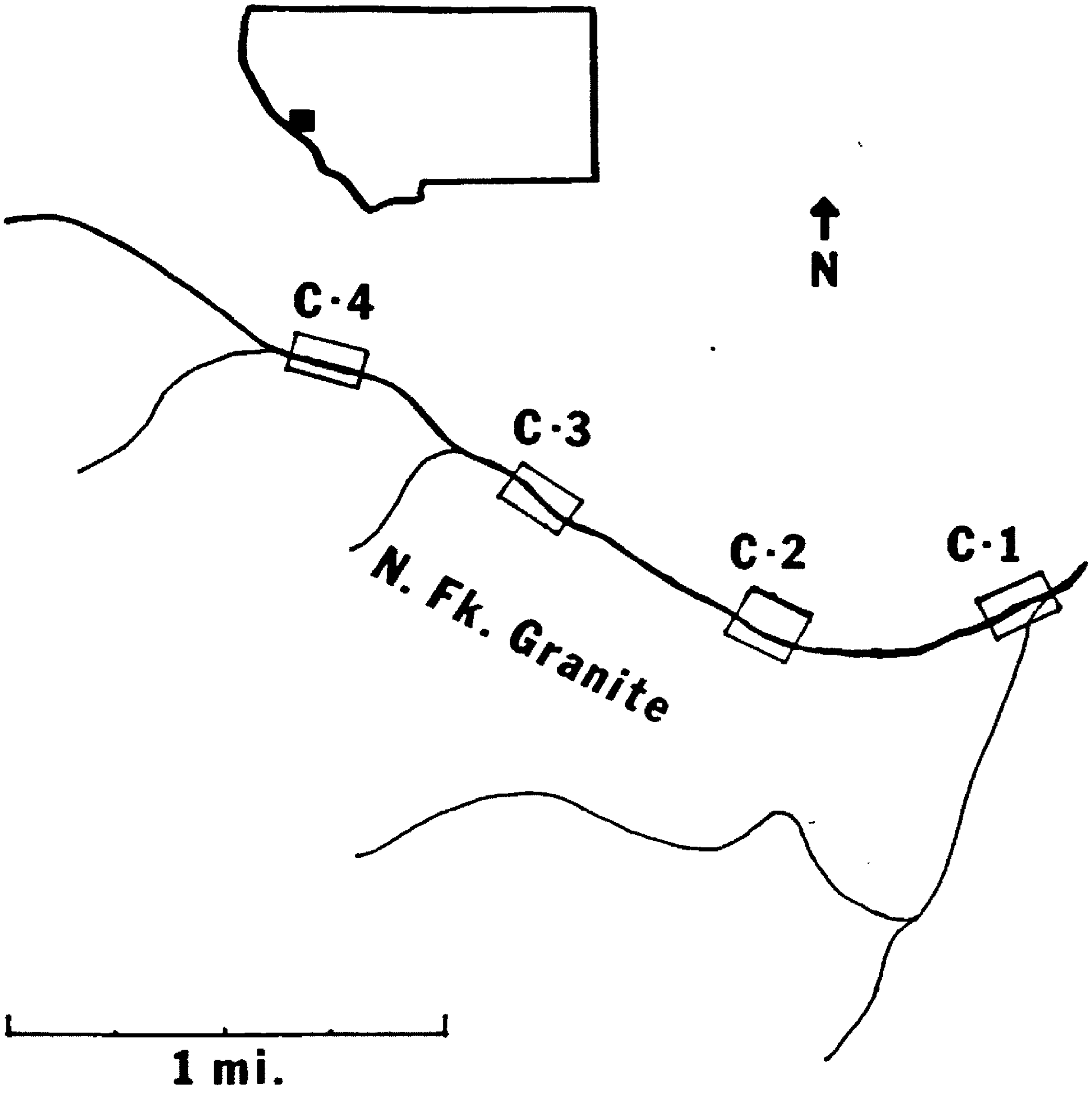

Figure 2. N. Fk. Granite Creek drainage and sample stations.

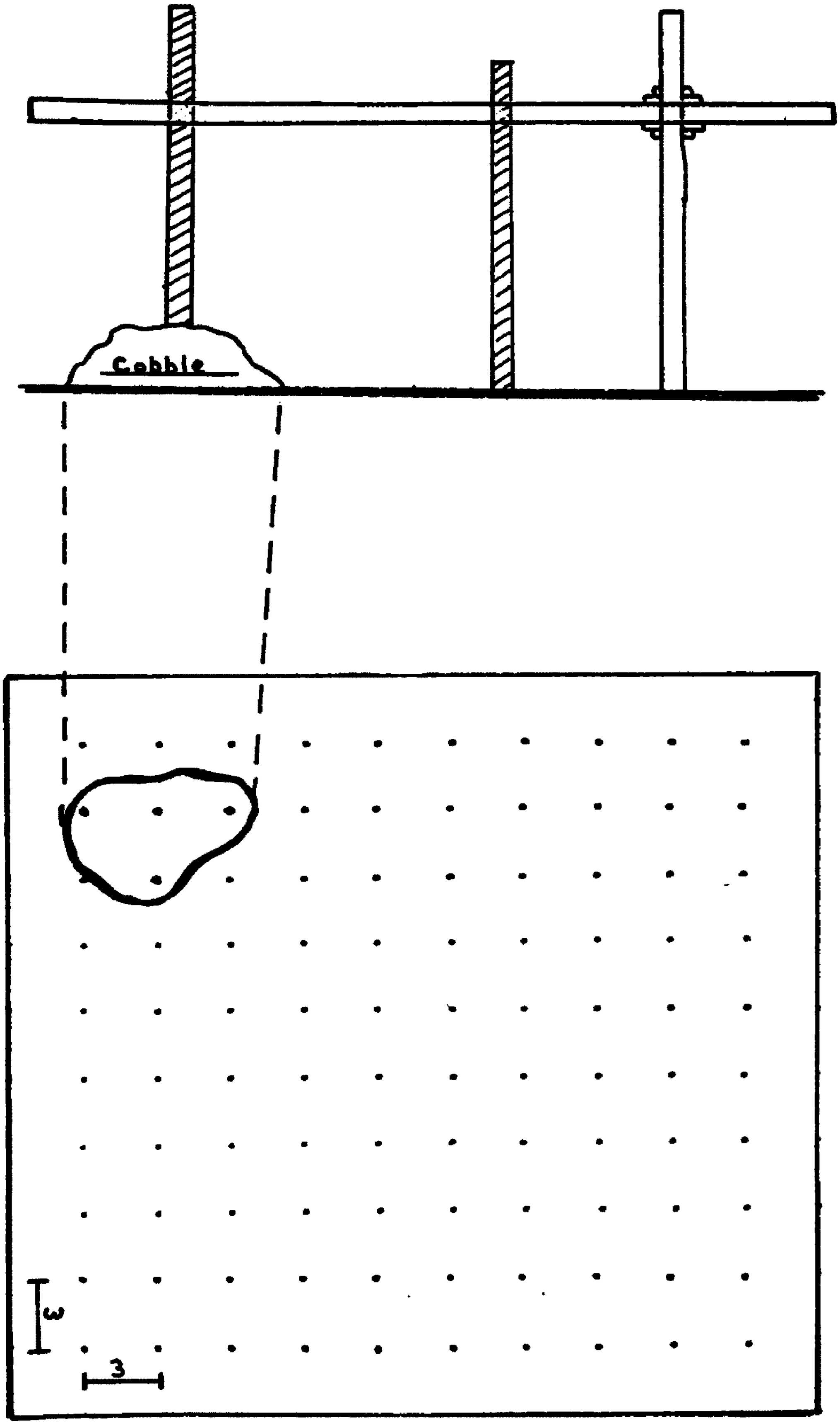

Figure 3 Substrate Profile Meter.

One hundred (100) individual measurements were taken of the substrate every 3 cm within the 0.1 sq.meter area. (See Fig. 3). The depth from the top of the substrate to the water surface was recorded at each of the point-measurement sites. From these data "substrate roughness" was computed for each 0.1 sq.meter site by calculating the sample standard deviation of the 100 points.

At each measurement point a visual estimate of streambed composition was recorded using the scale: (1) Sand. 0-2mm: (2) Gravel, 2-64mm: (3) Cobble, 64-256mm: (4) Boulder, > 256mm.

From these data "substrate diversity" (H), was computed for each 0.1 sq.meter site by calculating the proportion of each substrate class (sand, gravel, etc.), and applying the data to the Shannon-Weaver diversity formula (Shannon and Weaver, 1949);

$$H = -\sum pi \ln pi$$

where,

$$pi = ni/N;$$

and is the proportion of the i-th substrate class of N substrate classes within the sample, and ln pi is the (base e) logarithm of pi.

"Most common substrate class" was calculated for each cluster by counting the number of times each substrate class comprised the largest proportion of visual estimates per individual sample. For example, within the 20 individual samples in cluster 1 in Lee Creek, sand comprised the largest proportion of visual estimates in 2 samples, gravel in 13 samples, cobble in 4 samples, and boulder in 1 sample.

Benthic insects were collected in the same site where the 100 substrate point-measurements were taken using a Surber 0.1 square meter macroinvertbrate sampler. Benthic insect samples were collected after substrate measurements were taken. Samples were preserved in the field in 80% ethanol, then sorted, counted and identified in the laboratory to the genus level using taxonomic identification keys in Merritt and Cummins (1984).

Benthic insect communities were characterized by determining "density", "richness (genus)", and "order diversity" for each sample. "Density" in this study represents the total number of benthic insects collected per each 0.1 sq.meter sample. "Richness (genus)" constitutes the total number of genera represented in each 0.1 sq.meter sample. "Order diversity" was calculated for each sample using the Shannon diversity formula;

$$H = -\sum pi \ln pi$$

where,

$$pi = ni/N;$$

and is the proportion of the i-th Order of N Orders within the sample, and ln pi is the (base e) logarithm of pi. Orders of benthic insects represented in Lee Creek and North Fork Granite Creek include; Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), and Diptera (midges). Diversity was computed at the Order level rather than the genus level to reveal the degree of diversity that existed among the major taxonomic groups present.

Data Analysis:

1. Non-parametric tests.

As the substrate and insect data did not always depict normal distributions, nonparametric tests were applied to the data. A Kolmogorov-Smirnov (K-S) two-sample test (Seigel, 1956) was utilized in analyzing data between clusters, within stream data and between stream data. The test evaluates whether two independent samples have been drawn from the same population or from populations with the same distribution, and is based on an analysis of the agreement between two cumulative frequency distributions. A two-tailed test was used which is sensitive to any kind of difference in the distributions from which the two samples were drawn - differences in location (central tendency), in dispersion, in skewness, etc.

If two samples have been drawn from the same population distribution, then the cumulative distributions of both samples may be expected to be fairly close, and should show only random deviations from the population distribution. When sample cumulative frequency distributions are far apart at any point, this suggests that the samples come from different populations. Therefore, a large enough deviation (Dmax) between sample cumulative frequency distributions is evidence for rejecting the null hypothesis (Ho). The null hypothesis in this study is that samples from each stream were drawn from the same population.

Sets of data for each cluster were organized into group frequency distributions, using the same intervals for each characteristic tested. The null hypothesis was applied at the .05 level. The characteristics of substrate roughness, substrate diversity, most common substrate class, density, richness (genus) and order diversity were then tested between clusters in each stream; eg., the cumulative frequency distribution for substrate roughness (for 20 samples) in cluster 1 in Lee Creek was tested against the cumulative frequency distribution for substrate roughness (for 20 samples) in cluster 1 in North Fork Granite Creek, and so on. Tests were conducted for small sample sizes (n = 20) to determine if a small number of replicates would reveal differences in the biotic or abiotic characteristics in these streams, or if a larger number of replicates was necessary to detect such differences.

To compare clusters between streams the Kolmogrov-Smirnov two-tailed test for small samples was utilized. In this test the observed Dmax is compared to the critical value of Kd for N = 20 samples. Dmax equals:

$$D = \text{maximum } [Sn1(X) - Sn2(X)]$$

and Sn1(X) equals the observed cumulative step function of one of the samples. That is, $Sn1(X) = K/n1$, where K = the number of scores equal to or less than X, and Sn2(X) equals the observed cumulative step function of the other sample.

Between stream tests were also applied for pooled data within each category using a Kolmogorov-Smirnov two-tailed test for large samples at the .05 level where the critical value is computed by the formula,

$$1.36 \sqrt{\frac{n1 + n2}{n1n2}}$$

Data in each of the 6 categories listed above was pooled for each stream so that the cumulative frequency distribution for all 80 sample sites in one stream could be tested against a cumulative frequency distribution representing 80 sample sites in the other stream (i.e., between stream tests). Pooling the data allows one to transcend individual cluster versus cluster analysis, and analyze the data for a larger number of samples so that subtle differences in frequency distribution may become more obvious.

## 2. Correlation Analysis

In order to test whether associations between surface substrate characteristics and benthic insect populations existed within each stream, the Spearman Rank Correlation method was applied to the data. The Spearman Rank Correlation method is a measure of association which requires that both variables be measured in an ordinal scale so that the objects or individuals under study may be ranked in two ordered series (Seigel, 1956).

Data obtained for the variables substrate roughness, substrate diversity, density and richness (genus) for each stream were pooled, ranked and then correlated using the formula:

$$r = 1 - \frac{6 \sum (X - Y)^2}{n\ (n^2 - 1)}$$

where X and Y are the ranks of the two variables being measured.

The significance of each correlation coefficient was then tested at the .05 level using the formula:

$$t = [\ r\ ]\ /\ s$$

where

$$s = \sqrt{(1 - r\quad)/(n - 2)},$$

and the critical value of t is associated with n - 2 degrees of freedom.

## RESULTS AND DISCUSSION

### Between Cluster Tests

#### 1. Substrate Roughness:

Substrate roughness was computed for each of the 160 individual sample sites by calculating the sample standard deviation of the 100 point measurements at each individual sample site and cumulative frequency distributions were tested between clusters for each stream. Ideally, those individual sample sites displaying the largest standard deviation will have the greatest degree of irregularity or surface relief. Some researchers have suggested that greater substrate irregularity is associated with higher benthic invertebrate species richness (Hart, 1978). Theoretically, as the irregularity of the substrate increases, this should provide greater surface area for invertebrate colonization.

The highest mean substrate roughness for all clusters in Lee Creek was .35 (cluster 4), and the lowest mean value was .27 (cluster 1). (See Table 1). In North Fork Granite Creek the highest mean value was .33 (cluster 4) and lowest value was .30 (cluster 2). (See Table 1). The null hypothesis was accepted for all clusters tested, indicating that when individual clusters are tested against each other, substrate roughness in these two streams is not significantly different. A cursory visual observation of the substrate in these two streams suggests that substrate roughness is lower in Lee Creek due to the deposition of sediments in many sections which has appeared to "smooth out" the substrate. However, these two streams are not different statistically. An explanation for this may be that a majority of the sites sampled in both streams were erosional-type sites (i.e., riffles and runs) as opposed to depositional-type (i.e. pools and stream edges) where the majority of sediment has been deposited.

2. Substrate Diversity:

Some studies indicate that benthic invertebrate populations may reflect the diversity of their substrates. Allan (1975) found a positive relationship between substrate diversity and species richness and that different species preferred different types of substrate. Hence, the more types of substrata present, the more species are expected.

The highest mean substrate diversity for all clusters in Lee Creek was .36 (cluster 1), and the lowest mean value was .23 (cluster 3). (See Table 1). In North Fork Granite Creek the highest mean value was .33 (cluster 1), and lowest value was .27 (cluster 2). (See Table 1). The null hypothesis that sample substrate diversities in Lee Creek and North Fork Granite Creek are derived from similar populations was again accepted for tests between all clusters at the .05 level, demonstrating that substrate diversity between clusters in both streams is not significantly different. A similar discrepancy to that observed for substrate roughness above exists with substrate diversity in that a cursory visual observation of the two streams suggests that mean substrate diversity is lower in Lee Creek. In Lee Creek there appears to be more sections of stream where sand is the only substrate class. These areas are concentrated in depositional-type sections, such as pools, pool tail-outs and stream edges in lower gradient areas. Depositional type areas, however, constituted a minority of sample sites in both streams and may in part explain why substrate diversities in each stream are so similar.

3. Most Common Substrate Class:

"Most common substrate class" is the substrate class (i.e. sand, gravel, cobble, boulder) that most frequently characterizes the predominant substrate materials among 20 samples in each cluster. In Lee Creek the most common substrate class (when data from all clusters are pooled) is gravel, occurring as the predominant substrate type in 55 of 80 samples (69%). Second most common substrate class is cobble (15%), followed by boulder (10%) and sand (6.25%). In North Fork Granite Creek gravel was also the predominant substrate class (52.5%), followed by cobble (42.5%), boulder (5%) and sand (0%).

The null hypothesis was once again accepted for tests between all clusters indicating that samples from each stream came from similar populations and that the distribution of substrate classes (i.e., gravel > cobble > boulder > sand) is similar when compared between clusters in both streams. (See Table 2).

## 4. Benthic Insect Density:

Individual densities per 0.1 sq.meter sample ranged from a high of 55 in North Fork Granite Creek to a low of 0 in Lee Creek. (Note: 25% of all benthic samples in Lee Creek had 0 density). The highest mean density for all clusters in Lee Creek was 4.70 (cluster 2) and the lowest value was 2.10 (cluster 4). (See Table 3). The highest mean density for all clusters in North Fork Granite Creek was 13.70 (cluster 4) and the lowest value was 5.00 (cluster 2). (See Table 3). The null hypothesis that benthic insect density is similar between clusters was rejected in only two instances. Density was significantly different at the .05 level between cluster 1 in Lee Creek and cluster 1 in North Fork Granite Creek. and between cluster 4 in Lee Creek and cluster 4 in North Fork Granite Creek.

## 5. Richness (Genus):

Richness of benthic populations has been correlated with substrate diversity (Allan, 1975). and substrate irregularity (Hart 1978). Theoretically, as the diversity and irregularity of the substrate increases, the available habitat and space for invertebrate colonization should also increase. Some invertebrates prefer certain substrate sizes and types (Minshall and Minshall, 1977), and as the diversity of the substrate increases so should the potential for meeting a greater number of species habitat requirements.

Values for richness ranged from a high of 8 genera per sample in North Fork Granite Creek to a low of 0 in Lee Creek. The highest mean richness value for all clusters in Lee Creek was 2.2 (cluster 2) and the lowest value was 1.1 (cluster 4). (See Table 3). The highest mean richness value in North Fork Granite Creek was 3.2 (cluster 1) and the lowest value was 2.6 (clusters 2 & 4). (See Table 3). These low values for richness in both streams reflect the dominance of the benthic insect population by the plecopteran, Yoraperla. In Lee Creek, Yoraperla stonefly nymphs comprised 73% of the total insect fauna, while in North Fork Granite Creek, Yoraperla constituted 61%. Yoraperla is a detritivore (Merritt and Cummins, 1984), and is well suited to stream environments such as Lee and North Fork Granite Creeks where one of the main food components is decaying leaf and organic matter contributed by the heavy riparian cover along the stream banks.

Applying the Kolmogorov–Smirnov test at the .05 level revealed that the null hypothesis was rejected in only two situations.

6. Order Diversity:

Similar to the values obtained for richness above, diversity values in each stream were low due to the dominance of the benthic population by the Plecopteran, Yoraperla. The highest mean diversity among all clusters in Lee Creek was .18 and the lowest value was .13. (See Table 3). The highest mean diversity value among all clusters in North Fork Granite was .25 and the lowest value was .21. (See Table 3). When the Kolmogorov-Smirnoff test for small samples (n = 20) was applied between clusters in each stream the null hypothesis was accepted in all but one instance (Lee Creek cluster 3 vs. North Fork Granite Creek cluster 3).

## Between Stream Tests (Pooled Data)

Similar to the results of the tests applied above for substrate roughness and substrate diversity for small samples, the null hypothesis was once again accepted when these two categories were tested between streams with pooled data. (See Table 4a). This is in agreement with the results obtained above for tests conducted with small samples (n = 20), confirming that substrate roughness and diversity are similar in both streams. When data was pooled for the category most common substrate class, and cumulative frequency distributions for each stream were tested, the null hypothesis was rejected. (See Table 4a). This result is in conflict with the results of between cluster tests applied to small samples for this same category. This suggests that when the data is analyzed with a larger set of samples (n = 80) subtle differences appear in the frequency distributions for each stream that are not detected at the between cluster level (n = 20). The most obvious differences that are noted when the frequency distributions are examined for both streams is that although the gravel substrate class comprises the dominant substrate class in each stream (69% in Lee Creek; 52.5% in North Fork Granite Creek), the second most common substrate class in both streams, cobble, comprises a substantially lower percentage in Lee Creek (15%) than in North Fork Granite (42.5%). In addition, sand is absent as a predominant substrate class in North Fork Granite Creek (0%) while in Lee Creek it comprises 6.25% of the samples.

In light of these observed differences in most common substrate class, aquatic insects such as the Plecopteran, Yoraperla, the dominant insect in Lee Creek (73%), may exhibit a selective preference for gravel substrates. The lower abundance of Yoraperla in North Fork Granite Creek (61%), may reflect the higher percentage of cobbles in the substrata, which may meet the habitat needs of a wider variety of insect species. This premise is also supported by the higher values of order diversity exhibited by the benthic insect population in North Fork Granite Creek.

The Kolmogorov-Smirnov test found a significant difference in density, richness (genus) and order diversity when pooled data was tested. (See Table 4b). This suggests once again that when data is analyzed for a larger set of samples subtle differences between frequency distributions that were not revealed in a test of the smaller samples may become apparent, resulting in the rejection of the null hypothesis.

Within Stream Tests:

In order to test the degree of variability within each stream, a Kolmogorov-Smirnov test for small samples (n = 20) was conducted between the two clusters in each stream displaying the highest and lowest mean values within each of the 6 categories. For example, in Lee Creek, cluster 1 which had the lowest average substrate roughness for 20 samples was tested against cluster 4 which had the highest average substrate roughness for 20 samples. The same test was applied in North Fork Granite Creek between clusters 3 and 4 which displayed the highest and lowest mean values for substrate roughness in that stream. Similar testing was conducted for substrate diversity, most common substrate class, density, richness (genus) and order diversity. The null hypothesis was accepted in 11 of 12 tests conducted in all 6 categories indicating that samples drawn from the most dissimilar clusters within a stream were derived from similar populations. (See Table 5). These results suggest that there is a low degree of variability of the substrate and benthic insect population characteristics within each stream. This may be attributable to the fact that Lee Creek and North Fork Granite Creek are short in length and are totally confined within one type of geological zone (i.e., granitic), in contrast to longer, higher order streams that may traverse several different types of geological areas within total their length. The sediment type found in Lee and North Fork Granite Creek, for example, is a coarse, sandy sediment. In contrast, streams that flow through several different geological areas may have a greater range of sediment types (from fine silts to coarse sands) which may ultimately produce a higher degree of variablitity in the density and diversity of the benthic insect fauna.

## Correlation Analysis:

Correlation coefficients were generated using the Spearman Rank Correlation method for the variables "substrate roughness", "substrate diversity", "density" and "richness" (genus). Each of the four variables were tested for correlation for pooled data generated within each stream. Coefficients with values of $r = \geq 0.3$ or $r = \leq -0.3$ were taken as significant positive or negative correlations at the .05 level.

Significant correlations existed between substrate roughness and substrate diversity in both Lee Creek and North Fork Granite Creek. (See Table 6). In addition, when benthic insect density was compared with richness (genus), significant correlations appeared in both streams (See Table 6). However, no significant correlation existed in either stream when substrate roughness and substrate diversity was compared with density and/or richness (genus). These results suggest that for granitic streams, (such as these two streams) in which there is a low degree of substrate variability, and a full range of substrate types is not present (e.g., fine substrate types such as silts are not present) surface substrate characteristics may not serve as sensitive predictors of benthic insect density or diversity.

Further, where streams display little variability in surface substrate characteristics, more intensive sampling of surface substrate characteristics than was conducted in this study may be necessary to see correlations between surface substrate characteristics and benthic insect density and diversity. Such intensive sampling would not be practical for routine monitoring.

# SUMMARY AND CONCLUSIONS

1. Substrate roughness and surface substrate diversity do not appear to be good indicators of the differences in density, richness or diversity of benthic insects in Lee or North Fork Granite Creek. While the two streams differ significantly in their biotic characteristics, their abiotic characteristics are not significantly different.

2. Both stream's benthic faunas are dominated by a single genus of stonefly, _Yoraperla_, (73% in Lee Creek: 61% in North Fork Granite Creek), yet North Fork Granite Creek still supports an insect population that is significantly denser, richer and more diverse. The difference in benthic population characteristics in these two streams is not correlated to substrate roughness and surface substrate diversity, but may be related to other factors not isolated by this study. Location of food supply may be a major factor in regulating the microdistribution of detritivores such as _Yoraperla_ in Lee and North Fork Granite Creek as these streams receive substantial inputs of organic matter from the dense riparian vegetation bordering the length of both streams. Moreover, the density, richness and diversity of benthic insect populations in these two streams may be influenced by a variety of physical and biological variables interacting together (rather than one or two substrate

variables) to produce a set of responses that is unique to each species.

3. The difference in surface substrate composition (most common substrate class) between streams (n = 80) is significant, even though tests with a smaller sample size (n = 20) showed no significant differences. This emphasizes the importance of hypothesis testing with enough replication to detect subtle variations between streams that may not be revealed by testing smaller samples when the study streams exhibit a low degree of variability in substrate characteristics throughout their length. Though the most common surface substrate class in both streams was gravel (69% in Lee Creek; 52.5% in North Fork Granite Creek), North Fork Granite Creek contained a significantly higher percentage of cobble (42.5%) than Lee Creek (15%). When viewed in terms of the cumulative frequency distributions for each stream for n = 80 samples, this discrepancy in cobble percentage was enough to cause rejection of the null hypothesis. This difference in cobble percentage could be a factor in the differences exhibited in density, richness and order diversity between streams. Aquatic insects such as _Yoraperla_, the dominant insect in Lee Creek (73%), may exhibit a selective preference for gravel substrates. The lower abundance of _Yoraperla_ in North Fork Granite Creek (61%), may reflect the higher percentage of cobbles in the

substrata, which may meet the habitat needs of a wider variety of insect species. This premise is supported by the higher values of order diversity exhibited by the benthic insect population in North Fork Granite Creek.

4. Significant correlations exist between substrate roughness and substrate diversity in Lee Creek and North Fork Granite Creek. In addition, benthic insect density and richness are positively correlated in both streams. The differences in benthic insect populations in these two streams may be associated with other abiotic and biotic factors. In such streams more intensive analysis of substrate characteristics may be necessary to see a correlation between substrate and benthic insect populations.

5. In conclusion, while hydrologic monitoring by the Lolo National Forest indicates that sediment yield is significantly different in these two watersheds and that sediment yield has had an effect on water quality in Lee Creek, it appears that these differences have not had a measurable effect on the substrate roughness or surface substrate diversity characteristics in these two streams. Surface substrate composition (most common substrate class) and benthic insect populations in Lee and North Fork Granite Creek are significantly different when density, richness

(genus) and order diversity are compared between streams. The biotic differences may be most related to a combination of biotic and abiotic factors that include surface and subsurface substrate factors interacting to produce species specific responses that affect microdistribution.

TABLE 1. Variability of surface substrate roughness and surface substrate diversity in two granitic streams in the Lolo National Forest, MT.

SUBSTRATE ROUGHNESS: Mean/(standard deviation)

Lee Creek

| Site | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| | .27(.11) | .31(.17) | .30(.18) | .35(.15) |

N. Fk. Granite Creek

| Site | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| | .32(.13) | .31(.09) | .30(.10) | .33(.14) |

SURFACE SUBSTRATE DIVERSITY: Mean/(standard deviation)

Lee Creek

| Site | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| | .36(.12) | .29(.13) | .23(.13) | .32(.13) |

N. Fk. Granite Creek

| Site | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| | .33(.07) | .30(.18) | .27(.14) | .29(.12) |

TABLE 2. Variability of surface substrate composition in two granitic streams in the Lolo National Forest. MT.

SURFACE SUBSTRATE COMPOSITION: Mean/(standard deviation)

Lee Creek

| | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| Boulder | .05(.15) | .07(.18) | .16(.30) | .12(.25) |
| Cobble | .25(.18) | .26(17) | .17(.17) | .28(.19) |
| Gravel | .48(.21) | .63(.22) | .60(.33) | .50(.26) |
| Sand | .22(.25) | .04(.07) | .07(.23) | .10(.21) |

N. Fk. Granite Creek

| | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| Boulder | .17(.19) | .09(.14) | .04(.08) | .11(.17) |
| Cobble | .30(.21) | .43(.23) | .45(.27) | .34(.26) |
| Gravel | .53(.16) | .48(.21) | .52(.26) | .55(.26) |
| Sand | .00(.00) | .00(.00) | .00(.00) | .00(.00) |

TABLE 3 Variability of benthic insect density, richness (genus), and order diversity in two granitic streams in the Lolo National Forest, MT.

| | C-1 | C-2 | C-3 | C-4 |
|---|---|---|---|---|
| DENSITY: Mean/(standard deviation) | | | | |
| <u>Lee Creek</u> | 3.2(3.1) | 4.7(5.7) | 4.0(3.5) | 2.1(7.5) |
| <u>N. Fk. Granite Creek</u> | 11.0(6.85) | 5.0(4.8) | 7.1(6.8) | 13.7(12.3) |
| RICHNESS (Genus): Mean/(standard deviation) | | | | |
| <u>Lee Creek</u> | 1.6(1.19) | 2.2(2.55) | 1.3(0.73) | 1.1(0.91) |
| <u>N. Fk. Granite Creek</u> | 3.2(1.51) | 2.6(1.79) | 2.7(1.23) | 2.6(1.73) |
| ORDER DIVERSITY: Mean/(standard deviation) | | | | |
| <u>Lee Creek</u> | .17(.14) | .18(.14) | .13(.13) | .13(.14) |
| <u>N. Fk. Granite Creek</u> | .24(.22) | .21(.22) | .25(.13) | .21(.16) |

TABLE 4a. Kolmogorov-Smirnov test of differences in surface substrate roughness, diversity and most common substrate class in two granitic streams in the Lolo National Forest, MT (based on pooled data from each stream).

| | Observed Dmax. | Difference/Significant |
|---|---|---|
| Substrate Roughness | .13 | No |
| Substrate Diversity | .04 | No |
| Most Common Substrate Class | .23 | Yes |

TABLE 4b. Kolmogorov-Smirnov test of differences in benthic insect density, richness (genus) and order diversity in 2 granitic streams in the Lolo National Forest, MT (based on pooled data from each stream).

| | Observed Dmax. | Difference/Significant |
|---|---|---|
| Density | .36 | Yes |
| Richness (genus) | .40 | Yes |
| Order Diversity | .28 | Yes |

TABLE 5. Kolmogorov-Smirnov test comparing the most dissimilar sites for the variables surface substrate roughness, substrate diversity, most common substrate class, density, richness (genus) and order diversity in two granitic streams in the Lolo National Forest, MT.

| | Observed D-max. | Difference/Significant |
|---|---|---|
| <u>Substrate Roughness</u> | | |
| Lee Cr. (C-1)/Lee Cr. (C-4) | 4 | No |
| NFG (C-3)/NFG (C-4) | 2 | No |
| <u>Substrate Diversity</u> | | |
| Lee Cr. (C-1)/Lee Cr. (C-3) | 7 | No |
| NFG (C-1)/NFG (C-3) | 4 | No |
| <u>Most Common Substrate Class</u> | | |
| Lee Cr. (C-3)/Lee Cr. (C-4) | 2 | No |
| NFG (C-3)/NFG (C-4) | 5 | No |
| <u>Density</u> | | |
| Lee Cr. (C-2)/Lee Cr. (C-4) | 5 | No |
| NFG (C-2)/NFG (C-4) | 9 | Yes |
| <u>Richness (Genus)</u> | | |
| Lee Cr. (C-1)/Lee Cr. (C-4) | 4 | No |
| NFG (C-1)/NFG (C-2) | 4 | No |
| <u>Order Diversity</u> | | |
| Lee Cr. (C-2)/Lee Cr. (C-3) | 1 | No |
| NFG (C-3)/NFG (C-4) | 5 | No |

TABLE 6. Correlation between surface substrate and benthic insect characteristics in two granitic streams in the Lolo National Forest. MT (based on pooled data for each stream).

Lee Creek

| | SR | SD | D | R |
|---|---|---|---|---|
| SR | – | .31(S) | .03 | .07 |
| SD | – | – | .14 | .17 |
| D | – | – | – | .77(S) |
| R | – | – | – | – |

N. Fk. Granite Creek

| | SR | SD | D | R |
|---|---|---|---|---|
| SR | – | .52(S) | .19 | .13 |
| SD | – | – | .05 | .10 |
| D | – | – | – | .55(S) |
| R | – | – | – | – |

(S) = significant correlation

Key:
(SR) = substrate roughness
(SD) = substrate diversity
(D) = density
(R) = richness (genus).

APPENDIX A. List of taxa collected in Lee and North Fork Granite Creeks in 1985.

| | Lee Cr. | | | | N.Fk. Granite | | | |
|---|---|---|---|---|---|---|---|---|
| | C-1 | C-2 | C-3 | C-4 | C-1 | C-2 | C-3 | C-4 |
| EPHEMEROPTERA: | | | | | | | | |
| Ephemerellidae | | | | | | | | |
| Ephemerella | 3 | 2 | 4 | 3 | | 14 | 32 | 18 |
| Drunella | 2 | | | | 13 | 11 | 15 | 12 |
| Heptageniidae | | | | | | | | |
| Epeorus | | | | | 2 | 2 | | 3 |
| Cinygmula | 4 | 6 | 3 | 5 | 2 | 23 | 37 | 24 |
| Rhithrogena | 4 | 2 | | | 15 | 19 | 6 | 13 |
| Baetidae | | | | | | | | |
| Baetis | 5 | | | | 14 | 10 | 11 | 26 |
| Leptophlebidae | | | | | | | | |
| Paralept. | 2 | 2 | | | 2 | 3 | 6 | 5 |
| PLECOPTERA: | | | | | | | | |
| Peltoperlidae | | | | | | | | |
| Yoraperla | 50 | 91 | 74 | 28 | 179 | 51 | 169 | 294 |
| Perlodidae | | | | | | | | |
| Megarcys | 2 | | | | 14 | 4 | 3 | 6 |
| TRICHOPTERA: | | | | | | | | |
| Brachycentridae | | | | | | | | |
| Brachycentrus | | | | | 3 | 1 | | |
| Micrasema | 2 | | | | 4 | | | |
| Glossosomatidae | | | | | | | | |
| Glossosoma | 2 | 1 | | 1 | | 1 | | |

APPENDIX A. (continued)

| | Lee Cr. | | | | N.Fk. Granite | | | |
|---|---|---|---|---|---|---|---|---|
| | C-1 | C-2 | C-3 | C-4 | C-1 | C-2 | C-3 | C-4 |
| <u>Hydropsychidae</u> | | | | | | | | |
| Hydropsyche | 5 | 2 | 1 | 2 | 3 | 13 | 5 | 15 |
| Parapsyche | 4 | 3 | | 1 | | | 1 | |
| <u>Rhyacophilidae</u> | | | | | | | | |
| Rhyacophila | 4 | 1 | 2 | 3 | 4 | 3 | 7 | 8 |
| DIPTERA: | | | | | | | | |
| <u>Tipulidae</u> | | | | | | | | |
| Antocha | | | 2 | 2 | | | 1 | |
| Tipula | 2 | 4 | | | | 1 | | |
| <u>Simulidae</u> | | | | | | | | |
| Prosimulium | | 1 | | | 6 | 8 | 2 | |

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