RESEARCH TECHNICAL COMPLETION REPORT
PROJECT A—049—IDA

Comparison of Macroinvebrate Samplers And The Relationship of Environmental Factors To Biomass And Diversity Variability In A Small Watershed

WATER for IDAHO

By

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ABSTRACT

Variability in macroinvertebrate biomass and diversity between streams in a relatively undisturbed watershed was determined by sampling at 19 stations in first through fourth order streams of the Horse Creek drainage, Idaho. Macroinvertebrate biomass and diversity values varied significantly ($P<.05$) both between different stream orders, and between streams of the same order. Biomass and diversity variability was correlated with physical and chemical factors by stepwise regression analysis. A large percentage (>85%) of the variance in both biomass and diversity was accounted for by changes in four to five physical and chemical factors, which included substrate size, gradient, suspended sediment, water temperature, alkalinity, stream order and width. This indicates that predictive modeling of macroinvertebrate community structure is possible in a small, relatively undisturbed watershed. Basket, multiple-plate and Surber macroinvertebrate samplers were used to determine which sampler is most applicable for use in small, relatively undisturbed streams. Comparisons were made on the basis of sample biomass, diversity and taxonomic composition. Basket samples had more biomass and higher diversity than multiple-plate samples throughout the watershed, probably because they provided a better imitation of the natural substrate. Basket sample diversities were similar to Surber sample diversities in first and second order streams, but were much lower in third and fourth order streams. Both basket and multiple-plate samplers were found to be adequate for stream survey work. The inconsistancies found with Surber samplers indicated that they were most applicable only when time and resources were at a minimum, or when sampling was designed only to determine which taxa were present at a given site.

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INTRODUCTION

Freshwater biologists are frequently called upon to characterize the lotic aquatic resources of a large area. Every stream in an area cannot be sampled, so some assumption of homogeneity must be made for sampling to be of practical value. How much similarity can be assumed to exist between the macroinvertebrate communities of apparently closely related streams is largely unknown. On the other hand, any problem of biological variability between streams would be lessened if accurate predictive models were developed that could be used to account for differences found in macroinvertebrate community structure throughout a watershed, or other large area.

Current stream classifications are generally not helpful in characterizing streams for inventory, comparison and management (Harrell and Dorris 1968). These classification systems are often based on specific taxonomic groups such as fish, mayflies or caddisflies (Huet 1959, Ide 1935, Sprules 1947), and seldom include the entire macroinvertebrate community. Classification attempts also generally fail to incorporate the local stream-to-stream variability that exists in the factor(s) on which the classification system is based. Partially because of these problems, classification systems are often relied upon only in the immediate area where they were developed, or used only for broad, descriptive purposes (Hynes 1970, Pennak 1971).

Kuehne (1962) suggested that stream order analysis might be a good system for characterizing streams. Stream order, as proposed by Horton (1945) and Strahler (1957) is a method of grouping similar streams used for descriptive and analytical purposes in morphological and biological studies (Morisawa 1962, Kuehne 1962, Harrell and Dorris 1968). Stream order is easily determined from large scale topographic maps (± 1 order), but it has not been used extensively for quantitative comparisons of streams over large areas due to differences that occur between biomes. It is currently used for characterization of streams for inventory and management by agencies such as the U.S. Forest Service, which bases a number of management-practice regulations on stream order.

Pennak (1971), on the other hand, has proposed a more complicated system for characterizing streams and small rivers, based on a series of physical and chemical measurements. He contended that otherwise different lotic habitats similar in these features should have ecologically similar communities. Thus prediction of biological characteristics using relatively easily obtained physical and chemical data may be feasible. A successful modeling system based on such traits would, unlike present systems, be useful for ralatively local characterization of streams because the variability in macroinvertebrate community structure between similar streams could be taken into account using physical and chemical parameters.

One objective of this study was to compare and evaluate the validity and usefulness of these two methods of characterizing streams. To do this, macroinvertebrate biomass and diversity was measured in 13 streams of the Horse Creek drainage, a relatively undisturbed stream system in North-Central Idaho. Analysis of variance was used to evaluate the variability that exists in macroinvertebrate biomass and diversity between streams of both the same and different orders. Also, physical and chemical measurements similar to those suggested by Pennak (1971) were made at the macroinvertebrate sampling stations, and an attempt was made to correlate these factors, along with stream order, with macroinvertebrate biomass and diversity. Successful correlations of this type would indicate that predictive modeling of macroinvertebrate community structure is possible.

Another important problem facing biologists attempting to characterize the macroinvertebrate fauna of a large area is the selection of an appropriate sampler. Benthic macroinvertebrate sampling in small streams has been complicated in recent years by the development of many different samplers (Mundie 1971, Mason et al. 1967, Macan 1958). Studies using these new samplers are mostly descriptive in nature and do not generally include comparative, quantitative data (Hilsenhoff 1969, Radford and Hartland-Rowe 1971). In the present study comparative sampling characteristics of Surber, barbeque-basket and multiple-plate samplers were investigated in order to determine which sampler is most applicable for use in small streams. Samples were taken in first through fourth order streams of the Horse Creek drainage, Idaho, and compared on the basis of sample biomass, diversity and taxonomic composition.

The samplers compared were chosen because they are representative of different sampling strategies. Surber samplers sample the stream bottom directly and are easy to use. They have been the traditional choice for work in small streams (Macan 1958), although they are difficult to use in streams with large substrate material (Mundie 1971) and produce great variability between samples (Needham and Usinger 1956). Basket and multiple-plate samplers are colonization samplers, which facilitate comparisons between areas with different or variable substrates by providing a relatively uniform, reproducible substrate (Mason, et al. 1973). Other favorable properties include the ability to collect a wide range of aquatic invertebrates (Anderson and Mason 1973) and a tendency towards less variability between samples (Dickson, Cairns and Arnold 1971). Basket samplers, as described by Wene and Wickliffe (1940) and Dickson et al. (1971), use stones as their substrate and thus attempt to imitate the natural substrate to some extent. Multiple-plate samplers maximize the replicability of sampling conditions by avoiding any imitation of the natural substrate (Hester and Dendy 1962).

Beak et al. (1973) differentiated between sampling designed to monitor general water quality and sampling designed to measure complex biological parameters. In pollution survey work, reproducability of sampling conditions among sites is necessary in order to distinguish differences due to pollution from differences caused by site-specific sampling conditions. When accurate measurement of biological parameters such as biomass and diversity is important, close imitation of natural bottom conditions is required due to the need to find specific information about the benthic community of the particular site.

Mason et al. (1973) and Fullner (1970) found that basket and multiple-plate samplers compared favorably in terms of total individuals in major taxonomic groups. Their results indicated that both samplers were suitable for survey work aimed at the assessment of water quality in large rivers. Very little work has been done comparing these different colonization samplers and Surber samplers in small streams. Samples from the Horse Creek drainage were compared taxonomically to see which of the various samplers are suitable for general survey work in small streams. Also, macroinvertebrate biomass and diversity values were compared to determine how each sampler performed relative to the measurement of complex biological parameters.

DESCRIPTION OF STUDY AREA

The Horse Creek drainage is located in the Nez Perce National Forest, approximately 56 km east of Grangeville, Idaho (Fig. 1), and empties into Meadow Creek about 6 km upstream of its confluence with the Selway River. Geologically, the Horse Creek drainage is in the Precambrian Belt Supergroup, which includes most of Northern Idaho and much of the Northern Rocky Mountains. Most of the study area was located in the East and Main Fork drainages of Horse Creek, which are very similar in land form characteristics. The Main Fork has a drainage area of 15.3 km^2 and the East Fork drainage area is 13.1 km^2. Streams in the Horse Creek drainage are characterized by alternating riffles, pools and runs, with numerous cascades in the steeper sections. Debris jams and plunge pools are common.

Mid summer flow in the streams that were sampled ranged from an average of 0.58 m^3/min. in first order streams to 62 m^3/min. in the fourth order stream. Stream width, measured across a run, varied from 0.6 to 7 m. Gradients ranged from an average of 25% for first order streams to an average of 4% for third and fourth order streams. Substrate composition was extremely varied from stream to stream. Some of the first and second order streams contained mainly sand, silt and pebbles overlaying bedrock. Other streams contained mainly cobbles.

Sampling stations were located in 10 subdrainages of the Main Fork, in the Main Fork proper, in the East Fork and in Horse Creek below the confluence of the two forks (Fig. 1). One station was placed in each of the Main Fork subdrainages upstream of the small dams used by the Horse Creek Administrative-Research Project to measure sediment loads. The four stations that were placed in both the Main and East Forks of Horse Creek ranged from 0.2 to 5 km upstream of the confluence. Station locations were chosen to correspond with the sampling stations of the Horse Creek Administrative-Research Project.

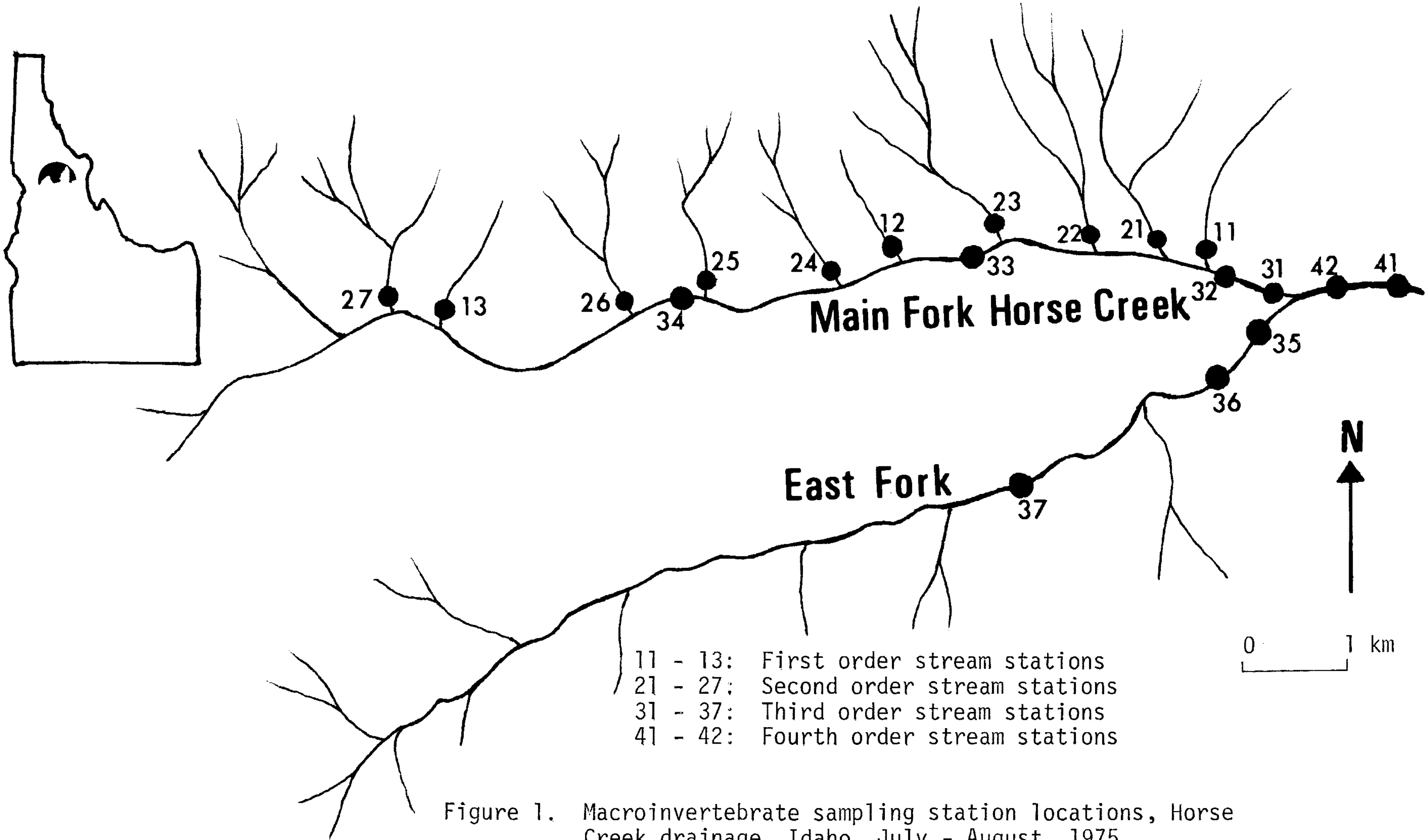

Figure 1. Macroinvertebrate sampling station locations, Horse Creek drainage, Idaho, July - August, 1975.

METHODS

Benthic macroinvertebrate communities were sampled using basket, multiple-plate and Surber samplers. Surber sampling was conducted with a standard Surber sampler (Surber 1937) which consists of a frame which encloses .09 m^2 of substrate, and a 30 mesh net positioned downstream of the frame which retains organisms dislodged from the substrate within the enclosed area (Fig. 2). The substrate within the Surber frame was disrupted and exposed to the current to a depth of 10-15 cm, and all pebbles and cobbles in the sampling area were individually wiped clean of organisms. Five Surber samples were taken at each station from July 30 - August 8.

Basket samplers (Fig. 2) consist of a cylindrical wire frame (35 x 17cm) which is filled with cleaned stream-bank stones 8-12 cm in diameter. Baskets were placed in the streams with the long axis parallel to the current, in a shallow depression formed by removing surface cobbles. The samplers were generally placed in runs, although in the smallest streams they could only fit in plunge pools. Two basket samplers were placed in the streams for a colonization period of one month ($\pm$ two days) following the procedure of Bergersen and Galat (1975). The baskets were removed using a screen-bottom pail (30 mesh) which was placed immediately downstream of the basket. The basket was lifted into the pail, removed from the stream and emptied. The rocks were cleaned in the pail with a wire brush and returned to the basket. Individual samples were then transferred to separate plastic zip-lock bags containing 70% ethyl alcohol.

Three multiple-plate samplers, similar to those described by Fullner (1971), were set out at the same time as the baskets. Each sampler consisted of 16 fiberboard plates (22.9 cm^2) arranged with spacers on a skewer (Fig. 2). The skewer was pushed into the substrate to hold the samplers in place. The multiple-plate samplers were removed and cleaned using the screen-bottom pail at the same time as the baskets, using the above described procedure.

Due to decreasing flow in the streams over the summer, some of the plates of a multiple-plate sampler, or part of a basket sampler were often out of the water by the end of the colonization period. Measurements were taken before the samplers were removed to adjust for the lost surface area.

In the laboratory, macroinvertebrates were sorted from the debris in the samples, counted and identified to species whenever possible. Keys by Usinger (1968), Ward and Whipple (1963) and Jensen (1966) were used in making identifications. Following enumeration of taxa and individuals, the Shannon-Weaver diversity index (Wilhm and Dorris 1966) was used to estimate a diversity value for each sample.

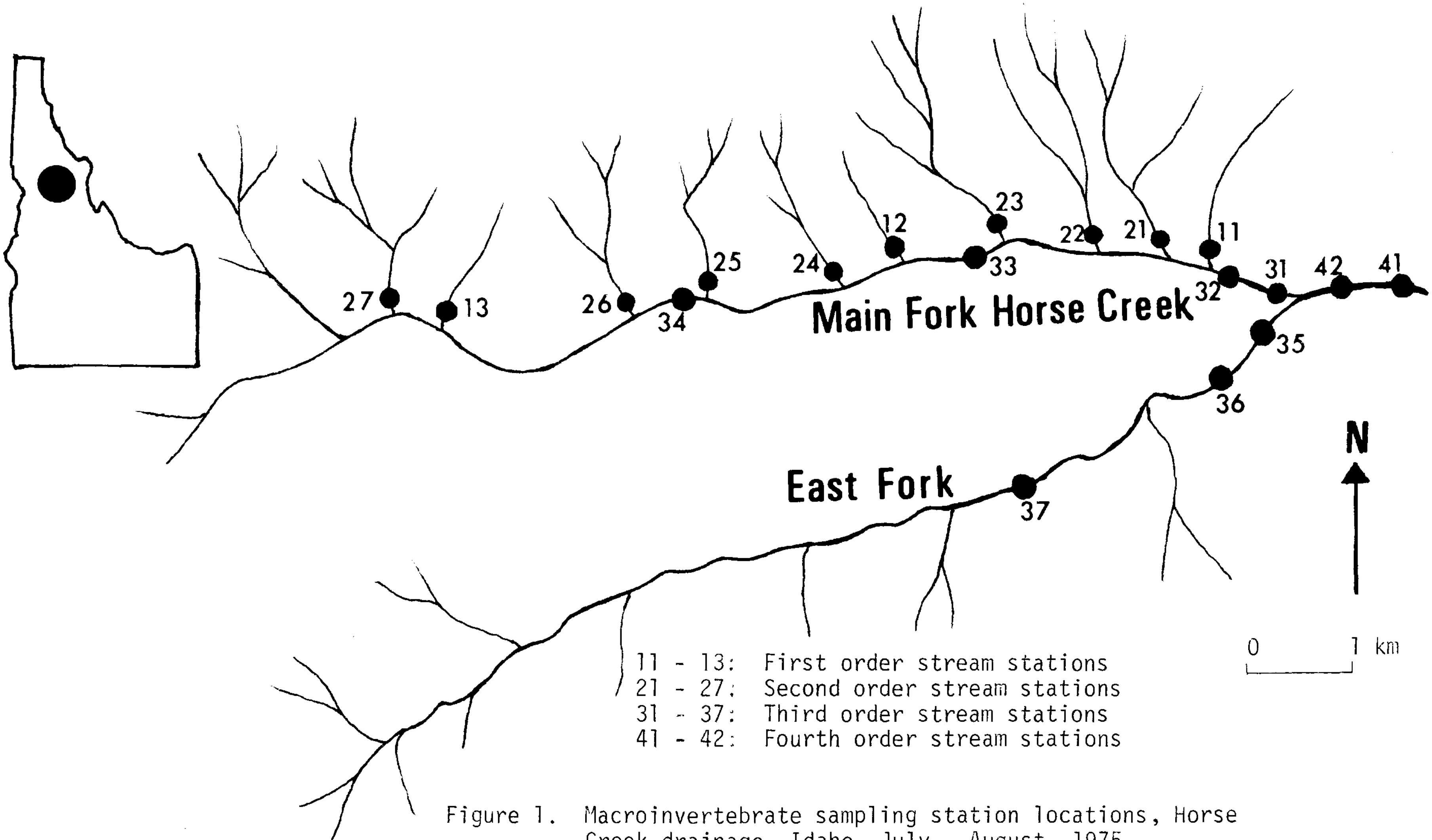

Figure 1. Macroinvertebrate sampling station locations, Horse Creek drainage, Idaho, July - August, 1975.

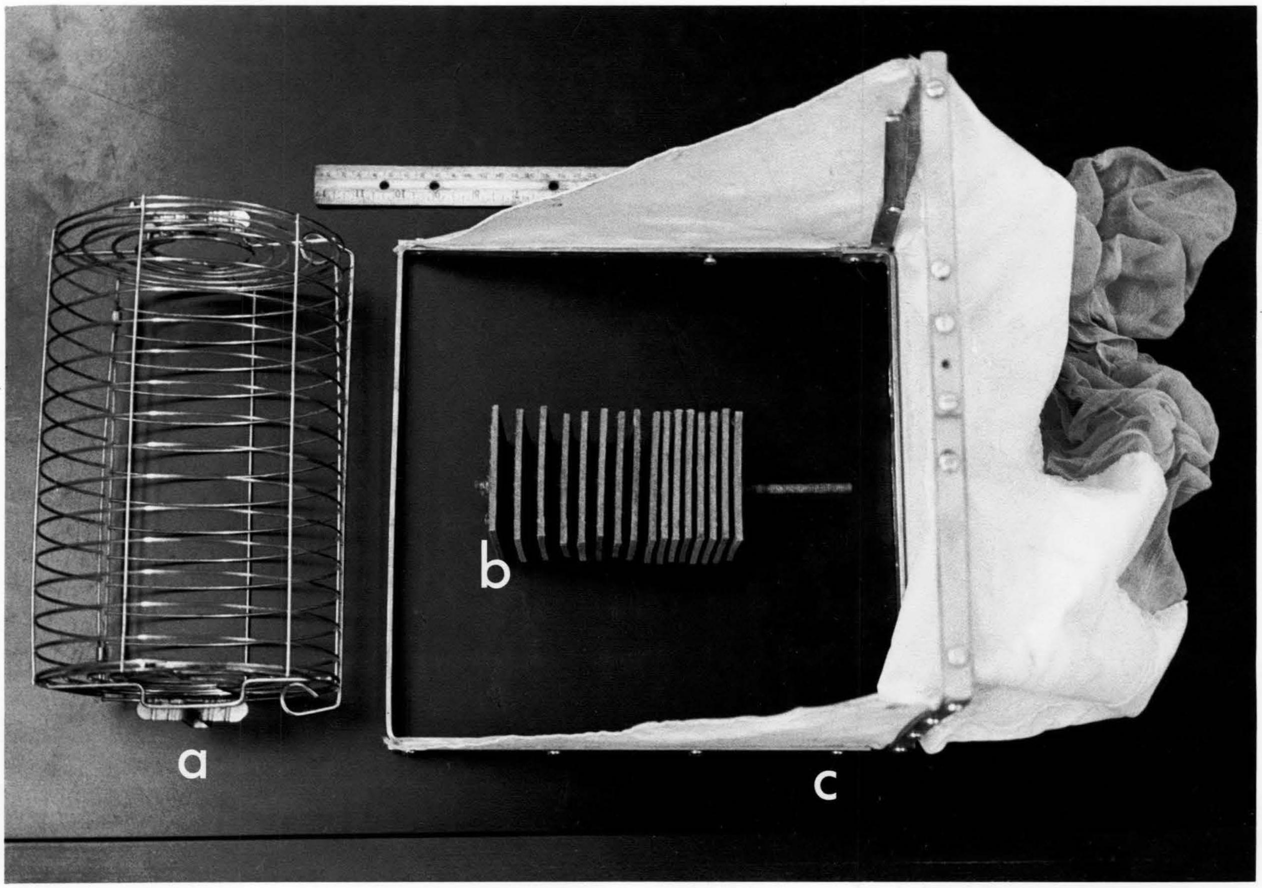

FIGURE 2. Macroinvertebrate samplers: a. basket sampler, b. multiple-plate sampler, c. Surber sampler.

Biomass (mg dry wt/cm^2) was determined using the dry weight procedure outlined by Cummins and Wuycheck (1971) and the surface area calculations used by Fullner (1971) for basket and multiple-plate samplers. Surber sample surface area was expressed in terms of the stream bottom surface area sampled.

First through fourth order streams of the Horse Creek drainage were sampled to determine the variability in macroinvertebrate biomass and diversity. Sampling stations were established at 19 locations, three in first order streams, seven each in second and third order streams and two in the fourth order stream (Fig. 1). Station locations were chosen to correspond with the stations of the Horse Creek Administrative-Research Project.

Physical and chemical factors measured at sampling sites were conductivity, alkalinity, suspended sediment, "hardness", stream wideth, flow, water temperature, median substrate diameter and gradient. Conductivity and alkalinity were measured by standard methods (American Public Health Association 1971). Hardness was determined by measuring Ca and Mg concentrations with atomic absorption spectrophotometry. Water temperature and flow data from H-flume gauging stations was provided by the Forest Service. Substrate samples were taken to a depth of 15 cm with a cylindrical sampler 20 cm in diameter. Median substrate diameter was found using Tyler screens and the procedure outlined by Cummins (1962).

Analysis of variance was used to determine if significant differences ($P<.05$) existed in macroinvertebrate biomass and diversity between streams of both the same and different orders. A stepwise linear regression was used to determine how much of the biomass and diversity variance between streams could be related to the physical and chemical factors measured.

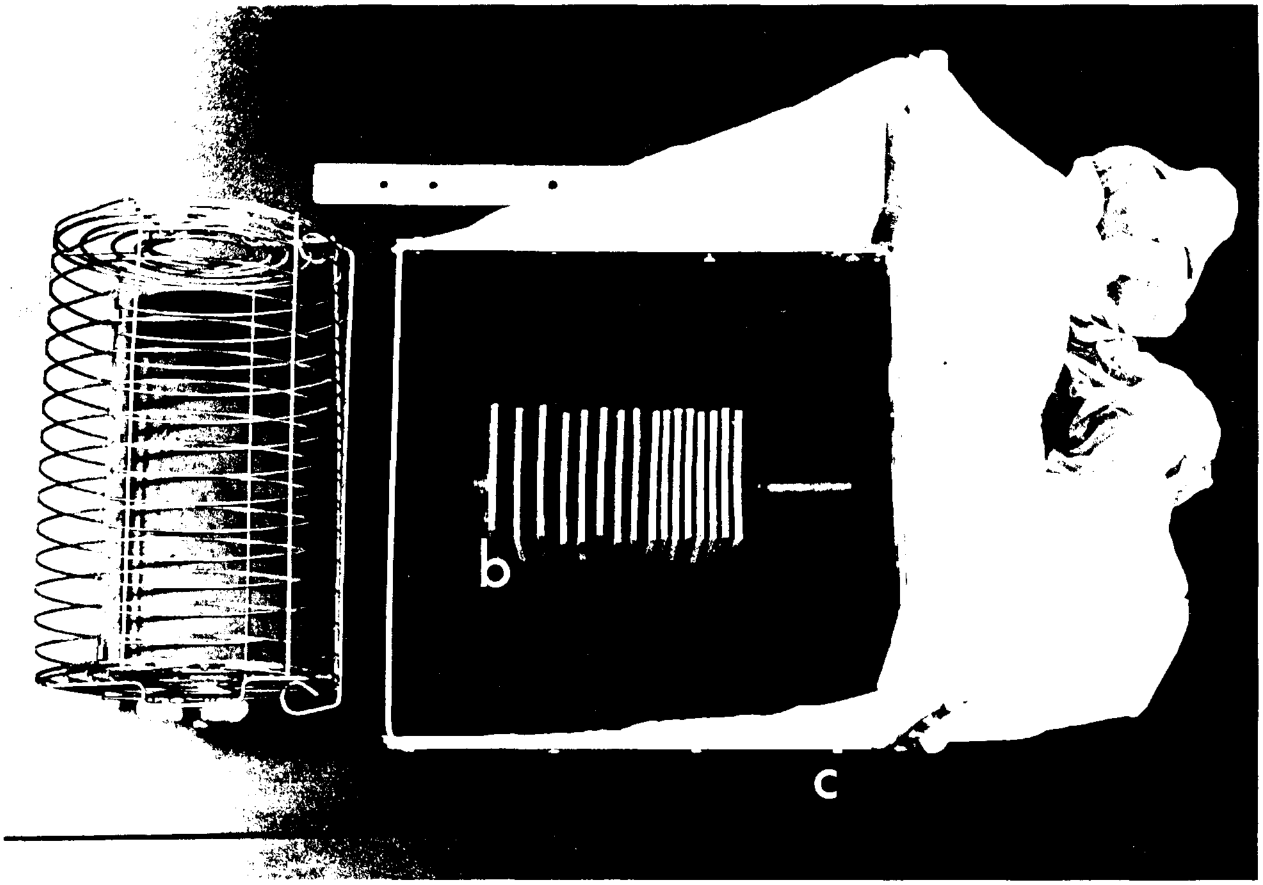

FIGURE 2. Macroinvertebrate samplers: a, basket sampler, b. multiple-plate sampler, c. Surber sampler.

RESULTS

Macroinvertebrate biomass per unit surface area of basket samplers was higher than that found with multiple-plate samplers throughout most of the Horse Creek drainage. Higher biomass readings were recorded in basket samples at 16 of the 19 stations (Fig. 3). Average summer biomass was significantly ($P<.01$) greater in basket samplers than multiple-plate samplers in second, third and fourth order streams. No significant difference between basket and multiple-plate samplers was found for biomass in the first order streams.

The greater biomass in basket samplers was due both to a larger number of organisms and a greater weight per organism (Table 1). In July, basket samples averaged 20% more organisms per unit surface area, and dry weight per individual was 25% greater than in the multiple-plate samplers. In August, basket samples averaged 20% more organisms per unit surface area and 19% more dry weight per individual.

TABLE 1. Comparison of Various Characteristics of Multiple-Plate, Basket and Surber Samples, Horse Creek Drainage, Idaho, July - August, 1975.

July	Samples	Total No. of Organisms	No. Organisms/sample	Total Surface Area Available (m^2)	Organisms/m^2	Avg. Dry wt./Organism (mg)
Multi-ple-plate	54	1655	30.6	7.93	208.1	1.72
Basket	38	2422	63.7	9.37	258.6	2.29
Surber	100	5683	56.8	9.41*	602.8*	0.68
August						
Multi-ple-plate	54	2089	38.7	8.19	255.5	1.57
Basket	39	3351	85.9	9.85	339.7	1.93
Average						
Multi-ple-plate	54	1872	34.7	8.06	231.8	1.64
Basket	39	2887	74.8	9.63	299.2	2.21

* "Surface area" for Surber sample data denotes surface area of stream bottom.

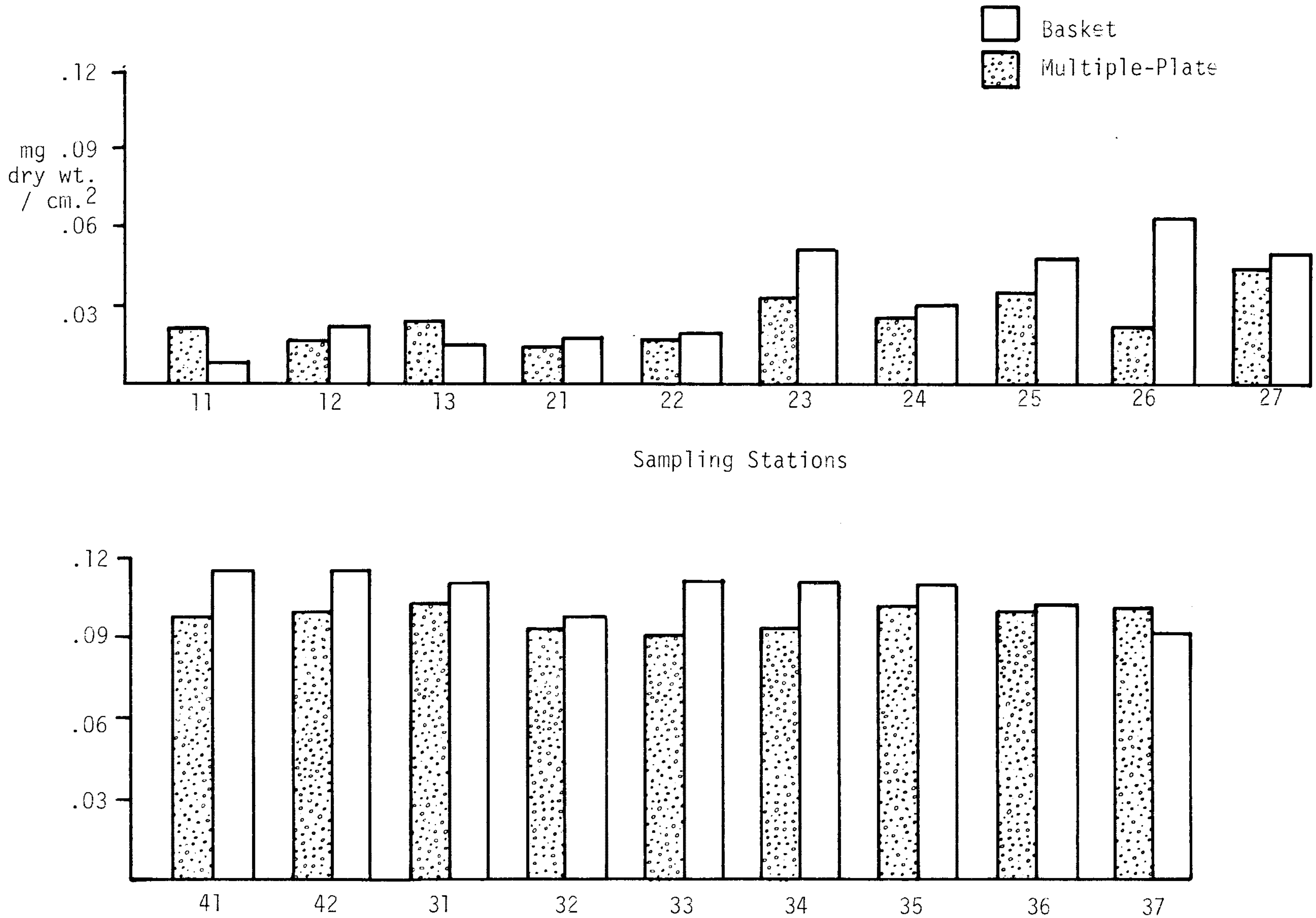

Figure 3. Average Macroinvertebrate Biomass at Sampling Stations in the Horse Creek Drainage, Idaho, July - August, 1975.

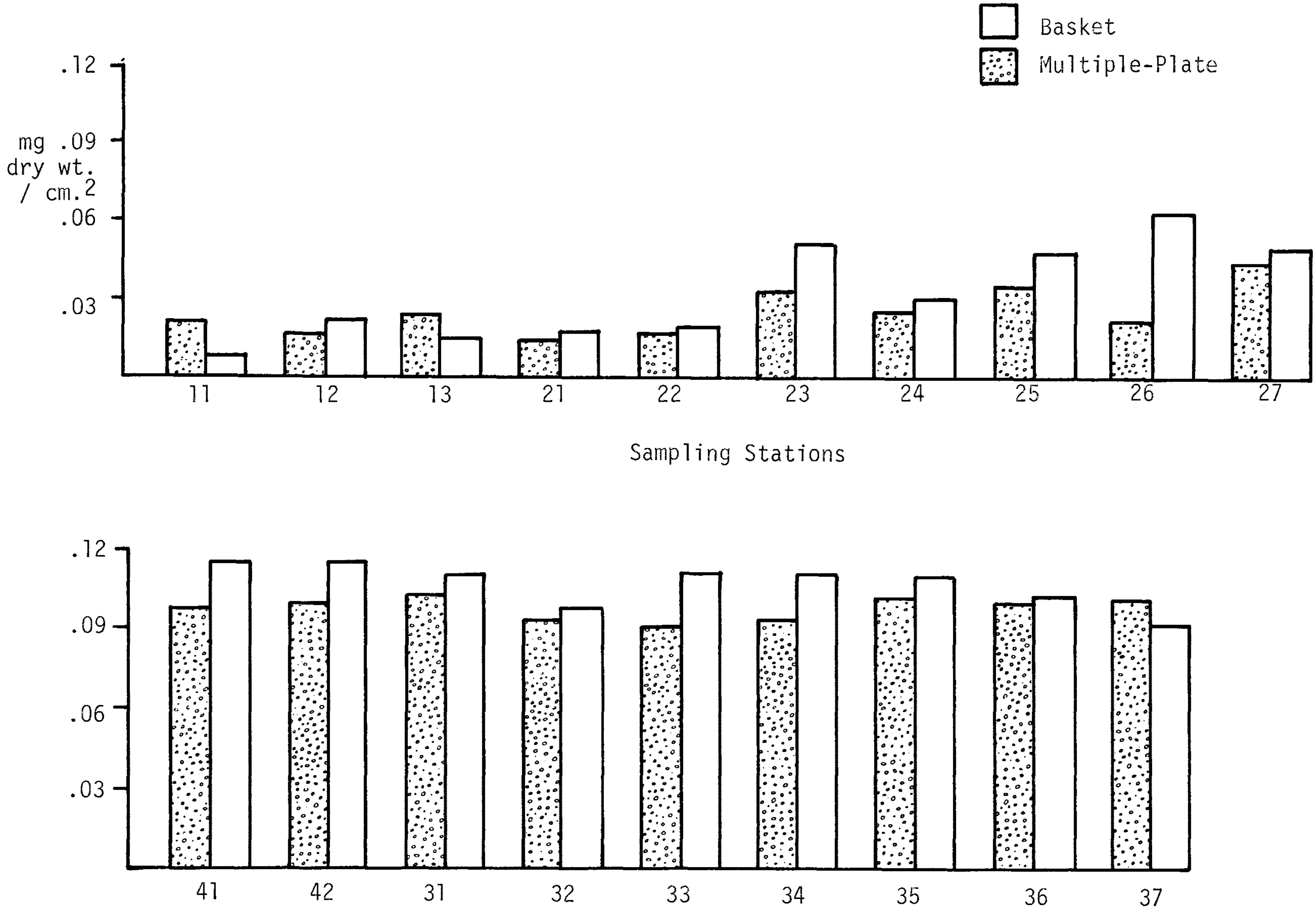

Figure 3. Average Macroinvertebrate Biomass at Sampling Stations in the Horse Creek Drainage, Idaho, July - August, 1975.

Biomass readings obtained with Surber units cannot be compared directly with basket or multiple-plate sample data because Surber samples measure biomass per unit area of surface available for colonization. Despite this difference, certain comparisons can be made. The average dry weight per organism in the Surber samples was only 0.68 mg, compared with 1.72 mg for multiple-plate samples, and 2.29 mg for the basket samples (Table 1). Baskets averaged 12% more organisms per sample than Surbers. This indicates a much greater collecting ability, as the volume contained in a basket cylinder is approximately one-half the volume of substrate sampled using a Surber sampler.

Basket and multiple-plate samples were quite similar taxonomically. The only significant ($P<.05$) differences in average proportions occured in Ephemeroptera and Trichoptera. On the average, Trichoptera made up 9.8% more of the basket samples than they did of the multiple-plate samples (Table 2). The proportion of Ephemeroptera was comparably higher in the multiple-plate samples, although basket samples actually contained more Ephemeroptera per unit area. This was due to the larger total number of organisms collected per unit area in the basket samples (Table 1).

TABLE 2. Average Percent Sample Composition of Major Taxa, Horse Creek Drainage, Idaho, July - August, 1975.

	Basket	Multiple-plate	Surber
Ephemeroptera	20.0	29.9	28.2
Plecoptera	31.9	30.1	26.1
Trichoptera	25.9	16.1	11.9
Coleoptera	5.2	3.9	27.3
Diptera	5.6	7.2	2.7
Other	5.4	6.8	3.8

Surber sample composition was markedly different from that of the basket and multiple-plate samples for Coleoptera and Trichoptera. Surber samples had a considerably lower percentage of Trichoptera than the colonization samplers, and a much higher percentage of Coleoptera (Table 2). Readings for the other taxonomic groups were all within 5% of the colonization sampler average.

Diversities in basket samples were significantly ($P < .05$) higher than diversities in multiple-plate samples in all four stream orders (Fig. 4). Both samplers showed increasing diversity with increasing stream order. Average July diversity was 3.28 for basket samples and 2.96 for multiple-plate samples. Slightly higher average diversities were recorded in August (3.32 for basket samples and 3.03 for multiple-plate samples). Surber sample diversities were similar to basket sample diversities in the first and second order streams, but dropped off considerably in the third and fourth order streams (Table 3). Basket sample data was used for further analyses.

TABLE 3. Average Diversity Found With Three Different Samplers in First Through Fourth Order Streams of Horse Creek Drainage, Idaho, July - August, 1977.

Stream Order	Basket	Multiple-Plate	Surber
1	3.06	2.34	3.01
2	3.08	2.89	3.24
3	3.41	3.24	2.88
4	3.88	3.22	2.80

A high correlation ($r = .85$) was found between increasing macroinvertebrate biomass and increasing stream order (Fig. 5). Highly significant ($P < .01$) differences in biomass existed between most of the different stream orders (Table 4), with summer averages ranging from .15 mg/cm^2 in the first order streams to 1.12 mg/cm^2 in the fourth order stream (Table 5). Macroinvertebrate diversity also increased with increasing stream order, although the correlation ($r = .49$) wasn't as high (Fig. 6). Significant ($P < .05$) differences in diversity existed between first and third, and first and fourth order streams (Table 4). Average diversity ranged from 3.01 in the first order streams to 3.82 in the fourth order stream (Table 5).

Biomass differed significantly ($P < .05$) only among second order stream stations, although differences greater than 100% existed between some individaul sampling stations in all but the fourth order stream. Diversity differed significantly in both first and second order streams. Differences in diversity of as much as .65 occured between individual stations in each of the first three orders.

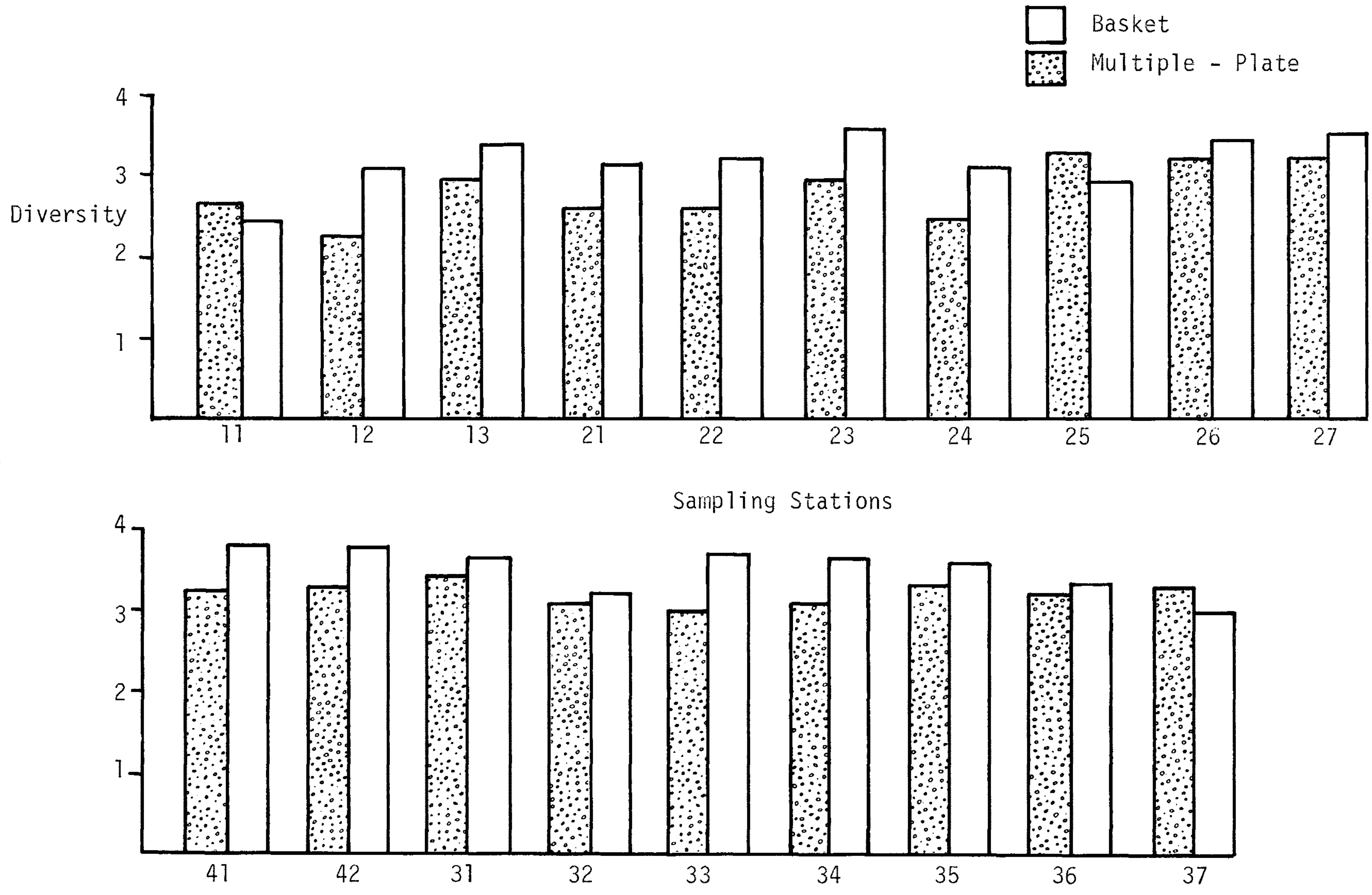

Figure 4. Average Macroinvertebrate Diversity at Sampling Stations in the Horse Creek Drainage, Idaho, July - August, 1975.

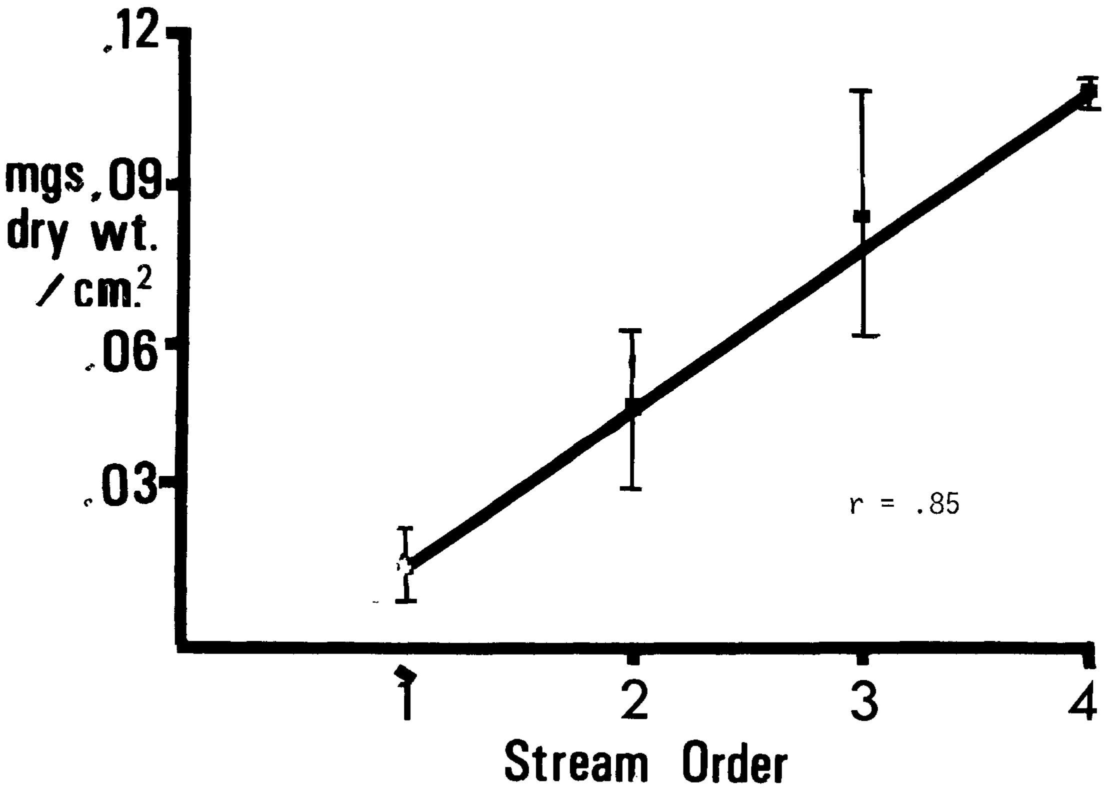

Figure 5. Macroinvertebrate biomass vs. stream order, Horse Creek drainage, Idaho, July - August, 1975.

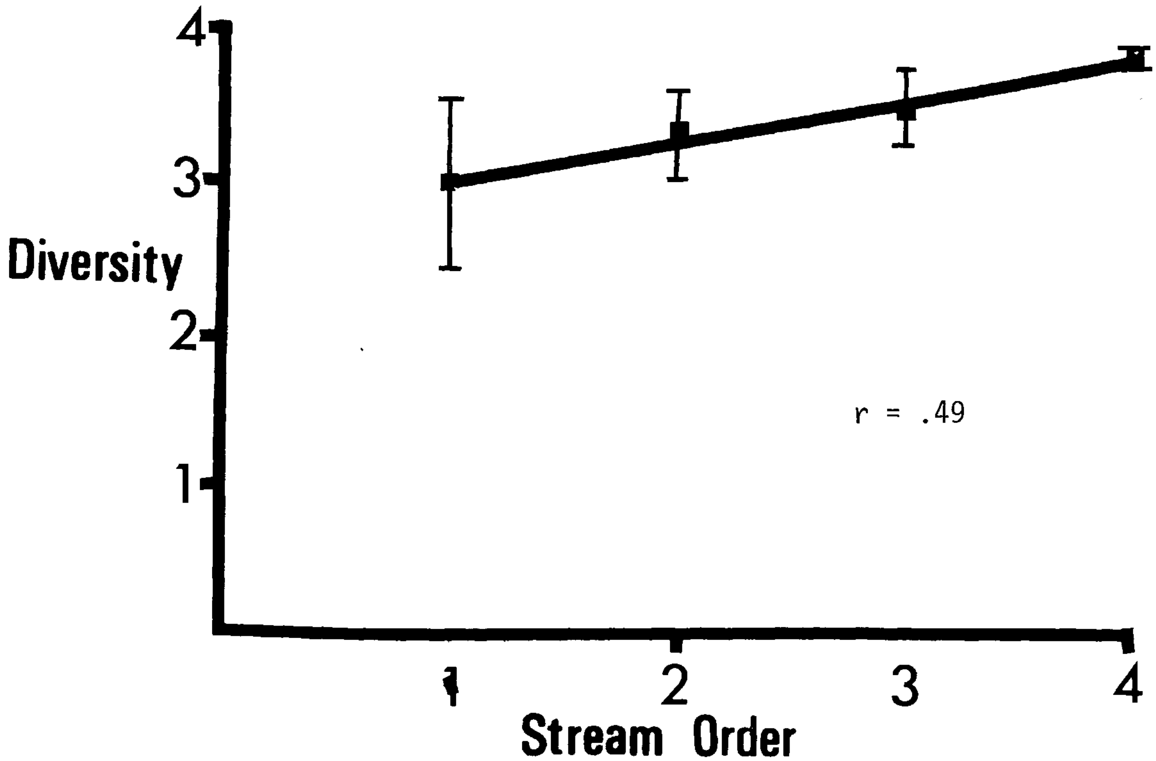

Figure 6. Macroinvertebrate diversity vs. stream order, Horse Creek drainage, Idaho, July - August, 1975.

TABLE 4. Variability of Macroinvertebrate Biomass and Diversity Between Streams of Different Orders, Horse Creek Drainage, Idaho, July - August, 1975.

Order Compared	Diversity	Biomass
1 to 2	0	0
1 to 3	X	XX
1 to 4	X	XX
2 to 4	0	XX
2 to 3	0	XX
3 to 4	0	0

0 = no significant difference; X = significant difference (P>.05); XX = highly significant difference (P<.01).

Water chemistry measurements (Table 6) show that streams in the Horse Creek drainage have low values for alkalinity, conductivity and hardness. A wide range of values was found for the various physical factors measured. Median substrate diameter, for example, varied from 6.0 to 91.6 mm (Table 6). Water chemistry data are not available for the fourth order stream, so all data pertaining to this stream order were excluded from further analysis.

Stepwise linear regression analysis revealed that a large percentage of the variation in biomass and diversity between individual streams could be accounted for using relatively few parameters (Tables 7-8). Eighty-eight percent of the biomass variance between streams can be related to changes in stream gradient, suspended sediment, stream order and alkalinity (in order of decreasing importance) (Table 7). Approximately 86% of the diversity variance between streams was related to changes in substrate size, suspended sediment, stream temperature, stream order and width (Table 8).

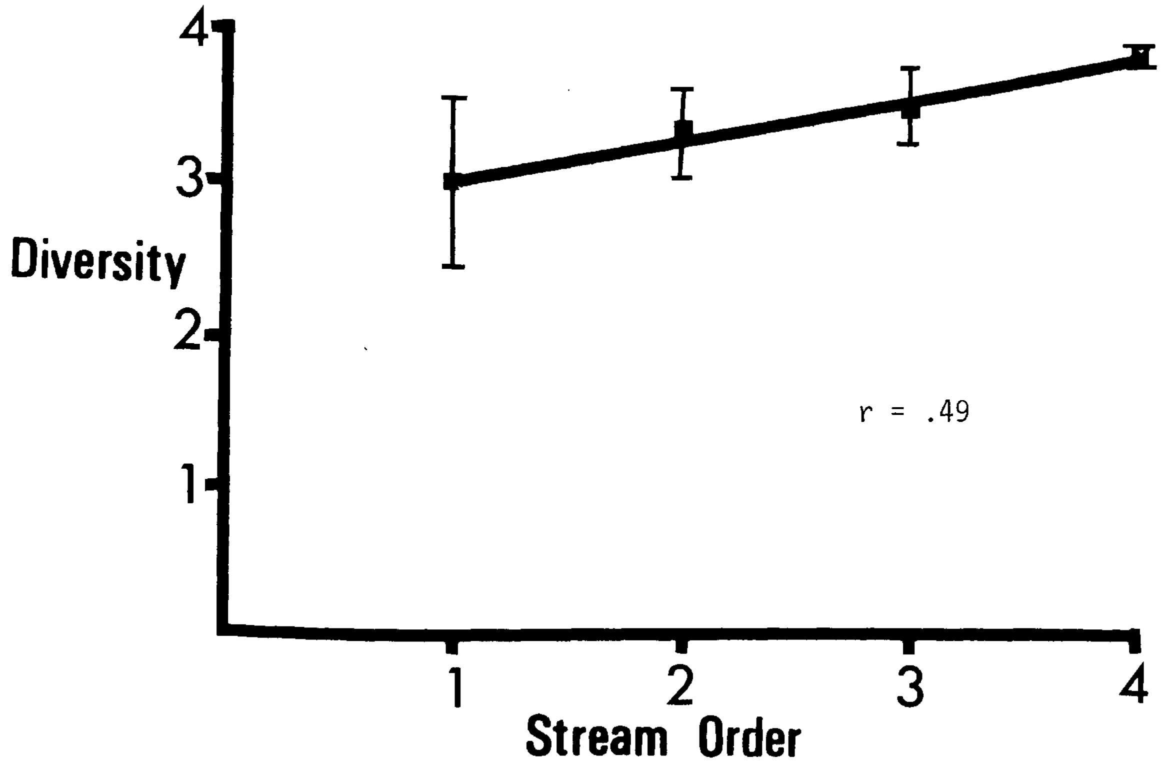

Figure 6. Macroinvertebrate diversity vs. stream order, Horse Creek drainage, Idaho, July - August, 1975.

TABLE 5. Average Macroinvertebrate Biomass and Diversity Found at Sampling Stations in Horse Creek Drainage, Idaho, July - August, 1975.

	Summer Biomass Averages (mg dry wt/cm^2)	Summer Diversity Averages (Shannon-Weaver Index)
First order stream stations		
1	.09	2.46
2	.23	3.15
3	.14	3.44
Average	.15	3.01
Second order stream stations		
1	.17	3.15
2	.20	3.26
3	.51	3.66
4	.45	3.28
5	.48	2.91
6	.64	3.44
7	.50	3.56
Average	.48	3.32
Third order stream stations		
1	.81	3.58
2	.67	3.24
3	1.03	3.74
4	1.02	3.66
5	1.16	3.65
6	.67	3.40
7	.45	3.07
Average	.86	3.48
Fourth order stream stations		
1	1.10	3.82
2	1.14	3.82
Average	1.12	3.82

TABLE 6. Physical and Chemical Parameters for Streams in the Horse Creek Drainage, July 30, 1975.

Stream	Gradient (%)	Median Substrate Diameter (mm)	Order	Width (m)	Flow (m^3/min)	Conduc. (mmhos/cm)	Alkalinity (mg/l)	Hardness (mg/l)	Sus. Sed. (mg/l)	Temp. C.
11	26.0	9.2	1	0.6	.71	17.5	13.9	4.88	1.76	11.0
12	24.5	14.9	1	0.6	.26	20.7	18.1	6.77	6.63	9.8
13	26.0	16.2	1	0.6	.77	20.2	14.9	6.68	4.71	7.0
21	31.6	10.1	2	1.2	1.91	20.7	17.1	6.07	1.23	10.9
22	18.6	18.7	2	0.8	1.50	24.4	19.2	8.16	.86	10.3
23	13.6	91.6	2	1.2	2.61	15.4	20.3	8.42	1.18	10.3
24	22.0	35.3	2	0.9	.90	25.3	21.8	10.30	1.27	9.6
25	23.4	6.0	2	0.9	1.57	26.4	22.8	11.23	1.67	8.0
26	24.0	17.2	2	0.9	1.36	20.6	15.0	6.77	13.46	13.5
27	12.6	39.6	2	0.9	4.19	16.1	12.8	5.14	2.61	6.5
31	4.1	70.2	3	5.6	34.45	20.2	17.5	6.62	2.50	10.7
32	5.5	51.0	3	5.0	27.49	17.1	16.0	4.18	2.03	11.2

TABLE 7. Results of the Stepwise Regression of Physical and Chemical Factors on Macroinvertebrate Biomass, Horse Creek Drainage, July - August, 1975.

Variable	Coefficient of Determination*
Gradient	0.64
Suspended Sediment	0.74
Stream Order	0.83
Alkalinity	0.88

*Coefficient of determination is the percent of the variance in biomass accounted for by the factor on the left, along with those listed above it. No other variables met the 0.50 significance level requirement. Gradient, suspended sediment and stream order were significant at the 0.01 level.

TABLE 8. Results of the Stepwise Regression of Physical and Chemical Factors on Macroinvertebrate Diversity, Horse Creek Drainage, Idaho, July - August, 1975.

Variable	Coefficient of Determination*
Substrate Size	0.45
Suspended Sediment	0.58
Water Temperature	0.68
Stream Order	0.79
Stream Width	0.86

*Coefficient of determination is the percent of the variance in diversity accounted for by the factor on the left, along with those listed above it. No other variables met the 0.50 significance level requirement. Only substrate size was significant at the 0.10 level.

DISCUSSION AND CONCLUSIONS

When sampling aquatic macroinvertebrates the qualities desirable in a sampler are, in part, determined by the objectives of the sampling program (Beak et al. 1973). Fullner (1971) concluded that multiple-plate samplers are suitable for sampling programs aimed at pollution detection because they collected a wide range of invertebrates with a taxonomic composition similar to that of the basket samples. They averaged only slightly fewer species per site than the baskets (Table 9). Surber samples also collected a wide range of invertebrates, and might be applicable for use in pollution survey work if all streams to be sampled were very small (first and second order) with small substrate size. The well documented problems with using Surber samplers in larger streams, and the greater sample variability they generally have (Mundie 1971, Needham and Usinger 1956) indicate they should not be used in a widespread, quantitative survey.

TABLE 9. Average Number of Taxa Collected Per Station Using Three Different Samplers. Horse Creek Drainage, Idaho, July - August, 1975.

Stream Order	Basket	Multiple-Plate	Surber
1	15.4	13.5	23.3
2	19.4	16.9	27.7
3	20.9	17.8	23.5
4	21.8	17.0	20.0
Average	19.5	17.2	23.6

When sampling is directed towards the measurement of macroinvertebrate biomass and diversity, basket samplers appear to be the most applicable of the three samplers tested. Basket and multiple-plate samples both showed increasing biomass and diversity with increasing stream order. This was expected, as biotic diversity generally tends to increase with stream order in first through fifth or sixth order streams (Harrell and Dorris 1968, Kuehne 1962). Surber samples had diversities similar to those of the basket samples in first and second order streams. The greatly decreased diversities they had in third and fourth order streams were probably a result of the problems Surber samplers have in larger streams. It is very difficult to prevent water from flowing under the Surber frame in streams of this type, and the resulting loss of organisms may have caused the drop in diversity.

Multiple-plate samples gave biomass and diversity readings that were consistantly lower than basket sample readings (Figs. 2 & 6). This is probably due to the baskets providing a better simulation of the wide variety of microhabitats available in the natural substrate. Many aquatic invertebrates are dependent on certain microhabitats (Cummins 1964), and the flat surfaces available for colonization in multiple-plate samplers probably could not accomodate these specific requirements as consistantly as the varied rubble in the baskets. Basket diversities did not seem artificially high, as they were similar to Surber sample diversities in the first and second order streams. Thus the biomass and diversity results indicate that multiple-plate samplers are not as satisfactory as basket samplers for a detailed analysis of the structure and composition of the benthic communities of small, rocky streams. Results also show that surveys using these different sampling techniques cannot be compared quantitatively.

Of the three samplers used in the Horse Creek drainage, baskets appear to be the most satisfactory for both comparative and quantitative work in low order, rocky streams, because of their ability to thoroughly sample the range of macroinvertebrate communities present in the drainage. Multiple-plate samplers appear to be applicable for use in comparative surveys, but did not give reliable readings for macroinvertebrate biomass and diversity due to their totally artificial substrate. Surber samplers gave results comparable to basket samplers in first and second order streams, and appear to be good samplers in small streams with small substrate size. The decline in both biomass and diversity in higher order streams, where increases were expected and found with other samplers, shows that Surbers are not a good choice when a wide range of stream sizes are expected. Surbers are the easiest of the three samplers to use, but should be avoided for comparative, quantitative sampling unless time and resources are at a minimum.

The increase in macroinvertebrate biomass and diversity found with increasing stream order parallels the results of Harrell and Dorris (1968). Kuehne's (1962) speculation that stream order alone might provide a good method of characterizing streams is made questionable by the fact that highly significant ($P<.01$) differences in macroinvertebrate biomass and diversity were found between the different second order streams. Significant ($P<.05$) differences in diversity were also found between the three first order streams. This indicates that macroinvertebrate community structure in first and second order streams of the Horse Creek drainage is too variable to be predicted on the basis of stream order alone. Thus an investigator cannot assume that the macroinvertebrate biomass and diversity values found for a given first or second order stream are representative of other streams in the drainage of the same order.

Lack of significant differences in biomass and diversity between different third and fourth order streams does not necessarily mean that local streams in these orders have "typical" values for these paramenters. More streams would have to be sampled before it could be concluded that no significant difference exists in macroinvertebrate biomass and diversity among the third order streams in the area, as only two third order streams were sampled.

Results of the stepwise regression analysis indicate that relatively few physical and chemical factors account for a large percentage (>85%) of the variance in both biomass and diversity of macroinvertebrate communities in the Horse Creek drainage (Tables 7-8). The factors that were found to relate well to the biomass and diversity differences between streams indicate that the natural variability found between macroinvertebrate communities is correlated to more than one type of parameter. Differences between communities were correlated to changes in a combination of physical factors, dissolved water quality factors and non-dissolved water quality factors.

The biological importance of the parameters that accounted for much of the variance in macroinvertebrate biomass and diversity shows that the correlations probably were not spurious. The most important factor relating to changes in macroinvertebrate diversity was substrate size. Cummins (1966) has reviewed a great deal of literature which shows that the nature of the substrate is important biologically due to the role it plays in providing spatial niches. Suspended sediment was the second most important parameter, probably as it relates to the food supply of the filter-feeding members of the macroinvertebrate community.

Stream temperature, order and width were other factors that were related to macroinvertebrate diversity. Pennak (1971) cites stream temperature and width as being important in determining the biology of lotic habitats. Harrell and Dorris (1968) found that stream order was highly correlated to a wide variety of factors important in determining macroinvertebrate community structure. This indicates that stream order acts as a "catch-all" parameter, and helps explain its relation to macroinvertebrate diversity.

Macroinvertebrate biomass was related to a combination of gradient, suspended sediment, stream order and alkalinity. Gradient is important as it relates to both current speed and substrate size, both of which help determine the biological characteristics of a stream (Cummins 1975). Alkalinity gives an indication of biological productivity (Pennak 1971) and would thus relate well to macroinvertebrate biomass. Suspended sediment and stream order were probably correlated to biomass for essentially the same reasons mentioned above for the correlations found with diversity.

The large percentage of the variance accounted for between communities shows that prediction of macroinvertebrate community structure is possible, at least in the Horse Creek drainage. The relatively few parameters needed suggests that predictions of this nature may not require extensive collections of physical and chemical data.

A predictive model for the macroinvertebrate communities of the Horse Creek drainage does not necessarily have widespread applicability. Further work needs to be done to demonstrate whether a model can be generated that would apply over a more widespread, heterogeneous area, such as an entire geomorphic province.

The variability found between the streams in the Horse Creek drainage suggests a need for modeling of this sort. Assumptions of homogeneity in macroinvertebrate biomass and diversity between streams of similar order were shown to be questionable, indicating that a detailed macroinvertebrate sampling program needs to be undertaken any time quantitative information on macroinvertebrate community structure in small streams is desired. Extensive sampling of this type is an expensive and time-consuming process, and precludes an exhaustive survey of streams in a widespread area. Modeling of macroinvertebrate community structure on the basis of correlations with a series of physical and chemical factors would be a step towards alleviating this problem.

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