REGIONAL COPPER-NICKEL STUDY
STREAM BENTHIC INVERTEBRATES

Minnesota Environmental Quality Board

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ABSTRACT

The benthic invertebrate communities of the streams in the Regional Copper-Nickel Study Area (Study Area) were sampled in 1976 and 1977. A large number of taxa were found scattered throughout the Study Area while a smaller number of taxa were widespread and dominated the invertebrate communities. Dominant taxa included Hydropsyche, Baetis, Paraleptophlebia Cricotopus, and Conchapelopia.

The relative abundance of the invertebrate functional groups was found to be related to stream order. Shredders of dead plant material were most abundant in 1st and 2nd order streams and least abundant in 5th order streams. Collectors (gathers and filter-feeders) were the dominant group in all stream orders but did increase in abundance with increasing stream order. The collector-filter-feeders became very abundant in the Kawishiwi River which is a series of lakes. The expected high abundance of scrapers was not observed in the Kawishiwi River.

While stream order did provide an easy method for classifying invertebrate communities problems with the method are discussed.

PURPOSE

This regional characterization is intended to describe the dominant taxa of the region and their relationships, as well as the similarities and differences between the sites sampled. It provides a basis for assessing the potential impacts of copper-nickel development. It does not, in general, provide the baseline data necessary to detect impacts of development at particular sites. Techniques for developing such a baseline and ways in which these data might be used in planning a baseline monitoring program are discussed in a separate report, Biological Monitoring of Aquatic Ecosystems (Regional Copper-Nickel Study 1978).

TABLE OF CONTENTS

TABLE OF CONTENTS Continued

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

INTRODUCTION

The study of benthic invertebrates in streams of the Regional Copper-Nickel Study Area (Study Area) was undertaken to characterize their communities. This characterization then provides a basis for assessing the potential impact of copper-nickel development (see general introduction). In addition, this study provides a basis for the development of site specific monitoring studies. This aspect of the invertebrate studies is included in a separate report (Regional Copper-Nickel Study 1978).

The characterization, which is presented in this report, is intended to describe the dominant benthic invertebrate taxa and their relationships as well as the similarity of streams based on dominant taxa and functional (trophic) groups. The data presentations in this report are semiquantitative and qualitative in nature and are not suitable for determining actual changes in the future.

Benthic invertebrates, which include groups such as aquatic insects, snails, clams, and crayfish, occupy several trophic levels in aquatic ecosystems. They are important in the transfer of energy from autochthonous (instream) and allochthonous (terrestrial) sources to fish (Cummins 1973; 1974; 1975). Invertebrates have been classified into functional groups by Cummins (1974; 1975; 1976) and Merritt and Cummins (1978) according to their preferred food source and method of food collection (Table 1). Many invertebrate larvae change their food source as they mature; some species when mature are food specific feeders others are opportunistic and feed on any available foods. The distribution of invertebrates is determined by the availability of preferred food sources and habitat requirements. Physical and chemical conditions which are important include current volocity, substrate type, temperature, and pH.

Changes in benthic invertebrate populations within a watershed have been reported by many investigators (Illes 1953, Whitney 1939, Sprules 1947, Maitland 1966, Kerst and Andersen 1975). In general, as one moves downstream from the headwaters, decreased gradients, increased discharge and reduced flow fluctuations are found. Chemical parameters such as pH, alkalinity and conductivity also tend to increase from the headwaters downstream. These physical and chemical changes have been correlated with changes in stream order which describe the position of a stream within a watershed.(See discussion of stream order in Regional Copper-Nickel Study 1978).

Cummins (1975; 1976) was the first to relate changes in invertebrate communities to changes in stream order. Cummins discussed the theory that invertebrate taxa in two streams can be different but the relative abundance of the functional groups would be similar if the two streams were of similar order. This assumes that the physical and chemical characteristics are related to stream order. Also, more importantly, Cummins assumes that the primary energy source is related to stream order. These energy sources are either autochthonous (produced within the stream) or allochthonous (derived from outside the system).

Invertebrates inhabiting heavily shaded headwater streams (generally first to third order) rely on allochthonous inputs for the majority of their energy. These streams typically have large populations of shredding invertebrates that process the allochthonous coarse particulate organic matter (CPOM) into fine particulate organic matter (FPOM) utilizing this material for energy. In these streams primary production is low because of shading, therefore scraper invertebrates which rely on autochtonous matter as a food source are not abundant.

In higher order streams (fourth to sixth order) the gathering, filter-feeding and scraping invertebrates dominate. These groups feed on periphyton and on FPOM previously processed by shredders. Shredders comprise a small portion of the fauna because of the reduced amounts of CPOM.

Rivers larger than sixth order are dominated by collectors which feed on planktonic plants and animals and FPOM from upper reaches of the stream. Periphyton growth is reduced because of the lack of substrate and low light penetration caused by high turbidity. Therefore, scraper populations are also limited in these rivers.

Cummins (1975; 1976) has suggested that an analysis of the functional group composition in a stream may be a more meaningful method of assessing environmental impact than traditional methods. Traditional methods have relied on an analysis of the invertebrate species composition, species diversity, and/or presence or absence of indicator species or groups (Gaufin 1973, Goodnight 1973). The significance of changes in these parameters is often difficult to interpret. The use of functional group analysis may simplify this task.

In order to determine the characteristics of the invertebrate communities in the Study Area, sampling was undertaken between May, 1976 and November, 1977. Sampling consisted of three methods:
1) Hester-Dendy artificial substrates; 2) drift nets; and 3) qualitative sampling. These methods were employed with varying intensity at stations within the area of greatest mineral potential. In this report the Hester-Dendy sampling is not discussed because of the difficulties encountered with their use during this project. In 1976, emphasis was placed on large streams which might be impacted, while in 1977, the relationsip of stream order to invertebrate

community composition was examined by increasing the sampling effort in small streams.

METHODS

Study Area

The Study Area comprises 5516 km^2 in Lake and St. Louis counties of northeastern Minnesota (Figure 1). This area is divided into two major watersheds by the Laurentian Divide. Water in the southern portion of the Study Area flows into Lake Superior via the St. Louis River system while water north of the divide flows into Hudson Bay via the Rainy River System. Within the Study Area there are 2623 km of streams in orders one through five.

Selected water quality parameters for streams in the Study Area are presented in Table 2. These streams are generally bog stained, soft water streams. Alkalinity ranges from 1 to 190 ppm $CaCO_3$ but is generally less than 50. Low pH is found in the headwater streams; median pH ranges from 6.4 in headwater streams to 7.5 in some downstream reaches. The streams consist of long flat reaches connected by short riffles. Average gradients range from .8 m/km to 4.7 m/km (Table 3). Substrates in Study Area streams are silt, sand, and/or detritus in pools and gravel, rubble, or bedrock in riffles.

Sampling Area and Stations

Invertebrate sampling was concentrated in the areas east of Biwabik and south of Ely in the area of greatest potential for copper-nickel development (shaded area of Figure 1). In 1976 sampling stations were located in riffle areas within those watersheds which have the greatest potential for impact from copper-nickel mining.

Stations sampled in 1976 were designated "primary," "secondary," or "tertiary" depending on the sampling intensity scheduled for the stations. Primary stations were located in downstream portions of the watershed and sampled the most intensively. These stations were selected to reflect overall conditions within the watershed. Secondary stations were sampled less intensively than primary stations and were located in upstream areas of the watershed or in areas already "impacted" by current mining. Tertiary stations were sampled least intensively and were located throughout the Study Area so that the overall distribution of invertebrates in the Study Area could be examined.

Additional stations were sampled in 1977 and were located over a larger portion of the Study Area. Many of these additional stations were located on headwater (1st and 2nd order) streams. These stations, designated stream classification station (SCS), were sampled in an attempt to determine the relationship between stream order and benthic invertebrate communities. The sampling instensity for each station type is described in Table 4, in addition to station locations and abbreviations.

Field Procedures

Invertebrates were sampled quantitatively with drift net samplers, 2.5 meters in length and a throat opening of 225 cm^2. Nets were anchored to the stream bottom with metal rods; and replicates were positioned at the surface, middle, and bottom of the water column. Positioning of the nets assured the sampling of organisms which may drift unevenly in the water column. Nets remained in the stream for 24 hours. Current velocities were measured in the net throat at the time of placement and retrieval. The sample was removed by washing the contents into the removable bag at the bottom of the net, transferred to a sieve and placed in a labeled jar containing ten percent formalin. Invertebrates clinging in the bag and net were removed with forceps and added to the sample.

Qualitative samples were collected with an aquatic insect net and by hand from submerged substrates. Riffles were sampled by disturbing the substrate upstream of the net to dislodge clinging organisms. Pools were sampled by dredging the bottom and sweeping submerged vegetation with an aquatic dip net. The samples were separated into riffle and pool fractions and preserved in 70 percent alcohol.

Laboratory Procedures

Organisms in quantitative samples were separated from debris by distributing the sample in a pan of water and removing the animals by hand, and preserving them in a labeled bottle containing 70 percent alcohol. Drift samples larger than the liter were subsampled in a plastic tray (62.23 x 45.7 cm) divided into 15 squares. A 26 percent aliquot was removed following procedures outlined by Weber (1973).

Further subsampling prior to identification was necessary for the chironomid portion of the sample when more than 50 chironmids were contained in a sample or subsample. For this group the total number of organisms in the sample or subsample was determined. These organisms were then suspended in water and an aliquot withdrawn. After identification of the organisms in the aliquot, the number of each taxa was calculated by multiplying the number identified by the proportion of organisms in the aliquot. Chironomids were mounted in CMCP-10 prior to identification. Invertebrates in 1976 were identified to the lowest taxonomic level possible except for the following orders: Diptera; Coleoptera, except the families Elmidae and Psephenidae; Hemiptera; Neuroptera; and lepidoptera; which were identified to genus.

Elmidae and psephenidae were identified to species. Levels of identification were changed in 1977 for the following orders to reduce that amount of time required for taxonomy: Coleoptera and Odonata were identified to family except for the colepterans Heloporus and Hydrochus which were identified to genus, and Elmidae and Psephenidae which were identified to genus and species respectively.

Generic and species determined were verified by the following consultants: P.A. Lewis (Stenonema and Stenacron: Ephemeroptera), W.P. McCafferty (all other Ephemeroptera), W.L. Hilsenhoff (Plecoptera), J.D. Unzicker (Trichoptera), W. Beck (Chironomidae: Diptera), E.F. Cook (all other Diptera), and R. Gundersen (Coleoptera). Voucherspecimens of each genus and species were placed in a reference collection.

Data Analysis

In the following results section "sample" is defined as the mean of the available replicates from a station on one date for the parameter discussed (e.g. diversity or relative abundance). For qualitative collection and quantitative collections where only one replicate was analyzed, a sample represents a single value rather than a mean but is used synonymously with the sample described above. Therefore, quantitative and qualitative data were treated similarly in the analyses but were always analyzed separately.

Annual means were calculated by averaging the sample value from the dates indicated on the specific table or in the text. Where samples were lacking for a station on any date, the annual mean was calculated on the available samples. The calculation of means for groups of sites (e.g. grouped by stream order) were calculated in a similar manner. Where data from sites were lacking, the mean was calculated on the available samples.

Shannon-Wiener diversity ($d = \Sigma P_i \log_2 P_i$) was calculated using sample values.

Calculations were made using only those identifications at the genus level; all other taxa were deleted from the calculation except family level identifications in the orders Diptera (except chironomidae), Hemiptera, Coleoptera (except Elmidae) and Odonata. Family level identification in these orders were used since they were the lowest identifications available.

Pooling of certain taxa into "groups" was done where the taxonomy was particularly difficult especially for early instars, and where all pooled taxa were from the same functional group. The following pooled groups were formed:

1) Baetis flavistriga group included B. flavistriga, B. phoebus B. intercalaris, and B. pluto;
2) Leptophlebia group included Paraleptophlebia spp. and Leptophlebia spp.;
3) Hydropsyche group included Hydropsyche spp. and Cheumatopsyche spp.; and
4) Simulidae included all Simulidae genera.

These groups were treated as genera in the calculation of diversity. Invertebrates were assigned to functional groups following the scheme by Cummins (personal communication) and Merritt and Cummins (1978). In deriving the relative abundance of the functional groups all invertebrates which could be assigned to a functional group were used in the calculation regardless of taxonomic level. Five of the eight functional groups were used in the discussion of functional groups. These were Shredders of dead plant material, Shredders of live plant material, Collector-gathers, Collector-filter-feeders, and Scrappers. The calculation of the relative abundances of these groups excluded the other functional groups; therefore the relative abundance of these five groups equals 100%. In general, these groups comprised greater than 90% of the invertebrate community.

Cluster Analysis

Analysis of patterns of similarity between benthic invertebrate communities using quantitative data was based on calculation of Bray-Curtis similarity coefficient using relative abundance percentages (Boesch 1977). This coefficient is also called "percentage similarity" when used in percentage data, or the Czekanowski coefficient. This coefficient of similarity was selected because it gives most weight to large differences in percent relative abundance rather than small differences (Boesh 1977, Clifford and Stephenson 1975). Because of the variability persent in the data it was thought that small differences might not be significant and therefore should not determine the similarity or dissmilarity of stations.

The percent similarity coefficient is as follows:

$S_{jk} = \Sigma \min (P_{ij}, P_{ik})$ where $P_{ij} = \dfrac{x_{ij}}{\Sigma x_{ij}}$ is the relative abundance of the ith taxon at site J. This coefficient ranges from 0 to 1 where 1 = identical sites.

Calculations of similarity between sites in one sampling period were based on an edited data matrix including only those taxa comprising at least 5% of the mean number of organisms per sample for at least one of the stations sampled. Relative abundance of a taxon was still calculated relative to the total abundance of all invertebrate taxa. Exclusion of the rare species has very little effect on the analyses and saves considerable amounts of computer time. The matrix of similarity coefficients between pairs of sites was analyzed by cluster analysis to determine whether sites could be classified into groups according to the patterns of relative abundance of dominant species. The method of clustering used has been called group average (Boesch, 1977) and unweighted pair-group method using arithmetic averages (UPGMA) (Sneath and Sokal, 1973). This is a hierarchical, agglomerative method in which sites are grouped so as to minimize the distance between two groups of entities, defined as the mean of all distances between members of one group to members of the other.

This method has been widely used in aquatic ecology (Boesch, 1977) and tends to preserve the original expressed in the matrix of similarity coefficients.

Cluster analysis of qualitative data employed the Jacard coefficient of similarity, and the group average method of clustering described above.

RESULTS AND DISCUSSION

Since most of the following observations were based on drift samples, factors influencing benthic invertebrate drift rates must be considered prior to interpreting the data. Waters (1972) discussed important factors that influence drift. Feeding activity was considered to be the main influence on drift density; other activities such as case building among caddisfly larvae, competition especially during periods of rapid growth, and prepupation and pre-emergence activity also affected drift rates. Additionally, high river discharge and light intensity influence the density of drift. Even though these factors influence the density of drifting invertebrates and it is difficult to separate the effects, drift does provide a measure of the relative productivity of streams. It also allows the collection of a variety of invertebrates from different stream habitats.

Composition of the Invertebrate Fauna in Drift Samples

Drift samples came primarily composed of Ephemeroptera, Trichoptera and Diptera (Figure 2). These orders combined represented from 39 to 98 percent of the invertebrates collected at primary and secondary monitoring sites during July, August and September 1976 and April, June and August 1977 (Table 5). Overall Ephemeroptera, Diptera and Trichoptera comprised 32, 20, and 19 percent of drift samples respectively in 1976 and 32, 24, and 7 percent of drift samples in 1977. While some shifting between the three orders occured between years at individual stations, the overall percentages remained relatively constant between years.

Ephemeroptera dominated the invertebrate fauna in spring and fall while Diptera and Trichoptera were most abundant during the summer (Figure 2). Trichoptera dominated in the early summer months and Diptera, the later summer months in 1976. The converse occured in 1977 during the summer. Diptera dominated the early months while Trichoptera was more abundant in the latter months.

A large number of genera were found in each of the three dominant orders although few genera were normally dominant (Table 6). Ephemeroptera were represented by 27 genera. The Baetis and Paraleptophlebia groups and the genera Ephemerella, Stenonema, and Hexagenia constituted the largest number of mayflies collected in the drift. The Hydropsyche group, Chimarra, and Neuroclipsis were the most abundant trichopterans. Forty-three other caddisfly genera were collected in the Study Area. Of 74 dipteran taxa collected the chironomids Cricotopus, Polypedilum, Conchapelopia, Eukiefferiella and Rheotanytarsus and the simulids were the most abundant. A complete list of invertebrate taxa collected in 1976 and 1977 is presented in Appendix 1.

Annual Abundance Cycles of the Major Taxa

Fluctuations of invertebrate abundance has been demonstrated to reflect life cycles (Hynes 1970). The begining of a life cycle is indicated by large increases in population size. Some time later population reductions commonly occur because of natural mortality and predation. Emergence and life cycle termination is evident as benthic populations diminish and flights of adults are observed.

The largest number of drifting invertebrates occurred in the spring and fall of 1976 and the spring and mid-summer in 1977 (Figure 3). Since river discharge as well as life cycles influence drift, the relationship between drift rates and discharge was examined at four sites where continuous records of discharge were available and where drift was sampled frequently. These sites were D-1, P-1, SL-1 and SR-2 (Figure 4). In 1976, no discernible relationship is evident between the number of invertebrates drifting and discharge at these four sites. In 1977, however, there does appear to be a relationship. In general, high drift occurred during periods of high stream discharge at D-1, SL-1 and SR-2. At P-1 no relationship was evident in either year. Not enough data are available to determine conclusively the effect of discharge on drift rates.

Figure 5 presents the observed cycles of the most abundant drifting invertebrate genera collected in the Study Area. Emergence periods are probably indicated by low points in the mean relative abundance. These insects generally emerged from June through early August in both 1976 and 1977. Peak abundance usually occurred in the fall and/or spring. Since limited sampling was conducted during the winter and early spring, the peak abundance and emergence of some insects was probably not observed.

The annual cycles of Ephemerella and the Paraleptophlebia group were the most obvious (Figure 5). Ephemerella species which matured in spring (E. subvaria, E. invaria, and E. rotunda) presumably after hatching in the fall, were observed to have a similar annual cycle in Michigan (Leonard and Leonard 1962). Ephemerella needham, E. simplex, and E. deficiens, common to both Michigan and Minnesota, matured during the summer in both regions.

Collections of the Paraleptophlebia group, comprised mainly of Leptophlebia from fall to spring, demonstrated two annual features: 1) fall hatching, indicated by large numbers of early instar larvae; and 2) spring migrations, an activity prior to emergence. Hayden and Clifford (1974) provided a detailed account of Leptophlebia cupida life history including the fall hatching period, spring migration prior to emergence and the influence of migration activities on drift rates. Peaks in the abundance of Paraleptophlebia group in July 1977 may have been caused by increasing river discharge.

Complete annual cycles for other taxa were difficult to delineate because as stated by Hynes (1970) invertebrate species have extended hatching periods, others have a number of cohorts produced over one summer and specific identifications cannot be made for many larval forms. Also, our sampling frequency could not accommodate the schedule of life cycle events for the large number of taxa found in the Study Area.

Distribution of Taxa within the Study Area

The relative abundance of the dominant taxa varied between sites within and between watersheds. The distribution of some dominant taxa at six primary sites which represent 5 major watersheds is presented in Figure 6. The Hydropsyche group was collected in greatest numbers in the Kawishiwi River while the Paraleptophlebia group was rarely found there. The Paraleptophlebia group favored the Embarrass, Partridge, Stony and St. Louis rivers. Cricotopus and Polypedilum were the most numerous in the St. Louis River with small populations in the Partridge and Embarrass rivers. The largest number of Conchapelopia and Simulidae was found in the Kawishiwi and Embarrass rivers. Other invertebrates were scattered among the watersheds and because of their low abundances it was difficult to discern patterns.

Association of Taxa with Different Stream Orders

Based on the combined frequency of occurrence of invertebrates in drift and qualitative samples, five groups of taxa were found associated with specific streams orders or combination of stream orders.

The first group of invertebrates was characterized by Amphinemura, Leuctra, Glyphopsyche, Heterotrissocladius, Anobolia, Palpomyia group and Gerris were most commonly associated with first through third order streams (Table 7). These taxa were rarely found in higher order streams and were scattered among the smaller streams.

The second group was found with greatest frequency in third and fourth order streams (Table 8). Although generally preferring larger streams than the first group, taxa in the second group were rarely found in Kawishiwi river riffles. Characteristic taxa included Pseudocloeon, Chimarra, and Polypedilum.

Stenonema, Ephemerella, Hydropsyche group, Cricotopus Eukiefferiella, Stenelmis and Hyalella were the characteristic taxa of the third group (Table 9). These invertebrates preferred third, fourth, and fifth order streams.

The fourth group were most common in second through fourth order streams (Table 10). Optioservus, Atherix, Shipsa and Oecetis were the characteristic taxa of this group.

The Baetis and Paraleptophlebia groups and Conchapelopia were the most frequently collected taxa in the fifth group (Table 11).
Invertebrates in this group were collected in all stream orders at approximately equal frequency.

Diversity

Diversity (Shannon-Wiener) at the generic level was generally high (>3) except in the Kawishiwi River (K-1 and K-8)(Figure 7a). Diversity at K-1 and K-8 were on the average less than three.

Diversity changed seasonally with lowest values in the fall and spring and reached maximum levels in summer. Mean spring and fall diversity at primary monitoring sites was 2.75 compared to 3.28 in summer.

Benthic community diversity was similar to other clean water communities reported by Wilhm (1970). Most Shannon-Weiner diversity values reviewed by Wilhm (1970) were between three and four. Mean diversity values at primary monitoring sites were between these values except the sites, K-1, and K-8.

Diversity generally decreased with increasing stream order during April and May (Figure 7b). In August the opposite trend occurred as diversity increased with increasing stream order, from first to fourth order as observed by Harrel and Dorris (1968). Fifth order sites(K-1 and K-8) which were Kawishiwi River stations, were lowest. These lake outfall stations are dominated by filter-feeding Trichoptera. Cushing (1963) found similar populations on the Montreal River below lakes; filter-feeding insects fed on planktonic matter which flowed from the lake. Exploitation of an abundant food source by a few taxa results in a reduction in species diversity (Margalef 1961). This is the probable reason for the reduced diversity below lakes in the Study Area.

Table 12 presents the average number of taxa collected qualitatively within each stream order during 1977. In both April and August, 1977, the number of taxa increased with increasing stream order. This is similar to the results of Harrel and Dorris (1968) who observed an increase in invertebrate taxa with increasing stream order.

Invertebrate Functional Group Analyses

Aquatic invertebrate functional groups and their principal food sources are presented in Table 1. The shredders, collectors and predators contained the largest number of taxa (Table 13). Plecoptera, Ephemeroptera, Trichoptera and Diptera were the main components of all groups except piercing predators which were chiefly Hemiptera (Table 13). The members of each functional group found in the Study Area are presented in Table 14. The taxonomic level used to assign a functional classification to aquatic invertebrates is indicated in Table 14.

Five functional groups: shredders of dead plant material (d.p.), shredders of live plant material (l.p.), collector gatherers, collector filter-feeders, and scrapers were used to determine the relationship between community function and stream order. The predator groups were not included in the analysis because Cummins (1975) reported no change in the relative abundance of these groups in all stream orders and because the five groups listed provide the most information on the changing trophic relationships within a stream. Piercing herbivores were excluded because they were infrequently collected.

Three sets of data were used in analyzing the invertebrate functional groups.

The first data set (data set #1) includes data from all sites on each sampling date in 1977. The second data set (data set #2) includes data from all sites sampled in April/May, 1977 and August, 1977. Data from the eight primary stream classification site (SCS) stations sampled between June and November, 1977, serves as a third data set. Data within any one data set have been generally averaged by stream order for the following discussion.

Relationship of Functional Groups to Stream Order

The relative abundance of shredders (d.p.) generally decreased while the relative abundance of collectors increased from stream order one to five. These trends were evident in data sets #1 and #2 (Figures 8 and 9).

While collectors as a whole increased between first and fifth order streams, the dominant group within the collectors changed (Figure 8). Filter-feeders dominated first and second order streams while gatherers dominated third and fourth order streams. Filter-feeders were the dominant collectors in fifth order streams.

The relationship between stream order and shredders (l.p.) or scrapers is not clear. The mean abundance of shredders (l.p.) was relatively constant between stream orders in data set #1 (Figure 8) but decreased with increasing stream order in data set #2 (Figure 9). The reason for this difference could be a result of the different dates used in calculating the means for each data set. Scrapers were not abundant in any stream order. They were at least abundant at fifth order stations (<1%) and most abundant at third or fourth order sites, although there were no major differences in first through fourth order streams.

The eight primary SCS stations were intensively sampled to further examine the functional group composition in stream orders one through four. The means over the four dates for each functional group at each stream order are shown in Figure 10. The relative abundance of shredders (l.p.) and scrapers was the same at first and second order stations, although the shredders (l.p.) decreased and scrapers increased thereafter. Shredders (d.p.) increased in relative abundance from first to second order, but declined steadily from second to fourth order. The collectors (gatherers and filter-feeders) varied inversely to the shredders (d.p.) increasing from second to fourth order after declining between first and second order streams. A further indication of these relationships was the shredder (d.p.)/collector ratio (Figure 11). This ratio increased from first to second order, but decreased from second to fourth order. A decreasing ratio would indicate a reduction in the importance of shredders and an increase in the importance of collectors.

These relationships generally agree with those presented by Cummins (1975, 1976). First and second order streams had the highest relative abundance of shredders (d.p.) while the fifth order sites had the lowest. Collectors were the dominant organisms in all stream orders, which is different from Cummins' proposal, but the increased relative abundance of collectors with increasing stream order is similar to Cummins' theory. The expected increase in scraper populations at the higher order streams was not observed. In fact, they were practically non-existent in the Kawishiwi River which was fifth order. However, this river is composed of a series of lakes commected by riffle areas and was dominated by filter-feeders feeding on suspended planktonic matter. Cushing (1963) reported a similar dominance in the Montreal River below lake outfalls. Therefore, the Kawishiwi River could be expected to be dominated by filter-feeders rather than scrapers because the most abundant food source in the Kawishiwi is plankton.

Effect of Canopy Cover on Functional Group Composition

The functional group composition in Study Area streams varied greatly between streams of similar stream order. One possible reason for this variability was thought to be the amount of canopy cover over a stream and therefore the amount of allochthonous material in the stream. Table 15 presents the relative abundance of shredders (d.p.), collector-gatherers and scrapers in heavily shaded (25-100% canopy cover) and open (<25% canopy cover) streams. Shredders (d.p.) were more abundant in the shaded streams than in the open streams. In most cases, scrapers were more abundant in open streams than shaded streams. No relationship was noted in the relative abundance of collector-gatherers. These results support the relationships described by Cummins (1975, 1976) which indicate that high shredder and low scraper populations would be found in small heavily shaded streams. While this type of stream is generally a headwater stream (first or second order), headwater streams are not all heavily shaded. For instance, some first order streams draining bog areas have very little canopy cover and the abundance of shredders is low and the abundance of scrapers is high.

Seasonal Changes in Functional Group Composition

The functional group composition changed seasonally. Data from sites SL-1 and SR-1/2 which are fourth order stations provide the most data to examine the seasonal trends in functional group abundance in the Study Area (Figure 12). Generally, shredders (d.p.) were least abundant in the summer and most abundant in spring and fall. Shredders (l.p.) and scrapers were most abundant in the summer and were least abundant in spring and fall. The abundance of the collector groups was somewhat less in the summer than in spring or fall.

Winter and fall sampling at P-1, a fourth order station frequently sampled, indicated that shredders (d.p.) were at their peak abundance while scrapers and shredders (l.p.) were low in number at this time of year (Figure 12). The collector group was again the dominant group.

Similar trends to those observed at fourth order sites were evident in data set #1 at all stream orders (Figure 13). Shredders (d.p.) were most abundant during the spring and fall while shredders (l.p.) and scrapers are most abundant during the summer. Collectors remain approximately equal throughout the year. The relative abundance of collector-gatherers and filter-feeders shifted throughout the year but no patterns are evident in Figure 13.

At the eight primary SCS stations, which include SL-1 and SR-1/2, similar trends were observed. Figure 14 presents the mean relative abundance over all stream orders of five functional groups for these eight sites versus time. The shredders (l.p.) and scrapers increased to their maxima through the summer months, and decreased to their minima in November. Shredders (d.p.) decreased through the summer months, but increased sharply to their maximum relative abundance in November. Collectors remained fairly constant throughout the period sampled. An inverse relationship between the collector-gatherers and collector-filter-feeders is apparent.

Taxonomic Composition of Invertebrate Functional Groups

The faunal composition of the shredder (d.p.) group changed with increasing stream order (Table 16). The plecopterans, *Amphinemura*, *Leuctra*, and *Paracapnia* were the most abundant shredders (d.p.) in the first and second order streams while *Endochironomus* (Diptera) became the most abundant shredder (d.p.) in the third, fourth, and fifth order streams. *Leuctra* and *Paracapnia* were present in third and fourth orders, but were less abundant; *Brillia*

(Diptera) was second most abundant in the fifth order. Trichopteran shredders (d.p.) were present in all stream orders but were not as numerous as Plecoptera and Diptera.

Seasonal changes in the taxonomic composition of the shredder (d.p.) group are presented in Table 17. In November when the shredder (d.p.) group was at its maximum, the genera Platycentropus, Nemotaulius and Lepidostoma (Trichoptera) and Taenipteryx and Paracapnia (Plecoptera)comprised 80% of this functional group.

The taxa comprising the shredder (l.p.) and collector-gatherer groups changed little with increasing stream order (Table 16). Cricotopus and Polypedilum (dipterans) were the most numerous shredders (l.p.) in all stream orders except first order where Helophorus and Haliplidae (Coleoptera adults) were more abundant than Polypedilum. No major seasonal changes were observed in the shredder (l.p.) groups (Table 18). Ephemeroptera, especially the Paraeptophlebia and Baetis groups, were generally the dominant collector-gatherers in all stream orders (Table 16). Two Diptera genera, Eukiefferiella and Chironomus and the amphipod, Hyalella, were other numerically important taxa. Paraleptophlebia was the most abundant gatherer in the spring and fall while a variety of taxa dominated during the summer (Table 19).

Simuliidae (Diptera), the Hydropsyche group, and Chimarra (trichopterans) were the most abundant collector-filterers (Table 16). Simuliidae dominated stream orders one through three. The Hydropsyche group became increasingly more abundant with increasing stream order. Simuliidae and the Hydropsyche group were equally abundant in the fourth order; in fifth order, the Hydropsyche group was the dominant filterer. Few seasonal changes are apparent in this group (Table 20).

Scraper composition changed with increasing stream order (Table 16). Gastropoda, Glossosoma (Trichoptera) and Chloroperlidae (Plecoptera) and the ephemeropterans, Pseudocloeon, Chloroterpes, and Heptagenia were the dominant scrapers. The ephemeropteran taxa were most abundant during the summer months, while Gastropoda was collected throughout all periods sampled (TAble 21). Glossosoma was collected primarily in late summer and fall.

Dominant taxa in functional groups observed at the eight primary SCS stations were similar to those discussed above. Table 22 lists the three most abundant taxa and their frequency of occurrence in each functional group on each date. Little variation was seen in the shredders (l.p.), collector-filter-feeders, and scraper taxa. The Hydropsyche group and Simuliidae were always the two most abundant filter-feeders and were collected at a large majority of stations on all dates. Pseudocloeon and the Gastropoda were commonly the most abundant scrapers. Polypedilum and Cricotopus were the most abundant and frequently occurring shredders (l.p.), although they were rare in November.

Greater variation was observed in the shredder (d.p.) and collector-gatherer taxa. Leuctra spp. was the most commonly occurring shredder (d.p.) in the summer, but was replaced by Platycentropus spp. and Paracapnia spp. in the fall. The greatest variation was observed among the collector-gatherer taxa. Seven of the ten listed taxa occurred in only one month, but in each case these taxa were collected at the majority of stations. On no occasion did two or more taxa occur together on more than one date. Baetis spp. did however occur abundantly and frequently in all three summer collections.

Effect of Taconite Mining Operations on Invertebrate Fauna and Functional Groups

Sites SL-1, P-1, P-5, BB-1, and D-1 are exposed to taconite mine dewatering.

In general, the concentrations of anions and cations were higher at these stations than at unaffected stations (Table 23). Site BB-1 was also affected by frequent flow fluctuations, copper and nickel leachates, unstable natural substrate. The overall mining effects on the aquatic biota at BB-1 are discussed in Regional Copper-Nickel Study (1978) and will not be discussed in this report, which will discuss the effect of taconite operations without Cu-Ni leachates.

Functional group relative abundance for sites exposed to mine dewatering effluents (experimental sites) were compared to unaffected sites (control) sites of the same stream order. SR-1 was considered a fourth-order control site for experimental fourth order SL-1 and P-1 (Figure 12); all are fourth order sites. Patterns of increase and decrease in functional group relative abundance were similar at all three sites. The greatest differences occurred with shredders (l.p.) in which the control site SR-1 had the lowest relative abundance. Collector-filter-feeders at SR-1 in July 1976 peaked higher than in experimental sites SL-1 and P-1. Although these differences were evident, the seasonal and relative abundance trends were consistent.

D-1, a third order site receiving mine dewatering effluent, was compared to E-1 (Figure 15). Ignoring differences because of a lack of samples at D-1 in fall, 1976, patterns are quite similar at D-1 and E-1.

P-5, a second order experimental site, was compared to KC-1 (Figure 16). The similarity between functional group relative abundances in 1976 at these stations suggests community functions at P-5 were not affected. In 1977, differences in sampling schedules prevented comparing PS and KC1.

The relationship between mine dewatering and density of drift does not appear to be very strong. Impacted sites with the highest alkalinity values (SL-1 and P-5) tended to have higher drift densities than their controls although this was not true for SL-1 in 1977 (Figure 17). However, the drift values at sites receiving mine dewatering effluents are not consistently different from control sites. Without data demonstrating similarities among the sites before the dewatering began, the differences between control sites and sites receiving mine dewatering effluents cannot be attributed to this factor. For example, P-5 and K-5 appear to be similar sites with P-5 receiving mine dewatering. Higher drift rates were observed at P-5 than at KC-1 which would support the conclusion that mine dewatering sites have higher invertebrate populations. Unfortunately, no historical data exist for these two sites. Further, the reason for the current differences may be the result of discharge. P-5 has continuous flow while KC-1 is affected by periodic no flow periods such as August, 1976.

Shannon-Wiener diversity and equitability were similar for all of these sites (Table 24). Lowest diversity was observed at KC-1, a control site.

Overall, water chemistry parameters altered by mine de-watering effluents entering streams did not appear to influence community function and diversity, although numbers of drifting organisms may be higher at stations with the highest alkalinity levels. High alkalinity has been associated with high benthic populations in the literature (Tarzwell 1938; Waters 1961).

Similarity of Functional Group Relative Abundance Temporal Trends

Because mine dewatering operations did not influence community function for sites P-5, P-1, SL-1, and D-1, it is appropriate to use these sites along with other sites of the same stream order to demonstrate the similarity of temporal patterns of functional group relative abundance between widely separated sites. Figures 12, 15, and 16 demonstrate the similarity of community function between sites of the same stream order. Temporal patterns of functional groups were different in 1976 and 1977, but the same patterns occurred at sites of the same stream orders within each year.

Most of these sites are in different watersheds many kilometers apart (Figure 1). KC-1 and P-5 (Figure 16) are second order sites, 20 km apart; third order sites D-1 and E-1 (Figure 15) are 26 km apart. SR-1 and SL-1 (Figure 12) two fourth order sites, are 45 km apart; P-1, also a fourth order site, is 5 km upstream on the Partridge River from SL-1. K-1 and K-8 (Figure 18) are in the same watershed 50 km apart. Seasonal trends and relative abundance of invertebrate functional groups at these sites were similar within years. Therefore, it appears that sites of the same stream order will show similar changes in the abundance of functional groups within any given year, although changes may occur from year to year.

Use of Stream Order to Classify Stream Invertebrate Communities

Various studies have observed a relationship between stream order and stream invertebrate communities. For example, Harrel and Dorris (1968) observed increases in the number of species and diversity with increasing stream order. While our quantitative data did not indicate an increase in diversity with increasing stream order (Figure 7b) there was an increase in the number of taxa collected qualitatively (Table 12). The number of taxa in qualitative samples may be a better diversity measurement than drift diversity because fewer factors affect qualitative sampling than affect drift sampling.

The number of invertebrates drifting tended to increase with increasing stream order (up to fourth) in April, 1977, and decrease in August, 1977 (Figure 19). A decrease in drift was noted between fourth and fifth order streams in April and an increase in August. Mean drift at the eight primary SCS stations tended to increase with increasing stream order except that first order had the highest mean drift rate (Figure 21).

The similarity of sites based on their functional group composition was examined through cluster analysis. This analysis of April, 1977 and August, 1977 data did not demonstrate the similarity of streams of similar stream order (Figures 21 and 22). This failure was apparently the result of the high data variability within and between sites. Further, as discussed earlier, sites with similar canopy cover were similar but a separate cluster analysis of shaded or open sites was not carried out.

Additional similarity analyses were performed on the data from the eight primary SCS sites. Table 25 presents the summation of the four monthly Czekanowski similarity values for each of the 28 combinations of stations. The summed values seem to fall into three groups. Four of the combinations had total values exceeding 3.0 (SC-1 and LI-3, SE-1 and LI-1, SE-1 and SL-1, and SL-1 and SR-2). The second group included nineteen combinations with values ranging between 2.3 and 3.0. The third group consisted of five combinations with values less than 2.3. Of the four combinations exceeding 3.0, three were of stations of the same stream order; the fourth was between a first and a third (SC-1 and LI-3). These site combinations then can be considered the most similar according to this analysis. Among the five combinations not totaling 2.3, three were stations of different order, two of the same order, both of which involved SC-1 and overall, only one of the five did not involve SC-1.

A dendrogram (Figure 23) displays the results of cluster analysis of the similarity coefficients between sites. The original data matrix for this analysis consisted of the means of the first five functional groups for each site for four dates. In general, third and fourth order stations clustered together and first and second order stations clustered together at a level of .82 or higher. Station SC-1 is the exception as it was in the previous analysis. SC-1, a third order station, clustered with LI-3, a first order station. SC-1 is located on a third order stream which has a small drainage basin; the streams responsible for its third order designation are all short (less than one mile). As a result, SC-1 has physical characteristics such as width, gradient and discharge, that one would expect to find in a first and second order stream.

Overall, then, knowledge of the order of a stream does allow one to generally describe the invertebrate community of the Study Area. Headwater streams (first and second order) generally have low invertebrate populations with few taxa. The community is dominated by a combination of shredders (d.p.) and collectors which feed on the abundant organic matter. In higher order streams (third and fourth order) the productivity increases. The importance of shredders (d.p.) decreases while the relative abundance of collectors and to a small degree, scrapers, increases. The Kawishiwi River (fifth order) is dominated by collector-filter-feeders. This group utilizes the rich planktonic food source available from the lakes in the Kawishiwi chain. High invertebrate productivity with a large number of taxa can also be found in the Kawishiwi.

While the invertebrate community is generally correlated to stream order, changing physical-chemical factors are responsible for the changing invertebrate communities. When these physical-chemical factors vary, the invertebrate community varies. For example, a first order stream flowing through a bog which has minimal overhanging vegetation can be expected to resemble third order streams rather than heavily shaded first order streams. On the other hand, a third order stream such as Snake Creek (SC-1) can resemble first order streams rather than other third order streams if the drainage areas are similar. Therefore, it is necessary to survey the streams before more than general statements can be made concerning the invertebrate community.

SUMMARY

Three general stream communities were described based on the invertebrate fauna. These were the headwater streams (1st and 2nd order), mid-reach streams (3rd and 4th order), and the Kawishiwi River (5th order).

The largest populations of dead plant shredders were found in headwater streams where they comprised from 12 to 22 percent of the invertebrate populations on an annual basis. The shredders were present throughout the year in headwater streams, although the highest relative abundance was from fall through early spring when the largest amounts of allochthonous material were present in the Study Area streams. Fall populations of shredders in headwater streams exceeded 45 percent of the invertebrates present. The relative abundance of shredders varie between the two types of headwater streams. Shredders were approximately 4 to 9 times more abundant in upland forest streams than in lowland bog streams.

The primary shredders in headwater streams were stoneflies (Plecoptera) and caddisflies (Trichoptera). In mid-reach streams and the Kawishiwi River, chironomids (Diptera) became increasingly important members of the dead plant shredder group. These organisms fed on the allochthonous material and also contributed to the breakdown of this material for use by other invertebrates.

The collector group was the dominant group of invertebrates in headwater streams as it is in all Study Area streams. Collectors comprised more than 66 percent of the invertebrates on an annual basis in all stream orders. These organisms utilized the fine organic matter found in the headwater streams. Collector-gathers were slightly more abundant in lowland streams

where much of the organic material drifting out of bogs were finer than the allochthonous material found in upland streams. Low populations of scraper invertebrates (5%) are found in headwater streams because of the low periphyton production in these streams.

In mid-reach streams, the proportion of dead plant shredders declines while the proportion of collector and scraper groups increases in mid-reach streams. The dominant taxa in these functional groups are listed in Table 16. There are few changes in dominant taxa in each functional group between headwater and mid-reach streams. Changes in the relative abundance of the dead plant shredder, collector, and scraper functional groups are related to the decrease in allochthonous inputs and the increase in periphyton production. The increased size of the collector group may indicate that fine particulate organic matter is present in greater quantities in these areas than upstream. The collector group is present in large numbers throughout the year and in all types of streams (Figures 8 and 13), although the dominant taxa change seasonally. Various mayfly (Ephemeroptera) taxa such as Paraleptophlebia, Baetis, and Ephemerella dominate the collector-gatherer group in all stream orders. A major shift in dominant taxa occurs in the filter-feeding portion of this group; in headwater areas Simuliidae (Diptera) are dominant, while in mid-reaches the Hydropsyche group (Trichoptera) is a dominant with Simulidae. In the Kawishiwi River, the Hydropsyche group becomes the only dominant filter-feeder.

In the Kawishiwi River, the abundance of dead plant shredders was low. The expected high relative abundance of the scrapers was not observed. The relative abundance of scrapers was lower in the Kawishiwi River riffles (less than 1%) than in mid-reach streams (6%). The dominant invertebrate group was the collector group. The filter-feeding portion of the collector group reached its maximum abundance (52%) in the Kawishiwi. The *Hydropsyche* group was the dominant collector-filterer and its abundance was the most distinctive feature of the Kawishiwi River riffles. These filter-feeding caddisflies comprised approximately 50 percent of the invertebrates in Kawishiwi riffles because of the large amounts of plankton flowing out of the lake portions of the Kawishiwi River.

While stream order provided an easy method for classifying Study Area stream communities, discretion must be used when applying the system. There are many cases in the Study Area where the populations of dead plant shredders were more abundant in a 4th order stream than in a 1st order stream. Therefore, stream order should be used only for general descriptions while more complete physical, chemical, and biological sampling is necessary to give detailed descriptions of the invertebrate fauna.

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Table 1. Invertebrate functional groups and their primary food sources (Cummins 1976)

FUNCTIONAL GROUP	INGESTED MATERIAL
Shredders of dead plant material (D.P.)	Detritus 1-4 mm; mainly leaf litter
Shredders of living plant material (L.P.)	Living vascular hydrophytes and macroalgae
Collector-gatherers	Detritus 1 mm; on or within the substrate
Collector-filterers	Detritus 1 mm; suspended in the water
Scrapers	Periphyton
Piercing Herbivores	Vascular hydrophytes and macroalgae
Piercing Predators	Animal body fluids
Engulfing Predators	Animal tissue

Table 2. Water quality parameters for stream order one through five for 1976. The data are mean values for each stream order from sites unaffected by mine dewatering effluents.

Stream Order	Specific Conductance mhos	Total Phosphorus μg/l	Total Nitrogen μg/l	pH	Alkalinity mg/l	Total Ca mg/l	Turbidity NTU
1	185.0	90.0	22.15	6.7	55	14.8	2.5
2	55.5	25.7	1158.3	6.4	18	4.6	2.0
3	86.9	29.3	1109.2	6.7	36.3	8.2	2.7
4	89.3	21.7	716.2	7.0	33.2	8.6	2.7
5	50.8	18.8	612.5	6.9	18.8	6.2	1.9

Table 3. Number of streams, total length, mean length, and stream gradient for stream orders one through five in the portion of the Study Area sampled biologically.

Stream Order	Number of Streams	Total Length (km)	Percent of Total Length	Mean Length (km)	Mean Gradient (m/km)
1	407	825.4	41.5	4.2	4.1
2	103	496.4	25.0	4.4	2.2
3	26	401.9	20.2	18.9	1.3
4	7	176.4	8.9	17.6	0.9
5	1	89.1	4.5	89.1	0.8

Table 4a. Sampling frequency and collection dates for all techniques.

Period	Dates	Sample Type	Station Type
1	1 May - 18 June, 1976	Qualitative	P,S,T
		Drift	P
2	28 June-15 July, 1976	Hester-Dendy	P,S
		Drift	P,S
4	9 Aug-20 Aug, 1976	Hester-Dendy	P
		Drift	P,S
6	11 Sept-1 Oct, 1976	Qualitative	P,S,T
		Hester-Dendy	P,S
		Drift	P,S
7	1 Feb-31 Mar, 1977	Qualitative	P,S
		Drift	P
8	1 April-13 May, 1977	Qualitative	P,S,T, SCS^1, SCS^2
9	16 May-31 May, 1977	Drift	P
10	1 June-24 June, 1977	Qualitative	P,S
		Drift	P,S, SCS^1
		Hester-Dendy	P,S
12	18 July-31 July, 1977	Drift	P,SCS^1
		Hester-Dendy	P
13	1 Aug-26 Aug, 1977	Qualitative	P,S,T,SCS^1, SCS^2
		Drift	P,S,SCS^1,SCS^2
14	29 Aug-3 Nov, 1977	Drift	P
		Hester-Dendy	P,S

P = primary S = secondary T = tertiary

SCS^1 = primary stream classification

SCS^2 = secondary stream classification

Table 4b. Benthic invertebrate sampling sites, locations, stream order and designation

Site	Township Range, Section	Stream Order	Stream Name	Site Designation	Years Sampled
BB-1	T.61, R.12, S.36	1	Unnamed Creek	S	1976
BC-1	T.61, R.15, S.36	2	Bear Creek	SCS[2]	1977
BI-1	T.62, R.12, S.23	3	Bear Island River	S	1976, 1977
C4-1	T.59, R.10, S.12	2	Coyote Creek	SCS[2]	1977
D-1	T.60, R.12, S.9	3	Dunka River	P	1976, 1977
D-2	T.60, R.12, S.27	3	Dunka River	T	1976, 1977
D-3	T.59, R.12, S.16	1	Dunka River	SCS[2]	
DC-1	T.61, R.11, S.28	3	Denley Creek	SCS[2]	1977
E-1	T.60, R.15, S.25	3	Embarrass River	P	1976, 1977
E-2	T.60, R.14, S.15	3	Embarrass River	T	1976, 1977
F-1	T.62, R.11, S.24	2	Filson Creek	S, SCS[2]	1976, 1977
F-2	T.62, R.11, S.25	1	Filson Creek	SCS[2]	1977
I-1	T.61, R.9, S.6	5	Isabella River	T	1976, 1977
K-1	T.63, R.11, S.3	5	Kawishiwi River	P	1976, 1977
K-2	T.63, R.12, S.26	4	Shagawa River	S	1976, 1977
K-3	T.63, R.11, S.20	5	Kawishiwi River	T	1976
K-4	T.63, R.11, S.32	5	Kawishiwi River	T	1976
K-5	T.62, R.11, S.31	5	Kawishiwi River	S	1976, 1977
K-6	T.63, R.10, S.24	4	Kawishiwi River	T	1976, 1977
K-7	T.62, R.11, S.23	5	Kawishiwi River	T	1976, 1977
K-8	T.62, R.10, S.6	5	Kawishiwi River	P	1976, 1977
KC-1	T.61, R.11, S.17	2	Keeley Creek	S, SCS[2]	1976, 1977
KC-2	T.61, R.11, S.10	1	Keeley Creek	SCS[2]	1977
LI-1	T.61, R.9, S.29	3	Little Isabella River	SCS[1]	1977
LI-2	T.59, R.8, S.5	2	Little Isabella River	SCS[1]	1977
LI-3	T.59, R.8, S.9	1	Little Isabella River	SCS[1]	1977
N-1	T.60, R.11, S.34	1	Nip Creek	SCS[2]	1977
NR-1	T.61, R.10, S.31	2	Nira Creek	SCS[2]	1977
NW-1	T.56, R.14, S.23	3	North Branch Whiteface River	SCS[2]	1977
P-1	T.58, R.15, S.13	4	Partridge River	P	1976, 1977
P-2	T.58, R.14, S.9	4	Partridge River	S	1976, 1977

Table 4b. Contd.

Site	Township Range, Section	Stream Order	Stream Name	Site Designation	Years Sampled
P-3	T.58, R.13, S.9	3	Partridge River	T	1976, 1977
P-4	T.59, R.13, S.25	2	Partridge River	T SCS[2]	1976, 1977
P-5	T.59, R.12, S.6	2	Partridge River	S	1976, 1977
SC-1	T.61, R.9, S.30	3	Snake Creek	SCS[1]	1977
SE-1	T.61, R.10, S.12	3	Snake River	SCS[1]	1977
SE-2	T.61, R.9, S.19	3	Snake River	SCS[2]	1977
SG-1	T.57, R.14, S.36	1	Spring Creek	SCS[2]	1977
Sh-1	T.64, R.13, S.1	1	Shiver Creek	SCS[2]	1977
SL-1	T-58, R.15, S.22	4	St. Louis River	P, SCS[1] **	1976, 1977
SL-2	T.58, R.13, S.30	3	St. Louis River	T, S	1976, 1977
SL-3	T.58, R.12, S.22	3	St. Louis River	S	1976
SP-1	T.61, R.9, S.29	2	Sphagnum Creek	SCS[1]	1977
SR-1	T.61, R.11, S.30	4	Stony River	P, T	1976, 1977
SR-2	T.60, R.11, S.8	4	Stony River	T, P***	1976, 1977
SR-3	T.60, R.10, S.28	4	Stony River	S	1976, 1977
SR-4	T.60, R.9, S.31	3	Stony River	T	1976, 1977
SR-5	T.59, R.10, S.21	3	Stony River	T	1976, 1977
T-1	T.57, R.12, S.27	1	Toimi Creek	SCS[2]	1977
SCS-33	T.60, R.11, S.18	1	Dunka Ditch	SCS[2]	1977

** SL-1 was both a primary and primary SCS station in 1977

*** SR-2 was both a primary and primary SCS Station in 1977

Table 4c. Frequency of benthic invertebrate sampling.

Station Type	Sample Type	No. of Sample Periods: 1976	No. of Sample Periods: 1977
Primary	Hester-Dendy	3	3
	Drift	4	3
	Qual.	3	2
Secondary	Hester-Dendy	2	2
	Drift	3	3
	Qual.	2	2
Tertiary	Qual.	2	2
SCS (primary)	Drift	-	4
	Qual.	-	2
SCS (secondary)	Drift	-	2
	Qual.	-	2

Table 5. Mean percent abundance of the orders Ephemeroptera, Trichoptera and Diptera at primary and secondary monitoring stations during 1976 and 1977. Means were calculated on data from July, August and September, 1976, and April, June, August 1977

	1976				1977			
Station	Ephem-eroptera	Trich-optera	Dip-tera	Total	Ephem-eroptera	Trich-optera	Dip-tera	Total
BB-1	14.5	73	10	98%	--	--	--	--
D-1	23	28	37	88%	16	1	79	96
P-5	8	31	12	51	13	2	39	54
SR-1/2	48	23	16	87	81	3	6	90
KC-1	23	31	33	87	0	5	86	91
SL-1	46	7	43	96	54	6	8	68
F-1	9	8	61	78	--	--	--	--
E-1	58	8	28	94	55	2	25	82
P-1	40	15	27	82	49	7	9	65
SL-2/3	34	26	19	79	67	4	13	84
K-2	13	18	84	39	46	83	41	90
P-2	21	3	50	74	34	6	45	85
BI-1	27	36	21	84	21	<1	71	92
SR-3	62	6	3	71	49	8	29	86
K-5	23	43	24	90	63	17	16	96
K-8	18	34	42	94	7	45	37	89
K-1	6	56	16	78	10	48	38	96

Table 6. Percent relative abundance of the most abundant taxa within each major order collected at monitoring sites during 1976 and 1977.

Taxa	Monitoring Sites 1976 Relative Abundance %	Monitoring Sites 1977 Relative Abundance %
Baetis group	42.6	8.6
Paraleptophlebia	24.1	39.6
Ephemerella	2.9	23.1
Stenonema	9.8	1.3
Hexagenia	6.5	10.2
Hydropsyche group	78.9	83.3
Chimarra	9.9	2.5
Neureclipsis	4.9	3.1
Cricotopus	18.5	12.1
Polypedilum	7.6	3.5
Conchapelopia	10.0	14.2
Eukiefferiella	11.7	3.0
Rheotanytarsus	19.2	0.8
Simulliidae	8.5	46.6

Table 7. Taxa preferring stream orders one through three indicated by frequency of occurrence percentages for each stream order. Percentages were calculated by averaging collection frequencies of qualitative and quantitative samples taken at sites within each stream order during two periods in 1977. * = 0.0% -25.0%, ** = 25.5% - 50.0%, *** = 50.5% - 75.0%, and **** = 75.5% - 100%.

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Limnophila	*									
Pseudolimnophila	*									
Psectrotanypus		*								
Lasiodiamesa	*									
Anopheles	*		*							
Aedes	*		*							
Zavrelia		*	*							
Ranatra	*			*						
Lethocerus		*		*						
Amphinemura		**		*	*	*				
Leuctra		**		**		*				
Glossosoma		*				*				
Brachycentrus	*			*		*				
Nemotaulius		*		*	*					
Paratendipes		*				*				
Glyphopsyche		**		*		*		*		
Heterotrissocladius		**		**		*	*			
Anabolia	**		**		**		*			
Ptilostomis	*		*	*	*	*	*			
Tipula	*		*	*	*		*			
Zavrelimyia	*	*		*		*		*		
Centroptilum		*				*		*		
Polycentropus		*			*		*			
Triaenodes		*			*	*	*	*		
Platycentropus	*		*				*			
C[illegible]ethira	*				*		*			
P[illegible]pomyia group	*	**	*	*	*	*	*		*	
Chironomus		**	*	*	*	*	*		*	
Gerris	***		**	**	**	*	*	*	*	**
Litobranchia			*	*						

Table 8. Taxa preferring third and fourth stream orders indicated by frequency of occurrence percentage for each stream order. Refer to Table 8 for further table explanation.

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Pseudocloeon		*		**		***		****		**
Chimarra	*	**	*	**	*	**	**	****	*	**
Polypedilum	*	**		*	**	***	*	***	**	*
Hexagenia	*		*	*	**	*	***	**	**	**
Procladius	*	**	**	*	**	*	***			**
Parametriocnemus	*	*	**	**	**	**	***	*	*	*
Isoperla	*	*	*	*	*	*	**	***		
Paracapnia	*		*		*		***			
Polycentropus	*	*	*		**	*	**	*		*

Table 9. Taxa preferring stream orders three through five indicated by frequency of occurrence percentages for each stream order. Refer to Table 8 for further table explanation.

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Stenonema	*	**	*	**	***	***	****	***	***	****
Ephemerella	*	*	*	**	***	*	****	*	****	**
Hydropsyche group	*	**	**	**	***	****	****	****	****	****
Cricotopus	**	**	***	**	***	****	****	****	****	**
Eukiefferiella	**	**	*	**	**	***	**	****	****	***
Stenelmis	*	*	*	*	**	***	****	****	**	****
Hyalella	*	*	**	**	***	***	***	****	****	****
Acroneuria	*	*		**	***	***	***	**	*	***
Orthocladius	**		**		**	*	***	*	***	
Stenacron		*	*	*	*	**	**	**	**	***
Neureclipsis	*		*	*	**	*	**	**	***	***
Rheotanytarsus	*	*	**	*	**	**	*	*	*	***
Endochironomus	*	*	*	*	*	*	**	**	**	***
Psectrocladius	**	*	*	*	**	*	**	*	**	***
Paragnetina	*	*	*	**	*	**	**	**	**	**
Microtendipes	*	*	*	*	**	*	**	*	**	
Rhagovelia		*		*		**		**		**
Heptagenia		*		*	*	*	*			**
Nyctiophylax	*	*	*		*	*	*	*	**	
Ceraclea		*	*		*	*	*	*	**	*
Macronychus		*		*	*	*	*		*	**
Nigronia	*		**	*	*	*	**	*	**	*
Siphloplecton			*		*		*		***	
Caenis			*	**	**	**	**	*	***	*
Hydroptila				*		*	*		*	*
Cardiocladius		*				*	*	**	**	
Parachironomus			*	*		*				**
enoa										
operla						*		*	*	
Perlesta						*		*	*	
Isonychia					*	*	**	*	*	

Table 9. Continued

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Heterocloeon						*		*	**	
Choroterpes						*		*		*
Tricorythodes						**		**		**
Antocha					*	*	*	*	**	*
Pentaneura						*				*
Phaenopsectra						*			*	
Strophopteryx							*			
Agraylea							*			
Coryneura								*		
Odontomyia							*			
Ectopria							**			
Baetisca							*	*	**	
Macronema							*	**	*	*
Isogenoides									*	
Lauterborniella										*

Table 9. Continued

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Heterocloeon						*		*	**	
Choroterpes						*		*		*
Tricorythodes						**		**		**
Antocha					*	*	*	*	**	*
Pentaneura						*				*
Phaenopsectra						*			*	
Strophopteryx							*			
Agraylea							*			
Corynoneura								*		
Odontomyia							*			
Ectopria							**			
Baetisca							*	*	**	
Macronema							*	**	*	*
Isogenoides									*	
Lauterborniella										*

Table 10. Taxa preferring stream orders two through four indicated by frequency of occurrence percentages for each stream order. Refer to Table 8 for further table explanation.

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Optioservus	*	***	**	**	****	***	***	***	**	*
Micropsectra	*	**		*	**	*	**	*	*	
L[illegible]iraphia	*	*		*	*	**	*	*	*	
Lepidostoma	*			**	*	*	*	*	**	*
Tanytarsus	*			*	*	**	*		*	*
S[illegible]alas	*		**	*	*	*	**	*	*	
Diplocladius	*		**	*	**		**		*	
Hydatophylax				*	*		*			
Mystacides			*	*	*					
Allocapnia				*	*	*	*	*		
Dicranota			*		*		*			
Larsia			*		*		*			
Cloeon				*		*		**	*	
Molanna			*				*	*		
Diamesia			*				*			
Rheocricotopus			*	*	**	*	*	*		
S[illegible]ipsa			*		*		**		*	
Phryganea				*		*		*		*
Oecetis				*		**		*		*
Einfeldia			*	*	*		*	*		*
Rheumatobates				*						*
Trepobates				*						*
[illegible]lostoma				*	*	*	*			*
Atherix				*	**	**	***	**		
Pteronarcys						*				
[illegible]imosta					*					
[illegible]ophylax					*					
[illegible]iophilus					*					
[illegible]imacia					*					
[illegible]lothauma						*				
Taeniopteryx					*		*			
Callibaetis					*	*	**			

Table 10. Continued.

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Ochrotrichia					*		*	*		
Agarodes					*		*			
Hexatoma					*	*	*			
Clinotanypus					*		*			
Nilotanypus						*	*			
Epoicocladius						*	*			
Epeorus						*	*			
Xenochironomus					*	*	*			
Metrobates						*		*		
Paraponyx						*	*			
Dolophilodes				*	*					
Limnephilus			*	*					*	

Table 11. Taxa not showing a preference for any stream order indicated by frequency of occurrence percentages for each stream order. Refer to Table 8 for further table explanation.

	1st Order		2nd Order		3rd Order		4th Order		5th Order	
	April/May	August	April/May	August	April/May	August	April/May	August	April/May	August
Baetis group		****	**	****	*	****	**	****	**	****
Paraleptophlebia group	*	****	**	***	****	***	****	**	****	*
Conchapelopia	*	****	***	****	***	****	****	****	****	****
Ablabesymia		**		*		**	*	**	*	**
Notonecta	*	*		*	*	*	*			*
E[illegible]llia	*	*	*		*	*	*		*	
Thienemanniella		*		*		*		*	*	
Trissocladius	*		*		*		*		*	
Ephemera	*		*		*	*	*	*		*
Agapetus	*	*		*	*	*	*		*	
Dicrotendipes	*	*		*	*	*	*	*	*	*
Siphlonurus		*				*	*		*	
Psychomyia	*	*				*	*		*	
Pycnopsyche	*				*	*	**			*
Cryptochironomus		*				*				*
Glyptotendipes		*			*	*	*	*	*	
Stenochironomus		*			*	*		*		*
Micrasema	*						*		*	
Helicopsyche	*		*					*	*	*

Table 12. Mean number of taxa collected qualitatively in 1977 in stream orders one through five.

	STREAM ORDER									
	1		2		3		4		5	
	April	Aug.	April	Aug.	April	Aug.	April	Aug.	April	Aug.
No. of Taxa	15	26	15	32	27	39	36	41	36	42
No. of Stations	7	7	7	9	13	15	9	9	5	5

Table 13. Major orders, number of taxa, and composition percentage of major percentage of major orders comprising each functional group during both 1976 and 1977 at all sites.

FUNCTIONAL GROUP AND MAJOR COMPONENTS	NUMBER OF TAXA	COMPOSITION PERCENTAGE
Shredders (d.p.)	29	
Plecoptera		38
Trichoptera		45
Diptera		17
Shredders (l.p.)	14	
Trichoptera		43
Coleoptera		21
Diptera		21
Lepidoptera		14
Collector-gatherers	74	
Ephemeroptera		27
Trichoptera		5
Coleoptera		11
Diptera		51
Other orders		6
Collector-filterers	20	
Ephemeroptera		5
Trichoptera		50
Diptera		40
Other orders		5
Scrapers	14	
Plecoptera		7
Ephemeroptera		29
Trichoptera		21
Coleoptera		14
Diptera		21
Other orders		8
Piercing Herbivores	9	
Hemiptera		11
Trichoptera		78
Coleoptera		11
Piercing Predators	18	
Hemiptera		78
Diptera		17
Other orders		5
Engulfing Predators	52	
Plecoptera		15
Ephemeroptera		2
Trichoptera		6
Megaloptera		4
Neuroptera		4
Diptera		38
Other orders		31

Table 14. Members of shredder, collector, scraper, herbivore and predator functional groups found in Study Area. The listed taxa represent the identification level required for functional group assignment. (Cummins 1976, Cummins personal communication, Merrit and Cummins 1978).

SHREDDERS OF DEAD PLANT MATERIAL

Plecoptera
- Pteronarcidae
- Nemouridae
- Leuctridae
- Capniidae
- Taeniopterygidae

Trichoptera
- Limnephilidae
- Lepidostomatidae
- Sericostomatidae

Diptera
- Tipulidae
  - *Erioptera* sp.
  - *Pedicia* sp
  - *Tipula* sp.
- Chironomidae
  - Orthocladinae
    - *Brillia* sp.
  - Chironomini
    - *Endochironomus* sp.

SHREDDERS OF LIVING PLANT MATERIAL

Trichoptera
- Phryganeidae
- Leptoceridae
  - *Nectopsyche* sp.
  - *Triaenodes* sp.

Lepidoptera
- Pyralidae

Coleoptera
- Haliplidae (larvae)
- Hydrophilidae (adults)
  - *Helophorous* sp.
  - *Hydrochus* sp.

Diptera
- Tipulidae
  - *Limonia* sp.
- Chironomidae
  - Orthocladinae
    - *Cricotopus* sp.
  - Chironomini
    - *Polypedilum* sp.

Table 14. Continued

COLLECTOR-GATHERERS

Decopoda
Turbellaria
Oligochaeta
Decopoda
    Amphipoda
        Talitridae
        Gammaridae
Insecta
    Collembola
    Ephemeroptera
        Siphlonuridae
            Siphlonurus sp.
        Heptageniidae
            Arthroplea sp.
            Rhithrogena sp.
            Stenacron sp.
            Stenonema sp.
        Baetidae
            Baetis sp.
            Callibaetis sp.
            Centroptilium sp.
            Cloeon sp.
            Heterocloeon sp.
        Leptophlebidae
            Leptophlebia sp.
            Paraleptophlebia sp.

        Ephemerellidae
        Tricorythidae
        Caeniidae
        Ephemeridae
        Polymitarcidae
        Baetiscidae

Trichoptera
        Brachycentridae
            Brachycercus sp.
        Molannidae
        Leptoceridae
            Ceraclea sp.
            Mystacides sp.

Coleoptera
        Elmidae (Adults and Larvae)
        Chrysomelidae (Larvae)

Diptera
        Chironomidae
          Podonominae
          Orthocladinae

Table 14. Continued

Coryneura sp.
Diplocoadius sp.
Epoicocladius sp.
Eukiefferiella sp.
Orthocladius sp.
Parametreocnemus sp.
Psectrocladius sp.
Rheocricotopus sp.
Smittia group
Thienmanniella sp.
Trissocladius sp.
Heterotrissocladius sp.
Cardiocladius sp.
Tanytarsini
Micropesctra sp.
Zavrelia sp.
Chironomini
Chironomus sp.
Dicrotendipes sp.
Einfeldia sp.
Glyptotendipes sp.
Paratendipes sp.
Stenochironomus sp.
Stictochronomus sp.
Nilothauma sp.
Pseudochironomus sp.
Pagastiella sp.
Cryptocladopelma sp.
Lauterborniella sp.
Tipulidae
Antocha sp.
Stratiomyidae
Odontomyia sp.
Culicidae
Aedes sp.
Psychodidae
Syrphidae
Helophilus sp.

COLLECTOR-FILTERERS

Ephemeroptera
Siphlonuridae
Isonychia sp.

Trichoptera
Philopotamidae
Psychomyiidae
Polycentropodidae
Neureclipsis sp.
Phylocentropus sp.

Table 14. Continued

Hydropsychidae
Brachycentridae
Brachycentrus sp.

Diptera
Culicidae
Anopheles sp.
Simuliidae
Chironomidae
Tanytarsini
Rheotanytarsus sp.
Tanytarsus sp.
Microtendipes sp.

Pelecypoda

SCRAPERS

Plecoptera
Chloroperlidae

Ephemeroptera
Heptageniidae
Epeorus sp.
Heptagenia sp.
Baetidae
Pseudocloeon sp.
Leptophlebiidae
Choroterpes sp.

Trichoptera
Glossosomatidae
Helicopsychidae

Coleoptera
Hydraenidae (Adult)
Psephenidae (Larvae)

Diptera
Blephariceridae
Chironomidae
Chironomini
Phaenopsectra sp.
Tribelos sp.

Gastropoda

Table 14. Continued

PIERCING-HERBIVORES

Hemiptera
    Corixidae

Trichoptera
    Hydroptilidae

Coleoptera
    Haliplidae

PIERCING-PREDATORS

Hemiptera
    Hebridae
    Hydrometridae
    Mesoveliidae
    Gerridae
    Veliidae
    Notonectidae
    Pleidae
    Naucoridae
    Nepidae
    Belostomatidae

Diptera
    Tabanidae
    Rhagionidae
    Chaoboridae

Acari

ENGULFING-PREDATORS

Nemotoda

Hirudinea

Plecoptera
    Perlidae
    Perlodidae

Ephemeroptera
    Metretopodidae

Odonata

Table 14. Continued

Trichoptera
- Polycentropodidae
  - *Nyctiophyla* sp.
  - *Polycentropus* sp.
- Leptoceridae
  - *Oecetis* sp.

Megaloptera

Neuroptera

Coleoptera
- Dytiscidae (Adult and Larvae)
- Gyrinidae (Adult and Larvae)
- Hydraenidae (Larvae)

Diptera
- Empididae
- Ceratopogonidae
- Tipulidae
  - *Dicranota* sp.
  - *Hexatoma* sp.
  - *Limnophila* sp.
  - *Pseudolimnophila* sp.
- Chironomidae
  - Tanypodinae
  - Chironomini
    - *Cryptochironomus* sp.
    - *Parachironomus* sp.
    - *Xenochironomus* sp.

Table 15. Mean shredder (d.p.), collector-gatherer, and scraper relative abundance and detritus dry weight in streams shaded and unshaded by a terrestrial canopy cover in two sampling periods during 1977.

Functional Group	Terrestrial Canopy Cover	April and May 1977 Stream Order					August 1977 Stream Order				
		1	2	3	4	5	1	2	3	4	5
Shredder (d.p.)	25%-100% Canopy	26.8	20.7	8.7	-	-	0.8	11.2	4.5	-	-
	< 25% Canopy	6.4	2.7	3.0	4.8	0.6	0	0.6	1.1	0.7	0.2
Scraper	25%-100% Canopy	0.2	1.1	3.9	-	-	2.3	1.0	3.4	-	-
	< 25% Canopy	13.2	0.7	0.4	1.0	0.2	3.7	3.8	15.8	8.9	.6
Collector-gatherers	25%-100%	23.5	5.2	81.5	-	-	31.6	39.9	31.3	-	-
	< 25%	26.7	34.5	86.2	82.2	40.9	90.0	37.6	36.2	32.0	15.3

Table 16. Annual functional group composition in stream orders one through five for all 1977 sites. The taxa are listed in order of decreasing abundance and either represent ≥ 80% of the individuals collected or the five most abundant taxa collected per sampling period.

Functional Group	STREAM ORDER				
	1	2	3	4	5
Shredders of dead plant material	Amphinemura Leuctra Playtycentropus Limnephilus Nemotaulius	Leuctra Paracapnia Endochirunomus Grammotaulius Lepidostoma	Endochironomus Leuctra Paracapnia Platycentropus Pycnopsyche	Endochironomus Paracapnia Lepidostoma Brillia Shipsa	Endochironomus Brillia Lepidostoma
Shredders of living plant material	Cricotopus Helophorus (Adult) Haliplidae (Adult) Polypedilum	Cricotopus Polypedilum	Cricotopus Polypedilum Haliplidae Ptilostomis	Polypedilum Cricotopus Ptilostomis Triaenodes	Cricotopus Polypedilum
Collector-gatherers	Paraleptophlebia-group Baetis-group Eukiefferiella Ephemerella Chironomus	Baetis-group Paraleptophlebia-group Eukiefferiella Hyalella Ephemerella	Paraleptophlebia-group Baetis-group Ephemerella Hexagenia Eukiefferiella	Paraleptophlebia-group Ephemerella Hyalella Tricorythodes Baetis-group	Paraleptophlebia-group Baetis-group Hexagenia Eukiefferiella Ephemerella
Collector-filterers	Simuliidae	Simuliidae	Simuliidae Hydropsyche-group	Simuliidae Hydropsyche-group Chimarra	Hydropsyche-group
Scrapers	Gastropoda Glossosoma Hydraenidae (Adult) Heptagenia	Gastropoda Chloroperlidae Pseudocloeon Epeorus Heptagenia	Pseudocloeon Gastropoda Heptagenia Choroterpes Epeorus	Choroterpes Pseudocloeon Gastropoda Heptagenia	Pseudocloeon Heptagenia Choroterpes Gastropoda

Table 17. Shredders of dead plant material (D.P.) composition for stream orders one through five during 1977. The taxa are listed in order of decreasing abundance and represent ≥80% of shredders (d.p.) collected per sampling period.

STREAM ORDER	APRIL AND MAY	JUNE	JULY	AUGUST	NOVEMBER
1	Limnephilidae Paracapnia	Lepidostoma	Nemouridae Limnephilus Emphinemura	Amphinemura Leuctra	Platycentropus Nemotaulius Taeniopteryx
2	Endochironomus Anabolia	Leuctra Lepidostoma Anabolia	Leuctra	Leuctra Lepidostoma Hydatophylax Limnephilus	Paracapnia Platycentropus
3	Nemouridae Paracapnia Endochironomus Anabolia Allocapnia	Endochironomus Leuctra Lepidostoma Nemotaulius Paracapnia	Leuctra Brillia	Leuctra Hydatophylax Amphinemura	Platycentropus Paracapnia Lepidostoma
4	Shipsa Endochironomus Paracapnia	Endochironomus	Brillia Amphinemura	Endochironomus Leuctra	Paracapnia
5	Brillia Lepidostoma	Endochironomus	no data gathered	Endochironomus	no data gathered

Table 18. Shredders of living plant material (l.p.) composition for stream orders one through five during 1977. The taxa are listed in order of decreasing abundance and represent ≥ 80% of shredders l.p. collected per sampling period.

STREAM ORDER	APRIL/MAY	JUNE	JULY	AUGUST	NOVEMBER
1	Helophorus	Cricotopus Haliplidae	Cricotopus	Polypedilum Cricotopus	Cricotopus
2	Cricotopus	Polypedilum Cricotopus	Polypedilum	Polypedilum Cricotopus	none collected
3	Cricotopus	Haliplidae Polypedilum Cricotopus	Cricotopus	Polypedilum Cricotopus	Ptilostomis
4	Cricotopus	Polypedilum Cricotopus	Polypedilum Cricotopus	Polypedilum Cricotopus	Ptilostomis
5	Cricotopus	Polypedilum Cricotopus	No data gathered	Polypedilum	No data gathered

Table 19. Collector-gatherer composition for stream orders one through five during 1977. The taxa are listed in order of decreasing abundance and represent ≥ 80% of collector-gatherers collected per sampling period.

STREAM ORDER	APRIL AND MAY	JUNE	JULY	AUGUST	NOVEMBER
1	Paraleptophlebia gr. Dicrotendipes Lasiodiamesa Ades Ephemerella Stenonema	Ephemerella Baetis gr. Hyalella Oligochaeta	Eukiefferiella Orthocladinae Hyalella Paraleptophlebia gr. Micropsectra	Baetis gr. Eukiefferiella Chironomus Paraleptophlebia gr.	Optioservus Paraleptophlebia gr.
2	Paraleptophlebia gr. Diplocladius Parametriocnemus Zavrelia Hexagenia	Dubiraphia Ephemerella Chironomus Hexagenia Baetis gr. Oligochaeta Paraleptophlebia gr. Dicrotendipes	Baetis gr. Tricorythodes Hyalella Optioservus	Baetis gr. Heterotrissocladius Eukiefferiella Hyalella Caenis Paraleptophlebia gr.	Paraleptophlebia gr. Orthocladinae Micropsectra Stenonema Eukiefferiella
3	Paraleptophlebia gr. Ephemerella	Baetis gr. Optioservus Caenis Ephemerella Hexagenia Hyalella Dubiraphia	Baetis gr. Paraleptophlebia gr. Caenis Stenelmis Hyalella Tricorythodes Optioservus Chironomus	Baetis gr. Eukiefferiella Caenis Paraleptophlebia gr. Stenonema	Ephemerella Paraleptophlebia gr.
4	Paraleptophlebia gr. Ephemerella Hexagenia	Hyalella Baetis gr. Stenelmis Hexagenia Caenis Ephemerella Paraleptophlebia gr.	Tricorythodes Hyalella Paraleptophlebia gr. Caenis	Hexagenia Baetis gr. Hyalella Eukiefferiella Caenis	Paraleptophlebia gr.
5	Paraleptophlebia gr. Ephemerella	Hexagenia Chironomus Eukiefferiella Stenelmis Baetis gr. Ephemerella	No data gathered	Hexagenia Eukiefferiella Baetis gr. Glyptotendipes	No data gathered.

PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW

Table 20. Collector-filterer composition for stream orders one through five during 1977. The taxa are listed in order of decreasing abundance and represent ≥ 80% of collector-filterers collected per sampling period.

STREAM ORDER	APRIL/MAY	JUNE	JULY	AUGUST	NOVEMBER
1	Simuliidae	Simuliidae Psychomyia Lype	Simuliidae	Simuliidae	Simuliidae
2	Simuliidae	Simuliidae	Simuliidae Dolophiloides	Simuliidae	Simuliidae Hydropsyche gr.
3	Simuliidae Rheotanytarsus Hydropsyche gr. Neureclipsis	Simuliidae	Simuliidae	Simuliidae Hydropsyche gr.	Hydropsyche gr. Simuliidae
4	Simuliidae Hydropsyche gr.	Simuliidae	Hydropsyche gr. Simuliidae Chimarra	Simuliidae Hydropsyche gr.	Hydropsyche gr. Simuliidae Chimarra
5	Hydropsyche gr.	Hydropsyche gr. Microtendipes Neureclipsis	No data gathered	Hydropsyche gr.	No data gathered

Table 21. Scraper composition for stream orders one through five during 1977. The taxa are listed in order of decreasing abundance and represent ≥ 80% of scrapers collected per sampling period.

STREAM ORDER	APRIL/MAY	JUNE	EARLY JULY	AUGUST	NOVEMBER
1	Hydraenidae Gastropoda	Gastropoda	Gastropoda	Gastropoda Glossosoma Heptagenia	Glossosoma
2	Chloroperlidae	Gastropoda Pseudocloeon Epeorus	Gastropoda	Gastropoda	Heptagenia Gastropoda
3	Heptagenia Gastropoda	Gastropoda Pseudocloeon	Choroterpes Epeorus Chloroperlidae	Pseudocloeon Gastropoda	Gastropoda
4	Gastropoda Heptagenia	Pseudocloeon Choroterpes Gastropoda	Choroterpes Pseudocloeon	Gastropoda Pseudocloeon	Gastropoda
5	Gastropoda	Gastropoda Choroterpes	No data gathered	Pseudocloeon Heptagenia	No data gathered

Table 22. The three most abundant taxa in five functional groups and their frequency of occurrence at primary SCS sites during June, July, August and November, 1977 (Frequency of occurrence = 8 = all sites).

Functional Group / Month	June	Frequency of Occurrence	July	Frequency of Occurrence	August	Frequency of Occurrence	November	Frequency of Occurrence
Shredders (dip.)	Leuctra sp. Lepidostonia sp. Nemotaulius sp.	4 6 2	Leuctra sp. Brillia sp. Tipulidae	4 3 4	Allocapnia Leuctra sp. Hydatophylax sp.	4 3 2	Platycentropus sp. Paropapnia sp. sp. Nemotaulius sp.	7 7 3
Shredders (l.p.	Polypedilum sp. Cricotopus sp. Haliplidae(adult)	5 6 4	Cricotopus sp. Polypedilum sp. Triaenodes sp.	7 7 1	Cricotopus sp. Polypedilum sp. Ptilostonis sp.	6 5 1	Ptilostomis sp. Cricotopus sp.	3 1
Collector/ Gatherers	Ephemerella sp. Stenelmis sp. Baetis sp.	8 5 8	Baetis sp. Hyalella sp. Caenis sp.	8 8 6	Baetis sp. Eukieffinella sp. Stenonema sp.	8 6 4	Paraleptophlebia gp. Ephemerella sp. Optioservus sp.	8 8 6
Collector/ filter-feeders	Hydropsyche sp. Simulidae Dolophiloidas sp.	6 8 3	Simulidae Hydropsyche sp. Dolophiloides sp.	8 7 2	Simulidae Hydropsyche sp. Chimarra sp.	7 8 5	Simulidae Hydropsyche sp. Chimarra	7 7 4
Scrapers	Gastropoda Pseudocloeon sp. Epeorus sp.	6 5 4	Choroterpes sp. Gastropoda Pseudocloeon sp.	2 6 4	Pseudocloeon sp. Glossosomatidae Gastropoda	5 3 3	Gastropoda Heptogenia sp.	5 1

Table 23. Water chemistry parameters for sites receiving mine dewatering effluents and control sites. These data are median values for 1976. Sites SR-1, E-1 and KC-1 acted as controls for P-1 and SL-1, D-1, and P-5 respectively.

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Sites	Water Chemistry Parameters						
	Specific Conductance µ mhos	Total Phosphorus µg/l	Total Nitrogen µg/l	pH	Alkalinity mg/l	Total Ca	Turbidity NTU
P-1	270	19	760	6.9	38	22.4	4.2
SL-1	351	16	1655	7.6	90	28.5	2.4
*SR-1	89	20	740	7.2	39	7.7	2.2
D-1	238	27	1970	7.0	32	16.0	2.6
*E-1	132	40	1205	6.8	44	12.8	3.7
P-5	372	no data	no data	6.9	130	26.5	4.6
*KC-1	39	20	1245	6.2	14	4.8	2.0

*Control sites

Table 24. Comparison of Shannon-Wiener diversity between sites receiving mine dewatering effluents and control sites. These data are mean values for 1976 and 1977. Sites SR-1, E-1, and KC-1 were considered as controls for P-1 and SL-1, D-1, and P-5, respectively.

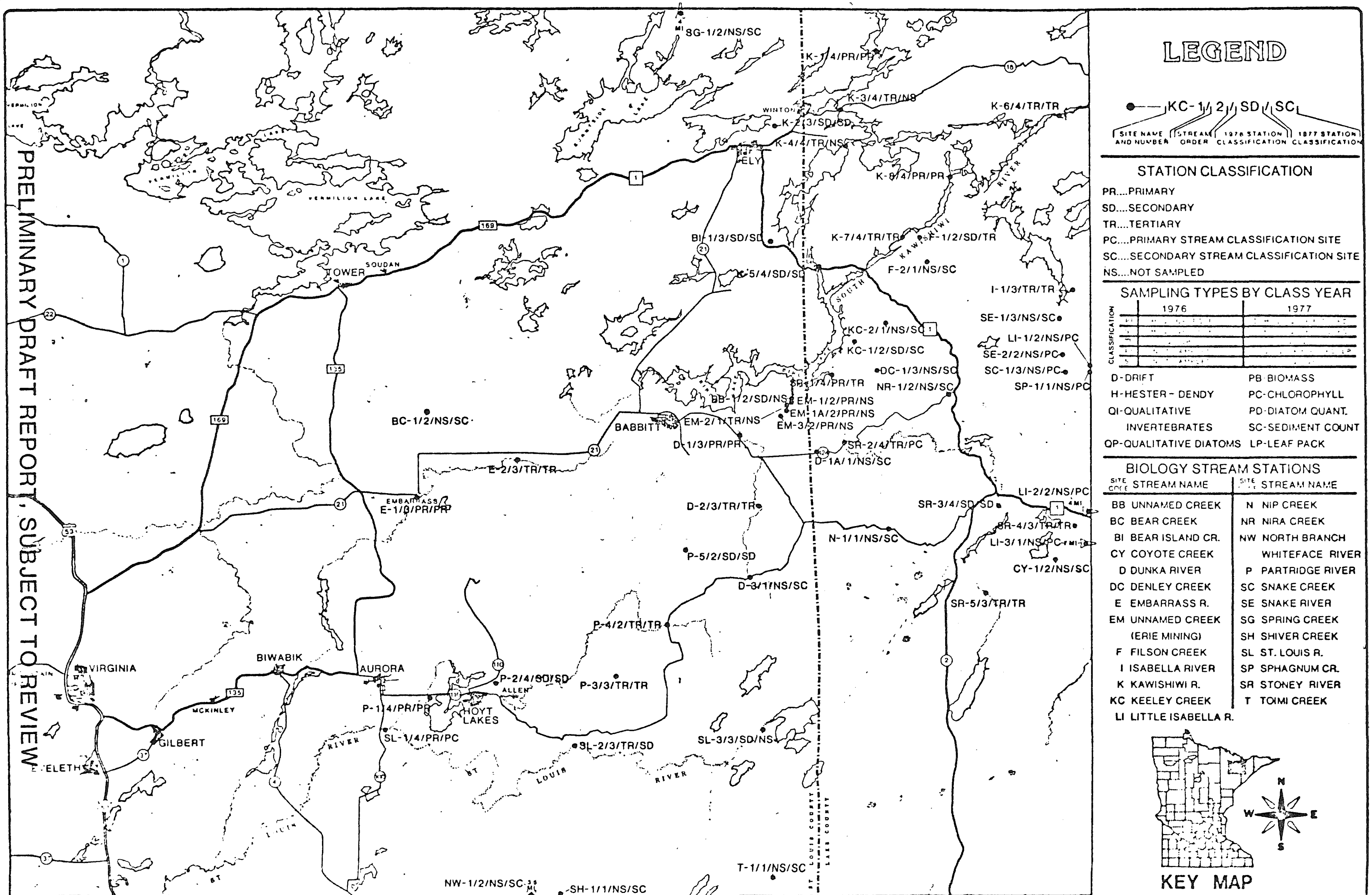
SITE	SHANNON-WIENER DIVERSITY
P-1	3,39
SL-1	3.33
SR-1*	3.43
D-1	3.31
E-1*	3.47
P-5	3.20
KC-1*	2.74

* Control sites

Table 25. The total similarity (four sampling periods) between eight stations based on five functional groups using the Czekanowski coefficient. Stream order is indicated in parentheses.

STATION DESIGNATION

	SP-1 (2)	LI-3 (1)	LI-1 (3)	LI-2 (2)	SC-1 (3)	SE-1 (3)	SR-2 (4)
LI-3 (1)	2.4						
LI-1 (3)	2.8	2.4					
LI-2 (2)	2.7	2.4	2.5				
SC-1 (3)	2.5	3.1	2.1	2.4			
SE-1 (3)	2.7	2.9	3.1	2.8	2.2		
SR-2 (4)	2.4	2.6	2.9	2.2	2.0	2.9	
SL-1 (4)	2.6	2.6	3.0	2.9	1.8	3.3	3.1



MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 1 STREAM STUDY STATIONS

Figure 2. Percent relative abundance of invertebrate orders in the Study Area.

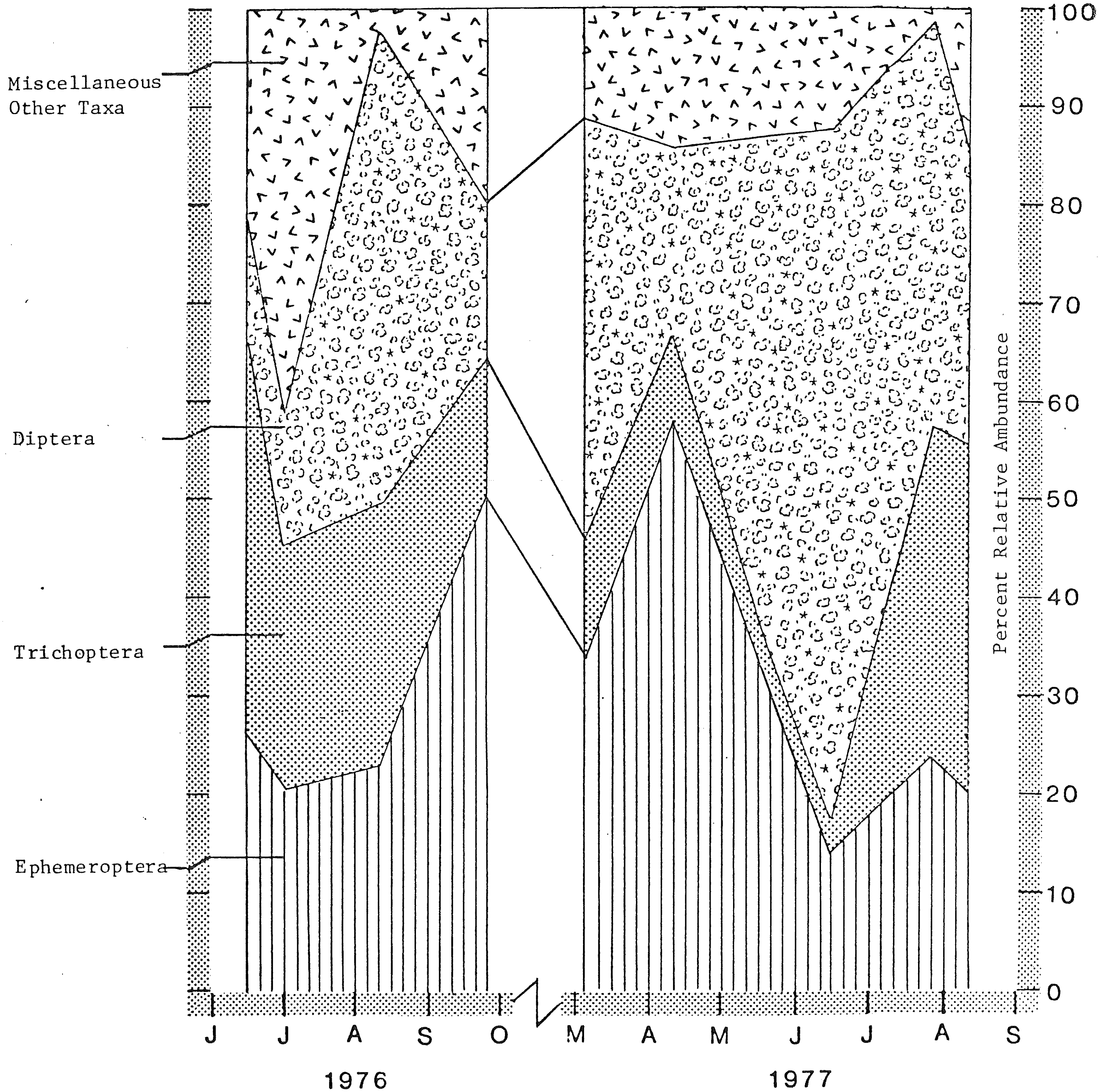


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Figure 3 Mean number of organisms per 1000/m^3 collected in drift nets at primary and secondary stations in the Study Area

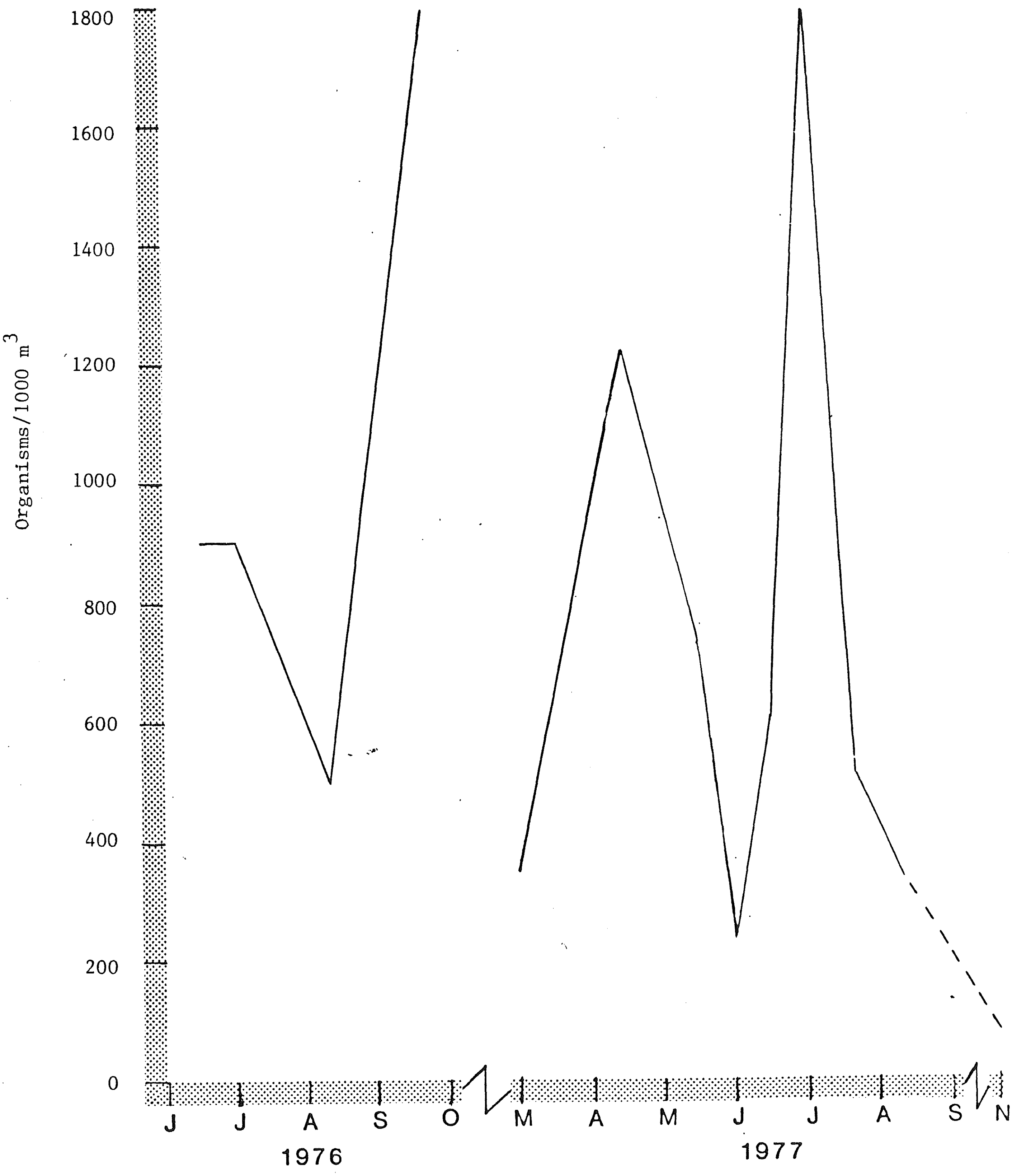

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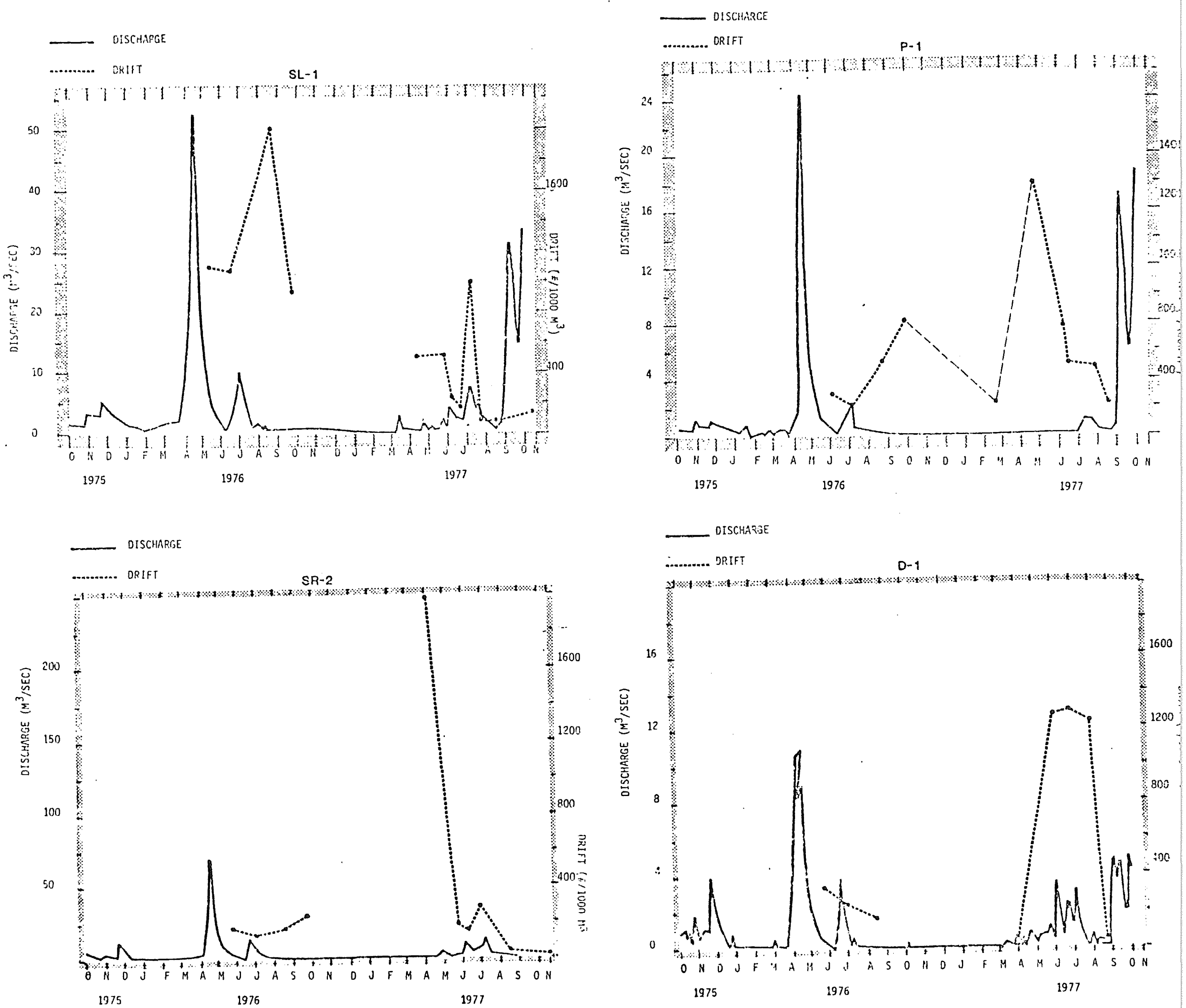
Figure 4. Discharge and, total drifting organisms at stations SL-1, P-1, SR-2, and D-1



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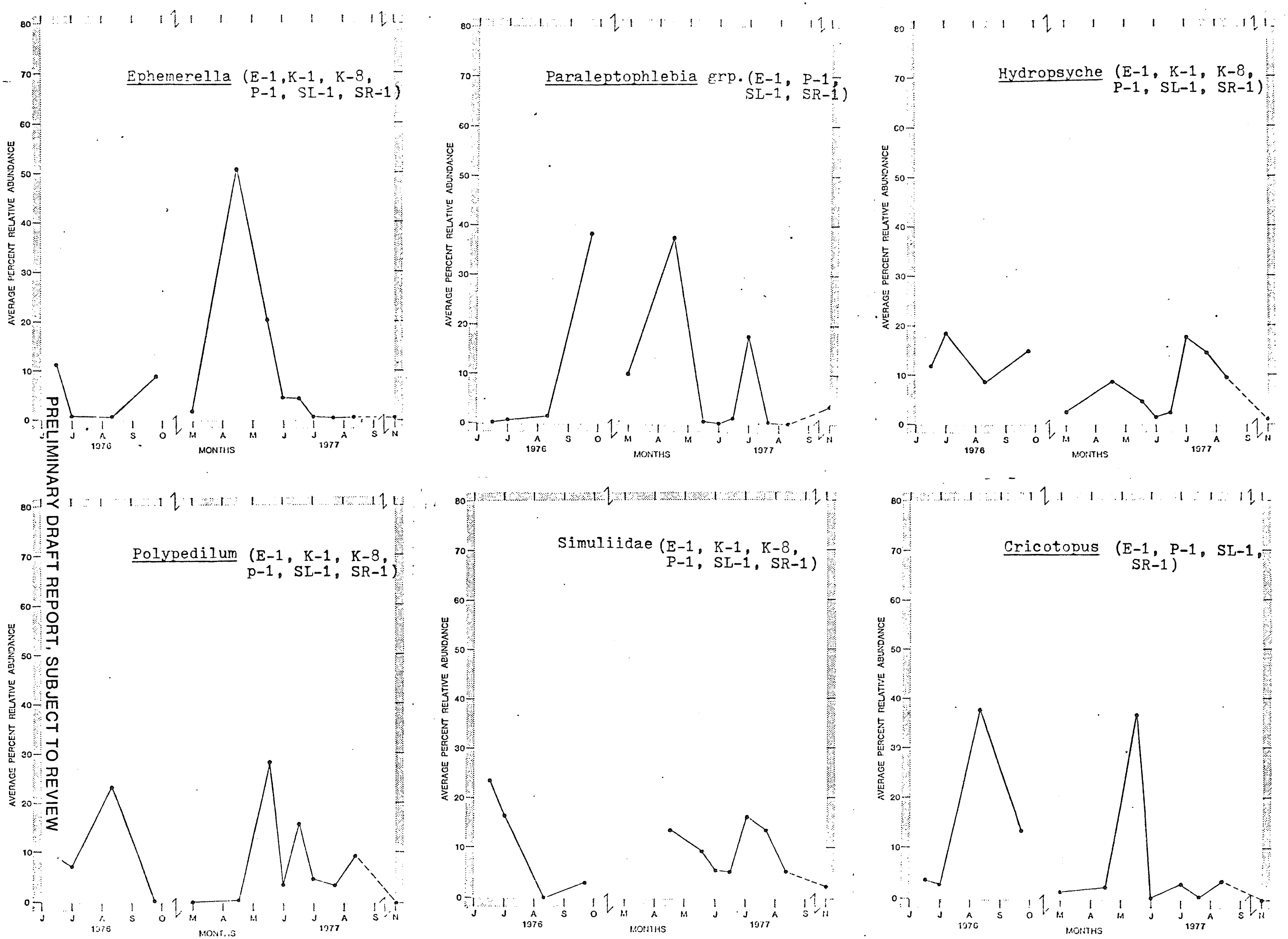

Figure 5. Observed cycles of invertebrate relative abundance of selected taxa collected at primary monitoring sites (indicated in parenthesis for each taxon)

Figure 6. Abundance of important taxa at six primary monitoring sites relative to the other sites. Percentages indicate the ratio of the number of organisms of a particular taxon which were collected at one site during 1976 and 1977 relative to the number collected at all six sites.

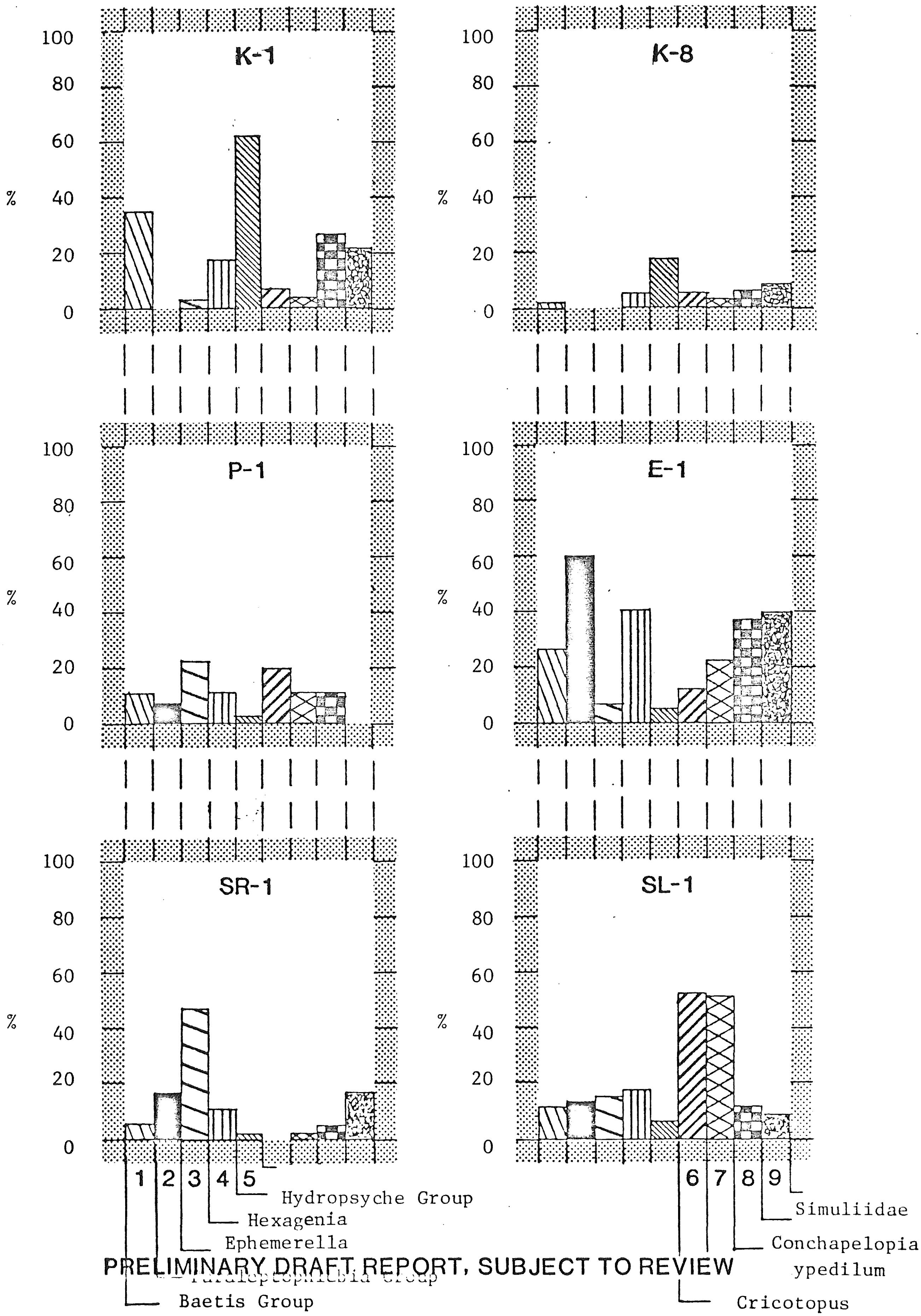

Figure 7a. Shannon-Weiner diversity of drift samples for primary monitoring stations during 1976 and 1977.

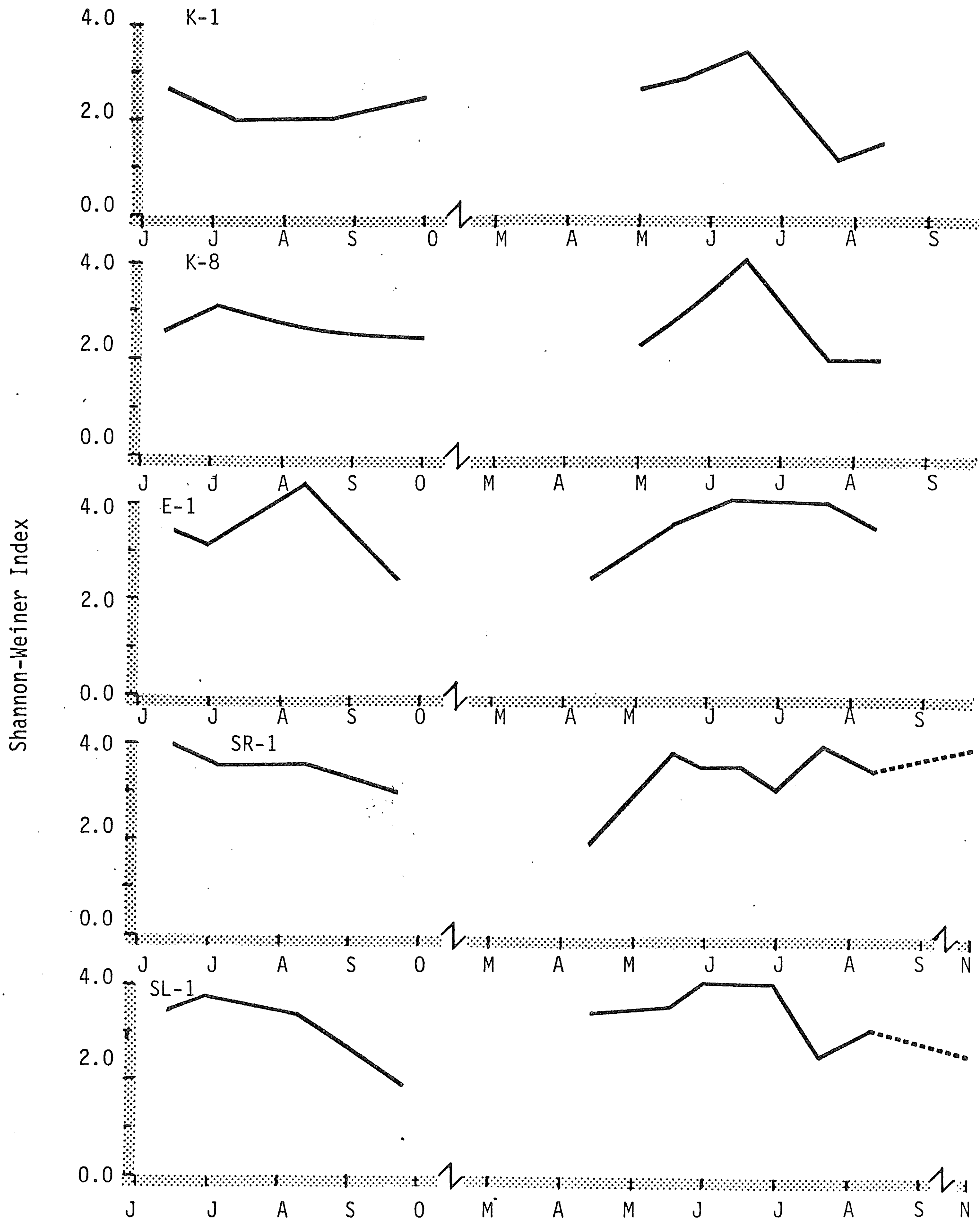

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Figure 7a continued

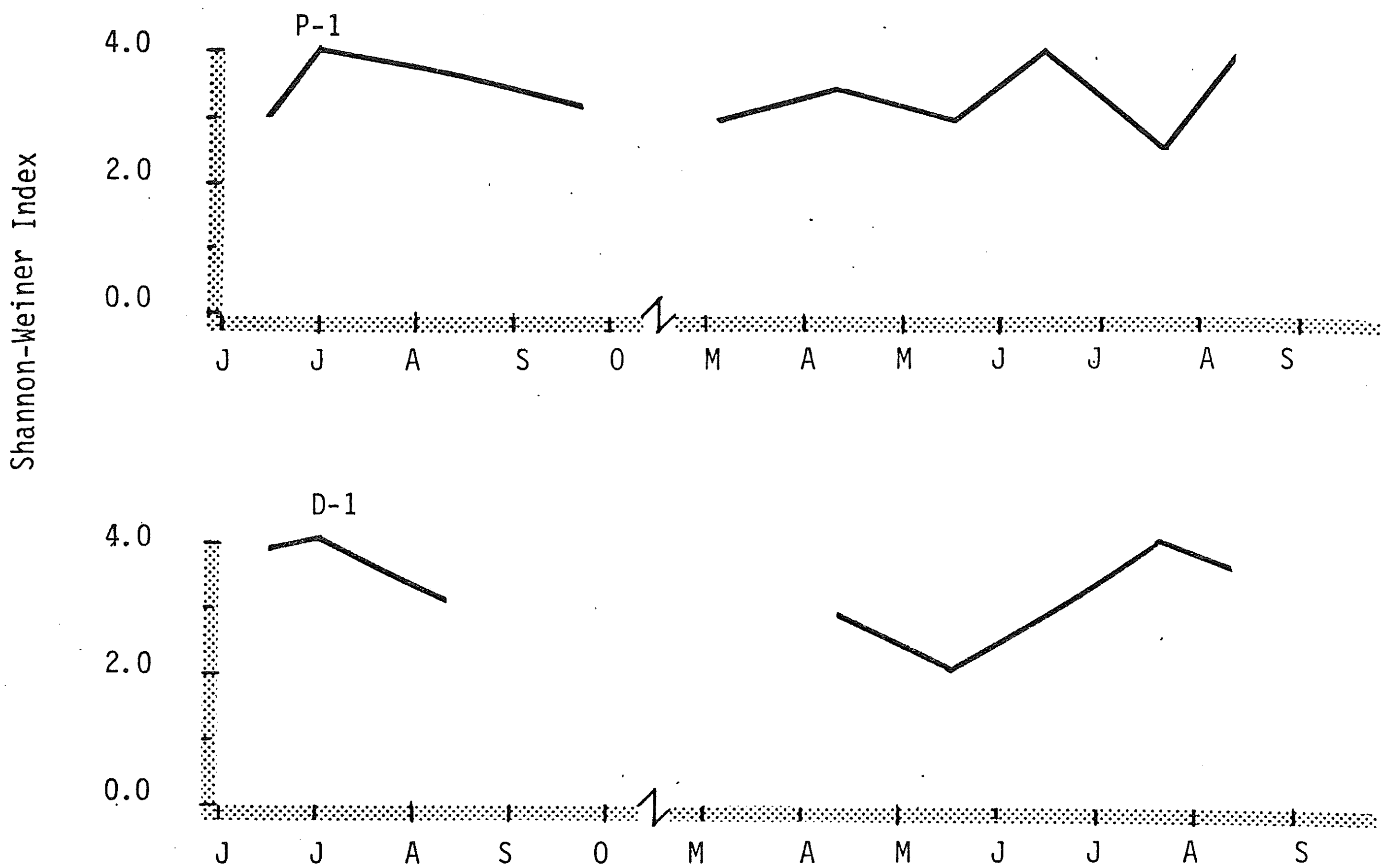

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Figure 7b. Shannon-Wiener diversity for stream orders one through five during 1977.

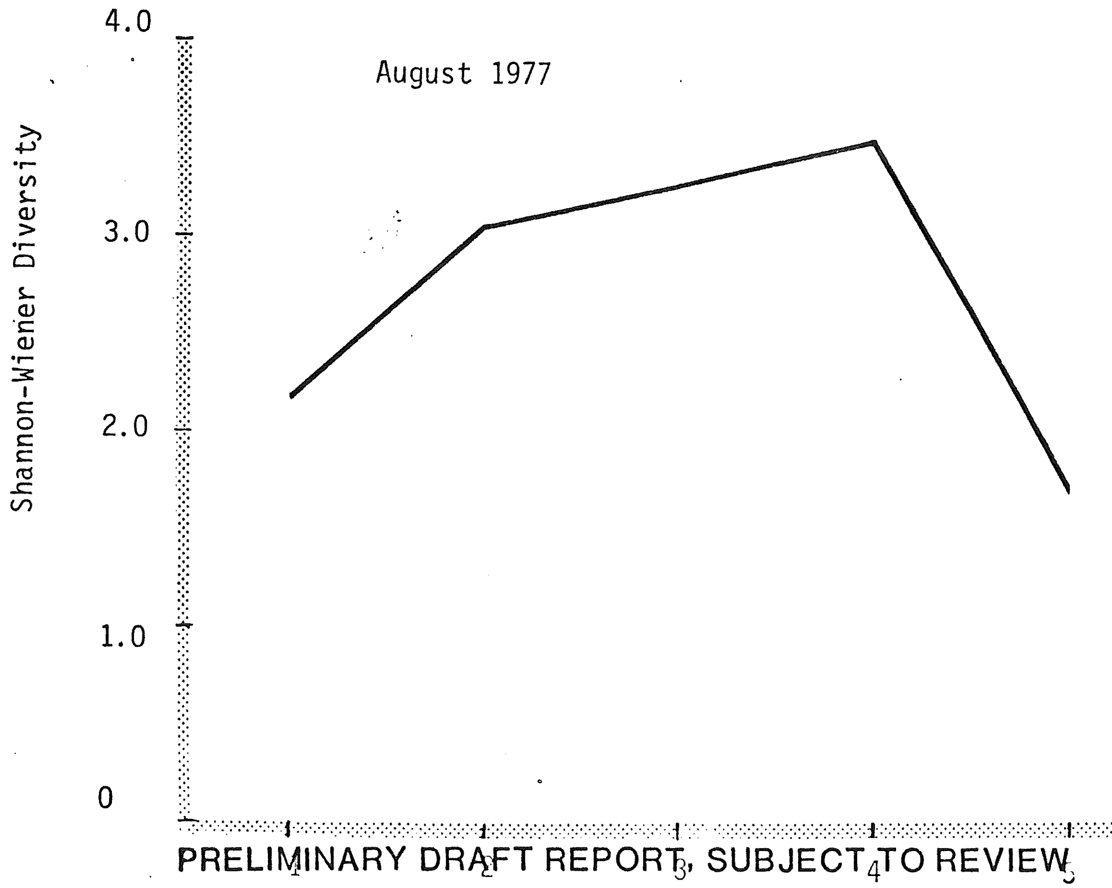

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Figure 8. Mean functional group relative abundance in stream orders one through five for all sites sampled in 1977. The mean relative abundance for each functional group represents the average percent relative abundance at all sites within a stream order sampled during April, May, June, July, August, and November 1977.

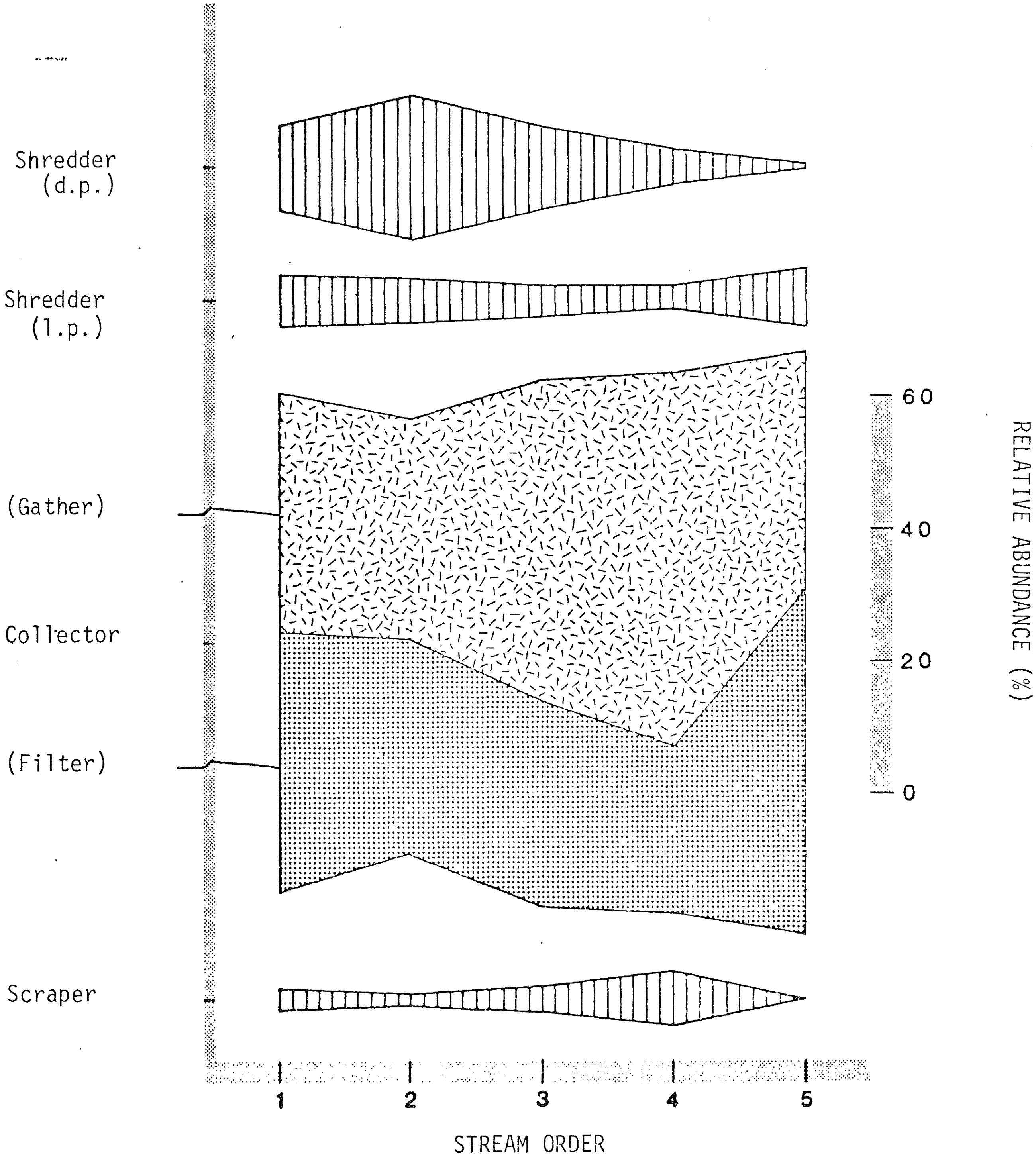

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Figure 9. Mean Functional group relative abundance at stream orders one through five in April/May and Augugust, 1977 (Data set #2).

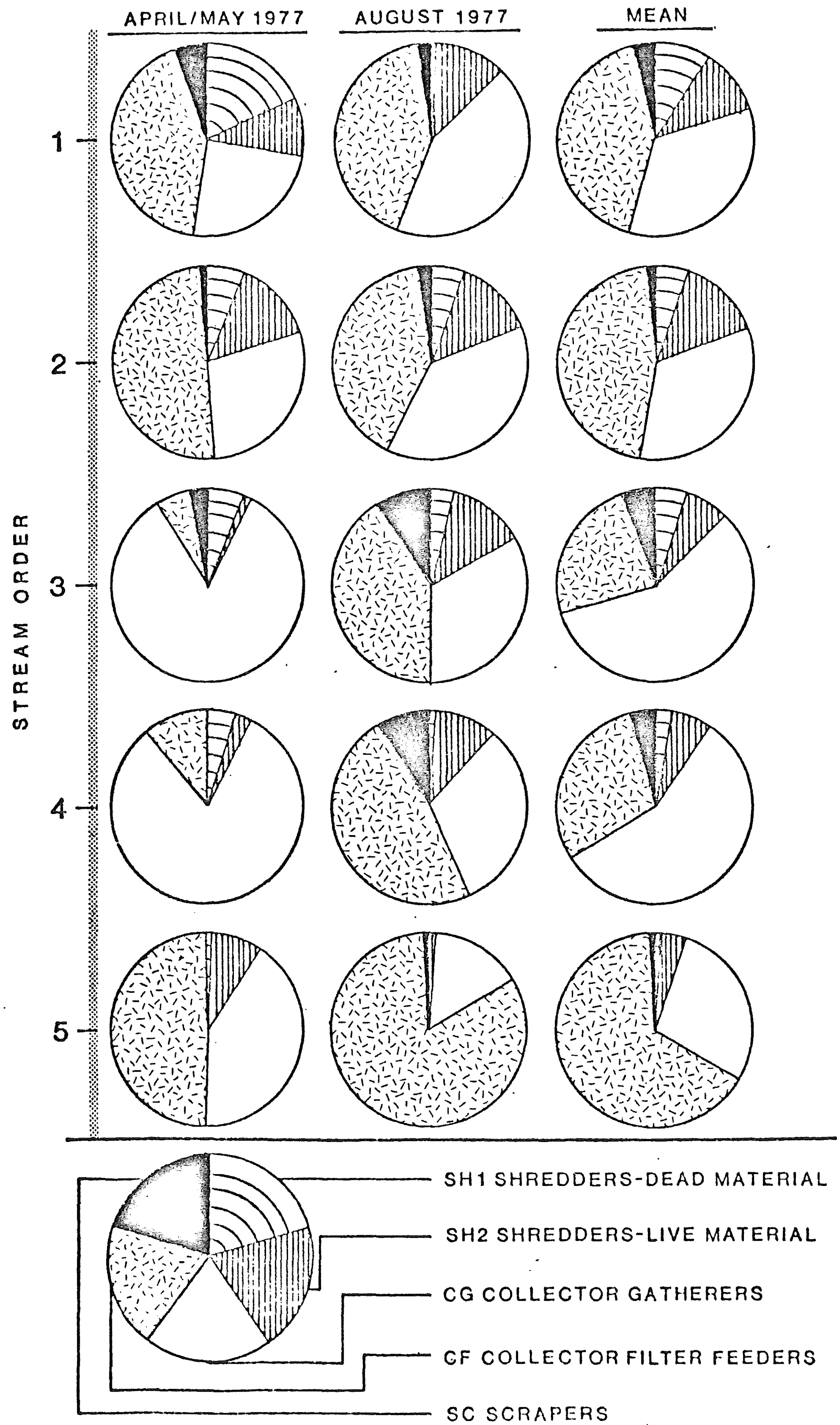

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Figure 10. The annual means (June, July, August, November, 1977) of four functional groups by stream order at the eight primary stream classification stations.

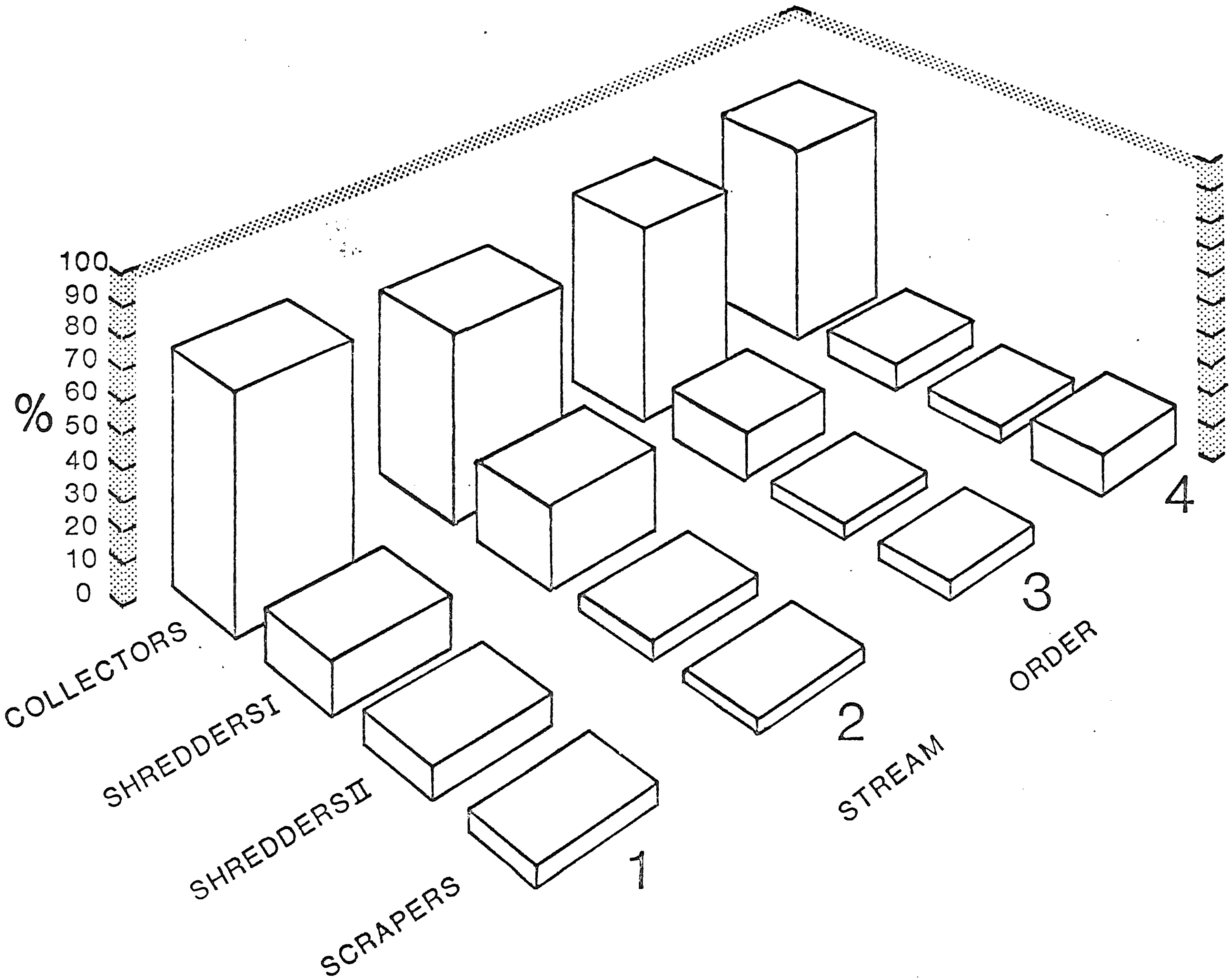

Figure 11. The mean shredder (dp) to collector (collectors plus filter-feeders) ratio of the eight primary stream classification stations during June, July, August and November, 1977.

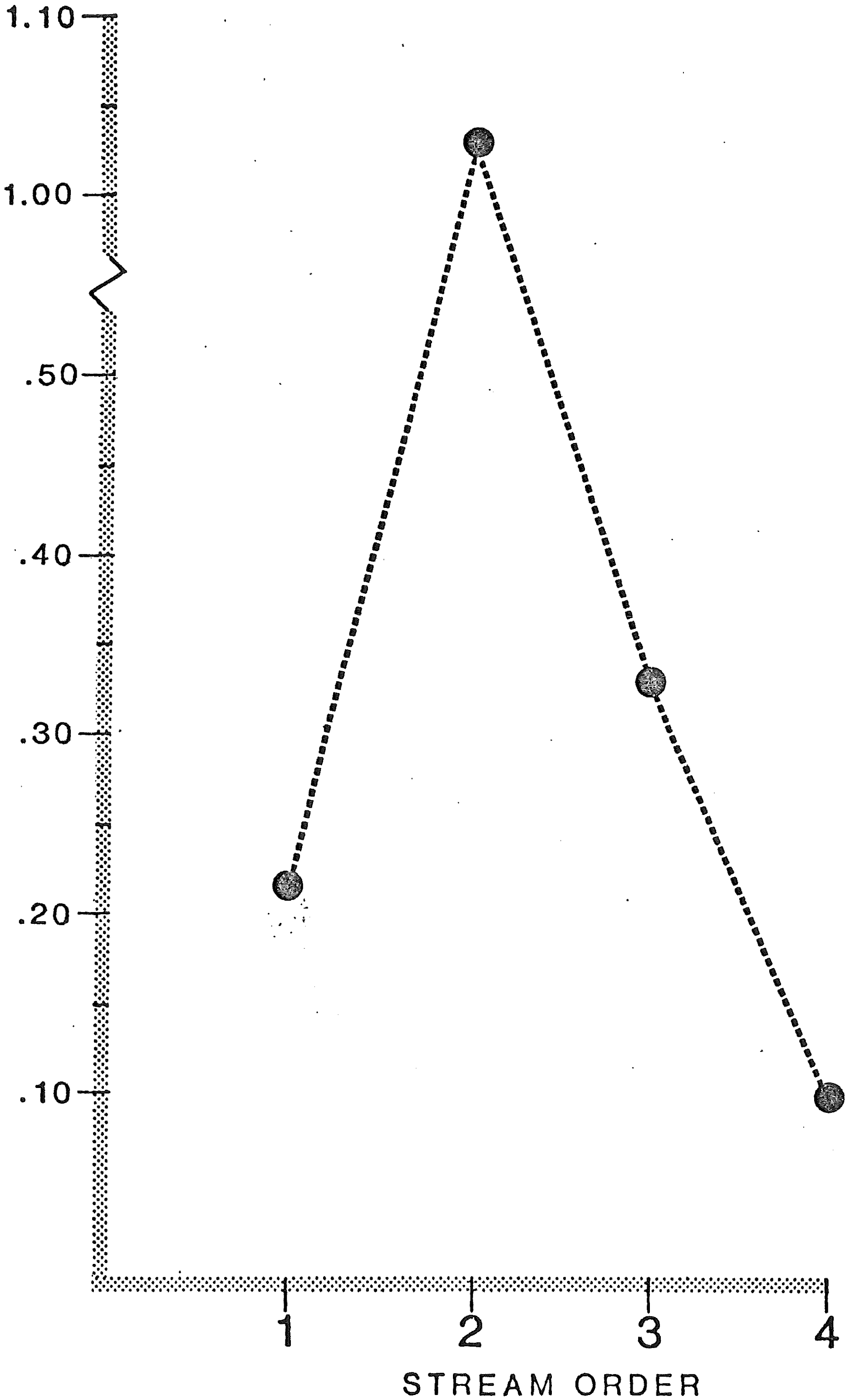

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Figure 12. Seasonal trends in functional groups relative abundance at stations P-1, SL-1, and SR 1/2.

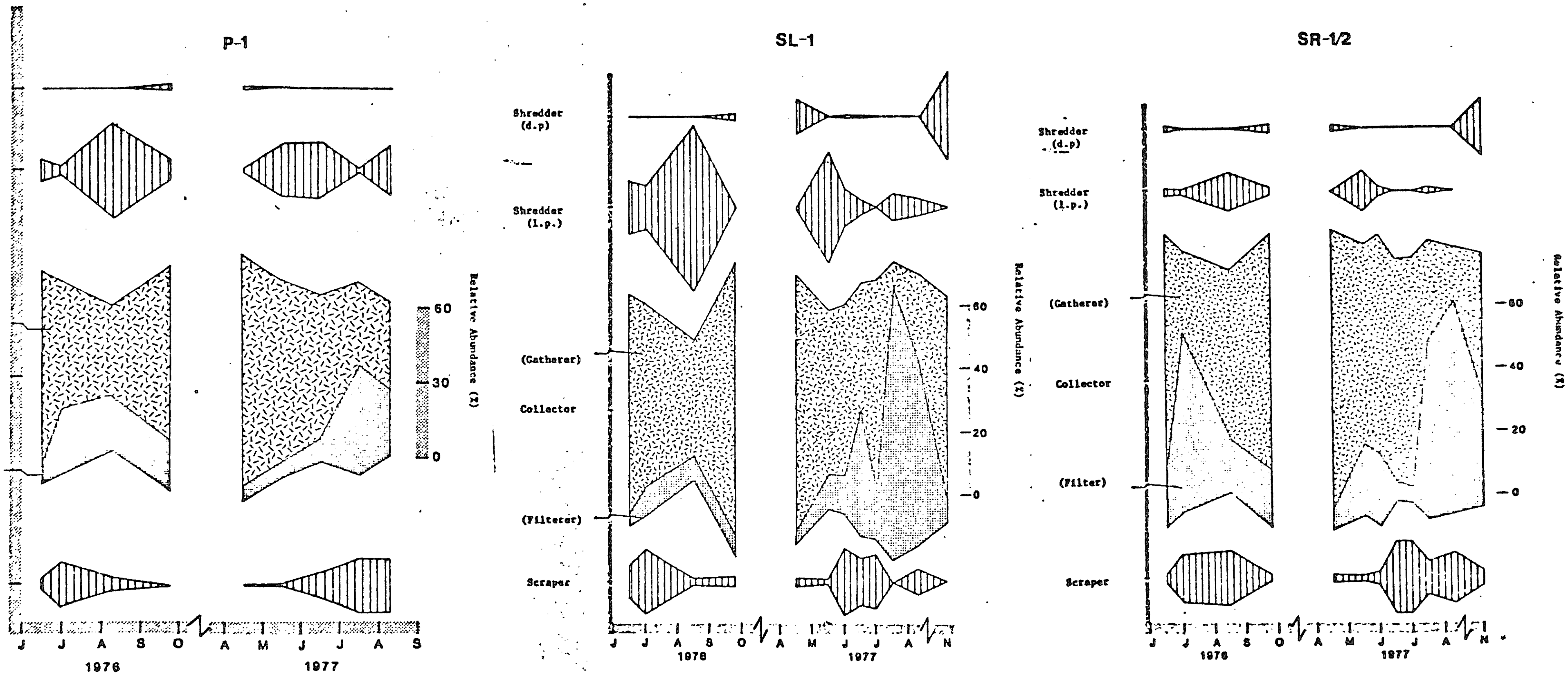
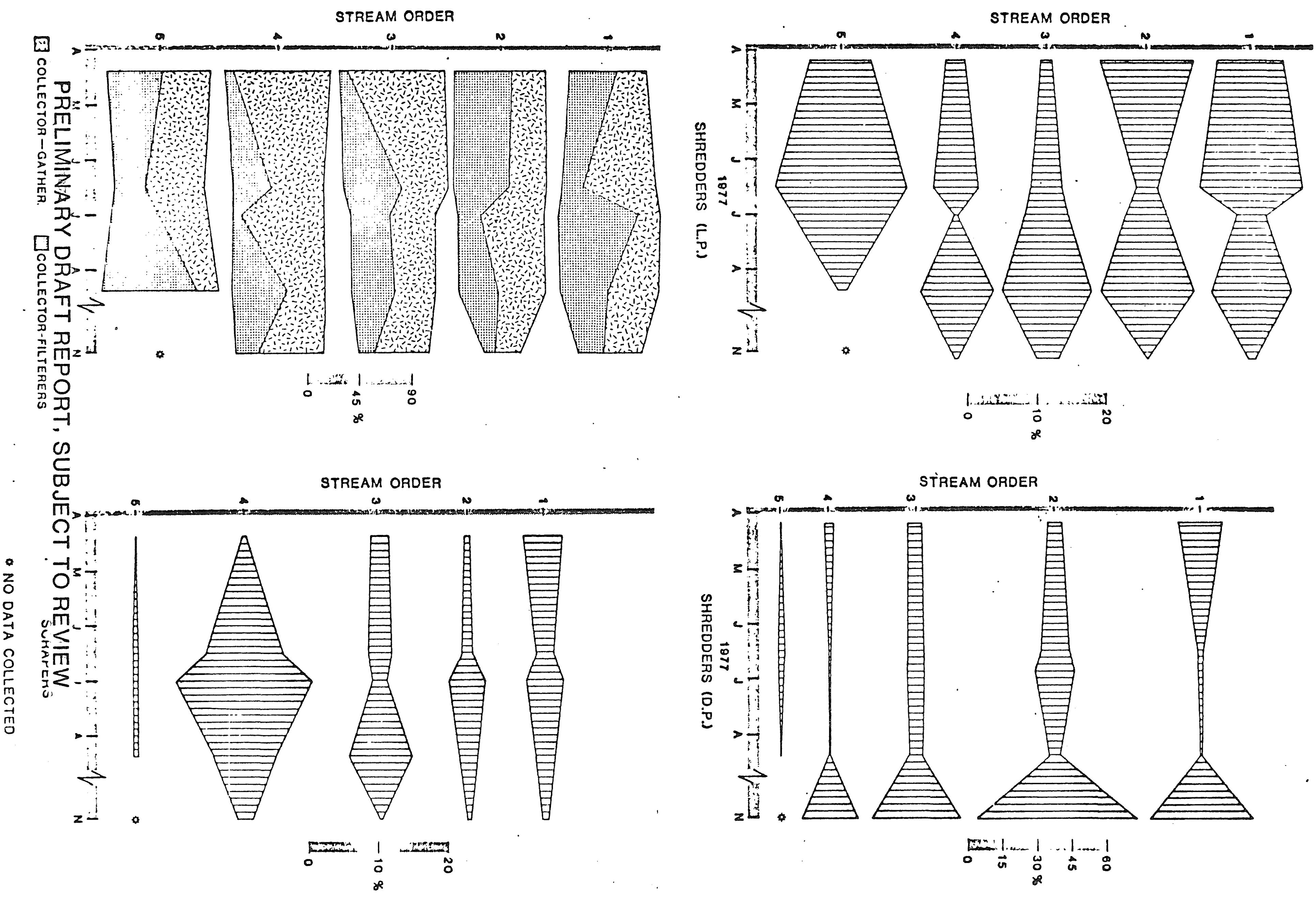


Figure 13. Seasonal trends in mean functional group relative abundance at stream orders one through five. Means calculated from all available data (data set #1).



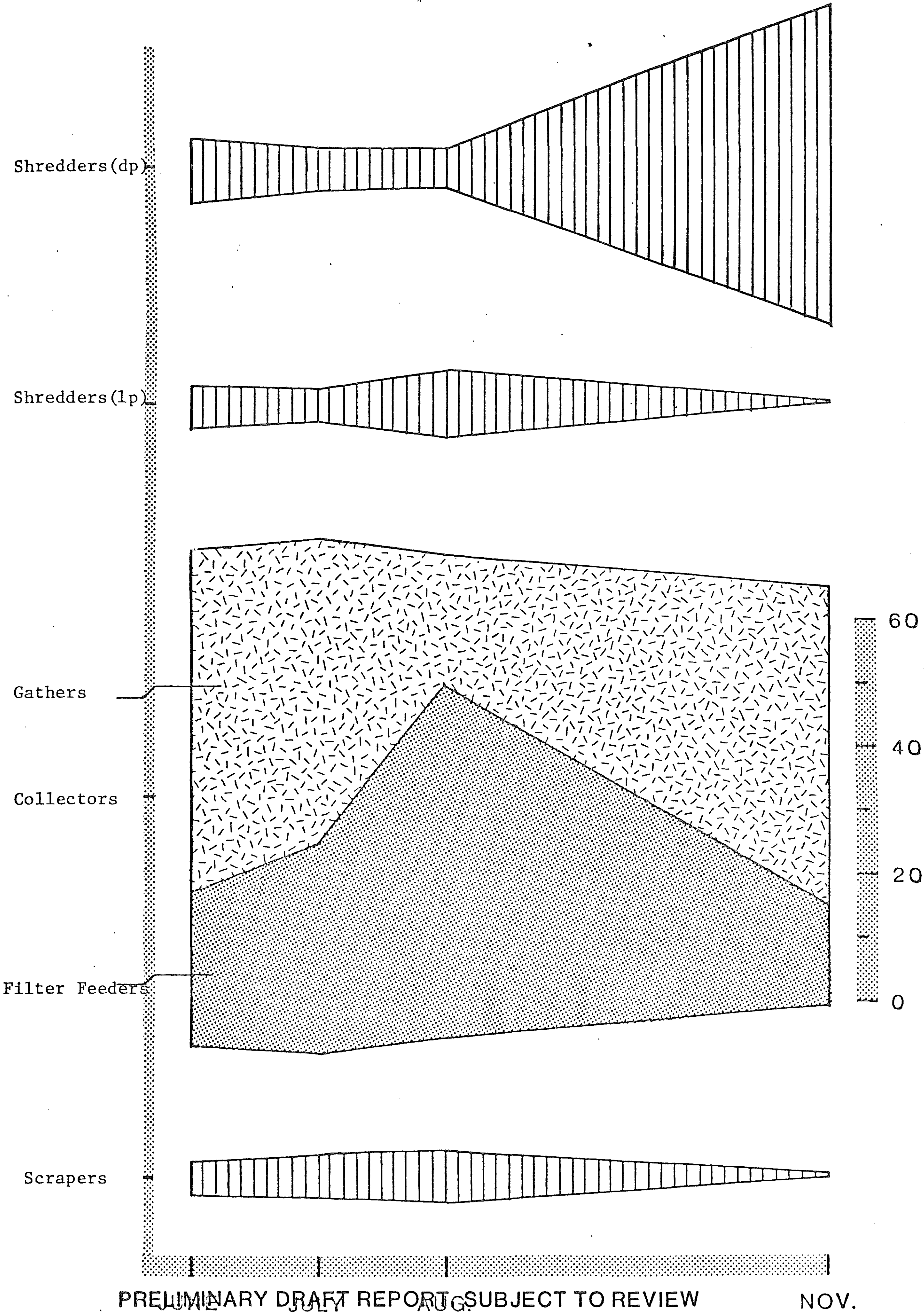


Figure 14. Mean relative abundance of invertebrate functional groups at the eight stream classification stations.

Figure 15. Seasonal trends in functional group relative abundance at stations D-1 and E-1 in 1976 and 1977.

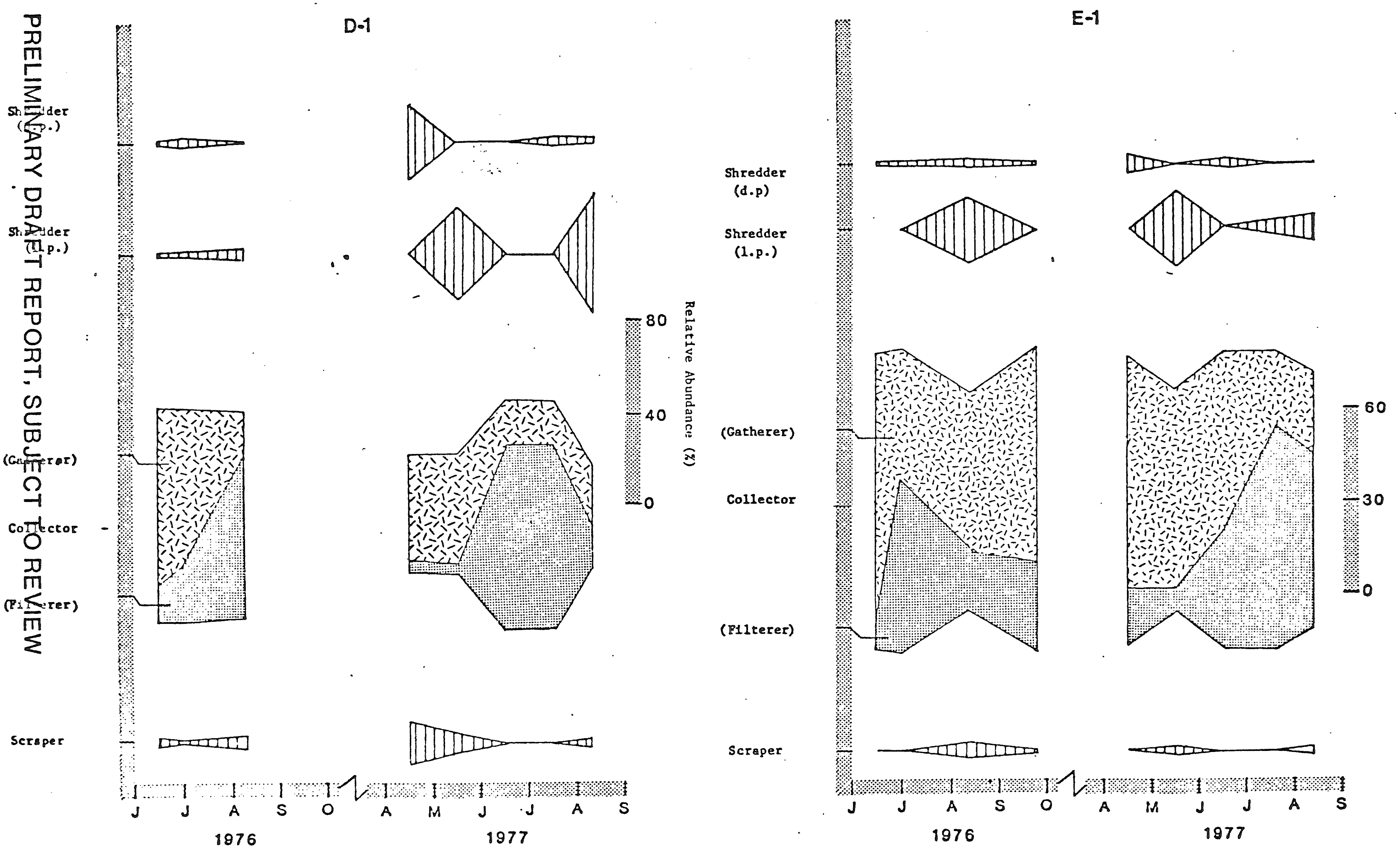


Figure 16. Seasonal trends in functional group relative abundance at stations P-5 and KC-1 during 1976 and 1977. These stations sampled only twice in 1977.

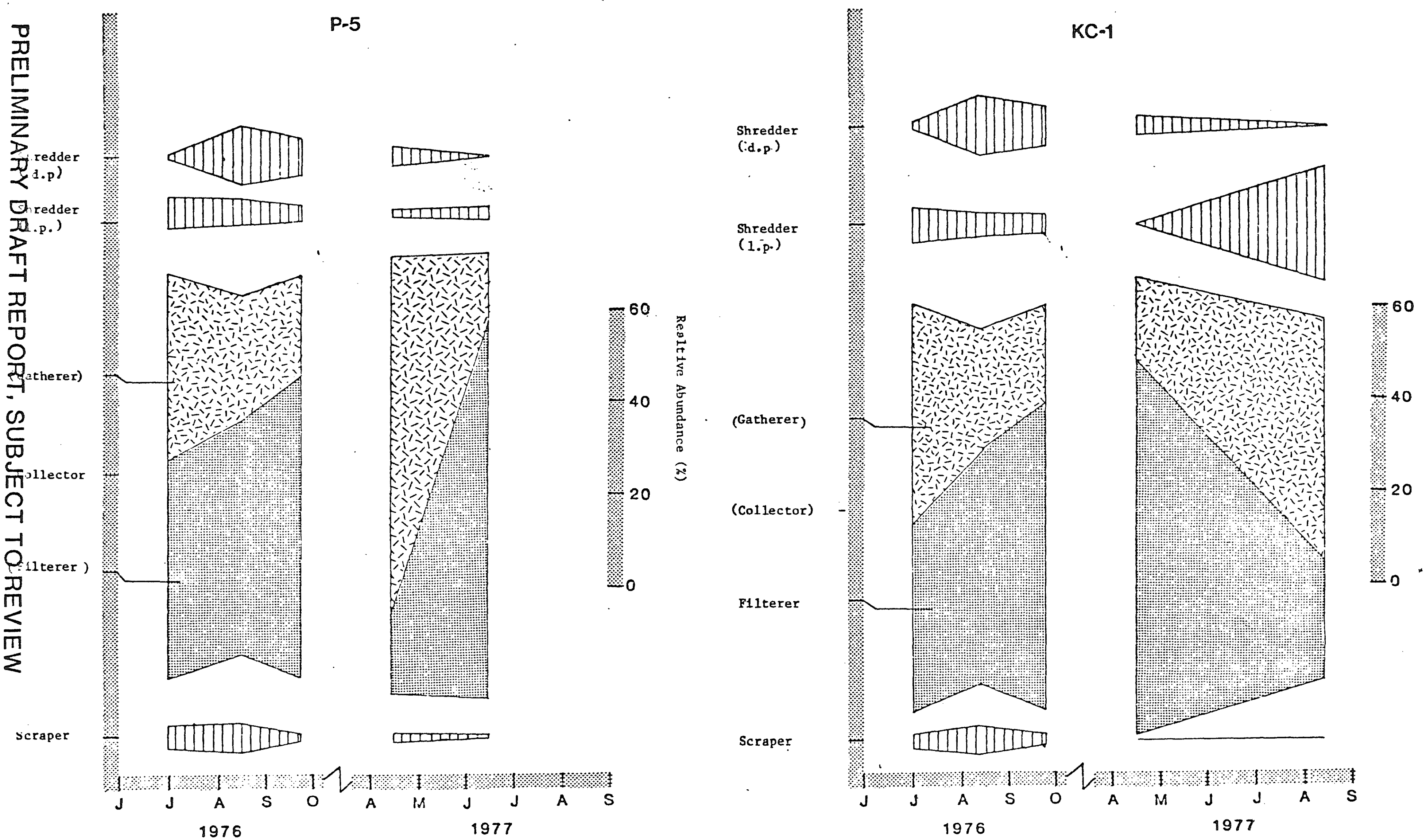
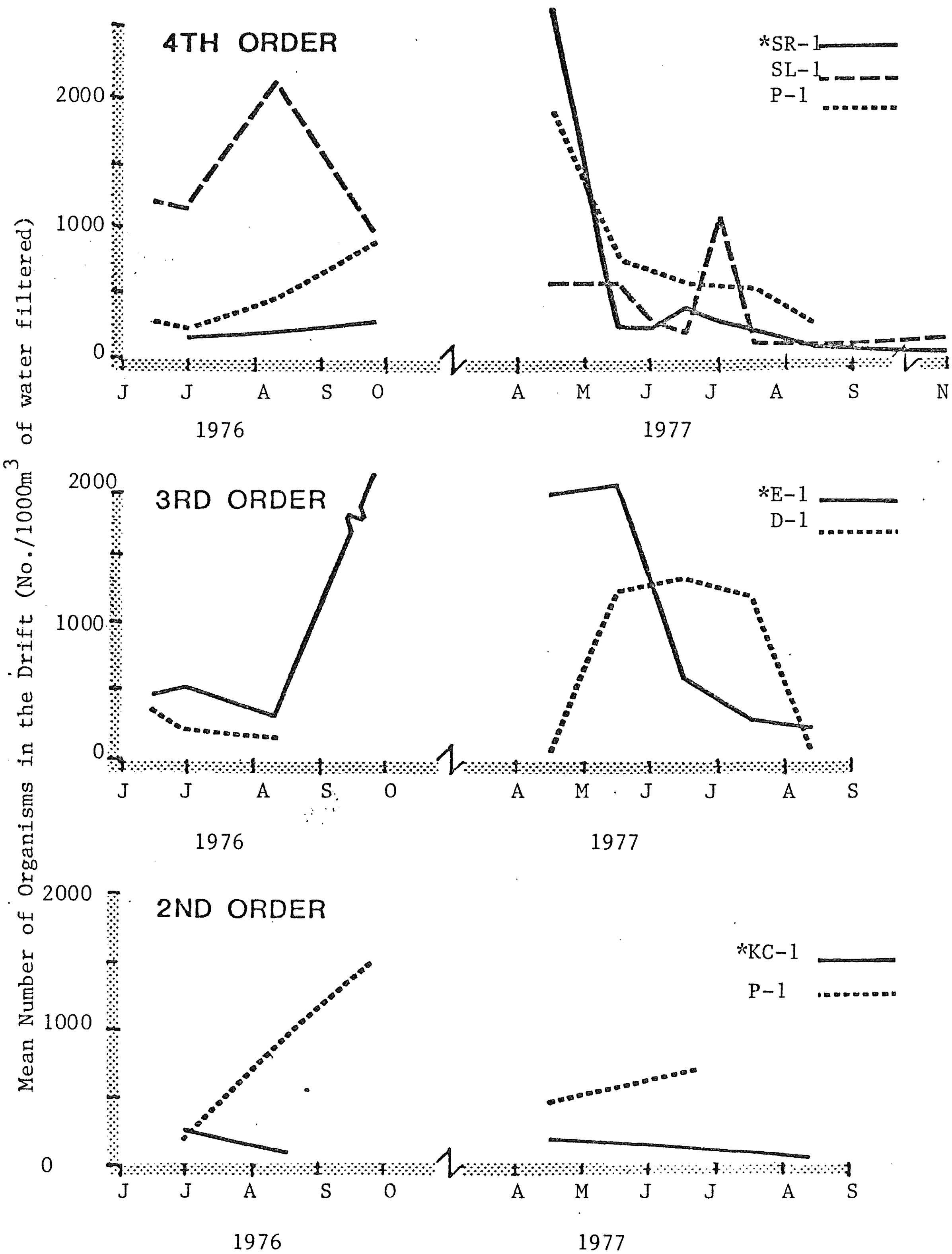


Figure 17. A comparison of total number of invertebrates drifting between sites receiving mine de-watering effluents and control sites. These data are mean number of organisms collected in three drift nets per $1000m^3$ of water filtered. Sites SR-1, E-1, and KC-1 act as controls for P-1 and SL-1, D-1, and P-5 respectively.



* control sites

Figure 18. Seasonal trends in functional group relative abundance at stations K-1 and K-8 in 1976 and 1977.

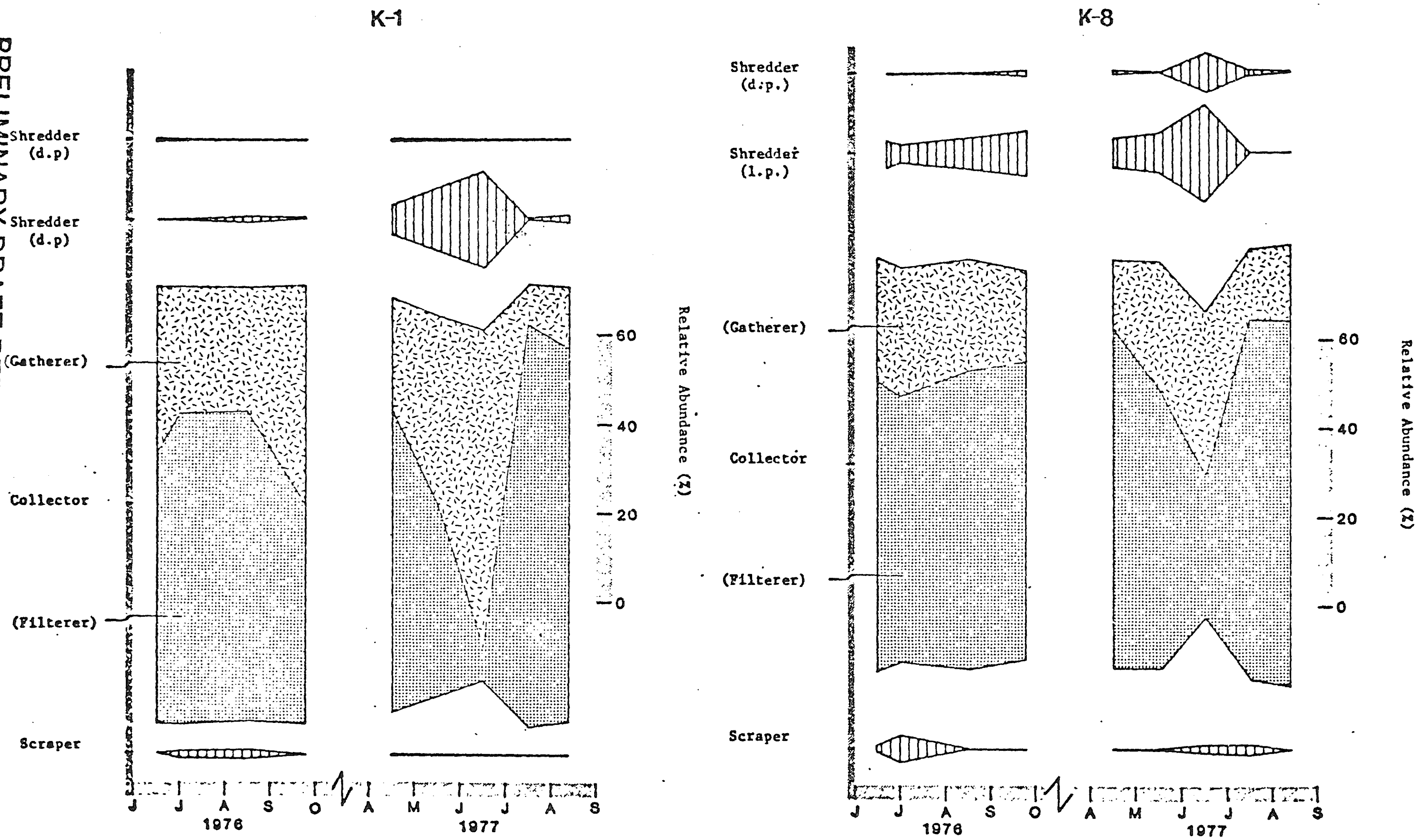


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Figure 19. Number of drifting organisms per 1000 m^3 collected at all sites in stream orders one through five during 1977.

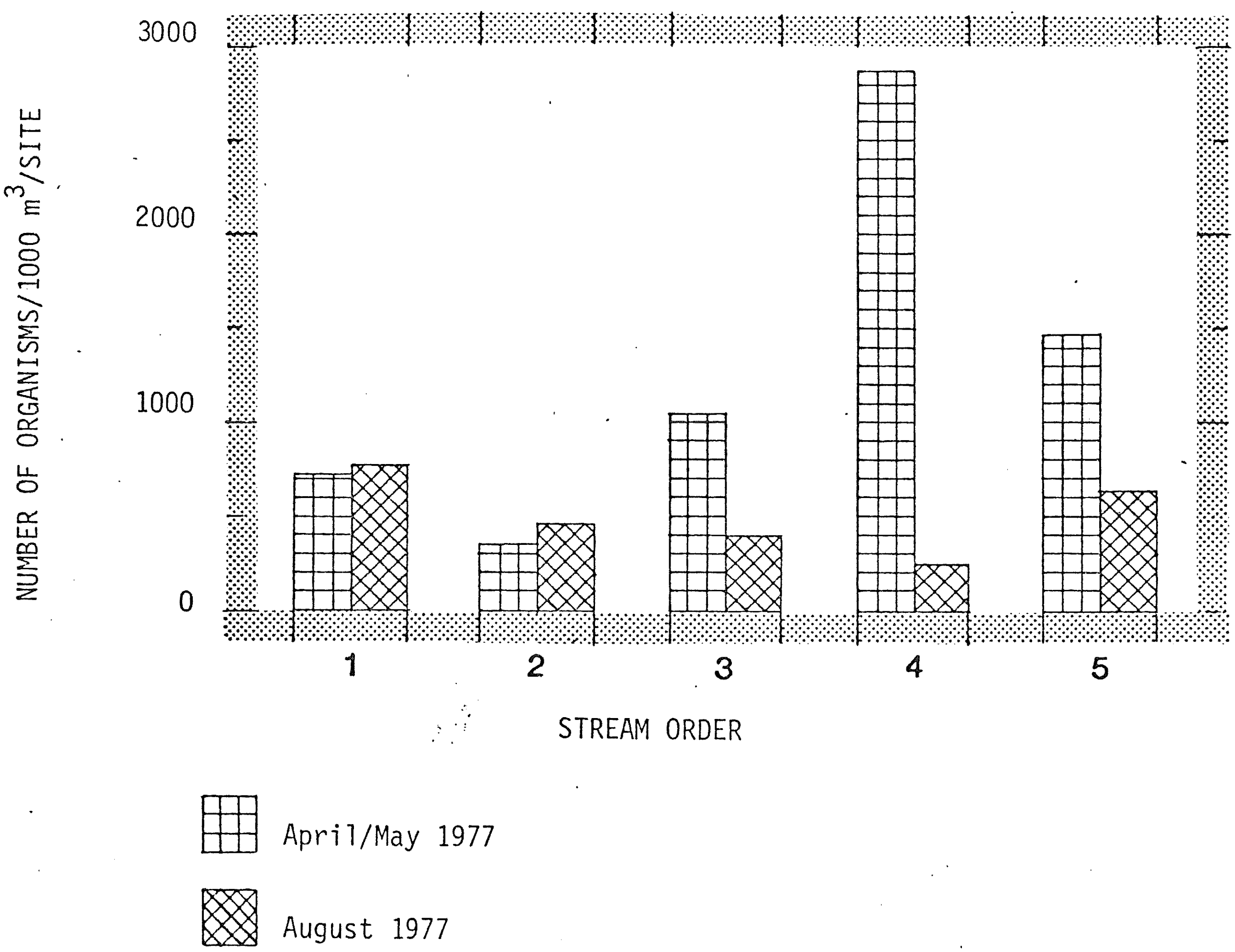

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Figure 20 The total number of organisms drifting by stream order at the eight primary stream classification stations in June, July, August, and November, 1977.

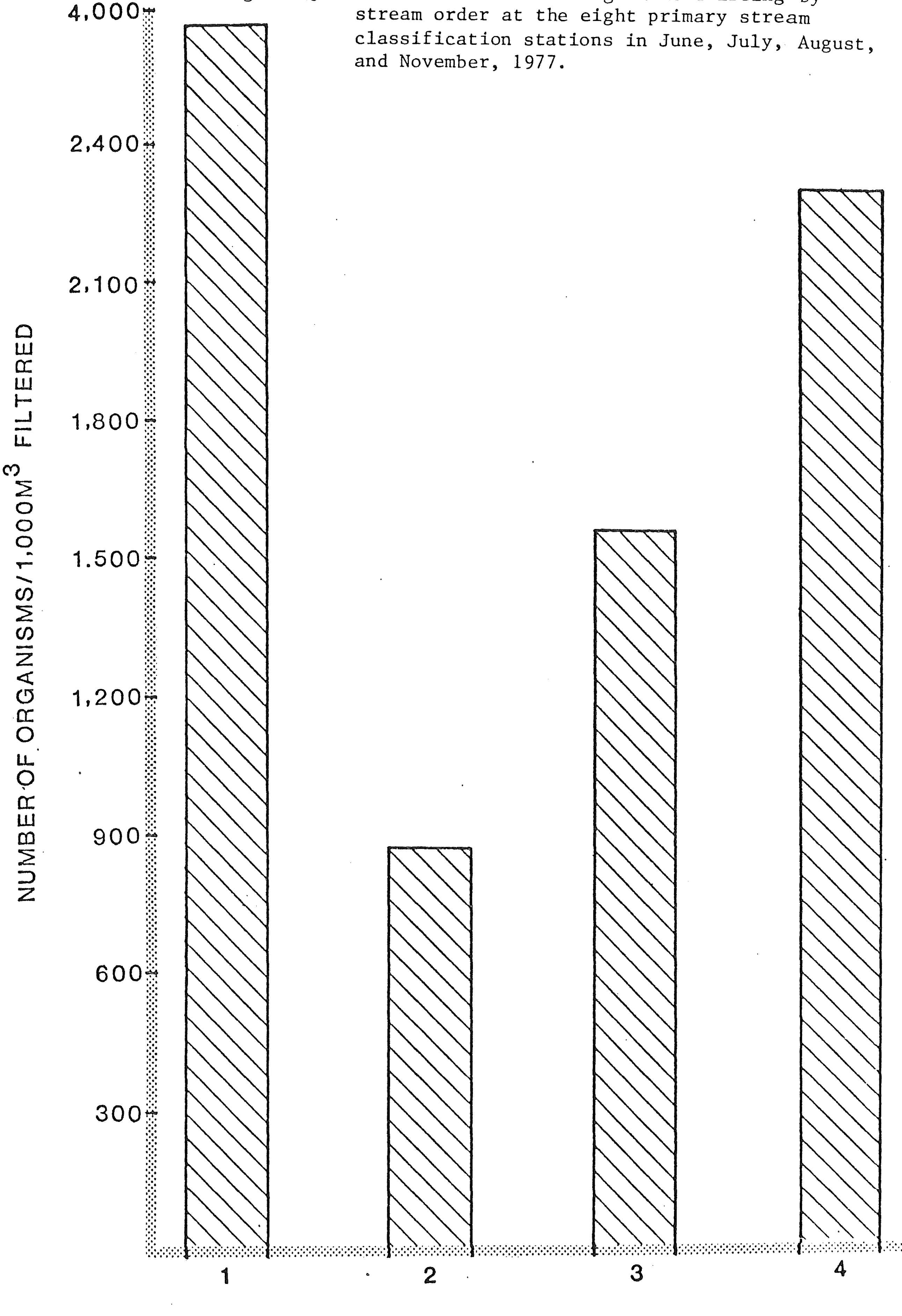

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Figure 21. Dendrogram of the cluster analysis of sites based on the functional group composition in April, 1977.

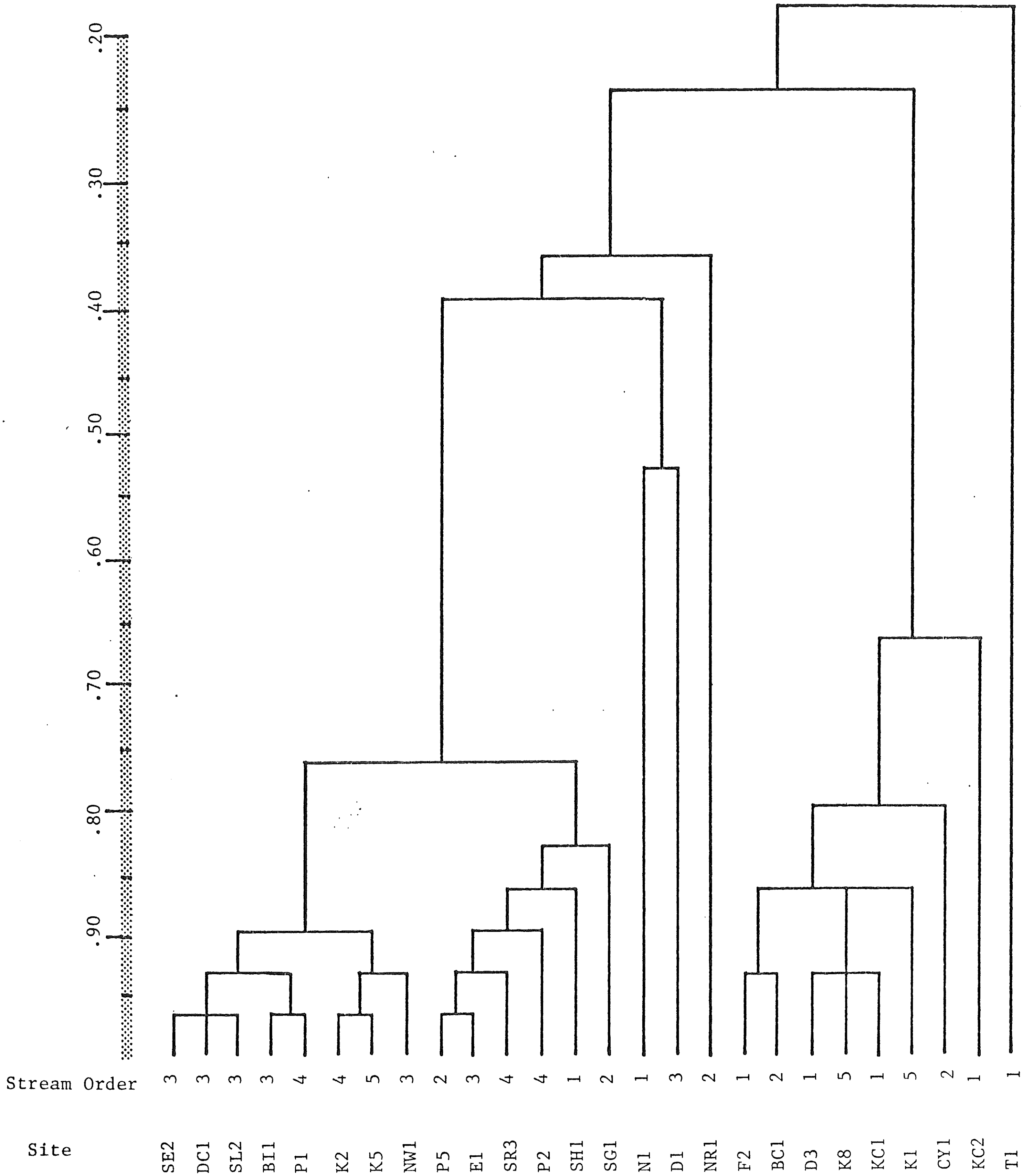

Figure 22. Dendrogram of the cluster analysis of sites based on the functional group composition in August, 1977.

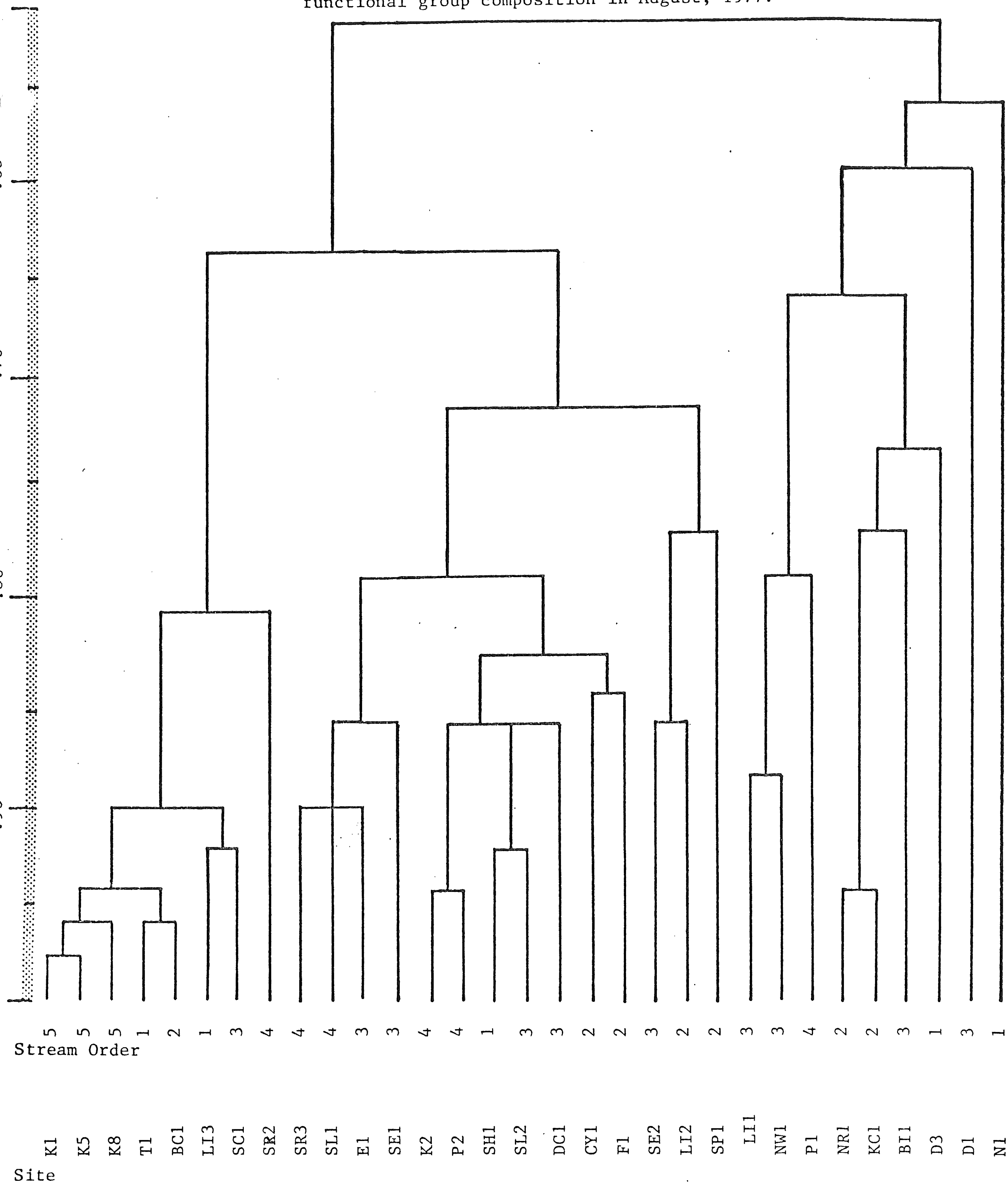

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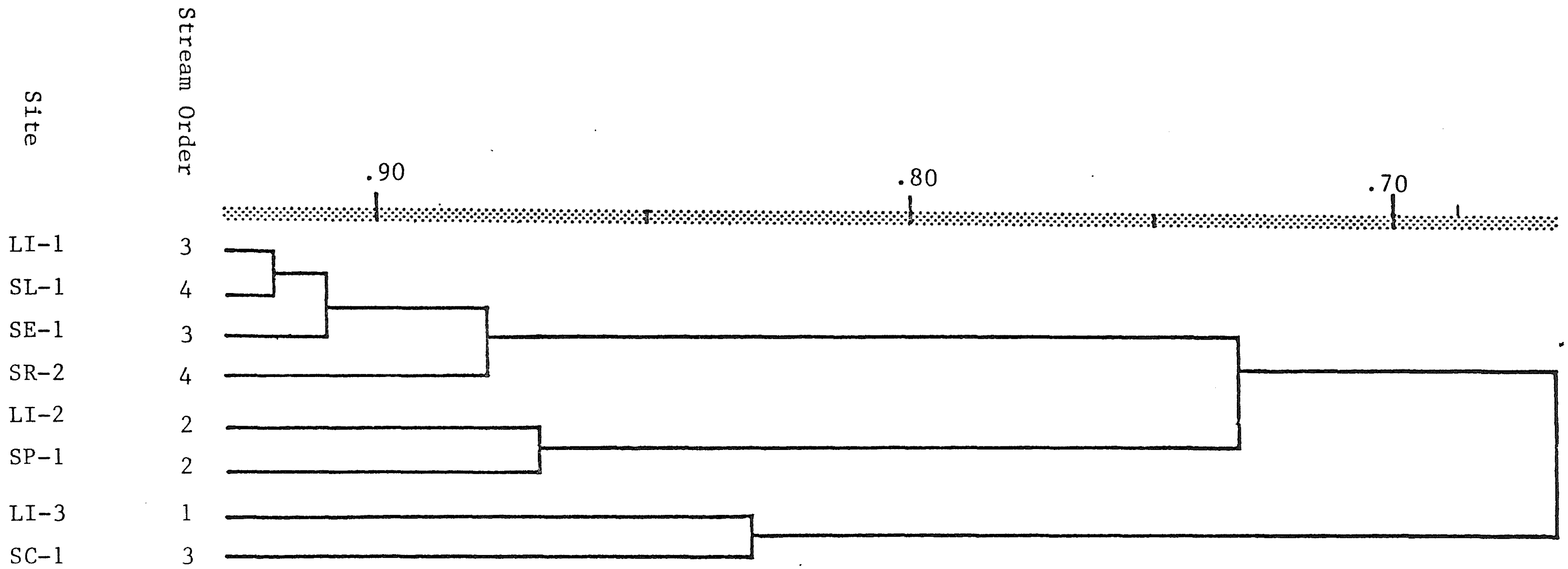
Figure 23. Dendrogram of the cluster analysis of sites based on mean functional group composition during June, July, August and November, 1977, at the eight primary stream classification stations.



Appendix 1. The taxa collected from all sites in 1976 and 1977 by qualitative and quantitative methods. Asterisks indicate identifications not verified by consultants.

Malacostraca
- Amphipoda
  - Talitridae
    - *Hyalella azeteca (Saussure)
  - Gammaridae
    - *Crangonyx sp.
  - Decopoda

Insecta
- Plecoptera
  - Pteronarcidae
    - Pteronarcys pictetii (Say)
  - Nemouridae
    - Amphinemura delosa Ricker
    - A. linda Ricker
    - Prostoia completa Walker
    - Shipsa rotunda Claassen
    - Podmosta macdunnoughi Ricker
  - Leuctridae
    - Leuctra ferruginea (Walker)
  - Capniidae
    - Allocapnia minima (Newport)
    - A. pygmaea (Burmeister)
    - *Capnia manitoba Classen
    - Paracapnia angulata Hanson
    - *P. opis (Newman)
  - Taeniopterygidae
    - Strophopteryx fasciata (Burmeister)
    - Taeniopteryx burski Ricker and Ross
    - T. nivalis (Fitch)
  - Perlidae
    - Acroneuria abnormis (Newman)
    - A. internata (Walker)
    - A. lycorias (Newman)
    - Neoperla clymene (Newman)
    - Paragnetina media (Walker)
    - Perlesta placida (Hagen)
    - Perlinella drymo (Newman)
    - Phasganophora capitata (Pictet)
  - Perlodidae
    - Isogenoides sp.
    - *Isoperla bilineata (Say)
    - I. dicala Frison
    - I. frisoni Illies
    - I. lata Frison
    - I. orata Frison
    - I. signata (Banks)
    - I. slossonae (Banks)
    - I. transmarina (Newman)
  - Chloroperlidae
    - Hastaperla brevis (Banks)

Ephemeroptera
  Siphlonuridae
    Isonychia sp.
    Siphlonurus alternatus (Say)
    S. marshalli Traver
  Heptageniidae
    Arthroplea bipunctata McDunnough
    Epeorus sp.
    Heptagenia flavescens (Walsh)
    H. hebe McDunnough
    Rhithrogena sp.
    Stenacron candidum (Traver)
    S. interpunctatum (Say)
    S. minnetonka (Daggy)
    Stenonema annexum traver
    S. exigumm Traver
    S. femoratum (Say)
    S. fuscum (Clemens)
    S. fuscum rivulicolum (McDunnough)
    S. integrum McDunnough)
    S. pulchellum (Walsh)
    S. quinquespinum Lewis
    S. rubrum McDunnough)
    S. smithae Traver
    S. terminatum (Walsh)
    S. tripunctatum (Banks)
  Metretopodidae
    Siphloplecton interlineatum (Walsh)
  Baetidae
    Baetis brunneicolor McDunnough
    B. flavistriga McDunnough
    B. hageni Eaton
    B. intercalaris McDunnough
    B. levitans McDunnough
    B. phyllis Burks
    B. pygmaeus (Gagen)
    B. vagans McDunnough
    Callibaetis sp.
    Cloeon sp.
    Heterocloeon curiosus (McDunnough)
    Pseudocloeon anoka Daggy
    P. carolina Banks
    P. cingulatum McDunnough
    P. dubium (Walsh)
    P. parvulum McDunnough
    Centroptilum sp.
  Leptophlebiidae
    Choroterpes basalis (Banks)
    Leptophlebia sp.
    Paraleptophlebia debilis (Walker)
    P. guttata (McDunnough)
    P. mollis (Eaton)
    P. praepedita (Eaton)
    P. volitans (McDonnough)

Ephemerellidae
- *Ephemerella attenuata* McDunnough
- *E. bicolor* Clemens
- *E. deficiens* Morgan
- *E. invaria* (Walker)
- *E. minimella* McDunnough
- *E. needhami* McDunnough
- *E. rotunda* Morgan
- *E. serrata* Morgan
- *E. simplex* McDunnough
- *E. sordida* McDunnough
- *E. subvaria* McDunnough
- *E. temporalis* McDunnough

Tricorythidae
- *Tricorythodes* sp.

Caenidae
- *Brachycercus* sp.
- *Caenis* sp.

Ephemeridae
- *Ephemera simulans* Walker
- *Hexagenia limbata* Serville
- *H. bilineata* (Say)
- *Litobrancha recurvata* (Morgan)

Polymitarcidae
- *Ephoron leukon* Williamson

Baetiscidae
- *Baetisca carolina* Traver
- *B. lacustris* McDunnough

Odonata

Calopterygidae
- *Calopteryx* sp.

Coenagrionidae
- *Argia apicalis* (Say)
- *Chromagrion conditum* (Hagen)
- *Enallagma* sp.
- *Ischnura/Anomalagrion* sp.

Cordulegastridae
- *Cordulegaster maculatus* Selys

Gomphidae
- *Dromogomphus spinosus* Selys
- *Hagenius brevistylus* Selys
- *Hylogomphus brevis* Hagen
- *Ophiogomphus aspersus* Morse
- *Stylogomphus albistylus* (Hagen)

Aeshnidae
- *Aeshna umbrosa* Walker
- *Basiaeschna janata* (Say)
- *Boyeria vinosa* (Say)

Macromiidae
- *Didymops transversa* (Say)
- *Macromia illinoiensis* Walsh

Corduliidae
- *Epitheca princeps* Hagen
- *Neurocordulia yamaskanensis* (Provancher)
- *Somatochlora linearis* (Say)

- *S. minor* Calvert
- *S. Williamsoni* Walker

- Hemiptera
  - Hebridae
  - Hydrometridae
    - **Hydrometra* sp.
  - Mesoveliidae
    - *Mesovelia* sp.
  - Gerridae
    - *Gerris remigis* (Say)
    - *Metrobates hesperius* Uhler
    - *Rheumatobates rileyi* Bergroth
  - Veliidae
    - *Rhagovelia obesa* Uhler
  - Notonectidae
    - *Buenoa* sp.
    - *Notonecta lunata* Hungerford
  - Pleidae
    - *Plea striola* Fieber
  - Naucoridae
    - **Pelocoris* sp.
  - Nepidae
    - *Ranatra* sp.
  - Belostomatidae
    - *Belostoma* sp.
    - *Lethocerus* sp.
  - Corixidae

- Trichoptera
  - Philopotamidae
    - *Chimarra feria* Ross
    - *C. obscura* (Walker)
    - *C. socia* Hagen
    - *Dolophilodes distinctus* (Walker)
  - Psychomyiidae
    - *Lype diversa* (Banks)
    - *Psychomyia flavida* Hagen
  - Polycentropodidae
    - *Neureclipsis* sp.
    - *Nyctiophylax moestus* Banks
    - *N. vestitus* (Hagen)
    - *Phylocentropus placidus* (Banks)
    - *Polycentropus centralis* Banks
    - *P. cinereus* Hagen
    - *P. interruptus* (Banks)
    - *P. remotus* Banks
  - Hydropsychidae
    - *Cheumatopsyche* sp.
    - *Hydropsyche betteni* Ross
    - *H. cuanis* Ross
    - *H. orris* Ross
    - *H. simulans* Ross
    - *H. slossonae* Banks
    - *Macronema zebratum* (Hagen)

Rhyacophilidae

- Rhyacophila vibox Milne

Glossosomatidae

- Agapetus sp.
- Glossosoma sp.

Hydroptilidae

- Agraylea sp.
- Hydroptila sp.
- Ithytrichia sp.
- Mayatrichia ayama Mosely
- Neotrichia sp.
- Ochrotrichia sp.
- Oxyethira sp.
- Stactobiella sp.

Brachycentridae

- Brachycentrus americanus (Banks)
- B. numerosus (Say)
- Micrasema sp.

Phryganeidae

- Agrypnia improba (Hagen)
- Banksiola crotchi Banks
- Phryganea cinerea Walker
- Ptilostomis sp.

Limnephilidae

- Glyphopsyche irrorata (Fabracius)
- Goera sp.
- Anabolia bimaculata (Walker)
- Hydatophylax argus (Harris)
- Limnephilus sp.
- Nemotaulius hostilis (Hagen)
- Neophylax nacatus Den
- Platycentropus sp.
- *Pseudostenophylax sp.
- Pycnopsyche suttifer (Walker)
- P. scabripennis (Rambur)

Lepidostomatidae

- Lepidostoma sp.

Sericostomatidae

- Agarodes distinctum Ulmer

Molannidae

- Molanna blenda Sibley
- M. tryphena Betten
- M. uniophila Vorhies

Helicopsychidae

- Helicopsyche borealis Hagen

Leptoceridae

- Ceraclea ancylus (Vorhies)
- C. annulicornis (Stephens)
- C. diluta (Hagen)
- C. maculata (Banks)

C. misca (Ross
C. neffi (Resh)
C. resurgens (Walker)
Mystacides sepulchralis (Walker)
Necotopsyche candida (Hagen)
Oecetis avara (Banks)
O. cinerascens (Hagen)
Triaenodes injusta (Hagen)
T. marginata Sibley
T. tarda Milne

Megaloptera
Corydalidae
Chauliodes rastricornis Ramur
Nigronia serricornis (Say
Sialidae
Sialis sp.

Neuroptera
Sisyridae
Climacia sp.
Sisyra sp.

Lepidoptera
Pyralidae
Nymphyla sp.
Paraponyx sp.

Coleoptera
Haliplidae
Haliplus sp.
Dytiscidae
Acilius sp.
Agabus sp.
Deronectes sp.
Hydrophorus sp.
Laccophilus maculosus (Germar)
Liodessus affinis (Say)
Neoscutopterous angustus (LeConte)
Rhantus sp.
Chrysomelidae
Domacia sp.
Gyrinidae
Dineutus hornii Roberts
Gyrinus bifarius Fall
G. borealis Aube
Hydrophilidae
Anacaena sp.
Berosus sp.
Crenitis digestus group
Cymbiodyta acuminata Fall
Enochrus ochraceus Melsh

Helophorus sp
Sperchopsis tessellatus (Ziegler)
Tropisternus blatchleyi d'Orchymont
Hydraenidae
Hydraena sp.
Psephenidae
Ectopria nervosa (Melsheimer)
Elmidae
Ancronyx variegata (Germar)
Dubiraphia quadrinotata (Say)
Macronychus glabratus Say
Optioservus fastiditus (LeConte)
O. trivittatus (Brown)
Stenelmis crenata (Say)

Diptera
Tipulidae
Antocha sp.
Dicranota sp.
Helius sp.
Hexatoma (Eriocera) cinerea Alexander
Limonia sp.
*Pedicia sp.
Pseudolimnophila sp.
Tipula sp.
*Psychodidae
Blephariceridae
Blepharicera tenuipes (Walker)

Culicidae
Aedes communis (Degeer)
Anopheles punctipennis (Say)
Chaoboridae
Chaoborus sp.
Simuliidae
Prosimulium sp.
Cnephia sp.
Simulium sp.
Eusimulium eurymandiculum Davies
Byssodon ruggelsi Nicholson and Mickel
Chironomidae
Tanypodinae
Ablabesmyia sp.
Clinotanypus sp.
Coelotanypus sp.
Conchapelopia sp.
Larsia sp.
Nilotanypus sp.
Pentaneura sp.
Procladius sp.
Psectrotanypus sp.
Tanypus sp.
Zavrelimyia sp.

Chironominae
- *Chironomus* sp.
- *Cryptochironomus* sp.
- *Dicrotendipes* sp.
- *Einfeldia* sp.
- *Endochironomus* sp.
- *Glyptotendipes* sp.
- *Micropsectra* sp.
- *Microtendipes* sp.
- *Parachironomus* sp.
- *Paratendipes* sp.
- *Phaenopsectra* sp.
- *Polypedilum* sp.
- *Rheotanytarsus* sp.
- *Stenochironomus* sp.
- *Stictochironomus* sp.
- *Tanytarsus* sp.
- *Tribelos* sp.
- *Xenochironomus* sp.
- *Nilothauma* sp.
- *Pseudochironomus* sp.
- *Paracladopelma* sp.
- *Lauterborniella* sp.
- *Zavrelia* sp.

Diamesinae
- *Diamesa* sp.
- *Potthastia* sp.

Podonominae
- *Lasiodiamesa* sp.

Orthocladinae
- *Brillia* sp.
- *Cardiocladius* sp.
- *Coryneura* sp.
- *Cricotopus* sp.
- *Diplocladius*
- *Epoicocladius* sp.
- *Eukiefferiella* sp.
- *Heterotrissocladius* sp.
- *Orthocladius* sp.
- *Parametreocnemus* sp.
- *Psectrocladius* sp.
- *Rheocricotopus* sp.
- *Smittia* group
- *Thienemanniella* sp.
- *Trissocladius* sp.

Ceratopogonidae
- *Palpomyia* group

Streatiomyiidae
- *Odontomyia* sp.

Athericidae
- *Atherix variegata* Walker

Tabanidae
Chrysops sp.
Empididae
*Phoridae
Syrphidae
Helophilus sp.

Arachnida
Acari
Mollusca
Gastropoda
Physidae
*Physa sp.
Lymnaeidae
*Stagnicola sp.
Planorbidae
*Gyraulus sp.
*Helisoma sp.
Ancytidae
*Ferrissia sp.
Viviparidae
Campeloma sp.

Pelecypoda
Sphaeriidae

APPENDIX II

Comparison of the Invertebrate Fauna of Pools and Riffles in the Regional Copper-Nickel Study Area.

INTRODUCTION

RESULTS

TABLE 1. Habitat preference of aquatic invertebrates collected in the Study Area.

TABLE 2. Habitat preference of aquatic invertebrates collected in the Study Area by functional group.

TABLE 3. Summary of habitat preference of the various orders of aquatic invertebrates collected in the Study Area.

INTRODUCTION

Invertebrate species exhibit habitat preference for the two main stream habitat types: riffles and pools. While most species exhibit a definite habitat preference, some species can be found in either habitat. Riffles are areas in streams with a continuous current which is often turbulent. Wave/action along lake shores often produces an environment similar to riffles. Pools are defined as areas of streams, ponds, or lakes where current is either nonexistant or slow enough where it has no effect on the immediate environment. At certain times of the year pools and riffles are well defined although during periods of high flow the entire stream will resemble a riffle.

To determine the habitat preference of the aquatic invertebrates in the Study Area, qualitative samples were collected from riffle and pool areas of streams in the Study Area during the spring and summer of 1977. The following report lists the taxa collected as either riffle, pool, or faculatative riffle invertebrates, those taxa with no obvious preference.

RESULTS

Qualitative invertebrate samples were collected from riffles and pools of streams in the Study Area during April and August of 1977. There were 76 samples collected from riffles and 74 samples from pools. The number of organisms of each taxon collected was multiplied by their frequency of occurance in riffles and pools to obtain a coefficient of occurance for each taxon in each habitat. The invertebrates were then listed phylogenetically as either riffle, pool, or faculative riffle organisms according to their coefficient of occurrence (Table 1). If the coefficient of occurrence was below 15 or if it was approximately equal for both the riffle and pool areas for any organism, the literature was surveyed to determine the habitat preference of these taxa. Table 2 lists the invertebrates in phylogenetic order within their functional groups as described by Cummins (1976) and Merritt and Cummins (1978). Based on Table 3 the following general observations can be made:

1) Riffle areas were inhabited by more taxa than pool areas. Eighty-five genera and 61 species were found in riffles while 56 genera and 17 species were considered pool organisms. Only 30 genera and 13 species are faculative riffle organisms.

2) More Diptera taxa were collected than any other order. The largest number of genera were considered riffle and facultative riffle organisms; the second largest number of genera were found in pools.

3) Plecopterans were found almost entirely in riffle areas. Of the 15 genera collected, only Amphinemura linda was found more abundantly in pools.

4) Of the ten mayfly (Ephemeroptera) families, five were primarily collected in riffles and four were found entirely in pools.

5) Trichopterans in general preferred flowing water; 12 tricopteran families were found in riffles. Five caddisfly families consisted primarily of pool invertebrates.

6) Odonates, hemipterans, and coleopterans preferred pool habitats. The odonate family Gomphidae, the coleopteran family Elmidae, and the hemipterans Rhagovelia sp., and Metrobates, were exceptions, they preferred riffle areas.

Shredders of live and dead plant material, collector-gathers, and engulfing predators appear to have no preference for either riffle or pool environments. Collector filter-feeders were found almost entirely in riffle areas as were scrapers. Piercing herbivores and predators were collected mainly in pools.

The majority of the organisms collected from the spring and summer sampling periods were riffle organisms. Of 171 genera, 50 percent were riffle invertebrates, 33 percent were from pools and 17 percent were faculative pool organisms. Several invertebrates were found to prefer pools, but according to the literature should have been equally or more abundant in riffles. These include: the plecopteran, _Amphinemura linda_; the ephemeropterans, _Stenonema tripunctatum_, _Siphloplecton interlineatum_, _Choroterpes_ and _Paraleptophlebia praepedita_; _Pycnopsyche_, a trichopteran genus; and the odonate family Cordulegastridae.

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Merritt R.W. and K.W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendal-Hunt, Dubuque.

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area (co = occurance coefficience).

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
PLECOPTERA	Plecoptera	0				
Pteronarcidae	Pteronarcys sp.	1				
Nemouridae	Prostoia completa*	1	Amphinemoura linda	1		
	Shipsa rotunda	1				
	Podmosta macdunnoughi	1				
Leuctridae	Leuctra sp.*	1				
	L. ferruginea*	1				
Capniidae	Paracapnia sp.*	1				
	P. angulata	1				
Taeniopterygidae	Strophopteryx fasciata*	1				
	Taeniopteryx burksi*	1				
Perlidae	Acroneuria sp.	8				
	A. lycorias	8				
	Neoperla clymene*	8				
	Paragnetina media	8				
	Perlinella drymo*	8				
	Perlista placida*	8				
	Phasganophora capitata*	8				
Perlodidae	Isoperla sp.	8				
	I. dicala*	8				
	I. slossonae*	8				
	I. transmarina	8				
EPHEMEROPTERA						
Siphlonuridae	Isonychia sp.	4	Siphlonurus sp.*	3		
Heptageniidae	Epeorus sp.*	5	Stenacron sp.	3		
	Heptagenia sp.	5	S. interpunctatum	3		
	H. hebe	5	S. minnetonka*	3		
	Stenonema sp.	3				

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
EPHEMEROPTERA						
Heptageniidae continued	S. annexum*	3	Stenonema tripunctatum	3		
	S. fuscum	3				
	S. puchellum	3				
	S. rubrum*	3				
	S. smithae*	3				
Metretopodidae	Sipholplecton sp.*	8	Siphloplecton interlineatum	8		
Baetidae	Baetis sp.	3				
	B. hageni					
					Bactis pygmaeus*	
	B. flavistriga group	3				
	B. vagans*	3				
	Heterocloeon curiosum	3	Callibaetis sp.	3		
	Pseudocloeon sp.	5	Cloeon sp.	3		
	P. carolina	5				
	P. cingulatum	5				
	P. dubium	5				
	P. parvulum*	5				
	Centroptilum sp.*	3				
Leptophlebiidae			Choroterpes sp.	5	Choroterpes basalis*	
	Paraleptophlebia sp.	3	Leptophlebia sp.	5		
	P. mollis	3	Paraleptophlebia praepedita	3		
Ephemerellidae	ephemerella sp.	3				
	E. bicolor*	3	Ephemerella temporalis	3		
	E. invaria	3				
	E. rotunda	3				
	E. subvaria	3				
Tricorythidae			Tricorythodes sp.	3		

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
EPHEMEROPTERA continued						
Caenidae			Caenis sp.	3		
Ephemeridae			Ephemera sp	3		
			Hexagenia sp.	3	Ephemera simulans	3
			H. limbata	3		
			Litobrancha recurvata	3		
Baetiscidae			Baethisca sp.*	3		
			B. carolina	3		
			B. obesa*	3		
TRICHOPTERA	Trichoptera	0				
Philopotamidae	Chimarra sp.	4				
	C. feria	4				
	C. obscura	4				
	C. socia	4				
	Dolophilodes distinctus*	4				
Psychomyiidae	Psychomyia sp.*	4				
	P. flavida*	4				
Polycentropodidae	Neureclipsis sp.	4				
	Nyctiophylax moestus	8			Polycentopus sp.*	8
	Polycentropus centralis*	8	Polycentropus cinereus	8		
Hydropsychidae	Cheumatopsyche sp.	4				
	Hydropsyche sp.	4				
	H. betteni	4				
	H. cuanis	4				
	H. orris	4				
	H. simulans*	4				
	H. slossonae	4				
	Macronema zebratum	4				

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
TROCOPTERA continued						
Glossosomatidae	Agaepetus sp.	5				
Hydroptilidae	Hydroptila sp.	6	Oxethira sp.*	6		
			Agraylea sp.	6		
			Ochrotrichia sp.	6		
Brachycentridae	Brachycentrus numerosus*	4				
	Micrasema sp.	3				
Phryganeidae			Phryganea sp.*	2		
			P. cinerea	2		
			Ptilostomis sp.	2		
Limnephilidae			Anabolia sp.	1	Limnephilus sp.*	1
			Eydatophylax argus	1		
	Neophylax nacatus*	1	Nemotaulius hostilis	1		
	Pycnopsyche guttifer*	1				
	P. scabripennis	1	Pycnopsyche sp.	1		
			Glyphopsyche irrorata	1		
Lepidostomatidae	Leipdostama sp.	1				
Sericostomatidae	Agrodes distinctum	1				
Molannidae			Molanna triphena	3		
Helicopyschidae	Helicopsyche borealis	5				

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
TRICOPTERA continued						
Leptoceridae	Ceraclea sp.	3			Ceraclea ancylus*	3
					C. annulicornus*	5
					C. diluta*	3
					C. musca*	3
					C. neffi*	3
			Mystacides sp.*	3	C. resurgens*	3
					Oecetis sp.*	8
	Oecetis avara*	8			Oecetis cinearscens*	
DIPTERA	Diptera	0				
Tipulidae	Tipula sp.*	1				
	Antocha sp.	3				
	Dicranota sp.*	8				
	Limnophila sp.*	8				
	Hexatoma sp.*	8				
	Pseudolmnophila sp.*	8				
Syrphidae			Helophilus sp.*	3		
Athericidae	Atherix variegata	7				
Chaorboridae			Chaoborus sp.	7		
Culicidae			Aedes sp.*	3		
Ceratopoganidae					Palpomyia sp.	8
Simuliidae	Prosimulium sp	4				
	Eusimulium sp.	4				
	Simulium sp.	4				
	Cnephia sp.	4				

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
DIPTERA continued						
Tanypodinae			Ablabesmyia sp.	8	Clinotanypus sp.*	8
					Conchapelopia sp.	8
	Nilotanypus sp.*	8	Procladius sp.	8	Larsia sp*	8
	Pentaneura sp.	8	Zaverlimyia sp.	8	Pseutroctanypus sp.*	8
Orthocladinae					Brillia sp.*	1
	Corynoneura sp*	3				
	Cricotopus sp.	3				
	Diplocladius sp.	3			Epiocladius sp.*	3
	Orthocladius sp.	3				
	Eukiefferiella sp.	3				
	Parametreocnemus sp.	3	Psectrocladius sp.	3		
	Pheocricotopus sp.	3				
	Thienemanniella sp.*	3				
	Trissocladius sp.*	3				
	Hetertrissocladius sp.*	3				
	Cardiocladius sp.	3				
Tanytarsini					Micropsectra sp.*	3
	Rheotanytarsus sp.	4	Tanytarsus sp.	4		
Chironomini					Chironomus ps.*	3
			Dicrotendipes sp.	3	Cryptochironomus sp.*	8
			Einfeldia sp.	3		
			Endochironomus sp.	1		
			Glyptotendipes sp.	3	Parachironomus sp.*	8
	Polypedilum sp.	2	Microtendipes sp.	4	Paratendipes sp.*	3
					Phaenopsectra sp.*	5
					Stenochironomus sp.*	3
	Nilothauma sp.	3			Stictochironomus sp.*	3
					Xenochironomus sp.*	8

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
ODONATA						
Calopterygidae			Calopterigidae	8		
			Calopteryx sp.			
Coenagrionidae			Coenagrionidae	8		
Cordulegastridae			Cordulegastridae	8		
	Cordulegaster sp*					
Gomphidae	Gomphidae	8			Hagenius brevistylus*	
	Ophiogompus sp.				Stylogomphus albistylus*	
Aesnidae			Aeshnidae	8		
					Aeshna sp.*	
	Basiaeshna sp.*					
	Boyeria sp.*					
Macromiidae			Macromiidae	8		
Corduliidae			Corduliidae	8		
Libellulidae			Libellulidae	8		
HEMIPTERA						
Gerridael	Metrobates sp.	7	Gerris sp.	7	Rheumatobates sp.*	7
					Trepobates sp.*	7
Veliidae	Rhagovelia sp.	7				
Notonectidae			Buenoa sp.	7		
			Notonecta sp.	7		
Nepidae			Ranatra sp.*	7		

PRELIMINARY DRAFT REPORT, SUBJECT TO REVIEW

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
HEMIPTEDA continued						
Belostomatidae			Belostoma sp.	7		
			Lethocerus sp.*	7		
Corixidae			Corixidae	6		
MEGALOPTERA						
Corydalidae	Nigronia sp.	8				
	N. serricornis	8				
Sialidae			Sialis sp.	8		
NEUROPTERA						
Sisyridae					Climacia sp.*	8
LEPIDOPTERA						
Pyralidae			Paraponyx sp.*	2		
COLEOPTERA						
Haliplidae			Haliplidae			
			Haliplus sp.	6		
Dytiscidae			Dytiscidae	8		
Gyrinidae			Gyrinidae			
			Gyrinus sp.	8		
Hydrophilidae	Helophorus sp.	2	Hydrophilidae	0		
			Hydrochus sp.*	2		

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
COLEOPTERA continued						
Hydraenidae			Hydraenidae*	5		
			Hydranea sp.			
Psephenidae	Ectopria nervosa*	5				
Elmidae	Optioservus sp.	3	Dubiraphia sp.	3	Macronychus glabratus	3
	O. fastiditus	3				
	O. trivitatus*	3				
	Stenelmis sp.	3				
	S. crenata	3				
Chrysomelidae	Donacia sp.*					
GASTRODOPA			Gastropoda	8		
PELECYPODA	Pelecypoda	4				
Sphaeriidae	Sphaeriidae		Physa sp.		Unionidae*	
Unionidae						
DECOPODA			Decopoda	3		
AMPHIDODA			Hyalella azteca	3		
			Crangonyx sp.	3		
NEMATODA					Nematoda	8
TURBELLARIA	Turbellaria	3				
HIRUDINEA	Hirudinae	8				
OLIGOCHAETA			Oligochaeta	3		

Table 1. Habitat preference of aquatic invertebrates collected in the Study Area. continued

Order Family	Riffle	co	Pool	co.	Facultative Riffle	co
COLLEMBOLLA			Collembolla*	3		

*habitat preference based on literature

Table 2. Habitat preference of aquatic invertebrates by functional group.

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
<u>SHREDDERS OF DEAD PLANT MATERIAL</u>						
PLECOPTERA						
	Pteronarcys sp.					
	Prostoia completa*		Amphinemura linda			
	Shipsa rotunda					
	Podmosta macdunnoughi					
	Leuctra sp.*					
	L. ferruginea*					
	Paracapnia sp.*					
	P. angulata					
	Strophoptery fasciata*					
	Taeniopteryx burksi*					
TRICOPTERA			Anabolia sp			
			Hydatophylax argus			
	Neophylax nacatus*		Nemotaulius hostilis		Limnephilus sp.*	
	Pycnopsyche guttifer*		Pycnopsyche sp.			
	P. scabripennis		Glyphopsyche irrorata			
	Lepidostoma sp.					
	Agrodes distinctum					
DIPTERA	Tipula sp.*		Endochironomus sp.		Brillia sp.*	
<u>SHREDDERS OF LIVE PLANT MATERIAL</u>						
TRICOPTERA			Phryganea sp.*			
			P. cinerea			
			Ptilostomis sp.			
DIPTERA	Polypedilum sp.					
LEPIDOPTERA			Paraponyx sp.*			
COLEOPTERA	Helophorus sp.		Hydrochus sp.*			
<u>COLLECTOR GATHERERS</u>						
EPHEMEROPTERA			Siphlonurus sp.*			
			Stenacron sp.			
			S. interpunctatum			
			S. minnetonka*			

Table 2. Habitat preference of aquatic invertebrates by functional group. continued.

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
<u>COLLECTOR GATHERERS</u> contd.						
EPHEMEROPTERA	Stenonema sp.		Stenonema tripunctatum			
	S. annexum*					
	S. fuscum					
	S. puchellum					
	S. rubrum*					
	S. smithae*					
	Baetis sp.					
	B. hageni				Baetis pygmaeus*	
	B. flavistriga grp					
	B. vagans*					
	Heterocloeon curiosus		Callibaetis sp.			
	Centroptilum sp.*		Cloeon sp.			
	Paraleptophlebia sp.		Leptophlebia sp.			
	P. mollis		Paraleptophlebia			
	Ephemerella sp.		praepedita			
	E. bicolor*		Ephemerella temporalis			
	E. invaria					
	E. rotunda					
	E. subvaria					
			Tricorythodes sp.			
			Caenis sp.			
			Ephemera sp.		Ephemera simulans	
			Hexagenia sp.			
			H. limbata			
			Litobrancha recurvata			
			Baetisca sp.*			
			B. carolina			
			B. obesa			
TRICHOPTERA	Ceraclea sp.		Molanna triphena		Ceracleu ancylus*	
					C. annulicornus*	
					C. diluta*	
					C. musca*	
					C. neffi*	
					C. resurgens*	
			Mystacides*			

Table 2. Habitat preference of aquatic invertebrates by functional group. continued.

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
<u>COLLECTOR GATHERERS</u> contd.						
DIPTERA	Antocha sp.		Helophilus sp.*			
			Aedes sp.*			
	Corynoneura sp.*					
	Cricotopus sp.					
	Diplocladius sp				Epiocladius sp.*	
	Orthocladius sp.					
	Eukiefferiella sp.					
	Parametreocnemus sp.		Psectrocladius sp.			
	Pheocricotopus sp.					
	Thienemanniella sp.*					
	Trissocladius sp.					
	Heterotrissocladius sp.*					
	Cardiocladius sp.				Chironomus sp.*	
	Micropsectra sp.		Dicrotendipes sp			
			Einfeldia sp.			
			Glypotendipes sp.		Paratendipes sp.*	
	Nilothauma sp.				Stenochironomus sp.*	
					Stictochironomus sp.*	
COLEOPTERA	Donacia sp.*		Dubiraphia sp.		Macronychus glabratus	
	Optioservus sp.					
	O. fastiditus					
	O. trivittatus*					
	Stenelmis sp.					
	Stenelmis crenata					
			Decopoda			
AMPHIPODA			Hyalella acteca			
			Crangonyx sp.			
	Turbellaria					
			Oligochaeta			
			Collembolla			

Table 2. Habitat preference of aquatic invertebrates by functional group. continued

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
COLLECTOR FILTERS FEEDERS						
EPHEMEROPTERA	Isonychia sp.					
TRICHOPTERA	Chimarra sp.					
	C. feria					
	C. obscura					
	C. socia					
	Dolophilodes distinctus*					
	Psychomyia sp.*					
	P. flavida*					
	Neureclipsis sp.					
	Cheumatopsyche sp.					
	Hydropsyche sp.					
	H. betteni					
	H. cuanis					
	Hydropsyche orris					
	H. simulans*					
	H. slossonae					
	Macronema zebratum					
	Branchycentrus numerosus*					
DIPTERA	Prosimulium sp.					
	Eusimulium sp.					
	Simulium sp.					
	Cnephia sp.					
	Rheotanytarsus sp.		Tanytarsus sp.			
			Microtendipes sp.			
	Pelecypoda					
SCRAPERS						
EPHEMEROPTERA	Epeorus sp.*					
	Heptagenia sp.					
	H. hebe					
	Pseudocloeon sp.					
	P. carolina					
	P. cingulatum					

Table 2. Habitat preference of aquatic invertebrates by functional group. continued

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
SCRAPERS contd.						
EPHEMEROPTERA contd.	P. dubium					
	P. parvulum*		Choroterpes sp.		Choroterpes basalis*	
TRICOPTERA	Agaepetus sp.					
	Heicopsyche borealis					
DIPTERA					Phaenopsectra sp.*	
COLEOPTERA	Ectopria nervosa*		Hydraenidae *			
			(Hydranea sp.)			
PIERCING HERBIVORES						
TRICOPTERA	Hydroptila sp.		Agraylea sp.			
			Ochrotrichia sp.			
			Oxethira sp.*			
HEMIPTERA			Corixidae			
COLEOPTERA			Haliplidae			
			(Haliplus sp.)			
PIERCING PREDATORS						
DIPTERA	Atherix variegata		Chaoborus sp.			
HEMIPTERA	Metrobates sp.		Gerris sp.		Rheumatobates sp.*	
	Rhagovelia sp.		Buenoa sp.		Trepoloates sp.*	
			Notonecta sp.			
			Ranatra sp.*			
			Belostoma sp.			
			Lethocerus sp.*			
ENGULFING PREDATORS						
PLECOPTERA	Acroneuria sp.					
	A. lycorias					
	Neoperla clymene*					
	Paragnetina media					

Table 2. Habitat preference of aquatic invertebrates by functional group. continued.

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
ENGULFING PREDATORS contd.						
PLECOPTERA	Perlinella drymo*					
	Perlista placida*					
	Phasganophora capitata*					
	Isoperla sp.					
	I. dicala*					
	I. slossonae*					
	I. transmarina					
EPHEMEROPTERA	Siphloplecton sp.*		Siphloplecton interlineatum			
TRICOPTERA	Nyctiophylax moestus*					
			Polycentropus cinereus		Polycentropus sp.*	
	P. centralis*				Oecetis sp.*	
	Oecetis avara*				Oecetis cinerascens*	
DIPTERA	Dicranota sp*					
	Limnophila sp.*					
	Hexatoma sp.*					
	Pseudolimnophila sp.*				Palpomyia grp.	
			Ablabesmyia sp.		Clinotanypus sp.*	
					Conchapelopia sp.	
	Nilotanypus sp.*		Procladius sp.		Larsia sp.*	
	Pentanura sp.		Zaverlimyia sp.		Pseutroctanypus sp.*	
					Cryptochironomus sp.*	
					Parachironomus sp.*	
					Xenochironomus sp.*	
ODONATA			Calopterygidae			
			Calopteryx sp.			
			Coenagrionidae			
			Cordulegastridae			
	Cordulegaster sp.*					
	Gomphidae				Hagenius brevistylus*	
	Ophiogompus sp.				Stylogomphus albistylus*	

Table 2. Habitat preference of aquatic invertebrates by functional group. continued

Functional Group	Riffle	co.	Pool	co.	Facultative Riffle	co.
<u>ENGULFING PREDATORS</u> contd.						
ODONATA			Aeshnidae		Aeshna sp.*	
	Basiaeshna sp.*					
	Boyeria sp.*		Macromiidae			
			Corduliidae			
			Libellulidae			
MEGALOPTERA	Nigronia sp.					
	N. serricornis		Sialis sp.			
NEUROPTERA					Climacia sp.	
COLEOPTERA			Dytiscidae			
			Gyrinidae			
			(Gyrinus sp.)			
			Gastropoda			
					Nematoda	
	Hirudinea					

*habitat preference based on literature

Table 3. Summary of habitat preferences of the various orders of aquatic invertebrates collected in the Study Area. Numbers indicate number of taxa within families (F), genera (G), and species (S) of the various orders which prefer the indicated habitat.

ORDER	RIFFLE			POOL			FACULTATIVE		
	F	G	S	F	G	S	F	G	S
Plecoptera	6	14	16	1	1	1	0	0	0
Ephemeroptera	6	12	19	9	15	10	3	3	3
Trichoptera	12	20	20	6	13	6	3	4	7
Diptera	5	27	1	5	13	0	3	16	0
Odonata	3	4	0	7	1	0	2	3	2
Hemiptera	2	2	0	5	6	0	1	2	0
Megaloptera	1	1	1	1	1	0	0	0	0
Neuroptera	0	0	0	0	0	0	1	1	0
Lepidoptera	0	0	0	1	1	0	0	0	0
Coleoptera	4	5	4	6	5	0	1	1	1
Total	39	85	61	41	56	17	14	30	13

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