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A BENTHIC INVERTEBRATE MONITORING STUDY ON THE ATHABASCA RIVER, WHITECOURT, ALBERTA, 1992

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Prepared for

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EXECUTIVE SUMMARY

Alberta Newsprint Company (ANC) operates an integrated thermomechanical pulp (TMP) and paper mill near Whitecourt, Alberta. A benthic invertebrate monitoring program is included as part of the environmental program for the mill, as required under the Clean Water Act, by Alberta Environment. Baseline benthic invertebrate monitoring programs were conducted during the spring and fall of 1989 and the spring of 1990 to establish pre-operational conditions in the Athabasca River (Beak Associates 1990, 1991). The pulp and paper mill became operational in August 1990. Water is obtained from the Athabasca River for process use and following treatment, effluent is discharged to the Athabasca River at a rate of about 15,000 m^3/day. During the fall of 1990, a benthic monitoring program was conducted to establish start-up conditions (Beak Associates 1991) and during 1991, to establish post-operational conditions in the Athabasca River (SENTAR 1992). The monitoring program was continued in 1992 to assess the effect of the pulp and paper mill effluent on the Athabasca River. The objectives of this program were to determine if there were any differences in benthic invertebrate community structure between sites, to evaluate the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure and to determine if there were any differences between pre-operational and post-operational conditions in the Athabasca River.

Benthic invertebrate sampling was conducted during the spring (24 to 27 April) and the fall (4 to 8 October) of 1992. Seven sites, which were established in 1989 were sampled for this survey. Sites 1 and 2 were located upstream of the ANC effluent outfall as background sites. Sites 3, 4 and 5 were located between the effluent outfall and the confluence of the McLeod River with the Athabasca River, as potential impact or recovery sites. Sites 6 and 7 were located approximately 13 and 33 km downstream of the effluent outfall, also as potential impact or recovery sites. These two sites were located downstream of the Millar Western Pulp Ltd. (Millar Western) effluent outfall, and Site 7 was also located downstream of the Whitecourt sewage treatment plant outfall.

Five replicate benthic samples were collected at each site using a modified Neill-Hess cylinder sampler enclosing an area of 0.0892 m^2. All sampling sites were in run areas and as similar as possible with regard to physical characteristics. Since it is not always possible to completely eliminate site variation, the physical characteristics of water velocity, water depth and substrate composition were documented at each sampling location. An estimate of the amount of algal growth on the substrates was made at each site. Water

quality sampling, consisting of standard field measurements, was conducted at each benthic site. Water samples were also collected at each site and analyzed by Alpha Laboratory Services Ltd. and Enviro-Test Laboratories of Edmonton for several parameters associated with the treated effluent discharge.

Each benthic sample was sorted by the subsampling method of Wrona et al. (1982) and enumerated in the laboratory. All organisms were identified to the lowest practical taxonomic level (genus where possible).

The basic computations of total number of taxa, number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, total number of organisms, total standing crop (number/m^2), standing crop of each major taxonomic group and Shannon-Weaver species diversity were calculated for each benthic sample. Statistical analyses were conducted using Analysis of Variance (ANOVA) to determine whether significant differences existed for the five variables of total number of taxa, number of EPT taxa, total number of organisms, number of EPT and number of Chironomidae between sites. *A priori* testing, using orthogonal contrasts, was conducted to determine differences between groups of sites (spatial contrasts) (background, near-field and far-field). The benthic data were also analyzed using reciprocal averaging ordination (RA), which groups samples into biological units (clusters) determined by faunal assemblages of highest similarity. A trophic guild (feeding group) analysis was used in conjunction with RA to determine the ecological implications of any noted differences in the benthic community structure between sites. The trophic guild analysis was intended only to provide a general indication of similarities and differences in feeding group structure between sites. A comparison was made between the pre-operational and post-operational data from 1989 to 1992, to assess the effects of pulp mill effluent on the benthic invertebrates of the Athabasca River. Spatial differences were statistically compared before and after the mill became operational for the five variables. A repeated measures design was used, with sites divided into areas (background, near-field and far-field) and the sites used as replicates within areas, re-sampled each year.

A Quality Assurance/Quality Control (QA/QC) program was implemented during this study and Standard Operating Procedures (SOP) were used for all field and laboratory procedures and reporting of data.

The physical data indicated that there were some variations in mean water velocity, water depth and substrate composition between sites and seasons. The differences between sites within a season were the result of hydraulic and other physical habitat differences between reaches of the river. The spring and fall surveys were conducted during flows which were only slightly above historical mean monthly flows in the Athabasca River. Substrates at all sites consisted mainly of cobbles and pebbles, with a few gravels. In April, pebbles were the dominant substrate at Sites 1, 2, 3 and 4, while at Sites 5, 6 and 7 cobbles were dominant. In October, cobbles were the dominant substrate at all sites, except Sites 1 and 3 where pebbles were dominant. In April, a light growth of algae was found on the substrates at Sites 5, 6 and 7, whereas no algal growth was obvious at Sites 1, 2, 3 and 4. In October, a light growth of algae was found at all sites, except at Sites 3 and 4, where there was a moderate growth of algae. The differences in physical characteristics, other than the presence of algae, did not likely cause any detectable differences in benthic community structure between sites within a season.

The water quality data indicated that the Athabasca River was a well oxygenated, alkaline stream during both the spring and fall surveys. Effluent discharge from the ANC mill did not affect pH, conductivity, dissolved oxygen, true color or total suspended solids concentrations at downstream sites. Biochemical oxygen demand (BOD_5) concentrations in the river were low during both surveys and were not affected by treated effluent discharge from ANC, Millar Western or the Whitecourt sewage treatment plant. Total phosphorus concentrations in April were higher at Sites 5, 6 and 7 than at background sites, likely as a result of effluent inputs. There was no affect on total Kjeldahl nitrogen concentrations in the river from effluent discharges.

Detailed water quality analyses at Sites 2 and 3 indicated that many parameters were below detection limits and/or did not exceed provincial (ASWQO) or federal (CWQG) guidelines. In April, concentrations of chromium, iron and mercury exceeded either the ASWQO or CWQG. Metals are not generally considered to be a major component of pulp mill effluent. The concentrations recorded in April were considered to be the result of natural processes. Resin and fatty acids were detected at both Sites 2 and 3 in April, however the concentrations were lower at Site 3 than at background Site 2. It is suspected that the source of these compounds originates upstream of ANC. Resin and fatty acids were not detected at either site in October.

A total of 131 taxa of benthic invertebrates has been identified from the 1989 to 1992 samples collected from the Athabasca River. Of these, 70 taxa were identified from the April 1992 samples and 77 taxa from the October samples.

In April, both the number of taxa and the number of EPT taxa were significantly higher at downstream than at background sites. However, there were no significant differences between near-field and far-field sites. The number of organisms was significantly higher at downstream than at background sites, but not between near-field and far-field sites. The species diversity values in April were lower at downstream than at background sites and were lower at far-field than at near-field sites. A low species diversity indicates that the majority of organisms present belong to only a few taxa and that other fauna are low in numbers, thus causing an uneven distribution. Ephemeroptera, Chironomidae and Oligochaeta were the dominant taxonomic groups at all sites during April, with Chironomidae having the highest standing crop at all sites. The number of EPT was not significantly different between background and downstream sites, but was significantly higher at near-field than far-field sites. The number of Chironomidae was significantly higher at downstream than background sites, but not between near-field and far-field sites.

In October, both the number of taxa and the number of EPT taxa were significantly higher at downstream than at background sites and were significantly higher at far-field than near-field sites. The number of organisms was not significantly different between downstream and background sites, but was significantly higher at far-field than at near-field sites. The species diversity values in October were higher at downstream sites than at background sites and were higher at far-field than at near-field sites. Ephemeroptera, Chironomidae and Oligochaeta were the dominant taxonomic groups at all sites during October, with Chironomidae having the highest standing crop at all sites, especially downstream Sites 5, 6 and 7. Both the number of EPT and the number of Chironomidae were not significantly different between background and downstream sites, but were significantly higher at far-field than near-field sites.

An increase in the amount of algal growth on the substrates was found at some downstream sites during April and October. However, there was no consistent relationship between the amount of algal growth and the number of taxa or standing crop of benthic invertebrates at sites.

The increase in mean standing crop at all downstream sites in April and at Sites 5, 6 and 6 in October was likely the result of organic loading from the ANC, the Millar Western and the Whitecourt sewage treatment effluents. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera, Trichoptera and Plecoptera), increased in numbers at downstream sites, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites, and in fact, there was a significant increase in the number of taxa at downstream sites in both April and October. This indicated that only mild organic enrichment was occurring in the Athabasca River as a result of organic loading from effluents.

The RA analysis of the April benthic data indicated that there were five sample clusters. Cluster I consisted of Site 1, Cluster II of Sites 2 and 3, Cluster III of Site 4, Cluster IV of Site 5, and Cluster V of Sites 6 and 7. The RA analysis of the October benthic data indicated that there were four sample clusters. Cluster I consisted of Site 2, Cluster II of Sites 1 and 3, Cluster III of Sites 5, 6 and 7, and Cluster IV of Site 4.

A number of taxa have been found to respond to organic enrichment, by increasing in numbers, as a response to an increase in food availability, if oxygen is not limiting. The community analysis indicated that the dominant taxa characteristic of both background and downstream sites in April were suited to mild organic enrichment. The increase in numbers of organisms, such as Orthocladiinae and Naididae, at downstream sites indicated that the ANC effluent appeared to contribute organic enrichment to the river. The Millar Western and the Whitecourt sewage treatment effluents also appeared to contribute additional organic enrichment at Sites 6 and 7, since no recovery of the benthic community structure was apparent at these downstream sites. During October, as in previous surveys, the dominant benthic community structure of the background sites indicated the presence of mild organic enrichment, especially at Site 2. The ANC effluent appeared to contribute some additional organic enrichment to the river, affecting both Sites 4 and 5. The Millar Western and Whitecourt sewage treatment effluents appeared to contribute further organic enrichment to the river at Sites 6 and 7.

The trophic analysis showed that all sites during both the spring and fall surveys were dominated by detritivore/herbivores and detritivores, which is a common natural trait of most streams in North America. These groups were followed by carnivores and omnivores. In April, all sites had similar percent compositions of the dominant feeding groups (detritivore/herbivore and detritivore), with the exception of a slight increase in omnivores at Site 4. This was the result of an increase in the number of *Brachycentrus* sp. at Site 4. In October, Sites 1, 2 and 3 had high percentages of detritivore/herbivores, followed by detritivores, and then similar percentages of carnivores and omnivores. Sites 4, 5, 6 and 7 had lower percentages of detritivore/herbivores and higher percentages of detritivores, compared to upstream sites. The difference in percentages of detritivore/herbivores and detritivores was the result of shifts between the numbers of *Cricotopus/Orthocladius* spp. (detritivore/herbivore) and *Rheotanytarsus* spp. (detritivore). The trophic analysis indicated that similar trends were apparent in the benthic data, as was found by the RA analysis. Increases in the numbers of certain organisms and shifts in the feeding group structure occurred as a result of the change in the nature of the food supply caused by organic enrichment in the Athabasca River from the pulp mill and sewage effluents.

In 1992, the benthic invertebrates of the Athabasca River at downstream sites responded to mild organic enrichment from the pulp mill and sewage treatment effluents by an increase in the populations of certain tolerant, as well as intolerant taxa. The benthic community structure also shifted to one of increasing proportions of tolerant taxa at downstream sites, which is a typical response to mild organic enrichment. Mild organic enrichment, due to nutrient addition (phosphorus) from the ANC, Millar Western and Whitecourt sewage treatment effluents, has over the years caused an increase in the abundance of tolerant taxa, such as Chironomidae, but oxygen depletion has not been sufficient to cause a decrease in the more sensitive EPT taxa.

The comparison of pre-operational and post-operational data for the spring and fall indicated that there was no evidence of major effects on the benthic community of the Athabasca River from the ANC discharge, when the impact over all downstream sites was compared between all pre-operational and post-operational years and when far-field effects were compared between all pre-operational and post-operational years. The spring results indicated that differences were noted between near-field and far-field sites between the two pre-operational years. These differences suggested that there were reduced effects from the Millar Western and/or Whitecourt sewage treatment effluents between 1989 and 1990. The results also indicated that differences were noted between both background and downstream sites and near-field and far-field sites between the two post-operational years. These differences suggested that there were increased effects downstream of the ANC mill in 1992. However, it should be noted that the effects included increases in the numbers of intolerant taxa (EPT taxa). The fall results indicated that differences were noted between background and downstream sites and near-field and far-field sites between the two post-operational years of 1990 and 1991. No significant differences were found between 1991 and 1992. These differences suggested that the effects downstream of the ANC mill in the fall occurred mainly between 1990 and 1991 and that there were not effects between 1991 and 1992.

1.0 INTRODUCTION

Alberta Newsprint Company (ANC) operates an integrated thermomechanical pulp (TMP) and paper mill near Whitecourt, Alberta. A benthic invertebrate monitoring program is included as part of the environmental program for the mill, as required under the Clean Water Act, by Alberta Environment. Baseline benthic invertebrate monitoring programs were conducted during the spring and fall of 1989 and the spring of 1990 to establish pre-operational conditions in the Athabasca River (Beak Associates 1990, 1991). The pulp and paper mill became operational in August 1990. Water is obtained from the Athabasca River for process use and following treatment, effluent is discharged to the Athabasca River at a rate of about 15,000 m^3/day. During the fall of 1990, the benthic monitoring program was conducted to establish start-up conditions (Beak Associates 1991) and during 1991, to establish post-operational conditions in the Athabasca River (SENTAR 1992). The monitoring program was continued in 1992 to assess the effect of pulp and paper mill effluent on the benthic invertebrate community and water quality of the Athabasca River.

Benthic invertebrates are a useful monitoring tool since their community structure can reflect general water quality conditions over time. Benthic invertebrates are good indicators of disturbance primarily because of the long term stability of their populations and because they constitute an easily sampled community which is abundant and diverse enough to be responsive to both gross and subtle environmental changes (Hynes 1960, Gaufin 1973, Kovalak 1981). If the physical characteristics (substrate, water velocity and depth) of the sampling sites are standardized, then the water quality can be used to determine the potential causes for any changes in the benthic community structure.

The objective of the spring and fall 1992 benthic invertebrate monitoring program was to assess the effects of pulp and paper mill effluent on the benthic invertebrate community and water quality of the Athabasca River, specifically:

- to determine if there were any differences in benthic invertebrate community structure between sampling sites in 1992,

- to evaluate the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure, and

- to determine if there were any differences between pre-operational and post-operational conditions in the Athabasca River.

2.0 METHODOLOGY

2.1 SITE LOCATIONS

Seven sites, which were established in 1989 (Beak Associates 1990) on the Athabasca River, were sampled for benthic invertebrates during the 1992 survey (Figure 1). Sites 1 and 2 were located upstream of the effluent outfall as background sites. Sites 3, 4 and 5 were located between the effluent outfall and the confluence of the McLeod River with the Athabasca River, as potential impact sites. Sites 3 and 4 were located on the north bank and Site 5 on the south bank of the river. Sites 6 and 7 were located approximately 13 and 33 km, respectively, downstream of the effluent outfall, on the south bank, also as potential impact or recovery sites. These two sites were located downstream of the Millar Western Pulp Ltd. (Millar Western) effluent outfall and Site 7 was also located downstream of the Whitecourt sewage treatment plant outfall.

2.2 BENTHIC INVERTEBRATE SAMPLING

Benthic invertebrate sampling was conducted during the spring between 24 and 27 April, and during the fall between 4 and 8 October 1992. Benthic samples were collected using a modified Neill-Hess cylinder sampler with a collecting net of 250 micrometre mesh and enclosing a surface area of 0.0892 m^2. During sampling, the sampler was forced into the substrate to a depth of 5 to 10 cm. Large substrates were removed and scraped into a bucket to ensure that attached organisms were collected. Smaller substrates were agitated in the sampler to the depth of sampler penetration to dislodge all other organisms which were then carried by the stream current into the collecting bottle. Samples consisting of organisms and detritus from the collecting bottle and bucket were concentrated over a 180 micrometre mesh standard sieve, stored in jars and preserved in 10% formaldehyde for laboratory identification and enumeration. Five replicate samples were taken at each site to ensure that all representative benthic communities were assessed and to provide an acceptable level of confidence on the data (Needham and Usinger 1956, Wilhm and Dorris 1968, Alberta Environment 1990).

2.3 PHYSICAL AND CHEMICAL SAMPLING

All sampling sites were in run areas and were as similar as possible with regard to water velocity, water depth and substrate composition to reduce inter-site variability. Since it is not always possible to completely eliminate natural site variation, the physical

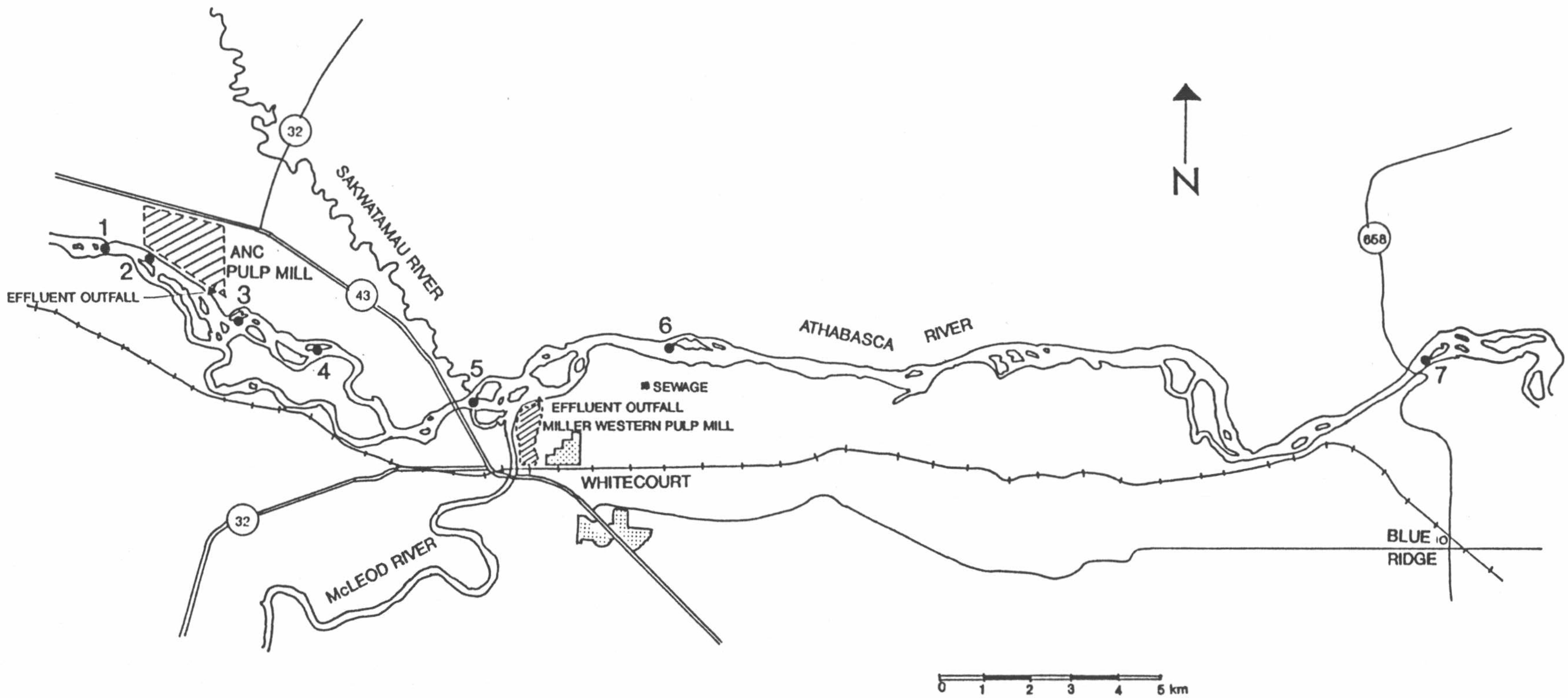


Figure 1. Benthic invertebrate sampling sites on the Athabasca River.

characteristics of each sampling location were documented. Any differences in habitat were then used in interpreting any naturally caused differences in benthic invertebrate distribution patterns and community structure between sites. Substrates at each sample location were classified using a modification of the Wentworth classification system (Cummins 1962). All loose substrates contained within the benthic sampler were removed, put into size categories using standard Tyler geologic screens, and weighed with a portable spring scale. These size category weights were then converted into percentages of the total substrate weight. Water velocity, taken 2 cm from the bottom with a Price AA current meter, and water depth were measured at each sample location. Three water velocity measurements were taken on a three point transect across each sample location, from which an average was calculated for each sample. All sites were photographed.

An estimate of the amount of algal growth, based on the thickness on the substrate was made at each site. The algal growth was classified into three categories: light (<1 mm thickness), moderate (2 to 5 mm) and heavy (6 to 10 mm). The depth of algal growth was measured for three cobbles with three readings for each rock at each site.

Water quality sampling, consisting of field measurements of pH using a pHep$^+$ Hanna Instruments pH meter (± 0.1 unit), conductivity using a Hach Model 16300 portable conductivity meter (± 10 μmhos/cm), dissolved oxygen using a YSI Model 54A dissolved oxygen meter (± 0.2 ppm), and water temperature using a pocket thermometer (± 0.5 °C) was conducted at each benthic site. Water samples were also collected at each site taking grab samples about 20 cm below the water surface. All bottles used for water samples were received from the analytical laboratory. Bottles were rinsed three times with site water prior to filling and standard preservatives were added, where required. All samples were kept cool on ice, until delivered to the laboratory. Water samples were analyzed by Alpha Laboratory Services Ltd. of Edmonton for true color, total phosphorus, total Kjeldahl nitrogen (TKN), total suspended solids (TSS) and biochemical oxygen demand (5 day) (BOD_5) using standard methods (APHA-AWWA-WPCF 1985) and approved Alberta Environment methods (Alberta Environment 1987). All BOD samples were shipped to the laboratory for analysis within 24 hours of sampling. A more detailed water chemistry analysis was conducted in both April and October for Site 2 (just upstream of the effluent outfall) and Site 3 (just downstream of the effluent outfall). Parameters analyzed at these sites included total phenols, total organic carbon, total metals, and resin and fatty acids. These parameters were analyzed using standard methods by Alpha Laboratories Services Ltd., except for resin acids which were analyzed by Enviro-Test Laboratories of Edmonton.

2.4 BENTHIC SAMPLE ANALYSIS

The benthic samples were stained with rose bengal prior to sorting in the laboratory. Each benthic sample was sorted by the subsampling method of Wrona et al. (1982). Subsampling was used because the samples contained a large portion of a homogeneous mixture and/or extremely large numbers of small benthic organisms which could not be feasibly counted. For subsampling, the benthic sample was initially sieved into coarse (>1 mm) and fine (0.180 to 1 mm) fractions. Organisms remaining in the coarse fraction were sorted and counted independently using a dissecting microscope. The fine fraction of homogeneously sized material was placed into the subsampling apparatus (an Imhoff cone) which was filled to a total volume of 1 L and agitated for five minutes to ensure thorough mixing. Five subsamples were removed from the agitated solution and organisms were sorted and counted using a dissecting microscope. The size of the subsamples varied (20 to 100 mL) for each site depending on the amount of fine material and numbers of organisms present in the samples. The numbers of each taxon occurring in the total fine fraction were then obtained by multiplying the respective counts by the volumetric proportion which the subsamples represented of the total fine fraction. These counts were then added to the counts obtained from the coarse fraction for each taxon.

A re-sorting of the sample residues was conducted on 10 % of the samples to determine the level of sorting efficiency. The number of invertebrates initially recovered from the sample was expressed as a percentage of the total number after the re-sort (total of initial and re-sort count).

All organisms were identified to the lowest practical taxonomic level (genus where possible). These organisms were then stored in vials with 70% isopropyl alcohol for archiving. A reference collection was produced for all species collected in 1992. Samples of chironomid larvae (midges) were mounted on microscope slides using CMCP-9 mounting medium and identified to genus by mouth parts using a compound microscope. The commonest chironomid species were distinguishable on the basis of gross morphology, requiring only a few mounts (5 to 10) as checks, while mounts were made for all rare or less commonly occurring species. All taxa were identified using the keys from the following references:

General:	Clifford (1991), Merritt and Cummins (1984), Pennak (1978), Brooks and Kelton (1967), Usinger (1956)

Plecoptera:	Baumann et al. (1977), Stewart and Stark (1988)
Trichoptera:	Wiggins (1977)
Ephemeroptera:	Edmunds et al. (1976)
Diptera (Chironomidae):	Bode (1983), Oliver and Roussel (1983), Wiederholm (1983), Wiederholm (1986)
Diptera (others):	McAlpine et al. (1981)

2.5 DATA AND STATISTICAL ANALYSES

Benthic invertebrate community structure is known to differ between seasons which is caused by the reduction and/or addition of numbers and species of organisms through emergence and recruitment (Hynes 1972). When analyzing data from a benthic monitoring survey to detect water quality changes and resulting biological effects, it is essential to deal with comparable seasonal data sets. The basic computations, statistical analyses and reciprocal averaging ordination (RA) were therefore conducted separately for each data set (April and October).

All new taxa identified from the 1992 samples were added to the 1991 species list (SENTAR 1992). The basic computations of total number of taxa, number of Ephemeroptera, Plecoptera and Trichoptera (EPT), total number of organisms, total standing crop (number/m^2) and standing crop of each major taxonomic group (Ephemeroptera, Trichoptera, Plecoptera, Chironomidae, Oligochaeta and remaining groups) were calculated for each sample and means were calculated for each site. Confidence limits for all means were calculated at the 95% level.

Shannon-Weaver species diversity was also calculated for each sample, and means and confidence limits for each site. Species diversity (Shannon and Weaver 1949), which reflects both the number of taxa and the evenness of distribution of the individuals among the taxa, was calculated as follows:

$$H' = - \sum_{i=1}^{s} p_i \ln p_i$$

where "s" is the number of species, "p_i" is the proportion of the total number of individuals consisting of the ith species, and "ln" is the natural logarithm. The use of a diversity index (a derived variable) to describe benthic community data was used for presentation purposes only, as suggested by Kovalak (1981).

Statistical analyses were conducted using analysis of variance (ANOVA) to determine whether total number of taxa, number of EPT taxa, total number of organisms (standing crop), number of EPT and number of Chironomidae were significantly different between sites during April and October 1992. *A priori* testing, using orthogonal contrasts, was conducted to determine differences between groups of sites (spatial contrasts). Sites were grouped into background (Sites 1 and 2), near-field (Sites 3, 4 and 5) and far-field (Sites 6 and 7). Spatial contrasts consisted of: (1) the difference between the average of downstream or impact sites (all five) and the average of the background sites, which tested for the average impact over all downstream sites, and (2) the difference between the average of the near-field sites and the average of the far-field sites, which tested for far-field effects.

Benthic invertebrate data are generally not normally distributed and rarely satisfy the basic assumptions of parametric statistics. However, violations of these assumptions, especially normality, do not necessarily invalidate the statistical test, since tests such as ANOVA are extremely robust (Glass et al. 1972, Green 1979). Therefore, ANOVA will generally be valid, even on extremely non-normal populations, especially when there are equal and large sample sizes (Glass et al. 1972, Harris 1975) and if appropriate transformations are used (Green 1979).

Transformations are used to normalize data or homogenize variances (Green 1979). The logarithmic transformation tends to be adequate, more comprehensible and more biologically meaningful than other transformations. If zeroes are present in the data set, then a $\log(x + c)$ transformation should be used, where "c" is the lowest non-zero value in the data set (usually 1).

The benthic data were also analyzed by RA, a pattern recognition technique (Hill 1973, Gauch et al. 1977) to determine the benthic invertebrate community structure of sites. This technique utilizes sample by sample data, treating each individually such that the analysis is completed without the loss of any original biological information. RA is a computer-assisted analysis technique which ordinates (aligns) sites on species by the method of successive approximation across environmental gradients (Hill 1973, Gauch et al. 1977). RA ranks species on a scale of 0 to 100 (ordination units) to approximate their positions along a species gradient. Site scores are produced by averaging the species scores which occur at each site. Species scores are recalculated from the initial site scores by averaging the scores of the sites which contain the species. This process is repeated for a maximum of 100 iterations or until site and species scores are stabilized. The result of this analysis is to group samples into biological units (clusters) determined by faunal assemblages of highest similarity.

RA can be used to relate changes in the physical and chemical environment to changes in the biotic community (Culp 1978, Crowther 1979, Culp and Davies 1980, Crowther and Luoma 1985). The separation and/or clustering of benthic communities indicated by RA is generally along the most significant environmental gradients. These environmental gradients are then used to interpret whether natural habitat differences or differences in water quality are causing the observed patterns in benthic community structure between sampling sites.

A trophic guild (feeding group) analysis was used to determine the ecological implications of any noted differences in the benthic community structure between sites. Each taxon was classified into a feeding group of either carnivore, detritivore, herbivore, detritivore/herbivore, herbivore/carnivore, carnivore/detritivore, or omnivore. This trophic classification depends on the dominant food consumed and/or feeding mechanisms of the species (Table 1) (modified from Merritt and Cummins 1984). The feeding group assigned to each taxon was determined from Merritt and Cummins (1984) for the insects and from the available literature (listed in Section 2.4) for all other organisms. The percent contribution of each feeding group of the total numbers per sample and site was calculated to determine any differences in benthic community feeding structure between sites. These differences were then compared to the separation of sites indicated by RA. The limited available literature and research to date does not allow the trophic guild analysis to be accurate at the species level or to take into account that organisms may change their feeding habits during their life history. The trophic guild analysis is intended only to provide a general indication of similarities and differences in feeding group structure between sites.

A comparison was made between the pre-operational and post-operational data from 1989 to 1992, to assess the effects of the ANC pulp and paper mill effluent on the benthic invertebrates of the Athabasca River. Spatial differences were compared before and after the mill became operational. The data were statistically analyzed using a repeated

Table 1. **Trophic classification of benthic invertebrates (modified from Merritt and Cummins 1984).**

Functional Feeding Group	Dominant Food	Feeding Mechanism
Carnivore (C)	Living animal tissue	Engulfers - whole animals or parts Piercers - attack prey and pierce tissues and cells and suck fluids
Detritivore (D)	Decomposing fine particulate organic matter	Collectors - filterers or suspension feeders-gatherers or deposit (sediment) feeders (includes surface film feeders)
	Decomposing coarse particulate organic matter or vascular plant tissue	Shredders - chewers and wood borers
Herbivore (H)	Living vascular hydrophyte plant tissue	Shredders - chewers and miners
	Periphyton - attached algae and associated material	Scrapers - grazing scrapers of mineral and organic surfaces
	Living vascular hydrophyte cell and tissue fluids or filamentous (macroscopic) algal cell fluids	Piercers - pierce tissues or cells and suck fluids
Detritivore/Herbivore (DH)	See above	See above
Herbivore/Carnivore (HC)	See above	See above
Carnivore/Detritivore (CD)	See above	See above
Omnivore (O)	All types - whatever is available	Various types

measures design with the sites divided into areas (background, near-field and far-field) and the sites used as replicates within areas, re-sampled each year (EVS 1992, Green 1993, Green pers. comm.). The variables analyzed were total number of taxa, number of EPT taxa, total number of organisms (standing crop), number of EPT and number of Chironomidae. Species diversity was not statistically analyzed, but was graphed to determine general trends between years.

Environmental stress can affect entire groups of benthic invertebrates (major taxonomic groups). Somewhat arbitrarily, benthic invertebrates have been divided into two types: "tolerant taxa" such as Chironomidae and Oligochaeta, which can withstand relatively important changes in their habitat, and "intolerant taxa" such as Ephemeroptera, Plecoptera and Trichoptera, which can withstand minor changes only (Anderson 1989). Although these two types of benthic invertebrates commonly cohabit, a marked deterioration or a marked improvement in water quality will usually result in the numerical dominance of one type over the other. In this study, the group of "intolerant taxa" (EPT group) and a "tolerant taxa" (Chironomidae group) were included as variables in the data analyses. Although, the individual taxa from the same major group tend to respond relatively uniformly, exceptions are not uncommon and the intensity of response can vary considerably among taxa (Anderson 1989). Therefore, an analysis of the community structure was also included to assess changes of dominant taxa between sites.

The basic computations were conducted using developed Basic programs. Statistical analyses were conducted using either Statistix (Version 4.0) (Analytical Software 1992) or SYSTAT (Wilkinson 1990). The RA (Fortran) program was run on the University of Calgary Honeywell Multics system. All input data were archived on a floppy disk.

2.6 QUALITY ASSURANCE/QUALITY CONTROL

A Quality Assurance/Quality Control (QA/QC) program was implemented during this study and it followed, where appropriate, the one described for conducting Environmental Effects Monitoring (EEM) studies (Environment Canada 1993). Standard Operating Procedures (SOP) were used for all field procedures (such as sample collection, sample shipping, sample storage, chain-of-custody forms), laboratory procedures (such as sample sorting, subsample size, re-sorting, reference collection) and reporting of data (including data entry checks). Documentation regarding QA/QC is provided in Appendix A.

3.0 RESULTS AND DISCUSSION

3.1 PHYSICAL CHARACTERISTICS

River flow conditions and the physical characteristics of sites can influence the water and habitat quality of the river and therefore, the benthic invertebrate community. Athabasca River flows recorded at Windfall (Station No. 07AE001) for the 1992 surveys, as well as previous surveys in 1989 to 1991, are shown in Figure 2 (Environment Canada 1990, 1991a and unpublished data). Flows during the spring 1992 survey were slightly lower than during the fall survey. The spring and fall 1992 surveys were conducted during flows which were only slightly above historical mean monthly flows. During the spring 1992 survey, mean daily discharge ranged from 156 to 167 m^3/s, while the mean monthly discharge for April was 128 m^3/s (Environment Canada unpublished data). The historical (1960 to 1990) mean monthly discharge for April was 103 m^3/s (Environment Canada 1991b). During the fall 1992 survey, mean daily discharge ranged from 197 to 251 m^3/s, while the mean monthly discharge for October was 176 m^3/s (Environment Canada unpublished data). The historical (1960 to 1990) mean monthly discharge for October was 179 m^3/s (Environment Canada 1991b).

The physical characteristics of water velocity, water depth and substrate composition were kept as similar as field conditions allowed between sample locations within a site, as well as between sites (Appendix B). There was some variation in mean water velocity and water depth between sites and seasons (Figure 3). In April, mean water velocity at the substrate surface between sites ranged from 42 to 58 cm/s, and in October from 36 to 50 cm/s. In April, mean water depth between sites ranged from 35 to 38 cm, and in October from 32 to 34 cm. Water velocity and water depth differences between sites within a season result from hydraulic and minor habitat differences between reaches of the river.

Substrates at all sites consisted mainly of cobbles and pebbles, with a few gravels (Figure 4). In April, pebbles were the dominant substrate at Sites 1, 2, 3 and 4, while at Sites 5, 6 and 7 cobbles were dominant. Pebbles comprised between 59.8 and 63.1 % of the substrate at sites where they were dominant, while cobbles comprised between 36.9 and 43.5 % of the substrate composition. At sites where cobbles were dominant, they comprised between 60.5 and 68.1 % of the substrate, while pebbles comprised between 25.6 and 38.4 % of the substrate composition. In October, cobbles were the dominant substrate at all sites, except Sites 1 and 3 where pebbles were dominant. Cobbles

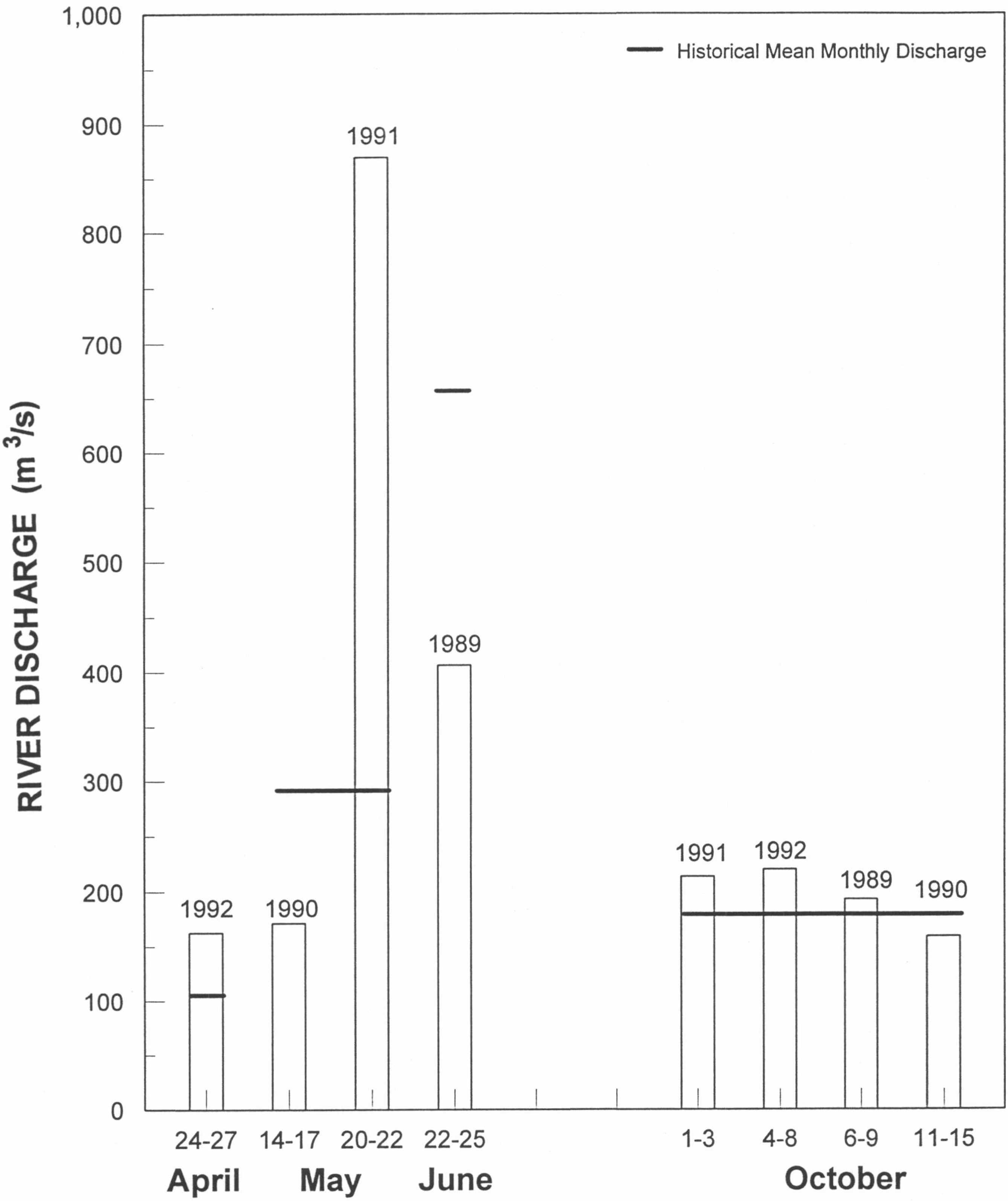


Figure 2. **Mean daily discharge during surveys and historical mean monthly discharge of the Athabasca River at Windfall (Station No. 07AE001).**

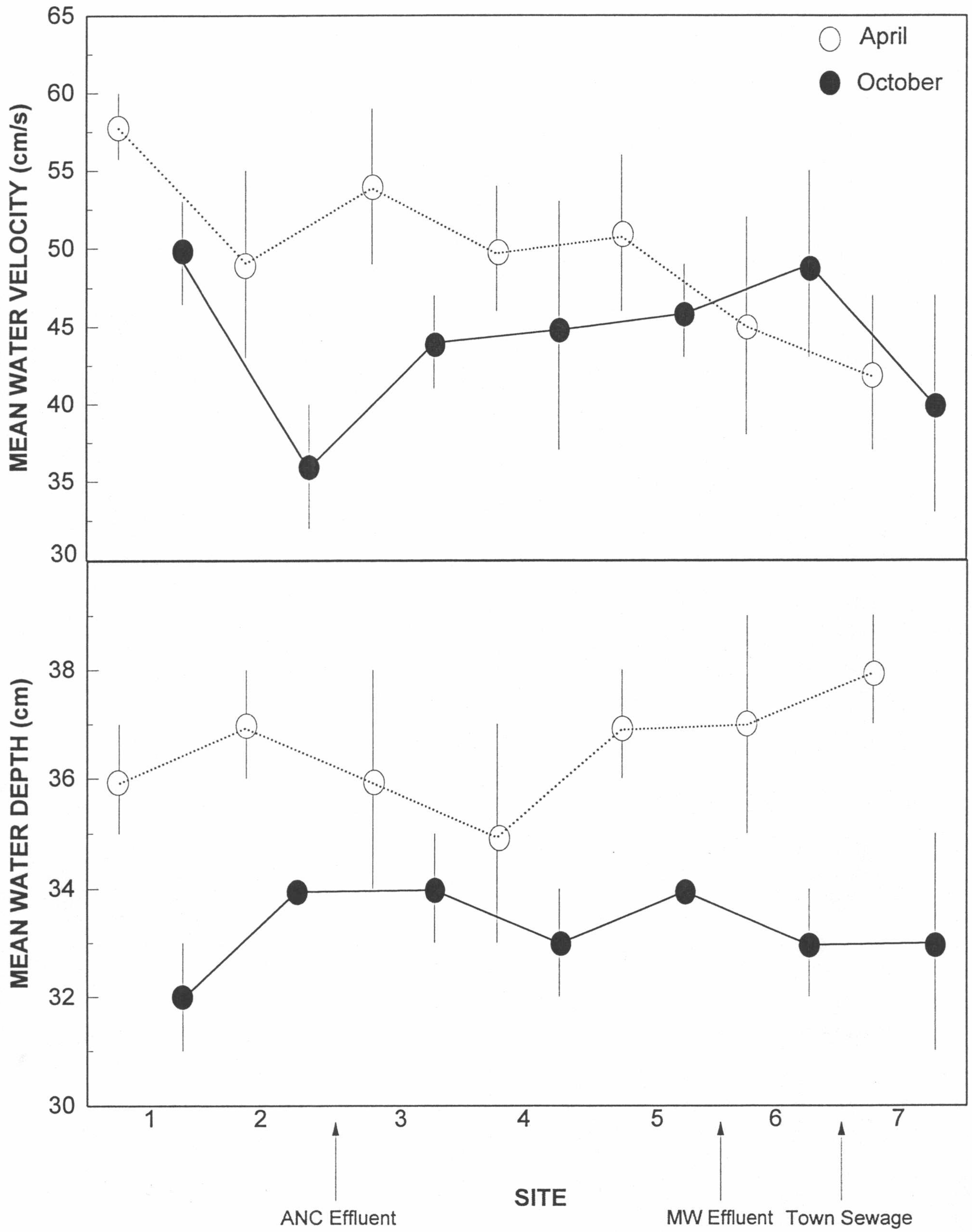


Figure 3. **Mean water velocity and water depth with 95% confidence limits for sites on the Athabasca River, April and October 1992.**

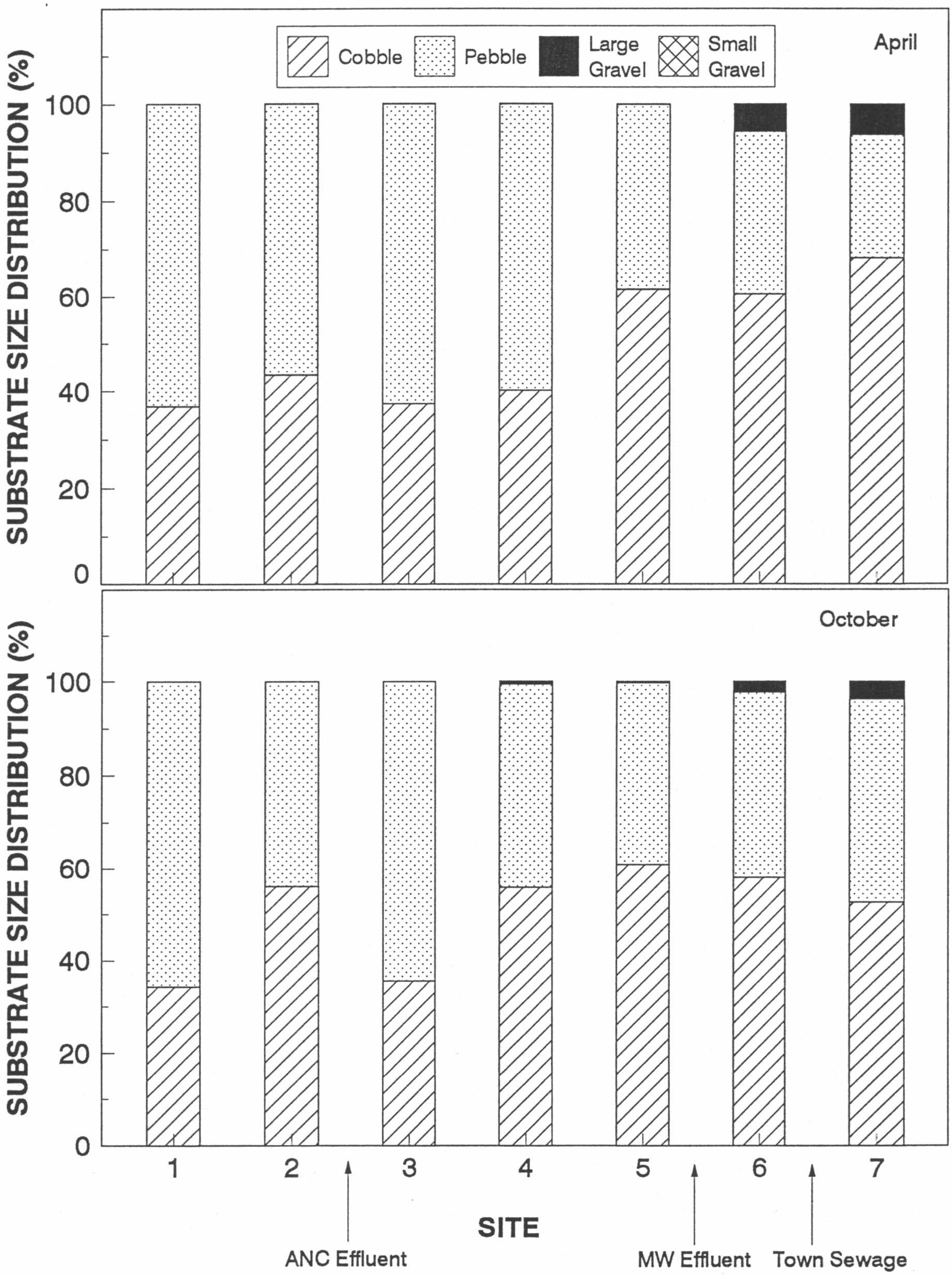


Figure 4. **Mean percent of substrate size distribution (by weight) for sites on the Athabasca River, April and October 1992.**

comprised between 52.7 and 60.8 % of the substrate at sites where they were dominant, while pebbles comprised between 38.9 and 44.0 % of the substrate composition. At Sites 1 and 3, pebbles comprised 65.7 and 64.4 %, and cobbles 34.3 and 35.6 %, respectively, of the substrate composition. Gravels comprised less than 7 % of the substrate composition in April and less than 4 % in October.

An estimate of the amount of algae found growing on the substrates in April indicated that only a light growth of algae was found at Sites 5, 6 and 7, whereas no algal growth was obvious at Sites 1, 2, 3 and 4 (Appendix B). In October, a light growth of algae was found on the substrates at all sites, except at Sites 3 and 4, where there was a moderate growth of algae (Appendix B).

Differences in physical characteristics, other than the presence of algae, did not likely cause any detectable differences in benthic community structure between sites within a season. Any habitat differences between sites within a season were, however, considered in the interpretation of the benthic invertebrate results.

3.2 WATER QUALITY

The results of the field and laboratory water quality analyses for the April and October 1992 surveys for all sites are presented in Tables 2 and 3. These data were based on single grab samples taken at each site and provide a description of water quality only at the time of sampling. ANC final treated effluent quality data for late winter/spring (February, March, April) and fall (August, September, October) 1992 are shown in Table 4. Mean daily treated effluent discharge to the river ranged from 16,872 to 19,390 m^3/d in late winter/spring and 15,400 to 16,902 m^3/d in the fall. A summary of Millar Western effluent quality data is presented in Appendix C.

The pH values recorded during the surveys ranged from 8.1 to 8.3 in both April and October. The pH values recorded at both background and downstream sites during the April and October survey were within both the Alberta Surface Water Quality Objective (ASWQO) of 6.5 to 8.5 and the Canadian Water Quality Guideline (CWQG) of 6.5 to 9.0 (Alberta Environment 1977, CCREM 1987). In the late winter/spring, the average monthly pH value of the ANC treated effluent ranged from 7.5 to 7.8, while in the fall, treated effluent pH ranged from 7.5 to 7.7. The pH of Millar Western's treated effluent was

Table 2. **Water quality results of samples collected from the Athabasca River, April and October 1992.**

	SITE															
	1		2		3		4		5		6		7			
Parameter	**27 Apr**	**6 Oct**	**27 Apr**	**6 Oct**	**27 Apr**	**6 Oct**	**26 Apr**	**6 Oct**	**25 Apr**	**8 Oct**	**25 Apr**	**5 Oct**	**24 Apr**	**4 Oct**	**ASWQO**	**CWQG**
pH (units)*	8.1	8.1	8.1	8.2	8.2	8.2	8.3	8.2	8.2	8.2	8.2	8.3	8.2	8.2	6.5 - 8.5	6.5 - 9.0
Conductivity (μmhos/cm)*	320	300	320	300	330	300	330	300	330	280	300	320	300	310	-	-
Dissolved Oxygen (ppm)*	11.0	11.3	10.9	11.3	10.7	11.2	11.0	11.4	11.5	11.6	11.2	10.8	10.9	10.5	5.0	5.0 - 9.5
DO (percent saturation)*	106	98	106	99	105	101	107	102	103	98	106	100	101	101	-	-
Temperature (^{o}C)*	10.0	6.0	10.5	6.5	11.0	7.5	10.5	7.0	7.0	5.0	9.5	8.5	8.5	10.0	Increase of 3^{o}C	-
Biochemical Oxygen Demand (5 day) (mg/L)	1.5	<1	1.4	<1	1.4	<1	1.4	<1	2	<1	2	<1	2	<1	-	-
True Color (Pt-Co units)	37	5	40	2.5	27	5	30	5	27	7.5	33	5	30	5	Increase of 30 units	-
Total Suspended Solids (mg/L)	11	5	13	4	11	6	10	7	20	4	17	4	22	2	Increase of 10 mg/L	Increase of 10 mg/L
Total Phosphorus (mg/L as P)	0.015	0.008	0.005	0.017	0.009	0.012	0.017	0.011	0.020	0.008	0.021	0.011	0.029	0.009	0.05	-
Total Kjeldahl Nitrogen (mg/L as N)	0.3	0.1	0.3	0.3	0.3	<0.1	0.3	<0.1	0.3	0.1	0.3	0.2	0.3	<0.1	1.0	-

*	Measured in the field.
ASWQO	Alberta Surface Water Quality Objectives (Alberta Environment 1977)
CWQG	Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987)
Pt-Co	Platinum Cobalt

Table 3. **Water quality results for selected parameters of samples collected at Sites 2 and 3 on the Athabasca River, April and October 1992. All values in mg/L unless otherwise stated.**

Parameter	Site 2 27 Apr	Site 2 6 Oct	Site 3 27 Apr	Site 3 6 Oct	ASWQO	CWQG
Total Phenols	0.004	<0.001	0.004	0.001	0.005	0.001
Total Organic Carbon	10	1	7	<1	-	-
Total Arsenic	<0.001	0.001	<0.001	0.001	0.01	0.05
Total Cadmium	<0.001	<0.001	<0.001	<0.001	0.01	0.0018*
Total Chromium	0.004	0.001	<0.001	0.001	0.05	0.002
Total Cobalt	0.001	<0.001	0.001	<0.001	-	-
Total Copper	0.004	0.002	0.003	<0.001	0.02	0.006*
Total Iron	0.38	0.08	0.34	0.10	0.30	0.30
Total Lead	<0.001	<0.001	<0.001	<0.001	0.005	0.007*
Total Manganese	<0.05	<0.05	<0.05	<0.05	0.05	-
Total Mercury	0.0003	<0.0005	0.0001	<0.0005	0.0001	0.0001
Total Molybdenum	0.006	0.001	0.005	0.002	-	-
Total Nickel	0.002	<0.001	0.001	<0.001	-	0.15*
Total Selenium	<0.001	<0.001	<0.001	<0.001	0.01	0.001
Total Silver	0.001	0.001	<0.001	<0.001	0.05	0.0001
Total Vanadium	0.005	0.001	0.003	0.003	-	-
Total Resin and Fatty Acids					0.1	-
Abietic Acid	ND	ND	ND	ND	-	-
Dehydroabietic Acid	ND	ND	ND	ND	-	-
Isopimaric/Levopimaric Acid	ND	ND	ND	ND	-	-
Neoabietic Acid	ND	ND	ND	ND	-	-
Palustric Acid	ND	ND	ND	ND	-	-
Pimaric Acid	ND	ND	ND	ND	-	-
Sandaracopimaric Acid	ND	ND	ND	ND	-	-
12-Chlorodehydroabietic Acid	ND	ND	ND	ND	-	-
14-Chlorodehydroabietic Acid	ND	ND	ND	ND	-	-
12,14-Dichlorodehydroabietic Acid	ND	ND	ND	ND	-	-
Arachidic Acid	ND	ND	ND	ND	-	-
Linoleic Acid**	0.0020	ND	0.0015	ND	-	-
Linolenic Acid	0.0014	ND	0.0013	ND	-	-
Myristic Acid	0.0012	ND	0.00095	ND	-	-
Oleic Acid**	0.00063	ND	ND	ND	-	-
Palmitic Acid	0.0039	ND	0.0029	ND	-	-
Stearic Acid	0.0014	ND	0.00085	ND	-	-
9,10-Dichlorostearic Acid	ND	ND	ND	ND	-	-
Total	0.0105	0	0.0075	0	-	-
Surrogate Recovery						
O-Methylpodocarpic Acid (%)	88	89	83	87	-	-
Tricosanoic Acid (%)	96	129	103	124	-	-

* At hardness > 180 mg/L ($CaCO_3$)

** Linoleic and oleic acid results have been method blank and glassware proof corrected, but they are also constituents of the detergent used in cleaning laboratory glassware.

ND Not Detected. Detection limit was 0.00063 mg/L in April and 0.00060 mg/L in October for all target compounds.

ASWQO Alberta Surface Water Quality Objectives (Alberta Environment 1977)

CWQG Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987)

Table 4. Average monthly concentrations of selected parameters for ANC final treated effluent, late winter/spring (February - April) and fall (August - October) 1992.

Parameter*	Winter/Spring			Fall		
	February	March	April	August	September	October**
Discharge (m^3/d)	19,390	17,603	16,872	16,902	16,027	15,400
pH (units)	7.5	7.7	7.8	7.5	7.6	7.7
Dissolved Oxygen (mg/L)	7.3	7.0	7.8	6.5	6.7	-
Dissolved Oxygen (percent saturation)	99	97	105	96	94	-
Temperature (°C)	26.4	28.0	26.6	31.6	28.8	26.3
Biochemical Oxygen Demand (mg/L)	11	24	7	8	8	8
True Color (Pt-Co units)	207	208	175	208	240	225
Total Suspended Solids (mg/L)	34	31	11	20	34	18
Total Phosphorus (as P) (mg/L)	4.08	7.29	5.46	7.41	2.16	2.15
Total Kjeldahl Nitrogen (mg/L)	2.76	3.31	2.52	3.36	3.75	1.24
Total Phenols (mg/L)	0.17	0.439	0.093	0.078	0.017	0.015
Total Resin and Fatty Acids (mg/L)						
Abietic Acid	ND	0.036	ND	ND	ND	ND
Dehydroabietic Acid	ND	ND	ND	ND	ND	ND
Isopimaric Acid	ND	ND	ND	ND	ND	ND
Levopimaric Acid	ND	ND	ND	ND	ND	ND
Neoabietic Acid	ND	ND	ND	ND	ND	ND
Palustric Acid	ND	ND	ND	ND	ND	ND
Pimaric Acid	ND	ND	ND	ND	ND	ND

(continued)

Table 4. (concluded)

Parameter*	Winter/Spring			Fall		
	February	March	April	August	September	October**
Sandaracopimaric Acid	ND	ND	ND	ND	ND	ND
Arachidic Acid	ND	ND	ND	ND	ND	ND
Linoleic Acid	0.022	0.053	ND	ND	ND	ND
Linolenic Acid	ND	ND	ND	ND	ND	ND
Myristic Acid	ND	ND	ND	ND	ND	ND
Oleic Acid	0.016	ND	ND	ND	ND	ND
Palmitic Acid	0.014	0.027	ND	0.015	ND	0.015
Stearic Acid	ND	ND	ND	ND	ND	ND
Total	0.052	0.116	0	0.015	0	0.015

Source: Alberta Newsprint Company (unpublished data)

* All monthly averages were based on daily values, except for total phosphorus and total Kjeldahl nitrogen, which were weekly values, and total phenols and total resin and fatty acids which were monthly values.

** Mill ran only 28 days in October 1992.

ND Not Detected. Detection limit was 0.01 mg/L.

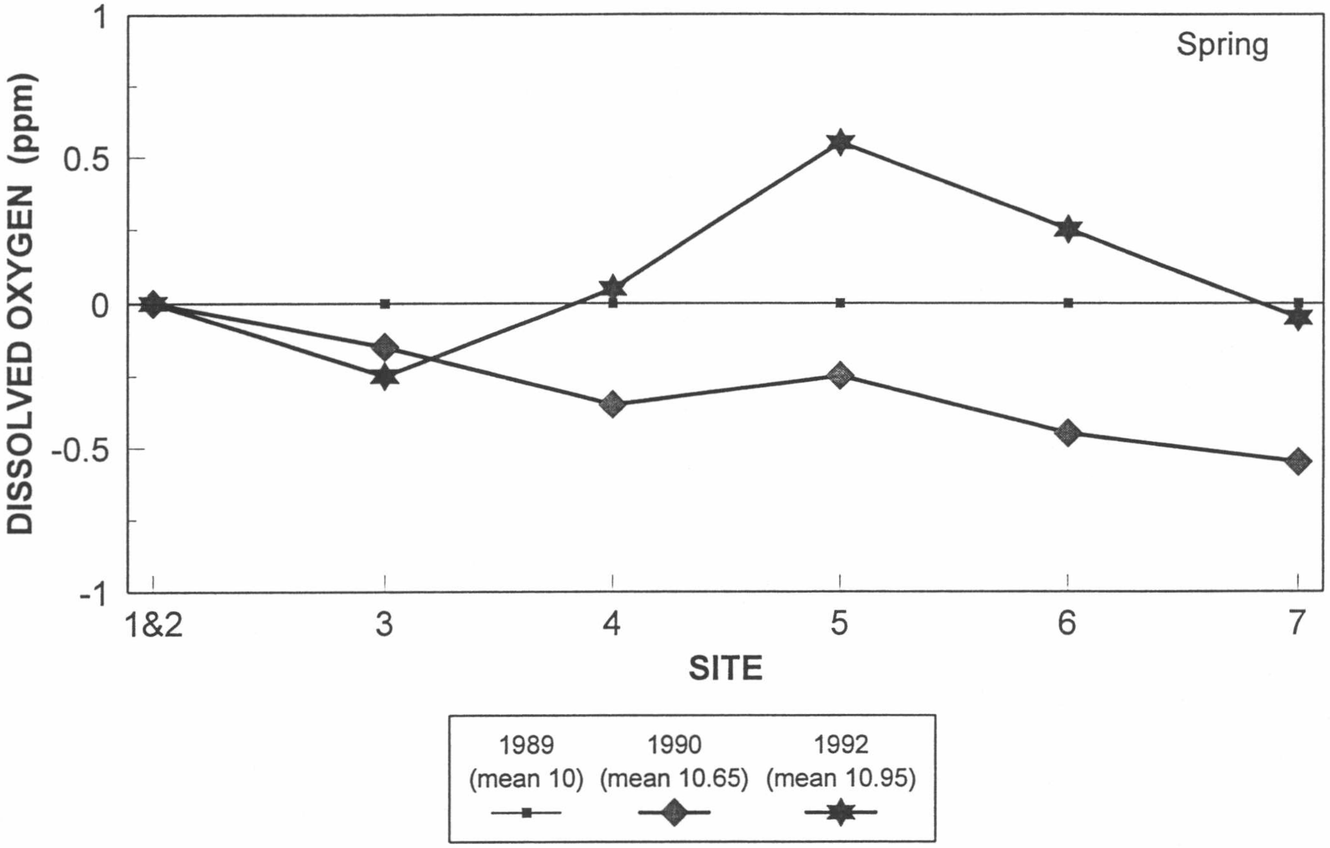
Pt-Co Platinum Cobalt

consistent during spring and fall, ranging from 8.3 to 8.4. Effluent discharge from both ANC and Millar Western, however, did not affect pH values at any downstream sites.

Conductivity values exhibited little seasonal variation and ranged from 300 to 330 μmhos/cm and 280 to 320 μmhos/cm during April and October, respectively. Conductivity values recorded in both April and October were not affected by discharge of treated effluent from ANC.

Dissolved oxygen concentrations during April ranged from 10.7 to 11.5 ppm, which represented 101 to 107 % saturation. Dissolved oxygen was slightly below background levels at Site 3 during the April survey (Figure 5). However, a more appropriate comparison would be in saturation levels, since the solubility of oxygen in water is temperature dependent and there were water temperature differences between sites during field measurements for dissolved oxygen. When saturation levels were compared, Sites 3, 5 and 7 exhibited a decrease below background levels, but the decrease between sites (106 % cf. 101 %) was considered marginal (Figure 6). In October, dissolved oxygen concentrations ranged from 10.5 to 11.6 ppm, which represented 98 to 102 % saturation. Although dissolved oxygen concentrations were below background levels at three sites (Sites 3, 6 and 7) (Figure 5), saturation levels exceeded background values at all sites downstream of ANC, except at Site 5 (Figure 6). ANC treated effluent quality data indicated that in late winter/spring, monthly average dissolved oxygen concentrations ranged from 7.0 to 7.8 ppm and saturation levels from 97 to 105 %. In the fall, dissolved oxygen concentrations and saturation levels of the treated effluent ranged from 6.5 to 6.7 ppm and 94 to 96 %, respectively.

Biochemical oxygen demand (BOD), a measure of the amount of oxygen required to oxidize organic matter in water, exhibited little variation between sites. In April, BOD_5 values ranged from 1.4 to 2.0 mg/L, while in October, concentrations at all sites were below the detection limit of 1 mg/L. The slightly higher values during the spring survey were probably the result of organic inputs associated with the onset of the spring freshet. The average monthly BOD concentration in the ANC treated effluent ranged from 7 to 24 mg/L in the late winter/spring; in the fall, concentrations were consistent at 8 mg/L. Although these values were above background levels in the river, dissolved oxygen concentrations, as discussed previously, were not affected by these BOD inputs.



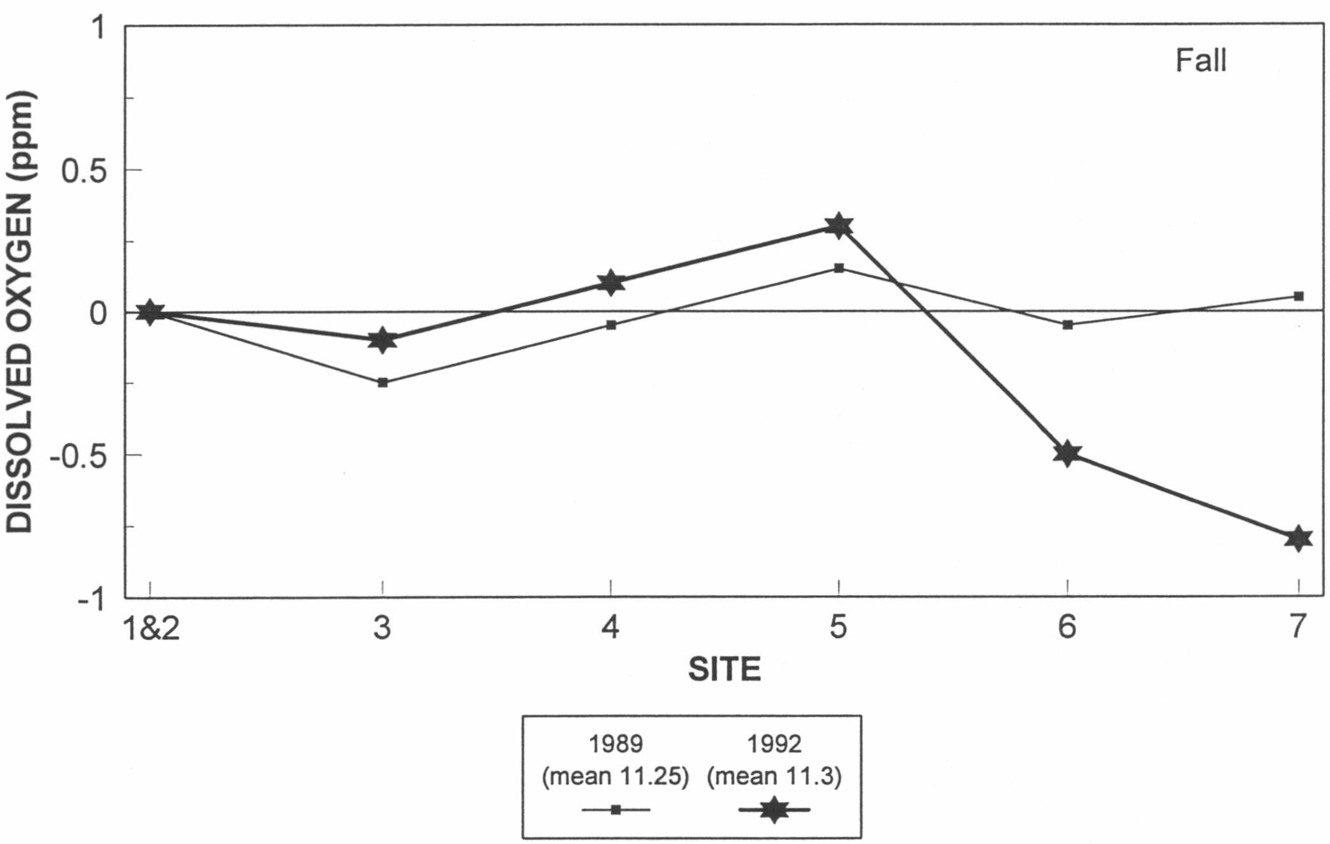


Figure 5. Dissolved oxygen concentrations for sites on the Athabasca River relative to mean of background Sites 1 and 2, spring and fall, 1992 compared to pre-operational years.

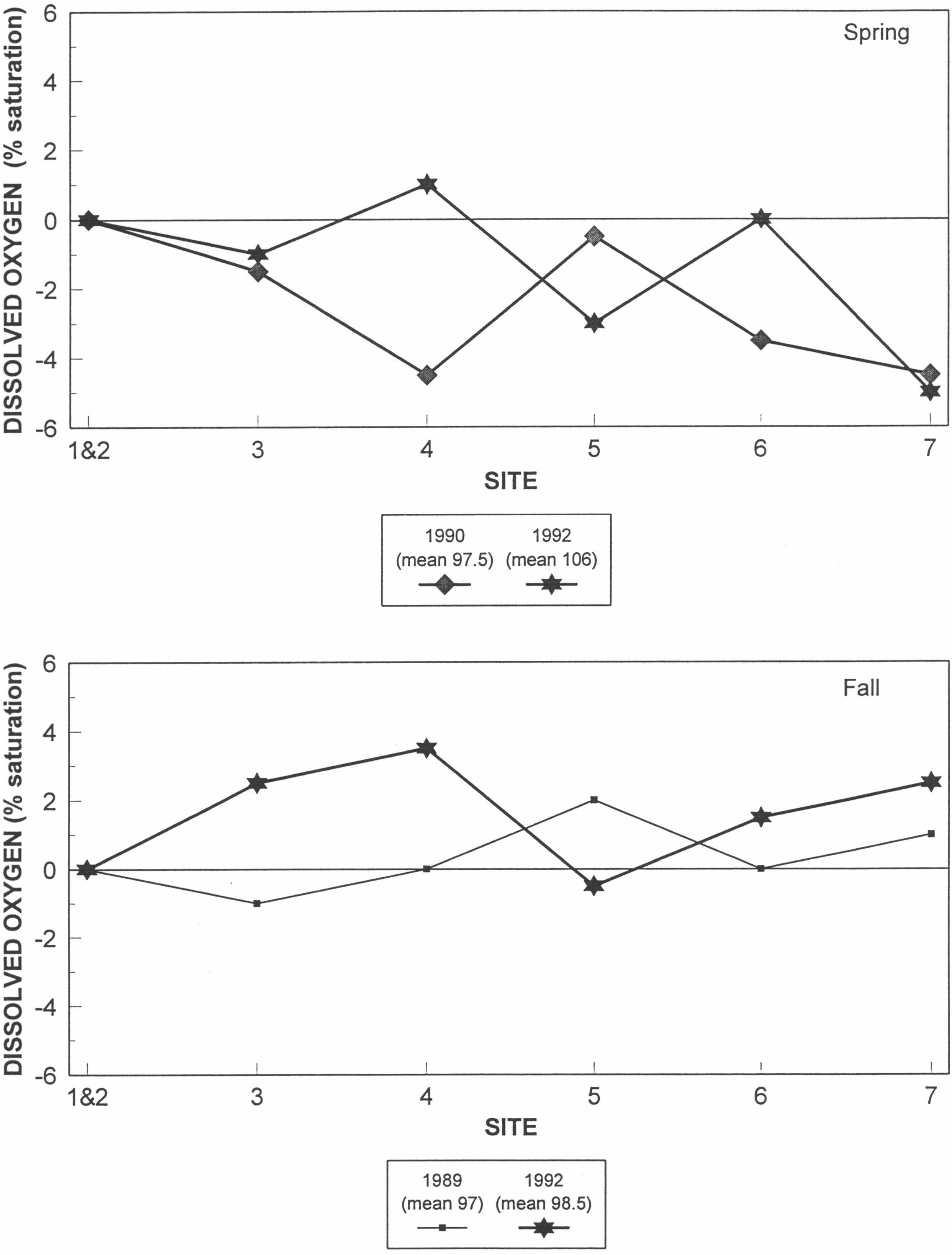


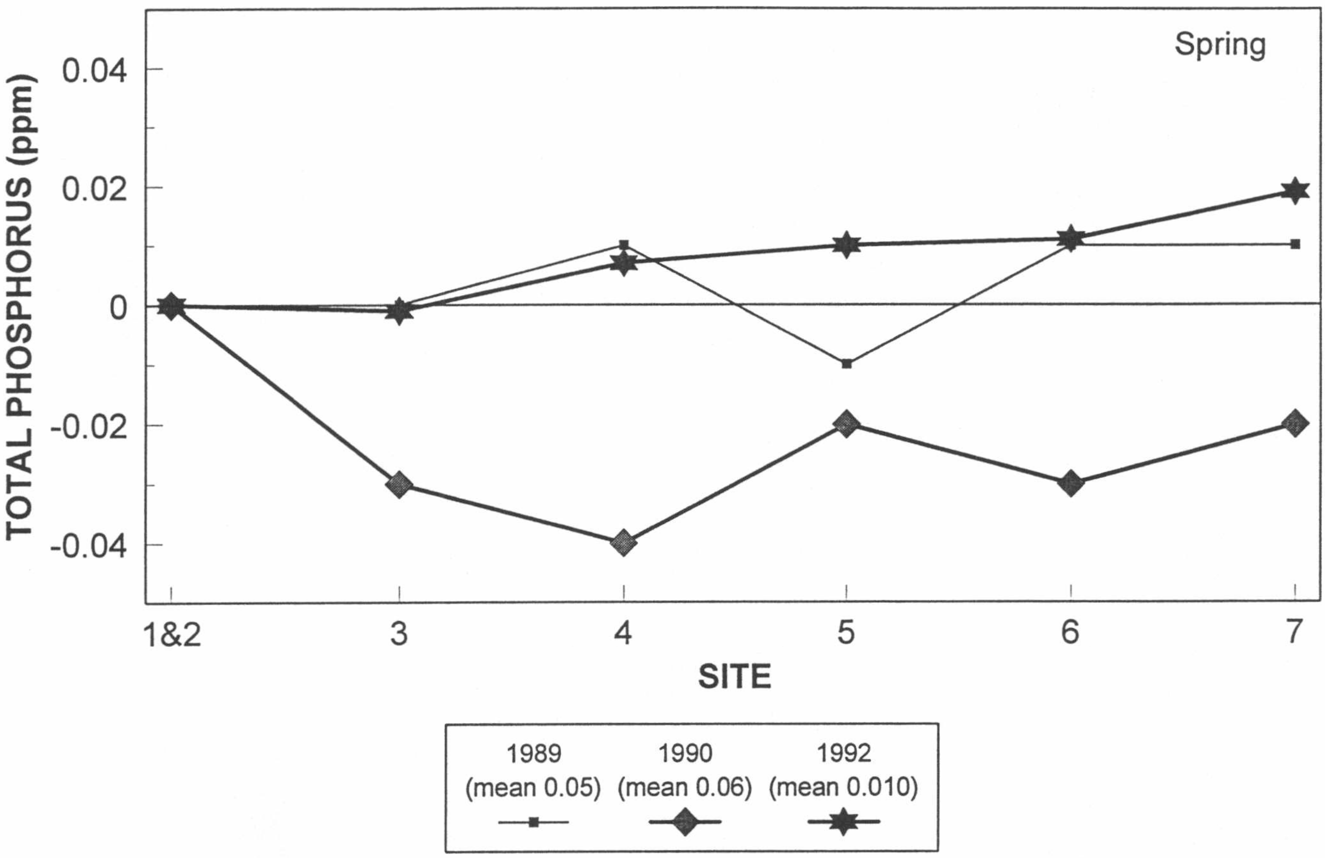
Figure 6. **Dissolved oxygen (% saturation) for sites on the Athabasca River relative to mean of background Sites 1 and 2, spring and fall, 1992 compared to pre-operational years.**

True color values recorded during the April survey ranged from 27 to 40 Pt-Co units, with all sites exhibiting levels lower than the background sites. In October, true color values were low and ranged from 2.5 to 7.5 Pt-Co units, with no discernible difference between background sites and sites downstream of the ANC effluent outfall. The monthly averages of true color values recorded for the ANC treated effluent ranged from 175 to 208 Pt-Co units in the late winter/spring and 208 to 240 Pt-Co units in the fall.

Total suspended solids concentrations exhibited slight seasonal variations. In April, total suspended solids concentrations ranged from 10 to 22 mg/L with a maximum value recorded at the lowermost site. Total suspended solids concentrations at sites immediately below ANC were not affected by effluent discharge. In the late winter/spring, total suspended solids concentrations in ANC treated effluent were low, ranging from 11 to 34 mg/L. In October, total suspended solids concentrations at sites on the river ranged from 2 to 7 mg/L, with little variation between the background sites and sites below ANC. Total suspended solids concentrations in ANC's final treated effluent ranged from 18 to 34 mg/L in the fall.

Phosphorus is generally regarded as the nutrient that limits productivity in freshwater ecosystems (Wetzel 1975). Total phosphorus (as P) concentrations ranged from 0.005 to 0.029 mg/L in April. In April, the maximum total phosphorus concentration of 0.029 mg/L was recorded at Site 7. Concentrations at sites immediately below ANC (Sites 3, 4 and 5) were similar to or slightly above the values recorded at the background sites (Figure 7). In October, total phosphorus concentrations ranged from 0.008 to 0.017 mg/L, with the maximum concentration recorded at Site 2, a background site. All concentrations were below the ASWQO of 0.050 mg/L total phosphorus. The average total phosphorus concentration in the ANC treated effluent during April and October was 5.46 and 2.15 mg/L, respectively, while in the Millar Western effluent it was 0.5 and 5.3 mg/L, respectively. The increase in total phosphorus concentrations at downstream sites in April was probably due to phosphorus inputs from effluent discharges.

Total Kjeldahl nitrogen (TKN) concentrations in April were consistent at all sites (0.3 mg/L). In October, TKN values ranged from <0.1 to 0.3 mg/L. The average monthly concentration of TKN in the ANC treated effluent in the late winter/spring ranged from 2.52 to 3.31 mg/L and 1.24 to 3.75 mg/L in the fall. However, it did not appear that effluent discharge had any significant affect on TKN concentrations in the



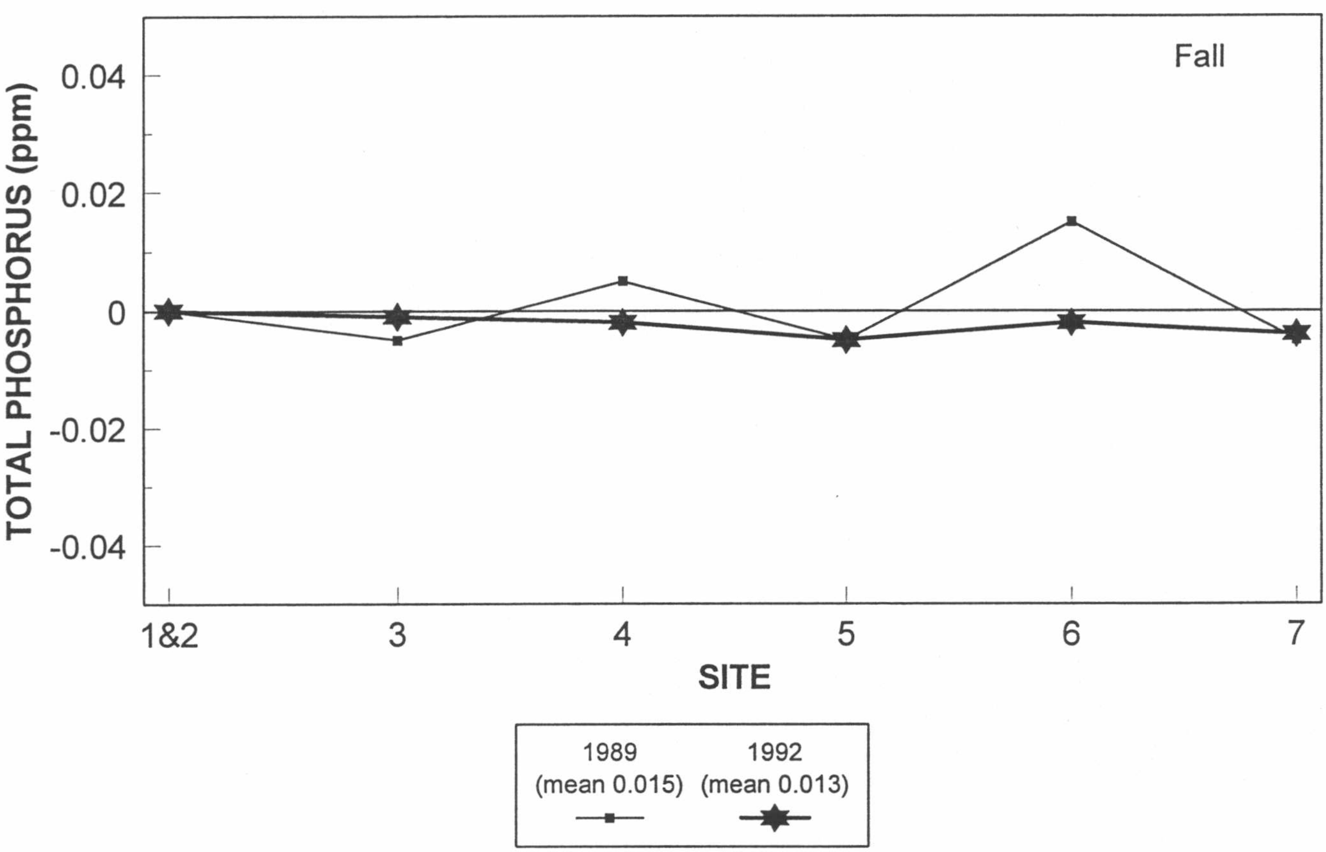


Figure 7. **Total phosphorus concentrations for sites on the Athabasca River relative to mean of background Sites 1 and 2, spring and fall, 1992 compared to pre-operational years.**

Athabasca River. All TKN values recorded during both surveys were below the ASWQO of 1.0 mg/L.

The detailed water quality results for Sites 2 and 3 in April and October are presented in Table 3. Total phenol concentrations in April were 0.004 mg/L at both Sites 2 and 3, while in October, a concentration of <0.001 mg/L was recorded at Site 2 and a concentration of 0.001 mg/L at Site 3. In the spring, phenol concentrations in ANC's treated effluent ranged from 0.093 to 0.439 mg/L, while in the fall, concentrations ranged from 0.015 to 0.078 mg/L. Effluent discharge did not appear to significantly affect total phenol concentrations in the Athabasca River. Phenolic compounds can occur naturally in the aquatic environment as decomposition products of aquatic plants and decaying vegetation (CCREM 1987). The total phenol values recorded during April and October at both sites were below the ASWQO of 0.005 mg/L, but were the same as, or exceeded the CWQG of 0.001 mg/L in April.

Total organic carbon concentrations showed little variation between sites and seasons. Total organic carbon values of 10 and 7 mg/L were recorded at Sites 2 and 3, respectively, in April, and 1 and <1 mg/L at Sites 2 and 3, respectively, in October.

Metal concentrations tended to be slightly higher during the April survey than in October, primarily as a result of the higher suspended sediment load during the spring. Metals such as copper, manganese and iron exhibit a strong affinity to adsorb to suspended particulate matter. In April, concentrations of chromium, iron and mercury exceeded either the CWQG or the ASWQO. Metals are not generally considered to be a major component of pulp mill effluent. The concentrations recorded in April were considered to be the result of natural processes. During October, metal concentrations were low and below both the ASWQO and CWQG.

Resin and fatty acids were detected at both Sites 2 and 3 during the April survey; several specific resin and fatty acids were common to both samples. However, the concentrations of these resin and fatty acids were lower at Site 3, just below ANC's effluent outfalll than at Site 2. It is suspected that the source of these compounds originated upstream of ANC. Resin and fatty acids were not detected at either site in October. Dehydroabietic, abietic pimaric, sandaracopimaric and neoabietic acids, commonly found in softwood pulp mill effluents (Taylor et al. 1988), were not detected during either the spring or fall surveys. Most resin and fatty acids concentrations in ANC's treated effluent in late winter/spring and fall were below the detection limit of 0.01 mg/L. The maximum total resin acid concentration recorded in the treated effluent in April was lower than the concentration recorded at Site 3 following dilution.

3.3 BENTHIC INVERTEBRATES

3.3.1 Basic Computations

A total of 131 taxa of benthic invertebrates has been identified (most to the generic level) from the 1989 to 1992 samples collected from the Athabasca River (Table 5). Of these, 70 taxa were identified from the April 1992 samples and 77 taxa from the October samples. A total of 9 new taxa (3 in April and 6 in October) was identified from the 1992 samples.

As part of the QA/QC program, the re-sorting of sample residues was conducted on five samples for each season to determine the level of sorting efficiency. The overall average sorting efficiency was 95 % for both the spring and fall samples (Appendix A).

The raw benthic data showing taxa identified and the number of organisms per sample for all sites are presented in Appendix D. Summary tables of the basic computations for each sample are presented in Appendix E. The total number of taxa, number of EPT taxa, total number of organisms, number of EPT and number of Chironomidae for both seasons were log-transformed for statistical analyses.

April

For the April data, sample 2-4 appeared to be an outlier. Some researchers prefer not to remove such data unless they are a result of obvious sampling or data entry errors (Grubbs 1969 and Green 1979). Therefore, sample 2-4 was not omitted from the data for statistical analyses.

The mean number of taxa at sites during April ranged between 18 and 29 taxa (Figure 8). The mean number of taxa was slightly higher at downstream sites than at background sites. The mean number of EPT taxa in April ranged between 6 and 11 taxa, with slightly higher values at downstream sites than at background sites (Figure 8). The mean number of taxa and EPT taxa at Site 2 (18 and 6 taxa, respectively) was slightly lowered by sample 2-4 which had 5 and 2 taxa, respectively. The mean number of taxa and EPT taxa at Site 2 omitting sample 2-4 was 22 and 7 taxa, respectively.

Table 5. **Benthic invertebrate species list with codes and functional feeding groups for the spring (S) and fall (F) 1992. Abbreviations for functional feeding groups as in Table 1.**

Species Code	Taxa	Functional Feeding Group	Season
	ARTHROPODA		
	INSECTA		
	Ephemeroptera (mayflies)		
	Ametropodidae		
001	*Ametropus neavei*	D	SF
	Baetidae		
002	*Baetis* spp.	DH	SF
003	*Acentrella insignificans*[a]	DH	F
	Ephemerellidae		
096	*Drunella coloradensis*	H	S
004	*Drunella doddsi*	H	SF
114	*Drunella grandis ingens*	H	SF
005	*Ephemerella inermis*	DH	SF
	Ephemeridae		
006	*Ephemera* sp.	D	S
	Heptageniidae		
007	*Epeorus* sp.	DH	S
008	*Heptagenia* sp.	DH	SF
009	*Rhithrogena* sp.	DH	SF
010	*Stenonema* sp.	DH	F
011	Heptageniidae (early instar)*	DH	S
	Leptophlebiidae		
129	*Leptophlebia* sp.	D	S
012	*Paraleptophlebia* sp.	DH	SF
	Metretopodidae		
013	*Metretopus borealis*	C	S
	Siphlonuridae		
014	*Ameletus* sp.	DH	SF
130	*Parameletus* sp.	DH	S
	Tricorythidae		
015	*Tricorythodes* sp.	D	SF
	Trichoptera (caddisflies)		
	Brachycentridae		
016	*Brachycentrus* sp.	O	SF
	Glossosomatidae		
115	*Glossosoma* sp.	H	F

(continued)

Table 5. (continued)

Species Code	Taxa	Functional Feeding Group	Season
	Hydropsychidae		
017	*Arctopsyche* sp.	O	SF
018	*Cheumatopsyche* sp.	O	SF
019	*Hydropsyche* spp.	O	SF
	Hydroptilidae		
020	*Hydroptila* sp.	H	SF
021	*Stactobiella* sp.	DH	S
	Lepidostomatidae		
022	*Lepidostoma* sp.	D	F
	Leptoceridae		
023	*Oecetis* sp.	HC	SF
	Limnephilidae		
116	*Apatania* sp	DH	SF
097	Limnephilidae (early instar)*	DH	F
	Polycentropodidae		
117	*Neureclipsis* sp.	O	F
	Psychomyiidae		
024	*Psychomyia* sp.	DH	SF
	Plecoptera (stoneflies)		
025	Capniidae[b]	D	SF
	Chloroperlidae		
	Chloroperlinae		
026	*Haploperla brevis*	HC	SF
098	*Triznaka* sp.	C	S
099	Chloroperlinae (early instar)*	C	SF
	Nemouridae		
100	*Nemoura sp.*	D	S
111	*Podmosta* sp.	D	S
027	*Zapada* sp.	D	SF
	Perlidae		
028	*Claassenia sabulosa*	C	SF
101	*Hesperoperla pacifica*	C	F
	Perlodidae		
029	*Cultus* sp.	C	SF
030	*Isogenoides* sp.	C	SF
031	*Isoperla* sp.	C	SF
032	Perlodidae (early instar)*	C	SF
	Pteronarcyidae		
033	*Pteronarcella badia*	DH	SF
034	*Pteronarcys dorsata*	DH	SF
	Taeniopterygidae		
035	*Taenionema* sp.	H	SF

(continued)

Table 5. (continued)

Species Code	Taxa	Functional Feeding Group	Season
	Diptera (flies, midges)		
	Athericidae		
036	*Atherix* sp.	C	S
	Blephariceridae		
118	*Bibiocephala grandis*	H	F
	Ceratopogonidae		
037	*Bezzia/Palpomyia gp.*[b]	C	SF
	Empididae		
038	*Chelifera* sp.	CD	SF
039	*Hemerodromia* sp.	CD	SF
119	*Wiedemannia* sp.	C	F
	Simuliidae		
040	*Simulium* sp.	O	S
	Tanyderidae		
120	*Protanyderus* sp.	DH	F
	Tipulidae		
123	*Dicranota* sp.	C	F
041	*Hexatoma* sp.	C	SF
042	*Limnophila* sp.	C	SF
043	Eriopterini Tribe	D	SF
	Chironomidae		
	Chironominae		
	Chironomini Tribe		
124	*Chironomus* sp.	DH	F
044	*Cryptochironomus* sp.	C	SF
045	*Microtendipes* sp.	D	SF
046	*Paracladopelma/Cyphomella* spp.[c]	D	SF
047	*Paralauterborniella nigrohalteralis*	D	S
112	*Paratendipes* sp.	D	S
125	*Phaenopsectra* sp.	DH	F
048	*Polypedilum* spp.	DH	SF
049	*Robackia demeijerei*	D	SF
050	*Saetheria* sp.	D	S
126	*Stenochironomus* sp.	D	F
051	Chironomini (early instar)*	D	SF
	Tanytarsini Tribe		
052	*Cladotanytarsus* sp.	D	SF
053	*Constempellina* sp.	D	S
054	*Micropsectra* sp.	D	SF
055	*Rheotanytarsus* spp.	D	SF
056	*Stempellinella* sp.	DH	SF
057	*Sublettea* sp.	D	SF
058	*Tanytarsus* sp.	D	SF
059	Tanytarsini (early instar)*	D	S

(continued)

Table 5. (continued)

Species Code	Taxa	Functional Feeding Group	Season
	Diamesinae		
	Diamesini Tribe		
102	*Diamesa* sp.	D	SF
060	*Pagastia* sp.	D	F
061	*Potthastia gaedii* gp.	DH	SF
127	*Potthastia longimana* gp.	DH	F
	Orthocladiinae		
103	*Brillia* sp.	D	SF
062	*Cardiocladius* sp.	C	F
104	*Corynoneura* sp.	D	SF
063	*Cricotopus/Orthocladius* spp.	DH	SF
064	*Eukiefferiella* spp.	DH	SF
105	*Heleniella* sp.	D	F
106	*Heterotrissocladius* sp.	D	SF
107	*Krenosmittia* sp.	D	SF
065	*Nanocladius* sp.	D	SF
108	*Orthocladius (Symposiocladius) lignicola*	D	F
066	*Paracladius* sp.	D	F
067	*Parakiefferiella* spp.	D	SF
068	*Parametriocnemus* sp.	D	SF
109	*Psectrocladius* sp.	DH	S
069	*Rheocricotopus* sp.	DH	SF
070	*Synorthocladius* sp.	D	SF
071	*Thienemanniella* sp.	D	SF
072	*Tvetenia* spp.	D	SF
073	Orthocladiinae (early instar)*	D	SF
	Prodiamesinae		
074	*Monodiamesa* sp.	D	SF
	Tanypodinae		
	Macropelopiini Tribe		
113	*Procladius* sp.	C	S
	Pentaneurini Tribe		
075	*Larsia* sp.	C	SF
131	*Monopelopia* sp.	C	S
076	*Nilotanypus* sp.	C	S
077	*Thienemannimyia* gp.	C	SF
078	Tanypodinae (early instar)*	C	F
	Coleoptera (beetles)		
	Dytiscidae		
079	*Oreodytes* sp.	C	F
	Elmidae		
080	*Optioservus* sp.	DH	S

(continued)

Table 5. (continued)

Species Code	Taxa	Functional Feeding Group	Season
121	Collembola (springtails)	DH	SF
	Hemiptera		
	Corixidae (water boatmen)		
081	*Callicorixa audeni*	C	SF
122	*Hesperocorixa atopodonta*	C	F
082	*Sigara decoratella*	DH	F
083	*Sigara solensis*	DH	F
	Odonata (dragonflies)		
	Gomphidae		
084	*Ophiogomphus* sp.	C	SF
	Megaloptera (alderflies)		
	Sialidae		
110	*Sialis* sp.	C	S
	ARACHNIDA		
085	Hydracarina (water mites)	C	SF
	CRUSTACEA		
	Podocopa (seed shrimps)		
	Candonidae[d]		
086	*Candona* sp.	O	SF
	ANNELIDA		
	OLIGOCHAETA (aquatic earthworms)		
	Haplotaxida		
087	Enchytraeidae	D	SF
088	Naididae	D	SF
089	Tubificidae	D	SF
	Lumbriculida		
090	Lumbriculidae	D	S

(continued)

Table 5. (concluded)

Species Code	Taxa	Functional Feeding Group	Season
	HIRUDINEA (leeches)		
	Rhynchobdellida		
	Glossiphoniidae		
091	*Helobdella stagnalis*	C	SF
092	**NEMATODA** (roundworms)	D	SF
	MOLLUSCA		
	GASTROPODA (snails)		
	Basommatophora		
	Lymnaeidae		
093	*Stagnicola catascopium*[e]	O	SF
	Planorbidae		
128	*Gyraulus* sp.	DH	F
	PELECYPODA (clams)		
	Heterodonta		
	Sphaeriidae		
094	*Pisidium* sp.	O	S
	PLATYHELMINTHES		
	TURBELLARIA (flatworms)		
	Tricladida (planarians)		
	Planariidae		
095	*Polycelis coronata*	CD	F

* The organisms indicated as early instars were too small to identify to the genus level.

a *Pseudocloeon* sp. has recently been placed into the *Acentrella* sp., along with the *Baetis* (*Laponica*) group (McCafferty and Waltz 1990).

b Definitive separation within the Capniidae family and the *Bezzia/Palpomyia* gp. is difficult with the keys presently available.

c *Cyphomella* sp. was previously (1989) identified as *Paracladopelma* sp. Definitive separation between these two genera is difficult with the present keys.

d *Candona* sp. has recently been moved from the Cypridae to the Candonidae family.

e *Stagnicola catascopium* was previously (1989-1991) identified as *Lymnaea* sp.

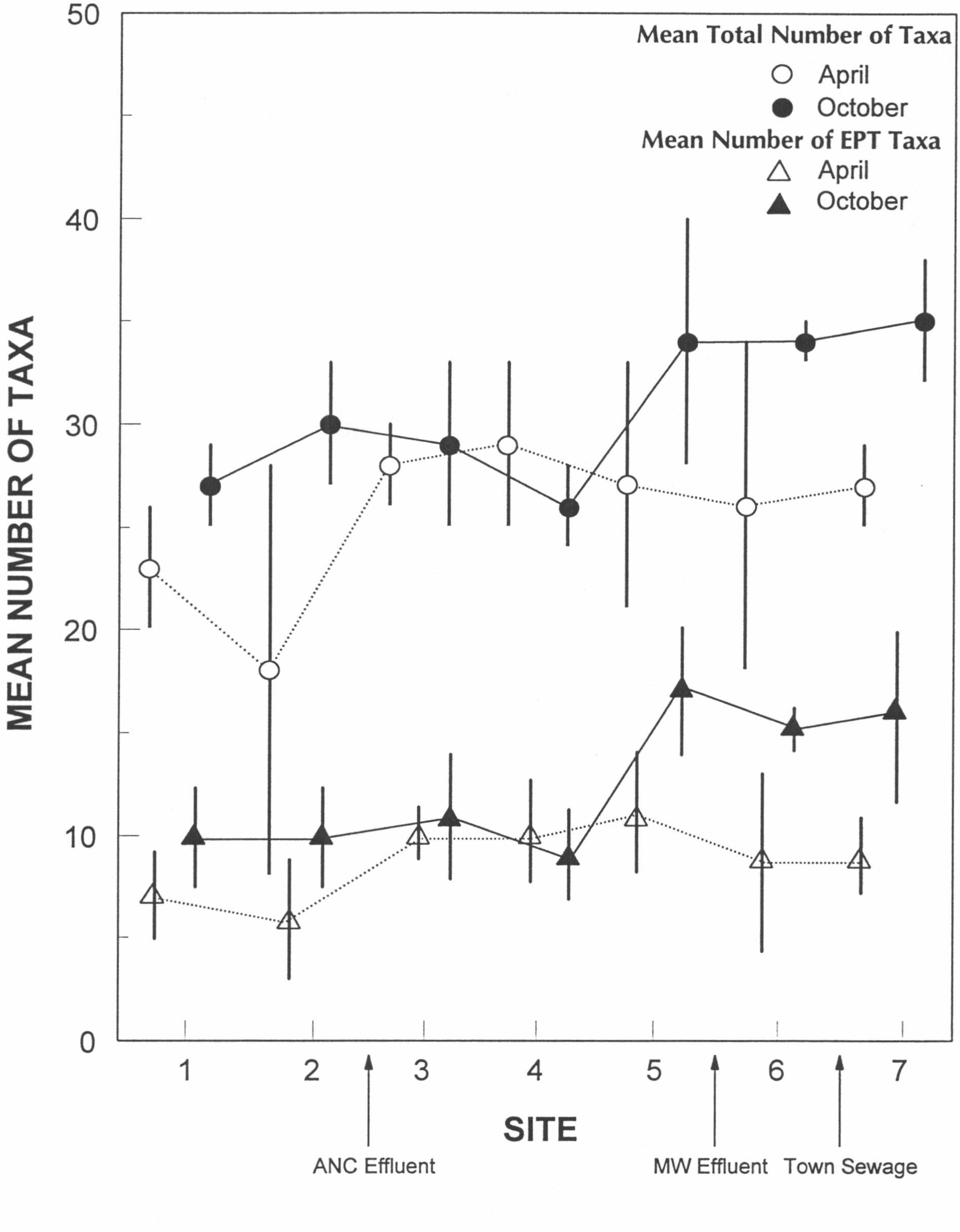


Figure 8. Mean number of taxa and mean number of EPT taxa with 95% confidence limits for sites on the Athabasca River, April and October 1992.

The results of the ANOVA indicated that there were significant differences during April in the mean number of taxa and the mean number of EPT taxa ($p < 0.05$) (Appendix F). *A priori* testing, using orthogonal contrasts, showed that both the number of taxa and the number of EPT taxa were significantly higher at downstream sites than at background sites ($p < 0.05$) during April. However, there were no significant differences in the number of taxa or the number of EPT taxa between near-field sites and far-field sites ($p > 0.05$).

The mean standing crop at sites during April ranged between 4,756 and 16,711 organisms/m^2 (Figure 9). The mean standing crop was higher at downstream sites than at background sites. At downstream sites, the mean standing crop decreased at Site 6 and then increased again at Site 7 to a value similar to Sites 3, 4 and 5. The mean standing crop at Site 2 (4,756 organisms/m^2) was lowered by sample 2-4 which had a standing crop of 157 organisms/m^2. The mean standing crop at Site 2 omitting sample 2-4 was 5,905 organisms/m^2.

The results of the ANOVA indicated that there was a significant difference during April in the mean number of organisms (or standing crop) between sites ($p < 0.05$) (Appendix F). The orthogonal contrasts showed that the number of organisms was significantly higher at downstream sites than at background sites ($p < 0.05$) during April. However, there was no significant difference in the number of organisms between near-field sites and far-field sites ($p > 0.05$).

The mean species diversity at sites during April ranged between 1.47 and 2.15 (Figure 10). The mean species diversity was lower at downstream sites than at background sites. At downstream sites, the mean species diversity decreased to the lowest value at Site 6 and then increased slightly at Site 7. The mean species diversity at Site 2 (1.88) was lowered by sample 2-4 which had a value of 1.44. The mean species diversity at Site 2 omitting sample 2-4 was 1.99. A low species diversity indicates that the majority of organisms present belong to only a few taxa and that other fauna are low in numbers, thus causing an uneven distribution.

The mean species diversity for all downstream sites (1.65) was lower than for background sites (2.02) during April. The mean species diversity for near-field sites (1.72) was higher than for far-field sites (1.54).

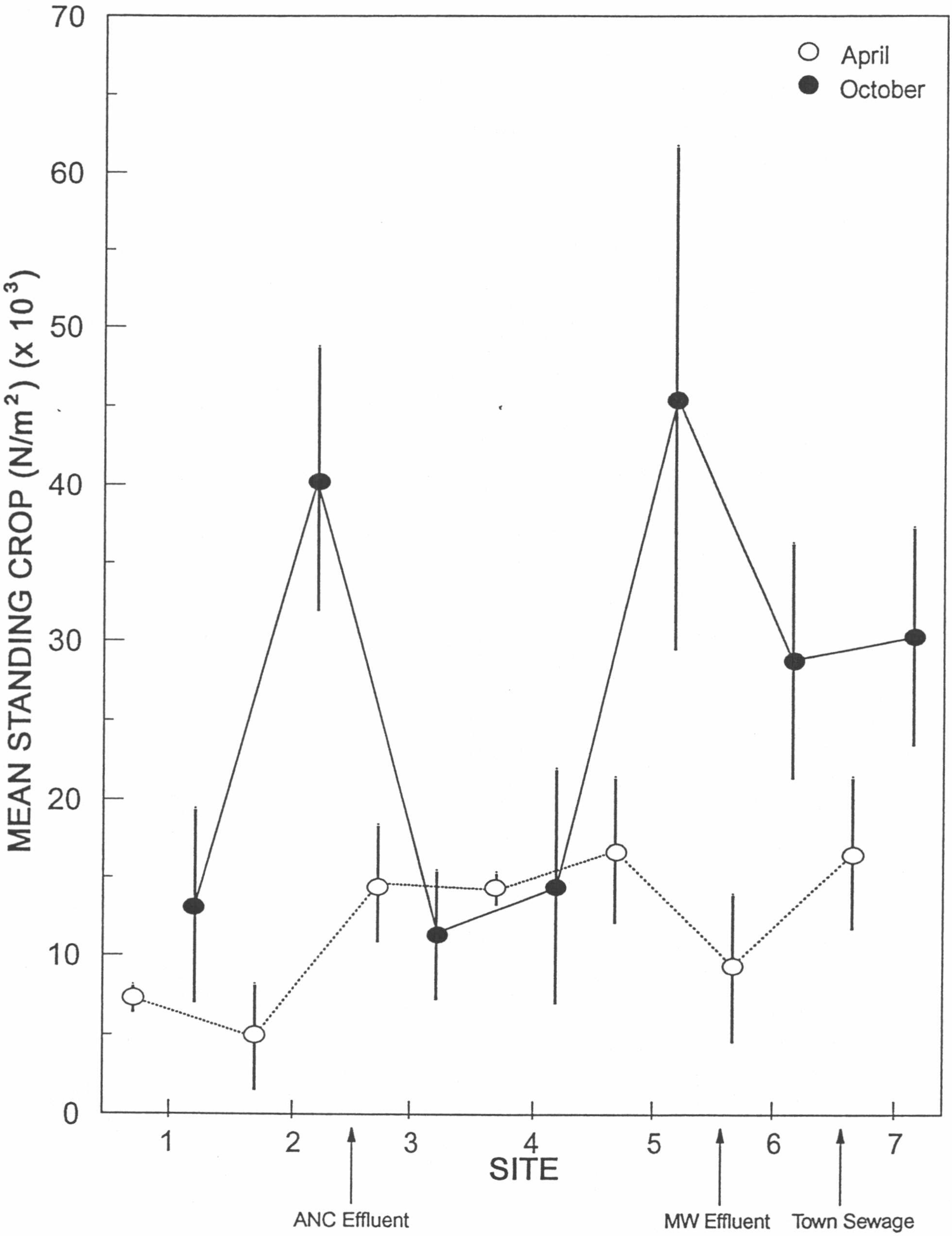


Figure 9. **Mean standing crop (number/m^2) with 95% confidence limits for sites on the Athabasca River, April and October 1992.**

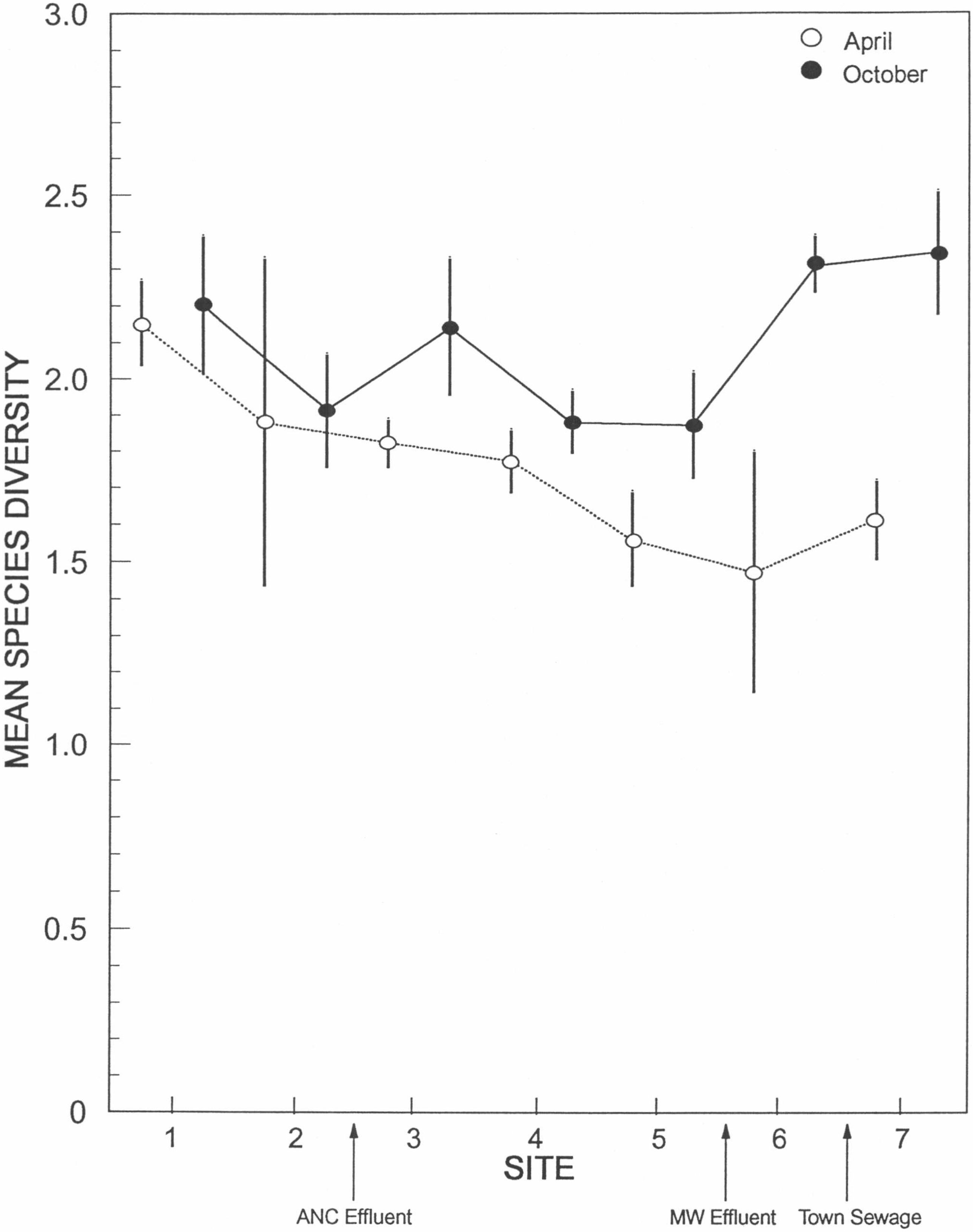


Figure 10. **Mean Shannon-Weaver species diversity with 95% confidence limits for sites on the Athabasca River, April and October 1992.**

Ephemeroptera (mayflies), Chironomidae (midges) and Oligochaeta (aquatic worms) were the dominant taxonomic groups at all sites during April (Figure 11). Plecoptera (stoneflies), Trichoptera (caddisflies) and the remaining groups were also present, but in smaller numbers. The mean standing crop of Ephemeroptera fluctuated between sites, with the highest values occurring at Sites 1, 3 and 5. The mean standing crop of Chironomidae was higher at all downstream sites than at background sites. A slight decrease in Chironomidae standing crop occurred at Site 6 compared to other downstream sites. Chironomidae was the main group contributing to the higher mean standing crop of organisms at downstream sites. The mean standing crop of Oligochaeta was highest at Sites 4 and 7, while values at Sites 3, 5 and 6 were similar to background values.

The results of the ANOVA indicated that there were significant differences during April in the mean number (standing crop) of EPT and the mean number of Chironomidae between sites ($p < 0.05$) (Appendix F). The orthogonal contrasts showed that the number of EPT was not significantly different between background sites and downstream sites ($p > 0.05$), but was significantly higher at near-field sites than at far-field sites ($p < 0.05$). The number of Chironomidae was significantly higher at downstream sites than at background sites ($p < 0.05$), but was not significantly different between near-field sites and far-field sites ($p > 0.05$).

October

The mean number of taxa at sites during October ranged between 26 and 35 taxa (Figure 8). The mean number of taxa at Sites 5, 6 and 7 was slightly higher than at Sites 1, 2, 3 and 4. The mean number of EPT taxa in October ranged from 9 to 17 taxa, with slightly higher values at Sites 5, 6 and 7 than at Sites 1, 2, 3 and 4 (Figure 8). The mean number of taxa and the mean number of EPT taxa during October was higher than during April at all sites, except Site 4.

The results of the ANOVA indicated that there were significant differences during October in the mean number of taxa and the mean number of EPT taxa ($p < 0.05$) (Appendix F). The orthogonal contrasts showed that both the number of taxa and the number of EPT taxa were significantly higher at downstream sites than at background sites ($p < 0.05$) and were significantly higher at far-field sites than near-field sites ($p < 0.05$) during October.

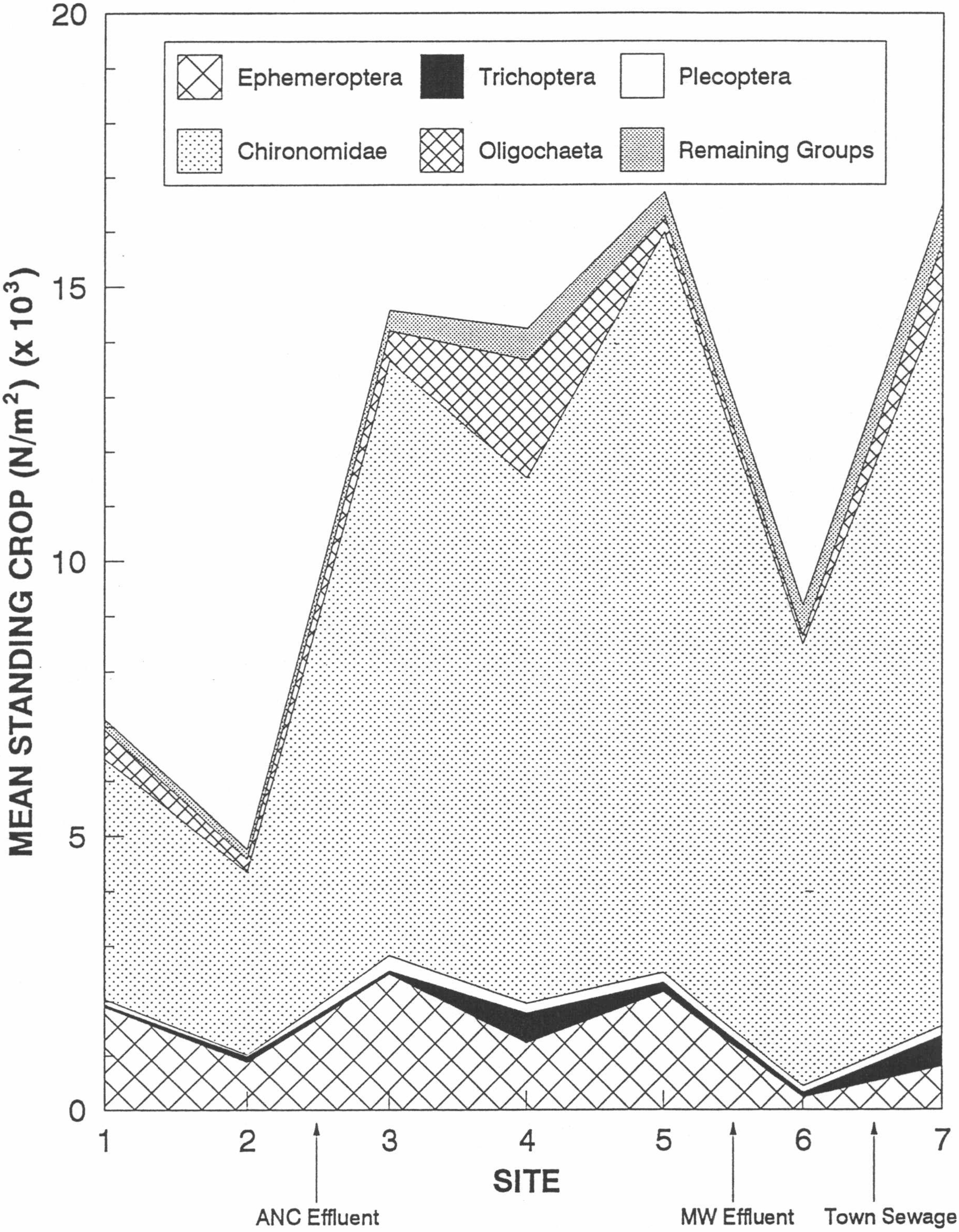


Figure 11. **Mean cumulative standing crop (number/m^2) of the major taxonomic groups for sites on the Athabasca River, April 1992.**

The mean standing crop at sites during October ranged between 11,274 and 45,536 organisms/m^2 (Figure 9). There was a large difference in mean standing crop between background Sites 1 and 2. The mean standing crop at Sites 3 and 4 was similar to Site 1, while Site 5 was slightly higher than Site 2. The mean standing crop at Sites 6 and 7 was intermediate to all other sites. The mean standing crop during October was higher than during April at all sites, except Site 3.

The results of the ANOVA indicated that there was a significant difference during October in the mean number of organisms (or standing crop) between sites ($p < 0.05$) (Appendix F). The orthogonal contrasts showed that the number of organisms was not significantly different between downstream sites and background sites ($p > 0.05$), but was significantly higher at far-field sites than near-field sites ($p < 0.05$) during October.

The mean species diversity at sites during October ranged between 1.87 and 2.34 (Figure 10). The mean species diversity at Site 3 was similar to background values, while at Sites 4 and 5 it was slightly below and at Sites 6 and 7 slightly above background values. The mean species diversity at all sites during October was higher than during April.

The mean species diversity for all downstream sites (2.11) was higher than for background sites (2.06) during October. The mean species diversity for near-field sites (1.96) was lower than for far-field sites (2.33). This was opposite to the April data.

Ephemeroptera, Chironomidae and Oligochaeta were the dominant taxonomic groups at all sites during October (Figure 12), similar to April. The mean standing crop of Ephemeroptera was lower at Sites 3 and 4 and higher at Site 5 than at background sites, while at Sites 6 and 7 it was similar to background sites. The mean standing crop of Chironomidae varied at background sites, with 8,596 chironomids/m^2 at Site 1 and 29,090 chironomids/m^2 at Site 2. The mean standing crop of Chironomidae at Sites 3 and 4 was similar to Site 1, while Site 5 was slightly higher than Site 2. At Sites 6 and 7, the mean standing crop of Chironomidae was intermediate to all other sites. The mean standing crop of Oligochaeta fluctuated between sites with the lowest value at Site 1, the highest values at Sites 2 and 4, and intermediate values at Sites 3, 5, 6 and 7. Trichoptera, Plecoptera and the remaining groups were present in smaller numbers. There was an increase in the mean standing crop of Trichoptera, Plecoptera and the remaining groups at downstream Sites 5, 6 and 7 compared to other upstream sites.

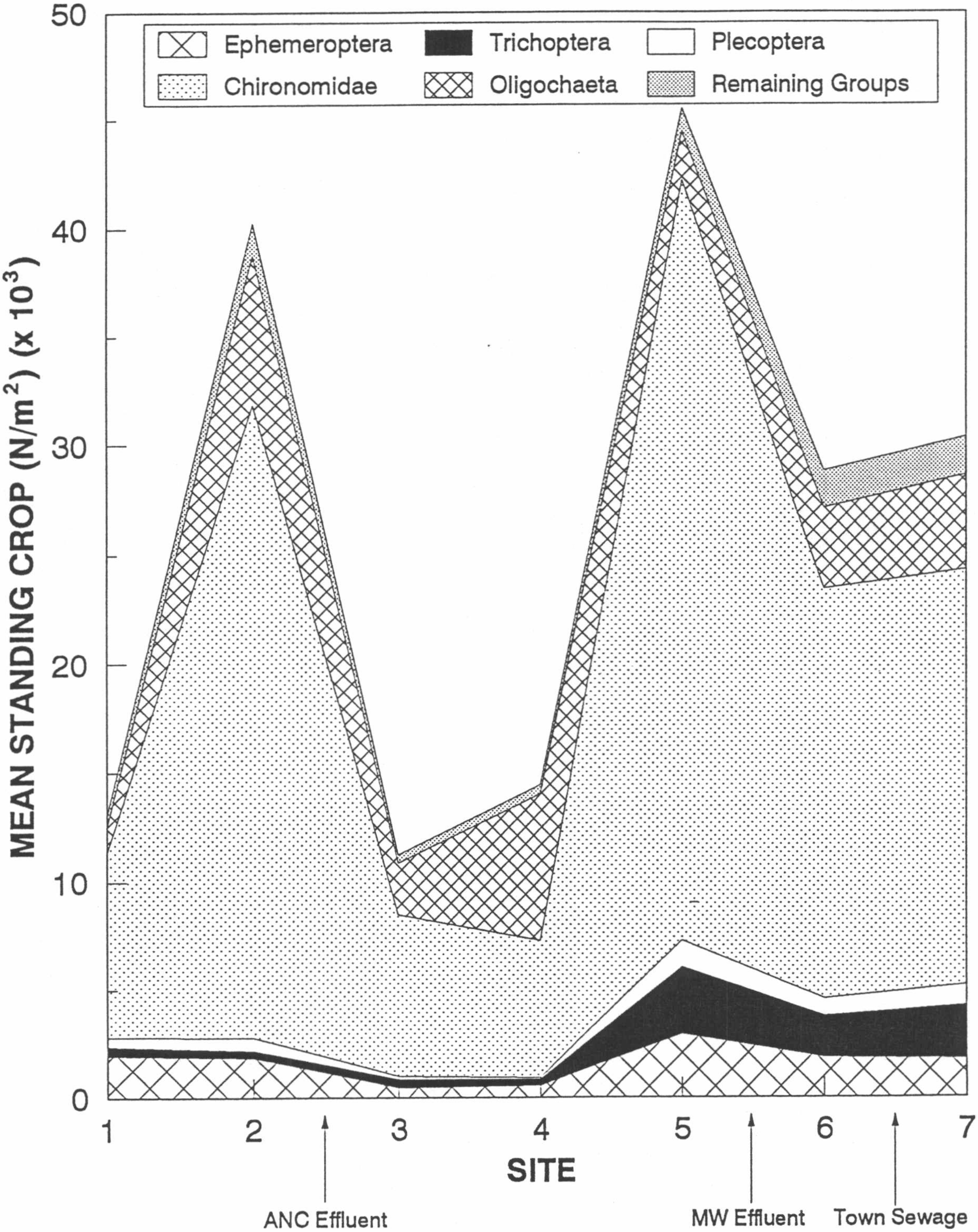


Figure 12. **Mean cumulative standing crop (number/m^2) of the major taxonomic groups for sites on the Athabasca River, October 1992.**

The results of the ANOVA indicated that there were significant differences during October in the mean number (standing crop) of EPT and the mean number of Chironomidae between sites ($p < 0.05$) (Appendix F). The orthogonal contrasts showed that both the number of EPT and the number of Chironomidae were not significant different between background sites and downstream sites ($p > 0.05$), but were significantly higher at far-field sites than at near-field sites ($p < 0.05$).

Organic Enrichment

Phosphorus is the nutrient that limits productivity in most freshwater ecosystems (Wetzel 1975). Increasing concentrations of phosphorus in streams often result in organic enrichment which increases biomass of algae, aquatic macrophytes and associated biota. Phosphorus inputs into the aquatic ecosystem can occur through either natural or anthropogenic sources. Natural sources of phosphorus include drainage from agricultural land, as well as leaching from soils that are high in phosphorus content (Hynes 1972). Effluents from pulp mills and sewage treatment plants can also elevate the phosphorus concentrations in receiving streams. Phosphorus is added to pulp mill effluents to enhance biological degradation of the pulping wastes. Benthic invertebrate enrichment has been reported downstream of pulp mills and sewage treatment plants as a result of organic loading from the effluents (Hynes 1972, Bothwell and Stockner 1980, Rabeni et al. 1985, Noton et al. 1989).

Organic enrichment usually results in a decrease in the number of taxa and an increase in the number of organisms (Lenat et al. 1980). Organic enrichment increases the food energy available in a system and in general, it is accompanied by an increased oxygen demand. This is a result of increased oxygen use by organisms (mainly bacteria) utilizing the additional food energy resources. The community structure may change such that organisms tolerant of low oxygen levels dominate the community and taxa intolerant of reduced oxygen conditions become eliminated over time. The additional food energy resources are available for use by tolerant taxa, such as Chironomidae (chironomids) and Oligochaeta (aquatic worms). They may be directly or indirectly used as a food resource and there may also be a reduction in predation and competition for the remaining species. In cases where organic enrichment does not result in a change in oxygen demand (such as for mild or moderate enrichment, or when oxygenation is maintained by a series of riffles in a lotic system), enrichment will tend to result in an increase in the number of organisms and an increase in the number of taxa (Pearson and Rosenberg 1978, Rabeni et al. 1985, Noton et al. 1989).

An increase in the amount of algal growth on the substrates was found at some downstream sites during April and October. However, there was no consistent relationship between the amount of algal growth and the number of taxa or standing crop of benthic invertebrates at sites.

The increase in mean standing crop of benthic invertebrates at all downstream sites during April and at downstream Sites 5, 6 and 7 during October, in comparison to background sites, was likely the result of organic loading from the ANC, the Millar Western and the Whitecourt sewage treatment effluents. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera, Trichoptera and Plecoptera), increased in numbers at downstream sites, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites, and in fact, there was a significant increase in the number of taxa at downstream sites in both April and October, indicating that only mild enrichment was occurring in the Athabasca River as a result of the organic loading from the effluents.

3.3.2 Community Analysis

The results of the RA analysis are shown as a species dominance distribution matrix for each sample site for both April and October (Appendix G). The taxa represented by the species codes in the matrices are listed in Table 5. These results were plotted as a two-axes (X and Y) ordination for site scores on a scale of 0 to 100 (ordination units) on each axis.

April

The initial April ordination separated sample 2-4 from all other samples (Appendix G). There was only 5 taxa present in sample 2-4, consisting of *Cricotopus/Orthocladius* spp., *Brachycentrus* sp., *Oecetis* sp., *Tvetenia* spp. and *Stagnicola catascopium*. This sample tended to mask any faunal separations between the other samples. Therefore, this sample was removed from the data set and the ordination was re-run to further assess the community structure of these other samples. A cluster of samples represents those which have similar benthic community assemblages. The degree of faunal homogeneity between samples within a cluster is represented by the closeness of the samples within the cluster.

The April site ordination (sample 2-4 omitted) indicated five sample clusters (Figure 13). Cluster I consisted of Site 1, Cluster II of Sites 2 and 3, Cluster III of Site 4, Cluster IV of Site 5, and Cluster V of Sites 6 and 7.

The dominant benthic community assemblage characteristic of each cluster, in order of numerical dominance (Appendix G), was a follows:

Cluster I: *Cricotopus/Orthocladius* spp., *Rhithrogena* sp., *Ephemerella inermis*

Cluster II: *Cricotopus/Orthocladius* spp., *Rhithrogena* sp., *Eukiefferiella* spp., *Baetis* spp., *Tvetenia* spp.

Cluster III: *Cricotopus/Orthocladius* spp., Naididae, *Brachycentrus* sp.

Cluster IV: *Cricotopus/Orthocladius* spp., *Rhithrogena* sp., Orthocladiinae

Cluster V: *Cricotopus/Orthocladius* spp., Orthocladiinae, Naididae

The mean standing crops (number/m^2) of the dominant taxa identified by RA for each site for April are shown in Figure 14.

A number of taxa have been found to respond to organic enrichment by increasing in numbers as a response to an increase in food availability, if oxygen is not limiting (Hynes 1960, Roback 1974, Godfrey 1978). Most of the dominant taxa within each cluster have been found to respond to organic enrichment from either natural or anthropogenic sources.

There appeared to be a gradient between sites in April. This was shown by one chironomid taxa, *Cricotopus/Orthocladius* spp. (Orthocladiinae), which was dominant in all clusters and increased in abundance from Cluster I to III, with the highest abundance occurring in Clusters IV and V (Appendix G). Orthocladiinae, such as *Cricotopus/Orthocladius* spp., have been found to respond to mild organic enrichment (Hynes 1960).

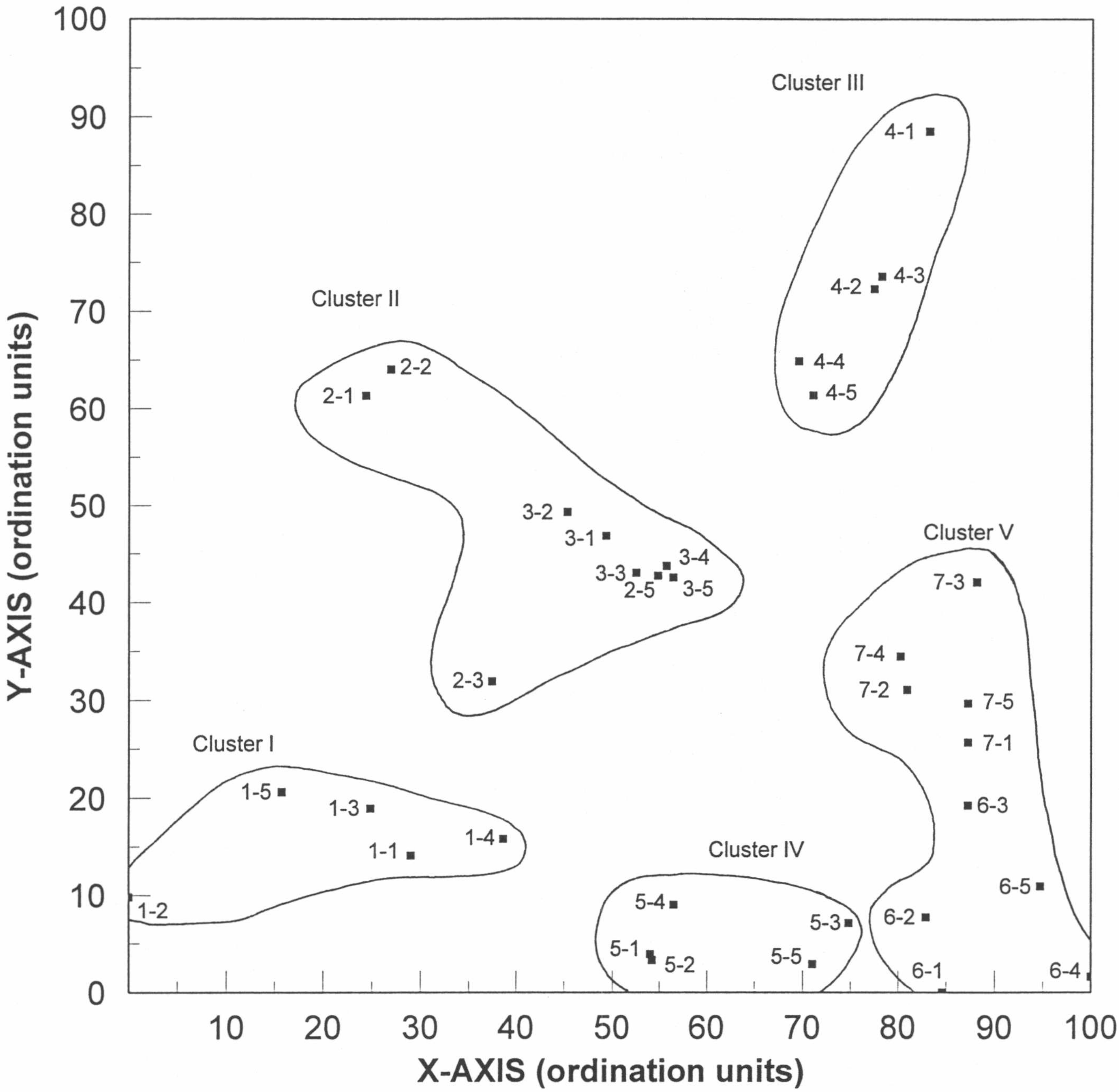


Figure 13. Reciprocal averaging ordination of site scores (sample 2-4 omitted), April 1992.

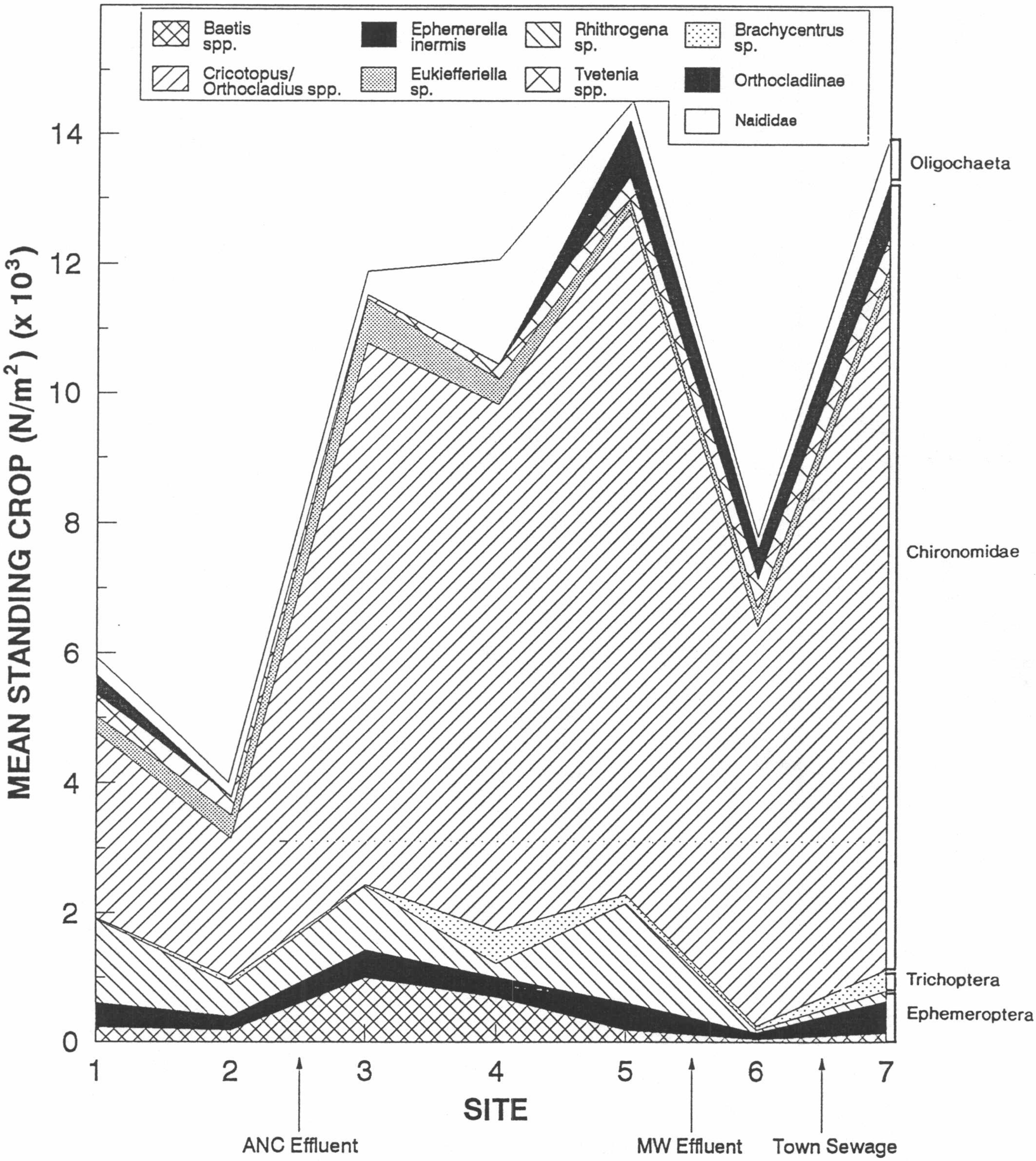


Figure 14. Mean cumulative standing crop (number/m^2) of the dominant taxa identified by RA for sites on the Athabasca River, April 1992.

The separation of Clusters I and II indicated that there were some differences in the benthic community structure of the two background sites. Downstream Site 3 had a similar benthic community structure to background Site 2. Site 1 (Cluster I) was dominated by *Cricotopus/Orthocladius* spp. and two Ephemeroptera (*Rhithrogena* sp. and *Ephemerella inermis*), while Sites 2 and 3 (Cluster II) were dominated by three Orthocladiinae (*Cricotopus/Orthocladius* spp., *Eukiefferiella* spp. and *Tvetenia* spp.) and two Ephemeroptera (*Baetis* spp. and *Rhithrogena* sp.). Most Ephemeroptera are grazers, feeding principally on algae and detrital materials (Merritt and Cummins 1984) and thus species, such as the dominant ones found in April, are suited to mild organic enrichment (Hynes 1960, Roback 1974).

Downstream Site 4 (Cluster III) was dominated by *Cricotopus/Orthocladius* spp., one Oligochaeta (Naididae) and one Trichoptera (*Brachycentrus* sp.). The Oligochaeta have been found to be reliable indicators of organic enrichment. The Naididae, in particular, have been found to thrive in organically enriched water, when a good supply of oxygen is provided by a current or turbulence (Hynes 1960). Trichopteran larvae construct various retreats, nets and cases which function as shelter and for food capture. *Brachycentrus* sp. (Brachycentridae) is a case builder and also a filter feeder, but has been reported to be more sensitive to organic loading than other Trichoptera, such as Hydropsychidae (Roback 1974).

The benthic community structure of Site 5 (Cluster IV) showed similarities to Sites 6 and 7 (Cluster V). Both clusters were dominated by two Orthocladiinae (*Cricotopus/Orthocladius* spp. and early instar Orthocladiinae). Site 5 was also dominated by an Ephemeroptera (*Rhithrogena* sp.), while Sites 6 and 7 were dominated by Naididae.

During April, the dominant taxa found at both background and downstream sites were ones which respond to organic enrichment. The increase in numbers of organisms, such as Orthocladiinae and Naididae, at downstream sites indicated that the ANC effluent appeared to contribute organic enrichment to the river. The Millar Western and the Whitecourt sewage treatment effluents also appeared to contribute additional organic enrichment at Sites 6 and 7, since no recovery of the benthic community structure was apparent at these downstream sites.

October

The site ordination indicated four sample clusters in October (Figure 15). Cluster I consisted of samples from Site 2, Cluster II of samples from Sites 1 and 3, Cluster III of samples from Sites 5, 6 and 7, and Cluster IV of samples from Site 4.

The dominant benthic community assemblage characteristic of each cluster, in order of numerical dominance (Appendix G), was as follows:

Cluster I: *Cricotopus/Orthocladius* spp., *Polypedilum* spp., Naididae, *Rheotanytarsus* spp.

Cluster II: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., Naididae, *Ephemerella inermis*, *Polypedilum* spp., *Rhithrogena* sp.

Cluster III: *Rheotanytarsus* spp., *Cricotopus/Orthocladius* spp., *Brachycentrus* sp., Naididae, Enchytraeidae

Cluster IV: Naididae, *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., Tubificidae

The mean standing crops (number/m^2) of the dominant taxa identified by RA for each site for October are shown in Figure 16.

A gradient of organic enrichment appeared to exist between clusters across the X-axis, which was shown by a chironomid, *Rheotanytarsus* spp. (Chironominae - Tanytarsini Tribe). There were lower numbers of this taxon in samples of Clusters I and IV and increasing numbers in Clusters II and III (Appendex G). Tanytarsini, like Orthocladiinae have been found to respond to mild organic enrichment, where oxygen levels are not seriously depressed (Hynes 1960).

The separation of Clusters I and II indicated that there were some differences in the benthic community structure of the two background sites. Downstream Site 3 had a similar benthic community structure to background Site 1, although it also showed similarities to Site 2. Site 2 (Cluster I) was dominated by *Cricotopus/Orthocladius* spp., two Chironominae (*Polypedilum* spp. of the Chironomini Tribe and *Rheotanytarsus* spp. of the Tanytarsini Tribe) and Naididae, while Sites 1 and 3 (Cluster II) were dominated by the

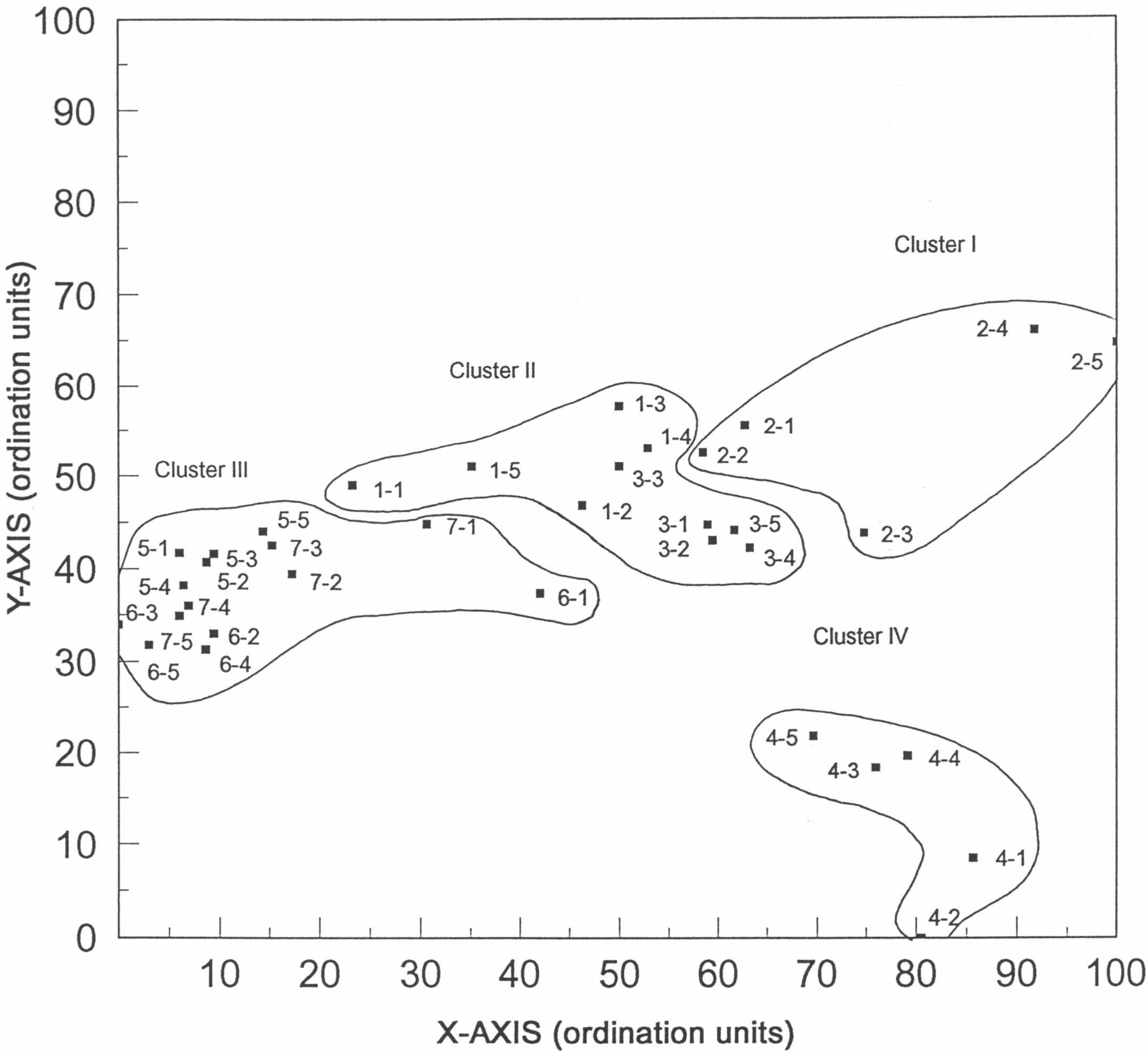


Figure 15. **Reciprocal averaging ordination of site scores, October 1992.**

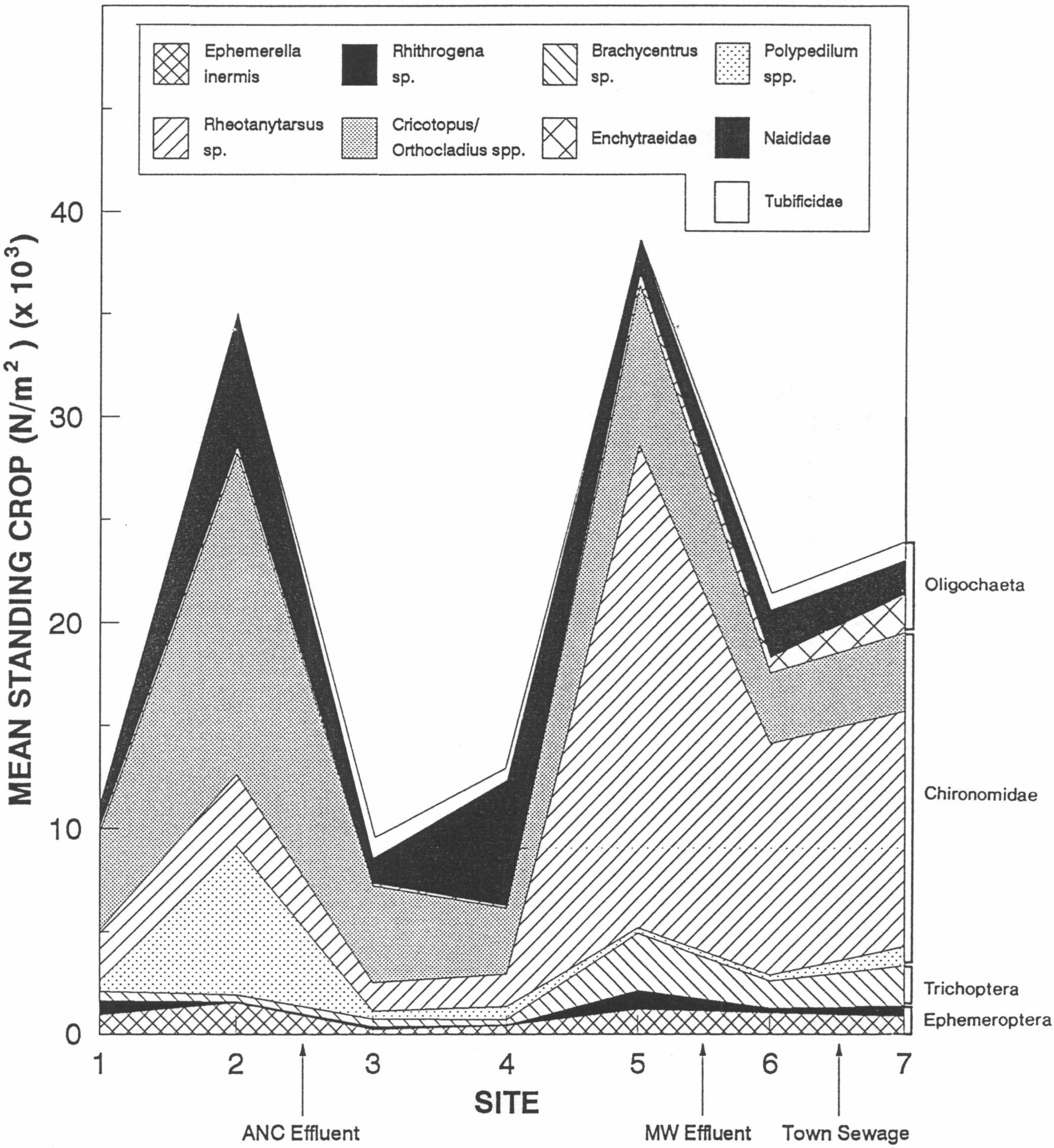


Figure 16. **Mean cumulative standing crop (number/m^2) of the dominant taxa identified by RA for sites on the Athabasca River, October 1992.**

taxa dominant in Cluster I, as well as two Ephemeroptera (*Ephemerella inermis* and *Rhithrogena* sp.).

The benthic community structure of downstream Sites 5, 6 and 7 (Cluster III) differed from background sites. The dominant community structure of Sites 5, 6 and 7 consisted of two Chironomidae (*Rheotanytarsus* spp. and *Cricotopus/Orthocladius* spp.), one Trichoptera (*Brachycentrus* sp.) and two Oligochaeta (Naididae and Enchytraeidae). *Cricotopus/Orthocladius* spp. was more dominant at background sites than *Rheotanytarsus* spp. There was a shift between these two chironomids at Sites 5, 6 and 7, so that *Rheotanytarsus* spp. was more dominant than *Cricotopus/Orthocladius* spp. The Enchytraeidae are generally always present in benthic samples but usually only in small numbers. There is little information available in the literature on either the taxonomy or ecology of the Enchytraeidae. One study found Enchytraeidae in large rivers with coarse sandy beds, living in the interstitial spaces (Hynes 1972).

Site 4 (Cluster IV) was dominated by Naididae, followed by *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp. and Tubificidae. The dominance of Naididae and Tubificidae caused this site to ordinate away from all other clusters. As mentioned above, Oligochaeta, such as Naididae, are generally reliable indicators of organic enrichment, when a good supply of oxygen is provided by a current or turbulence (Hynes 1960). Tubificidae, another family of Oligochaeta, are very tolerant of pollution and are found in large numbers in severely organically polluted water (Brinkhurst and Cook 1974). Tubificidae, although one of the dominant taxon at Site 4, was lower in numbers than the other dominant taxa.

During October, as in previous surveys (Beak Associates 1991, SENTAR 1992), the dominant benthic community structures of the background sites indicated the presence of mild organic enrichment, especially at Site 2. The ANC effluent appeared to contribute some additional organic enrichment to the river, affecting both Sites 4 and 5. The Millar Western and the Whitecourt sewage treatment effluents appeared to contribute further organic enrichment to the river at Sites 6 and 7.

3.3.3 Trophic Analysis

A trophic (feeding group) analysis of the benthic data was conducted to determine if there were any differences in benthic community trophic structure between sites for April and October. The availability of food is a factor which controls the occurrence and abundance of benthic invertebrates species (Hynes 1972). The percent contribution of each functional group for all samples sites for April and October are presented in Appendix H.

April

The trophic analysis showed that all sites were dominated by detritivore/herbivores followed by detritivores, in April (Figure 17). The detritivore/herbivores formed 68.8 to 79.1 % and the detritivores formed 16.3 to 24.2 % of the total benthic fauna. A dominance of benthic detritivore/herbivores and detritivores is a common natural trait of streams in North America (Egglishaw 1964, Minshall 1967, Hynes 1972, Fisher and Likens 1972, Cummins et al. 1973). The carnivores formed 2.0 to 4.7 % and the ominivores formed 0.7 to 4.6 % of the total benthic fauna. All other feeding groups formed less than 1 % of the total benthic fauna.

The percent contribution of the dominant feeding groups for each cluster of sample sites (using individual samples) identified by RA for the April data was as follows:

Cluster	DH	D	C	O
I (Site 1)	65.9-75.0	21.5-28.0	2.3-4.8	0.7-2.3
II (Sites 2, 3)	63.9-81.0	13.8-25.0	2.4-5.3	0.5-5.5
III (Site 4)	62.1-73.5	22.5-28.2	1.1-3.6	1.4-13.0
IV (Site 5)	73.7-82.5	13.0-22.2	1.5-3.8	0.2-2.8
V (Sites 6, 7)	62.4-78.1	12.1-29.4	2.3-6.2	0.2-6.8

All clusters had similar percent compositions of the dominant feeding groups, with the exception of a slight increase in omnivores at Site 4. This was the result of an increase in the number of *Brachycentrus* sp., which is an omnivore (filter feeder), at Site 4 (Figure 14). All other dominant taxa identified for each cluster were mainly detritivores/herbivores, with a few detritivores.

October

The trophic analysis showed that all the sites were dominated by detritivore/herbivores or detritivores in October (Figure 18). The detritivore/herbivores were dominant at Sites 1, 2 and 3, forming 49.7 to 61.4 % of the total benthic fauna, followed by the detritivores, which formed 35.4 to 43.4 % of the total benthic fauna. At Sites 4, 5, 6 and 7, the detritivores were dominant, forming 63.1 to 67.4 % of the total benthic fauna, followed by

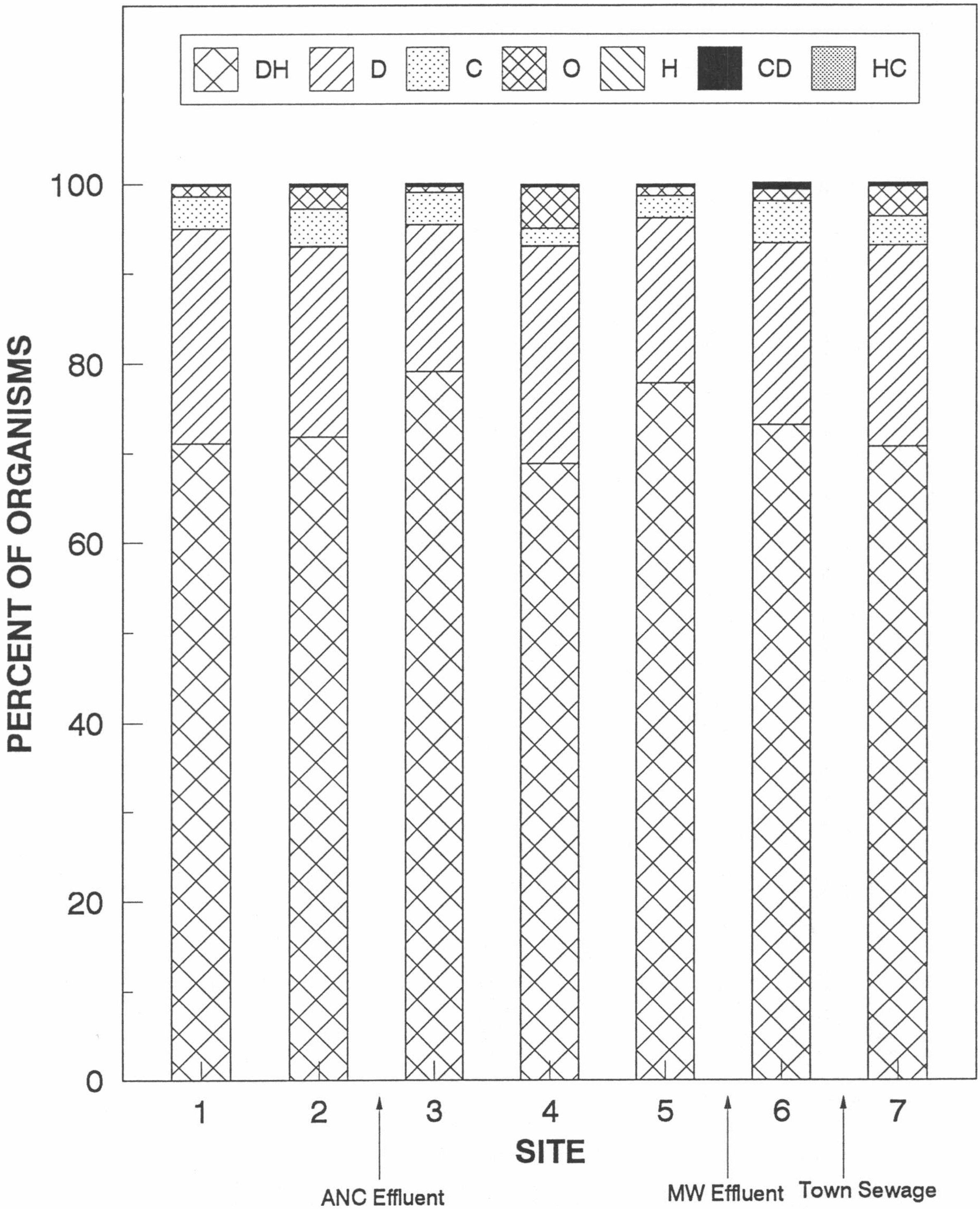


Figure 17. **Percent composition of benthic invertebrate functional feeding groups for sites on the Athabasca River, April 1992.**

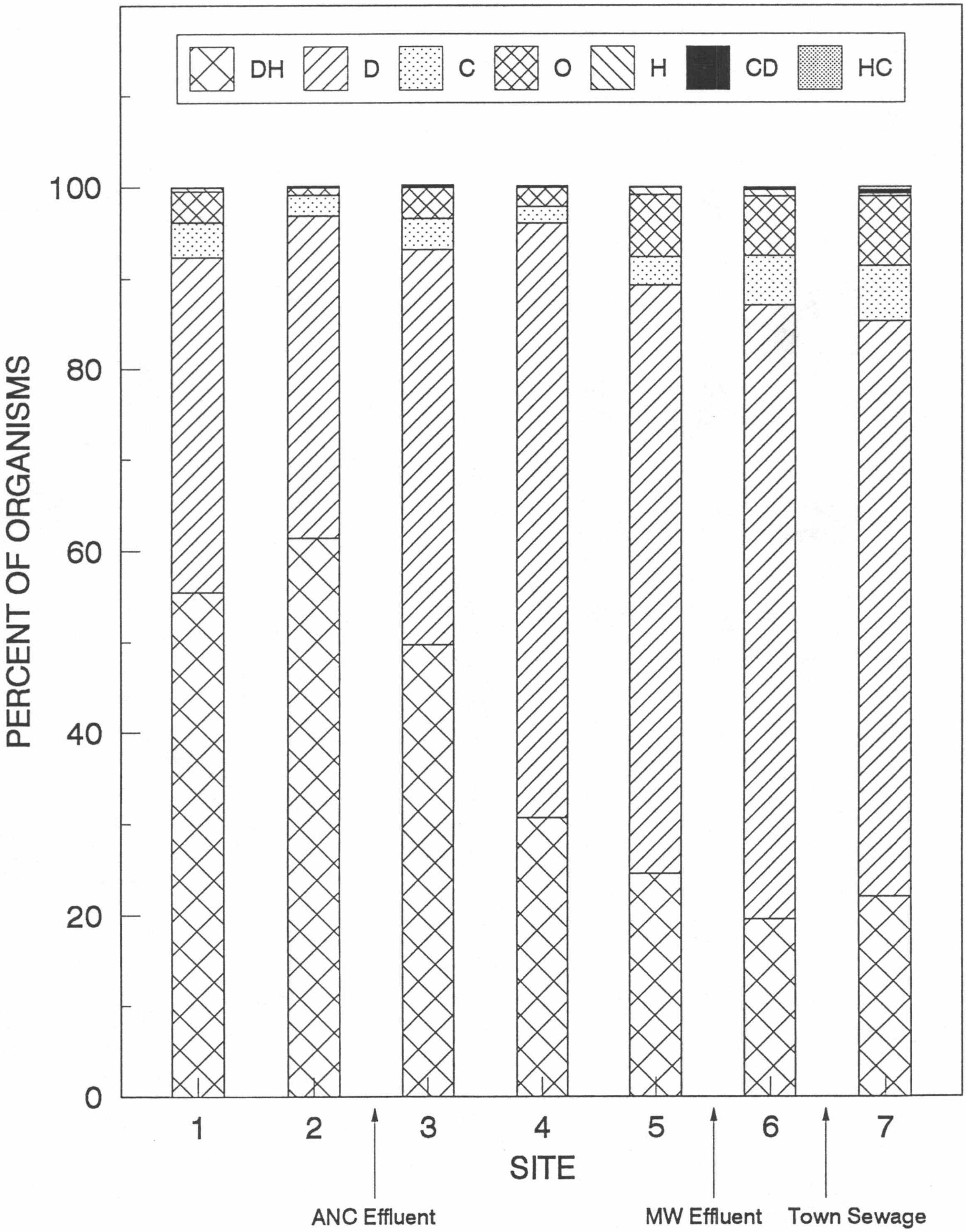


Figure 18. **Percent composition of benthic invertebrate functional feeding groups for sites on the Athabasca River, October 1992.**

the detritivore/herbivores, which formed 19.6 to 30.7 % of the total benthic fauna. The third and fourth dominant groups were the omnivores and carnivores, which formed 0.8 to 7.6 % and 1.8 to 6.1 %, respectively, of the total benthic fauna. All other feedings groups formed less than 1 % of the total benthic fauna.

The percent contribution of the dominant feeding groups for each cluster of sample sites (using individual samples) identified by RA for the October data was as follows:

Cluster	**DH**	**D**	**C**	**O**
I (Site 2)	54.9-68.9	28.2-42.2	2.0-2.6	0.6-1.3
II (Sites 1, 3)	42.8-60.3	32.7-46.1	2.4-6.0	1.0-7.6
III (Sites 5, 6, 7)	13.1-33.7	56.2-71.5	2.2-6.9	3.2-13.7
IV (Site 4)	15.1-35.3	61.9-78.8	1.2-3.9	1.5-3.9

Cluster I had a high percentage of detritivore/herbivores, followed by detritivores, and then similar percentages of carnivores and omnivores. Cluster II also had a high percentage of detritivore/herbivores, followed by detritivores, but had slightly higher percentages of carnivores and omnivores than Cluster I. Cluster III had a high percentage of detritivores, followed by detritivores/herbivores and then omnivores and carnivores. There was a lower percentage of detritivore/herbivores and a higher percentage of detritivores in Cluster III, compared to Clusters I and II. This was the result of higher numbers of *Rheotanytarsus* spp. (detritivore) in Cluster III compared to higher numbers of *Cricotopus/Orthocladius* spp. (detritivore/herbivore) in Clusters I and II (Figure 16). *Cricotopus/Orthocladius* spp. are gatherers, feeding on detritus, algae and diatoms, whereas *Rheotanytarsus* spp. is a filterer, feeding on decomposing fine particulate organic matter (Merritt and Cummins 1984). There was also a slightly higher percentage of omnivores in Cluster III, compared to Clusters I and II, as a result of the increase in the numbers of *Brachycentrus* sp. (Trichoptera). Cluster IV had a higher percentage of detritivores than detritivore/herbivores, similar to Cluster III, but with lower percentages of carnivores and omnivores.

The trophic analysis indicated that similar trends were apparent in the October benthic data, as was found by the RA analysis. Increases in the numbers of certain organisms and shifts in the feeding group structure occurred as a result of the change in the nature of the food supply caused by organic enrichment in the Athabasca River from the pulp mill and sewage effluents.

3.3.4 Comparison of Pre-Operational and Post-Operational Surveys

To assess the effects of pulp mill effluent on the benthic invertebrates of the Athabasca River, a comparison was made between the pre-operational and post-operational surveys. Pre-operational conditions existed in the spring and fall of 1989 and the spring of 1990, while start-up conditions existed in the fall of 1990. Post-operational conditions existed during 1991 and 1992.

Similar to differences between seasons, the benthic community structure can differ between years, as a result of numerous factors, such as hydraulic and other physical habitat conditions in the river. However, a comparison between pre-operational and post-operational data can be of importance in determining impact trends in the benthic community structure. A statistical test of whether the ANC discharge has affected benthic communities was conducted by comparing spatial differences or patterns before and after the mill became operational (i.e. combine temporal contrasts with spatial contrasts).

A repeated measures design was used to analyze five variables, consisting of total number of taxa, number of EPT taxa, total number of organisms (standing crop), number of EPT and number of Chironomidae (Tables 6 and 7). The number of taxa, the number of EPT and the number of Chironomidae for fall data and the number of organisms for both seasons were log transformed. The number of EPT for spring data and the number of EPT taxa for fall data were transformed using $\log(x + 1)$. All other variables were not transformed.

Spring

The spring data for the five variables are represented in graphs which compare the background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between the four years (Figures 19 to 23). The mean species diversity was also graphed to show the trends over the four years (Figure 24).

The results of the repeated measures analysis of benthic community variables for the spring data are provided in Table 6. There were no significant differences ($p > 0.05$) between downstream sites and background sites between the two pre-operational and two post-operational years for any of the five variables during the spring. There were also no significant differences ($p > 0.05$) between near-field sites and far-field sites between the two pre-operational and two post-operational years for any of the five variables. The

Table 6. **Results of repeated measures analyses of benthic community variables for spring samples, 1989 to 1992. Values are probabilities (p) (significant values of $p < 0.05$ are indicated by a *).**

Contrast		Variable				
Temporal	**Spatial**	**Number of Taxa**	**Number of EPT Taxa**	**Number of Organisms**	**Number of EPT**	**Number of Chironomidae**
1989, 1990 vs 1991, 1992	BG vs DS	0.775	0.664	0.722	0.944	0.531
	NF vs FF	0.833	0.562	0.530	0.589	0.050*
1989 vs 1990	BG vs DS	0.529	0.217	0.663	0.513	0.409
	NF vs FF	0.041*	0.007*	0.078	0.012*	0.110
1991 vs 1992	BG vs DS	0.048*	0.013*	0.057	0.090	0.021*
	NF vs FF	0.154	0.025*	0.371	0.042*	0.792
Year X Area Interaction		0.107	0.022*	0.094	0.017*	0.040*

DS Downstream
BG Background
NF Near-Field
FF Far-Field

Table 7. **Results of repeated measures analyses of benthic community variables for fall samples, 1989 to 1992. Values are probabilities (p) (significant values of $p < 0.05$ are indicated by a *).**

Contrast		Variable				
Temporal	**Spatial**	Number of Taxa	Number of EPT Taxa	Number of Organisms	Number of EPT	Number of Chironomidae
1989, vs 1990, 1991, 1992	BG vs DS	0.356	0.364	0.486	0.649	0.529
	NF vs FF	0.615	0.909	0.394	0.631	0.229
1990 vs 1991	BG vs DS	0.166	0.038*	0.059	0.970	0.049*
	NF vs FF	0.037*	0.022*	0.241	0.947	0.281
1991 vs 1992	BG vs DS	0.863	0.877	0.526	0.749	0.493
	NF vs FF	0.319	0.945	0.923	0.356	0.915
Year X Area Interaction		0.213	0.240	0.179	0.858	0.127

DS Downstream
BG Background
NF Near-Field
FF Far-Field

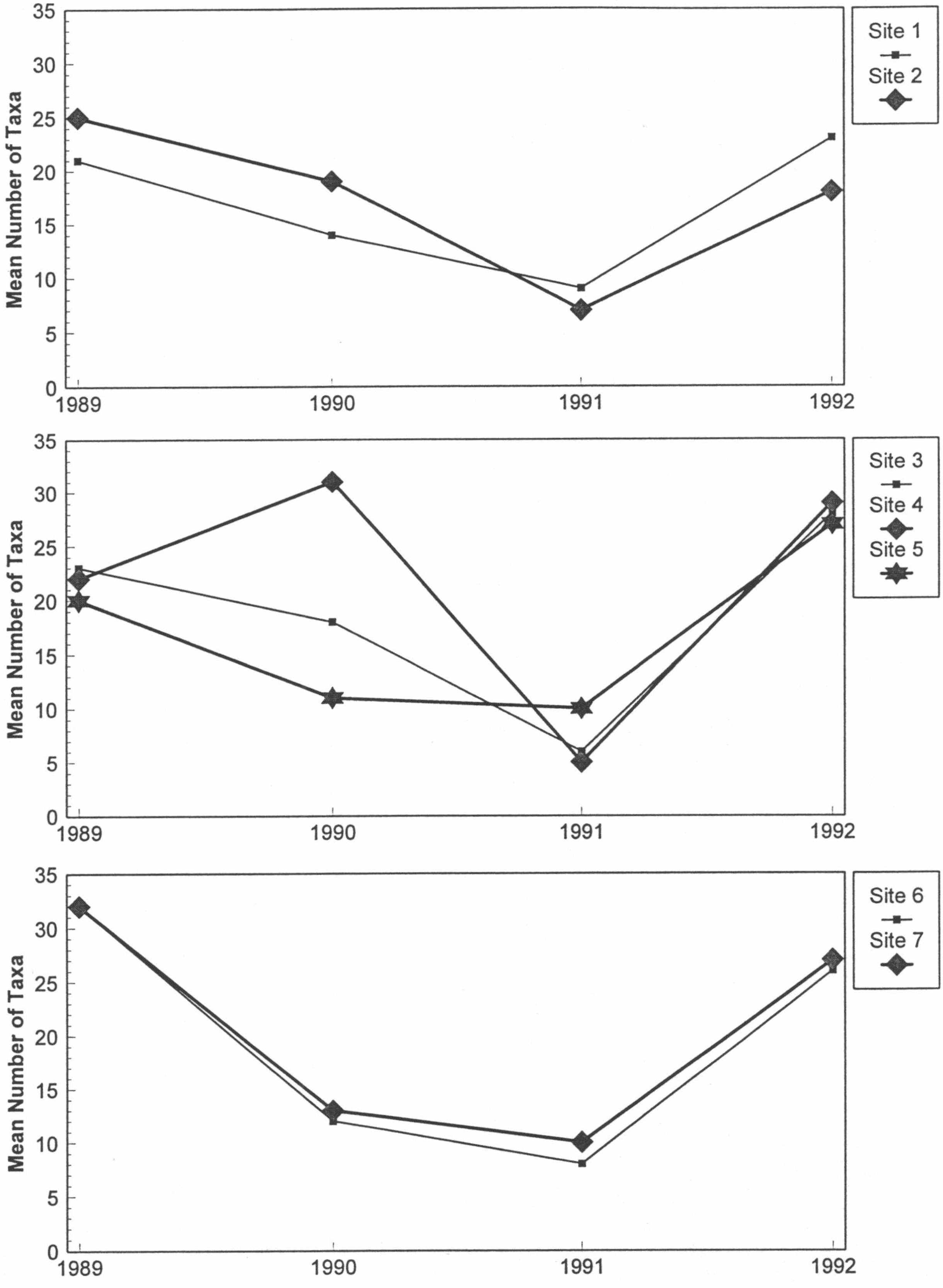


Figure 19. **Comparison of mean number of taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between spring 1989 to 1992.**

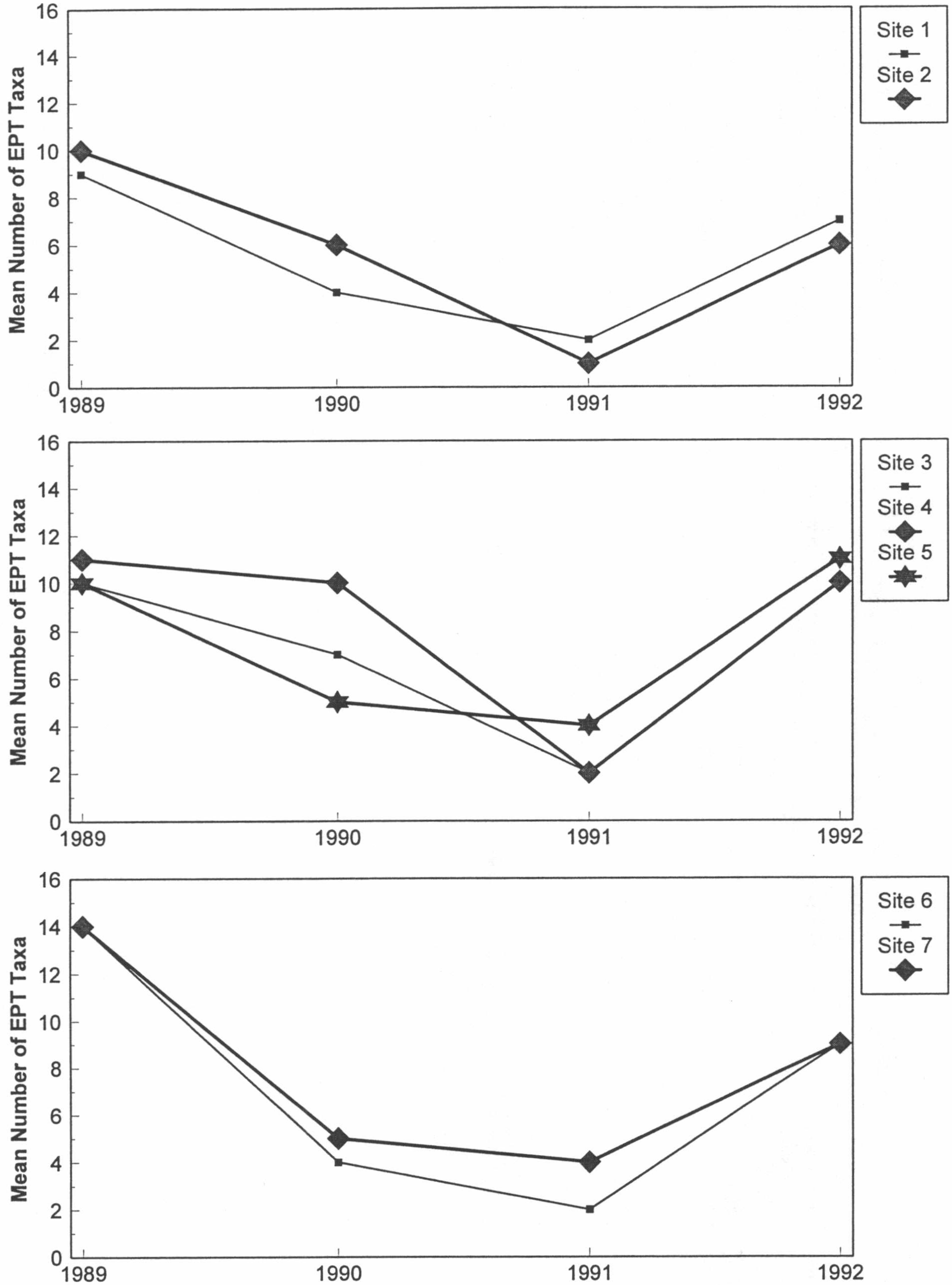


Figure 20. **Comparison of mean number of EPT taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between spring 1989 to 1992.**

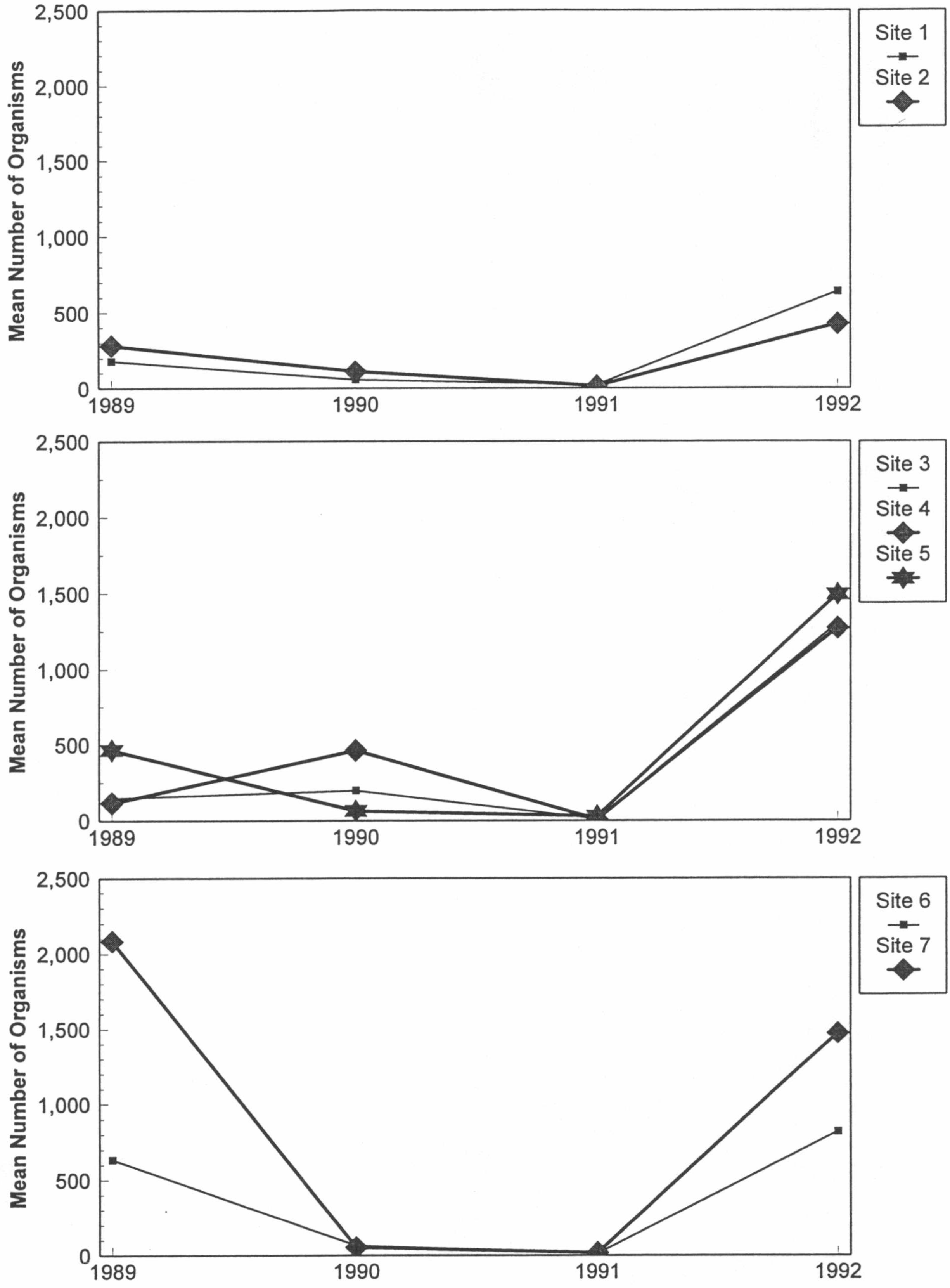


Figure 21. **Comparison of mean number of organisms for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between spring 1989 to 1992.**

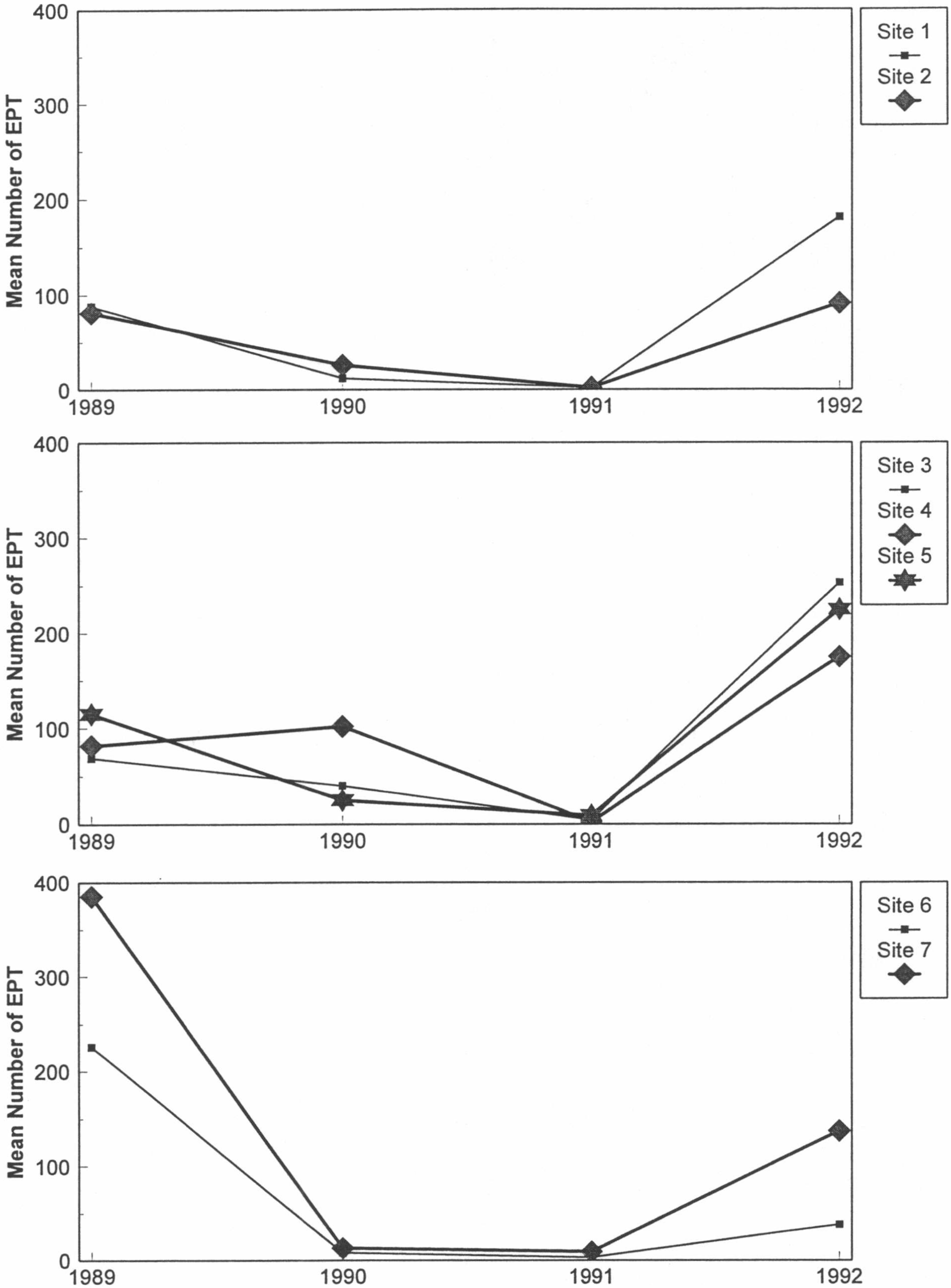


Figure 22. **Comparison of mean number of EPT for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between spring 1989 to 1992.**

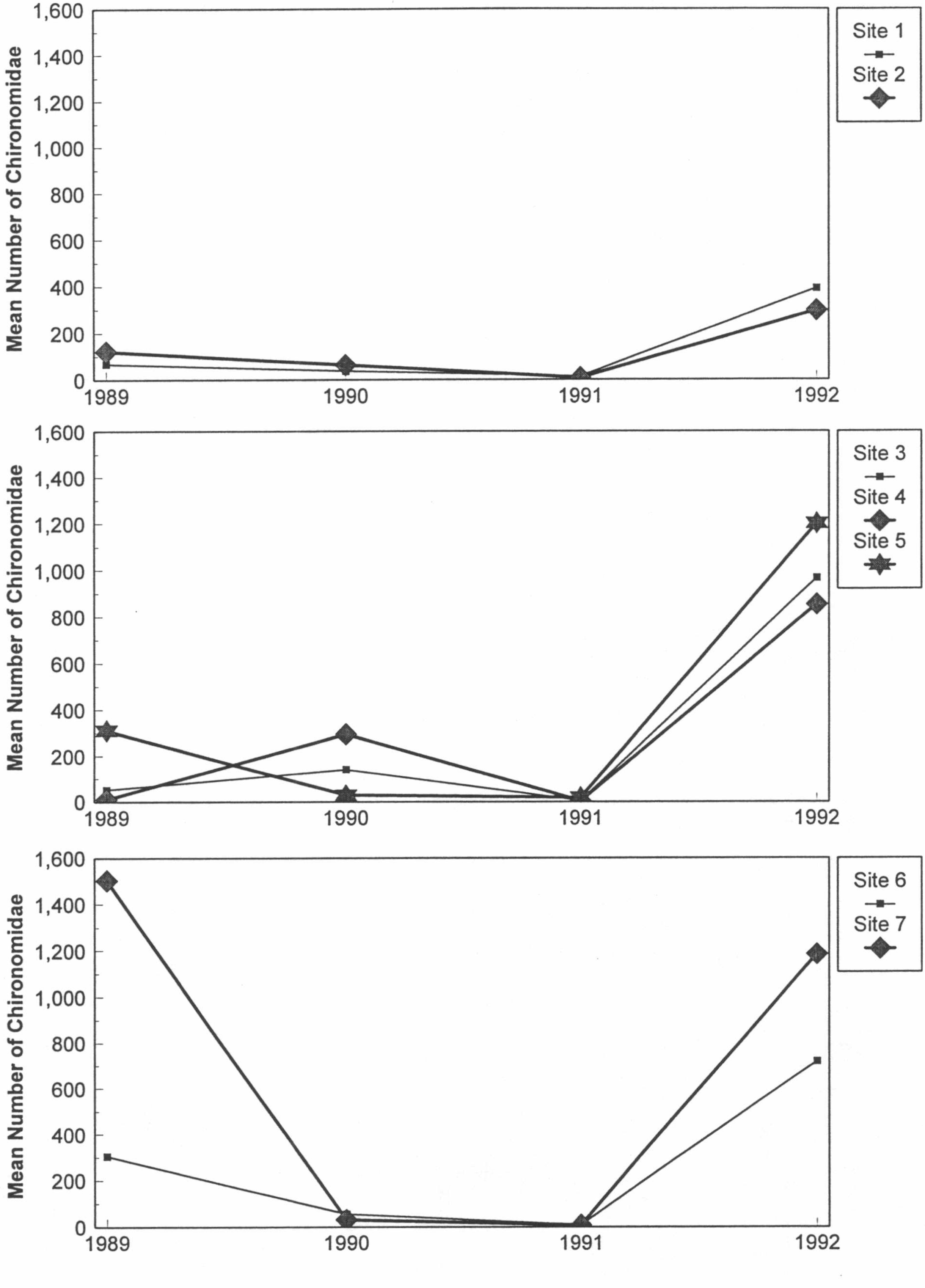


Figure 23. **Comparison of mean number of Chironomidae for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between spring 1989 to 1992.**

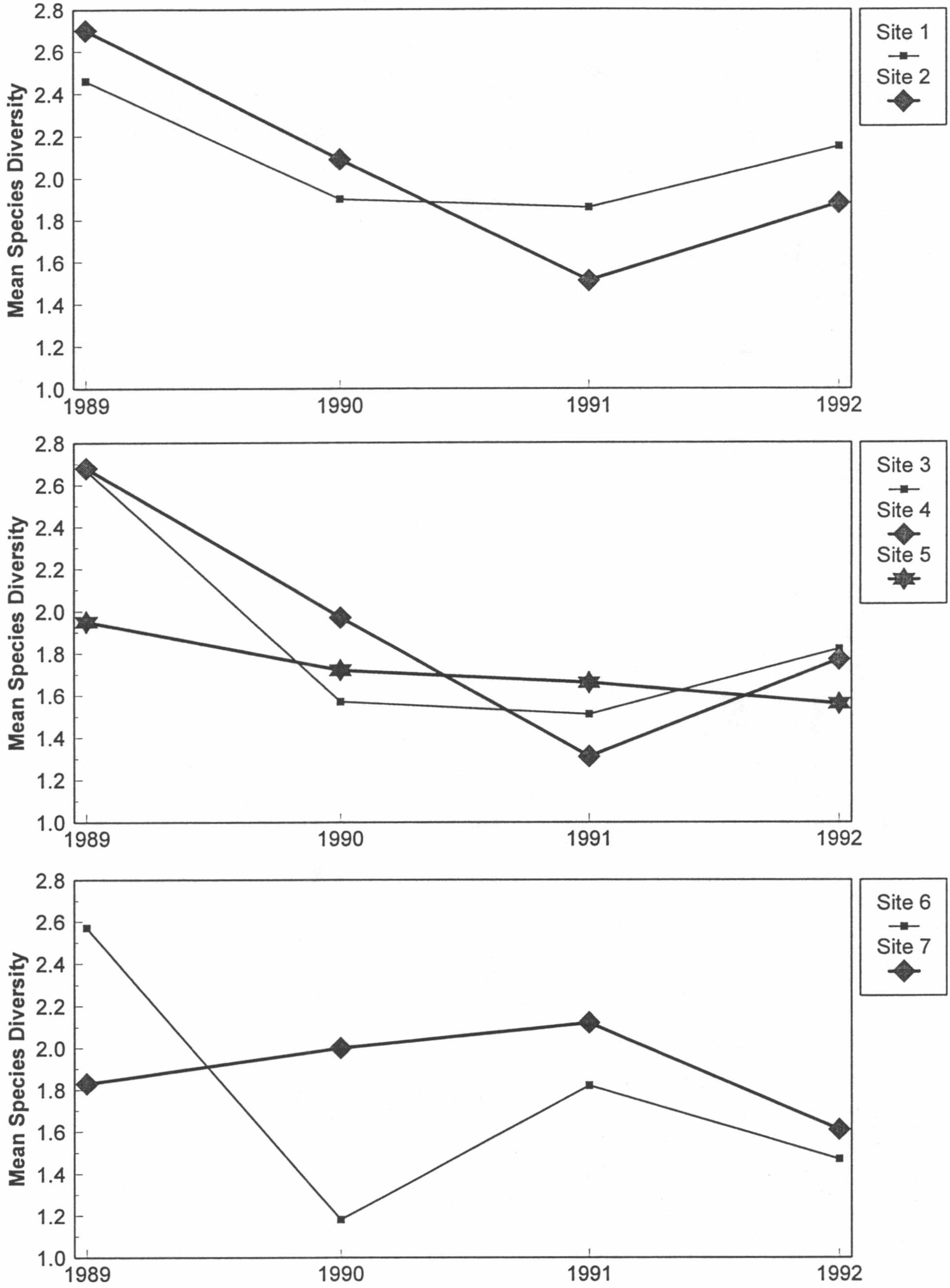


Figure 24. Comparison of mean species diversity for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between spring 1989 to 1992.

number of Chironomidae was "border-line" significant ($p = 0.05$), indicating that there may have been some differences in the numbers of Chironomidae between near-field sites and far-field sites between the pre-operational and post-operational years.

There were significant differences between near-field sites and far-field sites for the number of taxa, the number of EPT taxa and the number of EPT ($p < 0.05$) between the two pre-operational years (1989 and 1990). In the spring of 1989, the number of taxa, the number of EPT taxa and the number of EPT were higher at far-field sitees than at near-field sites, and in 1990, they were higher at near-field sites than at far-field sites (Figures 19, 20 and 22).

There were significant differences between background sites and downstream sites for the number of taxa, number of EPT taxa and the number of Chironomidae ($p < 0.05$) between the two post-operational years (1991 and 1992). In the spring of 1991, the number of taxa, the number of EPT taxa and the number of Chironomidae were similar between background sites and downstream sites, and in 1992, they were higher at downstream sites than at background sites (Figures 19, 20 and 23).

There were significant differences between near-field sites and far-field sites for the number of EPT taxa and the number of EPT ($p < 0.05$) between the two post-operational years. In the spring of 1991, the number of EPT taxa and the number of EPT were similar between near-field sites and far-field sites, and in 1992, they were higher at near-field sites than at far-field sites (Figures 20 and 22).

In the spring, the mean species diversity decreases at background sites between 1989 and 1991 and then increased slightly in 1992 (Figure 24). At near-field sites, the mean species diversity also decreased between 1989 and 1991, with a slight increase at Sites 3 an 4, but not at Site 5, in 1992. The mean species diversity varied between the two far-field sites and between years.

The spring analyses indicated that there was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the two pre-operational and two post-operational years and when far-field effects were compared between the pre-operational and post-operational years.

The spring results indicated that differences were noted between near-field and far-field sites between the two pre-operational years. These differences suggested that there were reduced effects from the Millar Western and/or Whitecourt sewage treatment effluents between 1989 and 1990. The results also indicated that differences were noted between both background and downstream sites and near-field and far-field sites between the two post-operational years. These differences suggested that there were increased effects downstream of the ANC mill in 1992. However, it should be noted that the effects included increases in the numbers of intolerant taxa (EPT taxa).

Fall

The fall data for the five variables are represented in graphs, as for the spring data, in Figures 25 to 29. The mean species diversity was also graphed to show the trends over the four years (Figure 30).

The results of the repeated measures analysis of benthic community variables for the fall data are provided in Table 7. There were no significant differences ($p > 0.05$) between downstream sites and background sites between the one pre-operational and three post-operational years for any of the five variables during the fall. There were also no significant differences ($p > 0.05$) between near-field sites and far-field sites between the one pre-operational and three post-operational years, for any of the five variables.

There were significant differences between background sites and downstream sites for the number of EPT taxa and the number of Chironomidae ($p < 0.05$) between the two post-operational years of 1990 and 1991. In the fall of 1990, the number of EPT taxa was similar between background sites and downstream sites, but in 1991, it was higher at downstream sites than at background sites (Figure 26). The number of Chironomidae was higher at downstream sites than at background sites in both 1990 and 1991, but there was a larger difference between background and downstream sites in 1990 than in 1991 (Figure 27).

There were significant differences between near-field sites and far-field sites for the number of taxa and the number of EPT taxa ($p < 0.05$) between the two post-operational years of 1990 and 1991. In the fall of 1990, the number of taxa was similar between near-field sites and far-field sites, but in 1991, it was higher at far-field sites than at near-field sites (Figure 25). The number of EPT taxa was slightly higher at near-field sites than at far-

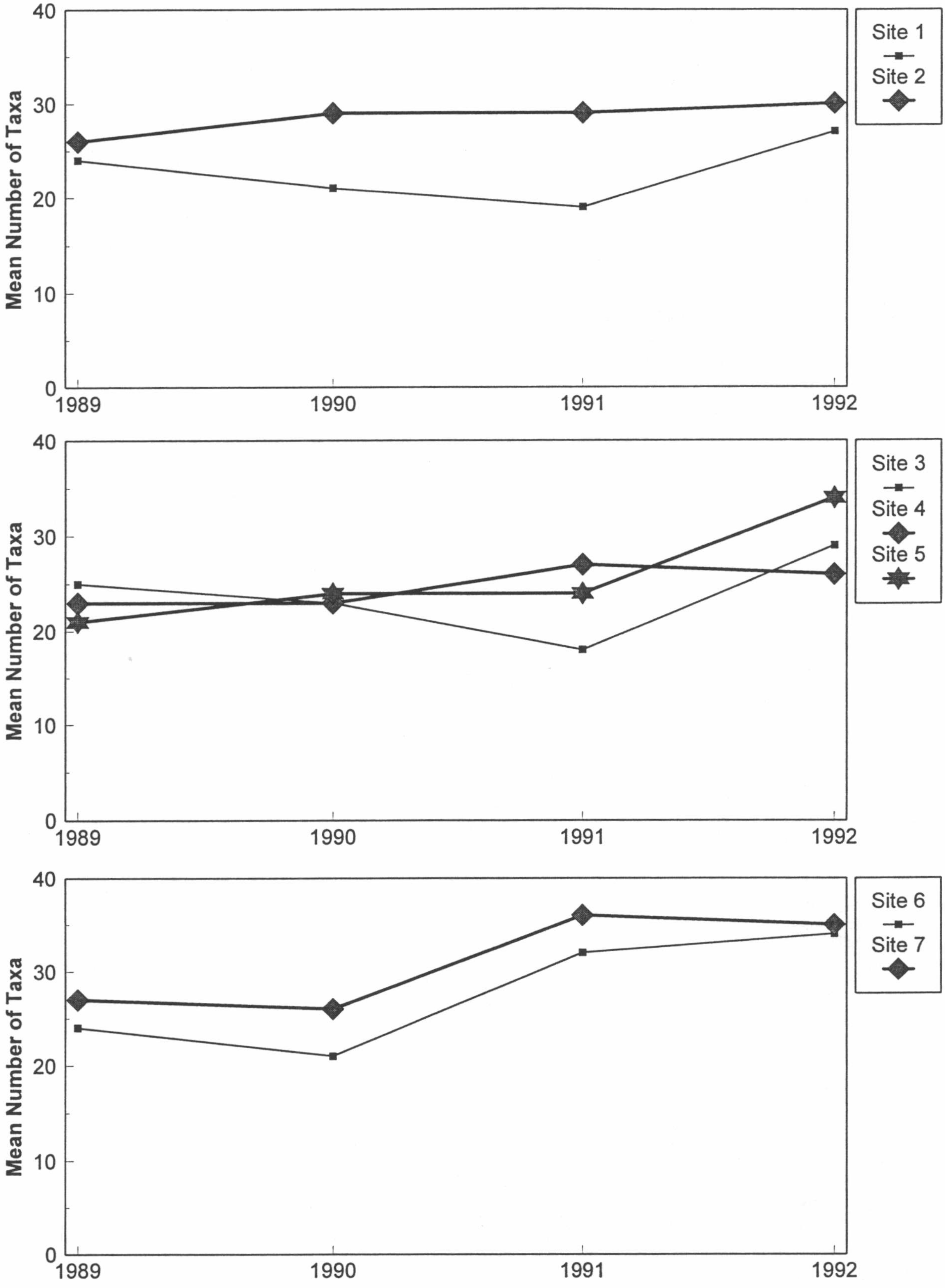


Figure 25. **Comparison of mean number of taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between fall 1989 to 1992.**

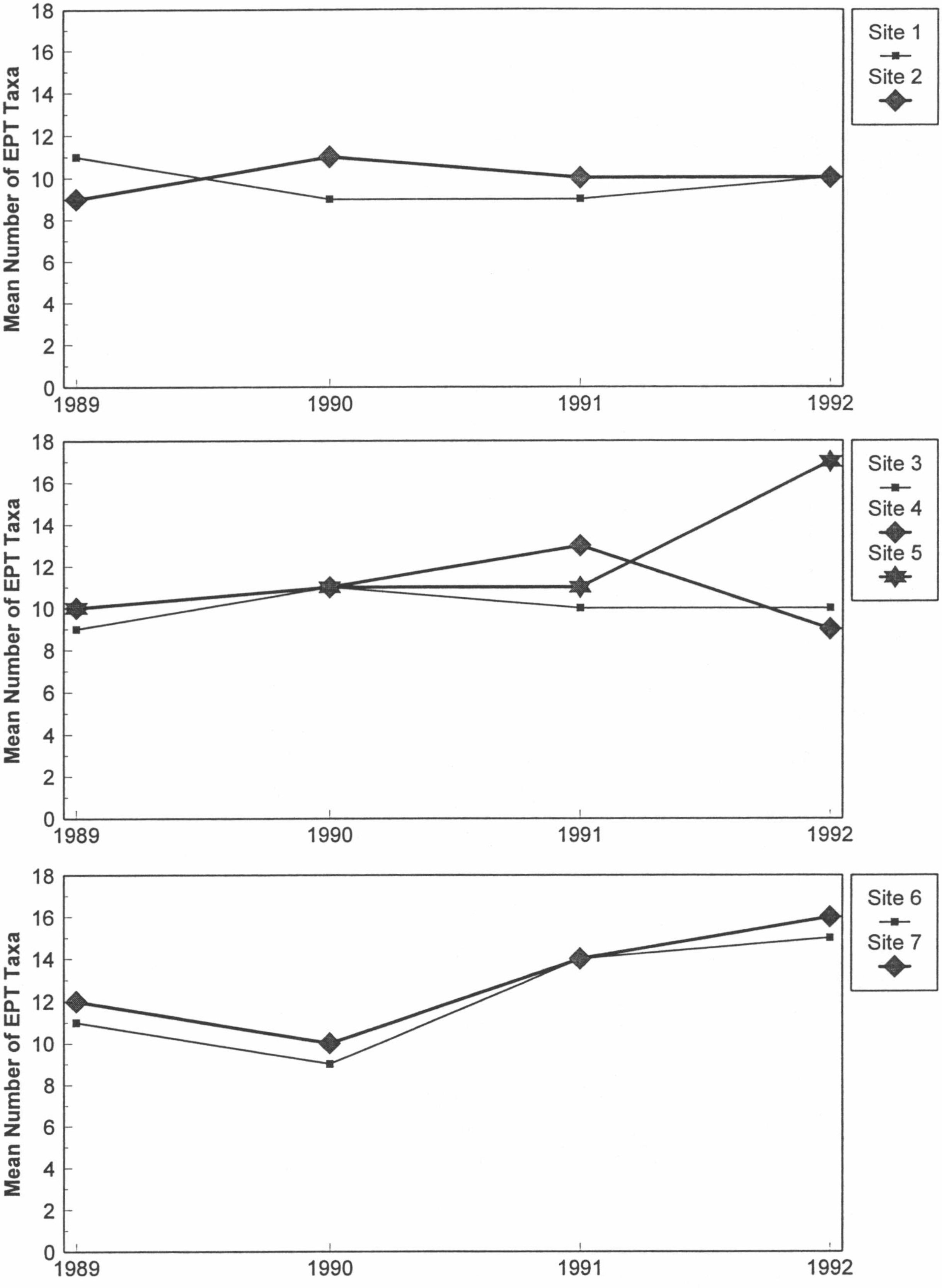


Figure 26. **Comparison of mean number of EPT taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between fall 1989 to 1992.**

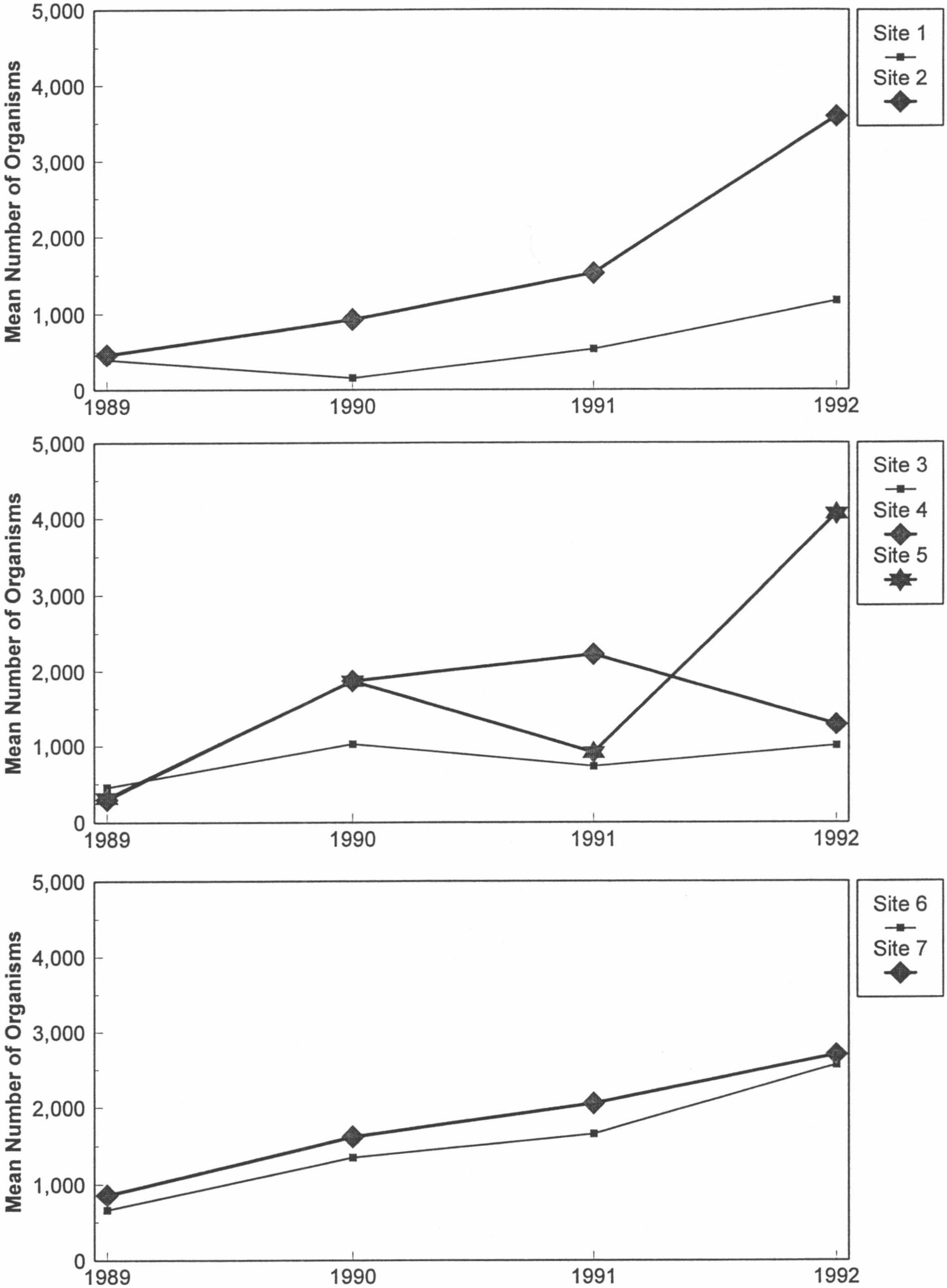


Figure 27. **Comparison of mean number of organisms for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between fall 1989 to 1992.**

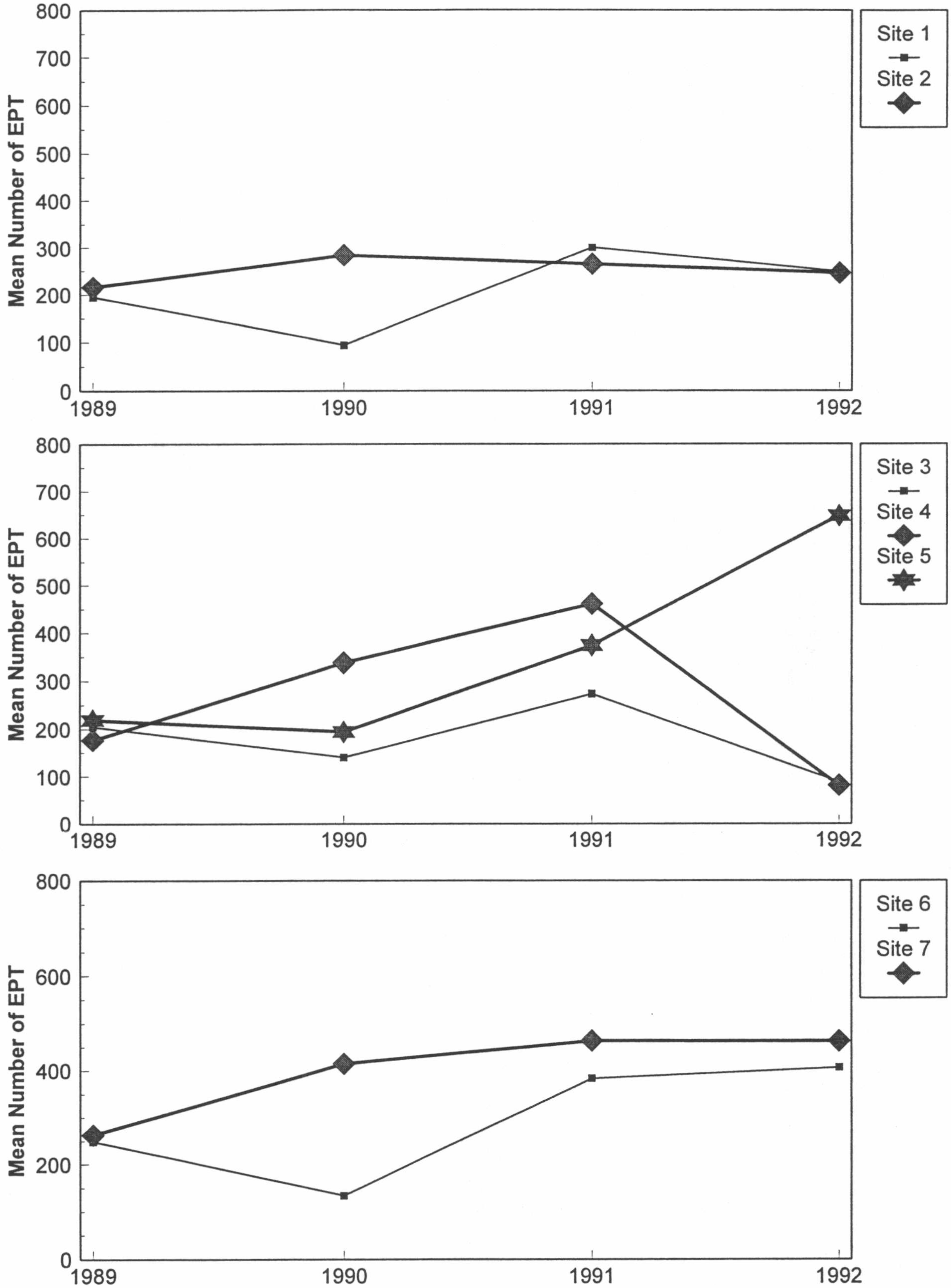


Figure 28. **Comparison of mean number of EPT for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between fall 1989 to 1992.**

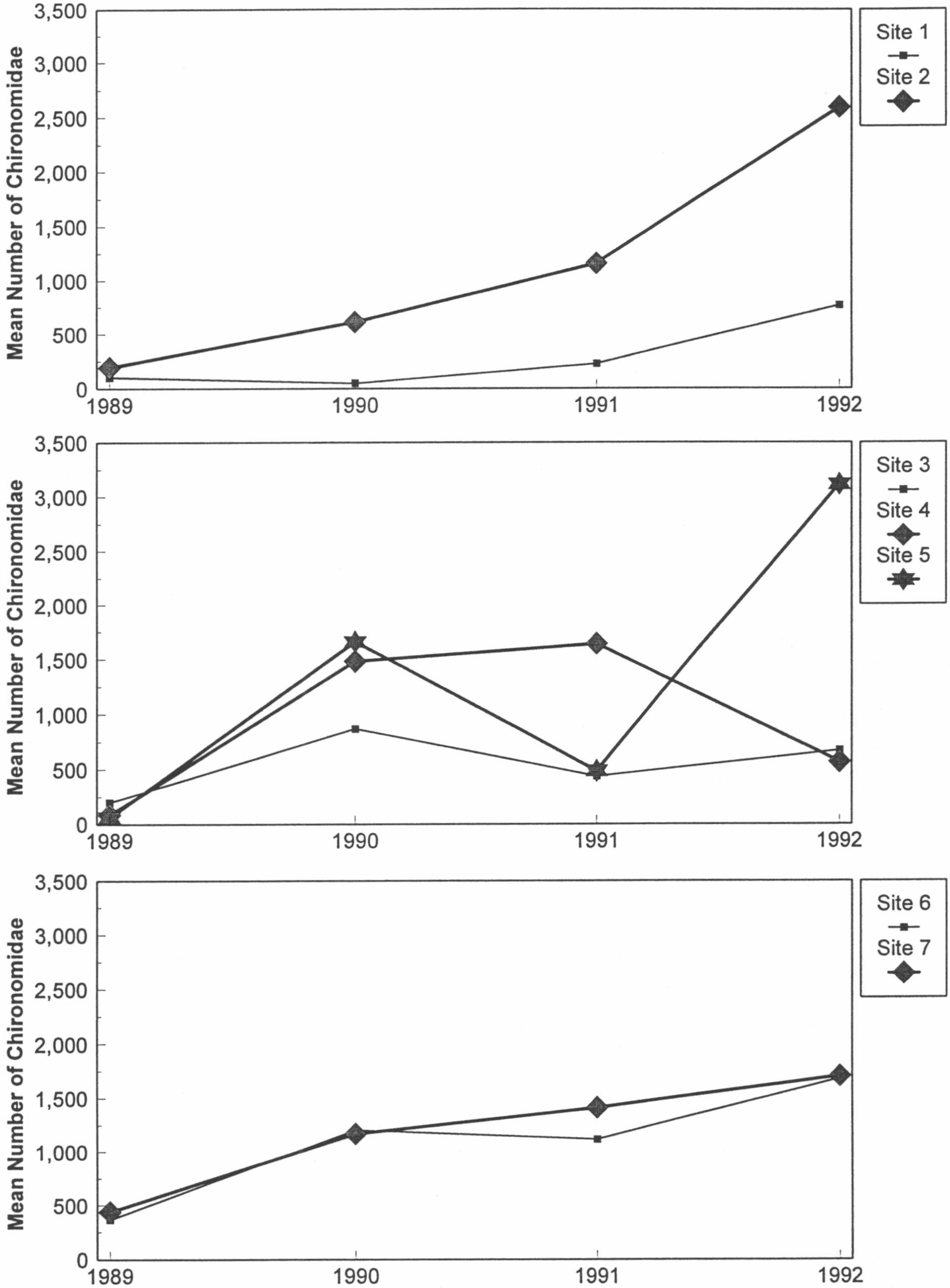


Figure 29. **Comparison of mean number of Chironomidae for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between fall 1989 to 1992.**

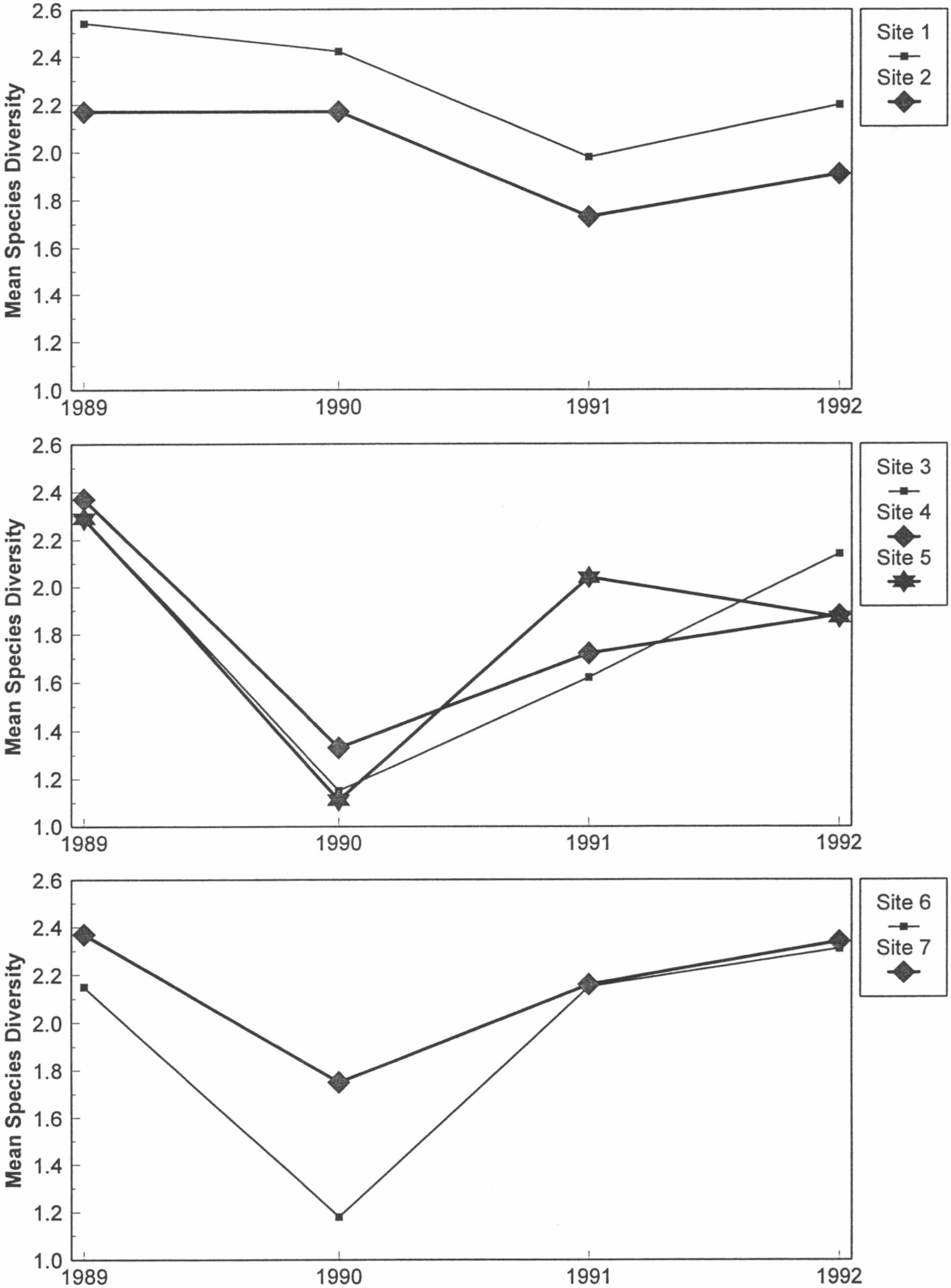


Figure 30. **Comparison of mean species diversity for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between fall 1989 to 1992.**

field sites in 1990, but in 1991, it was higher at far-field sites than at near-field sites (Figure 26).

The mean species diversity decreased at background sites between 1989 and 1991 and then increased slightly in 1992 (Figure 30). At both near-field and far-field sites, the mean species diversity decreased between 1989 and 1990 and then increased in 1991 and 1992.

The fall analyses indicated that there was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and three post-operational years and when far-field effects were compared between the pre-operational and post-operational years.

The results indicated that differences were noted between background and downstream sites and near-field and far-field sites between the two post-operational years of 1990 and 1991. No significant differences were found between 1991 and 1992. These differences suggested that the fall effects downstream of the ANC mill occurred mainly between 1990 and 1991 and that there were not effects between 1991 and 1992.

4.0 SUMMARY AND CONCLUSIONS

There were some variations in the physical characteristics of water velocity, water depth and substrate composition between sites and seasons. The differences between sites within a season were the result of hydraulic and other physical habitat differences between reaches of the river. The documented differences in physical characteristics, other than the presence of algae, did not likely cause any detectable differences in benthic community structure between sites within a season.

The water quality data indicated that the Athabasca River was a well oxygenated, alkaline stream during both the spring and fall surveys. Effluent discharge from the ANC mill did not affect pH, conductivity, dissolved oxygen, true color or total suspended solids concentrations at downstream sites. Biochemical oxygen demand (BOD_5) concentrations in the river were low during both surveys and were not affected by treated effluent discharge from ANC, Millar Western or the Whitecourt sewage treatment plant. Total phosphorus concentrations in April were higher at Sites 5, 6 and 7 than at background sites, likely as a result of effluent inputs. There was no affect on total Kjeldahl nitrogen concentrations in the river from effluent discharges.

Detailed water quality analyses at Sites 2 and 3 indicated that many parameters were below detection limits and/or did not exceed provincial (ASWQO) or federal (CWQG) guidelines. In April, concentrations of chromium, iron and mercury exceeded either the ASWQO or CWQG. Metals are not generally considered to be a major component of pulp mill effluent. The concentrations recorded in April were considered to be the result of natural processes. Resin and fatty acids were detected at both Sites 2 and 3 in April, however the concentrations were lower at Site 3 than at background Site 2. It is suspected that the source of these compounds originates upstream of ANC. Resin and fatty acids were not detected at either site in October.

In April, both the number of taxa and the number of EPT taxa were significantly higher at downstream than at background sites. However, there were no significant differences between near-field and far-field sites. The number of organisms was significantly higher at downstream than at background sites, but not between near-field and far-field sites. The species diversity values in April were lower at downstream than at background sites and were lower at far-field than at near-field sites. Ephemeroptera, Chironomidae and Oligochaeta were the dominant taxonomic groups at all sites during April, with

Chironomidae having the highest standing crop at all sites. The number of EPT was not significantly different between background and downstream sites, but was significantly higher at near-field than far-field sites. The number of Chironomidae was significantly higher at downstream than background sites, but not between near-field and far-field sites.

In October, both the number of taxa and the number of EPT taxa were significantly higher at downstream than at background sites and were significantly higher at far-field than near-field sites. The number of organisms was not significantly different between downstream and background sites, but was significantly higher at far-field than at near-field sites. The species diversity values in October were higher at downstream sites than at background sites and were higher at far-field than at near-field sites. Ephemeroptera, Chironomidae and Oligochaeta were the dominant taxonomic groups at all sites during October, with Chironomidae having the highest standing crop at all sites, especially downstream Sites 5, 6 and 7. Both the number of EPT and the number of Chironomidae were not significantly different between background and downstream sites, but were significantly higher at far-field than near-field sites.

The increase in mean standing crop at all downstream sites in April and at Sites 5, 6 and 6 in October was likely the result of organic loading from the ANC, the Millar Western and the Whitecourt sewage treatment effluents. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera, Trichoptera and Plecoptera), increased in numbers at downstream sites, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites, and in fact, there was a significant increase in the number of taxa at downstream sites in both April and October. This indicated that only mild organic enrichment was occurring in the Athabasca River as a result of organic loading from effluents.

A number of taxa have been found to respond to organic enrichment, by increasing in numbers, as a response to an increase in food availability, if oxygen is not limiting. The community analysis indicated that the dominant taxa characteristic of both background and downstream sites in April were suited to mild organic enrichment. The increase in numbers of organisms, such as Orthocladiinae and Naididae, at downstream sites indicated that the ANC effluent appeared to contribute organic enrichment to the river. The Millar Western and the Whitecourt sewage treatment effluents also appeared to contribute additional organic enrichment at Sites 6 and 7, since no recovery of the benthic community structure was apparent at these downstream sites. During October, as in previous surveys, the dominant benthic community structure of the background sites indicated the presence of mild organic enrichment, especially at Site 2. The ANC effluent appeared to contribute some additional organic enrichment to the river, affecting both Sites 4 and 5. The Millar Western and Whitecourt sewage treatment effluents appeared to contribute further organic enrichment to the river at Sites 6 and 7.

The trophic analysis showed that all sites during both the spring and fall surveys were dominated by detritivore/herbivores and detritivores, which is a common natural trait of most streams in North America. These groups were followed by carnivores and omnivores. In April, all sites had similar percent compositions of the dominant feeding groups (detritivore/herbivore and detritivore), with the exception of a slight increase in omnivores at Site 4. In October, Sites 1, 2 and 3 had high percentages of detritivore/herbivores, followed by detritivores, and then similar percentages of carnivores and omnivores. Sites 4, 5, 6 and 7 had lower percentages of detritivore/herbivores and higher percentages of detritivores, compared to upstream sites. The trophic analysis indicated that similar trends were apparent in the benthic data, as was found by the RA analysis. Increases in the numbers of certain organisms and shifts in the feeding group structure occurred as a result of the change in the nature of the food supply caused by organic enrichment in the Athabasca River from the pulp mill and sewage effluents.

In 1992, the benthic invertebrates of the Athabasca River at downstream sites responded to mild organic enrichment from the pulp mill and sewage treatment effluents by an increase in the populations of certain tolerant, as well as intolerant taxa. The benthic community structure also shifted to one of increasing proportions of tolerant taxa at downstream sites, which is a typical response to mild organic enrichment. Mild organic enrichment, due to nutrient addition (phosphorus) from the ANC, Millar Western and Whitecourt sewage treatment effluents, has over the years caused an increase in the abundance of tolerant taxa, such as Chironomidae, but oxygen depletion has not been sufficient to cause a decrease in the more sensitive EPT taxa.

The comparison of pre-operational and post-operational data for the spring and fall indicated that there was no evidence of major effects on the benthic community of the Athabasca River from the ANC discharge, when the impact over all downstream sites was compared between all pre-operational and post-operational years and when far-field effects were compared between all pre-operational and post-operational years. The spring results indicated that differences were noted between near-field and far-field sites between the two pre-operational years. These differences suggested that there were reduced effects from the Millar Western and/or Whitecourt sewage treatment effluents between 1989 and 1990. The results also indicated that differences were noted between both background and downstream sites and near-field and far-field sites between the two post-operational years. These differences suggested that there were increased effects downstream of the ANC mill in 1992. However, it should be noted that the effects included increases in the numbers of intolerant taxa (EPT taxa). The fall results indicated that differences were noted between background and downstream sites and near-field and far-field sites between the two post-operational years of 1990 and 1991. No significant differences were found between 1991 and 1992. These differences suggested that the effects downstream of the ANC mill in the fall occurred mainly between 1990 and 1991 and that there were not effects between 1991 and 1992.

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PERSONAL COMMUNICATION

R.H. Green, Department of Zoology, University of Western Ontario, London, Ontario.

APPENDICES

APPENDIX A

QA/QC

STATEMENT OF SENTAR'S QUALITY ASSURANCE/QUALITY CONTROL

The basis of SENTAR's Quality Assurance/Quality Control (QA/QC) program is the adherence to a Quality Management Plan. SENTAR's QA/QC program is practiced for all types of studies. The QA program consists of externally imposed technical and management practices which ensure that the generation of quality and defensible data commensurate with the intended use of the data. The QC program consists of internal techniques which are used to measure and assess data quality and remedial actions to be taken when the data quality objectives are not realized.

SENTAR's QA/QC program follows the QA/QC described for conducting EEM studies, where appropriate (Environment Canada 1992).

Objective

The objective of SENTAR's QA/QC program is to ensure that data generated for our clients is of known and defensible quality.

Organization

Project Manager:

- Communicates committment to and delegates responsibility for quality assurance.
- Allocates funds and resources for effective quality assurance.
- Establishes Standard Operating Procedures (SOP).

Quality Assurance Officer:

- Responsible for approval of all procedures.
- Authority for corrective action.
- Plans and evaluates QA/QC program.
- Reports any plans or problems of QA/QC to management.

Field Supervisor:

- Supervises compliance to QA/QC program.
- Helps establish SOP.
- Follows approved field, sample and data analyses procedures and reporting of data as outlined in SOP.

Field/Office Technicians:

- Have appropriate education and experience for the job.
- Follow approved field, sample and data analyses procedures and reporting of data as outlined in SOP.

Standard Operating Procedures

SENTAR's SOP outline detailed protocols for sample collection, field procedures, laboratory procedures and reporting of data. Any changes to SOP during a project are documented and justified.

All SOP include meticulous record-keeping, proper collection of samples, adequate replication, preservation, shipping and storage of samples, instrument calibration and maintenance and the use of chain-of-custody forms to ensure sample continuity.

Analytical Laboratories

The operations of any analytical laboratories used by SENTAR include the following Quality Control requirements as appropriate to the specific analysis: method blanks, laboratory duplicates, matrix spikes, analysis of reference materials, calibration control, surrogate spikes and internal standards.

SORTING EFFICIENCY

Project: ANC - Athabasca River

Project No.: 09-615-01-01

Sampling Date: April 1992

Site-Sample	Total Number of Organisms				Percent Recovery		
	Initial Sort		Re-Sort				
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Total
2-1	47	281	3	25	94	92	92
3-1	244	264	18	10	93	96	95
4-1	480	231	21	8	96	97	96
5-2	191	352	7	4	96	99	98
7-5	167	384	13	23	93	94	94
Average					94	96	95

SORTING EFFICIENCY

Project: ANC - Athabasca River

Project No.: 09-615-01-01

Sampling Date: October 1992

Site-Sample	Total Number of Organisms				Percent Recovery		
	Initial Sort		Re-Sort				
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Total
2-4	241	442	19	3	93	99	97
4-1	87	304	10	6	90	98	96
4-5	103	358	25	6	80	98	94
5-4	636	383	41	6	94	98	96
7-1	340	544	30	28	92	95	94
Average					90	98	95

REFERENCE COLLECTION

Project: ANC

Project No.: 09-615-01-01

Sampling Date: April and October 1992

Date Reference Collection Prepared: June 1993 - In prep. at the time of this report.

Date Reference Collection Updated: ______

Location of Reference Collection: SENTAR Consultants Ltd., Calgary, Alberta

Reference Collection Prepared By: Bob Saunders

Taxonomist: Bob Saunders

Total Number of Taxa in Collection: ______

1. OBJECTIVE

The objective of Alpha Laboratory Services Ltd.'s QA/QC Program is to ensure that data generated for our clients is of known accuracy to some stated quantitative degree of probability.

2. ORGANIZATION

A. Personnel

i) Laboratory Manager: Bob Lickacz, B.Sc., P.Biol.
ii) Supervisor, Analytical Services: Garry K. Ogletree
Quality Assurance Officer
iii) Laboratory Personnel:
Nadia Li, B.Sc.
Bill Durnford
Binh Luu
Phuc Truong
Angela Hollinger

B. Responsibilities

i) Laboratory Manager:
- communicates commitment to and delegates responsibility for quality assurance.
- allocates funds and resources for effective quality assurance.

ii) Quality Assurance Officer:
- plans and evaluates QA/QC program.
- reports any plans or problems of QA/QC to management.

Supervisor:
- supervises compliance to QA/QC program.
- trains employees in QA/QC operations.
- helps establish Standard Operating Procedures (S.O.P.)

iii) Laboratory Personnel:
- have appropriate education and experience for job.
- input in establishing Standard Operating Procedures.
- follows approved analytical procedures and reporting of data as per S.O.P.

3. QUALITY ASSURANCE DOCUMENTATION AND RECORD KEEPING

A. Laboratory Note Books

- Use bound consecutively numbered pages.
- All entries of raw analytical results are recorded in ink, and are dated and signed.
- Errors crossed out with a single line.
- All blank spaces are cancelled.

- All lab books are periodically inspected and signed by supervisor.
- New books are issued when the old books are turned in.
- Old books are archived in secure area and kept for ten years.

B. Sample Log In

- Chain of Custody forms (in triplicate) sent with sample bottles
- Chain of Custody signed by lab staff when samples received. Sample containers sealed, dated and stored in sample reception shelves.
- Samples are manually logged in by Supervisor.
- Are assigned a lab job number prior to any analysis being conducted. No samples brought into lab without being labelled with a job number.
- Sample log book contains:
  - lab assigned job number
  - name of client
  - name of contact
  - sample description
  - date of receipt.
- Chain of custody form is kept in job file for each job number.

C. Analytical Methods

All analysis of samples are conducted in accordance with the following:

a) the Latest Edition of "Standard Methods for the Examination of Water and Waste Water,"
b) Alberta Environment Methods Manual for Chemical Analysis of Water and Wastes,
c) latest EPA protocols.

D. Calibration Standards

Anions - Standards supplied by ERA (Environmental Resource Associates)
Metals and Cations - Fisher Scientific

All standards supplied with Certificates of Traceability. This documentation is stored in the QA/QC files.

A series of standards are analysed to establish a calibration curve for each parameter to be tested. Calibration curves are determined for each batch of samples tested.

E. Instrument Calibration Results

All calibration results are kept in the analysts' notebooks with the raw data with the exception of atomic absorption, ion chromatograph and total organic carbon analyses. These calibration results are included in the printout of analytical results and as such are stored with the individual job files.

All instrument operation manuals are kept in files with the instrument. Laboratory personnel initial inside cover of the manual after having read the manual, completed training and demonstrated competence in the operation of the instrument. All maintenance records are kept with this file.

4. QUALITY CONTROL

Listed are specific groups of parameters and the quality control methods used.

F. Quality Control Measures

Quality Control Measures

i) Proficiency Samples*
- Lab Duplicate
- Blind Duplicate (submitted by clients)
- Blind Samples (submitted by Lab Manager)
- External Standards (supplied by APG or ERA)
- Matrix Spikes

ii) Control charting of results of Proficiency sample data

iii) Interlaboratory Round Robins
- AWAC
- Alberta Environment

iv) External blind samples sent twice per year by APG and ERA

* Proficiency samples are run at the following frequency:

- Lab Duplicate - every 10 samples; independent aliquots tested
- Blind Duplicate - one or more submitted per group of samples (at the client's discretion)
- External Standards:
  - 1 per batch of samples for each parameter
  - 1 for each type of sample matrix
- Matrix Spikes - analysed to determine percent recovery of the parameter being analysed in the matrix present in a particular batch of samples

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CHEMICAL ANALYSIS REPORT

SENTAR CONSULTANTS
155, 2635 37 AVENUE N.E.
CALGARY, ALBERTA
T1Y 5Z6

Date: June 8, 1992

ATTN: MAIRE LUOMA

Lab Sample #: 92-D1264 Sampled By: CLIENT

Customer #: ______ Date Received: April 29, 1992

Sample Description: 2 water samples for resin and fatty acids analysis.

LAB SAMPLE #	SAMPLE I.D.	ANALYSIS REQUESTED
92-D1264-1	Site 2 04/27/92	Resin Acids
92-D1264-2	Site 3 04/29/92	Resin Acids

QA/QC

i. To ensure resin acid extraction efficiency, the effluent was fortified with a surrogate compound prior to extraction. Based on in-house data, the average % recovery for:

O-methylpodocarpic acid 83% ± 21%

ii. To ensure resin acid derivatization efficiency, the final extracts were fortified with tricosanoic acid prior to methylation with diazomethane. Based on in-house recovery data, the the average % recovery for:

tricosanoic acid 101% ± 14%

CERTIFIED BY: ______________________
Mahir Sidra, MSC., Chemist

APPROVED BY: ______________________
Detlef [Deib] Birkholz, MSc., PhD.
Manager, Environmental Services
Pulp and Paper Division

ALL SAMPLES WILL BE DISPOSED OF AFTER 30 DAYS FOLLOWING ANALYSIS. PLEASE CONTACT THE LAB IF YOU REQUIRE ADDITIONAL SAMPLE STORAGE TIME.

SENTAR Consultants Ltd.

[redacted]

CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 291-5080

Date Shipped: 25 April 1992

Carrier: Greyhound

Weigh Bill No.:

SHIP TO: AlphaLabs
[redacted]
Edmonton, Alta. T6E 0P5
[redacted]

SEND RESULTS TO: Maire Luoma
[redacted]
SENTAR Consultants Ltd.
#155, 2635-37th Avenue NE
Calgary, AB T1Y 5Z6

* *Please quote* [redacted] *project number on results* *

Project Name: ANC

Project No.: 09-615-01-01

P.O. No.:

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma			

Relinquished by: (Signature)	Received by: (Signature)	Date	Time

Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time

Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 5	Water Sample	25/04/92; 12:30 pm	BOD	
Site 6	"	25/04/92; 6:35 pm	BOD	
Site 7	"	24/04/92, 8:15 pm	BOD	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED [redacted]

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY [redacted] WITH FINAL RESULTS ***

Page 1 of 2

SENTAR Consultants Ltd.

[redacted]

CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 291-5080

Date Shipped: 28 April 1992

Carrier: In person

Weigh Bill No.:

SHIP TO: [redacted] Alpha Labs

SEND RESULTS TO: Maire Luoma [redacted]
SENTAR Consultants Ltd.
#155, 2635-37th Avenue NE
Calgary, AB T1Y 5Z6

* *Please quote* [redacted] *project number on results* *

Project Name: MW/ANC
09-616-01-01 09-615-01-01

Project No.: 09-615-01-01
~~09-616-01-01~~

P.O. No.:

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
[signature]	[signature]	28/04/92	10:40
Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
C Site 1	3 Water Samples	27/04/92; 12:45 pm	Conventional*; BOD, TKN	
JC Site 2	3 Water Samples	27/04/92; 3:20pm	Conventional* BOD, TKN	
JC Site 2	4 Water Samples	" "	Metals, Hg, TOC, Phenols	
JC Site 3	3 Water Samples	27/04/92; 5:50pm	Conv.*, BOD TKN	
JC Site 3	4 Water Samples	" "	Metals, Hg, TOC Phenols.	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED [redacted].

Special Instructions/Comments: *Conventional includes true color, total phosphorus, TSS, Dissolved Phosphorus
For metals - see list provided on 22 April 1992

Expected lab turn-around time: Rush (surcharge): Standard:

NOTE: Can you hold-off analyzing for Dissolved P until we decide whether we need to do it?

*** PLEASE RETURN WHITE COPY [redacted] WITH FINAL RESULTS ***

SENTAR Consultants Ltd.

[redacted]

CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 291-5080

Date Shipped: 28 April 1992

Carrier: In person

Weigh Bill No.:

SHIP TO: [redacted] Alpha Labs.

SEND RESULTS TO: [redacted] Maire Luoma
SENTAR Consultants Ltd. [redacted]
#155, 2635-37th Avenue NE
Calgary, AB T1Y 5Z6

** Please quote [redacted] project number on results **

Project Name: ANC/MW

Project No.: 09-615-81-01 / 09-616-81-01

P.O. No.:

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
[signature]	[signature]	28/04/92	10:40
Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
ANC Site 4	3 Water Samples	26/04/92; 6:15pm	Conv.*, BOD, TKN	
MW Site 1	2 Water Samples	27/04/92; 8:15am	Conv.* TKN	
MW Site 2	2 Water Samples	25/04/92; 12:20pm	Conv.*, TKN	
MW Site 3	2 Water Samples	26/04/92; 4:55pm	Conv.*, TKN	
MW Site 4	2 Water Samples	26/04/92; 12:00pm	Conv.* TKN	
MW Site 4A	2 Water Samples	26/04/92; 2:30pm	Conv.*, TKN	
MW Site 5	2 Water Samples	25/04/92; 6:35pm	Conv.*, TKN	
MW Site 6	2 Water Samples	25/04/92; 4:20pm	Conv.*, TKN	
MW Site 7	2 Water Samples	24/04/92; 8:15pm	Conv.*, TKN	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED [redacted]

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

*** PLEASE RETURN WHITE COPY [redacted] WITH FINAL RESULTS ***

Page 1 of 1

SENTAR Consultants Ltd.

[redacted]

CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 291-5080

Date Shipped: 29 April 1992

Carrier: In person

Weigh Bill No.:

SHIP TO: Envirotest Laboratories
9936 - 67th Avenue
Edmonton, Alta. T6E 0P5
ATTENTION: Dieb Birkholz

SEND RESULTS TO: Maire Luoma [redacted]
SENTAR Consultants Ltd. [redacted]
#155, 2635-37th Avenue NE
Calgary, AB T1Y 5Z6

** Please quote [redacted] project number on results **

Project Name: ANC - Whitecourt

Project No.: 09-615-01-01

P.O. No.:

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma	[illegible]	29 April 1992	13:27
Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 2	Water Sample	27/04/92; 3:20pm	Resin/Fatty Acids	
Site 3	Water Sample	27/04/92; 5:50pm	Resin/Fatty Acids	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED [redacted]

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY [redacted] WITH FINAL RESULTS ***

ETL Enviro·Test

A DIVISION OF ETL CHEMSPEC ANALYTICAL LIMITED

9936 - 67th Avenue — Edmonton, Alberta T6E 0P5 Telephone: (403) 434-9509 FAX: (403) 437-2311

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CHEMICAL ANALYSIS REPORT

SENTAR CONSULTANTS LIMITED
200, 1122 4th STREET S.W.
CALGARY, ALBERTA
T2R 1M1 ATTN: MAIRE LUOMA

Date: November 11, 1992

Lab Sample #: 92-D1567 Sampled By: CLIENT

Customer #: PROJ# 09-615-01-01 Date Received: October 11, 1992

Sample Description: 2 water samples for resin and fatty acids analysis.

LAB SAMPLE #	SAMPLE I.D.	ANALYSIS REQUESTED
92-D1567-1	SITE 2 10/06/92	RESIN AND FATTY ACIDS
92-D1567-2	SITE 3 10/06/92	RESIN AND FATTY ACIDS
92-D1567-3	SITE 1 10/06/92	ARCHIVE ONLY

92-D1567 (cont'd)

RESIN ACID QA/QC:

i. To ensure resin acid extraction efficiency, the effluent was fortified with a surrogate compound prior to extraction. Based on in-house data, the average % recovery for:

O-methylpodocarpic acid: 83% ± 19%

ii. To ensure resin acid derivatization efficiency, the final extracts were fortified with tricosanoic acid prior to methylation with diazomethane. Based on in-house data, the average % recovery for:

Tricosanoic acid: 102% ± 13%

CLIENT CHAIN OF CUSTODY FORMS:

Please see attached.

CERTIFIED BY: Lesley McFeeter

Lesley McFeeter, Residue Analyst

APPROVED BY:

Detlef [Deib] Birkholz, MSc., PhD.
Manager, Environmental Services
Pulp and Paper Division

ALL SAMPLES WILL BE DISPOSED OF AFTER 30 DAYS FOLLOWING ANALYSIS. PLEASE CONTACT THE LAB IF YOU REQUIRE ADDITIONAL SAMPLE STORAGE TIME.

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma
Phone: 269-9300

Date Shipped: 5 Oct. 1992
Carrier: Greyhound
Weigh Bill No.:

SHIP TO: Alpha Laboratories
17212-106 A Ave.
Edmonton, Alberta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC
Project No.: 09-615-01-01

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma		5 Oct. 1992	8:30 pm
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 6	Water Sample	5 Oct. 1992 4:30 pm	BOD	
Site 7	Water Sample	~~4~~ Oct. 1992 7:30 pm.	BOD	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: 6 October 1992

Carrier: Greyhound

Weigh Bill No.:

SHIP TO: Alpha Laboratories
17212 - 106A Ave.
Edmonton, Alberta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC

Project No.: 09-615-01-01

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma		6 Oct. 1992	8:30pm
Relinquished by: (Signature)	**Received at lab by: (Signature)**	**Date**	**Time**
Discarded at lab by: (Signature)	**Discard approved by: (Signature)**	**Date**	**Time**

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 1	Water Sample	6/10/92; 12:30pm	BOD	
Site 2	Water Sample	6/10/92; 3:15pm	BOD	
Site 3	Water Sample	6/10/92; 5:15pm	BOD	
Site 4	Water Sample	6/10/92; 7:30pm	BOD	
Site 5	Water Sample	6/10/92; 8:00pm	BOD	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

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TOTAL 28 BOTTLES

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: 8 October 1992

Carrier: in person

Weigh Bill No.:

SHIP TO: Alpha Laboratories
17212 - 106 A Avenue
Edmonton, Alberta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: MW/ANC

Project No.: 09-616-01-01 (MW) 09-615-01-01 (ANC)

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma	[signature]	8 Oct. 1992	2:15 pm
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 1 (ANC)	Water Sample	6/10/92; 12:30 pm	TKN	
Site 1 (ANC)	Water Sample	6/10/92; 12:30 pm	Color, True, TP, TSS, *	
Site 2 (ANC)	Water Sample	6/10/92; 3:15 pm	TKN	
Site 2 (ANC)	Water Sample	6/10/92; 3:15 pm	TC, TP, TSS, TOC**	
Site 2 (ANC)	Water Sample	6/10/92; 3:15 pm	Total Phenols	
Site 2 (ANC)	Water Sample	6/10/92; 3:15 pm	Metals***	
Site 3 (ANC)	Water Sample	6/10/92; 5:15 pm	TKN	
Site 3 (ANC)	Water Sample	6/10/92; 5:15 pm	TC, TP, TSS, TOC**	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:
* Analyze for true Color, total phosphorus (as P) (DL 0.001 mg/L), total suspended solids.
** Analyze for above three parameters plus total organic carbon

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Marie Luoma

Phone: 269-9300

Date Shipped: 8 October 1992

Project Name: ~~[illegible]~~ MW / ANC

Project No.: 09-616-01-01 / 09-615-01-01

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 3 (ANC)	Water Sample	6/10/92; 5:15pm	Total Phenols	
Site 3 (ANC)	Water Sample	6/10/92; 5:15pm	Metals***	
Site 4 (ANC)	Water Sample	6/10/92; 7:30pm	TKN	
Site 4 (ANC)	Water Sample	6/10/92; 7:30pm	TC, TP TSS *	
Site 1	Water Sample	5/10/92; 1:00pm	TKN	
Site 1	Water Sample	5/10/92; 1:00pm	TC TP TSS*	
Site 2	Water Sample	8/10/92; 10:45am	TKN	
Site 2	Water Sample	8/10/92; 10:45am	TC TP TSS*	
Site 3	Water Sample	7/10/92; 6:45pm	TKN	
Site 3	Water Sample	7/10/92; 6:45pm	TC TP TSS*	
Site 4	Water Sample	7/10/92; 1:30pm	TKN	
Site 4	Water Sample	7/10/92; 1:30pm	TC TP TSS*	
Site 4A	Water Sample	7/10/92; 5:30pm	TKN	
Site 4A	Water Sample	7/10/92; 5:30pm	TC TP, TSS*	
Site 5	Water Sample	5/10/92; 7:10pm	TKN	
Site 5	Water Sample	5/10/92; 7:10pm	TC TP TSS*	
Site 6	Water Sample	5/10/92; 4:30pm	TKN	
Site 6	Water Sample	5/10/92; 4:30pm	TC TP, TSS*	
Site 7	Water Sample	4/10/92; 7:30pm	TKN	
Site 7	Water Sample	4/10/92; 7:30pm	TC, TP, TSS*	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: *** Metals include total cadmium, total copper, total nickel, total lead, total arsenic, total mercury, total manganese, total cobalt, total chromium, total iron, total selenium, total zinc, total vanadium and total molybdenum.

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): M.L. / [illegible]

* PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS *

92-01567

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: 9 October 1992

Carrier: IN PERSON

Weigh Bill No.:

SHIP TO: Enviro-Test Laboratories
9936 - 67th Avenue
Edmonton, AB T6E 0P5

ATTENTION: Dieb Birkholz

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC

Project No.: 09-615-01-01

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma	W.L. Rodger	9 Oct. 1992	1515
Relinquished by: (Signature)	**Received at lab by: (Signature)**	**Date**	**Time**
Discarded at lab by: (Signature)	**Discard approved by: (Signature)**	**Date**	**Time**

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 2	Water Sample	6/10/92; 3:15pm	Resin/Fatty Acids*	
Site 3	Water Sample	6/10/92; 5:15pm	Resin/Fatty Acids*	
Site 1 ARCHIVE	Water Sample	6/10/92; 12:30pm	Resin/Fatty Acids**	

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:
* See attached list for the resin/fatty acids to be analyzed.
** Site 1 - Archive (Spare) - Do not analyze unless approved by SENTAR

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

APPENDIX B

PHYSICAL CHARACTERISTICS OF SAMPLE LOCATIONS, APRIL AND OCTOBER 1992

Appendix B-1. **Water velocity and depth for each sample location with means and 95% confidence limits (CL) per site, April 1992.**

Site-Sample	Water Velocity* (cm/s)	Water Depth (cm)
1-1	59	35
1-2	59	36
1-3	57	37
1-4	60	36
1-5	55	36
Mean ± 95% CL	58 ± 2	36 ± 1
2-1	41	37
2-2	51	38
2-3	51	38
2-4	53	36
2-5	50	38
Mean ± 95% CL	49 ± 6	37 ± 1
3-1	58	34
3-2	54	37
3-3	54	38
3-4	48	37
3-5	54	36
Mean ± 95% CL	54 ± 5	36 ± 2
4-1	50	33
4-2	50	36
4-3	56	37
4-4	50	35
4-5	46	36
Mean ± 95% CL	50 ± 4	35 ± 2
5-1	56	35
5-2	48	37
5-3	54	36
5-4	49	37
5-5	46	38
Mean ± 95% CL	51 ± 5	37 ± 1
6-1	42	38
6-2	36	39
6-3	47	36
6-4	48	36
6-5	50	38
Mean ± 95% CL	45 ± 7	37 ± 2
7-1	38	37
7-2	49	38
7-3	39	39
7-4	42	40
7-5	41	38
Mean ± 95% CL	42 ± 5	38 ± 1

* Water velocity for each sample was an average of three measurements.

Appendix B-2. **Water velocity and depth for each sample location with means and 95% confidence limits (CL) per site, October 1992.**

Site-Sample	Water Velocity* (cm/s)	Water Depth (cm)
1-1	47	31
1-2	50	32
1-3	51	33
1-4	54	32
1-5	50	33
Mean ± 95% CL	50 ± 3	32 ± 1
2-1	35	34
2-2	32	34
2-3	36	34
2-4	35	34
2-5	40	34
Mean ± 95% CL	36 ± 4	34 ± 0
3-1	44	33
3-2	41	34
3-3	48	34
3-4	42	35
3-5	44	34
Mean ± 95% CL	44 ± 3	34 ± 1
4-1	40	33
4-2	54	33
4-3	40	34
4-4	47	33
4-5	41	32
Mean ± 95% CL	45 ± 8	33 ± 1
5-1	49	34
5-2	44	34
5-3	44	34
5-4	47	34
5-5	45	34
Mean ± 95% CL	46 ± 3	34 ± 0
6-1	43	31
6-2	49	32
6-3	52	33
6-4	55	34
6-5	48	33
Mean ± 95% CL	49 ± 6	33 ± 1
7-1	39	30
7-2	50	32
7-3	36	35
7-4	39	34
7-5	38	32
Mean ± 95% CL	40 ± 7	33 ± 2

* Water velocity for each sample was an average of three measurements.

Appendix B-3. **Substrate size distribution (percentage by weight) for each sample location with means and 95% confidence limits (CL) per site, April 1992.**

Site-Sample	Cobble (64-256 mm)	Pebble (16-64 mm)	Large Gravel (4-16 mm)	Small Gravel (2-4 mm)	Coarse Sand (0.5-2 mm)
1-1	42.1	57.9	-	-	-
1-2	39.8	60.2	-	-	-
1-3	29.4	70.6	-	-	-
1-4	42.4	57.6	-	-	-
1-5	31.0	69.0	-	-	-
Mean ± 95% CL	36.9 ± 7.8	63.1 ± 7.8	-	-	-
2-1	43.0	57.0	0.1	-	-
2-2	46.2	53.8	-	-	-
2-3	43.8	56.2	<0.1	-	-
2-4	42.2	57.8	<0.1	-	-
2-5	42.4	57.6	-	-	-
Mean ± 95% CL	43.5 ± 2.0	56.5 ± 2.0	<0.1	-	-
3-1	25.3	74.6	0.1	-	-
3-2	42.6	57.4	<0.1	-	-
3-3	28.3	71.7	-	-	-
3-4	48.5	51.5	-	-	-
3-5	42.2	57.8	-	-	-
Mean ± 95% CL	37.4 ± 12.5	62.6 ± 12.4	<0.1	-	-
4-1	48.8	51.2	-	-	-
4-2	44.7	55.1	0.1	-	-
4-3	49.7	50.3	0.1	-	-
4-4	33.0	67.0	-	-	-
4-5	24.6	75.4	-	-	-
Mean ± 95% CL	40.2 ± 13.6	59.8 ± 13.6	<0.1	-	-
5-1	59.6	40.4	-	-	-
5-2	63.0	37.0	-	-	-
5-3	63.7	36.1	0.2	-	-
5-4	60.7	39.2	0.1	-	-
5-5	60.7	39.2	-	-	-
Mean ± 95% CL	61.5 ± 2.1	38.4 ± 2.2	0.1 ± 0.1	-	-
6-1	51.4	44.3	4.3	0.1	-
6-2	65.0	28.0	6.9	0.1	-
6-3	62.3	30.6	6.8	0.3	<0.1
6-4	72.0	23.6	4.3	0.1	<0.1
6-5	51.6	42.6	5.7	0.1	<0.1
Mean ± 95% CL	60.5 ± 11.1	33.8 ± 11.3	5.6 ± 1.6	0.1 ± 0.1	<0.1
7-1	68.0	23.9	7.8	0.3	<0.1
7-2	69.6	24.5	5.6	0.2	0.1
7-3	75.5	18.5	6.0	0.1	<0.1
7-4	58.2	36.9	4.7	0.2	<0.1
7-5	69.2	24.1	6.6	0.1	-
Mean ± 95% CL	68.1 ± 7.7	25.6 ± 8.4	6.1 ± 1.4	0.2 ± 0.1	<0.1

Appendix B-4. **Substrate size distribution (percentage by weight) for each sample location with means and 95% confidence limits (CL) per site, October 1992.**

Site-Sample	Cobble (64-256 mm)	Pebble (16-64 mm)	Large Gravel (4-16 mm)	Small Gravel (2-4 mm)	Coarse Sand (0.5-2 mm)
1-1	29.1	70.9	-	-	-
1-2	40.2	59.8	-	-	-
1-3	42.7	57.3	-	-	-
1-4	33.8	66.2	-	-	-
1-5	25.9	74.1	-	-	-
Mean ± 95% CL	34.3 ± 8.9	65.7 ± 8.9	-	-	-
2-1	63.0	37.0	-	-	-
2-2	52.2	47.8	-	-	-
2-3	67.4	32.6	-	-	-
2-4	47.8	52.2	-	-	-
2-5	49.4	50.6	-	-	-
Mean ± 95% CL	56.0 ± 10.8	44.0 ± 10.8	-	-	-
3-1	49.3	50.7	-	-	-
3-2	34.9	65.1	-	-	-
3-3	26.5	73.5	-	-	-
3-4	44.2	55.8	-	-	-
3-5	23.1	76.9	-	-	-
Mean ± 95% CL	35.6 ± 13.9	64.4 ± 13.9	-	-	-
4-1	57.6	42.0	0.4	-	-
4-2	46.5	53.3	0.2	-	-
4-3	67.0	31.5	1.5	<0.1	-
4-4	60.5	38.9	0.5	-	-
4-5	48.0	51.6	0.3	-	-
Mean ± 95% CL	55.9 ± 10.7	43.5 ± 11.3	0.6 ± 0.6	<0.1	-
5-1	50.6	49.2	0.2	-	-
5-2	63.2	36.4	0.4	-	-
5-3	70.9	28.8	0.4	-	-
5-4	61.4	38.3	0.3	-	-
5-5	57.8	41.8	0.4	-	-
Mean ± 95% CL	60.8 ± 9.2	38.9 ± 9.3	0.3 ± 0.1	-	-
6-1	56.8	38.4	4.6	0.2	<0.1
6-2	44.9	51.7	3.3	0.1	<0.1
6-3	73.6	24.1	2.2	0.1	<0.1
6-4	59.2	40.2	0.5	<0.1	-
6-5	55.3	44.1	0.5	0.1	<0.1
Mean ± 95% CL	58.0 ± 12.8	39.7 ± 12.5	2.2 ± 2.2	0.1 ± 0.1	<0.1
7-1	37.9	57.2	4.5	0.3	0.1
7-2	52.2	41.0	6.5	0.2	0.1
7-3	63.6	30.6	5.3	0.3	<0.1
7-4	65.0	33.5	1.4	0.1	<0.1
7-5	44.7	55.0	0.3	<0.1	-
Mean ± 95% CL	52.7 ± 14.6	43.5 ± 15.1	3.6 ± 3.3	0.2 ± 0.2	<0.1

Appendix B-5. The thickness of algal growth on the substrate for each site, April and October 1992.

Site	Algal Thickness (mm)* Cobble 1	Cobble 2	Cobble 3	Mean	Algal Growth Category
April					
1	-	-	-	-	None**
2	-	-	-	-	None
3	-	-	-	-	None
4	-	-	-	-	None
5	<1, <1, <1	<1, <1, <1	<1, <1, <1	<1	Light
6	1, 1, 1	1, 1, 1	1, 1, 1	1	Light
7	<1, <1, <1	<1, <1, <1	<1, <1, <1	<1	Light
October					
1	<1, 1, <1	1, <1, <1	<1, <1, <1	<1	Light
2	1, 1, <1	1, 1, <1	<1, <1, 1	<1	Light
3	4, 2, 4	2, 2, 1	3, 3, 4	3	Moderate
4	2, 2, 1	3, 1, 2	2, 1, 1	2	Moderate
5	2, 2, 1	1, 1, <1	1, <1, <1	1	Light
6	1, 1, 1	1, 1, <1	1, <1, <1	1	Light
7	<1, <1, <1	<1, <1, <1	<1, <1, <1	<1	Light

* Three measurements were taken for each cobble.

** None - no algal growth was obvious.

APPENDIX C

AVERAGE MONTHLY CONCENTRATIONS OF SELECTED PARAMETERS FOR MILLAR WESTERN FINAL TREATED EFFLUENT, LATE WINTER/SPRING AND FALL 1992

Appendix C. **Average monthly concentrations of selected parameters for Millar Western final treated effluent, late winter/spring (February - April) and fall (August - October) 1992.**

Parameter*	Winter/Spring			Fall		
	February	March	April**	August	September***	October
Discharge (m^3/d)	12,781	13,417	10,744	11,370	8,049	8,661
pH (units)	8.4	8.4	8.3	8.3	8.3	8.3
Dissolved Oxygen (mg/L)	5.8	5.4	5.4	5.3	4.9	4.7
Dissolved Oxygen (percent saturation)	83	79	78	80	69	61
Temperature (°C)	30.0	31.3	31.1	33.4	29.1	24.4
Biochemical Oxygen Demand (mg/L)	45	53	53	54	58	51
True Color (Pt-Co units)	751	674	703	740	800	783
Total Suspended Solids (mg/L)	104	90	112	201	466	392
Total Phosphorus (as P) (mg/L)	1.1	0.2	0.5	6.1	4.0	5.3
Total Kjeldahl Nitrogen (mg/L)	5.1	4.9	3.9	11.0	13.3	11.3

Source: Millar Western Pulp Ltd. (unpublished data)

* All monthly averages were based on daily values, except for total phosphorus and total Kjeldahl nitrogen, which were weekly values.

** Scheduled mill shutdown from 27 April to 2 May 1992. No effluent flow to river from 27 to 30 April 1992.

*** Scheduled mill shutdown from 22 September to 10 October 1992. No effluent flow to river from 23 to 27 September 1992.

APPENDIX D

SPECIES IDENTIFICATIONS AND NUMBERS PER SAMPLE, APRIL AND OCTOBER 1992

Site 1 - April 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis spp.	13	24	20	15	26
Ephemerellidae					
Ephemerella inermis	39	46	29	26	32
Heptageniidae					
Rhithrogena sp.	108	160	86	77	144
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	0	0	7	3
Hydropsychidae					
Hydropsyche sp.	6	0	1	1	2
Plecoptera					
Chloroperlidae					
Triznaka sp.	1	1	1	0	1
Perlidae					
Claassenia sabulosa	2	0	0	1	1
Perlodidae					
Isogenoides sp.	0	0	1	0	2
Perlodidae (early instar)	3	8	6	6	8
Diptera					
Empididae					
Chelifera sp.	0	0	0	0	2
Hemerodromia sp.	0	2	0	0	2
Chironomidae					
Chironominae					
Chironomini Tribe					
Polypedilum sp.	11	5	6	13	6
Saetheria sp.	4	1	2	1	17
Tanytarsini Tribe					
Micropsectra sp.	6	13	15	16	19
Rheotanytarsus sp.	0	0	2	0	0
Sublettea sp.	1	0	0	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	321	198	232	249	267
Eukiefferiella sp.	38	14	22	20	18
Parametriocnemus sp.	0	0	2	0	1
Tvetenia spp.	26	25	32	34	32
Orthocladiinae (early instar)	42	26	18	44	10
Prodiamesinae					
Monodiamesa sp.	20	13	25	19	17

(continued)

Site 1 - April 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Tanypodinae					
Pentaneurini Tribe					
Monopelopia sp.	4	2	6	4	8
Thienemannimyia gp.	4	6	3	6	4
Hydracarina	2	4	4	6	10
Podocopa					
Candonidae					
Candona sp.	2	4	4	6	2
Haplotaxida					
Enchytraeidae	42	30	22	18	30
Naididae	12	8	20	32	26
Lumbriculida					
Lumbriculidae	0	2	0	0	0
Nematoda	0	12	4	6	15

Site 2 - April 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis spp.	34	15	14	0	14
Ephemerellidae					
Ephemerella inermis	37	24	22	0	15
Heptageniidae					
Rhithrogena sp.	74	66	45	0	33
Trichoptera					
Brachycentridae					
Brachycentrus sp.	6	25	3	3	2
Hydropsychidae					
Arctopsyche sp.	1	0	0	0	0
Hydropsyche sp.	3	4	1	0	0
Leptoceridae					
Oecetis sp.	0	0	0	2	0
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	3	0	0	0	0
Perlodidae					
Isogenoides sp.	0	1	0	0	1
Isoperla sp.	0	1	0	0	1
Perlodidae (early instar)	4	0	0	0	2
Diptera					
Ceratopogonidae					
Bezzia/Palpomyia gp.	0	0	1	0	2
Empididae					
Chelifera sp.	0	0	0	0	2
Hemerodromia sp.	0	2	0	0	0
Simuliidae					
Similium sp.	0	2	0	0	0
Tipulidae					
Limnophila sp.	1	4	0	0	1
Chironomidae					
Chironominae					
Chironomini Tribe					
Saetheria sp.	1	16	4	0	12
Tanytarsini Tribe					
Rheotanytarsus sp.	32	40	26	0	30

(continued)

Site 2 - April 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Orthocladiinae					
Brillia sp.	2	8	0	0	2
Cricotopus/Orthocladius spp.	237	204	199	6	322
Eukiefferiella sp.	62	52	24	0	24
Parakiefferiella sp.	16	10	2	0	2
Thienemanniella sp.	0	2	0	0	0
Tvetenia spp.	24	31	38	2	28
Prodiamesinae					
Monodiamesa sp.	0	4	0	0	4
Tanypodinae					
Pentaneurini Tribe					
Monopelopia sp.	3	4	2	0	4
Thienemannimyia gp.	0	2	0	0	0
Hydracarina	18	18	14	0	2
Podocopa					
Candonidae					
Candona sp.	0	0	0	0	2
Haplotaxida					
Enchytraeidae	16	12	0	0	16
Naididae	28	18	0	0	12
Lumbriculida					
Lumbriculidae	0	0	0	0	1
Rhynchobdellida					
Glossiphoniidae					
Helobdella stagnalis	1	0	0	0	0
Nematoda	4	0	4	0	2
Basommatophora					
Lymnaeidae					
Stagnicola catascopium	0	0	0	1	0

Site 3 - April 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis spp.	83	126	86	92	53
Ephemerellidae					
Ephemerella inermis	37	46	37	42	34
Heptageniidae					
Heptagenia sp.	1	0	0	0	1
Rhithrogena sp.	92	122	87	92	48
Leptophlebiidae					
Paraleptophlebia sp.	0	0	0	1	0
Siphlonuridae					
Ameletus sp.	5	4	4	6	13
Trichoptera					
Brachycentridae					
Brachycentrus sp.	0	2	0	7	0
Hydropsychidae					
Hydropsyche sp.	6	0	8	0	2
Leptoceridae					
Oecetis sp.	4	0	0	0	1
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	7	6	4	11	5
Chloroperlinae (early instar)	0	0	0	1	0
Nemouridae					
Nemoura sp.	0	0	1	0	0
Podmosta sp.	0	1	0	0	0
Perlidae					
Claassenia sabulosa	4	0	0	1	0
Perlodidae					
Isogenoides sp.	0	1	0	0	0
Isoperla sp.	0	0	1	0	1
Perlodidae (early instar)	20	17	16	11	8
Taeniopterygidae					
Taenionema sp.	2	0	1	3	1
Diptera					
Empididae					
Chelifera sp.	0	0	1	1	3
Hemerodromia sp.	0	0	1	1	0

(continued)

Site 3 - April 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Chironomidae					
Chironominae					
Chironomini Tribe					
Polypedilum sp.	0	1	0	0	0
Saetheria sp.	40	89	50	52	38
Tanytarsini Tribe					
Micropsectra sp.	14	25	33	33	17
Rheotanytarsus sp.	23	20	16	36	19
Tanytarsus sp.	2	0	0	0	1
Orthocladiinae					
Cricotopus/Orthocladius spp.	711	855	751	881	519
Eukiefferiella sp.	71	92	66	54	26
Nanocladius sp.	0	5	2	0	0
Parakiefferiella sp.	13	31	26	31	18
Thienemanniella sp.	1	9	2	1	0
Tvetenia sp.	2	1	10	7	5
Prodiamesinae					
Monodiamesa sp.	0	8	2	4	7
Tanypodinae					
Pentaneurini Tribe					
Monopelopia sp.	8	12	14	8	2
Thienemannimyia gp.	9	16	17	8	9
Hydracarina	4	6	4	0	0
Podocopa					
Candonidae					
Candona sp.	0	4	8	8	2
Haplotaxida					
Enchytraeidae	28	24	16	24	10
Naididae	36	41	24	18	12
Lumbriculida					
Lumbriculidae	2	0	5	4	1
Nematoda	9	33	29	30	18

Site 4 - April 1992

Taxa	Number per Sample				
	1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis spp.	50	41	57	88	70
Ephemerellidae					
Drunella doddsi	0	0	0	1	1
Drunella grandis ingens	0	1	0	0	0
Ephemerella inermis	27	30	21	36	29
Heptageniidae					
Rhithrogena sp.	19	18	19	22	16
Siphlonuridae					
Ameletus sp.	0	1	1	0	0
Trichoptera					
Brachycentridae					
Brachycentrus sp.	122	26	36	31	10
Hydropsychidae					
Hydropsyche sp.	8	3	1	3	7
Limnephilidae					
Apatania sp.	0	1	0	0	0
Plecoptera					
Capniidae	0	0	2	0	0
Chloroperlidae					
Triznaka sp.	13	0	0	4	11
Chloroperlinae (early instar)	0	0	1	0	3
Nemouridae					
Nemoura sp.	0	1	0	0	0
Perlidae					
Claassenia sabulosa	0	1	0	1	0
Perlodidae					
Cultus sp.	1	0	2	0	5
Isogenoides sp.	0	1	0	0	0
Isoperla sp.	0	2	0	0	1
Perlodidae (early instar)	3	7	11	2	4
Taeniopterygidae					
Taenionema sp.	1	0	0	0	0
Diptera					
Empididae					
Chelifera sp.	1	0	3	4	5
Hemerodromia sp.	0	1	0	0	0
Tipulidae					
Hexatoma sp.	0	0	0	1	0
Limnophila sp.	0	2	1	1	0

(continued)

Site 4 - April 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Chironomidae					
Chironominae					
Chironomini Tribe					
Microtendipes sp.	0	1	0	0	0
Paracladopelma/Cyphomella spp.	2	0	1	0	4
Polypedilum spp.	4	3	1	6	18
Saetheria sp.	1	14	10	16	3
Tanytarsini Tribe					
Cladotanytarsus sp.	0	1	0	0	0
Micropsectra sp.	8	2	5	9	11
Rheotanytarsus spp.	17	9	16	14	12
Stempellinella sp.	0	1	0	0	0
Sublettea sp.	1	0	0	1	0
Tanytarsus sp.	1	0	0	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	716	691	763	749	693
Eukiefferiella sp.	18	23	20	63	48
Nanocladius sp.	0	1	0	0	0
Parakiefferiella sp.	5	0	10	12	3
Thienemanniella sp.	0	2	0	1	4
Tvetenia spp.	12	5	20	36	34
Prodiamesinae					
Monodiamesa sp.	7	7	23	21	36
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	3	20	6	5	9
Collembola	0	4	0	0	0
Hydracarina	0	8	0	0	1
Podocopa					
Candonidae					
Candona sp.	44	4	0	0	0
Haplotaxida					
Enchytraeidae	64	50	52	27	38
Naididae	153	140	179	120	131
Tubificidae	1	0	0	0	0
Lumbriculida					
Lumbriculidae	4	0	0	1	0
Nematoda	36	25	53	37	25

Site 5 - April 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis spp.	7	13	17	10	31
Ephemerellidae					
Ephemerella inermis	36	22	43	61	29
Heptageniidae					
Heptagenia sp.	4	0	0	0	0
Rhithrogena sp.	210	116	109	175	76
Siphlonuridae					
Ameletus sp.	0	0	1	0	0
Parameletus sp.	0	1	0	0	0
Trichoptera					
Brachycentridae					
Brachycentrus sp.	4	3	42	3	9
Hydropsychidae					
Arctopsyche sp.	0	0	0	0	1
Cheumatopsyche sp.	0	1	0	0	1
Hydropsyche sp.	2	0	6	0	0
Leptoceridae					
Oecetis sp.	4	2	4	0	0
Plecoptera					
Capniidae	0	0	1	0	0
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	4	7	10	6	5
Chloroperlinae (early instar)	2	1	1	0	1
Nemouridae					
Nemoura sp.	1	0	0	0	0
Perlidae					
Claassenia sabulosa	1	0	0	0	0
Perlodidae					
Cultus sp.	1	1	1	0	0
Isogenoides sp.	2	4	2	1	1
Perlodidae (early instar)	5	7	6	6	3
Diptera					
Empididae					
Chelifera sp.	2	6	0	1	8
Tipulidae					
Limnophila sp.	1	0	0	0	0

(continued)

Site 5 - April 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Chironomidae					
Chironominae					
Chironomini Tribe					
Paracladopelma/Cyphomella spp.	2	1	0	0	0
Polypedilum spp.	12	9	7	2	33
Saetheria sp.	37	26	34	83	48
Tanytarsini Tribe					
Cladotanytarsus sp.	0	0	0	1	0
Micropsectra sp.	36	37	82	78	96
Rheotanytarsus spp.	9	6	0	1	8
Sublettea sp.	4	0	0	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	1,063	518	1,090	997	1,035
Eukiefferiella sp.	17	7	6	12	26
Krenosmittia sp.	4	0	0	0	0
Parametriocnemus sp.	0	1	0	0	4
Synorthocladius sp.	0	0	0	0	1
Tvetenia spp.	44	9	37	45	24
Orthocladiinae (early instar)	60	44	132	84	72
Prodiamesinae					
Monodiamesa sp.	5	1	1	1	0
Tanypodinae					
Pentaneurini Tribe					
Monopelopia sp.	4	0	0	0	0
Thienemannimyia gp.	1	1	3	0	2
Hydracarina	36	13	16	12	20
Podocopa					
Candonidae					
Candona sp.	4	2	0	0	0
Haplotaxida					
Naididae	5	14	40	65	7
Nematoda	6	21	36	9	3

Site 6 - April 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	5	4	6	0	2
Ephemerellidae					
Drunella doddsi	0	1	0	0	0
Ephemerella inermis	9	23	11	1	4
Heptageniidae					
Heptagenia sp.	0	4	0	0	0
Rhithrogena sp.	0	12	4	0	0
Leptophlebiidae					
Leptophlebia sp.	1	3	5	2	1
Siphlonuridae					
Ameletus sp.	0	0	1	1	0
Trichoptera					
Brachycentridae					
Brachycentrus sp.	6	5	14	4	0
Hydropsychidae					
Cheumatopsyche sp.	0	0	2	0	0
Hydropsyche sp.	2	2	5	0	1
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	6	1	5	6	14
Chloroperlinae (early instar)	0	1	1	0	0
Nemouridae					
Nemoura sp.	1	0	0	0	0
Podmosta sp.	2	0	0	3	0
Perlodidae					
Cultus sp.	0	1	0	0	0
Isogenoides sp.	0	1	0	0	0
Isoperla sp.	0	0	2	0	0
Perlodidae (early instar)	3	1	3	0	0
Diptera					
Empididae					
Chelifera sp.	3	5	5	6	4
Hemerodromia sp.	0	4	0	0	0
Simuliidae					
Simulium sp.	4	1	0	0	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Polypedilum spp.	8	5	14	4	1
Saetheria sp.	7	4	0	0	4

(continued)

Site 6 - April 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Tanytarsini Tribe					
Micropsectra sp.	10	33	21	6	2
Rheotanytarsus sp.	4	1	0	2	0
Sublettea sp.	1	2	0	0	0
Orthocladiinae					
Brillia sp.	3	0	0	0	0
Cricotopus/Orthocladius spp.	418	931	538	381	481
Eukiefferiella sp.	14	50	32	16	12
Parametriocnemus sp.	7	0	2	0	0
Tvetenia spp.	58	92	4	23	24
Orthocladiinae (early instar)	57	64	19	38	30
Prodiamesinae					
Monodiamesa sp.	16	24	8	0	4
Tanypodinae					
Pentaneurini Tribe					
Monopelopia sp.	18	18	3	4	2
Thienemannimyia gp.	8	26	26	5	6
Coleoptera					
Elmidae					
Optioservus sp.	0	0	1	0	0
Hydracarina	5	8	8	0	12
Podocopa					
Candonidae					
Candona sp.	4	0	2	0	0
Haplotaxida					
Enchytraeidae	8	12	16	0	8
Naididae	5	8	6	0	3
Nematoda	34	61	13	33	33

Site 7 - April 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis spp.	4	17	6	18	12
Ephemerellidae					
Drunella doddsi	1	0	0	0	0
Ephemerella inermis	23	52	41	51	55
Heptageniidae					
Heptagenia sp.	0	0	0	1	0
Rhithrogena sp.	4	21	13	16	18
Trichoptera					
Brachycentridae					
Brachycentrus sp.	5	16	51	45	29
Hydropsychidae					
Cheumatopsyche sp.	0	1	0	4	1
Hydropsyche sp.	11	29	11	22	29
Plecoptera					
Chloroperlidae					
Chloroperlinae					
Triznaka sp.	9	8	3	1	5
Chloroperlinae (early instar)	0	0	0	0	4
Nemouridae					
Podmosta sp.	1	1	0	0	0
Perlodidae					
Isogenoides sp.	1	0	0	0	0
Isoperla sp.	0	0	0	1	0
Perlodidae (early instar)	4	11	7	10	10
Taeniopterygidae					
Taenionema sp.	0	0	0	3	0
Diptera					
Empididae					
Chelifera sp.	5	1	4	2	1
Hemerodromia sp.	0	0	0	2	4
Chironomidae					
Chironominae					
Chironomini Tribe					
Polypedilum sp.	4	0	4	0	0
Saetheria sp.	1	1	14	4	22
Tanytarsini Tribe					
Cladotanytarsus sp.	0	0	4	0	0
Micropsectra sp.	9	23	6	4	5
Rheotanytarsus sp.	77	88	53	34	84
Sublettea sp.	0	4	1	0	0

(continued)

Site 7 - April 1992 (concluded)

Taxa	Number per Sample				
	1	2	3	4	5
Orthocladiinae					
Cricotopus/Orthocladius spp.	757	1,156	1,065	629	1,119
Eukiefferiella sp.	25	60	4	12	14
Heterotrissocladius sp.	0	0	0	0	2
Krenosmittia sp.	0	0	0	0	2
Parakiefferiella sp.	0	4	0	2	1
Rheocricotopus sp.	4	0	0	2	1
Tvetenia spp.	49	81	61	24	1
Orthocladiinae (early instar)	58	60	84	62	104
Tanypodinae					
Pentaneurini Tribe					
Monopelopia sp.	10	12	0	6	4
Thienemannimyia gp.	2	5	1	0	1
Hydracarina	6	20	28	42	24
Haplotaxida					
Enchytraeidae	12	20	48	12	44
Naididae	29	48	128	30	40
Lumbriculida					
Lumbriculidae	4	10	15	0	4
Nematoda	20	44	41	4	63

Site 1 - October 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	20	13	14	23	30
Ephemerellidae					
Ephemerella inermis	58	70	119	69	85
Heptageniidae					
Heptagenia sp.	1	0	0	0	3
Rhithrogena sp.	34	26	56	60	143
Siphlonuridae					
Ameletus sp.	6	4	8	7	5
Trichoptera					
Brachycentridae					
Brachycentrus sp.	44	24	17	15	96
Hydropsychidae					
Hydropsyche sp.	0	0	0	1	0
Lepidostomatidae					
Lepidostoma sp.	1	0	0	0	0
Plecoptera					
Capniidae	32	16	39	27	33
Chloroperlidae					
Chloroperlinae (early instar)	1	3	0	0	0
Perlidae					
Claassenia sabulosa	0	0	0	0	1
Perlodidae					
Isogenoides sp.	1	0	0	1	2
Isoperla sp.	2	1	1	1	6
Taeniopterygidae					
Taenionema sp.	7	2	2	1	12
Diptera					
Empididae					
Hemerodromia sp.	0	0	0	1	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Microtendipes sp.	2	0	0	0	0
Paracladopelma/Cyphomella spp.	3	2	18	26	2
Phaenopsectra sp.	4	0	0	0	0
Polypedilum spp.	15	30	99	81	22
Tanytarsini Tribe					
Cladotanytarsus	0	2	26	14	4
Micropsectra sp.	0	1	2	2	0
Rheotanytarsus sp.	159	138	272	305	230
Tanytarsus sp.	0	2	2	0	0

(continued)

Site 1 - October 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Orthocladiinae					
Corynoneura sp.	0	2	0	0	0
Cricotopus/Orthocladius spp.	119	266	646	692	413
Eukiefferiella sp.	0	4	0	2	2
Nanocladius sp.	2	2	0	3	2
Parakiefferiella spp.	0	0	10	6	2
Synorthocladius sp.	2	12	32	27	14
Thienemanniella sp.	0	4	2	14	4
Tvetenia spp.	0	0	0	6	6
Orthocladiinae (early instar)	2	2	0	0	0
Prodiamesinae					
Monodiamesa sp.	0	0	3	3	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	4	8	15	17	21
Hydracarina	28	18	52	33	8
Haplotaxida					
Enchytraeidae	22	41	19	6	22
Naididae	19	93	73	160	83
Nematoda	13	27	34	11	11

Site 2 - October 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	30	50	16	2	1
Ephemerellidae					
Ephemerella inermis	189	158	128	118	84
Heptageniidae					
Heptagenia sp.	5	1	1	0	0
Rhithrogena sp.	3	17	2	0	0
Siphlonuridae					
Ameletus sp.	1	4	1	2	2
Trichoptera					
Brachycentridae					
Brachycentrus sp.	27	35	34	27	25
Hydropsychidae					
Arctopsyche sp.	0	0	0	1	0
Limnephilidae					
Apatania sp.	0	1	0	1	0
Plecoptera					
Capniidae	34	49	28	53	58
Chloroperlidae					
Chloroperlinae (early instar)	3	7	5	2	2
Perlodidae					
Cultus sp.	2	2	0	0	0
Isogenoides sp.	0	1	0	0	0
Isoperla sp.	0	4	1	0	1
Perlodidae (early instar)	0	0	0	2	0
Taeniopterygidae					
Taenionema sp.	1	2	0	0	8
Diptera					
Empididae					
Chelifera sp.	1	1	1	0	0
Hemerodromia sp.	9	4	0	0	0
Tipulidae					
Hexatoma sp.	0	1	1	0	1
Chironomidae					
Chironominae					
Chironomini Tribe					
Paracladopelma/Cyphomella spp.	42	16	43	90	149
Polypedilum spp.	280	296	400	1,109	1,156

(continued)

Site 2 - October 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Tanytarsini Tribe					
Cladotanytarsus sp.	16	11	8	48	16
Micropsectra sp.	0	5	16	8	0
Rheotanytarsus sp.	557	483	362	60	83
Tanytarsus sp.	0	5	16	16	0
Diamesinae					
Diamesini Tribe					
Potthastia longimana gp.	1	0	0	1	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	2,195	1,047	1,709	1,366	636
Nanocladius sp.	0	5	24	16	0
Paracladius sp.	0	0	0	8	8
Parakiefferiella spp.	8	15	16	41	32
Parametriocnemus sp.	8	0	0	0	0
Synorthocladius sp.	64	45	48	16	64
Thienemanniella sp.	24	20	32	8	8
Tvetenia spp.	8	20	64	8	0
Prodiamesinae					
Monodiamesa sp.	0	1	8	0	1
Tanypodinae					
Pentaneurini Tribe					
Larsia sp.	0	0	0	8	0
Thienemannimyia gp.	17	25	26	15	17
Hydracarina	80	31	50	54	48
Haplotaxida					
Enchytraeidae	57	28	40	16	8
Naididae	420	318	984	516	632
Tubificidae	2	0	0	63	3
Nematoda	73	68	44	98	87
Basommatophora					
Planorbidae					
Gyraulus sp.	0	0	0	0	8
Tricladida					
Planariidae					
Polycelis coronata	0	0	0	0	8

Site 3 - October 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	0	0	1	2	6
Ephemerellidae					
Ephemerella inermis	18	8	17	20	29
Heptageniidae					
Heptagenia sp.	5	4	0	1	1
Rhithrogena sp.	15	6	18	14	15
Leptophlebiidae					
Paraleptophlebia sp.	1	0	2	0	0
Siphlonuridae					
Ameletus sp.	8	9	9	3	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	26	26	40	40	27
Hydropsychidae					
Hydropsyche sp.	2	0	1	1	1
Leptoceridae					
Oecetis sp.	0	0	2	0	0
Limnephilidae					
Apatania sp.	0	0	2	3	4
Plecoptera					
Capniidae	10	11	10	4	3
Chloroperlidae					
Chloroperlinae (early instar)	2	2	1	1	1
Perlidae					
Claassenia sabulosa	1	0	0	0	0
Perlodidae					
Isoperla sp.	0	0	1	1	0
Perlodidae (early instar)	0	0	0	2	0
Pteronarcyidae					
Pteronarys dorsata	1	0	0	0	0
Taeniopterygidae					
Taenionema sp.	2	0	0	0	0
Diptera					
Empididae					
Chelifera sp.	0	0	2	0	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cryptochironomus sp.	0	0	0	1	0
Paracladopelma/Cyphomella spp.	10	5	2	8	8
Phaenopsectra sp.	0	0	0	4	0
Polypedilum spp.	36	10	29	58	36

(continued)

Site 3 - October 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Tanytarsini Tribe					
Cladotanytarsus sp.	0	2	0	2	2
Micropsectra sp.	2	4	2	0	2
Rheotanytarsus sp.	85	59	196	154	138
Diamesinae					
Diamesini Tribe					
Potthastia longimana gp.	0	1	0	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	281	250	474	515	574
Eukiefferiella sp.	2	2	0	2	0
Nanocladius sp.	2	0	0	4	2
Parakiefferiella spp.	4	0	6	4	4
Parametriocnemus sp.	2	2	0	0	0
Synorthocladius sp.	32	26	33	54	26
Thienemanniella sp.	0	2	6	8	8
Tvetenia spp.	8	13	10	14	28
Prodiamesinae					
Monodiamesa sp.	0	1	0	2	1
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	35	16	20	14	10
Hydracarina	2	14	6	20	20
Podocopa					
Candonidae					
Candona sp.	0	2	0	2	0
Haplotaxida					
Enchytraeidae	21	4	10	10	16
Naididae	79	70	51	179	162
Tubificidae	78	59	59	149	119
Nematoda	21	13	21	14	27
Basommatophora					
Lymnaeidae					
Stagnicola catascopium	0	0	0	2	0
Tricladida					
Planariidae					
Polycelis coronata	0	0	0	2	0

Site 4 - October 1992

Taxa	Number per Sample				
	1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	6	4	1	1	0
Ephemerellidae					
Ephemerella inermis	15	25	50	43	46
Heptageniidae					
Heptagenia sp.	5	0	2	1	3
Rhithrogena sp.	5	6	0	0	5
Siphlonuridae					
Ameletus sp.	2	5	4	2	5
Trichoptera					
Brachycentridae					
Brachycentrus sp.	23	13	26	18	37
Hydropsychidae					
Arctopsyche sp.	3	1	6	5	1
Limnephilidae					
Apatania sp.	0	0	0	1	1
Plecoptera					
Capniidae	2	9	3	4	4
Chloroperlidae					
Chloroperlinae (early instar)	2	1	0	0	1
Perlidae					
Claassenia sabulosa	1	0	0	1	1
Perlodidae					
Isogenoides sp.	1	0	0	0	0
Isoperla sp.	0	0	1	0	0
Taeniopterygidae					
Taenionema sp.	0	0	0	0	4
Diptera					
Ceratopogonidae					
Bezzia/Palpomyia gp.	0	2	0	0	0
Empididae					
Hemerodromia sp.	0	2	0	0	0
Tipulidae					
Hexatoma sp.	0	0	0	1	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Chironomus sp.	1	0	0	0	0
Paracladopelma/Cyphomella spp.	0	2	8	4	8
Phaenopsectra sp.	0	0	4	4	4
Polypedilum spp.	32	29	92	76	48

(continued)

Site 4 - October 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Tanytarsini Tribe					
Cladotanytarsus sp.	0	4	20	0	12
Micropsectra sp.	0	2	0	0	4
Rheotanytarsus sp.	25	69	243	155	220
Diamesinae					
Diamesini Tribe					
Potthastia longimana gp.	0	0	8	4	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	129	37	447	424	390
Eukiefferiella spp.	0	4	0	0	0
Nanocladius sp.	0	0	0	4	0
Parakiefferiella spp.	2	8	32	36	28
Synorthocladius sp.	4	10	36	24	24
Thienemanniella sp.	0	0	0	4	0
Tvetenia spp.	5	4	25	15	10
Orthocladiinae (early instar)	0	2	0	0	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	4	15	13	3	21
Hydracarina	8	10	8	16	8
Haplotaxida					
Enchytraeidae	3	14	8	12	20
Naididae	341	414	780	645	540
Tubificidae	58	22	43	29	71
Nematoda	17	13	38	41	19
Basommatophora					
Lymnaeidae					
Stagnicola catascopium	1	0	0	0	0

Site 5 - October 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	96	78	66	42	49
Ephemerellidae					
Ephemerella inermis	27	135	124	169	69
Heptageniidae					
Heptagenia sp.	4	1	5	5	2
Rhithrogena sp.	58	92	109	100	59
Leptophlebiidae					
Paraleptophlebia sp.	0	0	1	0	0
Siphlonuridae					
Ameletus sp.	1	1	1	0	1
Trichoptera					
Brachycentridae					
Brachycentrus sp.	188	219	291	351	196
Hydropsychidae					
Arctopsyche sp.	0	2	14	4	5
Cheumatopsyche sp.	1	0	3	2	0
Hydropsyche sp.	21	12	46	10	8
Hydroptilidae					
Hydroptila sp.	8	8	1	0	0
Limnephilidae					
Apatania sp.	1	4	1	3	4
Plecoptera					
Capniidae	41	47	73	84	87
Chloroperlidae					
Chloroperlinae (early instar)	0	8	3	3	4
Perlidae					
Claassenia sabulosa	0	2	2	1	1
Hesperoperla pacifica	0	1	1	0	0
Perlodidae					
Cultus sp.	0	1	7	1	4
Isogenoides sp.	0	2	0	1	3
Isoperla sp.	1	1	8	3	1
Pteronarcyidae					
Pteronarcella badia	0	0	1	0	0
Taeniopterygidae					
Taenionema sp.	28	62	18	27	17
Diptera					
Empididae					
Chelifera sp.	0	1	0	0	0
Hemerodromia sp.	0	9	12	0	0
Wiedemannia sp.	0	1	1	0	0

(continued)

Site 5 - October 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Tipulidae					
Hexatoma sp.	0	0	1	1	2
Chironomidae					
Chironominae					
Chironomini Tribe					
Paracladopelma/Cyphomella spp.	0	9	0	8	8
Polypedilum spp.	9	16	31	24	33
Stenochironomus sp.	0	0	2	0	0
Tanytarsini Tribe					
Cladotanytarsus sp.	24	40	30	16	16
Rheotanytarsus sp.	1,794	2,430	3,116	1,858	1,240
Diamesinae					
Diamesini Tribe					
Potthastia longimana gp.	0	8	0	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	600	778	1,120	377	593
Eukiefferiella sp.	16	32	0	33	16
Nanocladius sp.	0	8	20	48	8
Parakiefferiella spp.	0	32	20	16	24
Synorthocladius sp.	24	49	40	8	24
Thienemanniella sp.	16	8	40	24	24
Tvetenia spp.	123	108	189	165	103
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	33	42	51	23	29
Hydracarina	144	72	91	57	17
Haplotaxida					
Enchytraeidae	24	100	33	24	64
Naididae	89	179	199	202	81
Nematoda	27	16	13	10	21

Site 6 - October 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	34	36	56	61	53
Ephemerellidae					
Ephemerella inermis	75	66	91	118	97
Heptageniidae					
Heptagenia sp.	1	4	1	1	3
Rhithrogena sp.	12	19	26	17	32
Leptophlebiidae					
Paraleptophlebia sp.	0	0	1	1	0
Siphlonuridae					
Ameletus sp.	0	0	1	1	2
Trichoptera					
Brachycentridae					
Brachycentrus sp.	98	108	150	142	100
Hydropsychidae					
Arctopsyche sp.	0	2	0	2	0
Cheumatopsyche sp.	1	0	0	0	0
Hydropsyche spp.	10	26	119	58	23
Hydroptilidae					
Hydroptila sp.	0	0	5	0	0
Leptoceridae					
Oecetis sp.	1	0	6	0	1
Limnephilidae					
Apatania sp.	3	3	5	1	5
Psychomyiidae					
Psychomyia sp.	0	0	0	1	0
Plecoptera					
Capniidae	41	27	48	29	63
Chloroperlidae					
Chloroperlinae (early instar)	2	2	0	4	3
Perlidae					
Claassenia sabulosa	1	0	0	0	1
Perlodidae					
Cultus sp.	10	6	6	0	7
Isogenoides sp.	1	0	0	0	0
Isoperla sp.	2	1	12	2	1
Taeniopterygidae					
Taenionema sp.	0	13	32	35	9
Diptera					
Empididae					
Chelifera sp.	0	4	0	0	0
Hemerodromia sp.	8	8	8	0	0
Wiedemannia sp.	0	0	0	0	1

(continued)

Site 6 - October 1992 (concluded)

Taxa	Number per Sample				
	1	2	3	4	5
Tipulidae					
Dicranota sp.	0	0	1	0	0
Hexatoma sp.	0	0	0	1	1
Limnophila sp.	1	0	0	0	0
Chironomidae					
Chironominae					
Chironomini Tribe					
Cryptochironomus sp.	0	0	5	0	0
Microtendipes sp.	8	4	0	0	0
Paracladopelma/Cyphomella spp.	0	4	0	5	8
Polypedilum spp.	80	4	15	10	16
Tanytarsini Tribe					
Cladotanytarsus sp.	0	20	40	35	128
Rheotanytarsus sp.	629	743	1,258	984	1,397
Sublettea sp.	48	81	65	60	288
Diamesinae					
Diamesini Tribe					
Potthastia longimana sp.	0	0	0	15	1
Orthocladiinae					
Cricotopus/Orthocladius spp.	779	172	166	155	266
Eukiefferiella sp.	0	0	0	0	8
Heleniella sp.	0	0	0	1	0
Nanocladius sp.	16	4	10	5	56
Parakiefferiella spp.	16	0	5	5	32
Synorthocladius sp.	40	32	40	40	48
Thienemanniella sp.	32	12	5	10	8
Tvetenia spp.	32	35	53	41	51
Orthocladiinae (early instar)	0	4	0	0	0
Prodiamesinae					
Monodiamesa sp.	17	0	0	0	0
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	66	39	48	58	43
Hydracarina	97	24	110	50	88
Haplotaxida					
Enchytraeidae	124	52	55	75	24
Naididae	416	116	135	208	148
Tubificidae	64	47	21	29	113
Nematoda	151	82	51	30	41

Site 7 - October 1992

Taxa	Number per Sample 1	2	3	4	5
Ephemeroptera					
Baetidae					
Baetis sp.	35	16	10	33	90
Ephemerellidae					
Drunella doddsi	0	0	0	1	0
Ephemerella inermis	54	99	85	62	76
Heptageniidae					
Heptagenia sp.	0	0	0	0	2
Rhithrogena sp.	33	30	69	39	35
Siphlonuridae					
Ameletus sp.	0	1	1	5	0
Trichoptera					
Brachycentridae					
Brachycentrus sp.	97	188	203	258	149
Glossosomatidae					
Glossosoma sp.	0	3	0	0	1
Hydropsychidae					
Arctopsyche sp.	0	1	1	0	0
Cheumatopsyche sp.	0	0	0	1	1
Hydropsyche sp.	2	39	7	37	48
Lepidostomatidae					
Lepidostoma sp.	0	0	1	5	1
Leptoceridae					
Oecetis sp.	6	2	4	15	21
Limnephilidae					
Apatania sp.	4	3	4	7	4
Polycentropodidae					
Neureclipsis sp.	0	0	0	0	2
Psychomyiidae					
Psychomyia sp.	0	0	0	0	1
Plecoptera					
Capniidae	71	46	75	57	63
Chloroperlidae					
Chloroperlinae (early instar)	0	1	11	5	0
Nemouridae					
Zapada sp.	0	0	0	1	0
Perlidae					
Claassenia sabulosa	6	0	4	3	4
Perlodidae					
Cultus sp.	3	1	1	9	1
Isogenoides sp.	0	1	0	0	1
Isoperla sp.	0	7	8	4	3

(continued)

Site 7 - October 1992 (continued)

Taxa	Number per Sample 1	2	3	4	5
Taeniopterygidae					
Taenionema sp.	0	6	24	6	0
Diptera					
Empididae					
Chelifera sp.	5	1	1	1	10
Hemerodromia sp.	21	6	3	8	4
Chironomidae					
Chironominae					
Chironomini Tribe					
Cryptochironomus sp.	0	0	0	5	0
Microtendipes sp.	0	0	0	0	1
Paracladopelma/Cyphomella spp.	5	0	8	0	1
Polypedilum spp.	121	75	105	45	81
Tanytarsini Tribe					
Cladotanytarsus sp.	163	100	139	30	25
Micropsectra sp.	0	0	0	5	0
Rheotanytarsus sp.	990	724	1,355	764	1,256
Stempellinella sp.	0	0	0	0	1
Sublettea sp.	0	0	1	0	0
Tanytarsus sp.	10	0	0	10	8
Diamesinae					
Diamesini Tribe					
Potthastia longimana gp.	1	1	0	0	0
Orthocladiinae					
Cricotopus/Orthocladius spp.	777	266	510	91	57
Eukiefferiella spp.	5	16	18	0	24
Heleniella sp.	0	0	0	5	0
Nanocladius sp.	20	30	8	10	1
Parakiefferiella spp.	40	6	0	0	0
Synorthocladius sp.	80	25	0	5	0
Thienemanniella sp.	11	0	0	10	8
Tvetenia spp.	10	19	59	30	76
Tanypodinae					
Pentaneurini Tribe					
Thienemannimyia gp.	53	43	42	50	76
Hemiptera					
Corixidae					
Callicorixa audeni	1	0	1	0	0
Odonata					
Gomphidae					
Ophiogomphus sp.	1	0	0	0	0

(continued)

Site 7 - October 1992 (concluded)

Taxa	Number per Sample 1	2	3	4	5
Hydracarina	35	100	104	130	105
Haplotaxida					
Enchytraeidae	108	140	176	203	221
Naididae	199	130	156	115	116
Tubificidae	49	65	13	58	178
Nematoda	39	35	84	32	44
Microturbellaria	0	0	8	0	8

APPENDIX E

BASIC COMPUTATIONS OF BENTHIC INVERTEBRATE SAMPLES, APRIL AND OCTOBER 1992

Appendix E-1. Number (N) of taxa, number of EPT taxa, number of organisms, standing crop and species diversity of benthic invertebrate samples with means and 95% confidence limits (CL) per site, April 1992.

Site-Sample	Number of Taxa	Number of EPT Taxa	Number of Organisms	Standing Crop (N/m^2)	Species Diversity*
1-1	22	7	707	7,926	1.99
1-2	22	5	604	6,771	2.13
1-3	24	7	563	6,312	2.18
1-4	22	7	607	6,805	2.21
1-5	27	9	705	7,904	2.23
Mean ± 95% CL	23 ± 3	7 ± 2	637 ± 81	7,143 ± 907	2.15 ± 0.12
2-1	22	8	607	6,805	2.16
2-2	24	7	565	6,334	2.33
2-3	15	5	399	4,473	1.77
2-4	5	2	14	157	1.44
2-5	25	7	536	6,009	1.71
Mean ± 95% CL	18 ± 10	6 ± 3	424 ± 301	4,756 ± 3,371	1.88 ± 0.45
3-1	27	11	1,234	13,834	1.79
3-2	27	9	1,597	17,904	1.90
3-3	30	10	1,322	14,821	1.87
3-4	29	11	1,468	16,457	1.76
3-5	28	11	874	9,798	1.79
Mean ± 95% CL	28 ± 2	10 ± 1	1,299 ± 342	14,563 ± 3,829	1.82 ± 0.07
4-1	29	8	1,342	15,045	1.84
4-2	35	13	1,147	12,859	1.69
4-3	26	10	1,314	14,731	1.68
4-4	28	9	1,312	14,709	1.79
4-5	28	11	1,232	13,812	1.84
Mean ± 95% CL	29 ± 4	10 ± 2	1,269 ± 99	14,231 ± 1,110	1.77 ± 0.09
5-1	34	14	1,635	18,330	1.49
5-2	29	12	894	10,022	1.74
5-3	25	13	1,727	19,361	1.57
5-4	21	7	1,653	18,531	1.55
5-5	25	10	1,544	17,309	1.46
Mean ± 95% CL	27 ± 6	11 ± 3	1,491 ± 422	16,711 ± 4,729	1.56 ± 0.13
6-1	30	9	727	8,150	1.86
6-2	32	13	1,408	15,785	1.54
6-3	29	12	777	8,711	1.52
6-4	17	6	535	5,998	1.24
6-5	20	5	648	7,265	1.20
Mean ± 95% CL	26 ± 8	9 ± 4	819 ± 424	9,182 ± 4,756	1.47 ± 0.33
7-1	27	10	1,135	12,724	1.51
7-2	26	9	1,793	20,101	1.63
7-3	24	7	1,693	18,980	1.61
7-4	27	11	1,043	11,693	1.75
7-5	29	9	1,703	19,092	1.55
Mean ± 95% CL	27 ± 2	9 ± 2	1,473 ± 440	16,518 ± 4,935	1.61 ± 0.11

* Shannon-Weaver Index

Appendix E-2. **Number (N) of organisms for major taxonomic groups for each sample with total number, mean number and mean standing crop (SC) per site, April 1992.**

Site-Sample	Number of Organisms					
	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
1-1	160	6	6	477	54	4
1-2	230	0	9	303	40	22
1-3	135	1	8	365	42	12
1-4	118	8	7	406	50	18
1-5	202	5	12	399	56	31
Total Number	845	20	42	1,950	242	87
Mean Number	169.0	4.0	8.4	390.0	48.4	17.4
Mean SC (N/m^2)	1,894.6	44.8	94.2	4,372.2	542.6	195.1
2-1	145	10	7	377	44	24
2-2	105	29	2	373	30	26
2-3	81	4	-	295	-	19
2-4	-	5	-	8	-	1
2-5	62	2	4	428	29	11
Total Number	393	50	13	1,481	103	81
Mean Number	78.6	10.0	2.6	296.2	20.6	16.2
Mean SC (N/m^2)	881.2	112.1	29.1	3,320.6	230.9	181.6
3-1	218	10	33	894	66	13
3-2	298	2	25	1,164	65	43
3-3	214	8	23	989	45	43
3-4	233	7	27	1,115	46	40
3-5	149	3	15	661	23	23
Total Number	1,112	30	123	4,823	245	162
Mean Number	222.4	6.0	24.6	964.6	49.0	32.4
Mean SC (N/m^2)	2,493.3	67.3	275.8	10,813.9	549.3	363.2
4-1	96	130	18	795	222	81
4-2	91	30	12	780	190	44
4-3	98	37	16	875	231	57
4-4	147	34	7	933	148	43
4-5	116	17	24	875	169	31
Total Number	548	248	77	4,258	960	256
Mean Number	109.6	49.6	15.4	851.6	192.0	51.2
Mean SC (N/m^2)	1,228.7	556.1	172.6	9,547.1	2,152.5	574.0

(continued)

Appendix E-2. (concluded)

Site-Sample	Number of Organisms					
	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
5-1	257	10	16	1,298	5	49
5-2	152	6	20	660	14	42
5-3	170	52	21	1,392	40	52
5-4	246	3	13	1,304	65	22
5-5	136	11	10	1,349	7	31
Total Number	961	82	80	6,003	131	196
Mean Number	192.2	16.4	16.0	1,200.6	26.2	39.2
Mean SC (N/m^2)	2,154.7	183.9	179.4	13,459.6	293.7	439.5
6-1	15	8	12	629	13	50
6-2	47	7	5	1,250	20	79
6-3	27	21	11	667	22	29
6-4	4	4	9	479	-	39
6-5	7	1	14	566	11	49
Total Number	100	41	51	3,591	66	246
Mean Number	20.0	8.2	10.2	718.2	13.2	49.2
Mean SC (N/m^2)	224.2	91.9	114.3	8,051.6	148.0	551.6
7-1	32	16	15	996	45	31
7-2	90	46	20	1,494	78	65
7-3	60	62	10	1,297	191	73
7-4	86	71	15	779	42	50
7-5	85	59	19	1,360	88	92
Total Number	353	254	79	5,926	444	311
Mean Number	70.6	50.8	15.8	1,185.2	88.8	62.2
Mean SC (N/m^2)	791.5	569.5	177.1	13,287.0	995.5	697.3

Appendix E-3. **Number (N) of taxa, number of EPT taxa, number of organisms, standing crop and species diversity of benthic invertebrate samples with means and 95% confidence limits (CL) per site, October 1992.**

Site-Sample	Number of Taxa	Number of EPT Taxa	Number of Organisms	Standing Crop (N/m^2)	Species Diversity*
1-1	26	12	601	6,738	2.40
1-2	27	9	813	9,114	2.28
1-3	24	8	1,561	17,500	2.09
1-4	29	10	1,614	18,094	2.01
1-5	27	11	1,262	14,148	2.22
Mean ± 95% CL	27 ± 2	10 ± 2	1,170 ± 559	13,119 ± 6,262	2.20 ± 0.19
2-1	29	10	4,157	46,603	1.74
2-2	34	13	2,776	31,121	2.10
2-3	29	9	4,108	46,054	1.87
2-4	30	9	3,773	42,298	1.89
2-5	27	8	3,146	35,269	1.92
Mean ± 95% CL	30 ± 3	10 ± 2	3,592 ± 756	40,269 ± 8,474	1.91 ± 0.16
3-1	29	12	791	8,868	2.35
3-2	27	7	621	6,962	2.24
3-3	28	12	1,031	11,558	1.98
3-4	35	12	1,314	14,731	2.14
3-5	28	10	1,271	14,249	2.01
Mean ± 95% CL	29 ± 4	11 ± 3	1,006 ± 373	11,274 ± 4,176	2.14 ± 0.19
4-1	25	11	695	7,791	1.83
4-2	27	8	727	8,150	1.86
4-3	24	8	1,898	21,278	1.88
4-4	27	9	1,573	17,635	1.84
4-5	27	11	1,535	17,209	2.00
Mean ± 95% CL	26 ± 2	9 ± 2	1,286 ± 674	14,413 ± 7,561	1.88 ± 0.09
5-1	26	13	3,398	38,094	1.77
5-2	38	18	4,614	51,726	1.86
5-3	38	20	5,784	64,843	1.74
5-4	33	16	3,700	41,480	1.96
5-5	33	16	2,813	31,536	2.03
Mean ± 95% CL	34 ± 6	17 ± 3	4,062 ± 1,443	45,536 ± 16,174	1.87 ± 0.15
6-1	34	15	2,926	32,803	2.39
6-2	33	13	1,800	20,179	2.36
6-3	34	15	2,650	29,709	2.24
6-4	35	15	2,290	25,673	2.30
6-5	36	15	3,166	35,493	2.27
Mean ± 95% CL	34 ± 1	15 ± 1	2,566 ± 668	28,771 ± 7,494	2.31 ± 0.08
7-1	33	10	3,055	34,249	2.27
7-2	34	16	2,226	24,955	2.49
7-3	34	16	3,291	36,895	2.19
7-4	38	18	2,155	24,159	2.48
7-5	38	18	2,796	31,345	2.26
Mean ± 95% CL	35 ± 3	16 ± 4	2,705 ± 623	30,321 ± 6,980	2.34 ± 0.17

* Shannon-Weaver Index

Appendix E-4. **Number (N) of organisms for major taxonomic groups for each sample with total number, mean number and mean standing crop (SC) per site, October 1992.**

Site-Sample	Number of Organisms					
	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
1-1	119	45	43	312	41	41
1-2	113	24	22	475	134	45
1-3	197	17	42	1,127	92	86
1-4	159	16	30	1,198	166	45
1-5	266	96	54	722	105	19
Total Number	854	198	191	3,824	538	236
Mean Number	170.8	39.6	38.2	766.8	107.6	47.2
Mean SC (N/m^2)	1,914.8	443.9	428.3	8,596.4	1,206.3	529.1
2-1	228	27	40	3,220	479	163
2-2	230	36	65	1,994	346	105
2-3	148	34	34	2,772	1,024	96
2-4	122	29	57	2,818	595	152
2-5	87	25	69	2,170	643	152
Total Number	815	151	265	12,974	3,087	668
Mean Number	163.0	30.2	53.0	2,594.8	617.4	1,33.6
Mean SC (N/m^2)	1,827.4	338.6	594.2	29,089.7	6,921.5	1,497.8
3-1	47	28	16	499	178	23
3-2	27	26	13	393	133	29
3-3	47	45	12	778	120	29
3-4	40	44	8	844	338	40
3-5	52	32	4	839	297	47
Total Number	213	175	53	3,353	1,066	168
Mean Number	42.6	35.0	10.6	670.6	213.2	33.6
Mean SC (N/m^2)	477.6	392.4	118.8	7,517.9	2,390.1	376.7
4-1	33	26	6	202	402	26
4-2	40	14	10	186	450	27
4-3	57	32	4	928	831	46
4-4	47	24	5	753	686	58
4-5	59	39	10	769	631	27
Total Number	236	135	35	2,838	3,000	184
Mean Number	47.2	27.0	7.0	567.6	600.0	36.8
Mean SC (N/m^2)	529.1	302.7	78.5	6,363.2	6,726.5	412.6

(continued)

Appendix E-4. (concluded)

Site-Sample	Number of Organisms					
	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
5-1	186	219	70	2,639	113	171
5-2	307	245	124	3,560	279	99
5-3	306	356	113	4,659	232	118
5-4	316	370	120	2,600	226	68
5-5	180	213	117	2,118	145	40
Total Number	1,295	1,403	544	15,576	995	496
Mean Number	259.0	280.6	108.8	3,115.2	199.0	99.2
Mean SC (N/m^2)	2,903.6	3,145.7	1,219.7	34,923.8	2,230.9	1,112.1
6-1	122	113	57	1,763	614	257
6-2	125	139	49	1,154	215	118
6-3	176	285	98	1,710	211	170
6-4	199	204	70	1,424	312	81
6-5	187	129	84	2,350	285	131
Total Number	809	870	358	8,401	1,637	757
Mean Number	161.8	174.0	71.6	1,680.2	327.4	151.4
Mean SC (N/m^2)	1,813.9	1,950.7	802.7	18,836.3	3,670.4	1,697.3
7-1	122	109	80	2,286	356	102
7-2	146	236	62	1,305	335	142
7-3	165	220	123	2,245	345	193
7-4	140	323	85	1,060	376	171
7-5	203	228	72	1,615	515	163
Total Number	776	1,116	422	8,511	1,927	771
Mean Number	155.2	223.2	84.4	1,702.2	385.4	154.2
Mean SC (N/m^2)	1,739.9	2,502.2	946.2	19,083.0	4,320.6	1,728.7

APPENDIX F

STATISTICAL ANALYSES RESULTS, APRIL AND OCTOBER 1992

ANOVA on the Number of Taxa (Log Transformed) for Sites, ~~April~~ Spring ~~199~~2

Source	DF	SS	MS	F	P
Site	6	0.24045	0.04008	2.50*	0.0458
Within	28	0.44828	0.01601		
Total	34	0.68873			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-1.4750
SE (Contrast)	0.4734
SS (Contrast)	0.1554
T-Statistic	-3.12*
P (T-Statistic)	0.0042

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.2130
SE (Contrast)	0.3099
SS (Contrast)	0.00756
T-Statistic	0.69**
P (T-Statistic)	0.4976

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of EPT Taxa (Log Transformed) for Sites, ~~April 1992~~ Spring

Source	DF	SS	MS	F	P
Site	6	0.39022	0.06504	3.51*	0.0102
Within	28	0.51821	0.01851		
Total	34	0.90843			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-2.0962
SE (Contrast)	0.5090
SS (Contrast)	0.3139
T-Statistic	-4.12*
P (T-Statistic)	0.0003

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.4585
SE (Contrast)	0.3332
SS (Contrast)	0.0350
T-Statistic	1.38**
P (T-Statistic)	0.1798

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of Organisms (Log Transformed) for Sites, ~~April 1992~~ Spring

Source	DF	SS	MS	F	P
Site	6	2.30322	0.38387	4.78*	0.0018
Within	28	2.24942	0.08034		
Total	34	4.55264			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-4.8061
SE (Contrast)	1.0605
SS (Contrast)	1.6499
T-Statistic	-4.53**
P (T-Statistic)	0.0001

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.6027
SE (Contrast)	0.6943
SS (Contrast)	0.0605
T-Statistic	0.87**
P (T-Statistic)	0.3927

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of EPT (Log Transformed) for Sites, ~~April 1992~~ Spring

Source	DF	SS	MS	F	P
Site	6	3.10093	0.51682	7.03*	0.0001
Within	28	2.05737	0.07348		
Total	34	5.15830			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-1.1789
SE (Contrast)	1.0142
SS (Contrast)	0.0993
T-Statistic	-1.16**
P (T-Statistic)	0.2549

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	3.0000
SE (Contrast)	0.6640
SS (Contrast)	1.5000
T-Statistic	4.52*
P (T-Statistic)	0.0001

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of Chironomidae (Log Transformed) for Sites, ~~April 1992~~ Spring

Source	DF	SS	MS	F	P
Site	6	2.78156	0.46359	5.17*	0.0011
Within	28	2.50906	0.08961		
Total	34	5.29062			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-5.6405
SE (Contrast)	1.1201
SS (Contrast)	2.2725
T-Statistic	-5.04*
P (T-Statistic)	0.0000

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.2611
SE (Contrast)	0.7333
SS (Contrast)	0.0114
T-Statistic	0.36**
P (T-Statistic)	0.7244

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of Taxa (Log Transformed) for Sites, Autumn ~~October 1992~~

Source	DF	SS	MS	F	P
Site	6	0.08596	0.01433	9.62*	0.0000
Within	28	0.04171	0.00149		
Total	34	0.12767			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-0.4905
SE (Contrast)	0.1444
SS (Contrast)	0.0172
T-Statistic	-3.40*
P (T-Statistic)	0.0021

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-0.4473
SE (Contrast)	0.0945
SS (Contrast)	0.0334
T-Statistic	-4.73*
P (T-Statistic)	0.0001

* Significant ($p < 0.05$)

ANOVA on the Number of EPT Taxa (Log Transformed) for Sites, Autumn ~~October~~ ~~19~~92

Source	DF	SS	MS	F	P
Site	6	0.34301	0.05717	9.25*	0.0000
Within	28	0.17303	0.00618		
Total	34	0.51604			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-1.1931
SE (Contrast)	0.2941
SS (Contrast)	0.1017
T-Statistic	-4.06*
P (T-Statistic)	0.0004

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-0.6405
SE (Contrast)	0.1926
SS (Contrast)	0.0684
T-Statistic	-3.33*
P (T-Statistic)	0.0025

* Significant ($p < 0.05$)

ANOVA on the Number of Organisms (Log Transformed) for Sites, Autumn ~~October~~ ~~1992~~

Source	DF	SS	MS	F	P
Site	6	1.97240	0.32873	17.27*	0.0000
Within	28	0.53297	0.01903		
Total	34	2.50537			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-0.0191
SE (Contrast)	0.5162
SS (Contrast)	0.0000261
T-Statistic	-0.04**
P (T-Statistic)	0.9707

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-1.1743
SE (Contrast)	0.3379
SS (Contrast)	0.2298
T-Statistic	-3.47*
P (T-Statistic)	0.0017

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Autumn

ANOVA on the Number of EPT (Log Transformed) for Sites, ~~October 19~~92

Source	DF	SS	MS	F	P
Site	6	3.62537	0.60423	48.94*	0.0000
Within	28	0.34573	0.01235		
Total	34	3.97111			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-0.0386
SE (Contrast)	0.4158
SS (Contrast)	0.000106
T-Statistic	-0.09**
P (T-Statistic)	0.9268

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-2.4767
SE (Contrast)	0.2722
SS (Contrast)	1.0224
T-Statistic	-9.10*
P (T-Statistic)	0.0000

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

ANOVA on the Number of Chironomidae (Log Transformed) for Sites, Autumn ~~October 1~~992

Source	DF	SS	MS	F	P
Site	6	3.05428	0.50905	13.57*	0.0000
Within	28	1.05055	0.03752		
Total	34	4.10483			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)
Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	0.4581
SE (Contrast)	0.7248
SS (Contrast)	0.0150
T-Statistic	0.63**
P (T-Statistic)	0.5325

Contrast Number 2 (Near-field/Far-field)
Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-1.3869
SE (Contrast)	0.4745
SS (Contrast)	0.3206
T-Statistic	-2.92*
P (T-Statistic)	0.0068

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

APPENDIX G

RESULTS OF RA ANALYSIS, APRIL AND OCTOBER 1992

Appendix G-1. Species dominance distribution matrix for each sample site, April 1992.

Species Code																																			
Site	2	4	7	7	2	5	6	4	6	4	6	7	2	7	4	6	6	7	2	4	5	1	5	5	5	2	3	3	1	3	1	3	1	3	1
Sample	4	1	4	3	2	3	1	3	4	4	2	2	3	1	2	3	5	5	5	5	1	4	5	4	2	1	1	4	3	5	1	3	5	2	2
093	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
023	1	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	+	-	-	-	-	-
016	2	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	-	-	-	-	+	+	-
072	1	+	+	+	+	+	1	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
089	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
063	5	7	8	8	4	8	7	7	9	7	8	8	6	8	8	9	9	8	8	7	8	5	9	8	7	5	7	8	5	7	6	7	5	7	4
040	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
052	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
086	-	+	-	-	-	-	+	-	-	-	-	-	-	-	+	+	-	-	+	-	+	+	-	-	+	-	-	+	+	+	+	+	+	+	+
069	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
025	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
018	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-
103	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
046	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
042	-	-	-	-	+	-	-	+	-	+	-	-	-	-	+	-	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-
041	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
111	-	-	-	-	-	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
019	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	+	+	-	+	+	+	+	+	-	-
129	-	-	-	-	-	-	+	-	+	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
057	-	+	-	+	-	-	+	-	-	+	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-
088	-	1	+	1	+	+	+	1	-	1	+	+	-	+	1	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
056	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
121	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
045	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
090	-	+	-	+	-	-	-	-	-	+	-	+	-	+	-	-	-	+	+	-	-	-	-	-	-	-	+	+	-	+	-	+	-	-	+
004	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
029	-	+	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
055	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	-	+	-	+	-
031	-	-	+	-	+	-	-	-	-	-	-	-	-	-	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-
035	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	+	-	-	-
085	-	-	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	+
092	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
037	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
038	-	+	+	+	-	-	+	+	+	+	+	+	-	+	-	+	+	+	+	+	+	-	+	+	+	-	-	+	-	+	-	+	+	-	-
098	-	+	+	+	-	+	+	-	+	+	+	+	-	+	-	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
073	-	-	+	+	-	1	1	-	+	-	+	+	-	+	-	+	+	+	-	-	+	+	+	+	+	-	-	-	+	-	+	-	+	-	+
008	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-
100	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-

(continued)

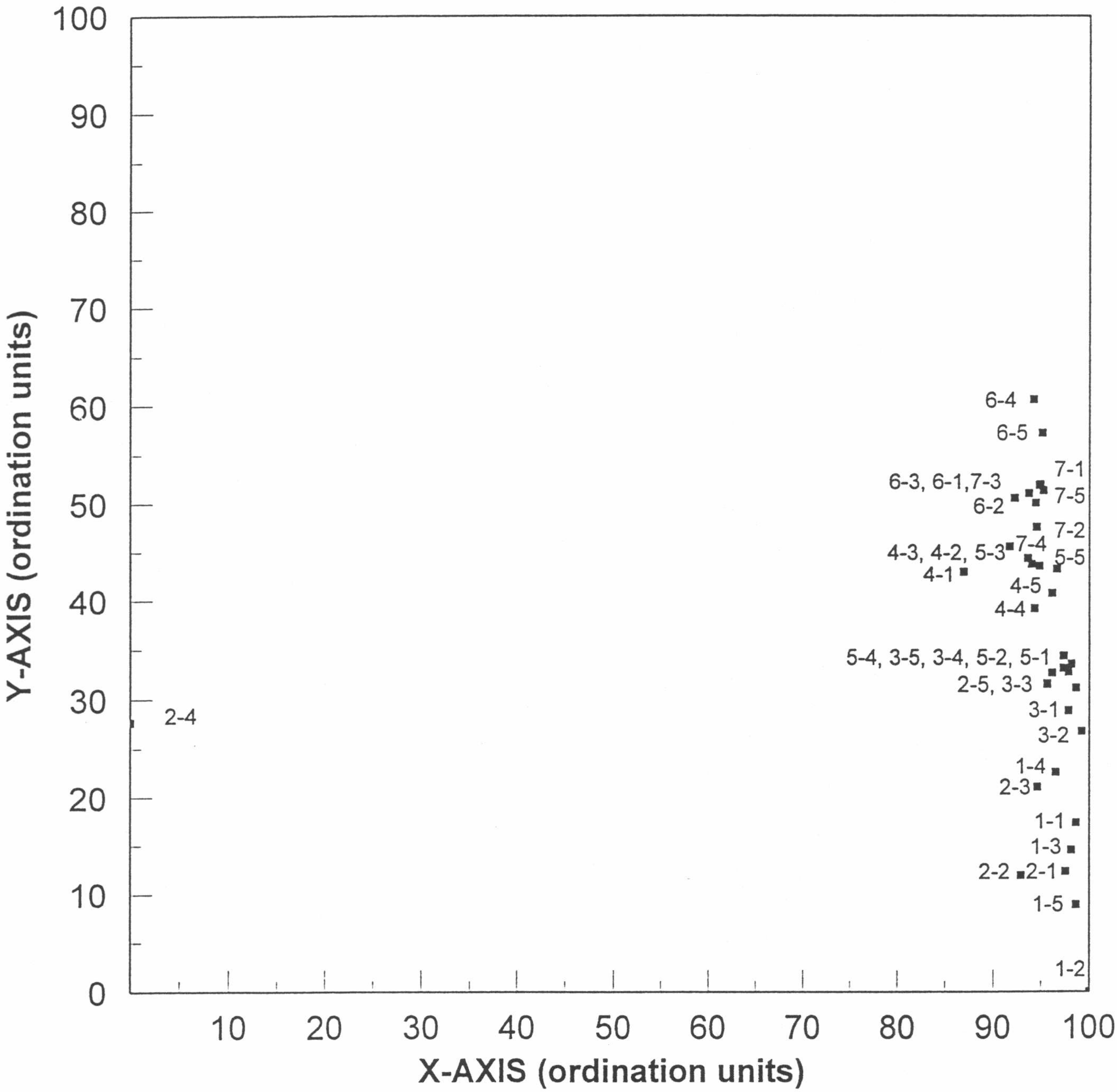
Appendix G-1. (concluded)

Species Code	Site 2	4	7	7	2	5	6	4	6	4	6	7	2	7	4	6	6	7	2	4	5	1	5	5	5	2	3	3	1	3	1	3	1	3	1
Sample	4	1	4	3	2	3	1	3	4	4	2	2	3	1	2	3	5	5	5	5	1	4	5	4	2	1	1	4	3	5	1	3	5	2	2
068	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	+	-	-
099	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	+	-	+	-	+	+	-	+	-	+	-	-	+	-	-	-	-	-	-	-
058	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-
087	-	+	+	+	+	-	+	+	-	+	+	+	-	+	+	+	+	+	+	+	-	+	-	-	-	+	+	+	+	+	+	+	+	+	+
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
039	-	-	+	-	+	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	+
131	-	-	+	-	+	-	+	-	+	-	+	+	+	+	-	+	+	+	+	-	+	+	-	-	-	+	+	+	+	+	+	+	+	+	+
077	-	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+
064	-	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+
048	-	+	-	+	-	+	+	+	+	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+	-	-	-	+	-	+	-	+	+	+
005	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1
030	-	-	-	-	+	+	-	-	-	-	+	-	-	+	+	-	-	-	+	-	+	-	+	+	+	-	-	-	+	-	-	-	+	+	-
002	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+
054	-	+	+	+	-	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+
074	-	+	-	-	+	+	+	+	-	+	+	-	-	-	+	+	+	-	+	+	+	+	-	+	+	-	-	+	+	+	+	+	+	+	+
070	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
071	-	-	-	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	+	+	-	-	-	+	-	+	-
032	-	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
067	-	+	+	-	+	-	-	+	-	+	-	+	+	-	-	-	-	+	+	+	-	-	-	-	-	+	+	+	-	+	-	+	-	+	-
050	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
009	-	+	+	+	1	+	-	+	-	+	+	+	1	+	+	+	-	+	+	+	1	1	+	1	1	1	1	+	2	+	2	+	2	1	3
017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-
130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
028	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-	-	+	+	-	-	+	-	+	-	-
091	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
014	-	-	-	-	-	+	-	+	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	+	-	+	-
012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
065	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-

+ present

- absent

1 to 9 weighted species abundance score



Appendix G-2. Reciprocal averaging ordination of site scores, April 1992.

Appendix G-3. Species dominance distribution matrix for each sample site, (sample 2-4 omitted) April 1992.

Site	1	1	2	1	2	1	2	1	3	3	3	5	5	2	3	3	5	4	4	5	5	4	4	7	7	6	4	6	7	7	6	7	6	6
Species Code / Sample	2	5	1	3	2	1	3	4	2	1	3	1	2	5	4	5	4	4	5	5	3	2	3	4	2	2	1	1	5	1	3	3	5	4
091	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
017	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
009	3	2	1	2	1	2	1	1	1	1	+	1	1	+	+	+	1	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	-	-
103	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
042	-	-	+	-	+	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
028	-	+	-	-	-	+	-	+	-	+	-	+	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
039	+	+	-	-	+	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+	-	+	-	+	-	-	+	-	-	-	-	-
037	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
030	-	+	-	+	+	-	-	-	+	-	-	+	+	+	-	-	+	-	-	+	+	+	-	-	-	+	-	-	-	+	-	-	-	-
067	-	-	+	-	+	-	+	-	+	+	+	-	-	+	+	+	-	+	+	-	-	-	+	+	+	-	+	-	+	-	-	-	-	-
074	+	+	-	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	+	+	+	-	-	+	-	+	-
005	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
071	-	-	-	-	+	-	-	-	+	+	+	-	-	-	+	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
002	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
064	+	+	1	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
032	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
065	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
087	+	+	+	+	+	+	-	+	+	+	+	-	-	+	+	+	-	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-
130	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
050	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
012	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
085	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	-	+	+	+	+	-	+	+	+	-	+	+	+	+	+	+	-
072	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+
023	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
086	+	+	-	+	-	+	-	+	+	-	+	+	+	+	+	+	-	-	-	-	-	+	-	-	-	-	+	+	-	-	+	-	-	-
048	+	+	-	+	-	+	-	+	+	-	-	+	+	-	-	-	+	+	+	+	+	+	+	-	-	+	+	+	-	+	+	+	+	+
131	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	+	+	+	-	+	+	+	+	-	+	+
058	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
054	+	+	-	+	-	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
014	-	-	-	-	-	-	-	-	+	+	+	-	-	-	+	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-	+	-	-	+
055	-	-	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	-	+
040	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
031	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	+	-	-	+	-	-	+	-	+	-	-	-	-	-	-	+	-	-	-
035	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-
088	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	1	1	+	+	1	1	+	+	+	1	+	+	+	+	1	+	-
063	4	5	5	5	4	6	6	5	7	7	7	8	7	8	8	7	8	7	7	9	8	8	7	8	8	8	7	7	8	8	9	8	9	9
107	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
077	+	+	-	+	+	+	-	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+

(continued)

Appendix G-3. (concluded)

Species Code	Site: 1	1	2	1	2	1	2	1	3	3	3	5	5	2	3	3	5	4	4	5	5	4	4	7	7	6	4	6	7	7	6	7	6	6
	Sample: 2	5	1	3	2	1	3	4	2	1	3	1	2	5	4	5	4	4	5	5	3	2	3	4	2	2	1	1	5	1	3	3	5	4
068	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-
008	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-
073	+	+	-	+	-	+	-	+	-	-	-	+	+	-	-	-	+	-	-	+	1	-	-	+	+	+	-	1	+	+	+	+	+	+
019	-	+	+	+	+	+	+	+	-	+	+	+	-	-	-	+	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-
090	+	-	-	-	-	-	-	-	-	+	+	-	-	+	+	+	-	+	-	-	-	-	-	-	+	-	+	-	+	+	-	+	-	-
057	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	+	-	-	-	+	-	-
046	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-
041	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
016	-	+	+	-	+	-	+	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	-	+
100	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-
070	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
029	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	-	+	-	+	-	-	+	+	-	-	-	-	-	-	-
092	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
098	+	+	+	+	-	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+
099	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	+	+	+	-	+	-	-	+	-	-	+	-	+	-	-	-
038	-	+	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+
025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
121	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
056	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
045	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
018	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	+	+	-	-	-	+	-	+	-	-	-
052	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-
089	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
069	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	-
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
129	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	+	-	+	+
111	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	+

+	present
-	absent
1 to 9	weighted species abundance score

Appendix G-4. Species dominance distribution matrix for each sample site, October 1992.

Site	6	6	7	5	5	7	6	5	5	6	5	7	7	1	7	1	6	1	1	3	1	2	3	3	3	2	3	4	2	4	4	4	4	2	2
Species Code / Sample	3	5	5	1	4	4	4	2	3	2	5	3	2	1	1	5	1	2	3	3	4	2	1	2	5	1	4	5	3	3	4	2	1	4	5
123	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
020	+	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
056	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
119	-	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
004	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
027	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
105	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
024	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
057	+	1	-	-	-	-	+	-	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
101	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
019	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	-	+	+	-	+	-	+	-	+	-	-	-	-	-	-	-	-
033	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
126	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
018	-	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
023	+	+	+	-	-	+	-	-	-	-	-	+	+	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
022	-	-	+	-	-	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
044	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
115	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
029	+	+	+	-	+	+	-	+	+	+	+	+	+	-	+	-	+	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
035	+	+	-	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	-	+	+	+	-	-	+	-	+	-	-	-	-	-	-	+
038	-	-	+	-	-	+	-	+	-	+	-	+	+	-	+	-	-	-	-	+	-	+	-	-	-	+	-	-	+	-	-	-	-	-	-
081	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
055	8	7	7	9	8	6	7	9	9	7	7	7	5	4	5	3	3	2	3	3	3	3	1	1	1	2	2	2	1	2	1	1	+	+	+
002	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	+	+	+	+	+	+
031	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	-	-	-	+	-	+	+	-	-	-	-	+
064	-	+	+	+	+	-	-	+	-	-	+	+	+	-	+	+	-	+	-	-	+	-	+	+	-	-	+	-	-	-	-	+	-	-	-
045	-	-	+	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
065	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	-	+	-	+	-	+	-	-	+	-
016	+	+	+	+	1	2	1	+	+	1	1	1	1	1	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
039	+	-	+	-	-	+	-	+	+	+	-	+	+	-	+	-	+	-	-	-	+	+	-	-	-	+	-	-	-	-	-	+	-	-	-
052	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	-	+	+	-	+	+	+	+	+	+	+	-	+	-	+	+
072	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
087	+	+	1	+	+	1	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
116	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	-	+	-	+	-	-	+	-	+	+	-	-	+	-	-	+	-
084	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
085	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
009	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-	-
025	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

(continued)

Appendix G-4. (concluded)

Site	6	6	7	5	5	7	6	5	5	6	5	7	7	1	7	1	6	1	1	3	1	2	3	3	3	2	3	4	2	4	4	4	4	2	2
Species Code / Sample	3	5	5	1	4	4	4	2	3	2	5	3	2	1	1	5	1	2	3	3	4	2	1	2	5	1	4	5	3	3	4	2	1	4	5
028	-	+	+	-	+	+	-	+	+	-	+	+	-	-	+	+	+	-	-	-	-	-	+	-	-	-	-	+	-	-	+	-	+	-	-
077	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
030	-	-	+	-	+	-	-	+	-	-	+	-	+	+	-	+	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-
071	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	+	-	+	+	+	+	-	+	-	+	-	-	+	+
041	-	+	-	-	+	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	+
005	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	1	+	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
073	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
127	-	+	-	-	-	-	+	+	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	+	-	-	+	-
042	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
012	+	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
099	-	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	+	+	-	+	-	+	+	+	+	+	+	+	+	-	-	+	+	+	+
058	-	-	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	+	-
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
092	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
070	+	+	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
008	+	+	+	+	+	-	+	+	+	+	+	-	-	+	-	+	+	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	+	-	-
063	1	1	+	3	1	+	1	2	3	1	3	2	2	3	4	5	4	5	7	8	7	6	6	7	7	9	6	4	7	4	4	+	3	6	3
089	+	+	1	-	-	+	+	-	-	+	-	+	+	-	+	-	+	-	-	1	-	-	1	1	1	+	1	+	-	+	+	+	1	+	+
125	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	-	-	-	-
014	+	+	-	+	-	+	+	+	+	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
017	-	-	-	-	+	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+	+	+	-
074	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	+	-	+	+	-	+	-	+	-	-	-	-	-	+
067	+	+	-	-	+	-	+	+	+	-	+	-	+	-	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
034	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
068	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-
086	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
054	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	+	+	-	-	+	-	+	-
088	+	+	+	+	+	+	1	+	+	1	+	+	1	+	1	1	2	2	+	+	1	2	1	1	2	1	2	6	4	7	7	9	8	2	3
046	-	+	+	-	+	-	+	+	-	+	+	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+
048	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	1	+	+	+	1	+	+	1	+	+	+	+	5	6
032	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-
093	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-
037	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
124	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
095	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+
075	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
066	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
128	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

\+ present
\- absent
1 to 9 weighted species abundance score

APPENDIX H

PERCENT COMPOSITION OF BENTHIC INVERTEBRATE FUNCTIONAL FEEDING GROUPS, APRIL AND OCTOBER 1992

Appendix H-1. **Percent composition of benthic invertebrate functional feeding groups for each sample and site (pooled samples), April 1992.**

	Functional Feeding Group (percent)						
Site-Sample	C	H	D	HC	DH	CD	O
1-1	2.3	-	21.6	-	75.0	-	1.1
1-2	3.5	-	21.5	-	74.0	0.3	0.7
1-3	3.7	-	25.2	-	70.2	-	0.9
1-4	3.8	-	28.0	-	65.9	-	2.3
1-5	4.8	-	23.7	-	69.9	0.6	1.0
Pooled Sample	3.6	-	23.9	-	71.1	0.2	1.2
2-1	4.9	-	20.3	-	73.1	-	1.6
2-2	5.3	-	25.0	-	63.9	0.4	5.5
2-3	4.3	-	18.5	-	76.2	-	1.0
2-4	-	-	14.3	14.3	42.9	-	28.6
2-5	2.4	-	20.3	-	76.1	0.4	0.7
Pooled Sample	4.2	-	21.2	0.1	71.8	0.2	2.5
3-1	4.2	0.2	13.8	0.3	81.0	-	0.5
3-2	3.6	-	18.0	-	78.0	-	0.4
3-3	4.2	0.1	16.3	-	78.0	0.2	1.2
3-4	2.7	0.2	16.3	-	79.6	0.1	1.0
3-5	2.9	0.1	16.7	0.1	79.4	0.3	0.5
Pooled Sample	3.6	0.1	16.3	0.1	79.1	0.1	0.7
4-1	1.5	0.1	23.2	-	62.1	0.1	13.0
4-2	3.6	0.1	22.5	-	70.9	0.1	2.9
4-3	1.6	-	28.2	-	67.1	0.2	2.8
4-4	1.1	0.1	22.5	-	73.5	0.3	2.6
4-5	2.8	0.1	24.4	-	70.9	0.4	1.4
Pooled Sample	2.0	0.1	24.2	-	68.8	0.2	4.6
5-1	3.5	-	13.0	0.2	82.5	0.1	0.6
5-2	3.8	-	17.9	0.2	76.7	0.7	0.7
5-3	2.3	-	21.0	0.2	73.7	-	2.8
5-4	1.5	-	22.2	-	76.0	0.1	0.2
5-5	2.1	-	17.0	-	79.7	0.5	0.7
Pooled Sample	2.5	-	18.3	0.1	77.8	0.2	1.0
6-1	5.5	-	29.4	-	62.4	0.4	2.2
6-2	4.0	0.1	21.6	-	73.1	0.6	0.6
6-3	6.2	-	12.1	-	78.1	0.6	3.0
6-4	2.8	-	20.0	-	75.3	1.1	0.7
6-5	5.2	-	16.8	-	77.2	0.6	0.2
Pooled Sample	4.7	<0.1	20.2	-	73.1	0.7	1.3
7-1	2.8	0.1	22.9	-	72.3	0.4	1.4
7-2	3.1	-	21.4	-	72.8	0.1	2.6
7-3	2.3	-	26.9	-	66.9	0.2	3.7
7-4	5.8	0.3	16.9	-	69.9	0.4	6.8
7-5	2.8	-	21.8	-	71.6	0.3	3.5
Pooled Sample	3.2	0.1	22.4	-	70.7	0.3	3.4

Appendix H-2. Percent composition of benthic invertebrate functional feeding groups for each sample and site (pooled samples), October 1992.

	Functional Feeding Group (percent)						
Site-Sample	C	H	D	HC	DH	CD	O
1-1	6.0	1.2	42.8	-	42.8	-	7.3
1-2	3.7	0.2	42.3	-	50.8	-	3.0
1-3	4.4	0.1	34.1	-	60.3	-	1.1
1-4	3.2	0.1	37.8	-	57.9	0.1	1.0
1-5	3.0	1.0	32.7	-	55.7	-	7.6
Pooled Sample	3.8	0.4	36.8	-	55.5	<0.1	3.4
2-1	2.5	<0.1	31.6	-	65.0	0.2	0.6
2-2	2.6	0.1	39.2	-	56.7	0.2	1.3
2-3	2.0	-	42.2	-	54.9	<0.1	0.8
2-4	2.1	-	28.2	-	68.9	-	0.7
2-5	2.2	0.3	36.5	-	60.0	0.3	0.8
Pooled Sample	2.3	0.1	35.4	-	61.4	0.1	0.8
3-1	5.1	0.3	44.8	-	46.4	-	3.5
3-2	5.2	-	43.6	-	46.7	-	4.5
3-3	2.7	-	39.4	0.2	53.5	0.2	4.0
3-4	3.0	-	46.1	-	47.3	0.2	3.4
3-5	2.4	-	43.0	-	52.4	-	2.2
Pooled Sample	3.4	<0.1	43.4	<0.1	49.7	0.1	3.4
4-1	2.3	-	65.8	-	28.1	-	3.9
4-2	3.9	-	78.8	-	15.1	0.3	1.9
4-3	1.2	-	65.1	-	32.0	-	1.7
4-4	1.3	-	61.9	-	35.3	-	1.5
4-5	2.0	0.3	62.5	-	32.7	-	2.5
Pooled Sample	1.8	0.1	65.3	-	30.7	<0.1	2.1
5-1	5.2	1.1	63.6	-	23.9	-	6.2
5-2	2.8	1.5	65.6	-	24.8	0.2	5.0
5-3	2.9	0.3	65.3	-	25.2	0.2	6.1
5-4	2.4	0.7	66.6	-	20.4	-	9.9
5-5	2.2	0.6	60.4	-	29.4	-	7.4
Pooled Sample	3.1	0.8	64.6	-	24.6	0.1	6.8
6-1	6.2	-	56.2	<0.1	33.6	0.3	3.7
6-2	4.0	0.7	70.2	-	16.9	0.7	7.6
6-3	6.9	1.4	67.4	0.2	13.7	0.3	10.2
6-4	5.0	1.5	68.0	-	16.6	-	8.8
6-5	4.6	0.3	76.0	<0.1	15.3	-	3.9
Pooled Sample	5.4	0.7	67.4	0.1	19.6	0.2	6.5
7-1	3.2	-	58.8	0.2	33.7	0.9	3.2
7-2	6.9	0.4	59.3	0.1	22.8	0.3	10.2
7-3	5.2	0.7	63.1	0.1	24.4	0.1	6.4
7-4	9.6	0.3	62.2	0.7	13.1	0.4	13.7
7-5	6.8	<0.1	71.5	0.8	13.3	0.5	7.2
Pooled Sample	6.1	0.3	63.1	0.4	22.1	0.4	7.6

APPENDIX I

REPEATED MEASURES ANALYSES FOR PRE-OPERATIONAL AND POST-OPERATIONAL DATA, 1989 TO 1992

Repeated Measures Analysis on the Number of Taxa, Spring ~~April 19~~92

Source	DF	SS	MS	F	P
Year	3	1389.715	463.238	27.143*	0.000
Year x Area	6	232.466	38.744	2.270**	0.196
Error	12	204.800	17.067		
Temporal 1989-1990 vs 1991-1992					
Spatial BG vs DS					
Hypothesis	1	10.039	10.039	0.093**	0.775
Error	4	429.947	107.487		
Spatial NF vs FF					
Hypothesis	1	5.461	5.461	0.051**	0.833
Error	4	429.947	107.487		
Temporal 1989 vs 1990					
Spatial BG vs DS					
Hypothesis	1	19.853	19.853	0.474**	0.529
Error	4	167.540	41.885		
Spatial NF vs FF					
Hypothesis	1	367.500	367.500	8.774*	0.041
Error	4	167.540	41.885		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	53.977	53.977	7.971*	0.048
Error	4	27.087	6.772		
Spatial NF vs FF					
Hypothesis	1	20.833	20.833	3.077**	0.154
Error	4	27.087	6.772		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of EPT Taxa, spring ~~April 1992~~

Source	DF	SS	MS	F	P
Year	3	285.767	95.256	59.462*	0.000
Year x Area	6	37.062	6.177	3.856*	0.022
Error	12	19.223	1.602		
Temporal 1989-1990 vs 1991-1992					
Spatial BG vs DS					
Hypothesis	1	3.106	3.106	0.220**	0.664
Error	4	56.547	14.137		
Spatial NF vs FF					
Hypothesis	1	5.633	5.633	0.398**	0.562
Error	4	56.547	14.137		
Temporal 1989 vs 1990					
Spatial BG vs DS					
Hypothesis	1	4.659	4.659	2.141**	0.217
Error	4	8.707	2.177		
Spatial NF vs FF					
Hypothesis	1	54.945	54.945	25.243*	0.007
Error	4	8.707	2.177		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	6.627	6.627	18.075*	0.013
Error	4	1.467	0.367		
Spatial NF vs FF					
Hypothesis	1	4.485	4.485	12.233*	0.025
Error	4	1.467	0.367		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of Organisms (Log Transformed), Spring ~~April 19~~92

Source	DF	SS	MS	F	P
Year	3	12.419	4.140	52.870*	0.000
Year x Area	6	1.120	0.187	2.383**	0.094
Error	12	0.940	0.078		
Temporal 1989-1990 vs 1991-1992					
Spatial BG vs DS					
Hypothesis	1	0.030	0.030	0.146**	0.722
Error	4	0.825	0.206		
Spatial NF vs FF					
Hypothesis	1	0.097	0.097	0.472**	0.530
Error	4	0.825	0.206		
Temporal 1989 vs 1990					
Spatial BG vs DS					
Hypothesis	1	0.072	0.072	0.221**	0.663
Error	4	1.300	0.325		
Spatial NF vs FF					
Hypothesis	1	1.804	1.804	5.550**	0.078
Error	4	1.300	0.325		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.291	0.291	7.000**	0.057
Error	4	0.166	0.042		
Spatial NF vs FF					
Hypothesis	1	0.042	0.042	1.016**	0.371
Error	4	0.166	0.042		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of EPT (Log (x + 1 Transformed), ~~April 1992~~ Spring 1992

Source	DF	SS	MS	F	P
Year	3	11.531	3.844	86.262*	0.000
Year x Area	6	1.124	0.187	4.203**	0.071
Error	12	0.535	0.045		
Temporal 1989-1990 vs 1991-1992					
Spatial BG vs DS					
Hypothesis	1	0.002	0.002	0.006**	0.944
Error	4	1.112	0.278		
Spatial NF vs FF					
Hypothesis	1	0.096	0.096	0.344**	0.589
Error	4	1.112	0.278		
Temporal 1989 vs 1990					
Spatial BG vs DS					
Hypothesis	1	0.047	0.047	0.515**	0.513
Error	4	0.363	0.091		
Spatial NF vs FF					
Hypothesis	1	1.729	1.729	19.052*	0.012
Error	4	0.363	0.091		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.186	0.186	4.945**	0.090
Error	4	0.151	0.038		
Spatial NF vs FF					
Hypothesis	1	0.327	0.327	8.699*	0.042
Error	4	0.151	0.038		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of Chironomidae, Spring ~~April 199~~2

Source	DF	SS	MS	F	P
Year	3	2397548.672	799182.891	15.385*	0.000
Year x Area	6	1008164.312	168027.385	3.235*	0.040
Error	12	623358.273	51946.523		
Temporal 1989-1990 vs 1991-1992					
Spatial BG vs DS					
Hypothesis	1	37770.430	37770.430	0.468**	0.531
Error	4	322822.747	80705.687		
Spatial NF vs FF					
Hypothesis	1	624732.421	624732.421	7.741*	0.050
Error	4	322822.747	80705.687		
Temporal 1989 vs 1990					
Spatial BG vs DS					
Hypothesis	1	194089.807	194089.807	0.849**	0.409
Error	4	914225.427	228556.357		
Spatial NF vs FF					
Hypothesis	1	954868.161	954868.161	4.178**	0.110
Error	4	914225.427	228556.357		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	576122.447	576122.447	13.470*	0.021
Error	4	171079.747	42769.937		
Spatial NF vs FF					
Hypothesis	1	3400.545	3400.545	0.080**	0.792
Error	4	171079.747	42769.937		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of Taxa (Log Transformed), Autumn ~~October~~ 1992

Source	DF	SS	MS	F	P
Year	3	0.051	0.017	5.957*	0.010
Year x Area	6	0.028	0.005	1.664**	0.213
Error	12	0.034	0.003		
Temporal 1989 vs 1990 - 1992					
Spatial BG vs DS					
Hypothesis	1	0.004	0.004	1.085**	0.356
Error	4	0.015	0.004		
Spatial NF vs FF					
Hypothesis	1	0.001	0.001	0.296**	0.615
Error	4	0.015	0.004		
Temporal 1990 vs 1991					
Spatial BG vs DS					
Hypothesis	1	0.012	0.012	2.855**	0.166
Error	4	0.017	0.004		
Spatial NF vs FF					
Hypothesis	1	0.039	0.039	9.464*	0.037
Error	4	0.017	0.004		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.000	0.000	0.034**	0.863
Error	4	0.040	0.010		
Spatial NF vs FF					
Hypothesis	1	0.013	0.013	1.295**	0.319
Error	4	0.040	0.010		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of EPT Taxa (Log (x +1) Transformed), ~~October 1~~992
Autumn

Source	DF	SS	MS	F	P
Year	3	0.032	0.011	3.034**	0.071
Year x Area	6	0.033	0.006	1.563**	0.240
Error	12	0.042	0.004		
Temporal 1989 vs 1990 - 1992					
Spatial BG vs DS					
Hypothesis	1	0.002	0.002	1.046**	0.364
Error	4	0.010	0.002		
Spatial NF vs FF					
Hypothesis	1	0.000	0.000	0.015**	0.909
Error	4	0.010	0.002		
Temporal 1990 vs 1991					
Spatial BG vs DS					
Hypothesis	1	0.019	0.019	9.272*	0.038
Error	4	0.008	0.002		
Spatial NF vs FF					
Hypothesis	1	0.028	0.028	13.381*	0.022
Error	4	0.008	0.002		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.000	0.000	0.027**	0.877
Error	4	0.055	0.014		
Spatial NF vs FF					
Hypothesis	1	0.000	0.000	0.005**	0.945
Error	4	0.055	0.014		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of Organisms (Log Transformed), ~~October~~ ~~199~~2 Autumn

Source	DF	SS	MS	F	P
Year	3	1.482	0.494	14.155*	0.000
Year x Area	6	0.379	0.063	1.812**	0.179
Error	12	0.419	0.035		
Temporal 1989 vs 1990 - 1992					
Spatial BG vs DS					
Hypothesis	1	0.036	0.036	0.588**	0.486
Error	4	0.242	0.061		
Spatial NF vs FF					
Hypothesis	1	0.055	0.055	0.912**	0.394
Error	4	0.242	0.061		
Temporal 1990 vs 1991					
Spatial BG vs DS					
Hypothesis	1	0.217	0.217	6.819**	0.059
Error	4	0.127	0.032		
Spatial NF vs FF					
Hypothesis	1	0.060	0.060	1.890**	0.241
Error	4	0.127	0.032		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.048	0.048	0.482**	0.526
Error	4	0.400	0.100		
Spatial NF vs FF					
Hypothesis	1	0.001	0.001	0.011**	0.923
Error	4	0.400	0.100		

*	Significant ($p < 0.05$)
**	Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of EPT (Log Transformed), Autumn ~~October~~ 1992

Source	DF	SS	MS	F	P
Year	3	0.231	0.077	1.497**	0.265
Year x Area	6	0.127	0.021	0.410**	0.858
Error	12	0.617	0.051		
Temporal 1989 vs 1990 - 1992					
Spatial BG vs DS					
Hypothesis	1	0.005	0.005	0.241**	0.649
Error	4	0.087	0.022		
Spatial NF vs FF					
Hypothesis	1	0.006	0.006	0.270**	0.631
Error	4	0.087	0.022		
Temporal 1990 vs 1991					
Spatial BG vs DS					
Hypothesis	1	0.000	0.000	0.002**	0.970
Error	4	0.241	0.060		
Spatial NF vs FF					
Hypothesis	1	0.000	0.000	0.005**	0.947
Error	4	0.241	0.060		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.016	0.016	0.117**	0.749
Error	4	0.531	0.133		
Spatial NF vs FF					
Hypothesis	1	0.145	0.145	1.089**	0.356
Error	4	0.531	0.133		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of Chironomidae (Log Transformed), ~~October 1992~~ Autumn

Source	DF	SS	MS	F	P
Year	3	2.797	0.932	12.716*	0.000
Year x Area	6	0.929	0.155	2.113**	0.127
Error	12	0.880	0.073		
Temporal 1989 vs 1990 - 1992					
Spatial BG vs DS					
Hypothesis	1	0.060	0.060	0.474**	0.529
Error	4	0.504	0.126		
Spatial NF vs FF					
Hypothesis	1	0.254	0.254	2.015**	0.229
Error	4	0.504	0.126		
Temporal 1990 vs 1991					
Spatial BG vs DS					
Hypothesis	1	0.498	0.498	7.823*	0.049
Error	4	0.254	0.064		
Spatial NF vs FF					
Hypothesis	1	0.099	0.099	1.552**	0.281
Error	4	0.254	0.064		
Temporal 1991 vs 1992					
Spatial BG vs DS					
Hypothesis	1	0.118	0.118	0.568**	0.493
Error	4	0.827	0.207		
Spatial NF vs FF					
Hypothesis	1	0.003	0.003	0.013**	0.915
Error	4	0.827	0.207		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)